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Introduction and summary

The United States in the 21st century faces an enormous challenge—successfully managing the transformation from a predominantly carbon-intensive economy to becoming a predominantly clean energy-based economy. The reality of global climate change due to rising carbon emissions makes it imperative that the U.S. economy dramatically cut its consumption of traditional fossil fuels, the primary source of carbon dioxide (CO_2) delivered into our atmosphere by human activity. Rising levels of CO_2 in the atmosphere is in turn the primary cause of global warming.

This economic transformation will engage a huge range of people and activities. But there are only three interrelated objectives that will define the entire enterprise:

- Dramatically increasing energy efficiency.
- Dramatically lowering the cost of supplying energy from such renewable sources of energy as solar, wind and biomass.
- Mandating limits and then establishing a price on pollution from the burning of oil, coal, and natural gas.

It is crucial for economic policymakers and the American people to understand the likely effects of these three overarching objectives as much as possible. Specifically, we need to gauge our success in curbing CO_2 emissions alongside the broader effects on the U.S. economy, particularly on employment opportunities, economic growth and people's incomes.

This paper examines these broader economic considerations—jobs, incomes, and economic growth—through the lens of two government initiatives this year by the Obama administration and Congress. The first is the set of clean-energy provisions incorporated within the American Recovery and Reinvestment Act, initiated by the Obama administration and passed into law by Congress in February. The second is the proposed American Clean Energy and Security Act, co-sponsored by Rep. Henry Waxman (D-CA) and Rep. Edward Markey (D-MA), which is now before Congress.

Our analysis in this paper shows that these two measures operating together can generate roughly $150 billion per year in new clean-energy investments in the United States over the next decade. This estimated $150 billion in new spending annually includes government funding but is notably dominated by private-sector investments. We estimate this sustained expansion in clean-energy investments triggered by the economic stimulus program and the forthcoming American Clean Energy and Security Act can generate a net increase of about 1.7 million jobs. This expansion in job opportunities can continue as long as the economy maintains a commitment to clean-energy investments in the $150 billion per year range. If clean-energy investments expand still faster, overall job creation will increase correspondingly.

These job gains would be enough—on their own—to reduce the unemployment rate in today's economy by about one full percentage point, to 8.4 percent from current 9.4-percent levels—even after taking into full account the inevitable job losses in conventional fossil fuel sectors of the U.S. economy as they contract. Our detailed analysis, based on robust economic-modeling methodologies that are explained in detail in the paper and in Appendix 1, beginning on page 48, calculates that roughly 2.5 million new jobs will be created overall by spending $150 billion on clean-energy investments, while close to 800,000 jobs would be lost if conventional fossil fuel spending were to decline by an equivalent amount. It is not likely that all $150 billion in new clean-energy investment spending would come at the expense of reductions in the fossil fuel industry. However, we present this scenario to establish a high-end estimate for reductions in conventional fossil fuel spending, and the net gains in employment that will still result through spending $150 billion per year on clean-energy investments. In appendix 2, we also present these figures on net job creation broken down on a state-by-state basis for all 50 states and the District of Columbia.

The stimulus program enacted in February to help the economy recover from a deep recession already in its 18th month includes a range of measures to begin building a clean-energy economy. These measures include:

- $24.4 billion in federal government spending to promote energy efficiency.
- $23 billion for transportation investments.
- $25.3 billion for renewable energy.

Some of this funding will be in 2010, but a significant amount will also spark new economic activity between 2011 and 2014.

Congress still must pass the American Clean Energy and Security Act, or ACESA, and the president must still sign it. But the legislation contains three broad categories of initiatives that are unlikely to change in substance:

- Regulations aimed at promoting clean energy.
- A mandated cap on carbon emissions that will be phased in through 2050.
- Measures designed to assist businesses, communities and individuals successfully manage the transition to a clean-energy economy.

The general thrust of this forthcoming legislation and the clean-energy provisions within the economic stimulus program is to promote energy efficiency and renewable energy. Yet as an economic stimulus program, ARRA operates through direct government spending and financial incentives to promote private investments in clean energy. In contrast, ACESA will boost clean-energy investments mostly by private businesses, investors and households through new regulations that encourage the clean and efficient use of energy and discourage the use of high-carbon fuels. Many of the regulatory initiatives proposed within the ACESA are not fully fleshed out within the legislation itself. As such, it is more difficult to estimate their effects on overall clean-energy investments than is true with the spending initiatives advanced by the ARRA.

In the following pages, this paper first examines the basic clean-energy features of the economic stimulus program and the proposed ACESA. Specifically, we will detail the distinct features of both measures and the ways in which they would operate in concert to encourage investments in clean energy and energy efficiency as well as discourage spending on conventional high-carbon fuels.

We will then explain how ARRA and ACESA operating in tandem would create new employment opportunities across the United States by spurring $150 billion a year over the next decade in new clean-energy investments. Understanding how we calculated these investment levels over 10 years requires an understanding of the different economic models available to analysts and why we chose a simple but reliable method for estimating employment effects based on data generated by the U.S. Commerce Department's industrial census. We explain the reasons for our analytical decisions on pages 15–20, beginning with how we estimated the effects on jobs of shifting spending in the U.S. economy away from high-carbon fuels and toward clean-energy investments. We will show why our simple approach offers a robust framework for understanding how a shift in spending from conventional fossil fuels to clean energy generates a net expansion of employment that will be sustained as long as the U.S. economy maintains its commitment to clean-energy investments.

We then present our detailed employment estimates. Our key finding is that clean-energy investments generate roughly three times more jobs than an equivalent amount of money spent on carbon-based fuels. We consider some of the implications of this result, including how a large-scale shift from conventional fossil fuels to clean-energy investments—on the order of $150 billion a year—would affect conditions in the U.S. labor market.

Our paper then turns to the various economic models used to estimate the impact of a carbon cap on the long-run growth trajectory of the U.S. economy. Our key finding: All of the models, without exception, forecast that a carbon cap, such as that proposed in ACESA, would have, at worst, a minimally negative impact on the U.S. economy's long-term growth path. Moreover, these models generate this basic finding without considering some of the major ways in which clean-energy policies can stimulate economic growth.

These include the expansion of employment opportunities itself, a reduction in the trade deficit, promoting technological improvements and thus falling prices in renewable energy sources, and reducing the negative impacts on economic activity of greenhouse gas emissions and unmitigated global warming.

To be sure, any economic modeling effort that estimates changes in employment growth, economic growth, and income growth will result in forecasts that are problematic by nature. We make this clear in our paper wherever we rely on our own economic models and those employed by others. But we also take pains to examine the relative strengths and weaknesses of all the modeling approaches—including our own. This enables us to cross check our own conclusions with those of other researchers to reach the most reliable possible understanding of the overall impact of advancing a clean-energy agenda within the U.S. economy.

Understanding the economic stimulus program and new clean-energy legislation

The clean-energy components of the American Recovery and Reinvestment Act programs and the entire American Clean Energy and Security Act now before Congress are designed to transition our economy from its reliance on high-carbon fuels to one operating more efficiently on clean energy. Understanding the specific features of ARRA and ACESA and how they will work in combination allows us to estimate the level of public- and private-sector investments in clean energy. As we will demonstrate, the two programs together could create $150 billion a year in new investment and 1.7 million net new jobs a year—that is, 1.7 million more jobs each year than would be the case without a $150 billion shift in spending from conventional fossil fuels to clean energy investments.

The economic stimulus program

There are three separate ways to break down the various spending categories on clean energy within the $787 billion economic stimulus program that kicked in after the passage of ARRA in February this year. The first is according to the specific categories of environmental spending. The second is the financial mechanism for allocating the federal funds. And the third is the amount of additional spending by state and local governments and private businesses that are likely to result through the incentives offered under ARRA (see Table 1). It is crucial to keep these distinctions clear, especially when we later consider the impact of ARRA in conjunction with the types of measures proposed in the ACESA.

Categories of environmental spending

As Table 1 shows, total federal environmental spending in ARRA amounts to about $100 billion, divided into nine categories: renewable energy, energy efficiency, transportation, the electrical grid, nuclear decontamination, carbon capture-and-storage technologies for fossil fuels, basic science, along with general categories "other" and "government administration." The four largest areas of federal spending are renewable energy, energy efficiency, transportation, and the electrical grid, accounting for about $86 billion of the $100 billion total.

TABLE 1

Environmental spending through the ARRA

Billions of dollars

Type of funding	Direct public spending	Grants	Tax incentives	Loan guarantees	Bonds	Total
Federal spending						
Renewable energy	$2.5	$2.3	$16.0	$4.0	$0.6	$25.3
Energy efficiency	7.2	14.4	2.0	0	0.8	24.4
Transportation	0.6	20.1	2.1	0	0.3	23.0
Grid	6.6	4.4	0	2.0	0	13.0
Nuclear decontamination	6.0	0	0	0	0	6.0
Fossil		3.4	0	0	0	3.4
Science	1.6	0	0	0	0	1.6
Other	2.3	0.7	0	0	0	3.0
Government admin	0.75		0	0	0	0.8
Total	$27.6	$45.3	$20.0	$6.0	$1.7	$100.5
State/local government and private investment						
State/local government and private spending induced by federal funds: *as proportion of federal funds*	0	Ranges by program between 0–3 times federal spending	Up to 2.3 times federal spending	Up to 10 times federal spending	Up to 3 times federal spending	–
State/local government and private spending induced by federal funds: *as dollar amounts*	0	$68 estimated *(= 1.5 times federal spending average)*	Up to $46	Up to $60	Up to $5.1	Up to $179.1
Total, all sources	**$27.6 billion**	**Up to $113.3**	**Up to $66**	**Up to $66**	**Up to $6.8**	**Up to $280.0**

Source: ARRA; grants.gov; irs.gov; www.staterecovery.org; www.dot.gov/recovery; edocket.access.gpo.gov; epa.gov; www.recovery.gov; cbo.gov; dsireusa.org.
Note: Totals may not add up due to rounding.

Financial mechanisms for allocating federal funds

There are five separate categories: direct public spending, grants, tax incentives, loan guarantees, and bonds. Direct public spending programs by the federal government—at $27.6 billion—represents only about one-fourth of the total $100 billion in federal spending. With the remaining $73 billion in federal spending that will be allocated through grants, tax incentives, loan guarantees and bonds, the federal ARRA funds are used as incentives to induce still higher levels of environmental investment spending both by state and local governments and even more so by private investors.

Additional spending by state and local governments and private business

How much additional clean-energy investments will the $73 billion in incentives for state and local governments and especially private businesses end up encouraging? Estimating this amount of additional spending beyond the $73 billion in incentives is difficult, because of the very nature of incentives. The federal government obviously does not have the power to force anyone to accept the incentives they are offering; nevertheless, it is essential to establish at least some broad parameters as to how extensive the non-federal environmental spending induced by ARRA is likely to be.

We therefore present in Table 1 some rough estimates of how much additional funding by state and local governments and the private sector is likely to occur because of the $73 billion in federal incentives. Our estimates vary due to the nature of the different incentives. Among the federal grants on offer, for example, are those that require no matching funds from state or local governments or private businesses, such as "transit capital improvements" and the "state energy program." And then there are those federal grants that do require matching investments, such as "concentrating solar power" and "transportation electrification." We assume an average level of matching funds at about 1.5 times the level of federal funds allocated for these grants, since this is a midpoint figure for the range of matching fund requirements in the various grant programs.

With the tax incentives, loan guarantees, and bond financing programs, the upward range by which federal funds may be matched by state and local government or private investments is more consistently specified within the ARRA legislation. Based on this information, we estimate that non-federal spending will range between 2.3 times federal spending for the various tax incentive measures to 10 times federal spending for the loan guarantees and bond financings to help finance investments in renewable energy and smart grid transmission systems. We explain in detail on page 49 of Appendix 1 how we derive these upper end estimates for non-federal spending induced by the ARRA.

Overall, as Table 1 shows, we estimate that the various grants, loan guarantees, tax incentives and bond financings could spur up to about $180 billion in total spending in addition to the $100 billion in federal spending in clean energy through the economic stimulus program. Yet the total level of investments could fall below that $280 billion if the private sector does not respond with sufficient enthusiasm to the incentive programs provided by ARRA. This could happen depending on the implementation of other clean-energy regulations and incentives.

This is the crucial point of convergence of the clean-energy incentives advanced through the economic stimulus program and the set of regulations and incentives currently included in the American Clean Energy and Security Act before Congress. This combination of incentives will create the overall investment environment for clean energy in the U.S. economy. But before we detail how this convergence will affect overall investment flows from state and local governments and the private sector over the next decade, we first must consider the rate at which clean-energy spending through the ARRA is likely to be distributed throughout the economy.

Rate of spending on economic stimulus programs

About 90 percent of the overall spending under the $787 billion American Recovery and Reinvestment Act is designed to occur between 2009 and 2014.[1] But ARRA's clean-energy components are largely designed to encourage private-sector participation, which means the rate of spending on clean energy will stretch out over a longer period of time. This is the case for several interrelated reasons. It takes longer for a private investor to decide to pursue an investment opportunity because of federal government incentives than for the federal government to undertake on its own a direct federal spending project. It then takes time to obtain financing for such projects and organize the various contracting and subcontracting parties involved in the project. Then and only then can the spending begin on a private sector clean-energy project operating with federal subsidies.

The Congressional Budget Office recognized these factors in a recent analysis. CBO developed an eight-year time frame for the nearly full disbursement of ARRA-related investment funds on renewable energy and energy efficiency—managed by the Department of Energy—with the bulk of spending on these projects occurring between 2010 and 2014. Table 2 shows the rate at which the CBO is assuming these ARRA funds will be spent.

The CBO assumes that 35 percent of total funding will be spent as of 2011, 90 percent by 2014, and 96 percent by 2015. We therefore assume that the rate of spending for the other clean-energy investment components of ARRA will proceed at roughly the same rate as these renewable-energy and energy-efficiency projects within the Department of Energy budget. We can conclude that all of the clean-energy components of the economic stimulus program will operate on a large scale for about five years, from 2010 to 2014.[2]

TABLE 2

Congressional Budget Office estimated rate of ARRA spending on renewable energy and energy efficiency

Year of ARRA spending	Percentage of total direct federal spending in given year	Cumulative percentage of direct federal spending as of given year
2009	2.6%	2.6%
2010	12.2%	14.8% (2009–10 spending)
2011	19.9%	34.7% (2009–11 spending)
2012	22.1%	56.8% (2009–12 spending)
2013	17.6%	74.4% (2009–13 spending)
2014	15.1%	90.0% (2009–14 spending)
2015	6.2%	95.7% (2009–15 spending)
2016	1.6%	97.3% (2009–16 spending)

Source: Congressional Budget Office, "Estimated Cost of the American Recovery and Reinvestment Act of 2009," "Estimated Cost for the Conference Agreement of H.R. 1, available at " http://www.cbo.gov/ftpdocs/99xx/doc9989/hr1conference.pdf.

If we then also assume that nearly $280 billion in total is spent by the public and private sectors over this five-year period, this would amount to an average level of clean-energy investments tied to ARRA of about $56 billion per year over five years. Nevertheless, the rate at which the federal money tied to incentive-based programs within the ARRA—the grants, loan guarantees, tax incentives and bond programs—are actually spent will depend on the broader set of regulations and incentives operating within the economy. As such, the policies proposed through the ACESA will play a central role in strengthening the clean-energy incentives introduced through the ARRA.

