Powering Up Colorado!
Using Energy Efficiency to Create New Jobs And Build a More Robust Economy

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Executive Summary

All interactions of matter involve flows of energy, yet the United States economy is not especially energy-efficient. At current levels of consumption economic activity within its borders, for example, the U.S. is an anemic 14 percent efficient – which means that we waste 86 percent of all the energy now burned to maintain the production of goods and services. Colorado is only marginally more energy-efficient; and both the Colorado and the U.S. economies are showing signs of becoming less robust because of the costs associated with that inefficiency. Compared to the historical trend for the period 1970 to 2012 in which Colorado's economy-wide productivity grew at nearly two percent annually, it appears productivity will barely average one percent annually over the next three decades. This may cost Colorado an average of 320,000 jobs per year. The good news, however, is that with upgraded investments in greater levels of energy efficiency, the state may have sufficient energy efficiency resources that might exceed more than 700 million barrels of oil equivalent. This magnitude of energy efficiency improvements may be sufficient to reduce the state's energy needs by 30 percent by the year 2030. Preliminary analysis indicates this could boost overall employment levels even as the returns on the efficiency investments strengthen the larger economic activity within the state.

I. Introduction

All interactions of matter involve flows of energy. This is true whether they have to do with earthquakes, the movement of the planets, or the various biological and industrial processes at work almost anywhere in the world. Within the context of a regional or national economy, the assumption is that energy should be used as efficiently as possible. A Colorado manufacturing plant employing 125 people, for example, may require more than one million dollars per year in purchased energy if it is to maintain operation. An average Colorado family may spend $1,800 or more per year for electricity and natural gas to heat, cool, and light their home as well as to power all of the appliances and gadgets within the house. And an over-the-road trucker may spend $60,000 or more on fuel to haul freight an average of 100,000 miles per year. Regardless of either the scale or the kind of activity, a more energy-efficient operation can lower overall costs for the manufacturing plant, for the household, and for the trucker. The question is whether the annual energy bill savings are worth either the cost or the effort that might be necessary to become more energy-efficient?[1]

This year residents and businesses in Colorado will spend an estimated $20 billion dollars to meet their total energy needs -- to cool and light their homes, to listen to music or watch television, to power commercial and industrial equipment, and to commute to work or run the many errands necessary to maintain a household. Although Coloradoans will derive many important benefits as they pay their various monthly energy bills, the current energy infrastructure also produces an estimated 55,000 tons of sulfur dioxide (SO_2) and 220,000 tons of nitrogen oxide (NO_x) air pollution annually. These and other pollutants are expected to add between $7 and $15 billion or more to Colorado's health care costs as the result of 1,200 premature deaths, 1,600 cases of acute bronchitis, and 50,000 episodes of respiratory distress. The noxious effects of these pollutants also include 200,000 lost work days due to illness and as many as 800,000 minor restricted activity days in which both children and adults must alter their normal activities because of respiratory health problems.[2]

Moreover, the use of energy – whether electricity from power plants or the gasoline that powers the many vehicles driven within the state – is also a large source of climate-disrupting carbon pollution. Indeed, the combustion of energy in Colorado results in an estimated 96 million metric tons of carbon dioxide (CO_2) that is emitted each year.[3] While this is a very small fraction of total emissions world-wide (about 0.3%), the full array of human activities across the globe is driving up the concentration of carbon dioxide and other heat-trapping gases in the atmosphere. In fact, atmospheric carbon dioxide levels have increased by more than 40 percent since the Industrial Revolution; current atmospheric concentrations of both CO_2 and methane (an even more potent greenhouse gas) are significantly higher than they have been for the last 800,000 years (EPA 2009).

1. The energy expenditures are derived from several working calculations by the author, drawing on a variety of data sources.
2. *See* Abt Associates, Inc., *User's Manual for the Co-Benefits Risk Assessment (COBRA) Screening Model (2013)* (author-derived estimates based on emissions scenarios for the year 2013 given various health effects identified by EPA's Co-Benefits Risk Assessment (COBRA) model).
3. Author calculations based on a variety of data available from the Energy Information Administration.

The need to mitigate these health and climate impacts is urgent. These circumstances and the emerging evidence have led prominent physicist and climate scientist James Hansen to reach the "startling conclusion" that the continued exploitation of fossil fuels threatens not only the planet, but also the survival of humanity itself (Hansen 2011 at ix). Furthermore, the continued inefficient use of energy will continue to a further weakening of the U.S. economy (Laitner 2013). As we shall see in this analysis, for example, the inefficient use of energy will also cost the economy nationwide an estimated 300,000 jobs over the next, which means, in turn, $16 billion in lost wages in that year.

There is little question that the production and use of energy holds great economic value for the Colorado and the United States. But there is also little question that the current energy infrastructure is imposing heavy burdens on Colorado citizens and in the form of health impacts, climate destabilization, water consumption, and job loss. In this working paper we ask the question of whether there is an opportunity cost being overlooked by current patterns of production and consumption of energy. In other words, might we encourage the more productive use of energy so that the reduced levels of waste can actually increase Colorado's social and economic well-being? In short, can the billions of dollars spent each year for energy be used in other ways to more productively strengthen both the U.S and the Colorado economy and reduce the harms imposed by fossil fuel fired generation? It turns out that, should we actively invest in more efficient use of energy, the answer is clearly yes.

In this working paper we set out to explore two questions. First we ask: How big is the energy efficiency resource within the Colorado economy? That is, how big of a benefit can energy efficiency deliver? And what scale of investment is required to drive productivity improvements? Second, we provide a first order review of the jobs and economic impacts of an accelerated efficiency-led economic development strategy. We provide an initial estimate of cost-effectiveness of the energy efficiency resource, and then explore how that change in spending might impact the state's ability to support a greater number of jobs. With that backdrop, Section II of this paper examines the energy efficiency resource potential and its link to a robust economy. In Section III we then provide an overview of the methodology we use to estimate the economic impacts of increased investment in energy efficiency. Section IV summarizes the major results of this inquiry while Section V offers several conclusions and observations. Finally, Appendix A presents further details about the economic model used to complete this assessment while Appendix B identifies the many references that guided our inquiry.

II. The Energy Efficiency Resource Potential

Energy efficiency has played an enduring and surprisingly critical role in the U.S. and the Colorado economy. Efficiency is an incredibly low-cost resource and its benefits are wide-ranging and significant. These benefits include both reduced energy bills and a surprising number of non-energy benefits, from reduced operations and maintenance costs at industrial plants to improved quality and speed in the production of our nation's goods and services. Not only could energy efficiency drive down a variety of air pollutants, mitigate adverse health effects, and bring down health costs associated with "business-as-usual" energy use, but the more productive investments could also stimulate a more robust economy by reducing the cost of energy services and spurring job creation.[4] The good news is that energy efficiency has been a critical but an almost invisible catalyst in driving forward the Colorado economy.

