MEASURING THE ECONOMIC IMPACTS OF UTILITY-SCALE SOLAR IN OHIO

A Study For:

Utility Scale Solar Energy Coalition
USSEC
of Ohio

Avangrid
First Solar
EDF
Geenex
Hecate Energy
Innergex
innogy
Invenergy
Leeward Renewable Energy, LLC
Lendlease
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Contents

Tables

Figures

Acronyms

AEP — American Electric Power
BEA — Bureau of Economic Analysis
BLS — U.S. Bureau of Labor Statistics
DC — Direct Current
EIA — Energy Information Administration
FTE — Full-Time Equivalents
GDP — Gross Domestic Product
GW — Gigawatt
IMPLAN — IMpact Analysis for PLANning
IO — Input-Output
JEDI — Jobs and Economic Development Impact
LBNL — Lawrence Berkeley National Laboratory
MIG — Minnesota IMPLAN Group
MW — Megawatt
MWh — Megawatt Hours
NREL — National Renewable Energy Laboratory
O&M — Operations and Maintenance
OPSB — Ohio Power Siting Board
PUCO — Public Utilities Commission of Ohio
PV — Photovoltaic
QCEW — Quarterly Census of Employment and Wages
RPS — Renewable Portfolio Standards
SB — Senate Bill
U.S. — United States

Executive Summary

This report details a comprehensive economic impact study for utility-scale solar energy projects in the State of Ohio, as conducted by the George V. Voinovich School of Leadership and Public Affairs at Ohio University,[1] and as supported by the Utility Scale Solar Energy Coalition of Ohio (USSEC). As large solar energy projects continue to be submitted and approved by Ohio's Power Siting Board, USSEC and other parties have had a growing interest in better comprehending, for the first time ever, the aggregate economic impacts of current and future scenarios of project deployment in the state. In order to support this request, the Ohio University research team conducted an economic impact analysis around three distinct deployment scenarios: a **"low" scenario (2.5 gigawatts (GW)),** a **"moderate" scenario (5 GW),** and an **"aggressive" scenario (7.5 GW)**. Our team also conducted a brief workforce analysis, a review of potential tax revenues, and production calculations (i.e., electricity produced and number of homes powered) from these utility-scale solar energy deployment scenarios.

Key findings from our employment impact calculations indicated that, in our low scenario, utility-scale solar would support a total of 18,039 one-time construction phase jobs, and 207 annual operations and maintenance (O&M) phase jobs over the life of the systems (i.e., 30–40 years), assuming 80% Ohio-based labor, and 30% Ohio-based materials. In our moderate scenario, we found that 36,074 construction phase jobs, and 413 O&M phase jobs, would be supported. Finally, our most aggressive scenario showed that 54,113 construction phase jobs, and 618 O&M phase jobs, would be supported. We note that these figures represent conservative estimates given the inputs and assumptions that we used (i.e., Ohio could see even larger employment impacts if additional in-state labor and materials were utilized for future projects).

Moreover, we determined that these three deployment scenarios would bring sizeable economic impacts to the state. First, we calculated a total of roughly $3.2B construction phase economic impacts to Ohio in our low scenario, with an annual estimate of $54M economic impacts over the life of the systems. In our moderate scenario, we calculated these construction phase impacts at $6.4B, with the annual O&M phase impact at almost $107M. Our aggressive deployment scenario increased these totals to $9.6B in the construction phase, and $160M annually in the O&M phase.

Our workforce section suggests that there may be enough labor supply in Ohio within the needed occupations to meet the *average* demand created by an individual project, yet this availability will depend on the number of concurrent solar facilities under construction. In the current, pandemic-driven recession, solar energy can be a low-cost to government solution to boost the economy through short-term construction jobs, as well as enhancing tax revenues to geographies that would greatly benefit from such dollars. We determined that Ohio could receive up to $22.5M in annual tax revenues in our low deployment scenario, $45M in our moderate scenario, and $67.5M in our aggressive scenario. Our team also calculated that nearly 503,000 homes could be powered by the utility-scale solar projects summing to 2.5 GW in our low scenario, compared to just over 1M homes in our moderate scenario, and over 1.5M homes in our aggressive scenario (which is enough to power all of the households in Ohio's largest city, Columbus, roughly four times over). Our report concludes with synthesizing takeaways of future utility-scale solar energy deployment in the State of Ohio, which has observable implications for grid modernization, electricity diversification, and energy and economic transitions occurring in the state.

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[1] See author biographies in Appendix B.

1. Introduction to the Study

Traditional electricity generation in the United States (U.S.) has relied on large, centralized assets, such as coal-fired power plants, to achieve economies of scale and supply inexpensive and reliable power to consumers. More recently, changes in consumer preferences and declining costs have pushed electric utilities and developers to new technologies and generation assets, such as large solar photovoltaic (PV) energy facilities. These investments have stemmed from state policy mandates (e.g., renewable portfolio standards (RPS)), the availability of tax credits, and corporate sustainability missions, among other key drivers. As the installed cost per watt of solar PV has declined by roughly 70% over the last decade,[2] project development has grown at an increasingly rapid rate, with approximately 10,000 projects sized over 1 megawatt (MW) currently in operation in the U.S., many of which are being sized at 100 MW or larger to achieve even better economies of scale.[3]

The State of Ohio is currently undergoing an energy transition, with at least 9 coal-fired power plants closing since 2010,[4] representing roughly 10,000 MW (or 10 gigawatts (GW)) of generation capacity, with Conesville being the most recent to fully close in May of 2020.[5] As part of this transition, in the utility-scale solar realm, the state has specifically seen seven projects, ranging from 80 to 300 MW, approved by the Ohio Power Siting Board (OPSB) since the beginning of 2018.[6] At the time of this writing, at least 10 additional projects, sized 50 MW or larger, are categorized as pending cases through the OPSB, and, in total (between both approved and pending), represent well over 2.5 GW of potential generation capacity coming on-line through these 17 "late-stage" projects (see Figure 1).[7] This is roughly a ten-fold increase from the roughly 265 MW of solar PV capacity currently installed in the state, which, to this date, has largely been small-scale, behind-the-meter distributed solar (i.e., small rooftop or ground-mounted arrays on homes and small businesses).[8] Currently, three of these 17 projects have begun construction: Hardin (150 MW in Hardin County), Hardin II (170 MW in Hardin County), and Hillcrest (200 MW in Brown County).