The American Clean Energy and Security Act of 2009

The current draft of ACESA sets out a variety of standards, regulations, and restrictions governing energy efficiency and carbon emissions. As of June 18, 2009 the bill was still under debate in Congress and will undergo further revisions before it reaches the president for his probable signature. But the basic framework and parameters of the measure will likely remain as presented in the draft legislation as it currently stands.

ACESA is primarily a piece of regulatory legislation, not a spending bill. Upon implementation, the law will influence the allocation of private resources and the direction of technological change, and thereby alter the ways in which energy is produced and consumed. This will happen most directly through the introduction of a carbon cap-and-trade program that will put a price on carbon emissions for the first time and then allow companies to trade carbon-emission credits among themselves as the cap on emissions rises.

This differs significantly from the clean-energy investment components of the economic stimulus program that, as we have seen, are direct spending measures or subsidies to promote private investment in these areas. Yet the underlying aim of the ACESA is also to encourage new investments in clean-energy activities and correspondingly discourage reliance on high-carbon fuels. Specifically, the new carbon cap-and-trade program will explicitly limit conventional fossil fuel production and consumption and encourage investors to meet market demand for energy by providing consumers with clean-energy alternatives.

ACESA boasts one section that deals directly with reducing carbon emissions through a cap-and-trade program. Other aspects of the bill would: increase energy efficiency; diversify sources of energy through the development of clean-energy alternatives; reduce dependency on imported high-carbon fuels; and modernize the energy transmission and distribution system through the adoption of "smart grid" technologies. Together, ACESA would promote clean-energy and energy efficiency; reduce our reliance on high-carbon fuels, and support companies, individuals and communities through the transition to a clean-energy economy.

Besides the cap-and-trade program, ACESA includes regulations governing a new national standard for electricity generation through renewable energy sources and a set of broad guidelines by which new standards and regulations would be determined through future legislative and regulatory initiatives. These major additional provisions in ACESA include:

- **A carbon capture-and-storage program.** The bill calls for a study to assess the barriers to the broad deployment of carbon capture-and-storage technologies alongside funds for pilot demonstration projects through a new Carbon Storage Research Corporation.

- **A low-carbon fuel standard.** The bill would establish a low-carbon fuel standard within three years after the bill is passed, but does not contain the details of such a standard in the actual legislation.

- **New energy-efficient building standards.** The bill would implement new standards based on the International Energy Conservation Code for commercial buildings and the American Society of Heating, Refrigeration, and Air Conditioning Engineers standards for residential buildings, with the two standards based on "each model code or standard released after the date of enactment of the Act."[3] The bill also requires the federal government to provide financial support for commercial and residential retrofits in order to achieve compliance with the standards.

- **New fuel-efficiency standards for motor vehicles.** The bill authorizes the president to set these new standards based on what is achievable by the automobile industry but designed to achieve emissions reductions at the same level as California law AB1493. The California regulations aim to reduce greenhouse gas emissions from new vehicles by 23 percent by 2012 and by 30 percent as of 2016.

- **New industrial energy-efficiency standards.** The bill would require the development of energy-efficiency standards for factories and other types of industrial plants, with the task of doing so assigned to the Secretary of Energy.

Because these additional provisions of ACESA do not include specific regulations, it is not possible to consider categorically what their impact is likely to be on employment or economic growth. But it is possible to calculate broadly how these new regulatory measures would operate along with the two measures in ACESA—the renewable electricity standard and the carbon cap-and-trade program—where detailed regulatory standards are presented. We therefore consider those two detailed regulatory programs within the ACESA.

Renewable energy electricity standard

ACESA proposes that six percent of all electricity generation supplied by retail electricity providers in the United States must come from renewable energy sources by 2012, rising to 15 percent by 2020. These renewable-energy sources include wind, solar, geothermal, biomass, municipal waste, and hydropower. The draft legislation includes a provision allowing utility companies that surpass the standard to trade their credits to other companies. Consequently, not all retail electricity companies will necessarily need to meet the standard themselves, though on average the standard would hold for all retailers.

To analyze the implications of this standard, we draw on the most recent energy forecasts in the *Annual Energy Outlook 2009*, published by the Department of Energy's Energy Information Administration. We specifically base our analysis of the forthcoming renewable energy electricity standards on the Energy Information Administration's so-called "reference case." This reference case takes into account existing policies to estimate the impact of this standard on the economy, but it does not consider how possible new policies or other future developments—such as new technological advances—could influence the ways a renewable energy standard would impact the economy's overall performance.

Based on this reference case from the EIA, the United States already meets the six percent renewable standard set for 2012. Moreover, based on the reference-case forecasts in the 2009 *Annual Energy Outlook*, the new regulations would not be difficult for retail energy suppliers to reach until around 2018, when the standard would rise to 14 percent.

But how much additional investment in renewable electricity generation would be needed to meet the 15 percent standard by 2020? The EIA estimates that our nation's overall available electricity supply would total 4,618 kilowatt hours by 2020. If 15 percent of this came from renewable sources, annual renewable electricity generation would total about 690 kwhs.

We estimate that total installed renewable-energy electricity generation capacity would have to increase by about 53 gigawatts from its current level to generate 690 kilowatts of electricity from renewable sources by 2020. The dollar value of this investment would total approximately $148 billion. If we spread out this level of investment over the next decade, it would amount to approximately $15 billion in investment each year (see Appendix 1 on page 48 for the detailed analysis).

The 15-percent renewable electricity mandate is not the only provision in ACESA that will encourage investments in the production of renewable energy-based electricity. Other provisions in ACESA—such as the cap-and-trade program—would also create incentives for the more rapid shift towards renewable energy. In this broader context, it is conceivable that the U.S. economy could exceed the 15 percent target by 2020, provided other complementary policies operate effectively in support of that goal.

To calculate the level of investment needed to reach a 20 percent renewable electricity standard by 2020, we draw again from the EIA database. We calculate that it would require an additional 104 gigawatts in total additional capacity to reach the 20 percent renewable standard, which would entail about $290 billion overall in new renewable-energy investments. Spread out over a decade, this level of renewable energy investment would be about $30 billion per year.

Carbon cap-and-trade system

ACESA contains a specific schedule for reducing greenhouse gas emissions through 2050 via a carbon cap-and-trade system. That proposed schedule is as follows:

- 2012: Three percent below 2005 emissions levels, which is 12 percent above 1990 emissions levels.
- 2020: Twenty percent below 2005, which is seven percent below 1990 emissions levels.
- 2030: Forty-two percent below 2005 (33 percent below 1990 levels).
- 2050: Eighty-three percent below 2005 (80 percent below 1990 levels).

Under this schedule—or any schedule ultimately endorsed by Congress and signed by the president—new costs would be imposed on businesses for emitting carbon into the atmosphere while businesses that use clean energy, or improve their efficiency, could see savings in their energy bills. Businesses will pass along a significant share of these costs and savings to consumers. The net result would be to discourage both businesses and consumers from consuming energy from carbon-emitting sources; and to correspondingly promote both energy efficiency and reliance on clean energy sources.

In this way, a carbon cap-and-trade system would operate in concert with the full range of incentives included in the economic stimulus programs and ACESA to shift overall energy production and consumption toward efficiency and renewable sources and away from high-carbon fuels. How much a carbon cap would reduce conventional fossil fuel consumption and encourage clean-energy sources and efficiency would depend on how large are the additional costs imposed by any such measure. It would also depend on how affordable are the clean-energy alternatives to conventional fossil fuel consumption.

We can illustrate this point with a simple example. According to the Environmental Protection Agency's most recent model of the ACESA draft, the carbon-cap component of the proposal would produce an increase in gasoline prices of about 10 percent relative to the reference case as of 2030; the reference case price is approximately $4.15 per gallon, while under cap-and-trade, EPA forecasts the price at about $4.50 per gallon. How much is a 10-percent increase in gasoline prices likely to affect economic activity more broadly?

According to many standard references in economic studies, what economists term the "price elasticity of demand" for gasoline is in the range of -0.3.[4] This price elasticity estimate refers to how much demand for gasoline would fall when the price of gasoline rises. The estimate of a -0.3 elasticity means that if the price of gasoline rises by 10 percent then demand would fall by three percent. Using the EPA model, gasoline prices will rise by 10 percent relative to the reference case—from about $4.15 to $4.50 per gallon—due to the carbon cap, which in turn will mean gasoline consumption would fall by 3 percent relative to the reference case.

Deriving this result is completely dependent on working with the price elasticity figure of -0.3. But the price elasticity could also be raised substantially if, for example, there were affordable and readily accessible options for raising efficiency and purchasing renewable energy sources. If accessibility to public transportation improved substantially and if biomass fuels became widely available and price competitive—two outcomes that are likely to happen because of economic stimulus programs within ARRA and the full range of incentives included in the ACESA—then we can imagine that the price elasticity for gasoline could increase from -0.3 to -0.6. This would mean that a 10-percent price increase in gasoline would reduce gasoline consumption by six percent rather than three percent. At the same time, consumers need not see their costs for transportation rise, since clean-energy investments are aimed precisely at encouraging energy-efficient vehicles, improving the quality of public transit offerings, and driving down the cost of renewable energy sources for automobile fuel.

Overall, we can see once again that the full effects of the cap-and-trade system interacting with other clean-energy incentives in the economy under ARRA and other elements of the ACESA will encourage businesses, households, state and local governments to embrace the clean-energy investment agenda, including the opportunities for their investments to be subsidized by federal government programs. We will now examine how this full range of incentives could generate in the range of $150 billion per year in new clean-energy investments throughout the U.S. economy.

Creating $150 billion a year in clean-energy investments

Our analysis of how the ARRA stimulus measure and ACESA will work together as complementary initiatives allows us to estimate an overall level of new clean-energy investments in the United States in the range of $150 billion per year over roughly the next decade. In addition to our assessment of the various incentives and subsidies provided by the ARRA, this calculation is based on our analysis of the potential size of the overall market for clean-energy investments in the United States, including unsubsidized investments by businesses as well as investments receiving some form of government subsidy.

A total level of clean-energy investment spending in this range would represent about eight percent of total annual private investment in the U.S. economy as of 2007 and about 1.1 percent of 2007 U.S. gross domestic product. By "investments" we refer to spending that either improves energy efficiency or contributes toward the expansion of renewable energy supplies. Retrofitting buildings, for example, is an energy-efficiency investment, while research on improving the cost competitiveness of biomass fuels and building wind farms are forms of renewable-energy investments.

A crucial feature of our approach is that we include in our $150 billion estimate only investments that have the potential to significantly expand employment opportunities in the U.S. economy. There are major areas of energy-efficiency investments that will not generate a large net expansion of employment, including building energy-efficient automobiles and appliances as well as construction of new buildings that operate at higher efficiency levels than the existing building stock. In these cases, the employment requirements are not likely to be larger than those for inefficient cars, appliances and buildings, though the gains in efficiency will make important contributions to reducing greenhouse gas emissions.

We can consider the overall level of clean-energy investments according to two criteria:

- Investments that are either completely funded by the federal government or are government-subsidized private investments.
- Unsubsidized private investments that result from the overall expansion of markets, new technologies and related opportunities in the clean-energy sector.

We first consider the scope of the subsidized market then address more broadly the overall market, including both the subsidized and unsubsidized segments.

Subsidized public- and private-sector investments

Establishing an estimate for government funded and subsidized investments requires us to work from two concrete reference points. The first is the spending levels that are likely to result through ARRA. In a previous section of the paper we estimated this high-end level at $56 billion per year between 2010 and 2014, including federal spending as well as state and local government spending and private investments that could be induced by the federal programs. This level of investment is predicated on private investors taking full advantage of the range of clean-energy investment initiatives being offered through the ARRA alongside the range of regulations and incentives included in ACESA.

The second reference point is our estimate that the total level of new investments in renewable energy electricity generating capacity would need to be around $15 billion per year over 10 years to meet the 2020 standard now included in ACESA. It is likely that a significant share of this new renewable energy investment capacity would be subsidized through ARRA-based incentive programs. As such, we would be double-counting to assume that all $15 billion per year in renewable energy electrical generating capacity would be an increment of investment spending in addition to the $56 billion year in clean-energy investments included in the ARRA. It is more reasonable to assume that some of the new renewable electricity capacity will be financed out of the $56 billion in ARRA spending, while a significant share will be come from unsubsidized private investors.

Expanding unsubsidized private-sector, clean-energy investments

Moving beyond the specific case of the renewable electricity standard detailed on pages 11–12, we can, more generally, expect that the opportunities generated by the combination of ARRA and ACESA will lead to an expansion of the new investment opportunities connected to clean energy, a corresponding rise in business opportunities, and a related increase in productive efficiencies as these investment projects take root across the country. That is, the *unsubsidized* market for clean-energy investments will expand as an outgrowth of the subsidized market as businesses create and profit from these new opportunities and as technologies improve. That in turn means the cost of producing clean energy or increasing efficiency will fall as linkages strengthen among companies operating in new clean-energy sectors and as financial institutions supply more funds to support these investments.[5]

Market potential for job-creating clean-energy investments

How large is the potential market for energy efficiency and renewable energy investments that will also generate job creation in the United States, including both the subsidized and unsubsidized segments of the market? We can obtain a sense of this by considering some of the possibilities in distinct parts of the overall market. As we will demonstrate, the potential market for energy efficiency investments that also are new sources of job creation is around $110 billion per year.[6] A rough approximation, which assumes an average investment in retrofits of around $4,000 per unit, implies an overall potential market of $400 billion.

Energy efficiency

Improving energy efficiency through building retrofits, public transportation, freight rail, and smart-grid electrical transmission systems involves technologies that are already known. The returns on investment are also fairly certain and rapid. Once a growing market infrastructure is established to support these investment activities, the private opportunities will become increasingly clear to a widening range of investors operating without government subsidies. Let's consider each of these investment categories in turn.

Building retrofits

An average-sized single-family home in the United States would require an investment of as little as $2,500 in energy-efficiency retrofits to produce a cost savings in the range of 30 percent per year.[7] This would involve caulking to plug air leaks in the house and adding insulation to attics and basement ceilings. For an additional $2,500, further energy savings are available through replacing windows with air leaks and installing energy efficient appliances.

Despite these potential savings, most homeowners have not retrofitted their homes because they are unaware of the costs savings available to them or they cannot afford the upfront expenses and time commitment involved. But these barriers to retrofit investments will come down through the specific government spending programs that finance retrofits, the building codes that establish higher efficiency standards in buildings, and the more general regulatory environment that raises the costs of burning conventional fossil fuels. As the market becomes more extensive and efficient, this will further encourage new investment in retrofits. In particular, banks, utility companies and various types of nonprofit groups will increasingly organize themselves to supply the upfront financing for these projects. In addition, construction crews will begin to organize their services to take advantage of the expanding opportunities.

The potential market for building retrofits is huge. There are roughly 110 million occupied housing units in the United States, including 80 million single-family detached homes, as well as smaller numbers of attached units, apartments, and trailers. As a rough approximation, assuming an average investment in retrofits would be around $4,000 per unit, implies an overall potential market of $400 billion. We would then add the corresponding market for non-residential structures. The U.S. Green Building Council surveyed the existing stock of these structures in 2008, including all educational buildings, hospitals, retail outlets, and office buildings of various sorts. They estimated the costs of retrofitting all of these buildings at $358 billion.[8]

In short, the potential market for building retrofits alone in the United States is in the range of $800 billion. If all of these structures were retrofitted over the course of a decade, then it would provide a high-end level of this type of energy efficiency investment at $80 billion per year.