As it turns out, Colorado expanded its economic output, or Gross State Product (GSP), by more than five-fold since 1970. The demand for energy and power resources, however, only doubled within that same period.[5] This decoupling of economic activity and energy consumption is a function of increased energy productivity: in effect, the ability to generate greater economic output (that is, to produce more goods and services), but to do so using less energy. Indeed, the evidence suggests that since 1970, energy efficiency, in its many different forms has met 72 percent of Colorado's new demands for energy services to maintain and enhance its overall economic well-being. Meanwhile, increased energy supplies have provided only 28 percent of the new energy service demands. Thus, as previously suggested, energy efficiency has been an invisible resource.

Unlike a new power plant or a new oil well, we don't see energy efficiency at work. A new car that gets 20 miles per gallon, for example, may not seem all that much different than a car that gets 50 miles or more per gallon. And yet, the first car may consume 500 gallons of gasoline to go 10,000 miles in a single year while the second car my need to only 200 gallons per year. In this example, energy efficiency is the energy we don't use to travel 10,000 miles per year. More broadly, energy efficiency may be thought of as the cost-effective investments in the energy we don't use either to produce, or even increase, the level of goods and services within the economy. While an invisible resource, we can turn to the data in Table 1 to explore the link between energy efficiency and Colorado's economy-wide productivity.

Table 1. The Link Between Energy Efficiency and Economy-Wide Productivity

Period	Energy Efficiency	Productivity
1970 to 1980	4.02%	3.63%
1980 to 1990	1.35%	1.15%
1990 to 2000	3.08%	3.43%
2000 to 2012	0.08%	-0.14%

Source: Woods and Poole (2013), and Energy Information Administration (2013).

The data arrayed in Table 1 highlights for Colorado the rate of energy efficiency improvements as they compare to the rate of economy-wide productivity of the state's economy. The table summarizes the average annual growth in energy and productivity in four decadal blocks of time over the period 1970 through 2012. Note that the two blocks of time highlighted with the light green shading (1970 to 1980 and 1990 to 2000) shows the biggest gains in energy efficiency even as they help drive the biggest gains in statewide productivity.[6] Similarly, the smallest

[4] By reducing U.S. energy use by 30 percent in 2020 and 55 percent in 2050, Laitner et al. (2010) estimate a range in savings per household from $81 in 2020 to $849 per household in 2050 as well as an increase in net jobs from 373,000 jobs created in 2020, 689,000 in 2030, and over 1.1 million in 2050.

[5] These and other economic and energy-related data cited are the author's calculations based on data drawn from various resources available from the Energy Information Administration (EIA 2013a and 2013b), and Woods & Poole (2013).

[6] Improvements in energy efficiency is the annual reduction in the amount of energy needed to support one dollar of economic activity. Productivity is a useful indicator of a robust economy, or the growth in the per capita well-being of any resident within the state. As used here, productivity is measured by the per capita Gross State Product (GSP), or per capita Gross Domestic Product (GDP at the national level).

improvements in energy efficiency are shown in the two unshaded decadal blocks (1980 to 1990 and 2000 to 2012). While there are other factors which influence overall productivity the connection to energy efficiency remains a critical link to driving the overall robustness of the Colorado economy. In short, greater rates of productivity have been accompanied by the greater pace of energy efficiency improvements. Over the period 1970 through 2012 the energy needed to support a dollar of economic activity has been cut by more than half, and this has benefited both Colorado and the U.S. economy.

Despite the significant improvement in energy efficiency since 1970, current levels of investments are still just scratching the surface. Building on Ayres and Warr (2009), Laitner (2013) estimates that, even with the significant improvements, the U.S. economy is about 14 percent energy (in)efficient, with 86 percent of applied energy wasted in the production of goods and services. As one can imagine, that level of waste creates a very large array of economic, social and environmental costs that tends to constrain the level of economic activity within Colorado and the U.S.

At the same time, recent studies by Lovins et al. (2011) and Laitner et al. (2012), among others, indicate that total energy requirements can be reduced by half, and do so in ways that actually increase overall economic activity. In other words, if the U.S. economy were to embrace a greater rate of infrastructure improvements together with displacement of the existing inefficiency equipment and appliances, by 2050, Laitner et al. (2012) report that we might achieve a 59 percent reduction in total energy use compared to the business as usual Energy Information Administration projection (consuming only 50 quads versus 122 quads by the year 2050). Simply put, demand side energy efficiency offers tremendous potential to reduce power sector greenhouse gas emissions while simultaneously reducing utility bills for American families and businesses, improving grid reliability, reducing co-pollutant emissions, improving energy security, and creating jobs in the energy efficiency sector. There is a strong historical record to suggest that energy efficiency can provide perhaps the largest single wedge of GHG emissions reductions – even as it boosts economic activity and provides new employment opportunities.[7]