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[2] Solar Energy Industries Association. (2020). *Solar industry research data*. Retrieved from https://www.seia.org/solar-industry-research-data.

[3] Solar Energy Industries Association. (2019). *Utility-scale solar power*. Retrieved from https://www.seia.org/initiatives/utility-scale-solar-power.

[4] United States Energy Information Administration. (2019). *Form EIA-860*. Retrieved from https://www.eia.gov/electricity/data/eia860/.

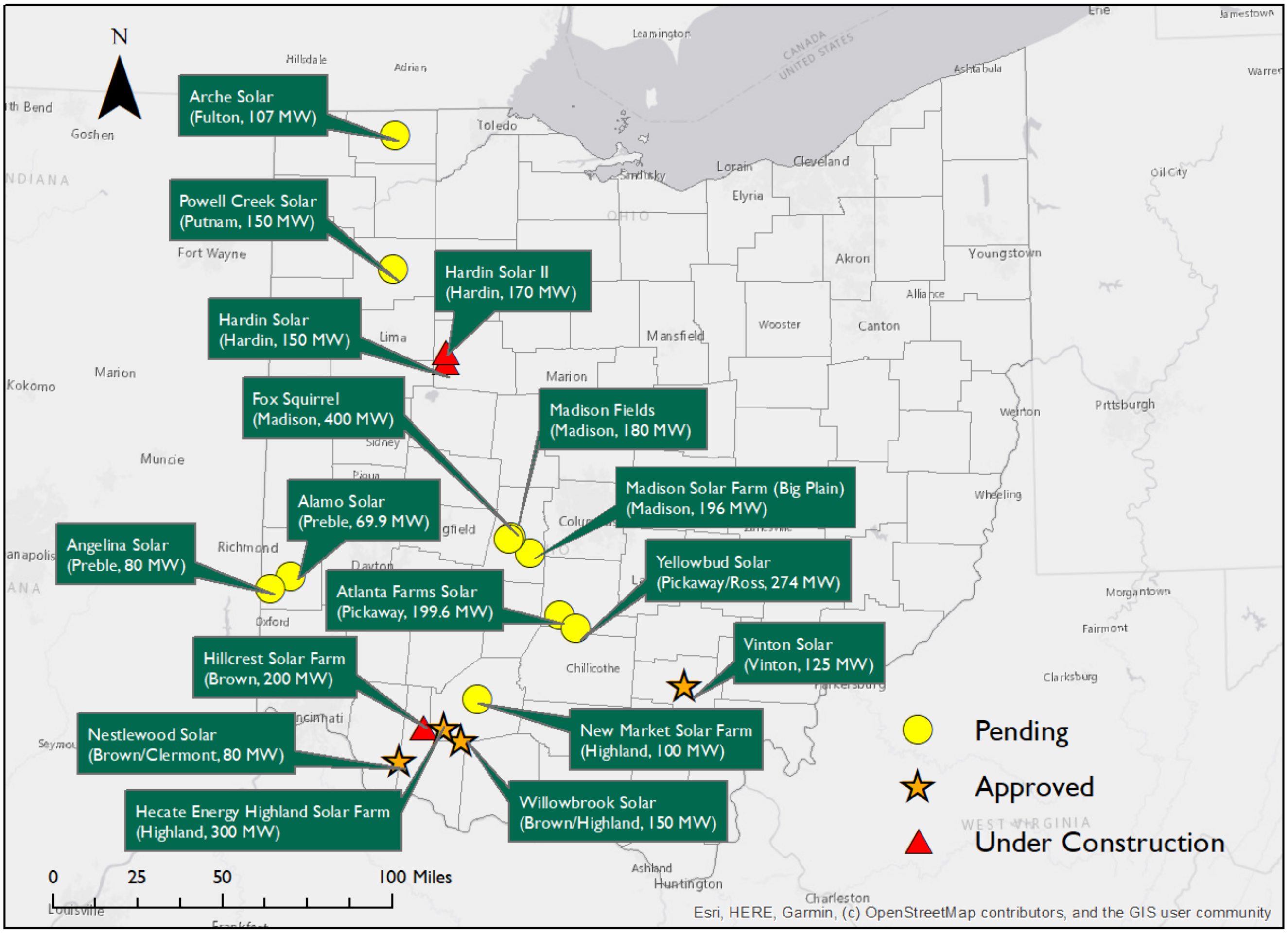
[5] Hayhurst, L. (2020, April 30). AEP Conesville reaches end of coal-burning era. *The Columbus Dispatch.* Retrieved from https://www.dispatch.com/news/20200430/aep-conesville-reaches-end-of-coal-burning-era.

[6] Ohio Power Siting Board. (2020). *Solar farm map and statistics*. Retrieved from https://opsb.ohio.gov/wps/portal/gov/opsb/about-us/resources/solar-farm-map-and-statistics. The OPSB is the state's regulatory agency that reviews and approves applications for the installation of energy capacity and transmission infrastructure.

[7] Ibid. The total figure is 2.93 GW, spanning over 28,000 acres, as of July 2020.

[8] The Solar Foundation. (2020). *Solar jobs census 2019: Ohio*. Retrieved from https://www.thesolarfoundation.org/solar-jobs-census/factsheet-2019-OH/.

