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Energy, Economic, and Environmental Benefits of the Solar America Initiative

S. Grover
ECONorthwest
Portland, Oregon

Subcontract Report
NREL/SR-640-41998
August 2007

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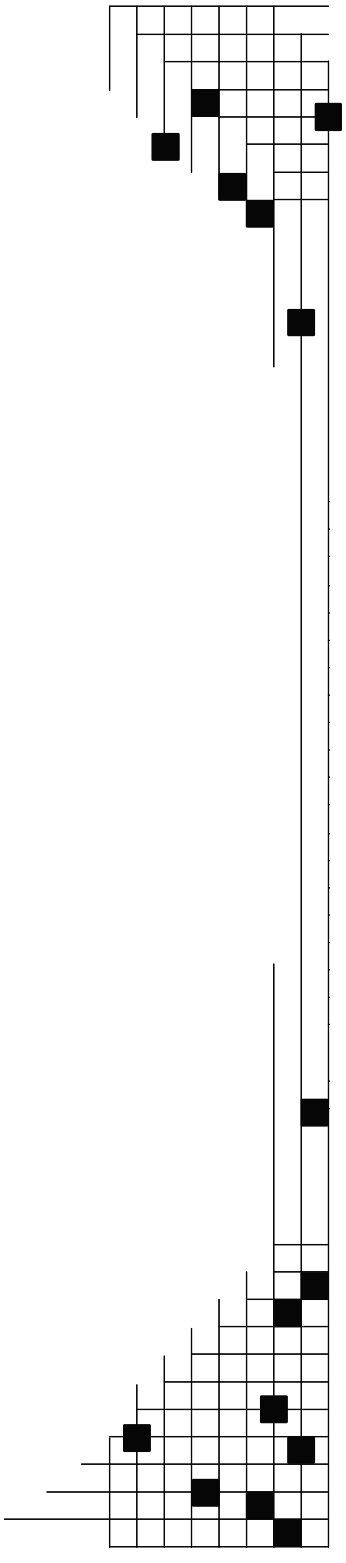

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1. INTRODUCTION

The President's Solar America Initiative (SAI) was launched in January 2006 as part of the administration's Advanced Energy Initiative. The SAI is being led by the U. S. Department of Energy (DOE) Solar Energy Technologies Program (SETP), with the National Renewable Energy Laboratory (NREL) providing analytical and technical support. The SAI has a goal of installing 5-10 GW of photovoltaic (PV) systems in the U.S. by 2015 and 70-100 GW of PV systems in the U.S. by 2030. To make PV cost competitive with other energy resources, this requires that the installed cost of PV fall from approximately $8/Wdc in 2005 to $3.3/Wdc in 2015 and $2.5/Wdc in 2030.

This report presents estimates of the potential benefits should the SAI PV installation goals be achieved. For this analysis, the areas researched include energy, economic, and environmental benefits. For the purposes of estimating these benefits, we assume that the SAI meets its PV installation goals. Other issues – such as estimating consumer demand for solar and determining the optimal market mechanism that will drive installation cost reductions – are important, but outside the scope of this project.

Throughout this report, benefits are calculated for both high and low scenarios for the SAI goals based on the target installation costs and amount of PV installed:

- The *Low Scenario* assumes that 5 GW of PV is installed by 2015 at $3.3/Wdc and 70 GW is installed by 2030 at $2.5/Wdc
- The *High Scenario* assumes that 10 GW of PV is installed by 2015 at $3.3/Wdc and 100 GW of solar is installed by 2030 at $2.5/Wdc.

To estimate the potential SAI benefits given these scenarios, ECONorthwest completed the following:

- The IMPLAN input-output model was used to estimate the economic impacts associated with the manufacture, installation, and operation of PV systems that would meet the SAI installation goals
- Existing model results and secondary research findings were used to estimate emissions and associated health benefits that will result with PV installations
- Benefit factors taken from secondary sources were used to estimate additional environmental and energy benefits created by the SAI.

The remainder of this report is organized as follows. The *Energy Benefits* section provides an estimate of the amount of electricity generation that will be provided by the SAI if its goals are met as well as estimates of the amount of natural gas displaced. Following this, the *Economic Benefits* section presents estimates of the economic benefits assuming that the SAI installation goals are achieved and builds on the energy results provided in the previous section. The *Environmental Benefits* section presents a discussion of environmental benefits and includes emissions reductions and health benefits that could be achieved with PV installations that meet the SAI goals. This is followed by an *Additional Benefits* section that presents additional information on energy-related benefits that will result from the SAI, including information on possible additional energy benefits such as blackout prevention, price effects, emergency power, and reduced transmission and distribution (T&D) losses. Finally, all of the estimated benefits are summarized in the *Summary and Conclusions* section. Additional IMPLAN model results are included in *Appendix A* and a technical discussion of the IMPLAN model is included in *Appendix B*.

2. ENERGY BENEFITS

Achieving the SAI goals for PV installation will result in a significant amount of electricity generation resources that will displace generation from more traditional sources. The first step in estimating the benefits of the SAI is to determine the amount of electricity generation that will result in both the high and low scenarios. The PV energy estimates are then used to determine the economic and environmental benefits in subsequent sections of this report.

Table 1 shows the estimated annual PV electricity generation that would result if the SAI achieved its PV installation goals in both the high and low scenarios. These results are based on an average annual solar capacity factor of 19 percent estimated by NREL based on national solar insolation data[1]. Actual insolation levels will vary based on location or orientation. In comparison, the Energy Information Administration (EIA) reports that in 2004, 397 MW of PV capacity was installed throughout the country, producing 579,000 annual MWh, for a capacity factor of approximately 17 percent[2].

Based on these assumptions, the SAI is projected to produce 10–20 TWh/yr of PV electricity generation in 2015 and 110–170 TWh/yr in 2030 based on the installed PV capacity in the high and low case scenarios. The EIA projects total U.S. electricity generation to be 4,713 TWh/yr in 2015 and 5,788 TWh/yr in 2030[3]. Attaining the SAI targets would therefore result in PV displacing approximately 0.2–0.4 percent of total U.S. electrical generation in 2015 and 2–3 percent of total generation in 2030. In terms of residential use, the EIA's Residential Energy Consumption Survey indicates that average U.S. household electricity consumption is about 10,000 kWh/yr (EIA 2001). Under the SAI, PV would therefore generate enough electricity to power 1–2 million homes in 2015 and 10–20 million homes in 2030.

Table 1: Estimated SAI PV Generation and Total U.S. Electricity Generation

Scenario	Installed PV Capacity (GW)	PV Generation (TWh/yr)	Total U.S. Generation (TWh/yr)	PV Percent of Total Generation
2015 Low	5	8.3	4,713	0.2%
2015 High	10	16.6	4,713	0.4%
2030 Low	70	116.5	5,788	2.0%
2030 High	100	166.4	5,788	2.9%

Natural Gas Displaced

One of the primary benefits of the SAI will be the displacement of natural gas used to generate electricity. PV generation is well suited to offset a portion of peak electricity demand, which is often met by natural gas power plants, as PV output is highly correlated with peak demand on the electricity system.

[1] Margolis (2006) bases this analysis of location-specific capacity factors from NREL's PVWatts PV simulation program available at: http://rredc.nrel.gov/solar/codes_algs/PVWATTS/version1/.

[2] EIA Renewable Energy Annual 2004. Tables 11 and 12.

[3] EIA Annual Energy Outlook 2007 (Early Release) Data for Figure 5 available at: http://www.eia.doe.gov/oiaf/aeo/electricity.html

Natural gas fuel savings were estimated for each of the SAI capacity scenarios using the following assumptions:

1. At relatively low penetration levels (less than 10 percent of total electricity generation), PV would displace fossil fuel generation on a one-to-one basis (Denholm and Margolis 2006).

2. Transmission and distribution (T&D) losses for fossil fuel generation are assumed to average about 7 percent based on several studies reviewed for this report. This reflects electricity that is lost as it travels through the wires from generating plants to end-users. Due to these losses, fossil fuel plants must generate 7 percent more electricity than PV systems to provide end-users with an equivalent amount of electricity.

3. Seventy-five percent of the PV generation would displace natural gas generation, as estimated by Connors et al. (2005) in a recent analysis of the load-shape following characteristics of the U.S. electricity generation system. (The other 25 percent of PV generation would mainly displace coal generation.)

4. The average heat rate for all natural gas plants offset by PV generation is estimated to be 7,100 BTU/kWh in future years[4]. Heat rates for natural gas plants vary greatly and depend on the type and vintage of the plant. While a typical natural gas combustion turbine (NGCT) has a heat rate of 11,100 BTU/kWh, new natural gas combined cycle (NGCC) plants in California have a much lower heat rate of 7,100 BTU/kWh (Margolis 2006). The EIA expects the heat rate of new NGCC plants to continue to decline over time, to as low as 6,333 BTU/kWh in 2015[5]. Since natural gas offset by PV will be from a mix of old and new NGCC and NGCT plants, an average heat rate of 7,100 BTU/kWh is assumed for this analysis.

Based on these assumptions, the projected natural gas savings under the SAI are roughly 0.05–0.1 quadrillion BTU (quads) in 2015 and 0.5–1.0 quads in 2030. The EIA projects that total U.S. natural gas consumption will be 26 quads in 2015 and 27 quads in 2030.[6] Thus, PV generation due to the SAI is expected to displace 0.2–0.4 percent of natural gas consumption in 2015 and 2–4 percent of natural gas consumption in 2030.

Another way to view the benefits of reduced natural gas consumption is to consider the potential impact on liquefied natural gas (LNG) imports. LNG imports to the U.S. increased 700 percent between 1997 and 2005, and much of this demand has been driven by increased natural gas consumption for electricity generation.[7] During this same period, natural gas use for electricity generation increased by 1.8 quads (43 percent).

In the future, increasing use of natural gas use for electricity generation is expected to drive further increases in LNG imports. LNG imports are projected to rise from approximately 0.5 quads in 2003 to 3 quads in 2015 and to 4 quads in 2030[8]. By offsetting a significant amount of natural gas generation, the

[4] The heat conversion rate provides a measure of thermal efficiency (BTU per kWh) for converting heat input to electricity output.

[5] EIA Annual Energy Outlook 2006.

[6] EIA Annual Energy Outlook 2007 (Early Release) Data for Figure 3 available at: http://www.eia.doe.gov/oiaf/aeo/consumption.html

[7] EIA. Natural Gas: U.S. Data. Available at: www.eia.doe.gov/oil_gas/natural_gas/info_glance/natural_gas.html.

[8] Ibid.

SAI could displace the equivalent of 2–3 percent of LNG imports by 2015 and 12–24 percent of LNG imports by 2030.

Natural Gas Plants Avoided

Since the SAI will result in PV installations that help provide electricity during peak demand periods, the need for constructing new natural gas peaking plants will be reduced. The following assumptions were used to determine the number of new natural gas plants avoided due to the SAI:

1. The average effective load carrying capacity (ELCC) of PV was assumed to be 60 percent (i.e., on average, 60 percent of installed PV capacity is available during peak generation periods) based on research by Perez et al (2006). Thus, each 1 GW of PV would displace the need for 0.6 GW of natural gas peaking generation capacity.

2. On average, new natural gas plants will be sized at 250 MW in the future. EIA data indicates that over the next few years, utilities plan to build natural gas plants in the 170–215 MW size range[9]. After that, the EIA projects that typical new plant sizes will continue to grow[10].

Under the SAI scenarios, PV systems would eliminate the need for 3–6 GW of new gas generating capacity through 2015 and 42–61 GW of new capacity through 2030. EIA projects that 48 GW of new natural gas electricity generation capacity will be required between 2005 and 2015, and 124 GW of new natural gas electricity generation capacity will be required between 2005 and 2030.[11] Given the forecasted demand, the estimated PV installations would be the equivalent of 6–13 percent of projected new natural gas capacity between 2005 and 2015, and 34–49 percent of new natural gas capacity between 2005 and 2030. Stated differently, attaining the SAI goals would avoid the construction of 12–24 natural gas plants by 2015 and 170–240 plants by 2030.

The following section uses these energy results to estimate the potential economic benefits should the SAI goals be achieved.

[9] EIA Electric Power Annual 2004. Table 2.5

[10] EIA Annual Energy Outlook 2006.

[11] Ibid.

3. ECONOMIC BENEFITS

Achieving the SAI's installation goals will stimulate a significant amount of economic activities as resources are directed toward solar-related industries. This activity will be offset to some degree by decreased economic activity in other sectors, however, as the new PV resources displace more conventional power sources.

The *gross impacts* of the SAI only account for activities related to PV construction, installation and maintenance, and do not consider the forgone spending in other energy sectors. For this analysis, ECONorthwest also compared the estimated impacts of the SAI to a counterfactual scenario in which most of the electricity that would be generated by PV is instead assumed to be provided by natural gas plants. The *difference* in economic impacts between the SAI scenario and the counterfactual scenario is referred to as the *net impact* of the SAI. For example, if a net impact of 100 new jobs is reported, this means that the SAI would result in 100 more jobs than would have occurred relative to the case where the SAI is not achieved and electricity is provided instead by natural gas generation. Both the gross and net impacts of the SAI are described in this section of the report.

SCENARIO ASSUMPTIONS

As with the energy benefits described in the previous section, the economic benefits were estimated using both a high and low scenario derived from the SAI goals:

- The *Low Scenario* assumes that 5 GW of PV is installed by 2015 at $3.3/Wdc and 70 GW is installed by 2030 at $2.5/Wdc
- The *High Scenario* assumes that 10 GW of PV is installed by 2015 at $3.3/Wdc and 100 GW of solar is installed by 2030 at $2.5/Wdc.

The energy benefits described in the last section were also used in the economic analysis for both the high and low scenarios.

The first step in estimating the economic impacts of the SAI is to determine the manufacturing and O&M costs (expenditures) associated with installing the new PV capacity. Table 2 summarizes the construction and O&M costs for 1 MW of PV installed at the different price points assumed for 2015 ($3.3/Wdc) and 2030 ($2.5/Wdc), and these costs are used as inputs into the estimation of economic benefits. PV costs are allocated as 70 percent in manufacture and 30 percent in installation.[12] This allocation remains fixed but the total system cost decreases over time as both the manufacturing and installation costs are assumed to decrease proportionately with price. PV maintenance costs are also assumed to decrease in direct proportion to system costs, decreasing from $35/kW in 2005 to $10.94/kW in 2030.[13]

[12] Installation costs also include design, site preparation, permitting, and other soft costs. Cost allocation based on information included in *Solar Energy Technologies Program Multi-Year Program Plan 2007-2011*. U.S. Department of Energy. Department of Energy Efficiency and Renewable Energy. 2006.

[13] Based on 2005 annual O&M costs of $42/kW for residential systems and $28/kW for commercial systems; $35/kW is the average of these values. Ibid.

Table 2: PV Installation and O&M Cost Assumptions

Cost Component	1 MW $3.30/Wdc 2015	1 MW $2.50/Wdc 2030
PV Manufacture (70%)	$2,310,000	$1,750,000
PV Installation (30%)	$990,000	$750,000
PV O&M ($35 decreasing to $10.94/kW annually)	$14,440	$10,940

For each scenario, the economic benefits are grouped into three distinct categories based on spending activity:

- *Construction* benefits include both the manufacture and installation of PV systems
- *Operations and Maintenance (O&M)* refer to maintenance costs plus the energy savings that result from the PV systems
- *Research and Development (R&D)* refers to the benefits resulting from that portion of the annual SAI budget that is spent on research through private (non-governmental) research agencies.

