Economic and Employment Impacts from Investments in Sustainable Aviation Fuel

Detailed Methods Description | March 2024

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Detailed Methods Description

Overview

Building on the information presented in the main body of this report, this appendix provides additional detail on the methods applied for estimating the employment impacts associated with the SAF investments and operational activities necessary to achieve the SAF goals set forth in the SAF adoption scenario. Additional detail is provided on the approach used for the estimation of direct employment impacts as well as the approach for assessing indirect and induced impacts. As explained in the main body text, direct employment impacts include those directly associated with the development and operation of facilities involved in the production of SAF, feedstocks for SAF production, or power systems that would support SAF production. Indirect impacts include those related to upstream supply chain interactions, and induced impacts are those effects associated with workers spending their wages.

Approach for Direct Employment Impacts

To assess the direct employment impacts associated with increased investments in SAF, we applied economic multipliers from the IMPLAN input-output model to the expenditure projections for each year. Input-output models are a well-established framework for assessing the employment impacts associated with a change in expenditures for one or several industries. Although these models can capture spillover effects to other industries, this analysis focuses on *direct* employment impacts only, as noted above. The direct employment multipliers that we apply from IMPLAN represent the number of jobs per million dollars of output, by industry. Using these multipliers, we estimate employment impacts associated with the upfront investments made for each technology (e.g., jobs related to the manufacture and installation of wind turbines) and, separately, the employment impacts related to ongoing operational activities stemming from those investments (e.g., operations and maintenance jobs for offshore wind facilities). Capturing investment- and production-related employment impacts separately is important for the overall accuracy of the results. Because the specific industries involved in designing and constructing facilities differ from those involved in operations, different IMPLAN data must be used for the analysis of investment impacts than for the assessment of operational impacts.

In the sections that follow, we describe the methods applied for the estimation of investment- and operation-related employment impacts. For investment-related impacts, we follow two separate but related approaches: one drawing from the National Renewable Energy Laboratory's (NREL's) IMPLAN-based Jobs and Economic Development Impact (JEDI) models for specific power sector technologies and a second based on IMPLAN data and technology-specific information from the literature. A single approach was applied for the assessment of operation-related employment impacts.

Estimation of Investment-Related Employment Impacts with JEDI for Select Power Sector Technologies

Our analysis of investment-related employment impacts for onshore wind, offshore wind, utility-scale solar, and transmission and distribution infrastructure is based, in part, on data from NREL's JEDI suite of models. Designed by NREL as user-friendly tools for the assessment of economic impacts associated with constructing and operating different types of energy facilities, JEDI includes detailed information on the composition of spending for several types of electricity generation technologies. Using this information, JEDI estimates the employment impacts associated with constructing and operating a new facility in the state where it is located. For the purposes of this analysis, however, we use the data in JEDI to estimate the total U.S. employment impacts associated with building new power facilities, in the states where these facilities are located *and* in other states, the latter of which is not captured in JEDI. Our approach involves the following steps:

- ***Estimate the percentage of investment expenditures that stay within the U.S.*** The magnitude of employment impacts associated with the design, manufacture, and installation of power technologies depends on the degree to which such technologies are sourced from U.S. suppliers. Therefore, as an initial step in estimating employment impacts, we specify the fraction of investment expenditures, by technology, directed to U.S.-based suppliers. Table A-1 presents this value for each of the power system technologies for which we rely on data from JEDI. As indicated in the exhibit, most of these values were derived from domestic production data from the U.S. Economic Census and imports and export data from USA Trade.[1] For wind, however, the sectoral definitions in these data were too aggregated to apply. We therefore used data from NREL's JEDI model instead.

Table A-1. Percent of Investment Expenditures Spent in U.S.