Figure 1. *Utility-Scale Solar Facilities in Ohio*



Note. Figure developed by authors, with data from the Ohio Power Siting Board (see: https://opsb.ohio.gov/wps/portal/gov/opsb/home). Pending cases, where an application was not yet filed, have their location plotted at the approximate midpoint of the county where they are to be located.

The Utility Scale Solar Energy Coalition of Ohio (hereafter referred to as "USSEC"), an organization of utility-scale solar developers and industry leaders,[9] is interested in better discerning the positive impacts that the increase of large solar projects would bring to Ohio in the coming years. To accomplish this task, our research team first conducted a review of the growing business demand for solar and other forms of renewable energy in the state. We then analyzed the economic impacts of utility-scale solar development in a given time period across three specific scenarios (i.e., "low" (2.5 GW), "moderate" (5 GW), and "aggressive" (7.5 GW)), during both the construction and operations and maintenance (O&M) phases, in terms of project costs, jobs supported, new value added, and total economic impacts. After brief workforce and tax impact analyses, we conclude with a synthesis of the results and high-level implications for future solar projects in Ohio. Overall, investigating these projected scenarios helps to provide a clearer, quantitative understanding of the economic potential of future utility-scale solar growth in the state.

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[9] In lieu of a website, see: https://puco.ohio.gov/static/OPSB/2020_rules/USSEC.pdf for more information on USSEC.

2. Business Demand for Renewables in Ohio

This section focuses on the potential demand for solar and other forms of renewable energy created by high-profile businesses in the State of Ohio. To illustrate, Facebook has committed to using 100% renewable energy by the end of 2020,[10] and just finished the process of constructing the first few buildings of what is now the largest data center in Central Ohio.[11] The company managed to obtain $37 million in tax incentives from the state, and it has plans to add two additional buildings to the data center campus, bringing the total number of facilities to five. The data center will, in total, create 150 new jobs and generate $1.4 million in annual taxes for New Albany, Ohio (its host city) by 2024; officials stated that this would be equal to 8% of the city's general fund budget.[12] Statements former Governor Kasich made on this project at the time it was announced suggest that this was part of a statewide strategy to diversify its economy.[13]

Amazon Web Services (AWS), Amazon's cloud service provider which is responsible for its data centers, similarly has a long-term commitment to utilize 100% renewable energy (by 2025),[14] and already owns multiple data centers in Central Ohio, with plans of adding roughly 10 more over the next few years.[15] As an incentive for the hundreds of millions of dollars Amazon reportedly plans to invest in this robust data center network, Amazon's real estate affiliate and American Electric Power (AEP) Ohio made a joint filing asking for a tiered discount on electricity as it expands, which the Public Utilities Commission of Ohio (PUCO) approved in January of 2018.[16] The joint filing also claimed that: "in just three years, the combined direct, indirect and induced effects of (Amazon's) investment could create thousands of new jobs in Ohio and hundreds of millions of dollars in new regional income and GDP in Ohio."[17]

Moreover, Google has started construction of a data center of their own in New Albany, Ohio. This data center will be a $600 million investment and has an approved $43.5 million-worth of tax incentives behind it;[18] to receive these incentives, Google must create at least 30 jobs at an average salary of about $80,000 and generate an annual $750,000 for the city by 2021, with higher targets to meet over time.[19] While Google reached their 100% renewable energy goal in 2019,[20] continued growth will be met with additional solar and renewable energy demand. Other high-profile companies with an Ohio presence and a renewable energy commitment include

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[10] Facebook. (2020). *Sustainability*. Retrieved from https://sustainability.fb.com/.

[11] Sole, S. (2020). *Facebook brings data center online, announces expansion in New Albany*. This Week News. Retrieved from https://www.thisweeknews.com/news/20200206/facebook-brings-data-center-online-announces-expansion-in-new-albany.

[12] Hill, J. (2017). *Facebook to build Central Ohio's largest data center in New Albany*. Columbus Business First. Retrieved from https://www.bizjournals.com/columbus/news/2017/08/15/facebook-to-build-central-ohio-s-largest-data.html & Ibid.

[13] Ibid.

[14] Amazon. (2020). *Sustainability*. Retrieved from https://sustainability.aboutamazon.com/.

[15] Ghose, C. (2018). *Amazon wins discount from AEP to expand Central Ohio data center network*. Columbus Business First. Retrieved from https://www.bizjournals.com/columbus/news/2018/01/10/amazon-wins-discount-from-aep-to-expand-central.html.

[16] Ibid.

[17] Ghose, C. (2017). *Amazon plans to expand to 15 Central Ohio data centers*. Columbus Business First. Retrieved from https://www.bizjournals.com/columbus/news/2017/11/10/amazon-plans-to-expand-to-15-central-ohio-data.html. para 3.

[18] Williams, M. (2019). *Google to go ahead with $600 million data center in New Albany*. The Columbus Dispatch. Retrieved from https://www.dispatch.com/business/20190213/google-to-go-ahead-with-600-million-data-center-in-new-albany.

[19] Williams, M. (2018). *Google considering New Albany for $600 million data-center project.* The Columbus Dispatch. Retrieved from https://www.dispatch.com/news/20181211/google-considering-new-albany-for-600-million-data-center-project.

[20] Google. (2019). *Environment*. Retrieved from https://sustainability.google/environment/.

Verizon (50% by 2025),[21] Citigroup (100% by 2020),[22] JPMorgan Chase & Co. (100% by 2020),[23] and Walmart (50% by 2025).[24]

While the general narrative exists that these companies and facilities would inherently create a demand for renewable energy, it remains uncertain whether this renewable energy will be Ohio-specific without additional buildout. A recent report by the Environmental Law Institute investigated corporate statements on their usage of renewable energy, finding some discrepancy in the outcomes of different methods of achieving these goals (e.g., purchasing unbundled renewable energy credits (RECs)).[25] However, this same report also noted "a trend in seeking to locate newly constructed facilities closer to sources of renewable energy, and...away from purchasing unbundled RECs and towards investing in renewable energy projects and green tariffs/products."[26] Many believe that this scenario is more likely, and that the specific availability of grid-supplied renewable energy (e.g., through power purchase agreements (PPAs) or other means), can be an influential factor in corporate location decisions.

