CLEAN ENERGY INVESTMENTS FOR THE U.S. ECONOMY:
RESEARCHING THE EFFECTS ON EMPLOYMENT OPPORTUNITIES AND ECONOMIC GROWTH

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In this discussion paper, we survey some of the main findings of our research to date as well as raise points on which we are currently focused in our ongoing work.[1] The areas on which we focus are as follows:

1) Our use of input/output modeling as a methodology for estimating the effects of clean energy investments on employment within the U.S. economy;
2) The main findings of our estimates based on the input/output model. These findings are generated based on amounts of dollars spent on clean energy as opposed to fossil-fuel based energy. To date, our model does not estimate the amount of energy generated through a given level of spending, a topic to which we return below;
3) Applying our basic estimating model within the context of a $150 billion/year level of spending on net job-generating clean energy investments within the U.S. economy;
4) Addressing concerns raised by critics that the net positive employment effects generated by clean energy investments are the result of three factors: a) lowering productivity; b) protectionism; and c) promoting low-wage employment;
5) Applying our input/output model to provide more detailed employment estimates, i.e. estimates based on individual clean-energy investment projects. This is work we have been conducting through our consulting with the Department of Energy;
6) Expanding our model to include employment estimates tied to levels of energy supplied, as opposed to only considering estimates tied to levels of spending;
7) Evaluating results of long-term growth forecasts of effects of carbon-cap legislation on economic growth and employment.

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[1] This discussion paper draws primarily from Pollin, Heintz, and Garrett-Peltier (2009), Pollin, Wicks-Lim, and Garrett-Peltier (2009), Pollin and Baker (2009), and Pollin (2009) as well as various internal reports written for the U.S. Department of Energy over the past year by Pollin, Heintz, and Garrett-Peltier.

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.

Input-Output Modeling for Estimating Job Creation

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. These data enable us to estimate, among other things, 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 is an example of how our methodology works (for a complete analysis, see the appendix to this paper). 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.

There are certainly limitations with using 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 evaluated in a broader sense: how serious are these issues within the context in which the model is applied, and are there alternative approaches that are more effective? As we discuss briefly below, after weighing all factors, we have concluded the simple input/output model is the most effective approach, even while recognizing its limitations.

Static model. Working with the input-output 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 have discussed in other papers (e.g. Pollin, Heintz, and Garrett-Peltier 2009). Given our objective of estimating employment creation associated with given amounts of additional spending, 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 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. For example, our model 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. To consider one important 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 roughly 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, considering manufacturing, transportation, and installation activities as a whole, the need to employ workers for incorporating these new 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.

Main Results from Our Input-Output Model

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 fossil 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.

We now examine 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.[2] Table 1 shows the extent of direct and indirect job creation generated by $1 million in expenditures on producing alternative energy sources.[3] We present the total job creation figures as absolute 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.

TABLE 1 BELONGS HERE

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.

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[2] We present a detailed discussion of our methodology in the appendix.
[3] This $1 million increase in expenditures is "final demand" expenditures within the input-output model.

Given the current weak recovery from a severe recession, 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 preliminary formal model to estimate the broad magnitude of the induced employment effects more systematically. We present our procedure's details in the appendix. 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 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. We are also now working on incorporating the effects of variation in capacity levels on our estimates.

Working with our current preliminary model, we find that the level of induced job creation is about 40 percent of the level of direct plus indirect job creation. For most of our work to date, 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 2. 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.

TABLE 2 BELONGS HERE

Overall Employment Effects: Clean Energy vs. Fossil Fuels

We combine and summarize these results on overall job creation in Figure 1 below. 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).[4]

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

[4] 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.

generate 5.3 jobs in total. Thus, 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 BELONGS HERE

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 per 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. Nevertheless, the average pay per job in the fossil fuel economy is higher than with green investments. This means that an given overall wage bill on green investments will produce more jobs than the same wage bill used for paying workers in the fossil fuel economy.