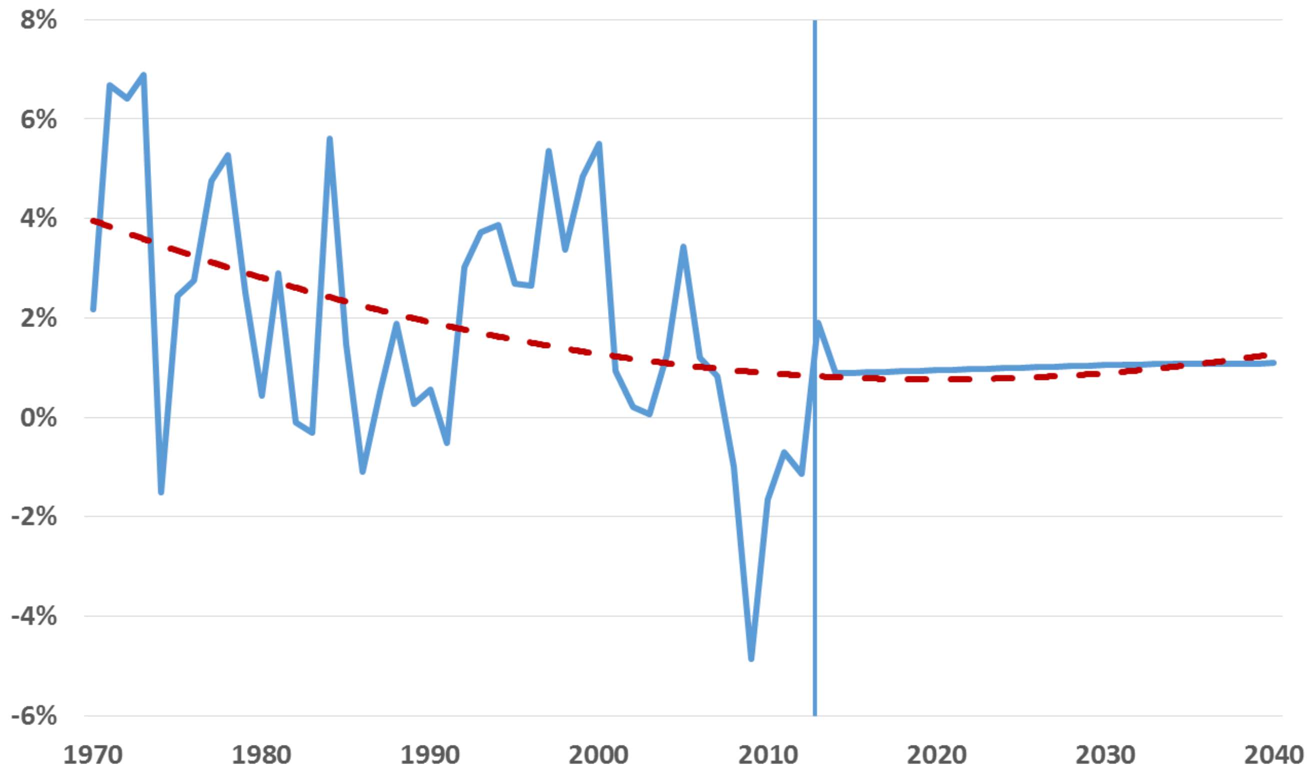
The evidence indicates that energy efficiency is not only a significant resource, but it also presents an immensely cost-effective pollution control strategy—with benefits exceeding costs over the investment life of individual measures or improvements. A study by the Lawrence Berkeley National Laboratory (Brown et al. 2007) demonstrated that one-third of electricity and natural gas use in buildings could be saved (along with respective emissions) at a cost of 2.7 cents per kilowatt-hour (¢/kWh) for electricity and between 2.5 and 6.9 dollars per million Btu for natural gas (all values in 2007 dollars). The study suggested that the cost savings over the life of the measures would be nearly 3.5 times larger than the up-front investment required (in other words, a benefit-cost ratio of 3.5). The financial analysis firm, Lazard Ltd (2013), further indicates that energy efficiency gains typically cost one-third the cost of new electric generating resources.[8] At the same time, Amann (2006) suggests that non-energy benefits of energy efficiency upgrades might range from 50 to 300 percent of household energy bill savings. These

[7] See also L.D. Harvey, *Energy Efficiency and the Demand for Energy Services* (2010); Committee on America's Energy Future, *Real Prospects for Energy Efficiency in the United States* (2010); Granade et al. 2009; American Physical Society, *Energy Future: Think Efficiency* (2008).

[8] See also, Friedrich et al. (2009) and Lazar and Colburn (2013).

added benefits range from financial savings to energy bill relief, comfort, aesthetics, noise reduction, health and safety, and convenience. Worrell et al. (2003) and Lung et al. (2005) found comparable non-energy benefits that greatly enhance the cost-effectiveness of energy efficiency within the industrial sector as well. Figure 1 provides an indication of the need to accelerate the rate of energy efficiency improvements within Colorado.

Figure 1: Trends in Colorado Economy-Wide Productivity 1970-2040

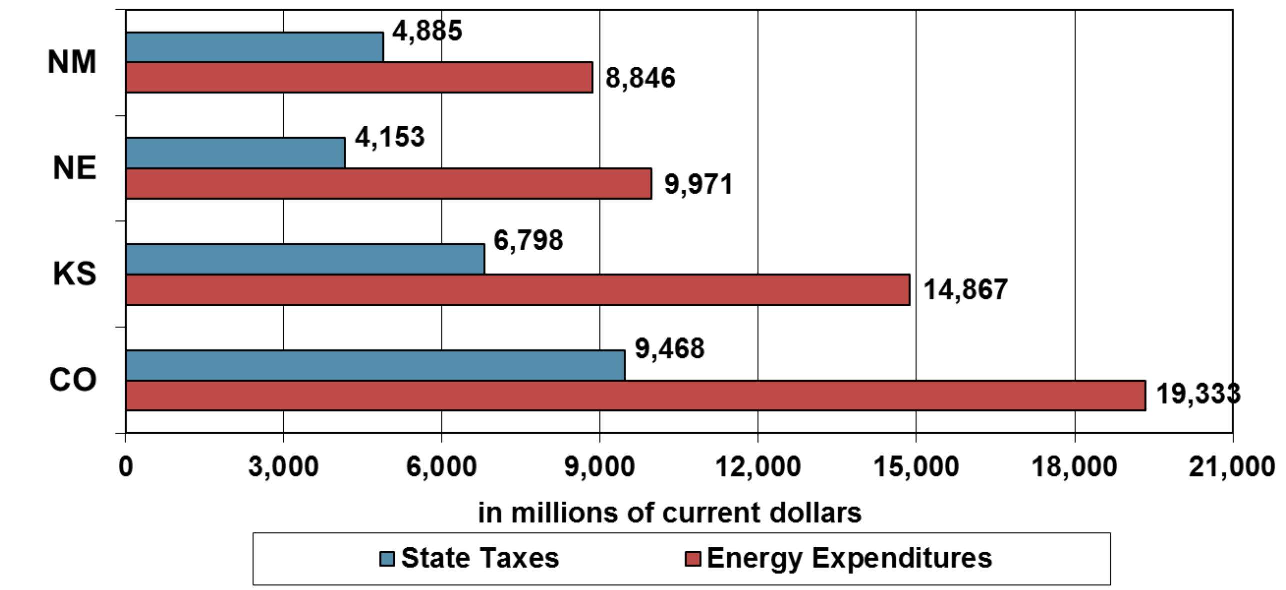


Source: Economic and Human Dimensions Research Associates using Woods & Poole (2013) data for Colorado.

Figure 1 extends the productivity information shown in Table 1 and examines the historical and anticipated future growth rates of annual productivity improvements within Colorado. The solid blue line shows the actual year-by-year data while the dashed red line highlights the general trend. The historical period 1970 to 2013 shows a progressive decline in the annual improvements, dropping from a 3 to 4 percent rate of improvement in the 1970s to a lagging one percent improvement in the recent years. More critically, the forecasted values show little, if any, improvement from the period 2013 through 2040. While not shown here, calculations suggest that the future rate of job creation will be significantly slowed as the result of a lagging economy. Compared to the somewhat more robust 30-year period of 1980 to 2010, the less robust future economic activity will support an average 300,000 fewer jobs over the period 2010 through 2040. All of this can be traced to a lagging rate of improvement in the economy-wide energy efficiency.