Additional utility-scale solar energy projects in Ohio represent an opportunity to attract and retain a variety of businesses, including Fortune 500 technology companies, to the state. Such industry leaders are inevitably procuring renewable energy to meet progressive corporate sustainability missions and hedge against future electricity price increases. Over 85% of U.S. corporations today now file corporate sustainability reports for their shareholders and stakeholders.[27] Continued solar project development will make Ohio more competitive in broader economic development strategies, given that sustainable strategies are deemed a signal of better corporate management coupled with a lower cost of capital.

3. Economic Impact Analysis

3.1. Overview

Economic impact analyses are a widely accepted research approach used to better comprehend the effect of an industry or event, such as the exogenous shock from the construction of utility-scale solar energy projects, to local and state economies. These analyses typically use an input-output (IO) methodology to re-create inter-industry linkages and calculate the total impact on a regional economy. In this report, we calculated the total economic impacts in a given time period from three projected installation scenarios (i.e., low = 2.5 GW; moderate = 5 GW, and aggressive = 7.5 GW) of utility-scale solar in Ohio, using input data provided directly by USSEC. Ohio is on pace to surpass our low scenario if all currently pending projects get approved, as 2.93 total GW of projects are currently under review by OPSB.[28]

Our research team used the National Renewable Energy Laboratory's (NREL) Jobs and Economic Development Impact (JEDI) and IMpact Analysis for PLANning (IMPLAN) (version 3.1) software packages. A

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[21] Verizon. (2020). *Sustainability*. Retrieved from https://www.verizon.com/about/responsibility/sustainability.

[22] Citigroup. (2020). *Environmental and social policy framework*. Retrieved from https://www.citigroup.com/citi/sustainability/data/Environmental-and-Social-Policy-Framework.pdf?ieNocache=33.

[23] JPMorgan Chase & Co. (2020). *Sustainability*. Retrieved from https://www.jpmorganchase.com/corporate/Corporate-Responsibility/environment.htm.

[24] Walmart. (2020). *Reducing greenhouse gas emissions*. Retrieved from https://corporate.walmart.com/global-responsibility/sustainability/sustainability-in-our-operations/reducing-greenhouse-gas-emissions.

[25] Yazykova, S., McElfish, J., & Reynolds, L. (2019). *Corporate statements about the use of renewable energy: What does the "100% Renewable" goal really mean?* Environmental Law Institute. Retrieved from https://www.eli.org/research-report/corporate-statements-about-use-renewable-energy-what-does-100-renewable-goal-really-mean.

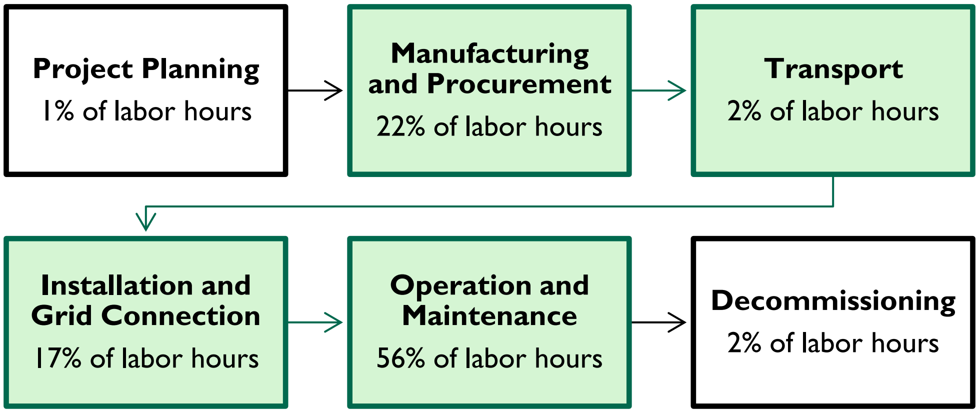
[26] Ibid. p. 23.

[27] Governance & Accountability Institute. (2019). *Flash report: 86% of S&P 500 Index® Companies publish sustainability / responsibility reports in 2018*. Retrieved from https://www.ga-institute.com/press-releases/article/flash-report-86-of-sp-500-indexR-companies-publish-sustainability-responsibility-reports-in-20.html.

[28] Ohio Power Siting Board. (2020). *Solar farm map and statistics*. Retrieved from https://opsb.ohio.gov/wps/portal/gov/opsb/about-us/resources/solar-farm-map-and-statistics.

blend of both software packages and data permitted the researchers to estimate the projected effects of the increase in demand that would result from new solar-related economic activity in the state in terms of employment, labor income, value added (i.e., increase in Ohio's gross domestic product (GDP)), and total output (i.e., total economic impact to the state). Figure 2 illustrates the development process for large, utility-scale solar energy projects. Note that the economic impacts modeled in this report do *not* cover the project planning and decommissioning phases of a large solar project (roughly only 3% of the labor hours).

Figure 2. *Utility-Scale Solar Project Development Process*



Note. Figure adapted from the International Renewable Energy Agency (IRENA).[29]

Modeling the economic impacts of utility-scale solar energy projects requires the examination of three distinct types of effects. An exogenous increase in economic activity in a given geographic area creates a ripple effect in the economy of that area. In this case, the proposed low, moderate, and aggressive solar scenarios in Ohio are going to require several manufacturing, construction, and O&M jobs. These jobs, and their associated compensation and output, are what we refer to as the *direct effect*. Beyond this initial effect, there will also be an increase in the demand for intermediate goods needed in the manufacturing, construction, and maintenance of these solar projects, which is what we call the *indirect effects*. Further, the additional income of workers within the construction and manufacturing industries is going to lead to added economic activity in terms of buying goods and services, which, in turn, creates new economic activity in a region. Individuals' spending will induce more spending. We call this last wave of impacts the *induced effects*. The total impact of the solar project is the sum of direct, indirect, and induced effects, as illustrated in Figure 3.