Table 3 below shows the key assumptions for the SAI and counterfactual scenarios as they pertain to each of these activity areas.

Table 3: SAI Scenario and Counterfactual Assumptions

Activity	SAI Assumption	Counterfactual Assumption
Construction	Dollars spent on PV manufacture and installation.	Equivalent $ spending on natural gas plant construction (based on 60% assumed ELCC), with remainder spent on household goods and services.
O&M	$35 to $10.94/kW annual cost for PV maintenance. Households receive $0.097/kWh in savings for PV generation.	Utilities lose $0.097 in revenue for every kWh generated from PV.
R&D Spending	50% of annual SAI budget goes to private sector research.	R&D dollars spent on other Federal government programs.

Additional assumptions are shown in Table 4 and all values are reported as 2007 dollars. Natural gas construction costs are set at $0.67/Wdc and do not vary over time. The O&M costs for natural gas plants are included in the retail price of electricity sold from these plants. For this analysis we assume that the retail price does not change over time (other than for inflation) in order to develop a conservative estimate of economic benefits. The effect of relaxing this assumption and allowing for price increases is discussed later in this report.

To convert the installed capacity of the PV systems to a natural gas kWh value, the same parameter assumptions are used that were discussed in the preceding *Energy Benefits* section of this report. To determine the amount of PV power generated, we apply a capacity factor of 19 percent based on average solar insolation in the United States. Given a 19 percent capacity factor, 1 GW of PV is assumed to produce 1,664 GWh of electricity annually. The kWh produced by PV is assumed to offset electricity purchased from utilities on a one-to-one basis (after adjusting for T&D losses). We also assume a 60 percent ELCC in our calculations to determine the amount of power generation offset by the SAI installations.

Finally, in the economic benefit calculations, the electricity bill savings are all allocated to household spending even though some of the PV systems will likely be installed in the commercial sector. This is done under the assumption that any savings achieved in the commercial sector will eventually be passed on through to households through lower prices. It also simplifies the input-output modeling, as we do not need to identify which specific commercial sectors will install solar.[14]

Table 4: Natural Gas Plant and Generation Assumptions

Assumption	Value	Source
Natural Gas Plant Construction Cost	$0.67/Wdc	University of Chicago study on nuclear power (2004), adjusted to 2007 $.
PV Capacity Factor	19 percent	Provided by NREL based on location-specific capacity factors used in the PV Watts simulation program
Transmission & Distribution Loss Factor	7 percent	Average based on U.S. Climate Change Technology Program (2003) and Connors et. al. (2005)
PV Effective Load Carrying Capacity	60 percent	Perez et. al. (2006)
Electricity Price	$0.097 kWh	EIA, 2005 average residential electricity price, adjusted to 2007 $.

For the construction impacts, a numerical example will help illustrate how the net impacts were calculated. In the analysis, solar installations are assumed to have an effective load carrying capacity (ELCC) of 60 percent relative to a new natural gas plant. That is, every gigawatt installed reduces the need to construct 600 MW of natural gas generating resources. A 1 GW PV plant at $3.5/Wdc would cost $3.5 billion and displace the need to build 600 MW of natural gas generation at a cost of $402 million (600 MW @ $0.67/Wdc). Since the natural gas plant costs less than the PV installations, the remaining portion ($3.1 billion) needs to be accounted for in the input-output model so that both scenarios assume

[14] Different commercial sectors will have potentially significant differences in benefits from PV depending on the energy intensity of that industry. Efforts to capture these effects on production efficiencies (and subsequent results on production costs and retail prices of goods) requires the use of more sophisticated general equilibrium models rather than the static IMPLAN model. Because the potential production gains through PV are omitted from this analysis, the economic benefit estimates should be considered conservative.

total spending of $3.5 billion. In the counterfactual scenario, we assume that the remaining $3.1 billion is spent by U.S. households following historical purchase patterns.

In this example, assume that the PV spending results in 15,000 jobs while spending in the natural gas counterfactual scenario results in 12,000 jobs. In this case, the *net impact* of the PV installations is the difference between the two scenarios, or 3,000 jobs (15,000 – 12,000).

Presenting the economic impacts in terms of net benefits results in numbers that are—by definition—lower than gross impact values, and in many cases lower than the gross impacts that have been reported in other studies. For example, the 2001 study *The Work That Goes Into Renewable Energy* published by the Renewable Energy Policy Project (REPP) found that there are approximately 35 jobs associated with the manufacture and installation of 1 MW of PV. We used these numbers to help develop the PV cost input values for our analysis. However, the final net benefit results reported here are lower than the REPP results, as they incorporate the natural gas counterfactual scenario presented above. In contrast, the REPP study did not incorporate any counterfactual information, and therefore the employment figures from that report reflect gross rather than net employment effects.

IMPLAN MODEL

The IMPLAN input-output model is used to estimate the SAI economic benefits based on the assumptions described above. Input-output analysis employs specific terminology to identify the different types of economic impacts resulting from economic activities. Expenditures made as a result of the SAI affect the U.S. economy *directly*, through domestic purchases of goods and services, and *indirectly*, as those purchases, in turn, generate purchases of intermediate goods and services from other, related sectors of the economy. In addition, the direct and indirect increases in employment and income enhance overall economy purchasing power, thereby *inducing* further consumption- and investment- driven stimulus. This cycle continues until the spending eventually leaks out of the U.S. economy as a result of taxes, savings, or purchases of non-locally produced goods and services or "imports." Throughout this report, results are presented for the direct, indirect, and induced effects described above.

Within this overall framework, the IMPLAN model reports the following economic impacts:

- ***Output*** is the value of production by industries for a specified period of time. Output can be also thought of as the value of sales including reductions or increases in business inventories.
- ***Personal Income*** represents the total payments to workers (wages) and business owners (proprietor and corporate income). Together, wages and business income are often referred to as personal income. Corporate income represents net business income or profits. These may be reinvested or paid as dividends to shareholders. Income excludes payments from one industry to another for the purchase of intermediate goods, and is often used as a measure of the value added during production.[15]
- ***Job*** impacts include both full and part time employment.
- ***Tax revenues*** for various state and local taxing jurisdictions.

[15] Alternatively, value added is measured as total output less purchases of intermediate goods and services. In either case, the measure of value added will be the same. However, to the extent that owners of corporations live outside the relevant study area, including corporate income will tend to overestimate the measure of value added in production.

The results for Output, Personal Income, and Jobs are presented in the main body of the report while detailed for these categories plus Tax Revenues are included in Appendix A. Additional technical detail on the IMPLAN model is provided in Appendix B.

GROSS ECONOMIC BENEFITS

This section describes the *gross* economic benefits that could be expected from the SAI, and does not take into account the changes in economic activity that would have occurred in other sectors (e.g., due to natural gas plant construction) if the goals of the SAI were not achieved. The tables in this section present selected analysis results from the input-output model runs. To keep the results to a manageable level, only selected years (2015 and 2030) are reported in the main report for both the high and low scenarios. For each year, the results for the construction, O&M, and R&D activities are reported.

Note that NREL assumes that 1 GW of PV capacity will likely be installed by 2015, and that 15 to 20 GW of PV capacity will be installed by 2030 even without the SAI. In this report, only the new PV installations that are caused by the SAI are used to calculate the economic impacts. In Table 5 (and all subsequent tables), a column labeled "Total Installed Capacity" shows the total PV installations for a particular year and includes capacity that is expected as part of the baseline. A second column labeled "SAI Induced Annual Installed Capacity" reflects only the PV installations that are assumed to result directly from the SAI. It is the capacity shown in this second column that is used to calculate the economic benefits shown in the rest of the table.

Table 5 shows the gross benefits of the PV system construction (manufacture and installation) for 2015. Again, these results do not adjust for impacts that would have otherwise occurred in the counterfactual scenario, which assumes natural gas plant construction. The construction results reflect the impacts that occur only during the construction period, which is assumed to be a single year.

For the high scenario, a cumulative total of 10 GW of new PV is installed by 2015. This construction will result in a gross increase in economic output of $27 billion during the construction period. This will also result in a gross increase in personal income of $8.7 billion over the same period, and total full-time and part-time jobs would increase by 162,890.

The bottom of Table 5 shows the same gross results in the construction phase assuming the low scenario of 5 GW of installed PV by 2015. In the low scenario, the SAI results in a gross increase of economic output of $8.2 billion and a gross increase in personal income of $2.6 billion. This also results in a gross increase in jobs of 49,370.

Table 5: Annual Gross Construction Impacts (2015)

Construction Gross Impacts	Total Annual Installed Capacity In 2015	SAI Induced Annual Installed Capacity In 2015	Direct	Indirect	Induced	Total
High Scenario						
Output	2.74	2.37	$7,989,362,000	$9,024,295,000	$10,087,769,000	$27,101,426,000
Personal Income	2.74	2.37	$2,486,000,000	$3,056,905,000	$3,158,265,000	$8,701,170,000
Jobs	2.74	2.37	36,500	51,440	74,950	162,890
Low Scenario						
Output	1.02	0.72	$2,421,746,000	$2,735,456,000	$3,057,818,000	$8,215,020,000
Personal Income	1.02	0.72	$753,560,000	$926,613,000	$957,337,000	$2,637,510,000
Jobs	1.02	0.72	11,060	15,590	22,720	49,370

Table 6 shows the gross impacts of PV O&M activities in 2015 for both the high and low SAI scenarios. The O&M impacts account for maintenance costs as well as money saved on electricity bills due to the PV systems. For the high scenario, O&M activities result in a gross increase in total economic output of

$3.6 billion annually based on the 10 GW of installed PV capacity. Personal income also shows a gross increase of over $1.1 billion annually and an additional 27,510 jobs are added due to the SAI in 2015.

The low scenario results are also shown in Table 6 for 2015. Since the low scenario is based on half of the installed PV capacity (5 GW rather than 10 GW in 2015), the economic impacts are also reduced by 50 percent relative to the high scenario, with slight differences due to rounding.

Table 6: Cumulative Gross O&M Impacts (2015)

O&M Gross Impacts	Total Cummulative Installed Capacity in 2015	SAI Induced Cummulative Installed Capacity in 2015	Direct	Indirect	Induced	Total
High Scenario						
Output	10.00	9.00	$1,399,807,000	$961,320,000	$1,301,392,000	$3,662,519,000
Personal Income	10.00	9.00	$453,592,000	$302,021,000	$407,449,000	$1,163,062,000
Jobs	10.00	9.00	11,860	5,980	9,670	27,510
Low Scenario						
Output	5.00	4.00	$622,136,000	$427,253,000	$578,397,000	$1,627,786,000
Personal Income	5.00	4.00	$201,596,000	$134,232,000	$181,089,000	$516,917,000
Jobs	5.00	4.00	5,270	2,660	4,300	12,230

Note: Table shows annual impacts in 2015 based on cumulative SAI PV installations.

The gross economic impacts resulting from the SAI R&D funding are shown in Table 7 and are based on the annual funding of $148 million. Of this budget, 50 percent is assumed to go to private research entities in the U.S. Funding is assumed to be constant between the high and low scenarios. The spending on solar R&D through the SAI results in a gross increase in economic output of $235 million with personal income increasing by $101 million. The R&D funding also results in a gross increase of 1,780 jobs.

Table 7: Annual Gross R&D Impacts (2015)

R&D Gross Impacts	Annual R&D Spending	Direct	Indirect	Induced	Total
High Scenario	$148,000,000				
Output		$73,634,000	$47,076,000	$114,377,000	$235,087,000
Personal Income		$48,979,000	$16,121,000	$35,809,000	$100,909,000
R&D Impacts - Gross		600	330	850	1,780
Low Scenario	$148,000,000				
Output		$73,634,000	$47,076,000	$114,377,000	$235,087,000
Personal Income		$48,979,000	$16,121,000	$35,809,000	$100,909,000
Jobs		600	330	850	1,780

The combined gross economic benefits for 2015 across all activities are shown in Table 8. Additional detail on individual years is provided in Appendix A.

Table 8: Gross Economic Benefit Summary (2015)

Economic Benefit Category (Gross Impacts)	Construction	O&M	R&D	Total
2015 High Scenario				
Output	$27,101,426,000	$3,662,519,000	$235,087,000	$30,999,032,000
Personal Income	$8,701,170,000	$1,163,062,000	$100,909,000	$9,965,141,000
Jobs	162,890	27,510	1,780	192,180
2015 Low Scenario				
Output	$8,215,020,000	$1,627,786,000	$235,087,000	$10,077,893,000
Personal Income	$2,637,510,000	$516,917,000	$100,909,000	$3,255,336,000
Jobs	49,370	12,230	1,780	63,380

Table 9 shows the annual gross construction impacts for 2030 for both the high and low SAI scenarios and assumes that PV costs have fallen to $2.5/Wdc. For the high scenario, a cumulative total of 100 GW of new PV is installed by 2030. This construction results in a gross increase of over $67 billion in economic output and personal income has a gross increase of $21.5 billion. The PV construction activity also results in a gross increase of 403,920 jobs in 2030.

The low scenario construction impacts are greater than the high scenario impacts, as the low scenario installs more capacity in the last year of construction (2030) compared to the high scenario, and construction impacts are shown for a single year. In the low scenario for 2030, output increases by almost $73 billion, personal income increases by $23.4 billion, and jobs show a gross increase of 438,690.[16]

Table 9: Annual Gross Construction Impacts (2030)

Construction Gross Impacts	Total Annual Installed Capacity In 2030	SAI Induced Annual Installed Capacity In 2030	Direct	Indirect	Induced	Total
High Scenario						
Output	10.40	7.77	$19,810,956,000	$22,377,245,000	$25,014,306,000	$67,202,507,000
Personal Income	10.40	7.77	$6,164,452,000	$7,580,107,000	$7,831,446,000	$21,576,005,000
Jobs	10.40	7.77	90,510	127,560	185,850	403,920
Low Scenario						
Output	10.31	8.44	$21,516,485,000	$24,303,706,000	$27,167,792,000	$72,987,983,000
Personal Income	10.31	8.44	$6,695,151,000	$8,232,681,000	$8,505,656,000	$23,433,488,000
Jobs	10.31	8.44	98,300	138,540	201,850	438,690

The 2030 O&M economic benefits are shown in Table 10 and reflect all of the benefits of PV O&M spending and electricity bill savings for the cumulative installations through 2030. In the high scenario, the O&M benefits total over $31.7 billion in gross economic output and $10 billion in increased personal income. The cumulative employment impact is a gross increase of 237,300 jobs.

In the low scenario, the O&M impacts remain very significant with a gross increase in economic output of $21.8 billion and personal income increasing by $6.8 billion annually. The low scenario also results in a gross increase in jobs of 163,150 based on the cumulative installed capacity of 70 GW of PV by 2030.

[16] For 2030, the impacts in the low scenario are greater than the high scenario due to growth rates used for this analysis. In this particular year, the incremental amount of PV added in 2030 in the low scenario is greater than the PV capacity added in the high scenario in 2030 (8.44 GW and 7.77 GW respectively).