Smart grid

A recent study by Mark Chupka, Robert Earle, Peter Fox-Penner, and Ryan Hledik[9] provides a basis for roughly estimating the potential market for smart grid investments over the next decade. They project future investment in electrical distribution and transmission infrastructure will need to be $44 billion per year to meet the growing demand for electricity over the 20-year period between 2010 and 2030. Their estimate includes all types of investment in electrical transmission equipment, including conventional and smart-grid distribution and transmission systems. They do not specify what they consider as a likely breakdown between conventional and smart-grid systems within this overall investment agenda.

One consideration here is that the use of electricity generation from renewable sources often entails accessing energy from more remote locations where wind, sun, or tidal waves can be relatively intense. Making increased use of these new electrical generating sources will correspondingly increase demand for investment in transmission lines. Operating electricity generating systems through renewable energy sources will also entail an improved capacity for transmission systems to deal with the intermittent flow of energy coming from wind and solar sources. This is a key feature of smart grid systems. We would argue that it is reasonable to assume that roughly half—for instance, about $20 billion of the overall $44 billion in annual investments—will represent energy efficiency improvements and investments needed to support the growth of renewable energy generation.

Public transportation

Funds for public transportation will come entirely from the public sector, but some of these funds will come from state and local governments to match levels of support provided by the federal government. The ARRA allocates $23 billion for all transportation investments. This includes highways and other road projects in addition to public transportation, but does not specify the breakdown in spending levels between these two broad areas.

Given the environmental benefits of public transportation and the country's needs for improved services, it is reasonable to assume that roughly half of these funds are devoted to public transportation. If we also allow that state and local governments match this level of funding on a one-for-one basis, then overall public investment funding would total about $25 billion.[10] Spread out on an annual basis, this would mean $5 billion per year over the full span of the economic stimulus program. We also anticipate this level of funding for public transportation will extend beyond the life of ARRA itself as one feature of a broader clean-energy investment push in the United States. This would mean, in total, $5 billion in investment over the full 10-year period being considered.

Cogeneration

Energy cogeneration systems utilize the heat generated by industrial processes to generate electricity on-site. These systems therefore offer a significant means for utilizing available energy sources at higher levels of efficiency. These investments will thus be encouraged—along with other energy efficiency investments—through regulations that set a cap on carbon emissions and subsequent increases in conventional fossil fuel prices. The Energy Information Administration projects that investment in on-site cogeneration is expected to grow by about 40 percent between 2007 and 2030.[11] It is reasonable to expect that this will roughly entail an additional $5 billion in investment each year.

Renewable energy

Investments in renewable energy—wind, solar, biomass, geothermal, and hydroelectric power—will aim at advancing technologies to the point where they are fully cost-competitive with conventional fossil fuels, and to integrate these cost-competitive technologies into the U.S. economy's ongoing operations. This will also proceed across the range of markets in which renewable energy sources are viable, including on- and off-grid electricity generation, non-electricity forms of energy generation, and alternative fuels.

On-grid renewable energy

As we have discussed, it would require about $15 billion a year in renewable energy investments in order to reach the 15 percent renewable electricity standard by 2020 as stipulated in the current draft of ACESA. The renewable electricity standard would apply to electricity retailers who supply energy to residential, commercial, and industrial customers through the national distribution system—that is, "the grid."

But if the investments in renewable electricity were to grow more rapidly as technologies improve, then renewable energy sources could supply as much as 20 percent of total electricity as of 2020 to the electricity grid. To achieve this level of renewable electricity supply by 2020, it would entail new investments of about $30 billion per year over the next decade.

Off-grid renewable electricity

It is reasonable to anticipate a comparable growth in renewable energy investments for end-users of electrical power. This includes businesses and households who generate electricity off the grid for their own use from solar, wind, geothermal, and biomass sources. The EIA, for example, projects that end-use generation of electricity from renewable sources will grow at an annual rate of 6.5 percent from 2007 to 2030. This level of off-grid power generation using renewable energy would involve approximately $56 billion in investment over approximately 20 years, or about $3 billion a year.[12] This figure does not include any effects on investment levels from climate change legislation. The rate of investment would therefore likely increase further as a result of the range of incentives and regulations established by the ACESA.

Nonelectric renewable energy

Electricity represents only one form of renewable energy that final users can generate themselves. There are other forms of decentralized renewable energy production such as geothermal pumps, solar hot water systems and even wood-burning stoves, in which individual households and businesses alike could invest. If we assume that the investment in these non-electrical forms of energy production is roughly equivalent to investment in renewable electricity generation by end-users—as calculated by the EIA—then investment by final users would total about $3 billion per year.

Alternative fuels for motor vehicles

Biofuels from non-food sources—for example, cellulosic biofuels—that can be used for motor vehicle transportation represent another area of growing clean-energy investment. By 2020, the market for ethanol from a variety of sources is expected to be about 20 billion gallons per year.[13] To produce one-third of this quantity of ethanol from cellulosic sources by 2020, additional investment of about $50 billion would be needed over 10 years, or about $5 billion per year.[14]

Clean-energy investments can total $150 billion a year

We calculate that overall clean-energy investments in the United States that also promote job creation could reach $150 billion per year (see Table 3). This estimate is based, first, on implementation of public policies included in the economic stimulus program and

TABLE 3

Breakdown of $150 billion in potential annual U.S. clean-energy investment

Includes only clean-energy investment areas that expand job opportunities

Clean-energy investment area	Potential annual investment level
Energy efficiency	
Building retrofits	$80 billion
Smart grid	$20 billion
Public transportation	$5 billion
Cogeneration	$5 billion
Renewable energy	
On grid renewable electricity	$30 billion
Off grid renewable electricity	$3 billion
Off grid renewable—nonelectrical	$3 billion
Alternative motor fuels	$5 billion
Total	**$151 billion**

Source: See discussion in text.

ACESA, including as much as $56 billion per year in direct public spending and subsidies for private investors over the life of ARRA, which will encourage state and local government clean-energy programs and private-sector investments. We also allow for the strong possibility that accelerated private investment rates could occur as technologies advance and market structures develop, producing a cumulative, self-reinforcing process of innovation and market expansion. This self-reinforcing process would proceed primarily without relying on government subsidies. At the same time, achieving this kind of self-reinforcing investment momentum in clean energy is precisely the aim of the combined incentives advanced through ARRA and ACESA. It is through taking account of these various factors that we conclude that the overall level of clean-energy investments that will boost employment growth in the United States can be in the range of $150 billion annually.

Methodologies for estimating employment and GDP growth

The consequences of public policies on U.S. economic growth and employment growth necessarily happen over time. That's why we cannot know with certainty what the effects of policy will be. That's also why we rely on economic models and various forecasting techniques to generate estimates of what future outcomes are likely to be.

But there is a wide range of approaches to generating such estimates. Before proceeding with our discussions as to how policies within ARRA and ACESA are likely to affect future employment and gross domestic income growth, it is important to consider these methodological points in some detail.

First, we have developed an approach to estimating the employment effects of clean-energy investments that is, in our view, generally reliable. Our approach is reliable because it operates on the basis of very few assumptions and is firmly grounded in the detailed realities of the contemporary U.S. economy. Specifically, it is based on observing the current detailed industrial survey data of U.S. business activity.

From these survey figures, as organized by the U.S. Department of Commerce into its input-output model, we undertake a very simple set of exercises. We consider in today's economy how employment levels would change when we shift the proportions of overall spending on energy from high-carbon sources to clean-energy and energy efficiency.

In contrast with our approach, models that attempt to estimate the effects of environmental policies such as a carbon cap on GDP growth over the next 20-40 years rely on a much larger number of assumptions about the economy's future growth path. These forecasting models are thus highly sensitive to the assumptions on which the models are based.

We will demonstrate that these models are generally unreliable in predicting future GDP growth even in the short term—much less over two to four decades. At the same time, these more complex forecasting models do offer useful perspectives on how one should think about the effects of a given policy, such as a carbon cap, on GDP growth. We will detail below why we consider our model to be the best way to calculate the employment effects of shifting energy spending from high-carbon fuels to clean-energy investments, why we think the long-term GDP forecasting models are highly fragile and unreliable, but also why these models nevertheless offer perspectives that are broadly useful in assessing the effects of a carbon cap on GDP.

Our approach to estimating employment growth

Our employment estimates are figures generated directly from data from the Commerce Department's surveys of businesses within the United States, and organized systematically within their input-output model. Within the given structure of the current U.S. economy, these figures provide the most accurate evidence available as to what happens within private and public enterprises when they produce the economies' goods and services. The data help us and others know how many workers were hired to produce a given set of products or services, and what kinds of materials were purchased in the process. Our methodology is to work within this detailed survey evidence and data set and to pose simple questions.

Here's one example of how our methodology works (for a complete analysis, see Appendix 1 on page 48). If we spend an additional $1 million on building retrofits, how will businesses utilize that money to actually complete the retrofit project? How much of the $1 million will they spend on hiring workers, and how much will they spend on non-labor inputs, including materials, energy costs, and renting office space? And when businesses spend on non-labor inputs, what are the employment effects through giving orders to suppliers, such as lumber and glass producers or trucking companies?

We also ask the same questions within the oil industry. To produce $1 million worth of petroleum that can be sold to consumers at gas stations as a refined product, how many workers will need to be employed, and how much money will need to be spent on non-labor inputs? Through this approach, we have been able to make observations as to the potential job effects of alternative energy investment and spending strategies at a level of detail that is not available through any alternative approach.

Estimating employment gains and losses within the input-output model is possible because we are comparing the impact of total spending within clean-energy sectors and conventional fossil fuel sectors. In particular, we do not distinguish between investment and spending in creating new productive capacity as opposed to all other forms of spending within each sector. But there is an important distinction here to note with respect to the type of spending that will be predominant within clean-energy industries versus conventional fossil fuel industries. In the case of clean energy, virtually all the new spending will be devoted to investments to either promote energy efficiency or to expand renewable energy generating capacity. This is precisely because the existing level of productive capacity in energy efficiency and renewable energy remains tiny relative to the long-term needs.

In contrast, conventional fossil fuel industries spend on extracting, refining, transporting, and delivering retail supplies within an already mature and vast productive infrastructure. New investments to expand the fossil fuel productive infrastructure will therefore account for a much smaller proportion of total spending within the sector than will be the case with clean energy. To be sure, exploring for new sources of oil and gas frequently entail enormous amounts of up front investments—this is less the case with coal, where the location of huge deposits of existing reserves are well known. Once companies are ready to extract new fossil fuel supplies, high levels of up-front investments will again be required. Overall though, these activities will operate within a fossil fuel energy infrastructure that is already highly developed, so that the ability to deliver these newly developed energy supply sources to market can proceed without requiring large-scale new investments.

There are certainly weaknesses with our use of the input-output model. The most important are that it is a static model, a linear model, and a model that does not take into account structural changes in the economy. But these flaws in our approach need to be considered in the context of alternative approaches that operate with even more serious deficiencies. So let's first consider these points about the static model, the linear model and structural change.

Static model

We make estimates as though everything is happening at one fixed point in time. A more realistic picture of the economy would of course have to recognize that the effects of public- and private-sector spending will take place in sequences over time, and that these timing effects are important. Adding a time dimension would make the model "dynamic," in the technical jargon.

The problem here is how to incorporate a time dimension in an effective way. In principle, a dynamic model does offer a more complete picture than a static model as to how the economy operates overtime. But dynamic forecasting models are generally unreliable in their forecasts, as we detail below. We therefore think it is preferable to work within a simpler framework, and draw out assessments within this simple framework of how transitions affect the results eventually.

Linear model

Our model also assumes that a given amount of spending will have a proportionate effect on employment no matter how much the level of spending changes, either up or down. For example, the impact of spending $1 billion on an energy efficiency project will be exactly 1,000 times greater than spending only $1 million on the exact same project.

The most significant consequence here is that we take no account of potential supply constraints in moving from a $1 million project to a $1 billion project. Under some circumstances, this could be a serious deficiency in the model. But under current conditions in the U.S. economy—with widespread slack in the midst of a severe recession, unemployment and with private-sector lending and investment almost flat—we are on safe grounds with our assumption that supply constraints will not exert a major influence on how the spending on green recovery effects the economy. Supply constraints could create problems for our estimation methods if the U.S. economy begins to approach full employment. But the economy has not approached full employment since the late 1990s, and then only briefly. We will certainly have time to make appropriate adjustments in our model if and when the economy again begins moving toward full employment.

Another dimension of our assumption of linearity is that it assumes that prices remain fixed, regardless of changes in demand. Our model, for example, does not take account of the effects of prices of solar panels when demand for these panels falls due to the recession. Again, a more fully specified model would take account of such factors—that is, if the recession leads to reduced demand for solar panels then prices of the panels will fall, all else being equal. This means that for a given level of spending more panels will be purchased at lower prices per panel. The upshot for employment estimates is that a given level of spending on panels will likely mean that more jobs will get created to build, deliver, and install the panels. But here again, the forecasting record of more fully specified models that do attempt to incorporate such price effects is not encouraging.

Structural change

Our employment estimates are derived from the most recent 2007 input-output model of the U.S. economy, and reflect the industrial structure of the economy as of the most recent industrial surveys. But it is certainly the case that the U.S. industrial structure will be evolving over time. This issue would seem especially relevant in considering employment conditions within the clean-energy economy, since our economy will certainly undergo significant structural changes as technologies develop. How does this reality of structural change affect the reliability of our employment forecasts?

In fact, the use of workers in clean energy industries and services will not change at an equivalently rapid pace over time even though clean energy technologies will be advancing substantially. Consider this example: A high proportion of energy-efficiency investments—such as for building retrofits, public transportation, and smart grid electrical transmission systems—will heavily rely on the construction industry. Detailed aspects of the work involved in retrofitting a home, for example, will change as retrofitting methods develop. But the overall level of demand for workers to conduct retrofits—whatever are the detailed features of such projects—is likely to remain fairly stable.

A similar situation is likely to hold with the production of renewable energy, regardless of whether the solar panels, wind turbines, or biomass fuel refining plants are more or less efficient because of technologies that convert their raw materials into useful energy. That is, the need to employ workers to manufacture, transport, and install these newly developed renewable energy products is likely to remain fairly stable as a proportion of overall activity in the industry.

Overall, then, we are confident that our input-output framework provides the basis for as accurate a set of job estimates as can be obtained through the existing available models and modeling techniques.

Forecasting models for GDP growth

Models that forecast long-term GDP growth face much more difficult challenges than our simple framework for estimating employment effects from a shift from high-carbon fuels to clean energy investments within the existing economic structure. This is because the long-term forecasting models not only aim to describe the economy as it functions at present but attempt to predict how its operations will evolve into the future. This becomes difficult, as basic features of the economy's future growth path are simply unknowable at the time the forecasts are produced.

There is little dispute about the dismal record of economic forecasting models in estimating the economy's growth path even over the short term. In this regard, it is useful to recall two highly relevant and interrelated cases in point. Few, if any, economic forecasting models predicted that by June 2008 crude oil would be selling at $140 a barrel—including forecasts generated less than one year before crude hit that record mark.[15] Once the price of crude oil did rise to $140 a barrel, few forecasters then predicted that the price would collapse to $35 a barrel only six months later.