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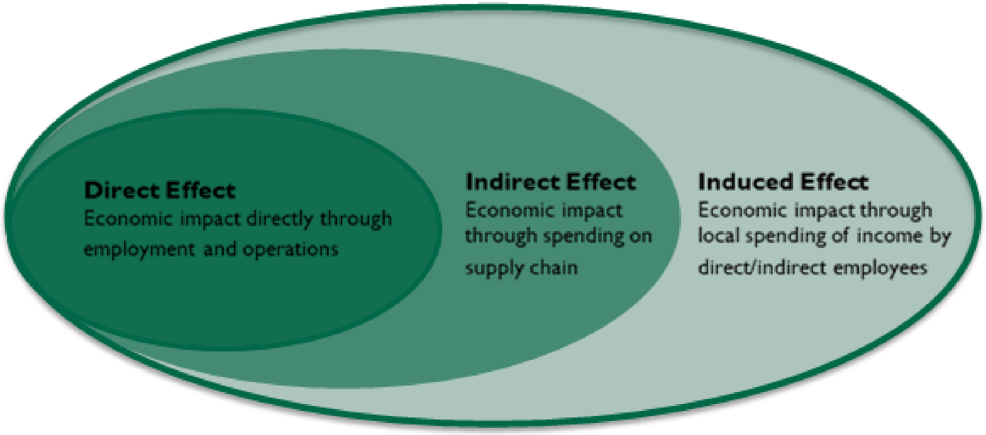
[29] International Renewable Energy Agency (IRENA). (2017). *Renewable energy benefits: Leveraging local capacity for solar PV*. Retrieved from https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/Jun/IRENA_Leveraging_for_Solar_PV_2017.pdf.

Figure 3. *Types of Economic Impacts for Solar Energy Projects*



Note. Figure developed by authors.

3.2. Methodology

The JEDI models are a series of tools developed by NREL that allow researchers to estimate the economic impacts of constructing and operating power generation facilities at the state level.[30] For this report, we utilized the JEDI solar PV model, which contains 22 aggregated industry sectors, as the central tool to estimate the number of solar jobs and economic impacts to the State of Ohio. We updated the solar JEDI models to include 2018 IMPLAN multipliers, as well as 2018 NREL benchmark costs.

As inputs, the JEDI tool requires project-specific data, state-specific IO multipliers, personal expenditure patterns, and price deflators. It should also be noted that JEDI models utilize multipliers and consumption patterns derived from the Minnesota IMPLAN Group (MIG) data. In essence, MIG compiles and aggregates national and regional economic/demographic data to model inter-industry linkages that allow researchers to estimate the impact of demand changes on economic activity at the local, state, and regional levels. In sum, JEDI applies the IMPLAN multipliers to the project-specific data while accounting for the idiosyncrasies of the solar electric power generation construction, a sector that does not exist in IMPLAN.

Beyond the aforementioned direct, indirect, and induced effects, Table 1 displays a list of additional economic impact analysis terminology that is used in this report.

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[30] National Renewable Energy Laboratory. (2018b). *JEDI: Jobs & economic development impact models*. Retrieved from https://www.nrel.gov/analysis/jedi/. The models can also be tailored to produce local-level estimates.

Table 1. *Economic Impact Analysis Terminology*

Variable	Definition
Employment	Employment refers to an industry-specific mix of full-time, part-time, and seasonal jobs. Expressed as full-time equivalents (FTE).
Labor Income	Labor income refers to all forms of employment income, including employee compensation (i.e., wages, salaries, and benefits) and proprietor income.
Value Added	Value added is the difference between an industry's total output and the cost of its intermediate inputs; it is a measure of the contribution to GDP.
Output	Output is the value of production by industry in a calendar year. It can also be described as annual revenues plus net inventory change. It is often referred to as total economic impact.
Multipliers	Multipliers describe how, for a given change in a particular industry, a resulting change will occur in the overall economy. For instance, employment multipliers describe the total jobs generated as a result of 1 job in the target industry.

Fundamentally, the economic multipliers used in the JEDI models are derived from IMPLAN's state and county data files, while model defaults are based on reports, industry surveys, studies, and interviews with industry experts and project developers.[31] However, the previously publicly available JEDI solar PV model uses 2016 IMPLAN multipliers. In addition, the model defaults (i.e., cost inputs and local content percentages) are also out of date.[32] Therefore, we first updated the JEDI models to use 2018 proprietary IMPLAN multipliers and personal expenditures patterns. In addition, we replaced the model default values for project costs in JEDI with cost inputs directly from the NREL report entitled, "U.S. Solar Photovoltaic System Cost Benchmark: Q1 2018,"[33] using one-axis tracker utility-scale cost benchmarks for our model.[34]

The aforementioned NREL report includes cost benchmarks by category (e.g., module, inverter, etc.) for 5 MW, 10 MW, 50 MW, and 100 MW project sizes. We ran a series of non-linear regressions of costs on project size to determine the different inputs for higher MW sized projects, acknowledging the condition of economies of scale for mounting, electrical, installation, permitting and business overhead. However, as shown in Table 2, the differences across project sizes were negligible (i.e., different by only a cent or two per watt), and, thus, we opted to use the NREL 100 MW cost inputs to be the most conservative and accurate in our calculations. A majority of the approved and pending solar energy facilities in Ohio fall within this 100–200 MW range.[35]

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[31] National Renewable Energy Laboratory. (2018a). *About JEDI*. Retrieved from https://www.nrel.gov/analysis/jedi/about.html.

[32] McCall, J. (2018, March 28). *Personal Communication*.