Table 10: Cumulative Gross O&M Impacts (2030)

O&M Gross Impacts	Total Cummulative Installed Capacity in 2030	SAI Induced Cummulative Installed Capacity in 2030	Direct	Indirect	Induced	Total
High Scenario						
Output	100.00	80.00	$12,162,729,000	$8,390,215,000	$11,190,494,000	$31,743,438,000
Personal Income	100.00	80.00	$3,866,276,000	$2,636,991,000	$3,503,604,000	$10,006,871,000
Jobs	100.00	80.00	101,970	52,190	83,140	237,300
Low Scenario						
Output	70.00	55.00	$8,361,876,000	$5,768,273,000	$7,693,465,000	$21,823,614,000
Personal Income	70.00	55.00	$2,658,065,000	$1,812,930,000	$2,408,728,000	$6,879,723,000
Jobs	70.00	55.00	70,110	35,880	57,160	163,150

Note: Table shows annual impacts in 2030 based on cumulative SAI PV installations.

The combined benefits for each activity area for 2030 are summarized in Table 11.

Table 11: Gross Economic Benefit Summary (2030)

Economic Benefit Category (Gross Impacts)	Construction	O&M	Total
2030 High Scenario			
Output	$67,202,507,000	$31,743,438,000	$98,945,945,000
Personal Income	$21,576,005,000	$10,006,871,000	$31,582,876,000
Jobs	$403,920	$237,300	$641,220
2030 Low Scenario			
Output	$72,987,983,000	$21,823,614,000	$ 94,811,597,000
Personal Income	$23,433,488,000	$6,879,723,000	$ 30,313,211,000
Jobs	438,690	163,150	$ 601,840

NET ECONOMIC BENEFITS

This section describes the *net* economic benefits that could be expected from the SAI, and takes into account (i.e., subtracts) the changes in economic activity that would have occurred in other sectors if the SAI were not implemented. For each year (2015 and 2030), the results for the construction, O&M, and R&D activities are reported. Detailed benefit estimates for all years (2005-2030) for these categories are included in Appendix A.

Table 12 shows the net benefits of the PV system construction (manufacture and installation) for 2015. Again, these results reflect impacts *over and above* what would have happened in the counterfactual scenario, which assumes natural gas plant construction. The construction results reflect the impacts that occur only during the construction period, which is assumed to be a single year.

For the high scenario, a cumulative total of 10 GW of new PV is installed by 2015. This construction will result in a gross increase in economic output of $8.5 billion during the construction period. This will also result in a gross increase in personal income of $2.9 billion over the same period.

For the net job impacts, the direct impacts for PV installation are a negative 17,850, meaning that there are more direct jobs initially created by the construction of natural gas plants combined with the spending from households than from the PV manufacture and installations occurring in 2015. However, when the indirect and induced effects of construction spending are taken into account, then the overall net job impact is positive. The overall effect is a net increase of 28,940 jobs over the employment that would occur in the counterfactual scenario.

The bottom of Table 12 shows the same net results in the construction phase assuming the low scenario of 5 GW of installed PV by 2015. In the low scenario, the SAI results in a net increase of economic output of $2.5 billion and a net increase in personal income of $879 million over the counterfactual scenario. This also results in a net increase in jobs of 8,770.

Table 12: Annual Net Construction Impacts (2015)

Construction Net Impacts	Total Annual Installed Capacity In 2015	SAI Induced Annual Installed Capacity In 2015	Direct	Indirect	Induced	Total
High Scenario						
Output	2.74	2.37	$988,946,000	$3,922,413,000	$3,610,641,000	$8,522,000,000
Personal Income	2.74	2.37	$327,745,000	$1,443,688,000	$1,130,363,000	$2,901,796,000
Jobs	2.74	2.37	-17,850	19,960	26,830	28,940
Low Scenario						
Output	1.02	0.72	$299,771,000	$1,188,967,000	$1,094,462,000	$2,583,200,000
Personal Income	1.02	0.72	$99,347,000	$437,613,000	$342,637,000	$879,597,000
Jobs	1.02	0.72	-5,410	6,050	8,130	8,770

Table 13 shows the net impacts of PV O&M activities in 2015 for both the high and low SAI scenarios. The O&M impacts are based on the entire installed PV capacity in 2015 and include maintenance costs as well as money saved on electricity bills due to the PV systems.

For the high scenario, O&M activities result in a net increase in total economic output of $518 million annually based on the 10 GW of installed PV capacity.[17] Personal income also shows a net increase of over $361 million annually and an additional 15,330 jobs are added due to the SAI in 2015.

The low scenario results are also shown in Table 13 for 2015. Since the low scenario is based on half of the installed PV capacity (5 GW rather than 10 GW in 2015), the economic impacts are also reduced by 50 percent relative to the high scenario, with slight differences due to rounding.

Table 13: Cumulative Net O&M Impacts (2015)

O&M Net Impacts	Total Cummulative Installed Capacity in 2015	SAI Induced Cummulative Installed Capacity in 2015	Direct	Indirect	Induced	Total
High Scenario						
Output	10.00	9.00	-$141,982,000	$263,195,000	$397,401,000	$518,614,000
Personal Income	10.00	9.00	$141,430,000	$95,235,000	$124,429,000	$361,094,000
Jobs	10.00	9.00	9,840	2,540	2,950	15,330
Low Scenario						
Output	5.00	4.00	-$63,103,000	$116,976,000	$176,622,000	$230,495,000
Personal Income	5.00	4.00	$62,857,000	$42,327,000	$55,302,000	$160,486,000
Jobs	5.00	4.00	4,370	1,130	1,310	6,810

Note: Table shows annual impacts in 2030 based on cumulative SAI PV installations.

The economic impacts resulting from the SAI R&D funding are shown in Table 14 and are based on the annual funding of $148 million. Of this budget, 50 percent is assumed to go to private research entities in the U.S. The net impacts are shown relative to the counterfactual scenario that assumes the SAI funding is spent on other Federal programs. Funding is assumed to be constant between the high and low scenarios.

[17] The negative direct effect for output is the result of lost utility revenues due to reduced power sales. This is made up in the indirect and induced effects as households use the money saved on their electricity bills to purchase other goods and services.

The spending on solar R&D through the SAI results in a net increase in economic output of $118 million with personal income increasing by $64 million. The R&D funding also results in a net increase of 910 jobs.

Table 14: Annual Net R&D Impacts (2015)

R&D Net Impacts	Annual R&D Spending ($M)	Direct	Indirect	Induced	Total
High Scenario	$148,000,000				
Output		$73,634,000	$47,076,000	-$2,704,000	$118,007,000
Personal Income		$48,979,000	$16,121,000	-$846,000	$64,254,000
Jobs		600	330	-20	910
Low Scenario	$148,000,000				
Output		$73,634,000	$47,076,000	-$2,704,000	$118,007,000
Personal Income		$48,979,000	$16,121,000	-$846,000	$64,254,000
Jobs		600	330	-20	910

The combined net economic benefits for 2015 across all activities are shown in Table 15. Additional detail on individual years is provided in Appendix A.

Table 15: Net Economic Benefit Summary (2015)

Net Economic Benefit Category (Net Impacts)	Construction	O&M	R&D	Total
2015 High Scenario				
Output	$8,522,000,000	$518,614,000	$118,007,000	$9,158,621,000
Personal Income	$2,901,796,000	$361,094,000	$64,254,000	$3,327,144,000
Jobs	28,940	15,330	910	45,180
2015 Low Scenario				
Output	$2,583,200,000	$230,495,000	$118,007,000	$2,931,702,000
Personal Income	$879,597,000	$160,486,000	$64,254,000	$1,104,337,000
Jobs	8,770	6,810	910	16,490

Figure 1 shows how the net gains in economic output are distributed across sectors for the construction, O&M, and R&D phases combined in 2015. The Manufacturing and Construction sectors show large increases due to the manufacture and installation of PV systems. Conversely, the Utility sector shows a net loss in economic activity due to lower electricity sales revenue resulting from the increasing amount of electricity provided by PV.

Figure 1: 2015 Net Output

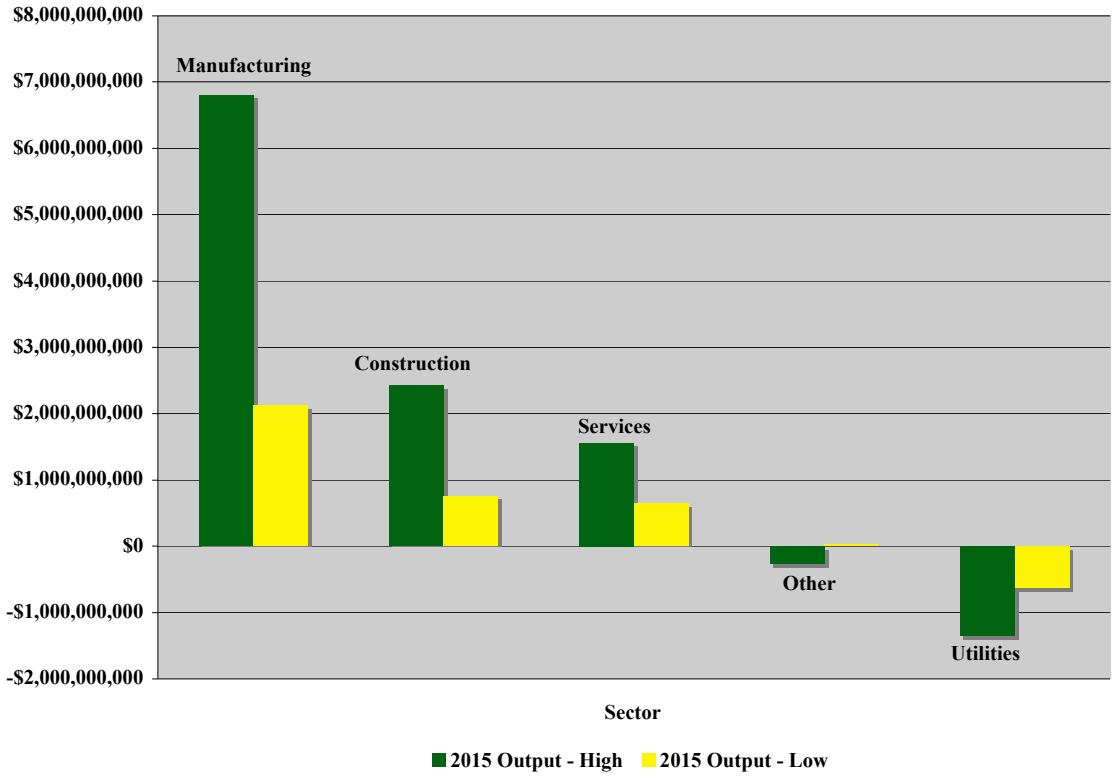


Figure 2 shows how the net change in jobs is distributed across industry sectors. As with economic output, the Manufacturing and Construction sectors show large increases in employment due to the increased production and installation of PV systems. The other sectors show relatively small changes in net employment. Note that while the Utility sector shows a large drop in economic output in Figure 1, a relatively smaller decrease in employment shown in Figure 2. This is due to the fact that the utility sector is not as labor intensive as other industries and that much of the lost economic output shown in Figure 1 is due to fuel purchases (or other non-labor inputs) rather than wages.

Figure 2: 2015 Net Jobs

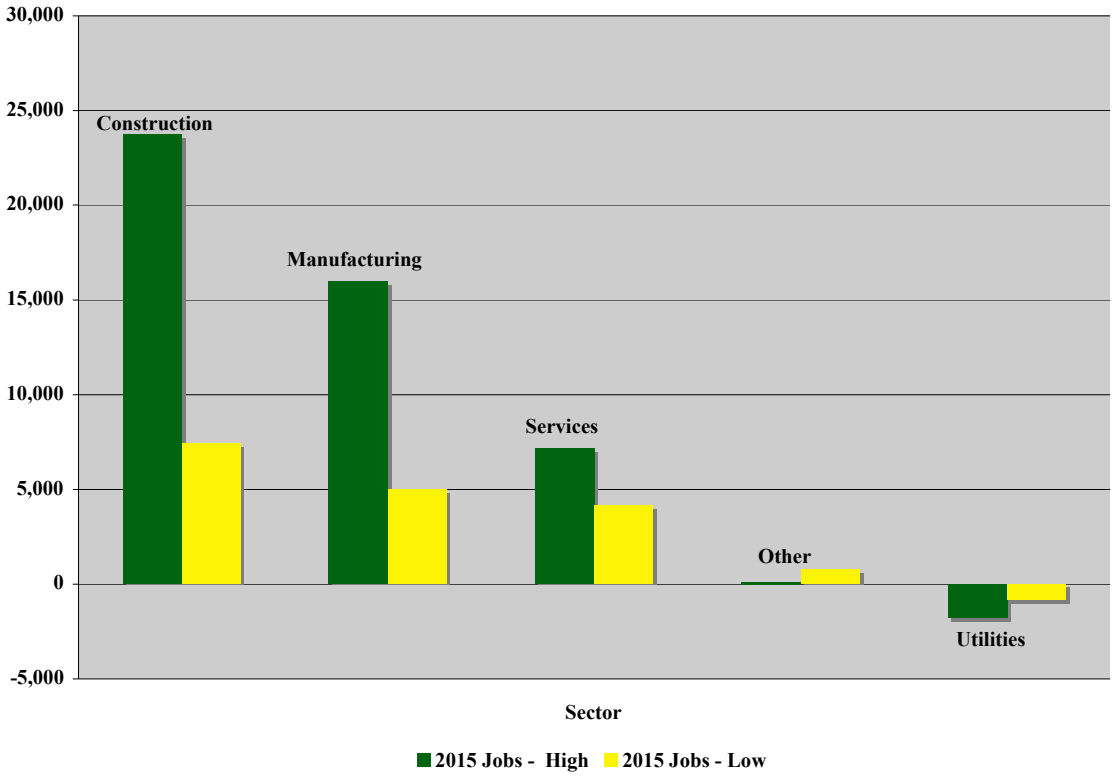


Table 16 shows the construction impacts for 2030 for both the high and low SAI scenarios and assumes that PV costs have fallen to $2.5/Wdc. In 2030, total installed capacity is 100 GW for the high scenario. The additional PV construction results in a net increase of $20.5 billion in economic output relative to counterfactual scenario and personal income has a net increase of almost $7 billion. The PV construction activity also results in a net increase of 69,280 in 2030.

The low scenario construction impacts are greater than the high scenario impacts for 2030, as the low scenario installs more capacity in this particular year compared to the high scenario (8.44 GW in the low scenario compared with 7.77 GW in the high scenario for 2030). In the low scenario for 2030, net output increases by $22 billion, personal income increases by $7.5 billion, and jobs show a net increase of 75,230.