Technology	Percent Domestic
Utility-Scale Photovoltaic Solar	56%
Transmission Lines	74%
Onshore Wind	58%
Offshore Wind	91%

- ***Distribute expenditures across states****:* To support the estimation of employment impacts at the state level, we allocated those expenditures that remain in the U.S. to individual states. Although the investment expenditure estimates generated by Evolved Energy Research's energy system modeling are at the state level, these data reflect where technologies are deployed. Many of the jobs associated with power system technologies are located where systems are designed and manufactured. We therefore developed a distribution distinct from the spatial distribution of deployment, following a two-step approach. First, for each technology type, JEDI includes an estimate of the percentage of project expenditures made in the state where a project is located; we applied these values in our analysis. We allocated the remaining portion of domestic

[1] U.S. Census Bureau. 2017a. Economic Census: Summary Statistics for the U.S., States, and Selected Geographies and U.S. Census Bureau. 2017b. USA Trade: Exports & Imports by NAICS Commodities.

expenditures based on the concept of economic gravity, a concept often used to characterize trade flows between countries and within large countries such as the U.S. The gravity concept posits that the economically larger two locations are and the closer they are to one another, the more likely they are to trade with one another. For the purposes of this analysis, we operationalize this concept using the standard economic gravity equation as follows:

$$(1) \quad \boldsymbol{E_{ns}} = \frac{\boldsymbol{F_{ns} D_{np}}}{\boldsymbol{d_{sp}}}$$

Where:

E_{ns} = Expenditures on technology *n* allocated to supplying state *s*;

F_{ns} = Labor force for technology *n* in supplying state *s*[2];

D_{np} = Demand for technology *n* in purchasing state *p* (i.e., expenditures for deployment in state *p*, as indicated in the Evolved Energy Research energy system model results);

d_{sp} = Distance between supplying state *s* and purchasing state *p* (based on the centroids of each state).

Because the standard gravity approach represented in Equation 1 does not constrain the values of E_{ns} such that total expenditures summed across individual states equals total expenditures remaining in the U.S. (excluding the portion remaining in the state where a project is located), we normalized E_{ns} to derive an estimate of the percentage of expenditures associated with an individual state:

$$(2) \quad \boldsymbol{P_{ns}} = \frac{\boldsymbol{E_{ns}}}{\sum_s \boldsymbol{E_{ns}}}$$

where P_{ns} is the fraction of expenditures for technology *n* allocated to state *s*. The estimated values for P_{ns} are applied to the total investment expenditures remaining in the U.S. for a given technology, excluding expenditures already allocated to the states where projects are located.

- ***Allocate expenditures across components of the value chain***: As an intermediate step in estimating the employment impacts of an energy project, JEDI distributes investment expenditures for the project across 14 broad value chain components (see Table A-2). The distribution across value chain components varies between project types (e.g., utility-scale solar versus onshore wind). Consistent with the approach in JEDI, we allocate investment expenditures to each of these value chain components for each technology. Table A-2 shows the distribution across value chain components for each technology.

[2] Labor force for each technology is based on employment data by NAICS code from U.S. Census Bureau (2017a).

Table A-2. Distribution of Power Sector Investment Spending Across Value Chain Components

Value Chain Component	Onshore Wind	Offshore Wind	Solar	Transmission Lines
Agriculture	0%	0%	0%	0%
Mining	0%	0%	0%	0%
Construction	58%	1%	43%	30%
Manufacturing	8%	1%	12%	1%
Fabricated Metals	0%	0%	12%	16%
Machinery	0%	0%	3%	0%
Electrical Equipment	0%	15%	2%	18%
TCPU	0%	41%	0%	1%
Wholesale Trade	0%	0%	0%	17%
Retail Trade	4%	0%	0%	0%
FIRE	0%	0%	0%	0%
Misc. Services	4%	1%	0%	1%
Professional Services	2%	31%	15%	13%
Government	23%	9%	13%	2%
Total	**100%**	**100%**	**100%**	**100%**

Source: National Renewable Energy Labs. 2016-2021. Jobs and Economic Development Impact Models. https://www.nrel.gov/analysis/jedi/models.html

- ***Apply IMPLAN Employment Multipliers***: As a final step, we apply IMPLAN employment multipliers specific to each value chain component and state to the corresponding expenditures (estimated based on the steps above). For each value chain component, these multipliers represent a composite of the multipliers for relevant industries.