More generally, almost no economic forecasts predicted that the U.S. economy would enter into a recession of historic severity in December 2007. This includes even the forecasts that were published after the recession had already begun.[16]

One faces still greater difficulties in attempting to provide accurate forecasts over a long time period—such as 20 to 40 years—of the effects on economic growth of a carbon cap, such as that proposed in ACESA. This is because the impact of any carbon cap-and-trade initiative will depend, first of all, on the overall policy agenda focused on counteracting global climate change. The economic stimulus program, for example, includes about $100 billion in federal funds to advance energy efficiency and the commercialization of renewable sources of energy, and another $180 billion of incentives for state and local governments and private businesses to invest in clean-energy projects.

Policy measures on this large a scale will certainly accelerate energy efficiency measures and lower renewable energy prices such that they become increasingly competitive with high-carbon energy sources. But we cannot know in advance the pace of this process. We cannot know how long such supportive measures for energy efficiency and renewable energy will be forthcoming from government policy.

These considerations will be decisive in determining the impact of a carbon cap, and related measures, on economic growth.[17] In short, we cannot assume that models that attempt to assess the impact of a cap-and-trade policy on U.S. gross domestic product in 2030 or 2050 are reliable in terms of their GDP forecasts. This is certainly true when judged relative to our simple input-output framework for estimating the employment effects of shifting investment priorities from conventional fossil fuels to clean energy within a given economic structure. Our input-output framework enables us to observe in detail how any such shifts in investment priorities—even within a given overall economy and at a given level of GDP, without making any assumptions at all about the pace of GDP growth—can themselves produce significant changes in employment opportunities.

At the same time, these other forecasting exercises can still offer useful frameworks and perspectives for our efforts at assessing how a cap-and-trade policy or related policy interventions would impact economic growth. In the discussion beginning on page 40, we therefore consider the effects of a cap-and-trade program on GDP growth that draws on a range of existing forecasting exercises focused on this question.

Job creation through clean-energy investments

Spending money in any area of the U.S. economy will create jobs since people are needed to produce any good or service that the economy supplies. This is true regardless of whether the spending is done by private businesses, households, or a government entity. But spending directed toward a clean-energy investment program will have a much larger positive impact on jobs than spending in other areas, including the oil industry even when taking into account all phases of oil production, refining, transportation, and marketing.

Spending on clean energy will create a higher net source of job creation in the United States relative to spending the same amount of money on high-carbon fuels because of the three sources of job creation associated with any expansion of spending—direct, indirect, and induced effects. These three effects in, say, investments in home retrofitting and building wind turbines can be described in this way:

- **Direct effects.** The jobs created by retrofitting homes to make them more energy efficient, or building wind turbines.
- **Indirect effects.** The jobs associated with industries that supply intermediate goods for the building retrofits or wind turbines, such as lumber, steel, and transportation.
- **Induced effects.** The expansion of employment that results when people who are paid in the construction or steel industries spend the money they have earned from producing these immediate and intermediate goods for clean energy industries on other products in the economy.

Now let's consider how these various sources of job creation operate with respect to investments in both the clean-energy and conventional fossil fuels.

Direct and indirect job creation

Our analysis here begins with the U.S. industrial surveys and input-output tables we used for our models to generate results on direct and indirect job creation.[18] Table 4 shows the extent of direct and indirect job creation generated by $1 million in expenditures on producing alternative energy sources.[19] We present the total job creation figures as absolute

TABLE 4

Employment impacts of alternative energy sources

Job creation per $1 million in output

Energy source	Direct job creation per $1 million in output (# of jobs)	Indirect job creation per $1 million in output (# of jobs)	Direct and indirect job creation per $1 million in output (# of jobs)	Direct and indirect job creation relative to oil (% difference)
Fossil fuels				
Oil and natural gas	0.8	2.9	3.7	–
Coal	1.9	3.0	4.9	+32.4%
Energy efficiency				
Building retrofits	7.0	4.9	11.9	+221.6%
Mass transit/freight rail (90% MT, 10% FR)	11.0	4.9	15.9	+329.7%
Smart grid	4.3	4.6	8.9	+140.5%
Renewables				
Wind	4.6	4.9	9.5	+156.8%
Solar	5.4	4.4	9.8	+164.9%
Biomass	7.4	5.0	12.4	+235.1%

numbers of jobs as well as in relative terms, as a percentage of job growth relative to that generated by spending $1 million on oil and natural gas.

As the table shows, spending $1 million on energy efficiency and renewable energy produces a much larger expansion of employment than spending the same amount on fossil fuels or nuclear energy. Among fossil fuels, job creation in coal is about 32 percent greater than that for oil and natural gas.

The employment creation for energy efficiency—retrofitting and mass transit—is 2.5 times to four times larger than that for oil and natural gas. With renewable energy, the job creation ranges between 2.5 times to three times more than that for oil and gas.

Induced job creation

It is more difficult to estimate the size of the induced employment effects—or what is commonly termed the "consumption multiplier" within standard macroeconomic models—than to estimate direct and indirect effects. There are still aspects of the induced effects we can estimate with a high degree of confidence.

In particular, we have a good sense of what is termed the "consumption function," or what percentage of the additional money people receive from being newly employed will be spent. But it is more difficult to project accurately what the overall employment effects will always be of that extra spending.

First, the magnitude of the induced effect will depend on existing conditions in the economy. If unemployment is high, then this will mean that there are a large number of people able and willing to take jobs if new job opportunities open up. But if unemployment is low, then there will be less room for employment to expand—even if newly employed people have more money to spend.

Similarly, if there is slack in the economy's physical resources, then the capacity to expand employment will be greater—and the induced effects larger. If the economy is operating at a high level of activity, there is not likely to be a large employment gain beyond what resulted from the initial direct and indirect effects.

Given the rapid deterioration of economic conditions over the past 18 months—including rapidly rising rates of unemployment—the U.S. economy is not likely to bump up against this kind of capacity constraint in the near future. Thus we would expect the induced effects to be significant in the current climate. More generally, the U.S. economy has not come close to approximating a full employment economy since the late 1990s, and even then, the tight labor market conditions were sustained only briefly, until the dot.com stock market bubble burst. Consequently, it is unlikely that the induced effects of a direct and indirect employment expansion will be diminished by excessively tight labor markets in the future.

We have developed a formal model to estimate the broad magnitude of the induced employment effects more systematically. We present our procedure's details in Appendix 1 on page 48. The basic approach is straightforward: We begin by estimating how much of the additional employment income earned as a result of the increased investments is spent

TABLE 5

Total employment creation through alternative energy sources

Direct, indirect, and induced effects for $1 million in spending (induced jobs = 0.4(direct + indirect jobs))

Energy source	Total job creation	Total job creation relative to oil
Fossil fuels		
Oil and natural gas	5.2	---
Coal	6.9	+32.7%
Energy efficiency		
Building retrofits	16.7	+221.2%
Mass transit/freight rail (90% MT, 10% FR)	22.3	+328.8%
Smart grid	12.5	+140.4%
Renewables		
Wind	13.3	+155.8%
Solar	13.7	+163.5 %
Biomass	17.4	+234.6%

on household consumption. Using our basic input-output model, we estimate the number of jobs that this additional consumption spending would generate, assuming that there is ample excess capacity in the economy due to the prevailing high levels of unemployment.

Working with this model, we find that the level of induced job creation is about 40 percent of the level of direct plus indirect job creation. For this study, we therefore proceed under the assumption that induced jobs will expand overall job creation by 40 percent beyond what occurs through the direct plus indirect effects. We present figures for total job creation for all investment areas in Table 5. We can now see the total level of job creation through spending $1 million in each energy area. The range is between 5.2 jobs in the oil industry to 22.3 jobs in mass transit.

Overall job growth—clean-energy investments vs. conventional fossil fuels

We combine and summarize these results on overall job creation in Figure 1. This figure shows the total number of jobs—direct, indirect, and induced—that we estimate would be created from spending $1 million in a combination of six clean energy investment areas—three energy efficiency investment areas (building retrofits, public transportation and freight rail, and smart grid electrical transmission systems) and three renewable energy areas (solar power, wind power, and biomass fuels).[20]

This combination of clean-energy investments will generate about 16.7 jobs per $1 million in spending. As Figure 1 also shows, $1 million in spending within the fossil fuel industry, divided according to the actual proportions of spending in these sectors as of 2007 will generate 5.3 jobs in total.

Spending a given amount of money on a clean-energy investment agenda generates approximately 3.2 times the number of jobs within the United States as does spending the same amount of money within the fossil fuel sectors.

FIGURE 1

Job creation through $1 million in spending

Green investments vs. fossil fuels

Source: Input-Output tables of U.S. Commerce Department.

Note: Employment estimates include direct, indirect, and induced jobs. Details of calculations presented in appendix.

Sources of greater job expansion through clean-energy investments

Why does a combination of clean-energy investments create in excess of three times more jobs per a given amount of spending than the fossil fuel industry? Three factors are at work:

- **Relative labor intensity.** Relative to spending within the fossil fuel industries, the clean-energy program—including the direct spending on specific projects plus the indirect spending of purchasing supplies—utilizes far more of its overall investment budget on hiring people, and relatively less on acquiring machines, supplies, land (either on- or offshore) and energy itself.

- **Domestic content.** The clean-energy investment program—again, considering direct plus indirect spending—relies much more on economic activities taking place within the United States—such as retrofitting homes or upgrading the electrical grid system in communities throughout the country—and less on imports than spending within conventional fossil fuel sectors. We consider this issue in more detail below.

- **Pay levels.** Clean-energy investments produce far more jobs at all pay levels—higher as well as lower-paying jobs—than the fossil fuel industry. Clean-energy investments also produce more jobs for a given dollar of expenditure due to the larger number of entry-level jobs relative to the fossil fuel industry. Workers thus benefit through the expansion of job opportunities at all levels within the U.S. labor market. We also return to this issue below.

TABLE 6

Green investments and jobs

Major areas for green investment agenda	Representative jobs
Building retrofitting	Electricians, heating/air conditioning installers, carpenters, construction equipment operators, roofers, insulation workers, carpenter helpers, industrial truck drivers, construction managers, building inspectors.
Mass transit/freight rail	Civil engineers, rail track layers, electricians, welders, metal fabricators, engine assemblers, bus drivers, dispatchers, locomotive engineers, railroad conductors.
Smart grid	Computer software engineers, electrical engineers, electrical equipment assemblers, electrical equipment technicians, machinists, team assemblers, construction laborers, operating engineers, electrical power line installers and repairers.
Wind power	Environmental engineers, iron and steel workers, millwrights, sheet metal workers, machinists, electrical equipment assemblers, construction equipment operators, industrial truck drivers, industrial production managers, first-line production supervisors.
Solar power	Electrical engineers, electricians, industrial machinery mechanics, welders, metal fabricators, electrical equipment assemblers, construction equipment operators, installation helpers, laborers, construction managers.
Cellulosic biofuels	Chemical engineers, chemists, chemical equipment operators, chemical technicians, mixing and blending machine operators, agricultural workers, industrial truck drivers, farm product purchasers, agricultural and forestry supervisors, agricultural inspectors.

Source: See appendix.

Range of jobs generated by clean-energy investments

As Table 6 shows, building a clean-energy economy would create new job activities. Some of these jobs will be in specialized areas such as installing solar panels and researching new building material technologies. But the vast majority of jobs are in the same areas of employment that people already work in today—in every region and state of the country.

Constructing wind farms, for example, creates jobs for sheet metal workers, machinists and truck drivers, among others. Increasing the energy efficiency of buildings through retrofitting requires roofers, insulators and building inspectors, and expanding mass transit systems employs civil engineers, electricians, and dispatchers. More generally, this overall clean-energy investment program will provide a major boost to the construction and manufacturing sectors throughout the United States.

In addition, all of these clean-energy investment strategies engage a normal range of service and support activities—including accountants, lawyers, office clerks, human resource managers, cashiers, and retail sales people. We have not listed these and other related occupations in Table 6 because these jobs are not linked in any particular way to our six clean-energy investment strategies. But new employment opportunities will certainly also open up in these areas as a result of the clean-energy investment program, through all of the same direct, indirect, and induced job creation channels that are also generating the jobs we have listed in Table 6.

Then there's the range of jobs by occupational groupings created through clean-energy investments. In Table 7 we present data on the distribution of job types that are created

TABLE 7

Economic activity by energy-related sector

Figures are percentages of total jobs for each sector

Energy source	Extraction	Agriculture	Manufacturing	Construction	Utilities	Trade	Transport	Independent admin/ professional
Fossil fuels								
Oil and natural gas	14.6	0.4	13.9	2.4	11.3	6.6	13.1	37.5
Coal	41.6	0.3	13.1	0.9	7.8	5.9	6.8	23.6
Energy efficiency								
Building retrofits	0.5	1.4	13.6	61.5	0.1	7.9	2.5	12.4
Mass transit/freight rail	0.3	0.6	7.8	21.7	0.1	4.4	54.4	10.7
Smart grid	0.4	0.6	38.1	15.7	0.2	6.3	2.8	35.9
Renewables								
Wind	0.6	0.9	47.4	20.3	0.2	7.1	3.7	19.8
Solar	0.5	0.9	37.4	23.7	0.2	6.9	3.2	27.4
Biomass	1.3	60.4	20.6	0.4	0.2	3.8	2.8	10.5

Source: See appendix.

through alternative-energy spending programs. As the table shows, employment is spread fairly evenly in the oil industry across a range of sectors, including extraction, manufacturing, utilities, transport, and administrative and professional occupations, such as lawyers, accountants, and technical/scientific personnel. Coal, by contrast, is much more heavily concentrated in extraction, with nearly 42 percent of total value coming from extraction.

Of course, different parts of the clean-energy economy also generate different combinations of job creation. Building retrofitting is dominated by the construction industry, with some economic activity in manufacturing and professional services. In wind and solar power generation, the largest proportion of new jobs created will be in manufacturing, with construction second. Wind and solar also draw heavily on independent professionals, including research and development personnel.

The overall point is that for a clean-energy investment program to provide a range of new employment opportunities comparable to what is made available through the oil industry, it will be necessary to promote the full array of clean-energy initiatives. The range of job opportunities available within the oil industry cannot be duplicated by any single clean-energy activity alone.

Employment effects of $150 billion a year clean-energy investments

To consider how a clean-energy program can create major economy-wide impacts, we have to consider the issue within the context of the $150 billion in new clean-energy investments that we have discussed above. As we have seen above, this level of clean-energy investments can be achieved through the combination of spending programs, subsidies, and regulations included in the ARRA and ACESA, along with continued advances in clean-energy technologies and a corresponding expansion of private markets and business investment opportunities.

As we see in Table 8, an annual $150 billion clean-energy investment level would generate a total of about 2.5 million jobs. By contrast, spending the same $150 billion within the fossil-fuel industry would produce about 800,000 jobs. This is a difference of roughly 1.7 million jobs. In Appendix 2, we break out these economy-wide estimates for net employment expansion through clean-energy investments on a state-by-state basis.

It is not likely that the funds to finance $150 billion in clean-energy investments would all come out of equivalent spending reductions on fossil fuels. Nevertheless, we emphasize a crucial point by comparing the expansion in employment through $150 billion in clean-energy investment spending relative to an equivalent decline in fossil fuel spending—clean-energy investments will generate a large *net expansion* in employment even after allowing for a maximum transfer of funds out of fossil fuel spending.