Table 16: Annual Net Construction Impacts (2030)

Construction Net Impacts	Total Annual Installed Capacity In 2030	SAI Induced Annual Installed Capacity In 2030	Direct	Indirect	Induced	Total
High Scenario						
Output	10.40	7.77	$2,352,777,000	$9,499,047,000	$8,651,896,000	$20,503,720,000
Personal Income	10.40	7.77	$718,510,000	$3,502,286,000	$2,708,602,000	$6,929,398,000
Jobs	10.40	7.77	-43,300	48,300	64,280	69,280
Low Scenario						
Output	10.31	8.44	$2,555,328,000	$10,316,822,000	$9,396,739,000	$22,268,889,000
Personal Income	10.31	8.44	$780,366,000	$3,803,798,000	$2,941,786,000	$7,525,950,000
Jobs	10.31	8.44	-47,030	52,450	69,810	75,230

The 2030 O&M economic benefits are shown in Table 17 and reflect all of the benefits of PV O&M spending and electricity bill savings for the cumulative installations through 2030. In the high scenario, the O&M benefits total over $3.7 billion in net economic output and $2.8 billion in increased personal income. The cumulative employment impact is a net increase of 129,120 jobs over the counterfactual scenario.

In the low scenario, the O&M impacts remain very significant with a net increase in economic output of $2.6 billion and personal income increasing by $1.9 billion annually. The low scenario also results in a net increase in jobs of 88,770 based on the cumulative installed capacity of 70 GW of PV by 2030.

Table 17: Cumulative Net O&M Impacts (2030)

O&M Net Impacts	Total Cummulative Installed Capacity in 2030	SAI Induced Cummulative Installed Capacity in 2030	Direct	Indirect	Induced	Total
High Scenario						
Output	100.00	80.00	-$1,542,062,000	$2,184,665,000	$3,155,011,000	$3,797,614,000
Personal Income	100.00	80.00	$1,091,503,000	$798,895,000	$987,867,000	$2,878,265,000
Jobs	100.00	80.00	84,060	21,620	23,440	129,120
Low Scenario						
Output	80.00	55.00	-$1,060,168,000	$1,501,957,000	$2,169,070,000	$2,610,859,000
Personal Income	80.00	55.00	$750,408,000	$549,240,000	$679,158,000	$1,978,806,000
Jobs	80.00	55.00	57,790	14,860	16,120	88,770

Note: Table shows annual impacts in 2030 based on cumulative SAI PV installations.

The combined net benefits for each activity area are summarized in Table 18 for 2030.

Table 18: Net Economic Benefit Summary (2030)

Net Economic Benefit Category (Net Impacts)	Construction	O&M	Total
2030 High Scenario			
Output	$20,503,720,000	$3,797,614,000	$24,301,334,000
Personal Income	$6,929,398,000	$2,878,265,000	$9,807,663,000
Jobs	69,280	129,120	$198,400
2030 Low Scenario			
Output	$22,268,889,000	$2,610,859,000	$24,879,748,000
Personal Income	$7,525,950,000	$1,978,806,000	$9,504,756,000
Jobs	75,230	88,770	$164,000

Figure 3 shows how the combined economic output estimates from the construction, O&M, and R&D activities for 2030 are distributed across economic sectors. Compared with the chart for 2015, the magnitude of the changes in output are much greater due to the much higher levels of PV installed in 2030 relative to 2015. As in 2015, the Manufacturing sector shows the largest net gains in economic output due to the increase in the manufacture and installation of PV systems. The Services and Construction sectors also see significant net gains in economic output due to the SAI relative to the counterfactual scenario. The Utility sector sees a significant decrease in economic output from the lower electricity sales that result from the increase in PV capacity by 2030.

Figure 3: 2030 Net Output

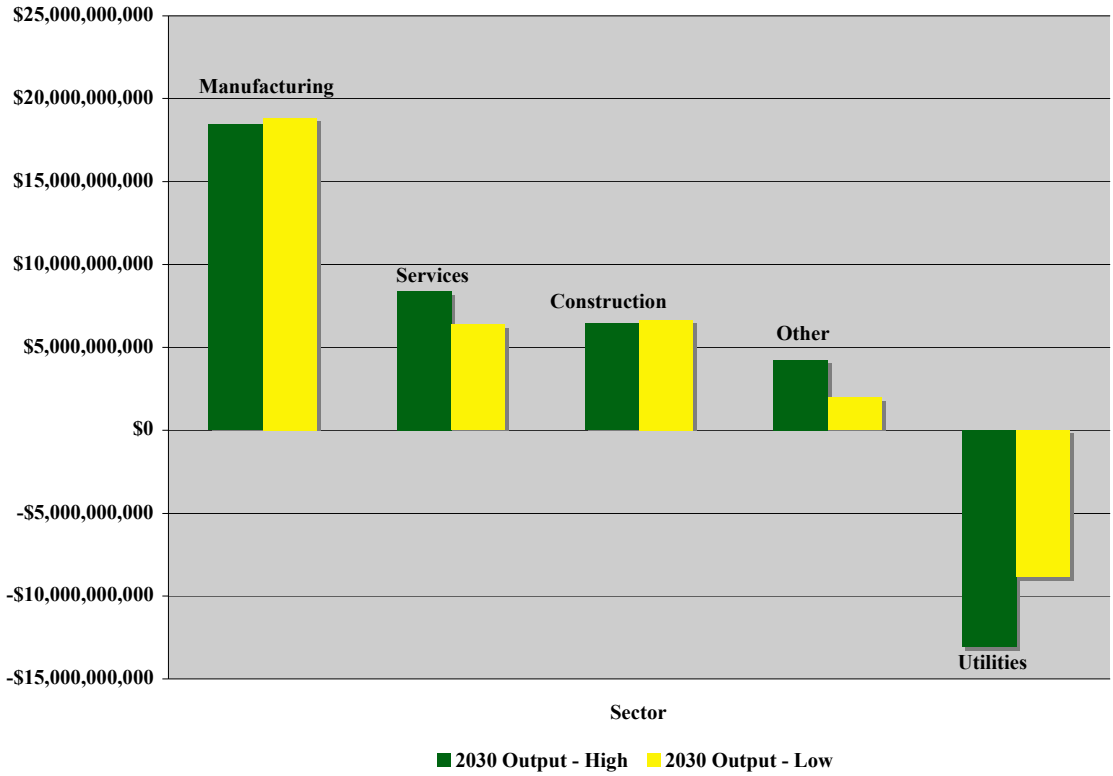
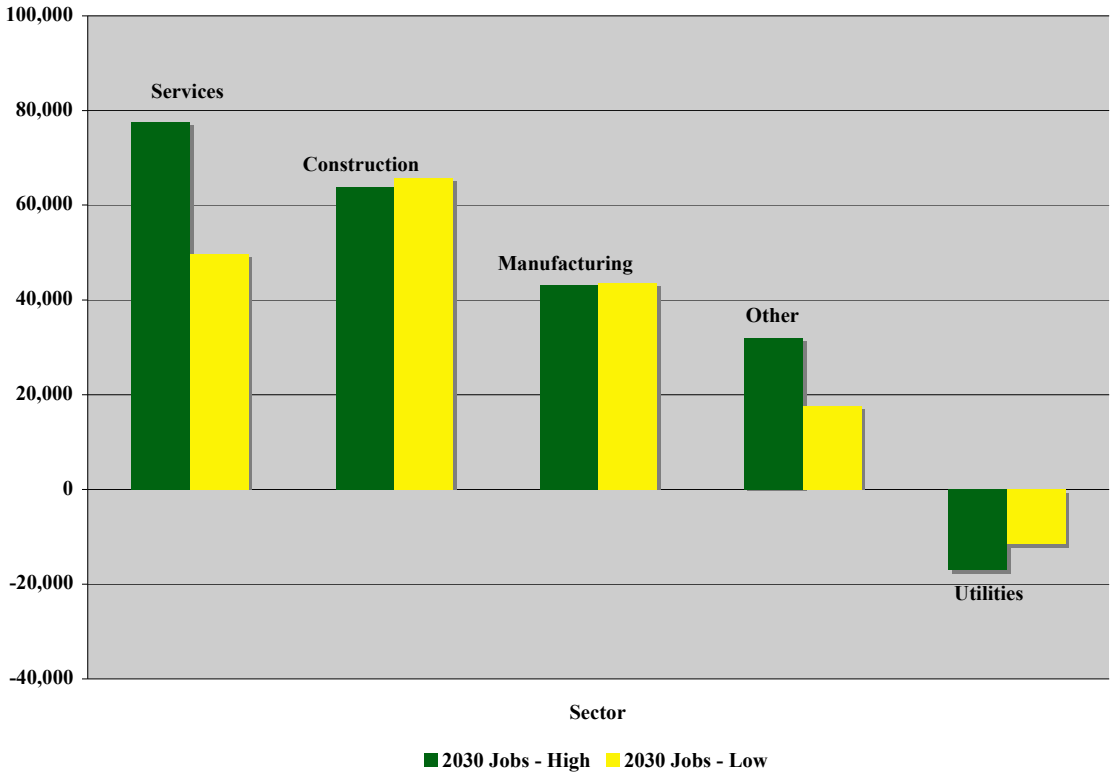


Figure 4 shows how the net change in jobs is distributed across industry sectors in 2030. The Services sector shows the largest gains in employment due to the SAI, followed by Construction and Manufacturing. Note that Services shows a large increase in employment relative to the change in output shown in Figure 3. The large increase in employment is due to the labor-intensive jobs that are included in the Service sector.

Figure 4: 2030 Net Jobs



All of the preceding economic benefit estimates assume a constant electricity price that has been adjusted for inflation but does not account for any additional price increases during the analysis period. If the electricity price does increase over time, then the economic benefits of the SAI will increase as customers with PV systems receive a greater benefit through reduced electricity bills. In the benefit framework discussed here, an increase in price will effect the benefit estimates only through the O&M benefits, as the Construction and R&D phases are unaffected by changes in the electricity prices.

The economic benefits are estimated assuming an electricity price of $0.0966/kWh. If this is increased by 1 cent to $0.1066/kWh, then the O&M jobs impacts are expected to increase by 8 to 9 percent. Similarly, a 1-cent increase in price will also increase personal income by 6 to 7 percent while the impact on economic output is expected to increase by 3 percent. This relationship is relatively consistent across years.

Selected price sensitivity examples are shown in Table 19 for the low scenario and the relative effects, in percentage terms, are the same in the high scenario (not shown). While only a 1-cent change is shown, the relationship is linear and each 1-cent change in the price of electricity will increase the net economic output by 3 percent, personal income by 6 to 7 percent, and jobs by 8 to 9 percent.

Table 19: Effect of a 1-Cent Electricity Price Change on O&M Benefits

O&M Economic Benefit Category	Electricity Price $0.0966/kWh	Electricity Price $0.1066/kWh	Percent Change
2015 Low Scenario			
Output	$230,495,000	$237,013,000	3%
Personal Income	$160,486,000	$170,023,000	6%
Jobs	6,810	7,370	8%
2030 Low Scenario			
Output	$2,610,859,000	$2,700,478,000	3%
Personal Income	$1,978,806,000	$2,109,935,000	7%
Jobs	88,770	96,360	9%

4. ENVIRONMENTAL BENEFITS

This section of the report describes the major environmental and health benefits that could be expected as a result of attaining SAI solar generation goals, and thereby reducing fossil fuel-fired electricity generation. In particular, we focus on the impacts of reducing CO_2, NO_X and SO_2 emissions. Our analysis of these benefits utilizes the energy calculations described in the *Energy Benefits* section of this report that show the amount of displaced electricity generation that will result should the SAI PV installation goals be achieved.

The U.S. Environmental Protection Agency (EPA) reports that electricity generation is currently the largest industrial source of air emissions in the United States. Fossil fuel-fired power plants are responsible for 40 percent of man-made carbon dioxide (CO_2) emissions, 23 percent of the nation's nitrogen oxide (NO_X) emissions, and 67 percent of sulfur dioxide (SO_2) emissions.[18] These emissions contribute to the formation of smog and haze, and are associated with a wide range of health problems. In addition, greenhouse gases (e.g., carbon dioxide) emitted by fossil fuel-fired power plants increase the risk of climate change. In comparison, the emissions from solar electricity generation are negligible as no fossil fuels are combusted to create electricity.

EMISSIONS REDUCED BY SAI

The emissions offset or reduced by new PV capacity are calculated by taking the amount of fossil fuel generation offset by PV and multiplying by the average emissions rates for those fuels. A wide range of fossil fuel emission rates for CO_2, NO_X and SO_2 was found in the literature. Most of these studies, however, were regionally based and were affected by local emissions regulations and trading schemes, unique plant types and emission cleaning technologies, and/or utilized highly refined regional economic dispatch models. For this analysis, we elected to use broader and more generic emission rates based on national generating plant data rather than use factors that were derived from a region-specific study.

Table 20 shows two sets of emission rates that could be applied for this analysis. One set of rates was calculated by EPA using national generating plant data from the eGRID 2000 database.[19] A second set of rates was calculated by ECONorthwest using the most current eGRID data available. These rates are based on plant *net* generation before entering the grid, which subtracts plant auxiliary power consumption (e.g., for scrubbers, cooling fans, turbine auxiliaries) from gross generation.[20]

The subsequent results for emissions avoided and associated health impacts are based on the more current eGRID 2006 emission rate estimates. These emission rates are generally lower than the 2000 rates, and likely reflect more efficient generating plants and growing adoption of emissions cleaning technologies to meet local and federal air quality standards.[21]

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[18] www.epa.gov/cleanenergy/emissions.htm

[19] See www.epa.gov/cleanenergy/natgas.htm and www.epa.gov/cleanenergy/coal.htm.

[20] Plants with negative net generation were not considered in the analysis. Plant gross generation and on-site power consumption are not provided in the eGRID 2006 data. The emission rates are based on total plant heat input, total emissions, and net generation.

[21] The ECONorthwest emission rates are based on calculated average heat conversion rates of approximately 9,900 Btu/kWh for natural gas plants and 10,500 Btu/kWh for coal plants. These heat rates are based on plant heat input and *net* generation.

Table 20: Average Emission Rates (lbs/MWh)

Source	Natural Gas			Coal		
	CO_2	NO_X	SO_2	CO_2	NO_X	SO_2
EPA, eGRID 2000	1,135	1.70	0.10	2,249	6.00	13.00
ECONorthwest, eGRID 2006*	1,169	0.69	0.02	2,164	3.50	10.30

*2004 plant level data

Table 21 shows the emissions that would by avoided, by fuel type, for the 2015 and 2030 PV capacity scenarios. The SAI is projected to reduce annual CO_2 emissions by 69 to 100 million tons in 2030. Annual NO_X emissions would be reduced by 68,000 to 99,000 tons, and SO_2 emissions would be reduced by 126,000 to 184,000 tons. These results assume that PV generation would replace fossil fuel generation on a one-to-one basis, and that 75 percent of the fuel displaced would be natural gas and 25 percent would be coal. PV systems only generate power during daylight hours and in many regions of the country they would reduce emissions from natural gas peaking units, as these are used in many regions to meet peak (usually daytime) electricity demand[22]. Some areas of the country, however, remain heavily coal-dependent, and meet increases in peak demand by increasing output at "spinning reserve" and "standby" plants that operate at less than full capacity.