Figure 2 shows a further insight that might prompt the serious attention of state legislators and other policymakers. Looking at both state Census data for 2011, as well as information from the Energy Information Administration's state energy profiles (EIA 2013a), it turns out that households and businesses within Colorado actually spend more money for their total energy purchases than for the annual state operating budget that is approved annually by the state legislature. For comparison, Figure 2 highlights totals for the states of New Mexico, Nebraska, and Kansas, as well as Colorado. In the latter case, Coloradoans pay about 9.5 billion dollars for state approved revenues compared to 19.3 billion dollars for total energy expenditures. Based on the earlier discussion it appears that the state legislature can do more to benefit the Colorado economy by enacting policies which direct investments toward greater rates of energy efficiency improvements.

Figure 2: Comparison of State-Generated Taxes to Statewide Energy Expenditures 2011



Sources: U.S. Statistical Abstract (2013) and Energy Information Administration (2013). Information on all 50 states are available and, while varying, show a similar trend.

III. Assessing Employment and Economic Benefits of Efficiency Investments

Having established that energy efficiency is a viable resource to stimulate more productive economic activity, we now provide an analytical framework to evaluate the net economic and employment impacts of this resource. We use a combination of the U.S. Energy Information Administration's annual modeling work and the Woods and Poole econometric projections for Colorado to establish a reference case, or "business as usual" (BAU) scenario. We compare this to an "Efficiency-Led Scenario" in which the state moves toward more productive investments in energy efficiency technologies, systems, and infrastructure. In this alternative scenario, a greater level of energy-efficient investments a less-costly pattern of spending that supports new and existing demands for energy services. In this section we lay out three elements that form the basis of our assessment: (1) a typical projection for Colorado energy consumption over the period 2012 through 2030; (2) the key characteristics of the alternative investment scenario; and finally, (3) a description of the DEEPER modeling system used to evaluate the efficiency scenario characterized in this working paper.

A. The Business-as-Usual Backdrop

The foundation for this assessment is the *Annual Energy Outlook* published by the Energy Information Administration (2013) as it applies to the Mountain region of the U.S. economy and the Woods & Poole (2013) data for Colorado specifically. Although the forecast of energy and other market trends covers all uses of energy within our economy (including electricity, transportation fuels, natural gas, and other resources), here we will explore the aggregate changes in the state's overall pattern of energy (measured as trillions of btus) beginning in 2012 through the year 2030. The information includes the growth in population, employment and Gross State Product (GSP) along with the anticipated growth in the demand for energy services by households and businesses. It also includes the anticipated growth in total energy expenditures as well as a discussion of potential drivers of important shifts in energy demand.

Table 1 below provides the assumed reference case projections for key metrics against which we will compare the impacts of an efficiency-led scenario.

Table 2. Reference Case Projections for Key Economic Metrics 2012 and 2030

Metric	2012	2030	Annual Rate	Total Growth
The Macroeconomy				
Population (thousands)	5,197	6,711	1.43%	29.1%
Gross State Product (billion 2005 dollars)	226.3	350.6	2.5%	59.4%
Per Capita GSP (2005 dollars)	43,542	52,245	1.0%	20.0%
Total Employment (thousands)	3,189.5	4,249.6	1.6%	33.2%
Energy Use				
Total Consumption (trillion Btu)	1,465	1,613	0.5%	10.1%
Total Expenditures (million 2011 dollars)	18,959	21,486	0.7%	13.3%

Source: Woods and Poole (2013), and Energy Information Administration (2013).

A quick review of key assumptions highlighted in the forecast summary in Table 1 above suggests several elements of good news. The economy will grow at a faster clip than either the population or their increased use of energy. Jobs will also increase. While energy expenditures will grow as well, they will rise more slowly than GSP. Clearly, the economy will make overall efficiency improvements in the way it uses energy in order to provide Colorado's homes and businesses with needed goods and services.

Yet the business-as-usual rate of efficiency improvement still requires a 10 percent increase in overall energy consumption since the economy is projected to grow more quickly than the rate of efficiency improvement.[9]

Fortunately, the state can do much better. The many studies summarized in Section II of this working paper indicate that a much larger set of energy efficiency gains beyond the business-as-usual improvements are possible. This is true for the residential, the commercial, the industrial and the transportation sectors of the economy. For example, if the energy efficiency

[9] Note that although Colorado's economy is projected to grow at an annual clip of about 2.5 percent over the period 2012, this is substantially slower than nearly 4 percent average growth rate in the prior four decades. While much of the overall growth was the result of a large growth in population, as shown in Figure 1, the prior decades showed a much greater rate of economic productivity which is projected to slow from 1.9 percent (1970 to 2012) to just 1 percent in the years 2012 through 2030.

opportunities highlighted in the study by Laitner et al. (2012) were to be developed and implemented, the total energy demand for 2030, as shown in Table 1, would *decline* to 1,129 trillion Btus rather than *increase* to 1,613 trillion Btus. This is a 30 percent reduction in the business-as-usual forecast. What may be less obvious, however, is that the efficiency gains will prove to be less expensive than increasing the generation capacity to meet the higher electricity demands. The next section of this working paper explores the cost and performance characteristics that might contribute to cost-effective electricity reductions in our homes, schools and businesses.

B. Key Attributes of the Energy Efficiency Scenario

In this assessment, we draw initially upon a previously-referenced study to define an exploratory scenario that helps evaluate energy efficiency as those investments might drive both significant cost savings and net gains in employment. Laitner et al. (2012) explored the long-term energy efficiency potential for two scenarios in the United States through the year 2050. The study examined a more complete set of efficiency options, including natural gas and petroleum efficiency improvements as well as electricity savings from all sectors of the economy. Although the two scenarios indicate a total energy savings ranging from savings of 42 to 59 percent from the reference case projected for 2050, the central case of this analysis is an assessment of the economic impacts of achieving a 30 percent efficiency gain by 2030.

To provide a sense of scale and cost-effectiveness of the efficiency resource more broadly, Table 3 highlights key metrics from the ACEEE scenarios. We also include three other studies: the *Energy Technology Perspectives* published by the International Energy Agency (IEA/ETP 2010), *Reinventing Fire* released by Lovins et al. (2011), and *Toward a Sustainable Future for U.S. Power Sector: Beyond Business as Usual 2011* (Keith et al 2011).

Table 3. Key Metrics from Year 2050 Alternative Energy Future Studies

Metric	Year 2050 Impacts				
	ACEEE-Advanced	ACEEE-Phoenix	IEA ETP	Reinventing Fire	Synapse[1]
BAU GDP Index (2010 = 1.00)	2.79	2.79	1.95	2.58	2.71
BAU Energy Use (2010 = 1.00)	1.24	1.24	1.05	1.27	1.41
Efficiency Scenario Energy Use (2010 = 1.00)	0.72	0.51	0.47	0.69	0.67
Investment (Trillion 2009 Dollars)[2]	2.9	6.4	5.9	4.5	1.4
Savings (Trillion 2009 Dollars)[2]	15.0	23.7	15.1	9.5	4.4
Index Savings to Investment[3]	5.2	3.7	2.6	2.1	3.5

Table Notes: (1) While the first four scenarios reflect economy-wide energy savings, the Synapse report captures only the savings from electricity production and consumption. (2) The investments and savings data reflect cumulative values in constant dollars over the period 2010 through 2050. (3) The savings to investment index is a simple comparison of suggested energy bill savings compared to the total cost of investments, also over the period 2010 through 2050. Because there is no way to compare the discounted streams of savings and expenditures over time, this simple index is indicative of, but should not be construed as, a true benefit-cost ratio.