Estimation of Investment-Related Employment Impacts for All Other Technologies

To estimate the employment impacts associated with investment in the other technologies included in this analysis, we applied an approach based on IMPLAN multipliers and technology-specific information obtained from the literature. We applied this approach to the technologies in the energy infrastructure category not assessed with the JEDI-based approach described above and all of the technologies in the fuels, feedstocks and inputs, and fossil fuel use reduction categories, as detailed in Table 1 in the main body of this report. The elements of this approach are as follows:

- ***Allocate investment expenditures between equipment and installation/construction:*** Because the sectors involved in the manufacturing of equipment may differ from those involved with the installation and construction of that equipment, we estimated the distribution between equipment costs and installation/construction costs for each technology based on technology-specific information identified in the literature, as summarized in Table A-3 for each technology.

- ***Estimate the percentage of equipment investment expenditures that stay within the U.S.:*** Similar to the approach outlined above for various forms of power infrastructure, we also estimate the fraction of equipment expenditures directed to U.S.-based suppliers.

Because expenditures flowing to suppliers outside the U.S. do not result in employment impacts for the U.S., accounting for the allocation between U.S. and non-U.S. suppliers is important for generating accurate employment impact estimates. The last column of Table A-3 shows the U.S. percentage, by technology.

- ***Identify IMPLAN sectors associated with equipment for each technology:*** To enable estimation of the employment impacts associated with equipment manufacturing, we identified the specific IMPLAN sectors associated with the equipment necessary for each technology/facility type. We made these determinations based on the specific types of equipment identified in the techno-economic literature for each technology. The IMPLAN sectors chosen are shown in Table A-4.
- ***Calculate equipment-related employment impacts:*** After identifying the sectors related to each type of equipment, we calculated the employment impacts associated with the production of that equipment by multiplying equipment expenditures (by year) by the fraction of equipment purchases domestically sourced and the employment multipliers obtained from IMPLAN.
- ***Allocate equipment-related impacts to the state level:*** After estimating equipment-related impacts at the national level, we allocated impacts to individual states based on the spatial distribution of activity for individual industries. To perform this allocation, we relied on the spatial distribution of industry activity represented by NAICS-level employment data as reported by the U.S. Economic Census.[3] We followed this approach rather than the gravity-based method specified above for power-system investments because the specialized nature of several of these technologies would complicate applying the more detailed, precise gravity-based approach.
- ***Identify IMPLAN sectors associated with installation/construction:*** Similar to the approach for equipment manufacturing, we also identified the IMPLAN sectors associated with installation and construction for each technology/facility type, based on information in the techno-economic literature. The IMPLAN sectors chosen are shown in Table A-4.
- ***Estimate portion of installation costs associated with labor (where possible):*** For some technologies, the techno-economic studies containing information on the cost of installation/construction specify the portion of installation costs related to labor. In such cases, we applied labor's share of installation costs, as derived from these studies, to our estimates of total investment costs associated with a given technology.
- ***Calculate installation-related employment impacts:*** To generate estimates of installation-related employment impacts, we multiplied installation expenditures by the employment multipliers obtained from IMPLAN. For the technologies for which we were able to estimate installation labor costs directly (see previous bullet), we calculated employment impacts by dividing installation labor costs by the average labor cost per worker, as derived from IMPLAN.

[3] U.S. Census Bureau. 2017a. Economic Census: Summary Statistics for the U.S., States, and Selected Geographies.

- ***Allocate installation-related impacts to the state level:*** The energy modeling outputs provided by Evolved Energy Research for this analysis specify investments in each technology at the state level. To spatially allocate installation-related impacts for a given technology, we assume that such impacts are distributed across states in proportion to investments for that technology.
- ***Sum equipment-related employment and installation-related employment:*** As a final step, we calculated total investment-related employment by summing our estimates of equipment-related employment impacts and installation-related employment impacts.

Table A-3. Equipment and Installation Method and Source Information for Select Technologies