Table 21: Emissions Avoided by Displaced Fuel (Annual Tons)

Scenario	Installed PV Capacity (GW)	Natural Gas			Coal			Total		
		CO_2	NO_X	SO_2	CO_2	NO_X	SO_2	CO_2	NO_X	SO_2
2015 Low	5	3,122,822	1,843	40	1,926,942	3,117	9,172	5,049,765	4,960	9,212
2015 High	10	7,026,350	4,147	90	4,335,621	7,012	20,636	11,361,970	11,160	20,726
2030 Low	70	42,938,805	25,345	551	26,495,459	42,853	126,111	69,434,264	68,198	126,662
2030 High	100	62,456,444	36,865	801	38,538,849	62,332	183,434	100,995,293	99,197	184,235

HEALTH BENEFITS

Table 22 shows the estimated health benefits that would result from reducing emissions from fossil-fired power generation. Health impacts were related to total emissions of NO_X and SO_2, which react with other chemicals to form fine particulate matter ($PM_{2.5}$) in the air. To estimate health benefits from reduced emissions, we used benefit estimates developed by EPA[23] and the Clean Air Task Force[24] in their analyses of the Clear Skies Act and alternative regulatory scenarios. In those studies, very detailed air quality models were utilized to estimate PM formation based on NO_X and SO_2 emissions. Since we did not have access to these air quality models for this analysis, we analyzed the assumed NO_X and SO_2 reductions in reported in these studies and found that they were highly correlated with the estimated health impacts. For this study, we applied the emissions/health relationships we discerned in the EPA studies to extrapolate health benefits from the NO_X and SO_2 emission reductions due to the SAI (rather than from PM formation, which is the method EPA and the Clean Air Task Force used).

[22] Connors, Stephen with Edward Kern, Michael Adams, Katherine Martin and Baafour Asiamah-Adjei. *National Assessment of Emissions Reduction of Photovoltaic (PV) Power Systems.* Prepared for US EPA Air Pollution Prevention and Control Division. 2005.

[23] United States Environmental Protection Agency. *Technical Addendum: Methodologies for the Benefit Analysis of the Clear Skies Act of 2003*. September 2003.

[24] Abt Associates Inc. *Power Plant Emissions: Particulate Matter-Related Health Damages and the Benefits of Alternative Emission Reduction Scenarios.* Prepared for Clean Air Task Force. Boston MA. June 2004.

As shown in the table, the emissions reductions resulting from the SAI will have a positive impact on a range of respiratory and cardio health issues. In particular, the reduced emissions are expected to have a significant effect on the amount of workdays lost or restricted as shown at the bottom of the table. Note that lost and restricted workdays are not included in the economic benefits discussed in the previous section and therefore reflect an additional economic benefit resulting from the SAI.

The EPA studies note that there do not appear to be any PM thresholds beyond which health problems increase significantly. Instead, there is limited evidence that for PM, health effects may actually be greater at lower levels of exposure, and lower at higher levels of ambient PM. While the emission reductions in our analysis are significantly below those analyzed in the Clear Skies studies, we did not adjust the health impact estimates up or down to account for potential ambient PM threshold issues, which is still a focus of ongoing air quality research.

Table 22: Health Impacts Due to Reduced Emissions

Scenario	**2015 Low**	**2015 High**	**2030 Low**	**2030 High**
Installed PV Capacity (GW)	**5**	**10**	**70**	**100**
Cases Reduced				
Mortality	22	49	300	437
Chronic Bronchitis	15	34	206	300
Heart Attacks	36	81	493	717
Hospital Admissions - Respiratory				
Chronic Lung, less Asthma (20-64)	1	2	14	21
Asthma (0-64)	2	4	25	36
Pneumonia (65+)	7	17	102	148
Chronic Lung (65+)	1	2	13	18
Total	11	25	153	223
Hospital Admissions - Cardiovascular				
All Cardiovascular (20-64)	4	8	51	74
All Cardiovascular (65+)	5	12	73	106
Total	9	20	124	180
Emergency Room Visits for Asthma	24	53	324	471
Acute Bronchitis	35	78	479	697
Lower Respiratory Symptoms	397	894	5,462	7,945
Upper Respiratory Symptoms	319	718	4,387	6,381
Work Loss Days	2,538	5,710	34,894	50,755
Minor Restricted Activity Days	17,439	39,239	239,791	348,787

5. ADDITIONAL ENERGY BENEFITS

In addition to the benefits described in the prior sections, the SAI has the potential to create additional, ancillary energy benefits that are less direct than the ones described earlier. For this analysis, we reviewed the current literature to identify the additional benefit areas that are relevant to the SAI. The potential benefits are discussed below along with a discussion of the potential magnitude of these benefits should the SAI goals be achieved.

Price Impacts

There have been several recent studies that show a link between increased renewable energy deployment and lower natural gas prices. This is an important benefit to consider as small price decreases can result in very large benefits given the large number of electricity customers that will be affected.

Wiser et al. (2005) reviewed several studies to assess how renewable energy development (to meet proposed renewable portfolio standards) could affect natural gas prices in the U.S. These studies, conducted by the EIA, the Union for Concerned Scientists (UCS) and the Tellus Institute indicate that increased use of renewable energy or higher levels of energy efficiency would put downward pressure on natural gas prices. From these studies, Wiser concludes that each 1 percent reduction in natural gas demand due to an increased supply of renewable energy or enhanced energy efficiency would lead to long-term average wellhead price reductions of between 0.8 and 2 percent. Wiser also concludes that in the short-term, the average consumer would not see reductions in their electricity bills; they would probably remain the same. While natural gas prices would fall somewhat, the cost of meeting national renewable portfolio standards of 10 to 20 percent renewable energy would be quite high, and will remain high in the short-term. That said, Wiser et al. (2004b) notes that increased renewable energy use would help to hedge natural gas price volatility due to supply shocks.

The Union of Concerned Scientists (UCS, 2003) also reports that increased use of renewable energy would cause a reduced natural gas demand and prices. For each 1 percent of renewable energy added to total electricity capacity in the U.S., the price of natural gas would fall between .45 and .60 percent, depending on how much renewable energy is installed. The UCS indicates that there would be a decreasing rate of gas price reduction as total generating capacity increases.

If the mid-point of Wiser et al's elasticity range is used (1.4), the expected effect of a 1 percent increase in the quantity of renewable energy would be a 1.4 percent decrease in natural gas prices. Recall that if the SAI goals are met, PV will displace 0.2 to 0.4 percent of forecasted natural gas demand in 2015 and 2 to 4 percent of natural gas demand in 2030. With the 1.4 inverse elasticity, the change in consumption would result in a similar decrease in natural gas prices of 0.3 to 0.6 percent in 2015 and 3 to 6 percent in 2030. This simple example obviously does not account for a host of other factors that will impact natural gas prices during the same period. Nevertheless, given the increasing U.S. demand for natural gas and the large number of natural gas customers, any decrease in natural gas prices due to the SAI will have wide reaching impacts.

T&D Benefits

Two primary costs associated with the transmission and distribution of electricity are the capital and operating costs of the infrastructure (e.g., lines, substations) and electricity that is lost as it travels through the wires from generating plants to end users (i.e., efficiency losses). Transmission and distribution costs can vary greatly depending on locational factors specific to a particular region (e.g., the dispersion of electricity users, geographic constraints that affect capacity expansions, plant locations) and time of day electricity use (i.e. demand patterns). An effective means for reducing these costs is to increase the use of

distributed energy resources, which do not rely on the T&D infrastructure. As this suggests, the SAI PV installations may produce significant benefits in terms of reduced T&D losses and stress on the existing T&D infrastructure.

In its planning study for the California Public Utilities Commission (CPUC), the Energy and Environmental Economics Group (E3, 2004) note that average electric transmission costs range widely from $1.16/kW-year to $18.81/kW-year in California, depending on the utility and geographic zone that is analyzed. These costs are for the construction of transmission and distribution infrastructure. Thus, on average, every kW of load that could be reduced by greater transmission efficiency is worth approximately $10.00 in savings per year in California.

The U.S. Climate Change Technology Program (2003) estimates that in the next decade, the demand for electricity transmission capacity will greatly exceed the construction of infrastructure. While line-miles are only projected to increase by 6 percent, demand is expected to increase by more than 20 percent. The amount of electricity that must be pushed through existing lines will increase, causing increased energy losses and transmission congestion. As a result, grid reliability will likely decrease, resulting in more transmission failures and blackouts.

In 1995, the U.S. transmission and distribution system had energy losses of 7.2 percent (Climate Change Technology Program), and other studies find similar rates ranging from 5 to 10 percent. Connors et al. (2005) estimated average line losses to be between 5 and 12 percent of net generation by comparing EIA data on net generation to retail electricity sales (the difference between the two is presumed to equal line losses). In another California study, Itron (2005) estimated that over the entire year, line loss costs range from $0.00 to $0.12 per kWh.

Based on these studies, we use 7 percent to account for T&D losses in our economic impact analysis as this is approximately the midpoint of the range of estimates found in the literature.

Blackout Prevention / Power Reliability

Consumers place a high value on the reliability of their electricity supply, and many authors have noted the potential reliability benefits of developing more distributed electrical generating systems (e.g., Young 2004, Itron 2005, Hadley et al. 2003). In particular, studies have focused on the causes and economic impacts of power blackouts, and the potential role that PV generation could play in mitigating blackouts.

Blackouts are typically caused by one or more of the following factors: unusually high demand, often related to extreme weather; equipment failure; high power transfer activity (which can lead to line overloads); and human/operator error. Gellings and Yeager (2004) estimated the annual cost of power blackouts in the US to be about $100 billion. Due to the unpredictability of blackout occurrences (i.e., frequency, location, duration, precise causes), however, this study does not try to quantify total "blackout prevention benefits" that could be attributable to PV generation under the SAI. That said, information is presented here that shows that the economic costs of blackouts are high, and that PV installations that lead to increased system stability could have significant economic benefits.

Several studies have also analyzed the August 2003 blackout that lost 62,000 MW of power and affected over 50 million people in the Northeast region of the country. ICF (2003) used preliminary information about the blackout and extrapolated findings from previous analyses to estimate the economic costs of this outage to be between $7 and $10 billion. Perez et al. (2004) subsequently analyzed the precise causes of the blackout, and estimated that the availability of less than 500 MW of PV resources would have been sufficient to prevent the cascading blackout. More specifically, Perez et al. found that regionally dispersed PV could have reduced the need for the large national power transfers that were occurring, and alleviated

conditions contributing to the eventual blackout. They also note that in the case of the 2003 Northeast blackout, PV effective capacity was particularly high in the region (due to little cloud cover) and was directly related to high air conditioning demand (the fundamental cause of the blackout). The authors conclude that in some situations, PV can act as a natural offset or hedge against blackout causes, and that PV (and other distributed generation sources) can work in conjunction with and in parallel to grid-supplied power to improve system reliability.

6. SUMMARY AND CONCLUSIONS

Based on our analysis, achieving the SAI PV installation goals will result in a wide range of significant benefits:

- The SAI is expected to produce significant economic benefits over and above what would be achieved in the counterfactual scenario where the SAI generation is instead supplied by conventional sources. If the 2015 SAI goals are reached, economic output will have a net increase of $2.9 to 9.1 billion and 16,000 to 45,000 new jobs will be created. By 2030, the SAI results in an increase of $25 billion in economic output and 165,000 to 199,000 new jobs.

- The economic benefits assume that the price of electricity remains constant (except for inflation) throughout the analysis period. Most predictions indicate the price of electricity will increase, however, particularly for electricity generated by natural gas, which is the most likely source to be offset by the SAI. When price increases are considered in the analysis, a 1-cent increase in electricity prices will increase the net economic output from PV O&M by 3 percent. Similarly, every 1-cent increase in electricity prices will also increase the PV O&M personal income benefit by 6 to7 percent and the net number of new jobs by 8 to 9 percent annually.

- The SAI PV installations will also have a significant effect in reducing emissions. If the 2015 SAI goals are met, emissions of CO_2 will decrease by 5 to 11 million tons annually, NO_X emissions will decrease by 5,000 to 11,200 tons annually, and SO_2 emissions will fall by 9,200 to 20,700 tons annually. By 2030, the SAI will result in decreased CO_2 emissions of 69 to 100 million tons annually, decreased NO_X emissions by 68,000 to 99,000 tons annually, and decreased SO_2 emissions by 126,000 to 184,000 tons annually. These emissions reductions will continue each year the PV equipment remains installed.

- The reduced emissions will have a corresponding influence on health benefits in addition to reductions in global warming and acid rain. In 2015, the reduced emissions should result in a decrease in mortality of 22 to 49, with this number increasing to 300 to 437 deaths avoided annually by 2030. The improved health benefits due to the SAI is also expected to reduce the lost number of work days, with lost work days falling by 2,500 to 5,700 annually in 2015 and decreasing 35,000 to 51,000 annually in 2030.

- Increasing the deployment of PV through the SAI will reduce demands on natural gas, which in turn will reduce the price of natural gas. If the inverse price elasticity of 1.4 is used, then the SAI PV installations will have the effect of reducing natural gas prices by 0.3 to 0.6 percent in 2015 and 3 to 6 percent in 2030. This has potentially far reaching effects, as even a small reduction in the price of natural gas will be felt by all customers that rely on natural gas for electricity generation.

- Finally, several studies have researched the potential benefits of using PV and other distributed energy resources to reduce the risk of blackouts. Large regional blackouts are expensive and disruptive to the economy and have been estimated to cost the U.S. $100 billion annually. Research suggests that 500 MW of PV may have been enough to avoid this blackout. The ability of PV to prevent specific blackouts will depend on very specific information on where the PV installations are installed and their ability to relieve pressure on the high stress points on the grid. While this level of detail is outside the scope of this study, it appears that there will be some potential benefit for blackout prevention should the SAI PV goals be achieved.

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APPENDIX A: DETAILED IMPLAN MODEL RESULTS

The following tables show the annual net benefits (relative to the counterfactual scenario) for each of the IMPLAN benefit categories of output, personal income, jobs, and tax revenues. For these tables, the total impacts are shown which are the sum of the direct, indirect, and induced effects discussed in the main body of the report.

For each year, the construction impacts are calculated based only the PV installations done in that year. Similarly, the R&D impacts reflect only the R&D spending for the individual year. For O&M expenses, these continue to accrue for each the PV system is installed. Therefore, the economic impacts are calculated based on the total installed capacity for that year. For example, the O&M benefits in 2015 are calculated based on the total installed capacity of 5 GW (low scenario) and 10 GW (high scenario).