[33] See: National Renewable Energy Laboratory. (2018c). *U.S. solar photovoltaic system cost benchmark: Q1 2018*. Retrieved from https://www.nrel.gov/docs/fy19osti/72399.pdf.

[34] Which is also the predominant form of large solar projects being built and proposed in Ohio.

[35] Specifically, the mean installed capacity of the 17 late-stage solar projects in the OPSB queue is 172.44 MW (2,931.5 MW / 17).

Table 2. *Economic Impact Model Cost Inputs*

Installation Costs (per watt)	100 MW	150MW	200 MW
Materials & Equipment			
Mounting	$0.132	$0.132	$0.130
Modules	$0.470	$0.470	$0.470
Electrical	$0.084	$0.078	$0.073
Inverter	$0.046	$0.046	$0.046
Labor			
Installation	$0.103	$0.103	$0.101
Other Costs			
Permitting	$0.001	$0.001	$0.001
Other Costs	$0.108	$0.112	$0.114
Business Overhead	$0.133	$0.121	$0.112
Total	**$1.078**	**$1.064**	**$1.047**

Note. Costs per watt for 150 MW and 200 MW are predicted using parameters produced from a non-linear regression based on NREL (2018) benchmarks. As seen, both the module and inverter costs ("hard costs") are constant per watt, regardless of project size in MW. Conversely, mounting, electrical, installation, permitting, and business overhead exhibit economies of scale. Only the "other costs" category exhibits diseconomies of scale. Note that these "other costs" include costs associated with land acquisition, interconnection fees, contingency allocations, and transmission lines. Transmission line costs increase with project size, and they drive the diseconomies of scale exhibited by the other costs category.

Using the 100 MW NREL costs for our JEDI models, we proceeded to calculate the economic impacts of the three noted scenarios. All dollar values are expressed in 2018 dollars to match the cost input year from NREL. The module material is assumed to be crystalline silicon, the most widely used PV technology,[36] which is also associated with one of the lowest annual degradation rates.[37] We used payroll parameter estimates from IMPLAN, which calculates the wages per economic sector using data from the BLS' Quarterly Census of Employment and Wages (QCEW), the Bureau of Economic Analysis' (BEA) Regional Economic Accounts, and the U.S. Census Bureau's County Business Patterns.

JEDI further requires assumptions on what products are locally manufactured, as well as what percent of materials and labor are purchased locally. In this report, we use one specific scenario, as directed by USSEC: 80% of the labor from Ohio,[38] and 30% of the materials from Ohio, for both construction and O&M phases. We also assume that "other costs" (i.e., architectural, office services, and permitting costs) are spent locally at the rate of 80%. To model the operation impacts of utility-scale PV, we use the NREL $14 per kilowatt (kW) per year estimate for O&M expenses, where 60% of that estimate goes towards labor and 40% towards material and equipment.[39] Finally, the last set of required JEDI inputs centers on tax information. Ohio has property and sales tax exemptions in place, which allows us to reasonably set the level of exemptions to 100% in the JEDI models.

JEDI allowed us to model the impact of the low, moderate, and aggressive deployment scenarios for the construction phase. We subsequently modeled the O&M phase impacts in Ohio using IMPLAN. The comparative advantage of JEDI is that it allows us to model the specific economic impact of solar energy related construction.

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[36] United States Department of Energy, Office of Energy Efficiency & Renewable Energy (2019). *Crystalline silicon photovoltaics*. Retrieved from https://www.energy.gov/eere/solar/crystalline-silicon-photovoltaics-research.

[37] Ishii, T., & Masuda, A. (2017). Annual degradation rates of recent crystalline silicon photovoltaic modules. *Progress in Photovoltaics: Research and Applications, 25*(12), 953–967.

[38] A requirement to enter Ohio's Payment in Lieu of Taxes (PILOT) agreement (see: http://www.bricker.com/documents/publications/2223.pdf).

[39] See: National Renewable Energy Laboratory. (2018c). *U.S. solar photovoltaic system cost benchmark: Q1 2018*. Retrieved from https://www.nrel.gov/docs/fy19osti/72399.pdf.

For instance, JEDI accounts for the costs specific to a solar project, and allocates a portion of the construction costs to high value-added sectors such as permitting and business overheads. Moreover, a solar energy specific construction sector does not exist in IMPLAN. JEDI also allows customization by offering a large set of options on the average annual system capacity factor, the procurement of materials and equipment, the detailed market sector share (i.e., residential, commercial, and utility-scale), and the solar module material. Modeling the impacts of the O&M phase of the project, we revert to using IMPLAN since it has a sector entitled, "Electric Power Generation - Solar Sector." Therefore, we no longer need to rely on JEDI to allocate costs to the appropriate sectors.

3.3. Economic Impacts by Phase

First, Table 3 presents utility-scale solar project expenses and local spending as a result of the construction and operation. The percent of the amount spent in Ohio will depend on the source of labor and materials. Here, we always assume that at least 80% of the labor originates in Ohio, given that the public utility personal property tax exemption only applies to projects where 80% of employees during the construction phase are Ohio-domiciled.[40] As previously noted, we present results from three different scenarios. The third row of Table 3 presents the total operational expenses, which is the sum of the direct operating, maintenance, and other annual costs. Other annual costs are debt payments, which may or may not impact Ohio. In this study, we assume that they do not, since we do not know if Ohio banks will be the source of financing for these projects. By assuming that the source of financing is not located in Ohio, we are producing conservative estimates.