Category	Technologies	Basis for Split Between Equipment and Installation	Equipment/ Installation Split	Share of Equipment Purchased from U.S. Suppliers
Energy Infrastructure for SAF Production	Hydrogen Electrolysis	Detailed electrolytic hydrogen facility cost data published by the Hydrohub Innovation Program for a 1 GW electrolysis plant (Van't Noordende and Ripson 2020)	Equipment: 68% Installation: 32%	80%
	Underground Hydrogen Storage	An Argonne National Lab study of underground hydrogen storage costs is used to distribute costs across sectors, though it does not explicitly differentiate between equipment and installation. A weighted average of IMPLAN regional production coefficients is applied to the relevant sectors to obtain the domestic production share.	N/A	87%
Fuels	HEFA	Natelson et al. (2015) provides detailed information on the capital costs associated with the production of HEFA jet fuel from camelina oil. It outlines the expenses involved in setting up a refinery for this purpose, including a comprehensive cost analysis for establishing a facility with a yearly capacity of 76,000 cubic meters of hydrocarbons.	Equipment: 39% Installation: 61%	99%
	Alcohol-to-Jet Fuel	Tao et al. (2016) provides a detailed analysis of the capital costs involved in producing jet fuel from alcohol. The production process includes fermentation, alcohol purification, recovery, and upgrading to jet fuel, along with wastewater treatment. The capital and production costs are based on nth-plant facility models, including alcohol dehydration, olefin oligomerization, and olefin hydrogenation	Equipment: 69% Installation: 31%	74%

Category	Technologies	Basis for Split Between Equipment and Installation	Equipment/ Installation Split	Share of Equipment Purchased from U.S. Suppliers
	Biomass Power Allam (with Carbon Capture)	The techno-economic analysis of natural gas-fueled direct sCO2 (complete combustion case) power plants in Weiland and White (2019) includes detailed information on the costs of individual equipment components for these facilities and the costs of installation, inclusive of indirect costs (e.g., engineering and legal).	Equipment: 70% Installation: 30%	58%
	Fischer-Tropsch (F-T) Liquids-to-Jet Fuel	The techno-economic analysis of power-to-liquid plants in Albrecht et al. (2016) includes detailed information on the costs of individual equipment components for these facilities, and the techno-economic analysis of power-to-liquid processes in Herz et al. (2021) includes applied factors to adjust equipment costs to account for installation.	Equipment: 68% Installation: 32%	86%
	Bio Gasification F-T (with Carbon Capture) Bio Gasification F-T (without Carbon Capture)	The techno-economic analysis of Fischer-Tropsch in Zhu et al. (2011) includes detailed information on the costs of individual equipment components for these facilities and the costs of installation, inclusive of indirect costs (e.g., engineering and legal).	Equipment: 27% Installation: 73%	75% for Fischer-Tropsch equipment 81% for CCS equipment
Feedstocks and Inputs	Purpose Grown Feedstocks Residue Feedstocks	For crops and crop residues used as feedstocks, the expenditure data from Evolved Energy Research does not include separate investment and O&M expenditures. Idaho National Laboratory (2013) identifies and allocates the equipment and labor components essential for the conversion of lignocellulosic biomass to hydrocarbon fuels. These data are used to allocate crop feedstocks to equipment and other inputs. In addition, for residue feedstock, we assume that half of expenditures are a direct transfer to generators of crop residues above and	No installation for equipment for this category.	98% (for purpose grown feedstocks only; no equipment purchases for residue feedstocks)

Category	Technologies	Basis for Split Between Equipment and Installation	Equipment/ Installation Split	Share of Equipment Purchased from U.S. Suppliers
		beyond the cost of collection and transportation.		
	Direct Air Capture	Derived from techno-economic assessment of DAC system presented in Keith et al. (2018).	Equipment: 82% Installation: 18%	74%
Fossil Fuel Use Reduction	Crude Oil Extraction	Employment losses for reduced crude oil extraction are calculated based on the relationship between crude production and oil industry employment. This method does not ascribe impacts specifically to equipment or installation.	N/A	N/A
	Jet Fuel Refining	Employment impacts for reduced refining of conventional jet fuel are calculated based on the relationship between refined product production and refining employment. This method does not ascribe impacts specifically to equipment or installation.	N/A	N/A

Table A-4. IMPLAN Sectors for Estimating Direct Employment Impacts Associated with Equipment Manufacturing and Installation