Table 23: Annual Construction Impacts - High Scenario

Year	Total Annual Installed Capacity (GW) - High	SAI Induced Installed Capacity (GW) - High	Construction Total Output	Construction Total Personal Income	Construction Total Jobs
2005	**0.11**	0.11	$1,009,491,000	$348,085,000	3,450
2006	**0.15**	0.15	$1,251,959,000	$431,356,000	4,290
2007	**0.21**	0.20	$1,552,160,000	$534,336,000	5,310
2008	**0.29**	0.28	$1,923,660,000	$661,604,000	6,580
2009	**0.40**	0.38	$2,383,135,000	$818,782,000	8,140
2010	**0.55**	0.51	$2,951,074,000	$1,012,754,000	10,070
2011	**0.76**	0.69	$3,652,613,000	$1,251,931,000	12,450
2012	**1.04**	0.94	$4,518,531,000	$1,546,564,000	15,390
2013	**1.44**	1.28	$5,586,461,000	$1,909,128,000	19,020
2014	**1.99**	1.75	$6,902,320,000	$2,354,770,000	23,460
2015	**2.74**	2.37	$8,522,000,000	$2,901,796,000	28,940
2016	**2.99**	2.57	$9,038,166,000	$3,076,249,000	30,680
2017	**3.27**	2.78	$9,585,255,000	$3,261,040,000	32,530
2018	**3.58**	3.01	$10,165,089,000	$3,456,772,000	34,490
2019	**3.91**	3.26	$10,779,599,000	$3,664,077,000	36,560
2020	**4.27**	3.52	$11,430,825,000	$3,883,629,000	38,760
2021	**4.67**	3.81	$12,120,921,000	$4,116,131,000	41,090
2022	**5.10**	4.13	$12,852,168,000	$4,362,333,000	43,560
2023	**5.58**	4.47	$13,626,979,000	$4,623,016,000	46,160
2024	**6.10**	4.84	$14,447,899,000	$4,899,021,000	48,930
2025	**6.67**	5.23	$15,317,622,000	$5,191,221,000	51,850
2026	**7.29**	5.66	$16,238,995,000	$5,500,542,000	54,950
2027	**7.96**	6.13	$17,215,025,000	$5,827,962,000	58,230
2028	**8.70**	6.63	$18,248,885,000	$6,174,512,000	61,710
2029	**9.51**	7.18	$19,343,936,000	$6,541,273,000	65,380
2030	**10.40**	7.77	$20,503,720,000	$6,929,398,000	69,280

Table 24: Annual Construction Impacts – Low Scenario

Year	Total Annual Installed Capacity (GW) - Low	SAI Induced Installed Capacity (GW) - Low	Construction Total Output	Construction Total Personal Income	Construction Total Jobs
2005	0.11	0.11	$1,009,491,000	$348,085,000	3,450
2006	0.14	0.13	$1,111,096,000	$382,823,000	3,800
2007	0.17	0.16	$1,222,532,000	$420,860,000	4,180
2008	0.21	0.19	$1,344,662,000	$462,470,000	4,600
2009	0.27	0.23	$1,478,411,000	$507,944,000	5,050
2010	0.34	0.28	$1,624,756,000	$557,587,000	5,550
2011	0.42	0.34	$1,784,734,000	$611,717,000	6,090
2012	0.52	0.41	$1,959,426,000	$670,656,000	6,680
2013	0.65	0.49	$2,149,958,000	$734,731,000	7,310
2014	0.82	0.60	$2,357,491,000	$804,273,000	8,010
2015	1.02	0.72	$2,583,200,000	$879,597,000	8,770
2016	1.19	0.85	$2,982,955,000	$1,015,284,000	10,130
2017	1.39	1.00	$3,444,452,000	$1,171,852,000	11,690
2018	1.62	1.18	$3,977,201,000	$1,352,498,000	13,500
2019	1.89	1.39	$4,592,181,000	$1,560,922,000	15,570
2020	2.21	1.63	$5,302,050,000	$1,801,375,000	17,980
2021	2.57	1.93	$6,121,415,000	$2,078,765,000	20,750
2022	3.00	2.27	$7,067,122,000	$2,398,748,000	23,950
2023	3.50	2.68	$8,158,602,000	$2,767,845,000	27,630
2024	4.09	3.15	$9,418,263,000	$3,193,563,000	31,890
2025	4.77	3.71	$10,871,949,000	$3,684,560,000	36,810
2026	5.56	4.38	$12,549,465,000	$4,250,809,000	42,460
2027	6.49	5.16	$14,485,171,000	$4,903,800,000	49,000
2028	7.57	6.08	$16,718,693,000	$5,656,770,000	56,540
2029	8.83	7.16	$19,295,710,000	$6,524,967,000	65,220
2030	10.31	8.44	$22,268,889,000	$7,525,950,000	75,230

Table 25: Annual O&M Impacts - High Scenario

Year	Total Cummulative Installed Capacity - High	SAI Induced Cummulative Installed Capacity - High	O&M Total Output	O&M Total Personal Income	O&M Total Jobs
2005	0.44	0.44	$51,601,000	$28,364,000	980
2006	0.59	0.59	$64,067,000	$35,934,000	1,270
2007	0.80	0.79	$79,920,000	$45,781,000	1,650
2008	1.09	1.07	$100,077,000	$58,597,000	2,160
2009	1.49	1.45	$125,720,000	$75,302,000	2,840
2010	2.04	1.96	$158,361,000	$97,109,000	3,740
2011	2.79	2.65	$199,955,000	$125,619,000	4,930
2012	3.84	3.60	$253,016,000	$162,960,000	6,540
2013	5.28	4.88	$320,800,000	$211,949,000	8,660
2014	7.26	6.63	$407,511,000	$276,331,000	11,520
2015	10.00	9.00	$518,614,000	$361,094,000	15,330
2016	12.99	11.57	$657,780,000	$460,551,000	19,630
2017	16.26	14.35	$805,054,000	$566,828,000	24,250
2018	19.84	17.36	$961,035,000	$680,454,000	29,230
2019	23.75	20.62	$1,126,362,000	$802,008,000	34,590
2020	28.02	24.14	$1,301,720,000	$932,103,000	40,340
2021	32.69	27.96	$1,487,844,000	$1,071,407,000	46,540
2022	37.79	32.08	$1,685,518,000	$1,220,635,000	53,220
2023	43.37	36.55	$1,895,586,000	$1,380,562,000	60,420
2024	49.47	41.39	$2,118,949,000	$1,552,014,000	68,170
2025	56.14	46.62	$2,356,573,000	$1,735,897,000	76,520
2026	63.42	52.29	$2,609,495,000	$1,933,169,000	85,520
2027	71.38	58.42	$2,878,827,000	$2,144,876,000	95,220
2028	80.09	65.05	$3,165,756,000	$2,372,139,000	105,680
2029	89.60	72.23	$3,471,563,000	$2,616,166,000	116,950
2030	100.00	80.00	$3,797,614,000	$2,878,265,000	129,120

Table 26: Annual O&M Impacts – Low Scenario

Year	Total Cummulative Installed Capacity - Low	SAI Induced Cummulative Installed Capacity - Low	O&M Total Output	O&M Total Personal Income	O&M Total Jobs
2005	0.44	0.44	$51,601,000	$28,364,000	980
2006	0.58	0.57	$62,239,000	$34,908,000	1,240
2007	0.75	0.73	$73,872,000	$42,315,000	1,530
2008	0.96	0.93	$86,674,000	$50,748,000	1,870
2009	1.23	1.16	$100,848,000	$60,404,000	2,280
2010	1.57	1.44	$116,624,000	$71,516,000	2,760
2011	1.99	1.78	$134,268,000	$84,353,000	3,310
2012	2.51	2.19	$154,089,000	$99,244,000	3,970
2013	3.16	2.68	$176,444,000	$116,575,000	4,770
2014	3.98	3.28	$201,750,000	$136,805,000	5,700
2015	5.00	4.00	$230,495,000	$160,486,000	6,810
2016	6.19	4.85	$275,635,000	$192,987,000	8,230
2017	7.58	5.85	$328,036,000	$230,966,000	9,890
2018	9.20	7.02	$388,893,000	$275,353,000	11,830
2019	11.09	8.41	$459,593,000	$327,246,000	14,100
2020	13.30	10.05	$541,752,000	$387,925,000	16,790
2021	15.87	11.97	$637,251,000	$458,889,000	19,940
2022	18.87	14.24	$748,284,000	$541,900,000	23,620
2023	22.38	16.92	$877,405,000	$639,015,000	27,960
2024	26.46	20.07	$1,027,585,000	$752,652,000	33,060
2025	31.23	23.79	$1,202,294,000	$885,634,000	39,030
2026	36.80	28.16	$1,405,567,000	$1,041,274,000	46,060
2027	43.29	33.32	$1,642,109,000	$1,223,457,000	54,320
2028	50.86	39.40	$1,917,403,000	$1,436,732,000	64,010
2029	59.69	46.56	$2,237,837,000	$1,686,431,000	75,400
2030	70.00	55.00	$2,610,859,000	$1,978,806,000	88,770

Table 27: Annual R&D Impacts – High and Low Scenarios

Year	Annual R&D Spending	R&D Total Output	R&D Total Personal Income	R&D Total Jobs
2005	$148,000,000	$118,007,000	$64,254,000	910
2006	$148,000,000	$118,007,000	$64,254,000	910
2007	$148,000,000	$118,007,000	$64,254,000	910
2008	$148,000,000	$118,007,000	$64,254,000	910
2009	$148,000,000	$118,007,000	$64,254,000	910
2010	$148,000,000	$118,007,000	$64,254,000	910
2011	$148,000,000	$118,007,000	$64,254,000	910
2012	$148,000,000	$118,007,000	$64,254,000	910
2013	$148,000,000	$118,007,000	$64,254,000	910
2014	$148,000,000	$118,007,000	$64,254,000	910
2015	$148,000,000	$118,007,000	$64,254,000	910

Table 28: Annual Tax Impacts - Construction

	High Scenario			Low Scenario		
Year	Total Federal Taxes - Construction	Total State and Local Taxes - Construction	Total Taxes - Construction	Total Federal Taxes - Construction	Total State and Local Taxes - Construction	Total Taxes - Construction
2005	$73,543,590	$14,513,980	$88,057,570	$73,543,590	$14,513,980	$88,057,570
2006	$91,206,530	$18,077,390	$109,283,920	$80,944,540	$16,043,450	$96,987,990
2007	$113,074,630	$22,517,600	$135,592,230	$89,061,180	$17,735,580	$106,796,760
2008	$140,135,530	$28,050,970	$168,186,500	$97,956,490	$19,607,990	$117,564,480
2009	$173,603,900	$34,947,640	$208,551,540	$107,697,600	$21,680,230	$129,377,830
2010	$214,971,580	$43,544,600	$258,516,180	$118,355,740	$23,974,120	$142,329,860
2011	$266,068,490	$54,262,860	$320,331,350	$130,006,010	$26,513,840	$156,519,850
2012	$329,135,610	$67,628,090	$396,763,700	$142,727,110	$29,326,390	$172,053,500
2013	$406,912,310	$84,297,110	$491,209,420	$156,600,830	$32,441,870	$189,042,700
2014	$502,740,750	$105,090,860	$607,831,610	$171,711,330	$35,893,820	$207,605,150
2015	$620,688,860	$131,035,690	$751,724,550	$188,144,040	$39,719,710	$227,863,750
2016	$658,277,500	$139,275,510	$797,553,010	$217,257,850	$45,966,490	$263,224,340
2017	$698,117,570	$148,034,680	$846,152,250	$250,867,840	$53,196,130	$304,063,970
2018	$740,341,760	$157,346,050	$897,687,810	$289,666,740	$61,563,350	$351,230,090
2019	$785,090,470	$167,244,460	$952,334,930	$334,453,730	$71,247,260	$405,700,990
2020	$832,512,150	$177,767,090	$1,010,279,240	$386,150,750	$82,455,110	$468,605,860
2021	$882,763,780	$188,953,420	$1,071,717,200	$445,821,260	$95,426,950	$541,248,210
2022	$936,011,280	$200,845,430	$1,136,856,710	$514,691,860	$110,440,450	$625,132,310
2023	$992,430,090	$213,487,800	$1,205,917,890	$594,177,350	$127,817,200	$721,994,550
2024	$1,052,205,610	$226,928,020	$1,279,133,630	$685,909,390	$147,929,340	$833,838,730
2025	$1,115,533,850	$241,216,630	$1,356,750,480	$791,769,670	$171,207,730	$962,977,400
2026	$1,182,621,900	$256,407,330	$1,439,029,230	$913,927,970	$198,151,110	$1,112,079,080
2027	$1,253,688,540	$272,557,320	$1,526,245,860	$1,054,886,330	$229,336,870	$1,284,223,200
2028	$1,328,964,960	$289,727,320	$1,618,692,280	$1,217,529,520	$265,433,320	$1,482,962,840
2029	$1,408,695,320	$307,982,060	$1,716,677,380	$1,405,183,360	$307,214,260	$1,712,397,620
2030	$1,493,137,530	$327,390,310	$1,820,527,840	$1,621,681,990	$355,575,390	$1,977,257,380

Table 29: Annual Tax Impacts - O&M

	High Scenario			Low Scenario		
Year	Total Federal Taxes - O&M	Total State and Local Taxes - O&M	Total Taxes - O&M	Total Federal Taxes - O&M	Total State and Local Taxes - O&M	Total Taxes - O&M
2005	-$3,249,310	$1,509,210	-$1,740,100	-$3,249,310	$1,509,210	-$1,740,100
2006	-$4,802,490	$1,781,260	-$3,021,230	-$4,665,430	$1,730,420	-$2,935,010
2007	-$7,011,170	$2,099,080	-$4,912,090	-$6,480,560	$1,940,210	-$4,540,350
2008	-$10,137,550	$2,464,930	-$7,672,620	-$8,779,820	$2,134,820	-$6,645,000
2009	-$14,544,140	$2,878,580	-$11,665,560	-$11,666,830	$2,309,120	-$9,357,710
2010	-$20,731,720	$3,335,520	-$17,396,200	-$15,267,720	$2,456,420	-$12,811,300
2011	-$29,390,800	$3,824,490	-$25,566,310	-$19,735,690	$2,568,080	-$17,167,610
2012	-$41,472,160	$4,323,570	-$37,148,590	-$25,256,790	$2,633,060	-$22,623,730
2013	-$58,283,630	$4,795,070	-$53,488,560	-$32,056,750	$2,637,360	-$29,419,390
2014	-$81,621,910	$5,177,610	-$76,444,300	-$40,409,230	$2,563,310	-$37,845,920
2015	-$113,953,120	$5,375,250	-$108,577,870	-$50,645,820	$2,388,990	-$48,256,830
2016	-$147,269,960	$6,487,760	-$140,782,200	-$61,711,670	$2,718,600	-$58,993,070
2017	-$183,622,700	$7,533,260	-$176,089,440	-$74,821,060	$3,069,590	-$71,751,470
2018	-$223,267,260	$8,502,900	-$214,764,360	-$90,347,640	$3,440,800	-$86,906,840
2019	-$266,481,150	$9,386,860	-$257,094,290	-$108,733,220	$3,830,150	-$104,903,070
2020	-$313,565,400	$10,174,060	-$303,391,340	-$130,500,110	$4,234,260	-$126,265,850
2021	-$364,846,510	$10,852,230	-$353,994,280	-$156,265,700	$4,648,100	-$151,617,600
2022	-$420,678,480	$11,407,680	-$409,270,800	-$186,759,830	$5,064,430	-$181,695,400
2023	-$481,445,240	$11,825,130	-$469,620,110	-$222,845,100	$5,473,460	-$217,371,640
2024	-$547,563,070	$12,087,680	-$535,475,390	-$265,541,070	$5,861,940	-$259,679,130
2025	-$619,483,400	$12,176,600	-$607,306,800	-$316,052,580	$6,212,360	-$309,840,220
2026	-$697,695,620	$12,071,080	-$685,624,540	-$375,803,560	$6,501,930	-$369,301,630
2027	-$782,730,380	$11,748,080	-$770,982,300	-$446,476,550	$6,701,210	-$439,775,340
2028	-$875,162,990	$11,182,220	-$863,980,770	-$530,059,650	$6,772,730	-$523,286,920
2029	-$975,617,070	$10,345,320	-$965,271,750	-$628,901,880	$6,668,810	-$622,233,070
2030	-$1,084,768,760	$9,206,400	-$1,075,562,360	-$745,778,530	$6,329,420	-$739,449,110

Table 30: Annual Tax Impacts - R&D

	High Scenario			Low Scenario		
Year	Total Federal Taxes - R&D	Total State and Local Taxes - R&D	Total Taxes - R&D	Total Federal Taxes - R&D	Total State and Local Taxes - R&D	Total Taxes - R&D
2005	-$2,975,790	$2,840,140	-$135,650	-$2,975,790	$2,840,140	-$135,650
2006	-$2,975,790	$2,840,140	-$135,650	-$2,975,790	$2,840,140	-$135,650
2007	-$2,975,790	$2,840,140	-$135,650	-$2,975,790	$2,840,140	-$135,650
2008	-$2,975,790	$2,840,140	-$135,650	-$2,975,790	$2,840,140	-$135,650
2009	-$2,975,790	$2,840,140	-$135,650	-$2,975,790	$2,840,140	-$135,650
2010	-$2,975,790	$2,840,140	-$135,650	-$2,975,790	$2,840,140	-$135,650
2011	-$2,975,790	$2,840,140	-$135,650	-$2,975,790	$2,840,140	-$135,650
2012	-$2,975,790	$2,840,140	-$135,650	-$2,975,790	$2,840,140	-$135,650
2013	-$2,975,790	$2,840,140	-$135,650	-$2,975,790	$2,840,140	-$135,650
2014	-$2,975,790	$2,840,140	-$135,650	-$2,975,790	$2,840,140	-$135,650
2015	-$2,975,790	$2,840,140	-$135,650	-$2,975,790	$2,840,140	-$135,650

APPENDIX B: IMPLAN MODEL TECHNICAL DETAIL

This appendix provides a detailed discussion of the modeling tools and analysis methods used to estimate economic impacts. This appendix begins with a discussion of what economic impacts are and how they can be measured using an input-output modeling framework. It then discusses the limitations of input-output analysis, with recommendations on when an input-output model should be used. This appendix concludes with a discussion of the IMPLAN modeling software, which is a widely used model for estimating economic impacts.