Table 3. *Summary of Costs*

	Low (2.5 GW)	Moderate (5 GW)	Aggressive (7.5 GW)
Project Construction or Installation Cost	$3,592,192,939	$7,184,385,877	$10,776,578,816
Local Spending	$1,654,565,448	$3,309,130,895	$4,963,696,343
Direct O&M Costs	$46,666,667	$93,333,333	$140,000,000
Local Spending	$28,000,000	$56,000,000	$84,000,000

Figure 4 presents the economic impacts in terms of employment during the construction phase across our three scenarios. In our low scenario, at 2.5 GW, the direct construction jobs supported is 8,536, with a total job impact of 18,039, taking into account the indirect and induced impacts. In our moderate scenario (5 GW), we anticipate 17,071 direct construction jobs in Ohio, with a total of 36,074 jobs including the indirect and induced impacts. Finally, the most aggressive scenario, at 7.5 GW deployed, sees 25,607 direct construction-related solar jobs, with a total of 54,113 jobs if we accommodate for the multiplier effect. For every direct construction phase job, about one additional job is supported in the state.

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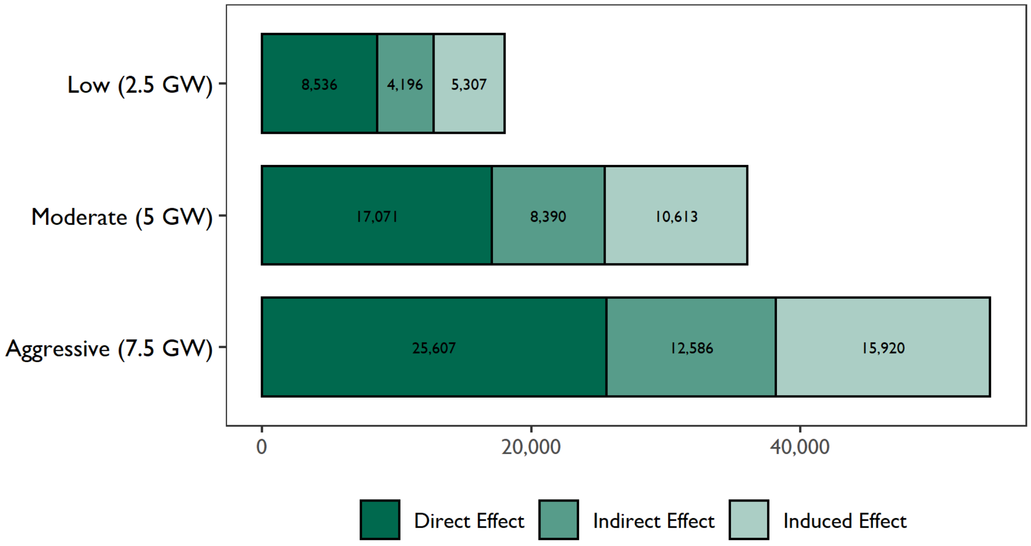
[40] See: Bricker & Eckler. (2011). *Ohio General Assembly reforms renewable and advanced energy tax policy*. Retrieved from http://www.bricker.com/documents/publications/2223.pdf & Ohio Revised Code. (2019). *5727.75 Exemption on tangible personal property and real property of certain qualified energy projects*. Retrieved from http://codes.ohio.gov/orc/5727.75.

Figure 4. *Construction Phase Employment Impacts*



Our next two figures, Figures 5 and 6, display the value added and total construction phase economic impacts of our low, moderate, and aggressive scenarios. In our low scenario, at 2.5 GW, the direct value added is $741M, with a total value added of about $1.6B, taking into account the indirect and induced effects. The direct economic impact is $1.7B, with a total economic impact of $3.2B. In our moderate scenario (5 GW), the direct value added is $1.5B, with a total value added of $3.2B. The direct economic impact is $3.3B, with a total economic impact of $6.4B. Finally, the most aggressive scenario, at 7.5 GW deployed, sees a direct value added of $2.2B, with a total value added of $4.8B. The direct economic impact is $5B, with a total economic impact of $9.6B.