TABLE 8

Impact of $150 billion in clean-energy investments on U.S. labor market

A) Overall employment expansion through $150 billion shift from fossil fuels to clean energy	
1) Job creation through $150 billion spending on clean energy.	2.5 million jobs
2) Job creation through $150 billion spending on fossil fuels.	795,000 jobs
3) Net job creation through shift to clean energy (row 1–2).	1.7 million jobs
B) Impact of clean energy job expansion on 2008 U.S. labor market	
1) Overall labor force.	154.3 million
2) Total employed before clean-energy investments.	145.4 million
3) Total unemployed before clean-energy investments.	8.9 million
4) Unemployment rate before clean-energy investments (= rows 3/1).	5.8% (=8.9 million/154.3 million)
5) Impact on total employment of shift from fossil fuels to clean energy.	Employment rises by 1.7 million jobs: 1.2% increase to 147.1million
6) Impact on unemployment rate of shift from fossil fuels to clean energy (= rows (3–5)/1)).	Unemployment falls from 5.8% to 4.7% (=7.2 million/154.3 million)

Source: U.S. Bureau of Labor Statistics and IMPLAN.

In the lower panel of Table 8, we then consider what the impact would have been on the 2008 U.S. labor market if there had been a net increase in employment of 1.7 million jobs. We know that, in reality, conditions in the labor market do not remain static, and that we are not describing what is actually likely to happen when we consider an immediate employment expansion. We present these data simply to provide a broad reference for gauging the impact of a net clean-energy investment transition—including reductions in fossil fuel spending—at the rate of about $150 billion per year.

Over the full year of 2008, there were 145.4 million people employed and 8.9 million unemployed, producing an unemployment rate for the year of 5.8 percent. A net increase of 1.7 million new jobs would therefore lower the unemployment rate to 4.7 percent.

This greater than one percentage-point reduction in the country's unemployment rate would generate a rise in wages across the board—particularly for low-income workers. According to the body of research surveyed by Timothy Bartik of the W.E. Upjohn Institute, a one percentage-point fall in the unemployment rate will in turn lead to a rise in average earnings of about two percent.[21] Bartik notes that this positive wage effect is likely to be somewhat stronger at the lower end of the labor market. This is probably because, other than the falling unemployment rate itself, those at the low end of the labor market are not likely to have other tools to help them raise their bargaining power.[22]

More jobs through low productivity, protectionism, and bad pay?

Some critics of our previous work comparing job growth in clean-energy industries and fossil fuel industries acknowledge—at least implicitly—that the clean-energy investments can be a positive source of job creation.[23] But they claim that the job expansion comes at a stiff price since it occurs through promoting low productivity, protectionism, and low wages. But, as we discuss below, these claims are wrong.

Low productivity is not the result of clean-energy investments

Let's begin with the critics' own framework for thinking about labor productivity, which is total output per worker. From this perspective, the matter is easy to settle, virtually as a matter of definition. By definition, if we increase labor intensity through clean-energy investments—if we generate about 17 jobs per $1 million through clean-energy investments versus about five jobs through fossil fuel spending—then we reduce labor productivity in the energy sector through shifting spending toward clean energy.

Yet this perspective ignores two crucial and widely understood considerations. First, by raising overall employment, clean-energy investments provide new opportunities to previously unemployed workers. This raises the productivity level of millions of workers from zero to a positive number. Any economy-wide measure of labor productivity has to take account of this effect. Similarly, clean-energy investments create new opportunities for underemployed workers—thereby raising their productivity from a lower to a higher level.

Second, given the global climate crisis, we need to begin incorporating environmental effects into the measurement of output and productivity. That is, spending on high-carbon fuels creates the output "good" of electrical power. But it also creates the output "bad" of pollution and greenhouse gas emissions. This point has long been recognized in discussions of the environmental costs of economic growth, and is included in virtually every introductory economics textbook. Thus, with every unit of energy generated by clean-energy investments as opposed to conventional fossil fuels, the net increase in output is greater to the extent that we are not producing the "bad" of pollution and greenhouse gas emissions.

This is why clean-energy investments will raise economy-wide labor productivity substantially through two channels:

- By expanding total employment per dollar of expenditure in the economy, it provides millions of people with new opportunities to become productive workers.
- By generating energy from clean sources, it increases the level of "goods" we produce and correspondingly reduces our production of "bads."

The critics' contention that clean-energy investments result in low productivity growth ignores this crucial set of considerations.

Clean-energy investments are not protectionist

The relatively high level of domestic content in clean-energy products and services is—along with relatively high labor intensity—a major factor generating the higher level of job creation relative to fossil fuels for a given level of spending. Yet it is crucial to recognize that the high domestic content for clean-energy products and services occurs

TABLE 9

Domestic content for alternative energy sources and energy-efficiency investments

Energy source	Domestic content as share of total industry output (in percentages)	Domestic content relative to oil (percentage-point difference)
Fossil fuels		
Oil and natural gas	82.9	
Coal	93.5	+10.6
Conservation		
Building retrofitting	97.3	+14.4
Mass transit/rail	96.7	+13.8
Smart grid	84.1	+1.2
Renewables		
Wind	87.8	+ 4.9
Solar	84.7	+1.8
Biomass	93.8	+10.9

Source: See appendix.

through the specific characteristics of the alternative investment activities spurred by clean-energy investments and will occur independent of any formal legal mandates regarding domestic content.

This becomes clear by considering the relative extent of economic activity provided by domestic sources for each of our specific energy sources. As Table 9 shows, there are major differences by energy sector in terms of their degree of domestic content. Oil and gas have the lowest relative domestic content, at around 83 percent of total value generated in producing this energy type. The domestic content of crude oil production, at about 50 percent of total crude oil sold in the United States, is much lower than for all other subsectors within the oil industry.[24] These other subsectors include the full range of administration, transportation, and marketing of crude and refined oil as well as natural gas—all activities that would be readily transferrable into a growing clean-energy sector.

The domestic content of coal production, at 94 percent, is significantly higher than the overall level for the oil industry. The three renewable energy sources operate with levels of domestic content roughly in line with the oil and coal sectors, with solar at 85 percent, wind at 88 percent, and biomass at 94 percent.[25] The smart grid is also in the same range, at around 84 percent. These are all areas where innovation in manufacturing clean-energy products and services will be central to raising domestic content.

The significant difference in domestic content occurs with retrofits, mass transit, and freight rail. In these cases, the level of domestic content is around 97 percent. For the most part this result is because these energy-efficiency investments are bound to specific locations. That is, retrofitting a home in Philadelphia can only be done in Philadelphia, and upgrading the Los Angeles electrical grid system will entail large-scale construction activity in Los Angeles. This is true even though some of the supplies for both the Philadelphia and Los Angeles projects could be imported. The point is that most of the spending on both projects will be on the local construction work itself, not the purchase of supplies.

By contrast, the more an energy sector is linked to manufacturing and extractive activity, the more it naturally becomes exposed to import competition. The United States is certainly capable of expanding its manufacturing capacity in areas such as wind turbines and solar panels. But unlike the retrofit case, where the bulk of the work is construction and that construction work must be performed on-site, there is no reason why a wind turbine needs to be manufactured within the United States.

Bad jobs are not the result of clean-energy investments

The single most important point to stress in evaluating the employment effects of clean-energy versus fossil fuel investments is that clean-energy spending creates far more jobs across all categories than spending on fossil fuels. We can see this clearly by considering the profile of jobs created according to the range of credential levels in clean-energy jobs versus those in the fossil fuel sectors. This discussion is based on a companion study we have conducted under commission with the Natural Resources Defense Council and Green For All, "Green Prosperity: How Clean-Energy Policies Can Fight Poverty and Raise Living Standards in the United States."[26] A fuller treatment on this and related questions is presented in this NRDC/Green For All study on page 12.

Working from that study, we provide evidence on this type of job breakdown in Table 10, where we sort the total number of jobs generated by $1 million in spending according to three job credential categories:

- High-credentialed jobs requiring at least a bachelor's degree and paying on average $24.50 an hour.
- Mid-credentialed jobs requiring some college but not a B.A. and paying on average $14.60 per hour.
- Low-credentialed jobs requiring a high school degree or less and paying on average $12.00 per hour.

We show these breakdowns both for clean-energy investments and fossil fuel investments and show the difference between the two based on all three of these categories. We also include as our final category the low-credentialed jobs that offer decent opportunities for advancement and higher wages over time. These are jobs in construction, manufacturing, and transportation.

TABLE 10

Breakdown of job creation through green investments versus fossil fuels by formal credential levels

Based on $1 million of spending

	1) Green investments	2) Fossil fuels	3) Difference in job creation (= column 1–2)
Total job creation	16.7	5.3	11.4
High-credentialed jobs • B.A. or above • $24.50 average wage	3.9 (23.3% of green investment jobs)	1.5 (28.3% of fossil fuel jobs)	2.4
Mid-credentialed jobs • Some college but not B.A. • $14.60 average wage	4.8 (28.7% of green investment jobs)	1.6 (30.2% of fossil fuel jobs)	3.2
Low-credentialed jobs • High school degree or less • $12.00 average wage	8.0 (47.9% of green investment jobs	2.2 (41.5% of fossil fuel jobs)	5.8
Note: Low-credentialed jobs with decent earnings potential • $15.00 average wage	4.8 (28.7% of green investment jobs)	0.7 (13.2% of fossil fuel jobs)	4.1

Note: Average wage is the median wage for all workers across all industries within each of the credential categories listed above.
Source: 2008 Current Population Survey, IMPLAN.

To begin with, we can see in Table 10 that the net job creation is substantially higher with clean-energy investments than conventional fossil fuels across all three credential categories. This is true even while the proportions of jobs created in the different categories differ. As a case in point, about 23 percent of the total clean-energy jobs created by investments in this sector are high credentialed compared to 28 percent in fossil fuel sectors, but clean-energy investments create 2.5 times more high-credentialed jobs.

Clean-energy investments also create three times more mid-credentialed jobs, but again the proportion of mid-credentialed jobs for fossil fuel spending, at 30.2 percent, is higher than with clean-energy investments. The most substantial difference is with low-credentialed jobs. Clean-energy investments create 7.7 jobs per $1 million in spending versus only 2.2 jobs per $1 million with fossil fuels. This is a difference of 5.5 jobs for low-credentialed workers.

What's more, these more numerous low-credentialed jobs resulting from clean-energy investments by and large lead to greater possibilities for advancement. In particular, industries in which low-income workers are better able to achieve decent earnings growth include construction first of all, but also durable goods manufacturing, employment services (temporary employment agencies), health services, public administration, social services, transportation and utilities, and wholesale trade. Workers employed in industries such as apparel and textile manufacturing, hotels, personal services (dry cleaning service), and restaurants and bars have far less opportunity to improve their earnings over time.[27]

What about job advancement opportunities in fossil fuel industries? In the final row of Table 10 we provide data comparing the clean-energy and fossil fuel investments in terms of the numbers of low-credentialed jobs they create with decent longer-term employment opportunities. The difference is particularly sharp. Clean-energy investments create 4.8 jobs per $1 million in spending while fossil fuel investments produce only 0.7 jobs. This is in the job category that is likely to be most crucial for generating decent new employment opportunities for low-income people through clean-energy investments under the economic stimulus program and American Clean Energy and Security Act now before Congress.

The overall message is that clean-energy investments offer a more favorable result for working people in the United States according to any criteria. There are more jobs created across the board—twice as many high-paying jobs and nearly four times more low-credentialed and low-paying jobs.

Forecasting the impact of a carbon cap on economic growth

The impact of the environmental regulations in ACESA, in particular the new cap-and-trade system, will produce higher prices over time for anyone using oil, coal, and natural gas. How much higher and how fast these prices will rise is uncertain.

Nor can we know in advance how much any increases in fossil fuel prices will affect the economy's overall performance over time. Offsetting savings from lower-cost, clean-energy and efficiency measures will, at worst, take much of the sting out of the price increases and at best reduce overall costs. Furthermore, increased U.S. competitiveness in growing clean-energy industries as conventional fossil fuels become less important will also improve U.S. economic conditions.

Taking all of these and related considerations into account, it is crucial to try to reach an overall assessment as to how the rise in fossil fuel prices will affect the economy's growth trajectory. This is true even though—as discussed above—the standard long-term growth forecasting models are fraught with serious pitfalls. It is nevertheless important to try to extract as much useful information as possible from these models.

The basic question that these models attempt to answer is: how much would a given energy price increase affect GDP growth? All the forecasts agree that this first depends on how large the price increases will be. It then also depends on the "elasticities"—how much the demand for a given source of energy would fall as the price of that energy source rises. For example, how much purchasing gasoline at the pump would fall when the price of gasoline rises.

The forecasting models that are calibrated to the Department of Energy's most recent (2009) *Annual Energy Outlook* predict that price increases that would be associated with a carbon cap such as that proposed within the ACESA will range from roughly 10 percent for gasoline to 20 percent for electricity and 29 percent for natural gas.

The Department of Energy model, however, also allows for increases in energy efficiency as well as rising consumption of clean-energy sources in response to the rise of fossil fuel prices. So even if gasoline prices are assumed to rise by 10 percent in a forecasting model, the amount of money people will spend on gasoline will not also rise by 10 percent but by something less. This is partly because people will respond to the 10-percent price increase by conserving on energy or shifting to clean-energy sources, where prices will tend to be falling due to technological advances. With all this in mind, let's examine several different forecasts.

Long-run GDP growth forecasts

The general approach with these exercises is to generate two long-term growth projections. The first is a baseline case in which the economy is operating without a carbon cap over the time period in question. The second is a projection in which a carbon cap-and-trade system has been in operation during the relevant time period.

Most of these forecasts are responding to the carbon cap proposal debated last year in Congress, which was the so-called Lieberman-Warner bill, named after its co-sponsors Sens. Joseph Lieberman (I-CT) and (the now retired) John Warner (R-VA). Because the cap-and-trade component of ACESA is similar to that of Lieberman-Warner, these previous forecasting exercises remain useful in assessing the effects of this more recent cap-and-trade proposal.

In addition, the Environmental Protection Agency recently produced two long-term forecasts of the effects on economic growth of the ACESA carbon cap proposal. We compare these most recent forecasts with those generated in response to Lieberman-Warner in Table 11.[28]

In considering first the forecasts of Lieberman-Warner in the upper panel of Table 11, one central finding stands out above all: According to *all* the forecasts—including the worst-case scenario developed by the most pessimistic forecasters, the American Council

TABLE 11

Comparison of alternative U.S. GDP growth forecasts under baseline scenario and with cap and trade

Figures are average annual growth rate forecasts for specified time periods

	1) Baseline GDP forecast	2) GDP forecast under Lieberman-Warner cap and trade	3) Difference between baseline and cap-and-trade growth forecasts (columns 1-2)
A) Forecasts based on Lieberman-Warner cap and trade			
MIT (2005 to 2050)	2.94%	2.93%	0.01%
Energy Information Administration (2005 to 2030)	2.47%	2.45%	0.02%
Clean Air Task Force (2005 to 2030)	2.89%	2.86%	0.03%
Environmental Protection Agency (2005 to 2050)	2.78%	2.72%	0.06%
ACCF/NAM—"High Cost Case" (2007 to 2030)	2.56%	2.45%	0.11%
B) Forecasts based on ACESA cap-and-trade			
EPA-1 (ADAGE model—2015–50)	2.41%	2.36%	0.05%
EPA-2 (IGEM model—2015–50)	2.35%	2.30%	0.05%

Source: References for models are all at Pew Center on Global Climate Change, "Insights from Modeling Analyses of the Lieberman-Warner Climate Security Act (S. 2191): (May 2008) available at http://www.pewclimate.org/docUploads/L-W-Modeling.pdf; Environmental Protection Agency, *EPA Preliminary Analysis of the Waxman-Markey Discussion Draft:* (April 20, 2009) available at www.epa.gov/climatechange/economics/pdfs/WM-Analysis.pdf.

on Capital Formation/National Association of Manufacturers—the impact of a cap-and-trade system on U.S. GDP growth will be negligible. According to most forecasts, it will be almost indiscernible.