Category	Technologies	Basis for Sectoral Allocations for Equipment and Installation	IMPLAN Sectors for Equipment	IMPLAN Sectors for Installation
Energy Infrastructure for SAF Production	Hydrogen Electrolysis	Van't Noordende and Ripson (2020) present detailed information on electrolytic hydrogen facility costs, with detail on balance of plant (compressors, gas treatment, heating/cooling, gas/liquid separators, and piping), utilities (process automation, piping, cooling towers, and demineralized water plant), power supply and electronics, stacks (catalyst-coated membranes, power-to-liquid, frame, and plates), engineering, construction, owner's costs, and civil/ structural/ architectural costs.	• Air and gas compressor manufacturing • Industrial gas manufacturing • Air conditioning, refrigeration, and warm air heating equipment manufacturing • All other industrial machinery manufacturing • Fabricated pipe and pipe fitting manufacturing • Industrial process variable instruments manufacturing • Concrete pipe manufacturing • Pump and pumping equipment manufacturing • Other electronic component manufacturing	• Architectural, engineering, and related services • Construction of new power and communication structures
	Underground Hydrogen Storage	Argonne National Lab (Ahluwalia et al., 2019) reports the distribution of costs across expected activities. Due to the lack of hydrogen-specific IMPLAN sectors, we assign activities to corresponding natural gas sectors likely to mirror the types of workers and materials needed.	• Drilling oil and gas wells • Support activities for oil and gas operations • Natural gas distribution • Air and gas compressor manufacturing • Pipeline transportation	Same sectors as for equipment.
Fuels	HEFA	Natelson et al (2015). provides a comprehensive analysis of producing HEFA jet fuel from camelina oil. It covers various	• Warehousing and storage • Oil and gas field machinery and equipment manufacturing	Same as sectors for equipment.

Category	Technologies	Basis for Sectoral Allocations for Equipment and Installation	IMPLAN Sectors for Equipment	IMPLAN Sectors for Installation
		aspects such as the process of hydrolysis, decarboxylation, and reforming camelina oil, along with detailed economic parameters and cost estimations.	• Petroleum Refineries • Turbine generator set units manufacturing • Waste management and remediation services • Welding equipment manufacturing • Air conditioning, refrigeration, and warm air heating combination units manufacturing • Othe real estate • Architectural, engineering and related services • Accounting, tax preparation, bookkeeping and payroll services. • Marketing research and all other miscellaneous professional, scientific, and technical services.	
	Alcohol-to-Jet Fuel	Tao et al (2016). delves into the costs and economics of this process, considering aspects like feedstock handling, saccharification, fermentation to ethanol, distillation, and product recovery for ethanol purification. The study also examines the upgrading of ethanol to jet fuel, encompassing steps like	• Other basic organic chemical manufacturing • Petrochemical manufacturing • Warehousing and storage • Water, sewage and other systems • Electric power generation, fossil fuel	Same as sectors for equipment.

Category	Technologies	Basis for Sectoral Allocations for Equipment and Installation	IMPLAN Sectors for Equipment	IMPLAN Sectors for Installation
		dehydration, oligomerization, and hydrotreating.		
	Biomass Power Allam (with Carbon Capture)	Weiland and White (2019) present detailed cost information for natural gas-fueled direct sCO2 (complete combustion case) power plants, which includes costs related to feedwater & miscellaneous BOP systems, cryogenic air separation unit (ASU), gas cleanup & piping, sCO2 combustion turbine and accessories, cooling water system, accessory electric plant, instrumentation and control, improvement to site, buildings & structures, and engineering, construction management, home office & fees.	• Scales, balances, and miscellaneous general purpose machinery manufacturing • Air purification and ventilation equipment manufacturing • Air and gas compressor manufacturing • Turbine and turbine generator set units manufacturing • Air conditioning, refrigeration, and warm air heating equipment manufacturing • Power, distribution, and specialty transformer manufacturing • Industrial process variable instruments manufacturing	• Architectural, engineering, and related services • Construction of other new nonresidential structures
	Fischer-Tropsch (F-T) Liquids-to-Jet Fuel	Albrecht et al. (2016) identify the following equipment components for power-to-liquid plants that were mapped to IMPLAN sectors: autothermal reformer, Fischer-Tropsch synthesis reactor, gas turbine cycle, gas/liquid separator, hydrocracker, selexol unit, solid-oxide-cell (electrolyser) unit, and steam turbine cycle. Herz et al. (2021) identify the following installation components for power-to-liquid plants that were mapped to IMPLAN sectors: instrumentation and control,	• Power boiler and heat exchanger manufacturing • Turbine and turbine generator set units manufacturing • All other industrial machinery manufacturing • Oil and gas field machinery and equipment manufacturing • Industrial gas manufacturing	• Architectural, engineering, and related services • Construction of other new nonresidential structures • Landscape and horticultural services • Office administrative services