ECONOMIC IMPACTS

Economic impacts are changes in economic activity as a result of some initial change in the economy. Although the initial stimuli can vary, economic impacts are typically measured as changes in output (or sales), income (value added), and jobs:

- **Output** is the broadest measure of economic activity. It represents the total value of production or, alternatively, business revenues. Output includes the costs of materials and labor, net business income (profits), and indirect business taxes.

- **Income** represents the total payments to workers (wages) and business owners (proprietor and corporate income). Together, wages and business income are often referred to as personal income. Corporate income represents net business income or profits. These may be reinvested or paid as dividends to shareholders. Income excludes payments from one industry to another for the purchase of intermediate goods, and is often used as a measure of the value added during production.[25]

- **Jobs** represent the number of additional jobs gained or lost as a result of some economic activity. Job impacts are the most popular measure of economic impacts because they are easy to understand.

Economic impacts often lead to changes in government revenues and expenditures. These *fiscal impacts* occur as changes in output, income, and jobs, lead to changes in the regional tax base and demand for government services.

Gross Versus Net Economic Impacts

Simply citing the economic impacts that occur as a result of some activity would produce an upper bound estimate of economic impacts. This upper bound estimate is often referred to as a measure of the "gross" economic impacts. Gross economic impacts offer a perspective on the magnitude of overall economic impacts that can be traced back to the activity. Gross economic impacts, however, do not accurately reflect the creation of new jobs or income as they do not take into account the jobs or income creation that would have occurred in absence of the activity being analyzed.

This problem is addressed by analyzing the "net" economic impacts of a given activity. An analysis of the net economic impacts requires that only economic stimuli that are new or additive to the local economy

[25] Alternatively, value added is measured as total output less purchases of intermediate goods and services. In either case, the measure of value added will be the same. However, to the extent that owners of corporations live outside the relevant study area, including corporate income will tend to overestimate the measure of value added in production.

be counted. To do this, the impact analysis must include a "base case" or "counterfactual" scenario that describes what would have happened in the absence of a change in the economy.

Establishing a base case affects an analyst's ability to properly identify cause-and-effect relationships. Attributing effects to causes, and doing so only once (i.e., avoiding double counting) is essential to an evaluation of net economic impacts. In impact analysis, this base case scenario is typically implemented by positing a counterfactual argument that only counts spending that "but for" the project or activity would not have occurred.

To get a better understanding of how this base case scenario affects the impact analysis, the three components of the counterfactual argument related to a net impact analysis of a new business activity, for example, are described below:

1. Net impacts include expenditures by non-local sources that would have gone to non-local businesses *but for* the local presence of the new business. (The new business is an "exporter" of goods and services. In this sense, the new business brings in new spending to the community.)

2. Net impacts include expenditures by local sources that would have been spent outside of the local economy *but for* the local presence of the new business. (This is called "import substitution." The new business keeps local spending in the community.)

3. Net impacts would make deductions for expenditures by local sources that would have gone to other local businesses *but for* the new business. (This is a form of "direct substitution." The new business may actually divert spending away from other local businesses. This spending should not be included in the impact analysis.)

Net impacts are often considerably smaller than gross impacts, but provide a truer picture of the benefits from a stimulus. Using a net impact approach, the analyst is better able to answer the following question: How much better off is the local economy because of the activity or project relative to the base case alternative?

At the outset, one should decide whether the question being posed for analysis requires that net or gross impacts be determined. A common mistake is to use the results from a gross impact analysis to answer a question about the benefits or improvement to an economy due to a project or activity. This often leads to unrealistic claims about economic impacts.

FEATURES OF INPUT-OUTPUT MODELS

Input-output models serve two general purposes. First, the input-output framework is useful for organizing information about the structure of a regional economy. Using standard accounting conventions, input-output models describe the flow of commodities between producing and consuming sectors, the flow of income between businesses and institutions, and the trade in commodities between regions. In this manner, the input-output modeling framework can be used for *descriptive* purposes. For instance, researchers can evaluate the relative importance of various industry sectors to the local economy, e.g., the number of jobs or purchases from other local industries.

Once the information on the various transactions within an economy has been gathered and organized using the input-output framework, the data can be manipulated using a special field of mathematics called matrix algebra. This phase of input-output modeling produces "multipliers" and allows researchers to use the input-output model for *prescriptive* purposes. For example, a researcher can estimate the "ripple" effect that a change in one sector has on the entire economy.

Economic Linkages

An input-output model begins with a transactions table that provides a reasonably comprehensive description of an economy and linkages between economic sectors. Table B-1 shows a hypothetical transactions table for an economy with three industry sectors. For exposition purposes, the table has been divided into four quadrants.

Table B-1: A Transactions Table for a Hypothetical Economy

		INTERMEDIATE DEMANDS			FINAL DEMANDS			
	Buyer / Seller	Agriculture	Manufacturing	Services	Household Demand	Other Demand	Exports	Total Outputs
	Agriculture	$600	$100	$400	$700	$100	$1,300	$3,200
	Manufacturing	$200	$700	$800	$1,400	$600	$300	$4,000
	Services	$200	$400	$1,500	$1,600	$200	$1,000	$4,900
FINAL PAYMENTS	Wages	$900	$600	$1,000	NONMARKET TRANSFERS			
	Other Earnings	$500	$400	$600				
	Imports	$800	$2,200	$1,200				
	Total Inputs	$3,200	$4,000	$4,900				

The top left quadrant of the transactions table describes the production relationships between industries in the economy. This portion of the table describes the way raw materials and intermediate goods are provided by some industries ("sellers") and used by other industries ("buyers") to produce final goods and services. Because industries are buying from other industries, it describes the *intermediate demands* for goods and services.

The upper right quadrant of the transactions table shows who consumes the final goods and services. In this simple hypothetical transactions table, the *final demand* sectors consist of households, others,[26] and exports. In more sophisticated input-output models, the final demand sectors are more extensive and explicitly identified in the model.

By combining the top two quadrants of the transactions table, researchers can trace the flow of goods and services from producing industries to other industries and final consumers. The sum of each row shows the total output or production of each industry. For instance, the value of total output produced by the agriculture sector is $3,200. Of this amount, $1,100[27] is used in production by other industries. The remainder is sold to final consumers—households consume $700 worth of agricultural output; government and businesses consume $100 worth of agricultural output; and $1,300 of the total agricultural output is sold to entities outside of the region. The rows in the transactions table describe the "forward linkages" in an economy.

The lower left quadrant of the transactions table describes the transactions between businesses and the suppliers of factors of production. Labeled *final payments*, this section of the input-output model depicts

[26] "Other demand" consists of government and business spending, including additions to business inventories.

[27] This amount represents the sum of the intermediate demands across all sectors, i.e., $600 agriculture, $100 manufacturing, and $400 services.

the flow of income from businesses to households (wages), others,[28] and imports. The income components, excluding imports, are the elements of value added.

The left side of the transactions table shows the purchases and payments by industries to other industries and other institutions within the economy. The sum of the entries for each column represents the total purchases by that industry. The agricultural sector shows large intra-sector purchases ($600) from others within the agriculture sector, e.g., to produce milk the dairy must buy significant quantities of feed. Firms in the agriculture sector will also hire workers and pay wages ($900). In addition, firms will pay taxes and earn profits ($500), and purchase imported goods and services ($800). From this example, we can trace all of the purchases for each sector of the economy. The columns in the transactions table describe the "backward linkages" in the economy.

As discussed previously, the input-output model is based on a double-entry accounting convention where inputs must be equal to outputs. Because government and businesses are implicitly included in Other Demand (government purchases, capital investment and inventories) and Other Earnings (taxes and profits), inputs must be equal to outputs. The agriculture sector of this economy produces $3,200 in output. To do this, the agriculture sector must purchase $3,200 in inputs from other industries, households, government, businesses and foreigners. The input-output model, thus, is a balanced or symmetrical model because total sales (outputs) of each industry equal the total purchases (inputs) by each industry.

In order to emphasize the relationships among businesses and institutions, the lower right hand quadrant of the transactions table labeled "Non-Market Transfers" has been left blank. This section of the transactions table contains information regarding inter-institutional transfers or non-market financial flows between households, businesses, government and foreigners.

Economic Multipliers

The transactions table provides a reasonably comprehensive description of the economy at a given point in time. Using annual data, it shows how much an industry produces, what it purchases, and to whom the final output is sold. It also distinguishes local from non-local sources of spending and production. In this form, the transactions table fully describes the linkages between the various sectors of the economy, but has no predictive or analytical capabilities.

The information contained in the transaction table can be expanded and then manipulated using matrix algebra to construct *multipliers* that measure the total impacts from a change in final demand on all industries in an economy. It is through this matrix operation that the input-output model is converted from a descriptive to a prescriptive model.

Economic impact multipliers allow researchers to follow the initial change in economic activity as it "ripples" through each industry sector. For any given type of change in economic activity, the impacts on the economy can be reported on one of three levels:

1. **Direct** impacts represent the initial change in final demand for the industry sector(s) in question. Direct impacts describe the changes in economic activity for sectors that first experiences a change in demand because of a project, policy decision, or some other stimuli.

[28] "Other earnings" includes small business income, corporate profits, and indirect business taxes paid to government.

2. **Indirect** impacts represent the response as supplying industries increase output in order to accommodate the initial change in final demand. These indirect beneficiaries will then spend money for supplies and services, which results in another round of indirect spending, and so on.

3. **Induced** impacts are generated by the spending of households who benefit from the additional wages and business income they earn through all of the direct and indirect activity. The increase in income, in effect, increases the purchasing power of households.

The following example illustrates how these types of impacts affect overall economic activity. Suppose that a new manufacturing facility comes to a region. The direct impacts would consist of the value of output produced at the facility, and the number of employees working at the facility and their payroll.

In order to operate, the manufacturing facility will purchase a host of goods and services including, for example, spare parts and equipment, repair services, electricity, water and sewer, etc. This spending generates the first round of indirect impacts. Suppliers and vendors to the manufacturing facility will also have to purchase additional goods and services. The local special trade contractor hired to repair a component on the manufacturing floor will purchase welding equipment and gases, lease equipment, and fuel their vehicles. This spending leads to another round of indirect impacts.

The direct and indirect increases in employment and income enhance the overall purchasing power in the economy. Workers at the manufacturing facility will use their income to purchase groceries or take their family to the theater. Workers at businesses who supply the manufacturing facility will do the same. This spending will generate induced economic impacts for workers and businesses in other sectors of the economy.

This cycle of spending does not go on forever. It continues until the spending eventually leaks out of the local economy as a result of taxes, savings, or purchases of non-locally produced goods and services or "imports". As discussed previously, we can now see how the definition of the study area affects the impact analysis. A larger study area will have greater economic linkages between businesses and institutions, and a smaller propensity to import. As a result, the initial economic stimulus filters throughout the economy more than it would for a smaller study area, and the multipliers are larger than they would be for a smaller study area.

LIMITATIONS OF INPUT-OUTPUT MODELING

The input-output modeling framework for economic impact analysis has grown in popularity. Much of this growth is due to significant improvements in computer technology that now make it possible to quickly perform the complex matrix operations. Some of this growth is due to improvements in government data collection efforts. Lastly, the growth in input-output modeling has been fueled by the desire of policy makers, industry officials, and others to obtain information that will help them to better understand and respond to economic change.

Like many quantitative tools, input-output models rely on a set of assumptions. Indeed, without simplifying assumptions it would be impossible for researchers to model something as complex and dynamic as a regional economy. The use of simplifying assumptions, however, also imposes certain limitations on the use of input-output modeling. These limitations should be fully understood and guide its use.

Input-Output Modeling—Static Models

Input-output models are static models in that they measure the flow of inputs and outputs in an economy at a point in time. With this information and the balanced accounting structure of an input-output model, an analyst can: 1) describe an economy at one time period, 2) introduce a change to the economy, and then 3) evaluate the economy after it has fully accommodated that change.

This type of analysis is called "partial equilibrium" analysis. Input-output models are just one of many economic models that fall under the rubric of partial equilibrium analysis. The logic of partial equilibrium analysis is straightforward: take a snapshot of an economy, posit a change to the economy, and then take another snapshot to measure what happened. Measurement in this sense is really a before and after comparison.

Partial equilibrium analysis permits comparison of the economy at two points in time, but yields little information about how the economy actually moves from one equilibrium to the next. In fact, in partial equilibrium analysis, other than the initial economic stimulus, the researcher assumes that all other relationships in the economy remain the same.

Their point-in-time construction and the assumption that nothing else changes, make static input-output models very different than dynamic models. Dynamic models have feedback effects that allow the events of one year to change the linkages in future years. In so doing, dynamic models simulate the expected long-term changes in the structure of the economy. Contrary to dynamic models, static models assume that there are no changes in wage rates, input prices, and property values. In addition, underlying economic relationships in input-output models are assumed constant, i.e., there are no changes in the productivity of labor and capital, and no changes in population migration or business location patterns.

The assumptions and their implications for input-output modeling are discussed below.

Fixed Production Relationships

Input-output models are a representation—as reported in the transactions table—of economic relationships that exist at a moment in time. For industries, this means that input-output models are based on production relationships that are fixed. This assumption results in:

- **Constant Returns to Scale** means that an industry's production function is linear, and an increase in output requires all inputs to increase proportionately. If the demand for milk doubled, for instance, then the demand for all of the inputs used to produce milk would also double. In the long run, production processes exhibit economies and diseconomies of scale that vary with the level of output. An industry with scale economies would be able to double production without necessarily doubling all inputs.