The differences in the forecasts of long-term average annual GDP growth range between 0.01 percent using the model developed by the Massachusetts Institute of Technology and 0.11 percent using the ACCF/NAM model. Even with the most pessimistic ACCF/NAM model, the impact of the carbon cap on economic growth amounts to a difference in average growth of between 2.6 percent per year when no carbon cap is in place versus 2.5 percent with a carbon cap in operation. Even assuming this most severe negative effect of a carbon cap on economic growth, it would still only require, over the course of 23 years, an additional 14 months for the U.S. economy to reach the same level of GDP under a carbon cap as against the baseline scenario.

The lower panel of Table 11 shows two separate forecasts from EPA based on ACESA specifically. The main difference between these forecasts and those for Lieberman-Warner is the general shifting downward of growth projections. Thus in the top panel of the table, the EPA's own forecasts with reference to the Lieberman-Warner proposal had ranged between 2.78 percent average annual growth under their baseline case versus 2.72 percent under a carbon cap—a difference of only 0.06 percent in average annual growth.

EPA's two forecasts both estimate a significant drop in the baseline growth rate, with the two forecasts at 2.35 percent and 2.41 percent. But these two forecasts also show a slightly smaller impact of the carbon cap itself relative to the baseline, with the growth decline due to the carbon cap now forecasted at 0.05 percent relative to the baseline.

Overall, then, these most recent EPA forecasts of the ACESA's impact on economic growth affirm the earlier conclusions of the forecasts derived from Lieberman-Warner—that a carbon cap will have no significant effect on the U.S. economy's long-term growth trajectory. These forecasts may all be wrong, but it is still notable that this is the overarching conclusion that emerges from these modeling exercises, without exception.

This basic finding is even more notable given that these models all leave out significant considerations that would tend to encourage the long-term growth rate to rise. These basic considerations include:

- The positive effects of higher employment.
- The benefits of a higher level of domestic content and thus a reduced trade deficit.
- The possibilities for major technological breakthroughs.
- The economic benefits of reducing greenhouse gas emissions.

Let's consider in turn each of these possible beneficial results that could derive from a $150 billion annual clean-energy investment program.

Benefits of higher employment

The forecasting models we are considering here—like many macroeconomic models developed over the past 20 years—assume that the economy is always operating at full employment.[29] These models do allow for people to make choices between working and leisure activities, but all within the framework of a full-employment economy.

This means that if people are out of work, it is because they have voluntarily chosen leisure over having a job. Thus, by assumption within these models, no benefits can result from an expansion of employment opportunities—no matter what is the source of this employment expansion. This is because, according to these models, everyone who wants to be employed is in fact always employed.

In contrast, we have shown that clean-energy investments will generate an expansion of job opportunities through direct plus indirect employment-creation channels. Because we do not assume that the economy operates at full employment, this expansion of job opportunities through the clean-energy investment agenda will produce a net increase of employment throughout the economy. More people will have jobs as well as additional money to spend.

When these newly employed workers increase their level of spending, this in turn creates more jobs through the induced-employment effect. The consequent fall in the unemployment rate should, in turn, encourage rising wages throughout the economy, which should expand overall market demand in the economy still further. Through this combination of channels that lead to lower unemployment, clean-energy investments will be supportive of a higher overall rate of economic growth.

Clean-energy investments and the trade deficit

The persistent gap between the total amount of imports we purchase and the exports we sell abroad now amounts to roughly 6 percent of U.S. GDP. This trade deficit is being financed by foreigners piling up their holdings of dollar assets. This in turn has become a major factor contributing to the instability of U.S. and global financial markets.

Clean-energy investments will almost certainly advance in conjunction with a decline in fossil fuel consumption, which in turn will lead to a reduction in the huge levels of spending the United States now devotes to oil imports. As of 2007, the last year before the onset of the financial crisis and recession, oil imports amounted to about $300 billion per year, or roughly half of total U.S. spending on fossil fuels. This level of spending on oil imports also accounted for 36 percent of the total U.S. trade deficit of $819 billion as of 2007. Overall, then, the net effects of clean-energy investments on the U.S. balance of trade will certainly be favorable. How soon, and to what degree, these positive effects on the U.S.

trade balance will emerge will depend on how quickly clean-energy elements of the economic stimulus package and the entirety of ACESA encourage clean-energy development and displace high-carbon fuels as an energy source.

Reducing the U.S. trade deficit through cutting oil imports means, by definition, a higher proportion of spending by U.S. households, businesses, and governments will happen within the domestic U.S. economy. This promotes faster U.S. GDP growth. Moreover, reducing the trade deficit will, in turn, contribute toward a more stable value of the dollar in international currency markets, and thereby facilitate the management of U.S. monetary policy. This should also contribute toward a faster rate of U.S. GDP growth. To achieve these benefits of a smaller trade deficit, moreover, will not require that the deficit be closed entirely and right away. The fact that the deficit is diminishing steadily over time will itself generate incremental benefits to the U.S. economy.

Furthermore, the introduction of ever-increasing quantities of clean energy and energy efficiency helps lower costs and decrease price volatility in the economy overall by diversifying the U.S. energy mix and reducing our susceptibility to volatile price fluctuations for primary fossil fuel commodities.

Incorporating the effects of technological change

EPA and related models build in assumptions as to how technological changes will affect energy prices over time. It is impossible to know how quickly the prices of, say, cellulosic biomass, wind, and solar energy will decline with time as technologies advance. But if the United States continues to increase its commitment to advancing these technologies through measures contained in ARRA and ACESA, then the opportunities will increase and renewable energy prices could fall faster than these models are forecasting.

Once government policies help create a supportive environment for introducing and commercializing new renewable energy technologies, this should accelerate the investment market for these clean sources of energy. An expanding market also then will raise the likelihood for larger jumps in technological change beyond the incremental pace of improvement built into standard long-term GDP forecasting models.

The potential for underestimating the effects of technological change is increased further because these models assume that households and businesses operate with full knowledge of how the economy will operate over time; the models assume "perfect foresight" on the part of households and businesses. Indeed, the models assume not only that we can accurately know the trajectory of technological change in the energy industry but also how households and businesses will react to these changes.

These models therefore leave aside by assumption the real possibility that energy technologies will improve quickly and produce a stronger positive expansion in employment than households or businesses operating in the models with "perfect foresight" could have anticipated.

Overall, then, we again see how changes in the policy environment as well as a rising level of public commitment to building a clean-energy economy can themselves generate positive pressures for an accelerated rate of technological improvements. These improvements, in turn, could contribute to a faster rate of GDP growth than the forecasting models are anticipating. The pace at which businesses and households invest in these efficiencies will depend on the success of ARRA and ACESA.

Benefits of lower carbon emissions

The main purpose of the forecasting models we have discussed above is to estimate the future costs of a carbon cap. But these models do not attempt to estimate any potential economic benefits accruing from the carbon cap or related policy interventions. In fact, it is difficult to quantify the economic benefits of insuring against climate change, even while we know that such benefits are potentially enormous.

Most climate scientists hold that global warming is contributing throughout the world to extreme weather patterns, a rising sea level, and significant shifts in many ecosystems. These patterns will intensify as long as we fail to limit carbon emissions.

Disruptions of normal economic activities will increase correspondingly. Economic welfare will decline as a result. This is certainly true in terms of an increase in environmental "bads," many of which—such as a rising sea level and destroying natural habitats for species—are not captured through traditional GDP statistics. But some of these negative effects are incorporated in GDP. One case in point is that costs of hurricane damages are included as part of GDP. Also included in GDP will be the costs that are already emerging (and will worsen over time) of managing water systems in arid Western states as droughts become more frequent and severe.[30]

Of course, the most important consideration here is to recognize the overall welfare costs, and especially the real dangers of an irreversible environmental crisis that could result through allowing carbon emissions to continue unchecked. These considerations transcend the issue of whether such costs and risks are captured within our conventional GDP statistics.

Still, considering models that attempt only to forecast future GDP, leaving broader welfare considerations outside the model, the benefits of controlling carbon emissions will be measureable and significant. Neglecting all such benefits means that future GDP forecasts—the baseline forecasts as well as those that allow for a carbon cap mandate—are likely to be understated.

Conclusion

The United States needs to promote an aggressive policy agenda now to defeat global warming. This fact is now widely if not universally recognized. The overarching challenge before us is therefore to determine a policy path that is effective in building a clean-energy economy as rapidly as possible and in promoting widespread employment opportunities and broadly shared well-being. The current severe recession has only intensified the need to pursue such a unified program that can both promote job creation and build a clean-energy economy.

The recently enacted American Recovery and Reinvestment Act and the proposed American Clean Energy and Security Act that Congress is now considering are both federal policy initiatives aimed at creating a clean-energy foundation for the U.S. economy. The two measures are distinct. The ARRA is a $787 billion spending program designed to counteract the recession, which includes clean-energy components as one tool among several others to stimulate job creation and economic growth. These components include both direct federal spending provisions as well as subsidies for private investors.

In contrast, ACESA will operate primarily by establishing regulations and incentives for private businesses to encourage energy efficiency and investments in renewable energy, and correspondingly discourage continued reliance on high-carbon energy sources. Among its main provisions are a carbon cap-and-trade program that would be phased in through 2050, and a renewable energy electricity standard that would be phased in through 2020.

The specific features of ARRA and ACESA complement each other. In this paper we have demonstrated how the two measures work in combination to advance clean-energy investments and the transition to a clean-energy economy. Specifically, we examined the effect these two measures are likely to have on job creation and economic growth. We conclude that these two measures operating effectively as a complementary set of policy initiatives, in conjunction with related initiatives both at the state and local government level and especially by private investors, could produce over the next decade about $150 billion a year in clean-energy investments that also expand job opportunities. The net expansion in employment through this combination of initiatives could be about 1.7 million jobs.

This $150 billion a year includes public spending and private investments. Within the private sector, it would include projects that are both supported by government subsidies of some sort as well as unsubsidized investments. We anticipate that the largest share of an overall $150 billion annual spending level would be unsubsidized private investments that are nevertheless encouraged by the expansion of markets and opportunities encouraged by ARRA and ACESA.

Our central finding on employment growth is that a combination of clean-energy investments—including building retrofits, public transportation, and constructing a smart grid, as well as promoting renewable energy sources such as wind, solar, and biomass power—will generate roughly three times more jobs than an equivalent amount of money spent on conventional fossil fuels. So if the United States proceeds with combined public- and private-sector investments in clean energy amounting to $150 billion a year, this would generate about 2.5 million jobs. In contrast, spending the same $150 billion within the fossil fuel sector generates about 800,000 jobs. Therefore, the net impact—jobs gained through expanding clean-energy investments by $150 billion minus jobs lost through reducing spending on fossil fuels by the same amount—would be a net gain of 1.7 million new jobs within the U.S. economy.

This expansion of job opportunities would occur strictly as a result of the shift in spending of a given $150 billion in favor of clean energy and away from fossil fuels. It will not be necessary for U.S. GDP to grow more quickly in order for these positive job effects to emerge through a clean-energy investment agenda.

Our overall conclusions are therefore that the clean-energy components of ARRA and ACESA will have significant economic benefits aside from the contributions they will make to reducing carbon emissions and combating global warming. The most important and most clearly established economic benefit is that clean-energy investments will be a substantial source of new employment opportunities throughout the United States.

Forecasting the impact of these measures on long-run economic growth is fraught with difficulties. But it is still useful to highlight the fact that all the models that attempt such forecasts find that any possible negative impacts of a carbon cap on economic growth will be minimal. It is also important to recognize that these models reach this common conclusion even though they do not take account of several channels through which the project of building a clean-energy economy will promote a wide range of new job opportunities and the broader expansion of well-being in the United States.

Appendix 1: Technical methods

Environmental investment in the ARRA

Estimating the overall level of environmental spending

The American Recovery and Reinvestment Act of 2009 contains funding for a number of environmental programs through various departments and agencies within the federal government. Estimates of clean-energy spending in the ARRA vary widely—depending on whether only funding through the Department of Energy is considered or whether a broader approach is taken. We have pursued the latter.

Our estimate of approximately $100 billion in environmental spending is derived by identifying and summing all of the programs in the ARRA which fall under the DOE, as well as any program in other departments and agencies (such as the Department of Transportation, the Environmental Protection Agency, the Department of Housing, the Treasury Department, etc.) that contains funding for energy efficiency, renewable energy, public transit, high-speed rail, and environmental management. Specifically, in addition to the DOE programs, our $100 billion estimate of environmental investments contains the following programs:

Government:	Building retrofits and efficient fleet procurement
Outdoors:	Conservation, national parks, environmental clean-up and wildfire management
Military:	Defense energy conservation projects
Veterans:	Energy efficiency in buildings
Transportation:	Amtrak, high-speed rail, and public transit improvements
Housing:	Energy efficiency on Indian lands, and energy efficiency and renewable energy for low-income housing
Tax provisions:	All tax incentives related to energy efficiency and renewable energy

Financial mechanisms for allocating federal funds

The roughly $100 billion of environment investments identified above are allocated according to various financial mechanisms. These include direct spending by the federal government (for efficient fleet procurement, for example), as well as grants, loan guarantees, bonds, and tax incentives. Each of these mechanisms, in turn, targets certain populations (local governments, private investors) and will induce additional spending by those populations.

In order to obtain a rough estimate of the level of funds likely to be spent by these entities in addition to the federal funds, we first identified the funding mechanism within the text of the ARRA. We then used a variety of websites (see below) to ascertain whether there were matching requirements or estimates of leveraged funds through the ARRA programs. For example, residential renewable energy property is eligible for a 30 percent tax credit. Thus for the total cost of the project, the federal government will pay 30 percent and the private investor will pay 70 percent, or 2.33 times the value of the federal funds. Therefore this credit, which amounts to $268 million of federal funding, will raise an additional $625 million in private funding for a total of $893 million economy-wide.

In order to ascertain the types of programs and the level of matching required, we consulted documents provided to us by the Department of Energy as well as the following sites:

www.grants.gov
www.dsireusa.org
www.staterecovery.org
www.treasury.gov/recovery
www.irs.gov
www.fms.treas.gov
www.dot.gov/recovery
Edocket.access.gpo.gov
www.epa.gov
www.fra.dot.gov
www.recovery.gov
www.cbo.gov
www.ustreas.gov/recovery

Assessment of new investment in electricity generation capacity to meet the revised 15-percent renewable energy standard in the ACESA

We base our analysis on two recent publications from the Energy Information Administration (U.S. Department of Energy): *Annual Energy Outlook 2009 (AEO 2009) and Assumptions to the Annual Energy Outlook 2009*. At the time of this writing, the ACESA would require that 15 percent of electricity generation would come from renewable sources by 2020. We use the projections of future electricity generation contained in AEO 2009, based on the Department of Energy's National Energy Modeling System, or NEMS, as the basis for our estimates of the dollar value of investments needed to comply with these standards.