Interestingly, there is a wide range in the assumed future GDP growth among the five scenarios outlined in Table 3. The IEA projects an economy in 2050 that is about 1.95 times bigger than in 2010. ACEEE and Synapse, generally following the EIA's *Annual Energy Outlook*, suggest economic activity that will be 2.71 to 2.79 times larger than 2010. Reinventing Fire suggests a more moderate growth path so that economic activity is 2.58 times larger in 2050 compared to 2010. In comparing the business-as-usual energy growth in the five scenarios with their respective 2050 efficiency gains, the evidence as previously noted suggests a potential 2050 savings that ranges between 42 and 59 percent.[10] Moreover, all of the scenarios suggest a net positive savings to investment ratio, ranging from 2.1 to 5.2 over the period of analysis within each scenario. To explore the idea of how effective efficiency might be as a productivity and job creation strategy, but reflecting larger uncertainties in the out-years, we take the analysis here only the year 2030.

The core scenario for this exploration assumes an energy savings that, beginning in 2014, slowly ratchets up to reach 30 percent by 2030. The benefit-cost ratio of this scenario is just under 2.0. As we explain further in the section that follows, we assume that program costs will drive investments that, in turn, generate a 30 percent reduction in conventional energy use by 2030 so that the energy bill savings, in constant dollars, are twice as big as the combination of program costs and investments, also in constant dollars.

We next turn to a description of the Dynamic Energy Efficiency Policy Evaluation Routine, or the DEEPER, Modeling System, which, in essence, is an econometric input-output analytical tool. Although recently given a new name, the model's origins can be traced back to modeling assessments that were first completed in the early 1990s (see Appendix A for historical information and other details on the DEEPER model).

C. Review of the DEEPER Economic Policy Model

The DEEPER model is "quasi-dynamic" in that the costs of energy efficiency improvements are based on the level of efficiency penetration over some period of time. The greater the efficiency penetration, the higher the costs, and the resulting payback periods begin to increase. Moreover, the model adjusts labor impacts given the anticipated productivity gains within key sectors of the U.S economy. As an example, if the construction and manufacturing sectors increase their output as a result of the alternative policy scenario, the employment benefits are likely to be affected – depending on assumptions about the expected labor productivity gains within each of those sectors.

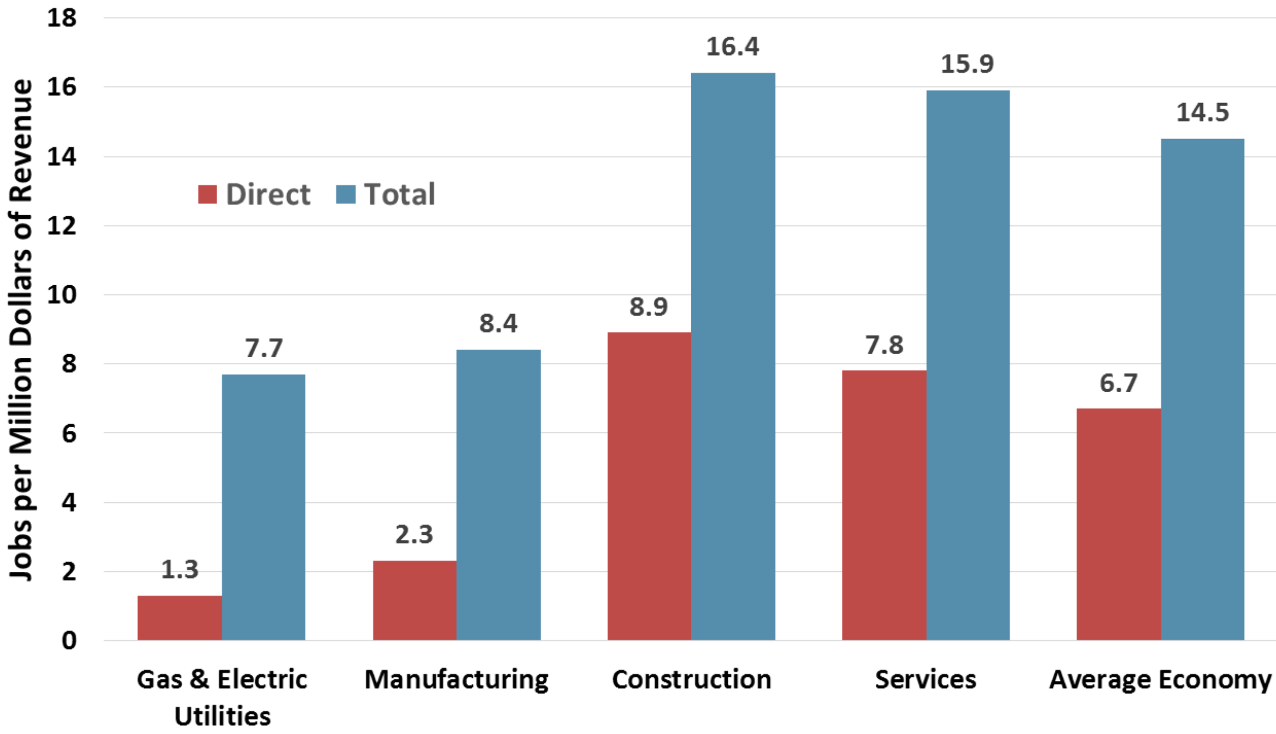
Input-output models initially were developed to trace supply linkages in the economy. For instance, an input-output accounting framework can show how purchases of lighting technologies or industrial equipment benefit the lighting and other equipment manufacturers in a state. In addition, because the input-output model has coefficients linking both directly and indirectly affected industries, the model can also reveal the multiplicative impacts that such purchases are likely to have on other industries and businesses that might supply the necessary goods and services to those manufacturers.

The net economic gains of any new investments in energy efficiency will depend on the structure of the economy, and which sectors are most affected by changes in new spending patterns that

[10] As an example, the Synapse study projects a BAU energy growth index of 1.41, with an efficiency use index that falls to 0.67. Hence, (0.67 / 1.41 – 1) *100 percent = 52 percent.

are promoted by investments in energy productivity rather than electricity supply. To illustrate this point, Figure 3, below, compares the direct and total employment impacts that are supported for every one million dollars of revenue received by different sectors of the U.S. economy. These include electric utilities, manufacturing, personal and business services, and construction.[11] For purposes of this study, a job is defined as sufficient economic activity to employ one person full-time for one year.