Employment Effects of $150 billion a Year Clean-Energy Investments

Constructing a clean energy economy will require spending trillions of dollars over the next 20 years, with most of the funds coming from the private sector. As an annual investment program, it is certainly within the realm of reason to assume that clean investment spending could be in the range of $150 billion per year. This is about one percent of U.S. GDP, eight percent of annual U.S. private capital expenditures just prior to the recession, and about equal in amount to annual U.S. spending in Iraq in 2008 and 2009. This level of annual clean energy investments can be achieved through a combination of spending programs, subsidies and regulations included in the February 2009 stimulus program; regulations that set a firm cap on carbon emissions; continued advances in clean energy technologies; as well as a corresponding expansion of private markets and business investment opportunities.

As we see in Table 3, an annual $150 billion green 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. It is not likely that the funds to finance $150 billion in green 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 3 BELONGS HERE

In the lower panel of Table 3, we then consider what the impact would have been on the 2009 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. As of January 2010, there were 138.3 million people employed in a 153.2 million person labor force, which means that 14.8 million people were unemployed. This translates into an unemployment rate for January 2010 of 9.7 percent. A net increase of 1.7 million new jobs would therefore lower the unemployment rate to 8.6 percent.

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.[5] But they claim that the job expansion comes at a stiff price since it occurs through promoting low productivity, protectionism, and low wages. These claims are either misleading at best or flat-out inaccurate. It is important to review the issues briefly.

Creating Jobs by Lowering Productivity?

By a standard definition, labor productivity simply measures total output per worker. From this perspective, the matter is easy to settle, virtually as a matter of definition. By this standard definition, if we increase labor intensity through clean-energy investments—if we generate about 17 jobs per $1 million through green investments versus about five jobs through fossil fuel spending—then we reduce labor productivity in the energy sector through shifting spending toward clean energy.

[5] See Pollin (2009) for references.

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—and thereby raising their productivity from a lower to a higher level.

Second, given the global climate crisis, we need to begin incorporating environmental effects in the measurement of output and productivity. That is, spending on fossil 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 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.

Clean-energy investments will therefore substantially raise economy-wide labor productivity—defined appropriately—through two channels: 1) By expanding total employment per dollar of expenditure in the economy, it provides millions of people with new opportunities to become productive workers; and 2) By generating energy from clean sources, it increases the level of "goods" we produce and corresponding reduces our production of "bads." In addition to these factors, overall productivity in more traditional terms rises by definition through investments that raise energy efficiency.

Are Clean-Energy Policies 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 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 4 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.[6] These other subsectors include the full range of administration, transportation, and marketing of

[6] The appendix provides a detailed breakdown of the subsectors within the oil industry and all other energy sectors.

crude and refined oil as well as natural gas—all activities that would be readily transferrable into a growing clean-energy sector.

TABLE 4 BELONGS HERE

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. 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. The main driver behind this result is straightforward: that these energy efficiency investments are bounded to specific locations. That is, retrofitting a home in Philadelphia can only be done in Philadelphia, and upgrading the Los Angeles public transportation system will entail large-scale construction activity in Los Angeles. This is true, even while 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. Of course, the U.S. is certainly capable of expanding its manufacturing capacity in areas such as wind turbines and solar panels (see Pollin and Baker 2009 for a full discussion on this). 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 necessary reason why, say, a wind turbine needs to be manufactured within the U.S.

Are Clean Energy Investments Really About Bad Jobs?

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.[7] 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. We provide evidence on this type of job breakdown in Table 5, 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 BA degree and paying, on average $24.50 an hour
- Mid-credentialed jobs requiring some college but not a BA and paying, on average, $14.60 per hour

[7] See Pollin, Wicks-Lim, and Garrett-Peltier (2009) for a full discussion on this set of issues.

- Low-credentialed jobs requiring a high-school degree or less and paying, on average, $12.00 per hour.

The table shows these breakdowns both for clean-energy investments and fossil-fuel investments. 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 5 BELONGS HERE

To begin with, we can see in Table 5 that the net job creation is substantially higher with green investments than fossil fuels across all three credential categories. This is true even while the *proportions* of jobs created in the different categories differ. For example, 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, though 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.

In addition, 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.

What about job advancement opportunities in fossil-fuel industries? The final row of Table 5 provides 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.

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.