According to the AEO 2009, electricity generation will total 4,618 billion kilowatt hours, or kwhs in 2020. If electricity generation from renewable sources were to meet the ACESA standard in 2020, 692 kwhs would have to come from renewable sources. We need to convert this amount of electricity generation into a measurement of capacity needed. Based on the estimates in AEO 2009, we estimate that on average across renewable sources of electricity, 0.2 gigawatts in capacity (net summer capacity) is associated with every 1 billion kwhs in generation. We use this ratio to calculate the shortfall in renewable capacity. Using this assumption, about 153.8 gigawatts in renewable capacity would be needed to generate 692 kwhs of electricity. According to AEO 2009, in 2007 renewable generation capacity was 100.8 gigawatts. Therefore, we would need an additional 53 gigawatts in renewable capacity to meet the 15-percent standard by 2020.

The publication *Assumptions to the Annual Energy Outlook 2009* provides estimates of the overnight capital cost of different sources of electricity generation. Using the actual composition of renewable energy from various sources contained in the AEO 2009, we calculate that a weighted average of the cost of capital would be $2,750 in 2007 dollars per kilowatt of capacity. For the purposes of our estimations we round this up to $2,800 per kilowatt of capacity. This means that the total additional investment needed to reach the 15-percent standard would be about $148 billion by 2020.

If the U.S. economy were able to achieve a goal of 20 percent renewable electricity by 2020, we estimate that the total capacity needed at that time would be 205 gigawatts—or an increase of 104.2 gigawatts over the 2007 level. This would require about $292 billion in investment.

Employment estimates

Employment multipliers

Data and methodology The employment estimates in this report are derived from an input-output model. The input-output model allows us to observe relationships between different industries in the production of goods and services. We can also observe relationships between consumers of goods and services, including households and governments, and the various producing industries. For our purposes specifically, the input-output modeling approach enables us to estimate the effects on employment resulting from an increase in final demand for the products of a given industry. For example, we can estimate the number of jobs directly created in the construction industry for each $1 million of spending on construction. We can also estimate the jobs that are indirectly created in other industries through the $1 million in spending on construction—industries such as lumber and hardware. Overall, the input-output model allows us to estimate the economy-wide employment results from a given level of spending.

For this report, we used the IMPLAN 2.0 software and IMPLAN 2007 data set constructed by the Minnesota IMPLAN Group, Inc. This data provides 440-industry level detail and is based on the Bureau of Economic Analysis input-output tables.

Using IMPLAN to estimate direct and indirect effects in energy industries

To perform the kind of employment analysis featured in this report we needed to match the various energy spending categories with the industrial categories in the IMPLAN data set in order to calculate employment multipliers. IMPLAN's data is based on the Bureau of

Economic Analysis input-output tables. The BEA, in turn, organizes industries according to the North American Industrial Classification System, or NAICS. This system unfortunately does not identify energy industries as such. While certain industries such as oil and gas extraction or coal mining are identified in the tables, others such as wind and solar are not. Furthermore, the oil and gas industry does not consist solely of extraction but also of research, manufacturing, and distribution. Therefore for both identified and unidentified energy industries we must make certain assumptions in using the input-output tables to study output and employment.

For each energy strategy, we identified the industries most relevant to the strategy and assigned weights for the share of that industry within the energy strategy. These weights were chosen based on various industry journals and energy reports, as well as our best judgment when information was unavailable. So, for example, we defined the coal industry as 44 percent coal extraction, 8 percent support activities for coal mining, and 48 percent coal products manufacturing. In this way we were able to use weighted averages of the figures in the output and employment tables to generate estimates of output and employment in the coal industry, given a certain level of demand for that industry's product. In order to ensure that our employment estimates for each energy strategy were not driven primarily by the weights we assigned, we ran the model with various alternative weighting schemes and found that the results were in fact quite robust and varied only slightly even when weights changed quite drastically. The final weights that we selected for each energy strategy are listed at the end of this section.

In order to be able to compare employment estimates between various energy strategies, we needed a common metric to use as a basis for comparison. We chose to compare job estimates in relation to a given amount of spending rather than a given amount of energy production. So for instance we compare the employment estimates in solar energy versus coal by showing how the same level of spending in each category results in a certain number of jobs. The alternative, which is to show how many jobs are supported by a given level of energy production, would produce inflated estimates in industries with high energy costs. If we had used a given level of BTUs as the basis for comparison, then the number of jobs needed to produce a given level of BTUs in solar would be very high compared to the number of jobs needed to produce that level of energy production through coal. This would have simply been due to the fact that the cost per BTU for solar power is still much higher than the cost per BTU of coal. Therefore we chose to compare the number of jobs created by a given level of spending, which is not sensitive to the current prices of these various energy sources and technologies.

Energy industries—sectors and weights

Biomass

25 percent	grain farming
25 percent	logging
25 percent	other new construction
12.5 percent	refining
12.5 percent	scientific R&D

Building weatherization

50 percent	nonresidential repair construction
50 percent	residential repair construction

Coal

44 percent	coal mining
08 percent	support activities for coal mining
48 percent	coal product manufacturing

Oil and gas

23 percent	oil and gas extraction
07 percent	drilling oil and gas wells
04 percent	support activities for oil and gas extraction
10 percent	natural gas distribution
45 percent	petroleum refineries
08 percent	petroleum product manufacturing
03 percent	pipeline transport

Smart grid

25 percent	construction
25 percent	machinery
25 percent	electronic equipment
12.5 percent	electrical power goods
12.5 percent	storage batteries

Solar

30 percent	construction
17.5 percent	hardware manufacturing
17.5 percent	electrical equipment
17.5 percent	electronic components
17.5 percent	scientific and technical services

Transit and rail

45 percent	other construction
10 percent	rail transportation
45 percent	ground passenger transportation

Wind

26 percent	construction
12 percent	plastic products
12 percent	fabricated metal
37 percent	machinery
03 percent	mechanical power transmission equipment
03 percent	electronic components
07 percent	scientific and technical services

"Green program"

40 percent	building weatherization
20 percent	transit and rail
10 percent	smart grid
10 percent	wind
10 percent	solar
10 percent	biomass

Induced effects

Induced effects refer to the additional employment, output, and value added that is produced when the additional employment income generated by an initial demand stimulus—as captured by the direct and indirect effects—is spent. The magnitude of the induced effects depends on how the additional employment income translates into household expenditures and the size of the multiplier effects associated with the increase in household spending.

Induced effects are often estimated by endogenizing the household sector in the input-output model. The assumption is that increases in employee compensation (or value added) finance greater household spending, as reflected in the vector of household consumption in overall final demand. The endogenous household model often yields very large induced effects, in part because the propensity to consume out of employee compensation (or value added) implicit in the endogenous household input-output model is large.

Instead of relying on the consumption function that is implicit in the input-output accounts, we estimate the relationship between real gross employee compensation and real personal consumption expenditures econometrically using a dynamic empirical model. This gives us a more accurate sense of how household consumption responds to changes in employee compensation. We then integrate this estimated relationship into our basic input-output model to calculate induced effects.

The first step of the process is to estimate the relationship between personal consumption expenditures and employee compensation. To do this, we begin with the following dynamic empirical model:

$$C_t = \alpha + \beta_1 C_{t-1} + \beta_2 C_{t-2} + \beta_3 C_{t-3} + \gamma E_t + \mu_t$$

In the above equation, C_t represents real personal consumption expenditures in time period "t," E_t represents real employee compensation, and μ_t is a stochastic error term. We are interested in how changes in employee compensation affect changes in personal consumption expenditures. Therefore, we estimate the model in first differences. First differencing also insures that the variables are stationary (based on augmented Dickey-Fuller unit root tests). The GDP-deflator for personal consumption expenditures is used to transform nominal values into real variables. The time series is quarterly, and extends from 1950 to 2007. All data comes from the Bureau of Economic Analysis, U.S. Department of Commerce.

The estimated model is (rounding off the coefficients):

$$C_t = \underset{(3.2)}{7.83} + \underset{(1.7)}{0.10\, C_{t-1}} + \underset{(3.5)}{0.20\, C_{t-2}} + \underset{(3.6)}{0.21\, C_{t-3}} + \underset{(5.9)}{0.30\, E_t}$$

T-values are reported in parentheses. From this model, we can calculate the impact of a change in employee compensation on personal consumption expenditures, taking into account the dynamic feedback effects captured by the lag endogenous variables:

$$\frac{\gamma}{1-(\beta_1+\beta_2+\beta_3)} = \frac{0.2952}{1-0.5186} = 0.6132$$

This implies that a \$1 million increase in gross employee compensation will be associated with a \$613,200 increase in household consumption.

Next, we need to estimate the feedback effects—that is, the impact of the increase in household consumption on employee compensation. Additional household consumption expenditures will increase the vector of final demand in the input-output model and, through direct and indirect employment effects, raise employee compensation.

Using our input-out model and restricting the estimates to direct and indirect effects only, we find that a \$1 increase in household final demand is associated with an increase in employee compensation of \$0.416.[31]

We can now estimate the number of jobs that would be created for each additional \$1 million in employee compensation generated by the direct and indirect effects of any particular final demand stimulus. First, we calculate the total impact on household consumption of a \$1 increase in employee compensation. This would be given by the following expression:

$$\text{Total impact on HH consumption} = x + x^2y + x^3y^2 + x^4y^3 + \ldots\ldots$$

In which 'x' is the estimated propensity to consume out of additional employee compensation (0.6132 according to our estimates described above) and "y" is the additional employee compensation generated by a \$1 increase in final household demand (0.416 from the basic input-output model). We can factor out a single "x," giving us:

$$\text{Total impact on HH consumption} = x[1 + xy + (xy)^2 + (xy)^3 + \ldots\ldots]$$

The expression in the brackets is an infinite series. Since $xy<1$, we know that the series converges to:

$$\text{Total impact on HH consumption} = x/(1-xy).$$

Using our estimates, the total impact on household consumption expenditures of a \$1 increase in employee compensation is +\$0.8232.

Finally, we use these estimates to calculate a general induced employment multiplier. From the basic input-output model, we estimate that a \$1 million change in final household consumption would create 10.6 additional jobs. However, we are interested in the number of jobs that would be generated by an additional \$1 million in employee compensation. We know that \$1 in employee compensation will generate \$0.8232 in induced household consumption. Therefore, \$1 million in additional employee compensation generates \$823,200 in new household expenditures and approximately 8.7 additional jobs (10.6 * 0.8232)—when all dynamic multiplier effects are taken into account.

We can apply this general analysis of induced effects to any specific stimulus. All we need to know is the direct and indirect effects of the stimulus in terms of employee compensation. For each \$1 million in additional employee compensation generated, we know that 8.7 additional jobs would be generated through induced effects. For example, an additional \$10 million spent on building weatherization generates \$5.42 million in additional employee compensation through the direct and indirect effects. These direct and indirect effects would generate about 127 new jobs. These numbers come directly from the basic input-output model. The induced job creation—taking into account all multiplier effects—would amount to approximately 47 additional jobs (5.42*8.7) for a total employment impact of 174 jobs.

Characteristics of jobs generated by clean-energy investments and fossil fuel investments

In this report we are concerned not only with the overall level of job creation, but also with the types of occupations and the credentials needed by workers in these occupations. Our basic strategy for identifying the types of jobs that would be added to the economy due to an investment in the clean-energy or fossil fuel sectors (as defined above) involves two steps. The first step is to calculate each industry's share of total employment created through either an investment in clean energy or fossil fuels. We calculated the percentage of new employment generated in each of the 440 sectors in our input-output model. These industry shares take into account the direct, indirect, and induced effects as discussed above. The second step is to combine this information on the industry composition of new employment created by investing in each energy sector—clean energy or fossil fuels—with data on workers currently employed in the industries. We use the characteristics of these workers to determine the types of occupations (and the credential requirements of these occupations) that will add jobs with an investment in each energy sector. Our data on current workers comes from the 2008 Current Population Survey, or CPS, maintained by the Bureau of Labor Statistics.

Specifically, we used the industry shares to weight the worker data in the CPS so that the industry composition of the workers in the CPS sample matches the industry composition of the new jobs that will be added by investing in the energy sector we are analyzing. We do this by using the industry shares to adjust the CPS-provided sampling weights. The CPS-provided sampling weights weight the survey sample so that it is nationally representative. We use the industry shares to adjust these sampling weights so that the sample of workers in the CPS is representative of the industrial mix of jobs that IMPLAN estimates will be produced by new investments in clean energy or fossil fuels.

In order to create the weights we first aggregated the 440 industry shares to the three-digit level NAICS industries (for a total of 69 industries). This allowed us to merge the industry share data to the CPS worker data using the most detailed industry variable provided in the CPS. So, for example, at the 440 sector level there are seven construction sectors while at the three-digit NAICS level there is one construction industry

We adjust the CPS-provided sampling weights by multiplying each individual worker's sampling weight with the following:

$$S \times \frac{\text{IMPLAN's estimate of the share of new jobs in worker's industry I}}{\Sigma \text{ (CPS sampling weights of all workers in industry I)}}$$

where *S* is a scalar equal to the number of jobs produced overall by the particular level and type of investment being considered, and I represents a particular industrial sector.

We use these adjusted sampling weights to estimate the proportion of workers in each energy sector that has 1) a high school degree and no college experience; 2) some college but no bachelor's degree; and 3) a bachelor's degree or more. We then assume that the same proportion of jobs in each energy sector requires each level of education credentials. These figures are presented in the main text in Table 10.

Appendix 2: The employment impact of clean-energy investments across individual states

We report here a state-by-state breakdown of the overall employment expansion that would result through shifting $150 billion in overall spending out of the fossil fuel industry and into clean-energy investments. Before reporting the figures themselves, we begin by discussing the approach we have taken for allocating both the expansion in clean-energy investments in each state and the corresponding decline in fossil fuel spending. Our estimates of the net employment effects of the transition to a clean-energy economy are based on the amounts by which clean-energy investments increase and fossil fuel spending decreases in each state. The employment figures we report in the second part of this appendix are the result of both of those calculations.

As described in the main text, we have derived the $150 billion level of economy-wide clean-energy investment spending based on two criteria: 1) our assessment of the combined impact on the U.S. economy of the American Recovery and Reinvestment Act and the set of incentives and regulations included in the American Clean Energy and Security Act, now being debated in Congress; and 2) developments that are likely to occur in the private clean-energy investment market, driven primarily by advances in clean-energy technologies and the maturation of the institutions and linkages serving this market. Of course, these two broad sets of factors—the impact of government policies and advances in technologies and market practices—are also closely interrelated.

To proceed with a state-by-state breakdown of this $150 billion in total clean-energy investment spending throughout the U.S. economy, we first need to establish criteria for estimating how the funds are likely to be distributed. And based on the worst-case scenario assumption that we describe in the main text (page 33) that the total $150 billion in clean-energy investments will be matched dollar-for-dollar by declines in fossil fuel spending, we also need to establish criteria for distributing the decline in fossil fuel spending across the states that will total to $150 billion. In fact, we conclude that the same approach is appropriate for both distributing the gains in clean-energy investments and declines in fossil fuel spending. That is, as we explain in detail, we generate both the clean-energy investment increases and the fossil fuel spending declines as equally weighted averages of the level of GDP and the level of population in each state.