Figure 3. Labor Intensities for Key Sectors of the Colorado Economy



Source: Economic and Human Dimensions Research Associates using IMPLAN (2013) Data for Colorado.

Of immediate interest in Figure 3 is the relatively small number of direct and total jobs supported by energy sector spending, in this case gas and electric utilities. Within Colorado utility industry provides, for example, only 7.7 total jobs per million dollars of revenues that it receives. This total includes 1.3 jobs directly supported by the industry as well as those jobs linked to businesses which, in turn, provide goods and services to maintain the utilities' operation. Adding the jobs induced as the wages from both the utilities and their supply chain are spent within the state, the total expands to the 7.7 jobs shown above. On the other hand, one million dollars spent in construction supports a total of 16.4 jobs, both directly and indirectly.

48. The model used for the assessment described here relies on the IMPLAN datasets for the United States. IMPLAN stands for "IMpact Analysis for PLANning." These 2011 historical economic accounts (IMPLAN 2013) provide a critical foundation for a wide range of modeling techniques, including the input-output model used as a basis for the assessment described here. For more information on the use of this kind of analysis, see the discussion in Appendix A of this report. For more recent examples of an assessment undertaken in the policy arena, see Busch et al. (2012) and Rifkin et al. (2013).

As it turns out, much of the job creation from energy efficiency programs is derived by the difference between jobs within the energy industry and the jobs that are supported by the respending of energy bill savings in other sectors of the economy.

D. An Illustration: Jobs from Improvements in Commercial Office Buildings

To illustrate how a simplified job impact analysis might be done, we will use the example of installing one million dollars of efficiency improvements in a large Colorado office building. Office buildings (traditionally large users of energy due to heating and air-conditioning loads, significant use of electronic office equipment, and the large numbers of persons employed and served) provide substantial opportunities for energy-saving investments. The results of this example are summarized in Table 4 below.

The assumption used in this example is that the investment has a positive 4-year payback. In other words, the assumption is that for $1 million of energy efficiency improvements, the upgrades might be expected to save an average of $250,000 in reduced energy costs over the useful life of the technologies. This level of savings is conservatively low but consistent with the low end of ranges cited elsewhere in this report. At the same time, if we anticipate that the efficiency changes will have an expected life of roughly 15 years, then we can establish a 15-year period of analysis. In this illustration, we further assume that the efficiency upgrades take place in the first year of the analysis, while the energy bill savings occur in years 1 through 15. Moreover, we assume that only half the savings occur in the first year as it may take several months to actually start an average project with savings not beginning until halfway through the year.

Table 4. Job Impacts from Government Building Energy Efficiency Improvements

Expenditure Category	Amount (Million $)	Employment Coefficient	Job Impact
Installing Efficiency Improvements in Year 1	1.0	16.4	16.4
Diverting Expenditures to Fund Efficiency Improvements	-1.0	15.9	-15.9
Energy Bill Savings in Years 1 through 15	3.6	15.9	57.2
Lower Utility Revenues in Years 1 through 15	-3.6	7.7	-27.7
Economy-Wide Productivity Gains in Years 1 through 15	4.8	14.5	69.6
Net 15-Year Change			99.6

Note: The employment multipliers are taken from the appropriate sectors found in Figure 3. Based on the efficiency costs described in the text, the annual savings are about $250,000 with only one-half available in the first year. The more robust economy, together with productivity gains might drive a $300,000 greater level of economic activity. The jobs impact is the result of multiplying the row change in expenditure by the appropriate row multiplier. On average, this building upgrade would be said to support a net gain of about 6.6 jobs per year for 15 years. For more details, see the text that follows.

The analysis further assumes that we are interested in the *net effect* of employment and other economic changes. This means we must first examine all changes in business or consumer expenditures—both positive and negative—that result from a movement toward energy efficiency. Each change in expenditures must then be multiplied by the appropriate multiplier (taken from Figure 3) for each sector affected by the change in expenditures. The sum of these products will then yield the net result.

In our example, there are four separate changes in expenditures, each with their separate effect. As Table 3 indicates above, the net impact of the scenario suggests a gain of 99.6 job-years (rounded) in the 15-year period of analysis. This translates into an average net increase of about 6.6 jobs each year for 15 years. In other words, the efficiency investment made in the office building is projected to sustain an average 6.6 net jobs each year over a 15-year period compared to a "business-as-usual" scenario. Roughly speaking, if comparable projects like this scaled to more like $100 million in a single year, the number of jobs gained would similarly scale upward (to just under 100,000 job-years).[12]

E. Appropriate Modifications in the Energy Efficiency Scenarios

The economic assessment of the alternative energy scenarios was carried out in a very similar manner as the example described above. That is, the changes in energy expenditures brought about by investments in energy efficiency and renewable technologies were matched with their appropriate employment multipliers. There are several modifications to this technique, however.[13]

First, it was assumed that only 80 percent of both the efficiency investments and the subsequent savings are spent within Colorado. We based this initial value on the 2011 IMPLAN dataset as it describes local purchase patterns that typically now occur in Colorado. We anticipate that this is a conservative assumption since most efficiency projects are likely to be (or could be) carried out entirely by contractors and dealers within the state. By way of illustration, if the set of policies encourages local participation so that the share was increased to 100 percent, for example, the net jobs might grow another five percent or more compared to our standard scenario exercise.

Second, an adjustment in the employment impacts was made to account for assumed future changes in labor productivity. As outlined in the Bureau of Labor Statistics *Outlook 2010–2020*, productivity rates are expected to vary widely among sectors (BLS 2012). For instance, the BLS projects an economy-wide 1.5 percent annual average productivity gain as the economy better integrates information technologies and other improvements. To illustrate the impact of productivity gains on future employment patterns, let us assume a typical labor productivity increase of 2.2 percent per year. This means, for example, that compared to 2012, we might expect that a $1 million expenditure in the year 2030 will support only 68 percent of the number of jobs as in 2012.[14]

Third, for purposes of estimating energy bill savings, it was assumed that current energy prices in Colorado would follow the same growth rate as those published by the Energy Information Administration in its *Annual Energy Outlook* 2012 (EIA 2013b). Fourth, it was assumed that the large-scale efficiency upgrades are financed by bank loans that carry an average 5 percent interest rate over a 5-year period. While this does raise the cost to end-users as a result of the

[12] While this idea of scale more or less holds true, as costs begin to rise with a greater level of penetration of energy efficiency measures, the idea of diminishing returns could reduce overall cost-effectiveness of individual scenarios as a function of the total level of savings that might be achieve – in this case, for the year 2030. See generally the discussion on this point as highlighted by Table 6 that follows the main finding of this exploratory effort.