Generating Project-Level Job-Creation Estimates

In our consulting work with the Department of Energy, we needed to refine our estimating model to be able to generate employment estimates on a project-by-project basis, to take account of the employment effects of all the clean energy projects supported by the February 2009 stimulus program, the American Recovery and Reinvestment Act. For example, considering only the ARRA-based program that subsidizes investments in clean-energy manufacturing projects, the 48 applicants for support within the solar sector alone includes investors in thin film solar modules, silicon cells and modules, vinyl fluoride monomers, and solar-grade polysilicon. Each of these projects are likely to have significantly different production functions. Previously, we had developed estimates at higher levels of aggregation that did not take full account of these distinct production functions.

The refinements to our modeling approach required for our Department of Energy consulting have been quite useful beyond the DOE work itself, enabling us to establish a firmer foundation for our more macro-level findings. Pushing the model down to this level of specificity also underscores the flexibility one has in working with the input-output model that would be difficult to replicate with other modeling approaches.

Our approach is as follows: We worked with an online-search database (www.webstersonline.com/) to identify companies engaged in the same activities as those detailed activities described in the Department of Energy descriptions of their ARRA-related projects. From this search engine, we were able to establish six-digit NAICS codes for each of the activities listed by the DOE. Once we had assigned six-digit NAICS codes for each of the firms listed in the DOE spreadsheet, we could then work with those NAICS codes within the Economic Census database to establish figures for employment/output and employment/capital ratios.

Incorporating Energy Supply and Demand into Our Estimations

A complete model of the employment effects of a clean-energy transition must of course, at some point, frame the issue in terms not only of spending money on investments and thereby create jobs, as we have done to date; but also to anchor the analysis in terms of how to supply energy needs over time. At this point, the issue thereby becomes one of estimating energy supply and demand over time. This in turn becomes a matter of 1) considering the effects of investments in energy efficiency on reducing the level of energy demand per level of per capita GDP; and 2) How much of a given level of future energy demand, after taking account of efficiency effects, can be met through renewable energy sources.

To date, we have done lots of preliminary work in grappling with these questions. We intend to work intensively on this question in the next few months. For now, it may be useful to simply raise one of the most basic challenges in working on this matter, this being the extremely wide range of estimates as to the attainable levels of renewable energy capacity that can be built over the next 10 – 30 years.

The basic problem here is that, for the most part, renewable energy technologies are in their early stages of development. A high proportion of the new spending in this area needs to go into advancing R&D, then pushing promising technologies into commercial development. A reasonably good model for this process is the developments that occurred over the 1980s – 1990s in biotechnology, including the support the Department of Energy provided to advance the Human Genome Project.

Given this context, we face two difficult methodological problems in trying to extract employment creation estimates based on megawatts of energy, as opposed to dollars of spending:

A) Spending on R&D and commercialization will not generate any new energy per se, even while it is a crucial part of the overall spending package; and

B) The figures based on energy units are subject to rapid change, precisely because the technologies are expected to improve a lot over the next several years. And by "improve," we mean that the costs will fall significantly per BTU or megawatt of energy.

Related to this latter point, it also follows that, if we make employment estimates per energy units using existing renewable energy technologies, we will have very high job figures for renewable energy. But this will only be because the level of spending necessary to extract a given amount of usable energy from renewable sources is much higher now than from traditional sources. That is, we could conclude that renewable energy is a big source of job creation, but highly inefficient source of energy. In our view, these matters need to be sorted out more carefully than they have heretofore.

These issues become more clear in considering the range of forecasts as of only 2020—10 years from now—in both solar and wind energy generating capacity. As we see from Table 6, the range for solar from serious sources is between 3.4 and 66.2 GW. Even considering only estimates from federal agencies, the range is between 9.7 and 29.2 GW. With wind, the range we report is between 17.2 and 100 GW, with the federal agency estimates starting at 68.9 and moving up to 100 GW.

TABLE 6 BELONGS HERE

In our current research, our aim is to sort through these various estimates, to see if we can narrow the range of reasonable figures. If we can accomplish that, the next task will be to generate employment estimates linked to the projects of creating and subsequently operating this new capacity from renewable energy sources.