Clean-energy investment increases

One way to allocate the flow of clean-energy investment funds would be to make a determination as to which states have advantages in various investment areas, such as solar or wind power, urban density for mass transit investments, or agriculture to produce targeted advances in next-generation biofuels. But whatever funding assumptions we would establish from these criteria would inevitably be highly sensitive to our assumptions. That is, we do not have an empirically rigorous way to balance the importance of these geographic or climatic advantages for any given state or region relative to the economic resources available in other regions.

With this in mind, we considered two approaches to assigning investment levels for each state based on two easily observable and measurable traits for each state: state gross domestic product and population levels.

Distributing the total $150 billion in clean-energy investments on the basis of each state's share of total GDP means assigning proportions of spending based on existing patterns of financial investments and levels of development. This provides an accurate measure of how clean-energy investments would flow if they followed current levels of economic development across the states. Distributing the funds based on each state's population assumes a more egalitarian approach, with each person in the country effectively receiving an equal dollar claim on the overall pool of investment funds. We then try to balance these two considerations, recognizing that building retrofits, for example, will in part follow a pattern based on population density, but that new capital investment will also naturally flow toward areas of pre-existing capital investment in industry, infrastructure, and building stock.

In our view, both a GDP-share and a population-based allocation of funds represent reasonable criteria for estimating what state-level clean-energy investments should be. This is because, regardless of a state's topography or climate, major opportunities for clean-energy investments exist now and will grow with time. Accordingly, our approach is to calculate what the allocation of new investment funds would be under both the GDP- and population-based approaches, and use the midpoint of these two calculations as our figure for each state's allocation of the total $150 billion in new clean-energy investments.

Fossil fuel spending declines

Similar issues arise in deciding an approach for estimating the distribution of declines in fossil fuel spending across the states. One approach would be to distribute the cuts in proportion to the existing levels of fossil fuel spending in each state. According to this standard, oil-producing states such as Texas, Louisiana, and Oklahoma and coal-producing regions such as the Appalachian region and Montana would experience larger overall spending reductions than other states in which the fossil fuel industry plays a less significant role.

Under this scenario, the costs of the transition from a fossil fuel to a clean-energy based economy would therefore fall disproportionately on states that have large-scale fossil fuel industries. But if we used this criterion for allocating the distribution of fossil fuel spending declines, we would be contradicting a principle incorporated into the draft language of the ACESA, which is to compensate people and communities tied to the fossil fuel industry as one feature of the transition to a clean-energy economy.

Thus, to remain consistent with the policy approach incorporated into the ACESA, we follow the same principle which we used for allocating the spending increases in each state. That is, in our approach, the declines in fossil fuel spending in each state are distributed across states as an equally weighted average of each state's population and GDP. How could this weighting scheme be made compatible with the fact that states do have very different levels of fossil fuel expenditures? Following the principle of equitable impacts across all regions, the simplest way is to assume that states with larger-than-average fossil fuel industries will also be given disproportionate levels of compensation through the ACESA compensation programs. Related to this, we would also assume that states with relatively large fossil fuel industries will also receive a disproportionate level of government support for investments in clean energy, in particular clean-energy projects that are necessarily tied to specific locations, such as building retrofits, public transportation, and smart grid.

State-by-state employment changes through shift to clean-energy investments

The table below reports the net effects of the shift in employment from fossil fuels to clean-energy investments on employment by state, according to the approach described above. We also place these net employment effects into the broader context of the state's employment conditions as of 2008. That is, we show what the actual level of unemployment was in each state over 2008, and how much that unemployment rate would have declined had each state been affected by the $150-billion shift in spending from fossil fuels to clean-energy investments. As we see, for all states, there would be a net reduction in unemployment in the range of 0.8 - 1.7 percentage points.

State-by-state net job effects of $150 billion clean-energy investment program

	Net change in employment from $150-billion shift from fossil fuels to clean-energy investments	Actual unemployment rate in state for 2008	Unemployment rate in 2008 with $150-billion shift from fossil fuels to clean-energy investments
Alabama	+ 29,173 jobs	5.0%	3.7%
Alaska	+ 3,730	6.7%	5.6%
Arizona	+ 29,548	5.5%	4.6%
Arkansas	+ 17,732	5.1%	3.8%
California	+ 174,927	7.2%	6.3%
Colorado	+ 28,149	4.9%	3.9%
Connecticut	+ 16,741	5.7%	4.8%
Delaware	+ 5,726	4.8%	3.5%
DC	+ 5,514	7.0%	5.3%
Florida	+ 94,725	6.2%	5.2%
Georgia	+ 58,816	6.2%	5.0%
Hawaii	+ 7,146	3.9%	2.9%
Idaho	+ 8,504	4.9%	3.7%
Illinois	+ 69,624	6.5%	5.4%
Indiana	+ 38,013	5.9%	4.7%
Iowa	+ 18,290	4.1%	3.0%
Kansas	+ 17,070	4.4%	3.2%
Kentucky	+ 25,705	6.4%	5.2%
Louisiana	+ 29,095	4.6%	3.2%
Maine	+ 9,957	5.4%	4.0%
Maryland	+ 26,605	4.4%	3.5%
Massachusetts	+ 38,410	5.3%	4.1%
Michigan	+ 53,816	8.4%	7.3%
Minnesota	+ 30,263	5.4%	4.4%
Mississippi	+ 19,007	6.9%	5.4%
Missouri	+ 35,989	6.1%	4.9%
Montana	+ 6,303	4.5%	3.2%
Nebraska	+ 11,059	3.3%	2.2%
Nevada	+ 10,553	6.7%	5.9%
New Hampshire	+ 7,686	3.8%	2.8%
New Jersey	+ 47,519	5.5%	4.4%
New Mexico	+ 11,443	4.2%	3.0%
New York	+ 109,441	5.4%	4.3%
North Carolina	+ 51,210	6.3%	5.2%
North Dakota	+ 4,257	3.2%	2.0%
Ohio	+ 67,356	6.5%	5.4%
Oklahoma	+ 27,684	3.8%	2.2%
Oregon	+ 20,931	6.4%	5.3%
Pennsylvania	+ 71,667	5.4%	4.3%
Rhode Island	+ 4,540	7.8%	7.0%
South Carolina	+ 24,757	6.9%	5.8%
South Dakota	+ 5,272	3.0%	1.9%
Tennessee	+ 39,128	6.4%	5.1%
Texas	+ 152,760	4.9%	3.6%
Utah	+ 16,149	3.4%	2.3%
Vermont	+ 4,270	4.8%	3.6%
Virginia	+ 44,668	4.0%	2.9%
Washington	+ 33,505	5.3%	4.4%
West Virginia	+ 10,334	4.3%	3.0%
Wisconsin	+ 35,238	4.7%	3.6%
Wyoming	+ 3,522	3.1%	1.9%

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Endnotes

1 Congressional Budget Office, "Estimated Cost for the Conference Agreement of H.R. 1," available at" http://www.cbo.gov/ftpdocs/99xx/doc9989/hr1conference.pdf

2 At the same time, the CBO is projecting a relatively slow pace for the disbursement of these funds given that the bulk of overall ARRA spending will be completed by 2011. If anything, we might anticipate that larger proportions of the total green investment allocations will be distributed more quickly than projected by the CBO.

3 *American Clean Energy and Security Act of 2009*, Title II, Sec. 304 (Draft: March 31, 2009)., p. 158.

4 These references include Dahl and Sterner (1991), Espey (1996 and 1998), and Puller and Greening (1999).

5 We are referring here to a process of endogenous growth fueled by technical innovation and adaptation that, in turn, will have been induced by government incentives such as those advanced in the ARRA and ACESA. In various forms the analyses of such a growth process has been at the heart of research in economics over the past two decades on the interaction of technical innovation, the diffusion of such new technologies, the expansion of markets that results through diffusion, and the impacts of these cumulative processes on economic growth. For excellent surveys of the extensive literature on what are termed "endogenous growth" theory and "induced innovation" see Aghion and Howett (1997) and Ruttan (2001)

6 In a careful study that attempts to estimate the overall size of the energy efficiency market in the United States, Ehrhardt-Martinez and Laitner (2008) estimate the level of investment, as of 2004, to be $300 billion per year. They also estimate that the level of investment could potentially rise to $700 billion per year "in an environment of accelerated market transformation," (p. vii). The reason their estimate of the potential market for efficiency investments is so much larger than ours—ours being in the range of $110 billion as opposed to their $700 billion figure—is that they are including in their accounting all energy-efficiency investments, including ones that will not have any appreciable impact on employment creation. That is, their figure includes all investments in energy-efficient appliances and transportation vehicles. It also includes all new building projects that incorporate energy-efficient features, such as efficient windows, roofing, and insulation. When we exclude these categories of energy-efficient investments from their calculations, their total figures for current market size and potential future size in the remaining categories—i.e. building retrofits, public transportation, smart grid, energy recycling, and freight rail—are similar to our $110 billion figure for potential market size over the next decade.

7 See Pollin, Garrett-Peltier, Heintz, and Scharber (2008) and Pollin, Wicks-Lim, Garrett-Peltier (2009) for discussions on this.

8 This figure is derived in an unpublished memorandum circulated by the Green Building Council in April 2008.

9 Mark W. Chupka and others, "Transforming America's Power Industry: The Investment Challenge 2010-2030," Research report prepared for the Edison Foundation (2008). We use an estimate of $298 billion in transmission investment and $582 billion in distribution investment (based on the selected methods of estimating investment needs reported in the study). The total investment of $880 billion, spread over 20 years, amounts to $44 a year.

10 See Pollin, Wicks-Lim, and Garrett-Peltier (2009) for an extensive discussion on public transportation needs and benefits for low-income communities in particular from new investments in this area.

11 Table A6, pp. 121-23, *Annual Energy Outlook* 2009. In 2007, industrial generation capacity from combined heat and power systems was 25.4 gigawatts—this is projected to grow to 45.7 gigawatts by 2030.

12 Approximately 20 gigawatts in capacity would need to be installed by end-users over this period, based on projections from the *Annual Energy Outlook 2009*. Using a cost of capital of $2,800 per kilowatt (based on a weighted average of the cost of capital used by the Energy Information Administration) yields an estimate of $56 billion.

13 The Annual Energy Outlook 2009 projects that ethanol consumed as E85 and in motor gasoline would total 1.66 quadrillion btus by 2020. Ethanol contains about 80,000 btus per gallon. Using this conversion factor, the estimated ethanol market for motor vehicle use would be 20 billion gallons.

14 Energy Information Administration, "Annual Energy Outlook 2007" (February 2007). See "Biofuels in the transportation sector,". available at www.eia.doe.gov/oiaf/analysispaper/biomass.html. This report contains a recent estimate of the capital cost required for a cellulosic ethanol plant with a capacity of 50 million gallons a year, which is $375 million. Current cellulosic ethanol production in the United States is very limited. If one-third of the 20 billion gallons of ethanol were to be generated from cellulosic production, it would involve increasing capacity by about 6.7 billion gallons, requiring total investment of about $50 billion at current capital costs. These costs will be reduced with technological progress and would potential lead to more widespread adoption of cellulosic ethanol production.

15 Three prominent forecasts published in 2007 of where crude oil prices would be in 2008 include JP Morgan in August 2007, estimating $59.75 a barrel; Goldman Sachs in September 2007, estimating $85 a barrel; and the U.S. Energy Information Agency, also in September 2007, estimating $71.17 a barrel. Crude oil prices in the U.S. market are reported at: http://tonto.eia.doe.gov/dnav/pet/hist/wtotworldw.htm

16 This general problem of making accurate economic forecasts was captured well by former Federal Reserve Chair Alan Greenspan's unintentionally amusing observation made at the 1999 annual meeting of the International Monetary Fund and World Bank that "The fact that our econometric models at the Fed, the best in the world, have been wrong for fourteen straight quarters does not mean they will not be right in the fifteenth quarter" (Martin Mayer 2001, *The Fed*, p. 180).

17 It is through consideration of such factors that we have established a $150 billion annual level of investment on clean energy as a level that is desirable as well as realistic within our existing economy, but not something that will emerge inevitably due to any single policy measure.

18 We present a detailed discussion of our methodology in the appendix.

19 This $1 million increase in expenditures is "final demand" expenditures within the input-output model.

20 The allocation of total investment funds that we are working with is 40 percent retrofits; 20 percent mass transit/freight rail; and 10 percent each for smart grid, wind power, solar power, and biomass fuels. Adjusting the budgetary allocations would affect the job total estimates, but not by a dramatic extent. These proportions are closely aligned with the green investment spending priorities of the government ARRA program. Appendix 1how we derived the overall job figures based on this proportioning of overall clean-energy investments.

21 A range of estimates exist on the impact of unemployment on earnings. For example, Bartik's 2001 survey of five studies (Bartik 1991, 1994, 2000; Blank and Card 1993; Card 1995) provides a range of a 1.5- to 3.5-percent increase in average real earnings when the unemployment rate falls by 1 percent. Additionally, Bartik's 2001 study estimates that the average household experiences a 1.9-percent increase in real earnings when the unemployment rate falls by 1 percent. Finally, Hines, Hoynes, and Krueger (2001) estimate that the average family earnings increases by 1.3 percent for a 1-percent fall in the unemployment rate. A simple average of the seven estimates produced by these various studies suggests that the impact of a 1-percent decline in the unemployment rate produces approximately a 2-percent rise in earnings.

22 If an employment expansion leads to a disproportionate rise in the labor force participation rate, the subsequent disproportionate rise in the labor supply is likely to counteract positive bargaining effect for low-income workers. The key factor is that however much the labor force participation rate rises, the unemployment rate must still fall by one percentage point in order for workers to see wage increases resulting through this channel.

23 See Pollin (2009) for references.

24 We provide a detailed breakdown of the subsectors within the oil industry and all other energy sectors in Appendix 1.

25 These figures are for the synthetic wind, solar, and biomass industries that we have created from the input-output tables. The actual level of current domestic content may be somewhat different than this estimate. We will obtain a better sense of this once we are able to incorporate figures from our ongoing survey of the renewable energy/energy efficiency sectors.

26 See Pollin, Wicks-Lim, and Garrett-Peltier (2009).

27 Their findings are also consistent with the research of Cancian and Meyer (2000) who found that when women initially work in clerical, cleaning, professional, production, or manufacturing occupations after leaving welfare their wages rise faster over time compared to retail sales, food services, or private housekeeping.

28 The main difference between the two measures is over offsets, which are the investments in emissions reductions that fossil fuel industry firms can make outside of the regulations stipulated in the carbon cap law. For example, carbon-generating firms could receive offset credits against their emission limits by investments in tree planting or in clean-energy projects in other countries. The ACESA effectively corrects a conceptual flaw with the Lieberman-Warner approach to offsets. Many offsets are long-run investments whose effects would last years. Under Lieberman-Warner, such long-run investments could become invalid after the initial investment occurs, as the total number of allowances drops. The ACESA sets the initial level of allowable offsets at around the same level as Lieberman-Warner. However, if the regulated entities invest in approved offsets, those investments would remain valid (in terms of counting toward emissions allowances) even as the number of allowances drops. New offsets may be precluded, but existing investments in offsets would not be invalidated.

29 So-called "market clearing" macroeconomic models are described in most contemporary intermediate textbooks. Perhaps the most systematic textbook presentation of this approach is Barro (2008).

30 These and related issues are analyzed carefully in Ackerman and Stanton (2008).

31 We use the IMPLAN calibrated model and restrict our focus to households with annual incomes between $10,000 and $100,000, under the assumption that the vast majority of the jobs created would affect households with incomes in this range.

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