Category	Technologies	Basis for Sectoral Allocations for Equipment and Installation	IMPLAN Sectors for Equipment	IMPLAN Sectors for Installation
		installations (piping system, electrical systems, buildings, and service facilities), yard improvements, engineering, construction expenses, legal expenses, and contractor's fees.		
	Bio Gasification F-T (with Carbon Capture) Bio Gasification F-T (without Carbon Capture)	Zhu et al. (2011) identify the following equipment components for Fisher-Tropsch facilities that were mapped to IMPLAN sectors: air separation units, feed prep and drying, gasification with tar reforming and heat recovery, syngas cleanup and steam reforming, Fisher-Tropsch synthesis, hydrocracking and product separation, steam system and power generation, and remainder offsite battery limits	Non-CCS Equipment: • All other industrial machinery manufacturing • Automatic environmental control manufacturing • Power boiler and heat exchanger manufacturing • Industrial process furnace and oven manufacturing CCS Equipment: • Plastics material and resin manufacturing • Fabricated pipe and pipe fitting manufacturing • All other industrial machinery manufacturing • Heating equipment (except warm air furnaces) manufacturing	• Architectural, engineering, and related services • Management of companies and enterprises • Office administrative services • Construction of new power and communication structures
Feedstocks and Inputs	Purpose Grown Feedstocks	Idaho National Laboratory (2013) identifies and allocates the equipment and labor components essential for the conversion of lignocellulosic biomass to hydrocarbon fuels.	• Support activities for agriculture and forestry • Grain farming	• Not applicable.
	Residue Feedstocks	No equipment purchases assumed for residue feedstocks.	• Not applicable.	Not applicable.

Category	Technologies	Basis for Sectoral Allocations for Equipment and Installation	IMPLAN Sectors for Equipment	IMPLAN Sectors for Installation
	Direct Air Capture	Detailed cost distribution for equipment obtained from Keith et al. (2018) includes costs related to air contactor, pellet reactor, calciner-slaker, air separation unit, CO_2 compressor, steam turbine, power plant, fines filter, other equipment, buildings, and transformer. Because Keith et al. (2018) do not provide similar detail for installation costs, we apply the same IMPLAN sectors to installation as applied for equipment. As noted in Exhibit 4, installation accounts for just 18% of expenditures for DAC.	• Automatic environmental control manufacturing • Power boiler and heat exchanger manufacturing • Industrial process furnace and oven manufacturing • Support activities for oil and gas operations • Air and gas compressor manufacturing • Turbine and turbine generator set units manufacturing • Power, distribution, and specialty transformer manufacturing • Industrial and commercial fan and blower and air purification equipment manufacturing • Engineering services	• Automatic environmental control manufacturing • Power boiler and heat exchanger manufacturing • Industrial process furnace and oven manufacturing • Support activities for oil and gas operations • Air and gas compressor manufacturing • Turbine and turbine generator set units manufacturing • Power, distribution, and specialty transformer manufacturing • Industrial and commercial fan and blower and air purification equipment manufacturing • Engineering services
Fossil Fuel Use Reduction	Crude Oil Extraction	Crude Oil Extraction employment is adjusted according to the expected drop in production following the transition to SAF.	• Oil and gas extraction	• Oil and gas extraction
	Jet Fuel Refining	Refining employment is adjusted according to the expected drop in production following the transition to SAF.	• Petroleum refineries	• Petroleum refineries

Estimation of O&M-Related Employment Impacts

For O&M-related employment impacts, we follow an approach similar to that outlined above for investment-related impacts outside the power sector, based on O&M expenditures generated by Evolved Energy Research, IMPLAN multipliers, and technology-specific information obtained from the literature. We applied this approach to all of the technologies in the energy infrastructure, fuels, feedstocks and inputs, and fossil fuel use reduction categories, as detailed in Table 1 in the main body of this report. The elements of this approach are as follows:

- ***Identify IMPLAN sectors associated with O&M for each technology:*** To enable estimation of the employment impacts associated with O&M, we identified the specific IMPLAN sectors associated with the operations and maintenance of each technology. The IMPLAN sectors chosen are shown in Table A-5.
- ***Estimate portion of O&M costs associated with labor (where possible):*** For some technologies, the techno-economic studies containing information on the cost of O&M specify the portion of O&M costs related to labor. In such cases, we applied labor's share of O&M, as derived from these studies, to our estimates of total O&M associated with a given technology.
- ***Calculate O&M-related employment impacts:*** To generate estimates of O&M-related employment impacts, we multiplied O&M expenditures by the employment multipliers obtained from IMPLAN. For the technologies for which we were able to estimate installation labor costs directly (see previous bullet), we calculated employment impacts by dividing O&M labor costs by the average labor cost per worker, as derived from IMPLAN.
- ***Allocate O&M-related impacts to the state level:*** The energy modeling outputs provided by Evolved Energy Research for this analysis specify O&M expenditures for each technology at the state level. We assume O&M employment is distributed across states in proportion to state-level O&M expenditures.

Table A-5. Key Parameter for Assessment of Economic Impacts Related to O&M

Category	Technology	Labor Share of O&M Costs	IMPLAN Sectors for O&M
Energy Infrastructure for SAF Production	Utility-Scale Photovoltaic Solar	Not specified	• Electric power generation - solar
	Onshore Wind	Not specified	• Electric power generation - wind
	Offshore Wind	Not specified	• Electric power generation - wind
	Hydrogen Electrolysis	Not specified	• Commercial and industrial machinery and equipment repair and maintenance • Other basic inorganic chemical manufacturing • Other administrative services
	Underground Hydrogen Storage	Not specified	• Pipeline transportation
Fuels and Inputs	HEFA	Not specified	• Commercial and industrial machinery and equipment repair and maintenance • Office administrative services • Water, sewage and other systems
	Alcohol-to-Jet Fuel	7% (Tao et al., 2017)	• Other basic organic chemical manufacturing • Biological product (except diagnostic) manufacturing • Other miscellaneous chemical product manufacturing • Industrial gas manufacturing • Office administrative services
	Biomass Power Allam (with Carbon Capture)	27% (Weiland and White, 2019)	• Commercial and industrial machinery and equipment repair and maintenance • Office administrative services • Accounting, tax preparation, bookkeeping, and payroll services • Water, sewage, and other systems
	Fischer-Tropsch (F-T) Liquids-to-Jet Fuel	94% (Albrecht et al., 2017)	• Commercial and industrial machinery and equipment repair and maintenance • Electronic and precision equipment repair and maintenance • Water, sewage, and other systems • Office administrative services

Category	Technology	Labor Share of O&M Costs	IMPLAN Sectors for O&M
			• Accounting, tax preparation, bookkeeping, and payroll services
	Bio Gasification F-T (with Carbon Capture)	18%, as derived from Bressanin et al. (2020) and IEA Bioenergy (2020)	• Other basic organic chemical manufacturing • Commercial and industrial machinery and equipment repair and maintenance • Industrial gas manufacturing
	Bio Gasification F-T (without Carbon Capture)		
Feedstocks and Inputs	Purpose Grown Feedstocks	35% (Idaho National Laboratory, 2013)	• Forestry, forest products, and timber production • Grain farming • Support activities for agriculture and forestry • Rail transportation • Water transportation • Truck transportation • Warehousing and storage
	Residue Feedstocks	35% (Idaho National Laboratory, 2013)	• Forestry, forest products, and timber production • Grain farming • Support activities for agriculture and forestry • Rail transportation • Water transportation • Truck transportation • Warehousing and storage
	Direct Air Capture	8%, based on Keith et al. (2018), McQueen et al. (2020), and NASEM (2019)	• Electric power generation – hydroelectric • Electric power generation – fossil fuel • Electric power generation – solar • Electric power generation – wind • Electric power generation – geothermal • Electric power generation – biomass • Electric power generation – all other • Industrial gas manufacturing