[13] For a historical review of how this type of analysis is carried out, see Laitner, Bernow, and DeCicco (1998).

[14] The calculation is $1/(1.022)^{18}$ * 100 equals 1/1.4796 * 100, or 68 percent.

interest that must be paid on bank loans, raising or lowering the interest rates in this analysis will not appreciably affect the net outcome of the results otherwise reported. Also, to limit the scope of the analysis, no parameters were established to account for any changes in interest rates as less capital-intensive technologies (i.e., efficiency investments) are substituted for conventional supply strategies, or in labor participation rates—all of which might affect overall spending patterns.

While the higher cost premiums associated with the energy efficiency investments might be expected to drive up the level of borrowing (in the short term), and therefore interest rates, this upward pressure would be offset to some degree by the investment avoided in new power plant capacity, exploratory well drilling, and new pipelines. Similarly, while an increase in demand for labor would tend to increase the overall level of wages (and thus lessen economic activity), the job benefits are small compared to the current level of unemployment or underemployment. Hence, the effect would be negligible.

Fifth, for the buildings and industrial sectors it was assumed that a program and marketing expenditure would be required to promote market penetration of the efficiency improvements. Based on other program reviews, this was set at 15 percent of the efficiency investment in the early years but declining to 5 percent of the much larger investments in the last year of the assessment.[15]

Finally, it should again be noted that, by design, this analysis does not account for the full effects of the efficiency investments since the savings beyond 2030 are not incorporated into the modeling assumptions. Nor does the analysis include other productivity benefits that are likely to stem from the efficiency investments. These can be substantial, especially in the industrial sector. Industrial investments that increase energy efficiency often result in achieving other economic goals such as improved product quality, lower capital and operating costs, increased employee productivity, or capturing specialized product markets.[16] These "co-benefits" are highlighted as "economy-wide productivity gains" in Table 4.

IV. Economic Impact of a Cost-Effective Energy Efficiency Scenario

The investment and savings data from the efficiency identified above (again reaching a 30 percent energy savings through efficiency gains by 2030) were used to estimate the financial and the economy-wide impacts for the key benchmark years of 2014, 2020, 2025, and 2030. Each change in sector spending was evaluated by the Investment and Spending module within the DEEPER model for a given year—relative to the baseline or business-as-usual scenario. These were then matched to their appropriate sector impact coefficients. These negative and

[15] The assumption here is that program spending is necessary to encourage, monitor, and verify the requisite efficiency gains. In addition, training programs as well as increased research & development expenditures may also be needed to improve technology performance and market penetration. This range is generally consistent with the findings of Friedrich et al. (2009). For other examples that integrate program spending into efficiency policy assessments, see Laitner et al. (2010) among other studies.

[16] For a more complete discussion on this point, see Elliott, Laitner, and Pye (1997), Lovins et al. (2002), and Worrell et al. (2003).

positive changes were further evaluated by DEEPER's macroeconomic module to estimate the larger net job and wage benefits for the U.S. economy.

Starting with very small impacts in 2014, the end-use energy efficiency target of a 30 percent savings by 2030 spurs both program costs and technology investments that, in turn, begin to change the patterns of electricity consumption and production. Program spending of $200 million in 2014 is assumed to drive an initial $900 million in technology investments in that year. The initial impacts on energy consumption are relatively small, reducing energy bills by an estimated $400 million (about 2 percent of the reference case electricity expenditures otherwise projected in that year). However, the efficiency investments rise to 2,400 millions of dollars by 2030.

Table 4. Key Annual Financial and Economic Impacts from the Efficiency Scenario

Economic Impact	Metric	2014	2020	2025	2030	Average 2014-2030
Efficiency Gain	Savings from Ref Case	2.1%	13.7%	22.3%	30.0%	**16.8%**
Program Cost	Million 2011 Dollars	200	300	300	300	300
Investment	Million 2011 Dollars	900	1300	1800	2400	1,500
Energy Bill Savings	Million 2011 Dollars	400	2,700	4,600	6,300	3,400
Efficiency-Driven Employment	Net Jobs	1,700	19,600	33,800	47,300	25,000
Productivity Employment	Net Jobs	3,900	30,200	56,200	86,100	42,000
Total Employment Gains	Net Jobs	5,600	49,800	90,000	133,400	67,000

Source: Analysis as described in the text of the working paper.

The savings on energy bills is just over $7 billion (rounded) in 2030. As might be expected, the program spending and changed investment patterns have a distinct economic impact. The second set of impacts in Table 4 highlights the key employment benefits for the same years. Net employment benefits begin with about 5,600 jobs in 2014, but grow steadily as both investments and energy savings increase over time. By 2030, the net employment benefits reach about 133,400 jobs when we include both the efficiency-driven employment benefits as well as the productivity-driven employment benefits.

In short, mobilizing energy efficiency as a critical economic development strategy can provide dramatic improvements in the Colorado job creation potential. Achieving a 30 percent improvement in efficiency by 2030 could generate a net gain of about 133,000 jobs for Colorado residents. This is a 3 percent boost compared to the total jobs that might otherwise be available within the state's economy.

V. Conclusions

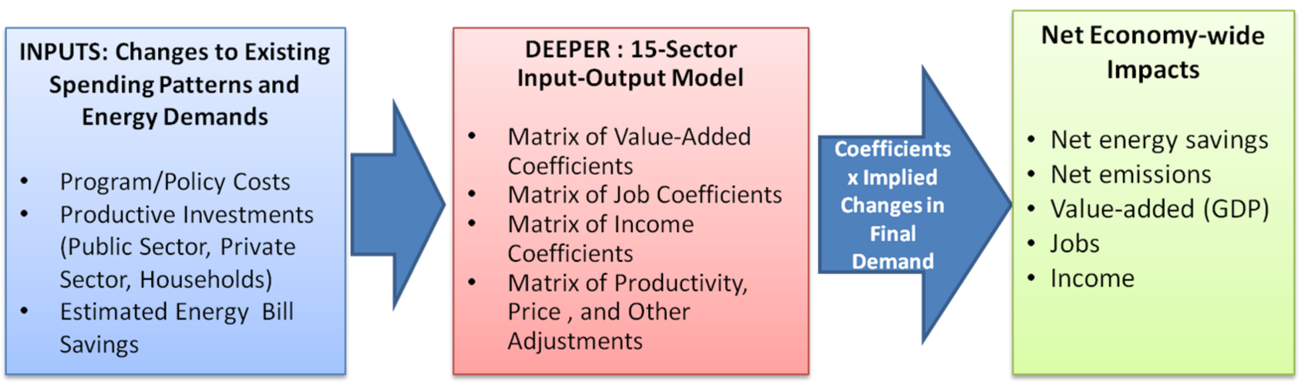
A systematic approach promote end-use energy efficiency can drive a meaningful improvement in Colorado economic productivity as well as a large gain in employment opportunities. The evidence presented here documents the critical role that energy efficiency can play in positively shaping both the state's economy and the environment. If Colorado chooses to develop energy efficiency resource as characterized in this working paper, a 30 percent energy savings by the year 2030 can catalyze large net consumer savings as well as launch an important opportunity to stimulate greater job creation – even as we bring about a substantial reduction in carbon pollution and other harmful air pollutants.