- **Fixed Commodity Input Structure** means that input-output models do not allow changing input prices to affect the production decisions of businesses. Input-output models assume that changes in an economy will affect the output of industries but not the mix of inputs that they use. Using the previous example, dairies respond to the increase demand for milk by simply increasing production of milk. Input-output models, in effect, ignore possible changes in the prices of inputs used to produce milk. Depending on the size of study area and the economic stimulus, an increase in demand for output could cause one or more input prices to increase. If the increase in demand for milk caused the wage of dairy workers to increase, then economic theory suggests that dairy farmers would have an incentive to substitute other inputs for labor.

No Supply Constraints

Input-output models show how local industries respond to some initial change in final demand, but assume that supplies of raw materials and intermediate goods are unlimited, i.e., perfectly elastic. Under an assumption of no supply constraints, an industry simply responds to a change in final demand by increasing output, and it increases output by acquiring inputs that are readily available at current prices.

Sector Homogeneity

An industry consists of businesses producing goods and services—these are called commodities in input-output modeling. Businesses can produce more than one type of commodity, i.e., they produce a primary commodity, but can also produce secondary commodities or by-products.

In input-output modeling, industry sectors are assumed to be homogenous. That is, all businesses within an industry sector 1) produce commodities in fixed proportions and 2) produce identical commodities that are perfectly substitutable. Using the previous example, an increase in demand for milk will cause dairy farms to increase production of milk as well as other by-products such as buttermilk, cottage cheese, and sour cream. If the demand for milk doubled causing milk production to double, then the output of by-products will also double. In addition, dairy farms are assumed to produce milk that is perfectly identical across farms.

Input-Output Modeling—Practical Considerations

Apart from the limitations imposed by the static nature of input-output models, there are also some very practical considerations that should also guide their use. These practical considerations are discussed below.

Lag Between Data Collection and Modeling

Input-output models can be constructed for almost any geographic region. Typically, their structure is based on a national input-output model[29] that is then combined with national and regional economic data to tailor the model to a specific study area. However, there is often a lag between actual data collection and incorporation of that data into the modeling software. With this "implementation" lag, changes in the structure of an economy—such as improvements in technology, changes in demand, and changes in regional trade patterns—will affect the multipliers and make the results less reliable. Obviously, input-output models constructed with the most current data available will provide the most accurate results.

Time

Economic impacts occur over time. As discussed previously, depending on their occurrence, impacts can be categorized as direct, indirect, and induced. These impacts are far from instantaneous. The implications for impact analysis are two-fold.

First, sometimes the effects of a large project can span several decades. The direct hires and payment of wages and benefits will also span that period of time. In this context, the researcher must consider the fact that inflation erodes purchasing power over time. If economic impacts are to be reported accurately, each

[29] The U.S. Bureau of Economic Analysis constructs national benchmark input-output accounts every five years. The most current version available is the 1997 benchmark accounts. BEA estimates that the 2002 benchmark accounts will be completed by the summer of 2007.

dollar needs to be presented in terms of its economic value today. Economists must use a base year when conducting input-output analysis. All transactions that occur after that base year should be discounted by some factor to account for expected changes in the relative value of the dollar.

The inflation assumptions that are built into an input-output analysis can have a profound impact on its results. Underestimating inflation by just one percent will inflate the net present value of a multi-million dollar project by a wide margin.

Second, the indirect and induced impacts take time to filter through the economy. Researchers use economic multipliers calculated in input-output analysis as a mathematical short cut for providing an estimate of final impacts. These final impacts are generated as spending cycles between businesses, consumers, governments and foreigners. This multiplier process takes time.

THE IMPLAN INPUT-OUTPUT MODELING SOFTWARE

One of the most common software packages used to conduct input-output analyses is IMPLAN (IMpact analysis for PLANning). IMPLAN was developed by the US Forest Service in cooperation with the Federal Emergency Management Agency and the Bureau of Land Management to assist federal agencies in their land and resource management planning. Since 1993, IMPLAN has been maintained and distributed by the Minnesota IMPLAN Group, Inc.[30] Currently there are over 1,500 public and private users of the IMPLAN modeling software.

Applications of IMPLAN by the US Government, public agencies, and private firms span a wide range of projects. Examples include new factories, resorts, proposals for developing coal mines, and harvesting timber. IMPLAN can also be applied to a variety of policy issues. Predicting the effects of a tourism marketing campaign or measuring the importance of an existing industry on a local community are common examples.

The Structure of the Input-Output Model in IMPLAN

IMPLAN uses a commodity/industry accounting framework that corresponds closely to that used in the Bureau of Economic Analysis "Input-Output Study of the U.S. Economy," and those recommended by the United Nations.

IMPLAN Database

IMPLAN uses a large database of regional and national data to forecast economic activity. The main sources of data are:

- US Bureau of Economic Analysis 1997 Benchmark I/O Accounts
- US Bureau of Economic Analysis Output Estimates
- US Bureau of Economic Analysis REIS Program
- US Bureau of Labor Statistics Covered Employment and Wages or ES202 data
- US Bureau of Labor Statistics Consumer Expenditure Survey
- US Census Bureau County Business
- US Census Bureau Decennial Census and Population Surveys
- US Census Bureau Economic Censuses and surveys

[30] For additional information, see the Minnesota IMPLAN Group's website at www.implan.com.

- US Department of Agriculture Crop and Livestock Statistics
- US Geological Survey

In IMPLAN, the process that develops county-level input-output models generates coefficients that are internally consistent, in that county data sum to state totals and state data sum to national totals. This generally is not the case with survey-based input-output models, which limits their applicability to large-scale projects that affect a number of interrelated regions.[31]

Sectors

A sector consists of industries that produce similar products or services. IMPLAN breaks an economy down to 509 separate industry sectors based on the North American Industrial Classification System ("NAICS").

Final Demands

Final demand is sum of all purchases of goods and services for final consumption within an economy. In the IMPLAN model, final demands are in producer prices and are allocated among industry sectors. In addition, final demands are adjusted or "margined" to reflect the transportation, wholesale, and retails costs of getting products from industries to consumers.

The IMPLAN model has the following major categories of final demand:

- **Personal Consumption Expenditures.** The largest component of final demand comes from household spending. Households consume a wide variety of goods and services, including food, energy, housing, and transportation. They also use some of their personal income to pay taxes, save for the future, pay debts, or purchase new housing. In IMPLAN, households are disaggregated by income levels to account for different spending patterns across income levels.

- **Federal Government Purchases.** Government purchases are broken down into two categories: military and non-military. Military expenditures include any purchases made in the interest of national defense. Non-military expenditures include all other purchases made by the federal government for the remaining services it provides.

- **State and Local Government Purchases.** State and local government purchases are also broken down into two categories: education and non-education. Spending on public education goes primarily to compensate teachers, but also includes things like textbooks and supplies. Non-education spending includes anything not spent for public education such as police, fire and emergency services, and state-sponsored healthcare.

- **Inventory Purchases.** Inventories accumulate anytime an industry fails to sell all of its output in a given year. Goods can be sold out of inventory any time sales exceed production. Industries rarely sell exactly what they produce each year, so this category is a widely used tool for reconciling economic activities.

[31] Arguably, however, an input-output model estimated from survey data has more accurate coefficients, because the survey can be customized to the problem at hand. In contrast, IMPLAN *derives* its coefficients using a combination of the national input-output survey model and local activity data; conceivably, this will produce somewhat different results from a direct, local survey. Given the difficulty and expense of input-output surveys, however, the disadvantages of the IMPLAN approach are slight.

- **Capital Formation.** A large component of productive capability is capital. Industries use varying quantities of capital depending on the nature of goods and services they provide. The manufacturing sector, for example, tends to require large investments in property, plant, and equipment for the goods it produces. This category of final demand contains all spending on capital equipment.

- **Foreign Exports.** Just as some economies must import goods and services from outside their borders, other economies sell a significant portion of their output overseas. Demand for final goods and services that come from beyond a region's borders falls into this category. Although the consumption happens elsewhere, input-output analysis is concerned with where the goods and services are produced.

Types of impacts

IMPLAN reports economic impacts as measured by changes in output, incomes (value added), jobs and taxes. The value added or income measure is broken out into four categories. These measures of economic impacts consist are:

- **Output**: The total value of the production of a sector is its output. For most sectors, output approximately equal to sales. The notable exceptions are government and the trade sectors. The output of government sectors is approximately equal to revenues. For the trade sector, which consists of firms that buy goods and re-sell them, output is roughly the difference between what they sell goods for and what they paid to procure them. The trade sector consists of wholesalers and retailers.

- **Value Added:** This is a measure of the value added to the economy by a sector. It equals the sum of the wages, proprietor income, other income, and indirect business taxes.

- **Wages** represent the total cash and non-cash compensation of workers on payroll. This includes the value of benefits.

- **Proprietor Income**, sometimes called small business income, is the amount earned by self-employed workers and the working owners of small businesses.

- **Other Income** counts all other sources of income. The largest source of income is usually rents, but it may also include royalties, dividends, and corporate profits.

- **Indirect business taxes** are the excise and sales taxes paid by individuals to businesses.

- **Employment:** The total number of payroll employees, including part time workers. The self-employed are not counted, however, their earnings are captured under proprietor income.

- **Taxes:** Total Federal, state, and local tax revenues.

Modeling

The process of modeling in IMPLAN involves three steps:

1. Creation of study area database;
2. Customization of IMPLAN coefficients; and
3. Estimating the impact of an activity on the model of the study area economy.

The IMPLAN model allows substitution and incorporation of primary data at each stage of the model-building process, greatly increasing the model's accuracy and flexibility. In addition to being able to directly modify the IMPLAN database statistics, the user can alter import and export relationships, utilize modified input-output functions, and change industry groupings. IMPLAN allows the creation of aggregate models consisting of industries grouped together for a specific purpose.

The key to input-output analysis is the construction of the input-output or transactions table, which shows the flow of commodities from each of a number of producing industries to all consuming industries and final demand (ultimate consumers). Given that many industries produce more than one commodity, production information is often tabulated on an industry-by-commodity basis into a "Make" matrix, containing the value of commodities produced by different industries, and a "Use" matrix, containing the value of commodities used by each industry in the production process. These matrices are combined to produce the input-output transactions table showing each industry buying and selling from other industries.

From these industry flows, two other structural tables are developed: (1) a table of technical coefficients or direct requirements and (2) a table of direct and indirect coefficients or total requirements. The entries in the former are interpreted as the dollar value of the minimal requirements from each of the contributing industries in order for each producing industry to produce one dollar's worth of output. The entries in the latter table are to be interpreted as the amount of output from the contributing industries required, both directly and indirectly, to deliver one dollar's worth of the producing industry's output to final demand.

Customizing the IMPLAN Coefficients

The process of customizing the IMPLAN model does not stop with the development of the study area databases. Part of the expertise of input-output practitioners is in the customization of the model coefficients. Depending on the type of analysis, this enables the analyst to:

- Vary structural, technological, and/or trade factors within the model. For instance, the user may add or remove sectors from the model, or change the size of an industry, or the user may change production functions, or make changes in commodity imports and exports.

- Exclude expenditures that do not generate current economic activity, such as depreciation and amortization.

- Exclude expenditures that are known to occur outside the local economy. The IMPLAN model contains purchasing assumptions[32] for each industry sector that are specific to the study area. Instead of relying entirely on these purchasing assumptions, the analyst can identify and remove spending that is known to occur outside of local economy.

The IMPLAN system permits a sector-by-sector breakout of transportation, wholesale, and retail margins, and allows the user to over-ride these margin assumptions using primary source data if available. For instance, instead of the estimated retail margin embedded in the IMPLAN model, the analyst can use actual retail margins for the activity.

[32] These purchasing assumptions are called "Regional Purchase Coefficients." They specify the ability of local suppliers to meet or satisfy a change in demand for a good or service.

Estimating Multipliers

The last step in building the model is to estimate the multipliers. Multiplier analysis is used to estimate the regional economic impacts resulting from a change in final demand. Impacts can be in terms of direct and indirect effects (commonly known as Type I multipliers), or in terms of direct, indirect, and induced effects (Type II and Type III multipliers).

More specifically, direct effects are production changes associated with the immediate effects of final demand changes. Indirect effects are production changes in backward-linked industries caused by the changing input needs of directly affected industries. Induced effects are the changes in regional household spending patterns caused by changes in household income—generated from the direct and indirect effects.

IMPLAN calculates two types of multipliers for each of the five impact measures. The first output multiplier represents the value of production, from indirect and direct effects, required from all sectors by a particular sector in order to deliver one dollar's worth of output. The second output multiplier adds in the induced requirements. The size of the multiplier is not a measure of the amount of activity or the importance of a given industry for the economy. It is an estimation of what would happen if that industry's sales to final demand increased or decreased. In other words, output multipliers can be used to gauge the interdependence of sectors; the larger the output multiplier, the greater the interdependence of the sector on the rest of the regional economy.

Performing Impact Analysis

Once the input-output model is built, impact analysis can be performed on the model. There are two general types of impact analysis. At a very simple level, an analyst can evaluate economic changes using industry sectors contained in the IMPLAN model. In this case, business revenues or employment are used to model changes in demand in the relevant industry sector.

In some cases, such as the entry of a new business, the industry sector may not be represented in the IMPLAN model of that region. This type of analysis is more complicated and requires the use of expenditure and revenue data to develop a spending pattern (or "production function") that is specific to the activity. Under this type of analysis:

- The **direct effects** are based on output, employment and personal income data supplied by the client.

- The **indirect effects** are measured by identifying changes in output for each industry from which goods and services are purchased. What is specified as direct impacts in this model are more precisely described as the first round of indirect impacts. Subsequent rounds of indirect impacts occur as vendors and suppliers purchase goods and services from other businesses, who will also need to buy goods and services. The indirect impacts of the activity are what the IMPLAN model reports as direct and indirect impacts in this model.

- The **induced impacts** are based, in part, on estimates of the direct personal income generated in production. This data is fed into a consumption function specific for that household income group and region. What is specified as direct impacts in this model are actually the first round of induced impacts, so what is reported as induced impacts are the total impacts from this model plus the induced impacts from the model inter-industry expenditures.

The IMPLAN model is perhaps the most popular input-output modeling system in use today. Of course, any software is susceptible to the "garbage in—garbage out" phenomenon. Thus, the accuracy of its

results is dependent on the quality of the data used in the modeling process as well as the skills of the analyst in conducting the analysis.

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The President's Solar America Initiative (SAI) was launched in January 2006 as part of the administration's Advanced Energy Initiative. The SAI is being led by the U.S. Department of Energy (DOE) Solar Energy Technologies Program (SETP), with NREL providing analytical and technical support. The SAI has a goal of installing 5-10 GW of photovoltaic (PV) systems in the United States by 2015 and 70-100 GW of PV systems in the United States by 2030. To make PV cost-competitive with other energy resources, this requires that the installed cost of PV fall from approximately $8/Wdc in 2005 to $3.3/Wdc in 2015 and $2.5/Wdc in 2030. This report presents estimates of the potential energy, economic, and environmental benefits that could result should the SAI PV installation goals be achieved.

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