Category	Technology	Labor Share of O&M Costs	IMPLAN Sectors for O&M
			• Other miscellaneous chemical product manufacturing
Fossil Fuel Use Reduction	Crude Oil	Employment losses for reduced crude oil extraction are calculated based on the relationship between crude production and oil industry employment. This method does not ascribe impacts specifically to O&M.	• Oil and gas extraction
	Jet Fuel	Employment impacts for reduced refining of conventional jet fuel are calculated based on the relationship between refined product production and refining employment. This method does not ascribe impacts specifically to O&M.	• Petroleum refineries

Approach for Spillover Employment Impacts

Complementing the assessment of direct employment impacts, we also estimate the spillover employment impacts associated with increased reliance on SAF. This includes two categories of spillover effects: indirect impacts and induced impacts. Indirect impacts reflect inter-industry purchases and arise from firms purchasing inputs from their suppliers. For example, in the context of expenditures on SAF production infrastructure, indirect impacts would include the employment associated with producing the steel used in facility piping. Induced impacts, by contrast, result from wages paid to workers, who may spend these wages on consumer electronics, clothing, etc. Again, in the context of SAF production infrastructure, induced effects include the employment impacts associated with workers involved in the construction of SAF production facilities spending their earnings. We analyze indirect and induced effects both nationally and at the state level.

Similar to the approach outlined above for direct employment impacts, we analyzed indirect and induced impacts based on expenditure outputs from the energy system modeling conducted by Evolved Energy Research. These expenditures were applied as inputs in Inforum's Status input-output model for the U.S., integrated with Inforum's State Employment Modeling System (STEMS) to disaggregate the national results from Status to the state level. We describe both models and our approach to applying them in this analysis in the sections that follow.

The *Status* Model

Status is an input-output model based on the industry and commodity database maintained by Inforum, an economic research organization affiliated with the University of Maryland. The *Status* input-output model used for this analysis is based on the industry and commodity database maintained by Inforum based on data published by the U.S. Bureau of Economic Analysis and other U.S. government agencies. The model has 121 commodity sectors and 71 industry sectors, classified according to the 2012 North American Industry Classification System (NAICS). The input-output framework on which *Status* is built contains annual data in both current and constant prices, from 1997 to 2021. Projections of the database after 2021 are obtained from a standard projection of Inforum's sectoral and commodity database, which includes projections of changes in input-output coefficients over time. The *Status* model has been used in multiple analyses for federal agencies, including an assessment of domestic output and jobs related to agricultural exports and imports (for the U.S. Department of Agriculture's Economic Research Service) and analysis of the direct and indirect components of health care supply (for the Center for Medicare and Medicaid Services). IEc and Inforum also used *Status* in a previous analysis for Third Way on the employment impacts associated with various economic stimulus policies.

Our application of Status for this analysis involved the following steps for each stimulus policy:

- ***Specify dollar amounts to be modeled in Status***: The dollar amount specified for individual technologies is based on the SAF adoption scenario as modeled by Evolved Energy Research.

- ***Specify sectors in Status for modeling investment expenditures***: When modeling the employment and other economic impacts associated with stimulus investments, these expenditures must be allocated to individual industries within Status, as the impacts associated with increased demand for one industry's output may differ from the corresponding impacts associated with output produced by another industry.

- ***Perform Status runs***: Based on the investment amounts for each stimulus policy and the allocation of this investment spending to individual sectors in Status, we performed Status model runs that estimated the indirect and induced employment and other economic impacts associated with each policy.

  Allocate impacts to the state level: The Status model generates results at the national level. To allocate results to the state level, we follow two separate approaches: one for direct impacts and another for indirect and induced impacts. We allocate indirect and induced impacts using Inforum's State Employment Modeling System (STEMS). Using data derived from the Bureau of Labor Statistics' Employment and Earnings data, STEMS estimates employment for individual industries in each state. The industries are divided into two groups: base and secondary. Estimates for the base group industries are dependent on national levels of employment and trends in state shares of national employment. Estimates for the secondary group industries are also dependent on national levels and state trends, as well as on estimates for the base industries in the same state. Base industries are those engaged in manufacturing, agriculture, and mining, along with federal government "industry". Secondary industries are those engaged in providing services, and the construction industry. Employment estimates in STEMS are not based on constant shares, but instead respond to trends in individual industries. State-level outputs from STEMS are consistent with the national estimates from Status, which serve as controls on national employment estimates. Procedures within the STEMS model ensure that state-level estimates add up exactly to national estimates.

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