Appendix A: Methodology of the DEEPER Modeling System

To evaluate the macroeconomic impacts of reductions in fossil fuel-fired plant emissions from demand-side efficiency improvements, we use the proprietary **D**ynamic **E**nergy **E**fficiency **P**olicy **E**valuation **R**outine, or DEEPER model. The model was developed by John A. "Skip" Laitner and has a 23-year history of use and development, though it was renamed "DEEPER" in 2007. One recent use of the model was a collaborative assessment by the BlueGreen Alliance and the American Council for an Energy-Efficient Economy (ACEEE) to evaluate the net job impacts of the recently enacted fuel economy standards (Busch et al. 2012). The most recent use of DEEPER was for the development of the Third Industrial Revolution Master Plan for Nord-Pas de Calais, a former coal-mining region and still heavy manufacturing region of 4 million people in Northeastern France (Rifkin et al. 2013).

The DEEPER Modeling System is a 15-sector[17] quasi-dynamic input-output (I/O) model[18] of the U.S. economy that draws upon social accounting matrices[19] from the MIG, Inc. (formerly the Minnesota IMPLAN Group),[20] energy use data from the U.S. Energy Information Administration's Annual Energy Outlook (AEO), and employment and labor data from the Bureau of Labor Statistics (BLS). The Excel-based tool contains approximately eight interdependent worksheets. The model functions as laid out in the flow diagram below:

The DEEPER Modeling System



DEEPER results are driven by adjustments to energy service demands and alternative investment patterns resulting from projected changes in policies and prices between baseline and policy scenarios. The model is capable of evaluating policies at the national level through

64. The current mix of 15 sectors reflects the analyst's efforts to reflect key economic impacts while maintaining a model of manageable size. It is possible to expand and reduce the number of sectors in the model with relatively easy programming adjustments. If the analyst chooses to reflect a different mix of sectors and stay within the 15 x 15 matrix, that can be easily accomplished through minor changes.
65. Input-output models use economic data to study the relationships among producers, suppliers, and consumers. They are often used to show how interactions among all three impact the macroeconomy.
66. A social accounting matrix is a data framework for an economy that represents how different institutions — households, industries, businesses, and governments — all trade goods and services with one another.
67. See http://implan.com/V4/Index.php. The entire IMPLAN database for the U.S. economy can be expanded to more than 400 sectors as needed (IMPLAN 2013).

2050. However, given uncertainty surrounding future economic conditions and the life of the impacts resulting from the policies analyzed, it is often used to evaluate out 15–20 years. Although the DEEPER Model, like most I/O models, is not a general equilibrium model,[21] it does provide accounting detail that balances changes in investments and expenditures within a sector of the economy. With consideration for goods or services that are imported, it balances the variety of changes across all sectors of the economy.[22]

The Macroeconomic Module contains the factors of production — including capital (or investment), labor, and energy resources — that drive the U.S. economy for a given "base year." DEEPER uses a set of economic accounts that specify how different sectors of the economy buy (purchase inputs) from and sell (deliver outputs) to each other.[23]

The DEEPER model is typically used to evaluate impacts of selected policies in 15 different economic sectors that are usually affected by changes in energy use and investment. For purposes of this project assessment we propose the following sectors: (1) Agriculture, (2) Coal Mining, (3) Other Mining, (4) Electric Utilities, (5) Construction, (6) Automobile Manufacturing, (7) Iron, Steel and Aluminum Manufacturing, (8) Chemicals, (9) Electronics, (10) Other Manufacturing, (11) Wholesale and Retail Trade, (12) Personal and Business Services, (13) Financial Services, (14) Education, Defense and Other Government Services, and (15) Households.[24] The model looks at different labor intensities[25] in different sectors to provide insights about the net employment benefits to the economy.

The Macroeconomic Module translates the selected different policy scenarios, including necessary program spending and research and development (R&D) expenditures, into an annual array of physical energy impacts, investment flows, and energy expenditures over the desired period of analysis. DEEPER evaluates the policy-driven investment path for the various financing strategies, as well as the net energy bill savings anticipated over the study period. It also evaluates the impacts of avoided or reduced investments and expenditures otherwise required by the electric and natural gas sectors. These quantities and expenditures feed directly into the final demand worksheet of the module that generates the net changes in sector spending.

The resulting positive and negative changes in spending and investments in each year are converted into sector-specific changes in aggregate demand.[26] These results then drive the I/O matrices utilizing a predictive algebraic expression known as the Leontief Inverse Matrix.[27]

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68. General equilibrium models operate on the assumption that a set of prices exists for an economy to ensure that supply and demand are in an overall equilibrium.
69. When both equilibrium and dynamic input-output models use the same technology assumptions, both models should generate a reasonably comparable set of outcomes. See Hanson and Laitner (2005) for a diagnostic assessment that reached that conclusion.
70. Further details on this set of linkages can be found in Hanson and Laitner (2009).
71. Household spending is allocated to each of the sectors using the personal consumption expenditure data provided in the IMPLAN data set.
72. This is the magnitude of jobs supported by a given level of investment.
73. This is the total demand for final goods and services in the economy at a given time and price level.
74. For a more complete discussion of these concepts, see Miller and Blair (2009).

Employment quantities are adjusted annually according to assumptions about the anticipated labor productivity improvements based on forecasts from the Bureau of Labor Statistics. The DEEPER Macroeconomic Module traces how changes in spending will ripple through the U.S. economy in each year of the assessment period. The end result is a net change between the reference and policy scenarios in jobs, income, and value-added,[28] which is typically measured as Gross Domestic Product (GDP) or value-added Gross Regional Product (GRP) for the study region (e.g., the national, state, or local economies).

Like all economic models, DEEPER has strengths and weaknesses. It is robust by comparison to some I/O models because it can account for price and quantity changes over time and is sensitive to shifts in investment flows. It also reflects sector-specific labor intensities across the U.S economy. However, it is important to remember when interpreting results for the DEEPER model that the results rely heavily on the quality of the information that is provided and the modeler's own assumptions and judgment. The results are unique to the specified policy design. The results reflect differences between scenarios in a future year, and like any prediction of the future, they are subject to uncertainty.

75. This is the market value of all final goods and services produced within a country in a given period.

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