Forecasting the Impact of a Carbon Cap on Economic Growth

The impact of a carbon cap or related legislation will produce higher prices over time for anyone using oil, coal and natural gas. This is the direct intention of such measures, such as that which the House of Representatives passed in the June 2009, the American Clean Energy and Security Act (ACESA) or Waxman-Markey bill, and its predecessor, the Lieberman-Warner bill. The explicit purpose of such measures is to limit the production of energy sources that generate greenhouse gas emissions. When supply of these energy sources is limited, then prices will rise. This should then also encourage further initiatives in behalf of energy efficiency and renewable energy.

However, we cannot know in advance how much higher and how fast the prices of fossil fuels will rise through such legislation. 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 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 impact the economy's growth trajectory. This is so, even while, as we discuss at length in Pollin, Heintz, and Garrett-Peltier (2009), 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.

There are two common factors to all the forecasts: how much energy price increases will affect GDP growth depends on a) how large the price increases will be; and b) how much demand for energy from a given source will fall as the price of energy from that source rises. For example, the forecasting models that are calibrated to the Department of Energy's most recent (2009) *Annual Energy Outlook* predict that price increases, in 2030, 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 10 percent for natural gas.

However, the model reported in the Annual Energy Outlook 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 because, at least in part, 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, we now consider the results of several different forecasting exercises.

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.

Some of these forecasts are responding to the carbon cap proposal debated in 2008 in Congress, the Lieberman-Warner bill. 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, more recently, the Environmental Protection Agency, Energy Information Agency and American Council on Capital Formation/National Association of Manufacturers have also generated new forecasts based on the cap-and-trade provisions of the ACESA specifically. In Table 7, we compare these most recent forecasts with those generated in response to Lieberman –Warner.[8]

TABLE 7 BELONGS HERE

In considering first the forecasts of Lieberman-Warner in the upper panel of Table 7, 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 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 from 0.01 percentage points—i.e. one one-hundreth of one percent—using the model developed by the Massachusetts Institute of Technology, to 0.11 percentage points—eleven one-hundreths of one 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 change from 2.6 percent average growth rate per year when no carbon cap is in place to a 2.5 percent average annual growth rate

[8] 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 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 towards emissions allowances) even as the number of allowances drop. New offsets may be precluded, but existing investments in offsets would not be invalidated.

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 in the baseline scenario.

The lower panel of Table 7 summarizes the results of five separate forecasts based on the ACESA version of cap-and-trade. As we see, these forecasts are not significantly different than the previous ones based on the Lieberman-Warner provisions of cap-and-trade.

Thus, according to the most recent EIA forecasts, average annual economic growth is projected as somewhat faster than their previous forecasts, regardless of whether cap-and-trade is established. That is, their new baseline forecast is a 2.71 percent average annual growth rate relative to their earlier baseline forecast of 2.47 percent. They then forecast the impact of the cap-and-trade provision of the ACESA as lowering growth to between 2.66 and 2.67—that is, a growth reduction due to the ACESA of between 0.04 and 0.05 percentage points. This is slightly larger than their earlier estimate of a growth reduction of 0.02 percentage points.

The most recent forecasts of the EPA, by contrast, project somewhat *lower* annual average growth regardless of whether a cap-and-trade system is established. They have also lowered slightly their estimate of the reduction in economic growth due to cap-and-trade. In their current forecasts, the average annual growth reduction due to cap-and-trade ranges between 0.05 – 0.06 percentage points, compared to their previous forecast, based on Lieberman-Warner, of a 0.06 percentage point reduction in growth rates.

Finally, ACCF/NAM have also lowered their baseline long-term growth forecasts, from 2.56 to 2.31 percent. However, their "high-cost" estimate of the impact of cap-and-trade on long-term economic growth has remained unchanged in their most recent forecast, at 0.11 percentage points per year.

Overall, then, these most recent forecasts of the impact on economic growth of the ACESA 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 briefly 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.[9] These models do allow for people to make choices between working and leisure activities, but all operate 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

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[9] 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).

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. In addition, to the extent the U.S. is successful in building a renewable energy manufacturing sector, that will also contribute to improving the U.S. trade balance.

Reducing the U.S. trade 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 to 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.

Incorporating the Effects of Technological Change

EPA and related models build in assumptions as to how technological changes will affect energy prices over time. As we have discussed above, 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 the ARRA and the ACESA, then the opportunities will increase for renewable energy prices to 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 know accurately 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, producing a stronger positive expansion in employment than households or business—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.

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.[10]

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 that allow for a carbon cap mandate are likely to be understated.

[10] These and related issues are analyzed carefully in Ackerman and Stanton (2008).

Appendix on Employment Estimates

Employment multipliers

Data and methodology

The employment estimates 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 paper, 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

<u>Transit and rail</u>

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

<u>Wind</u>

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

<u>“Green program”</u>

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):

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

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.[11]

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:

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:

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:

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.

[11] 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.

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:

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

where S is a scalar equal to the number of jobs produced overall by the particular level and type of investment being considered.

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 L7.

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Table 1.
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 + indirect job creation per $1 million in output (# of jobs)	Direct + 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	+321.6%
-- Mass Transit/Freight Rail *(90%MT, 10%FR)*	11.0	4.9	15.9	+429.7%
-- Smart Grid	4.3	4.6	8.9	+240.5%
Renewables				
-- Wind	4.6	4.9	9.5	+256.8%
-- Solar	5.4	4.4	9.8	+264.9%
-- Biomass	7.4	5.0	11.4	+308.1

Sources: Appendix and Pollin, Heintz, and Garrett-Peltier (2009).

Table 2.
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	**(3) Total Job Creation**	**(4) 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	+321.2%
-- Mass Transit/Freight Rail *(90%MT, 10%FR)*	22.3	+428.8%
-- Smart Grid	12.5	+240.4%
Renewables		
-- Wind	13.3	+255.8%
-- Solar	13.7	+263.5 %
-- Biomass	16.0	+307.7%

Sources: See Appendix and Pollin, Heintz, and Garrett-Peltier (2009).

Table 3.
Impact of $150 Billion Green 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

Sources: See Pollin, Heintz, and Garrett-Peltier (2009).

B) Impact of Clean Energy Job Expansion on January2010 U.S. Labor Market

1) Overall Labor Force	153.2 million
2) Total Employed before Clean Energy Investments	138.3 million
3) Total Unemployed before Clean Energy Investments	14.8 million
4) Unemployment Rate before Clean Energy Investments (= rows 3/1)	9.7% (=14.8 million/154.2 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 9.7% to 8.6% (=13.1 million/154.2 million)

Sources: See Appendix and Pollin, Heintz, and Garrett-Peltier (2009)

Table 4.
Domestic Content for Alternative Energy Sources

	Domestic Content as share of total industry output *(in percentages)*	**Domestic Content relative to oil** *(percentage point difference)*
Energy Source		
Fossil Fuels		
-- Oil and Natural Gas	82.9	
-- Coal	93.5	+10.6
Nuclear		
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	+4.710.9

Sources: See Appendix and Pollin, Heintz, and Garrett-Peltier (2010).

Table 5.
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 ***-- BA 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 BA*** ***-- $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.
Sources: See Pollin,Wicks-Lim, and Garrett-Peltier (2009)

TABLE 6. PROJECTIONS AS OF 2020 FOR SOLAR AND WIND ENERGY ANNUAL GENERATING CAPACITY IN THE UNITED STATES

Solar Power Projections (gigawatts)

Projection (2010-2020)	Source
66.2 GW	Utility Solar Assessment Study, Clean Edge and Coop America, June 2008 (66.2 GW = difference between 2010 and 2020 projections)
29.2 GW	NREL, EERE Estimate. Power Technologies Energy Databook (4^{th} edition, 2006)
9.7 GW	Annual Energy Outlook, 2009, baseline scenario. Use 2008 estimate of existing capacity.
3.4 GW	U.S. Solar Market Trends 2008 (assuming a constant investment of 335 MW, the level of capacity increase in 2008, each year over a decade).

IREC – Interstate Renewable Energy Council. NREL – National Renewable Energy Laboratory, Energy Efficiency and Renewable Energy (U.S. Department of Energy).

Wind Power Projections (gigawatts)

Projection (2010-2020)	Source
100 GW	EERE. 2008 Wind Technologies Market Report (July 2009). Assumes that the average EER annual projections for 2010-2012 hold for the entire decade 2010-2020.
68.9 GW	NREL, EERE Estimate. Power Technologies Energy Databook (4^{th} edition, 2006)
17.2 GW	Annual Energy Outlook, 2009, baseline scenario. Use 2008 estimate of existing capacity.

TABLE 7.
Comparison of Alternative U.S. GDP Growth Forecasts under Baseline and with Cap-and-Trade
(figures are average annual growth rate forecasts for specified time periods)

A) Forecasts based on Lieberman-Warner cap-and-trade

	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)*
MIT (2005 to 2050)	2.94%	2.93%	0.01%
Energy Information Admin. (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%

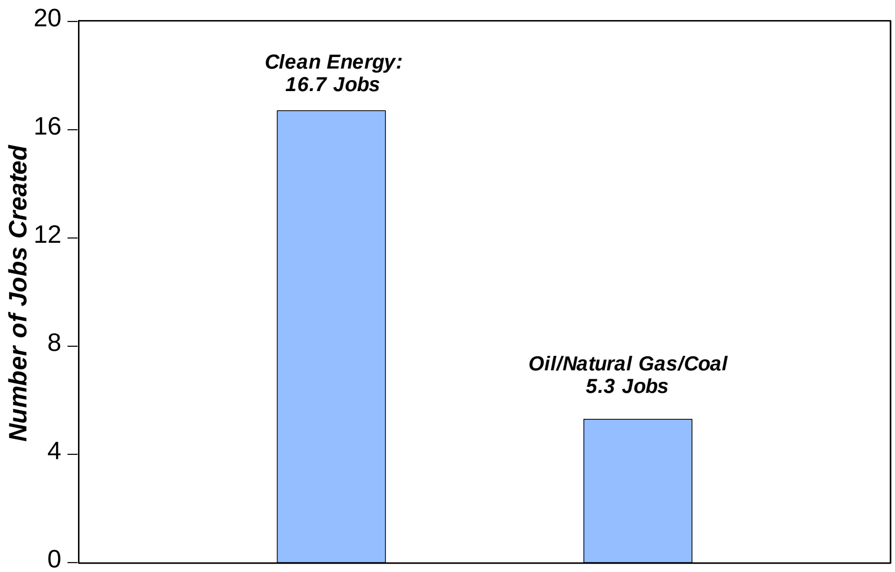
Sources: References for models are all at Pew Center on Global Climate Change, "Insights from Modeling Analyses of the Lieberman-Warner Climate Security Act (S. 2191), May 2008, http://www.pewclimate.org/docUploads/L-W-Modeling.pdf.

B) Forecasts based on ACESA

	1) Baseline GDP Forecast	*2) GDP Forecast under Waxman-Markey Cap and Trade*	*3) Difference between Baseline and Cap-and-Trade Growth Forecasts (columns 1-2)*
Energy Information Admin. (basic scenario 2010-2030)	2.71%	2.67%	0.04%
Energy Information Admin. (high-cost scenario 2010-2030)	2.71%	2.66%	0.05%
Environmental Protection Agency-1 (ADAGE model—2015-50)	2.41%	2.36%	0.05%
Environmental Protection Agency-2 (IGEM model—2015-50)	2.38%	2.32%	0.06%
ACCF/NAM—"High Cost Case" (2007-30)	2.31%	2.21%	0.11%

Sources: EIA, *Energy Market and Economic Impacts of H.R. 2454, the American Clean Energy and Security Act of 2009; EPA Analysis of the American Clean Energy and Security Act of 2009, H.R. 2454 in the 111th Congress*, June 23, 2009. www.epa.gov/climatechange/economics/pdfs/HR2454_Analysis.pdf; ACCF/NAM, *Analysis of the Waxman-Markey Bill 'The American Clean Energy and Security Act of 2009,' ((H.R. 2454) using the National Energy Modeling System.*

Figure 1. Job Creation through $1 Million in Spending: Clean Energy Investments vs. Fossil Fuels



Sources: See Pollin, Heintz, Garrett-Peltier (2009).