Figure 5. *Construction Phase Value Added Impacts*

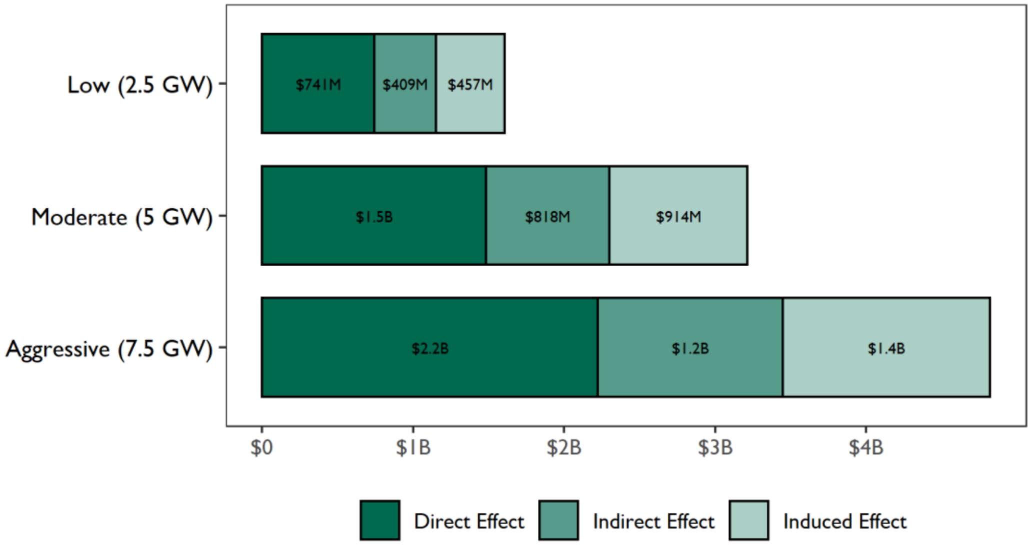
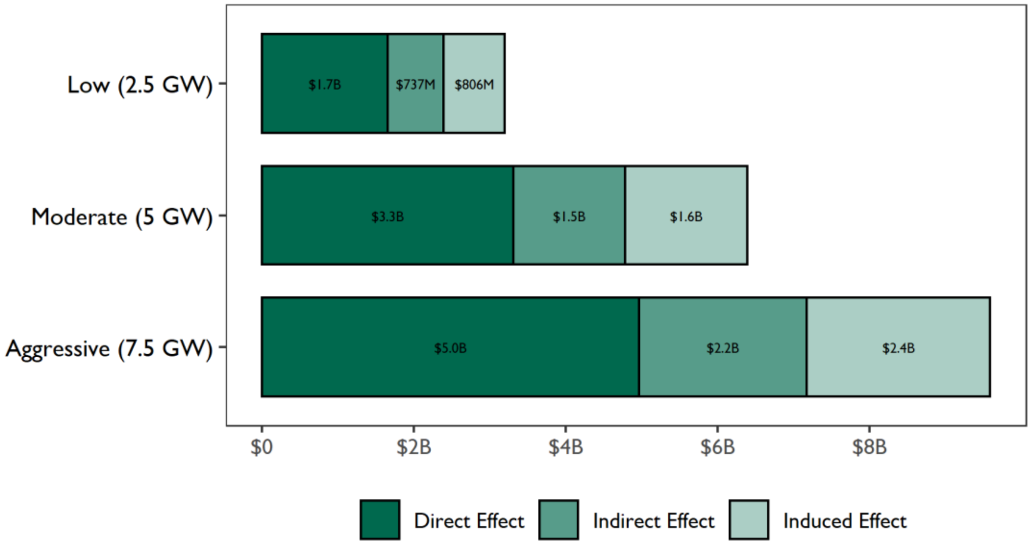
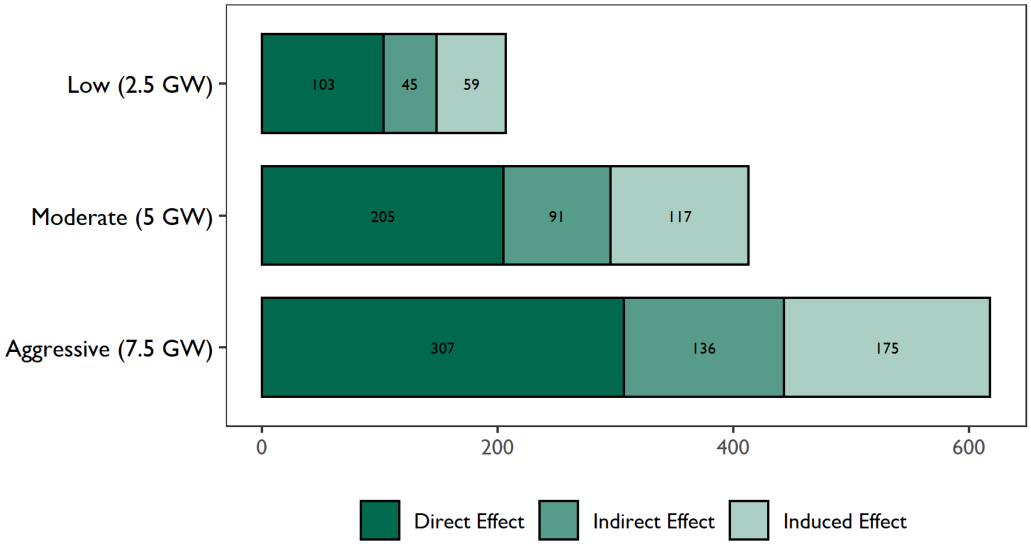


Figure 6. *Construction Phase Total Economic Impacts*



Next, Figure 7 presents the economic impacts in terms of employment during the O&M phase across our three scenarios. In our low scenario, at 2.5 GW, the direct construction jobs supported is 103, with a total job impact of 207, taking into account the indirect and induced impacts. In our moderate scenario (5 GW), we anticipate 205 direct construction jobs in Ohio, with a total of 413 jobs including the indirect and induced impacts. Finally, the most aggressive scenario, at 7.5 GW deployed, sees 307 direct construction-related solar jobs, with a total of 618 jobs if we accommodate for the multiplier effect. For every direct O&M job for the utility-scale solar industry in Ohio, about one additional job is supported.

Figure 7. *O&M Phase Employment Impacts*



Our next two figures, Figures 8 and 9, display the value added and total O&M phase economic impacts of our low, moderate, and aggressive scenarios. In our low scenario, at 2.5 GW, the direct value added is $14M, with a total value added of about $27M, taking into account the indirect and induced effects. The direct economic impact is $28M, with a total economic impact of $54M. In our moderate scenario (5 GW), the direct value added is $29M, with a total value added of $55M. Here, the direct economic impact is $56M, with a total economic impact of $107M. Finally, the most aggressive scenario, at 7.5 GW deployed, sees a direct value added of $43M, with a total value added of $83M. The direct economic impact is $84M, with a total economic impact of $160M.

Figure 8. *O&M Phase Value Added Impacts*

Figure 9. *O&M Phase Total Economic Impacts*

Compared to other power generating technologies, solar energy facilities have relatively lower O&M requirements. Regular maintenance such as inverter servicing, ground-keeping, module cleaning, or site security is relatively easy, and can be done by locally trained staff. The monitoring of facility performance can be achieved remotely by the original equipment manufacturer or another asset manager.[41] Finally, we also note that decommissioning is *not* analyzed in this study, but it is likely additive and will increase the economic benefits of future solar projects in the State of Ohio. Our full economic impact tables for this section, broken down by manufacturing, onsite labor, and annual O&M impacts, can be found in Appendix A.

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[41] International Finance Corporation. (2015). *Utility-scale solar photovoltaic power plants*. Retrieved from https://www.ifc.org/wps/wcm/connect/f05d3e00498e0841bb6fbbe54d141794/IFC+olar+eport_Web+08pdf?MOD=AJPERES.

4. Ohio Solar Workforce

Ohio currently ranks 7th in the nation in solar energy labor force, with 2,058 available solar manufacturing employees, and 4,146 onsite labor employees.[42] In addition, from the same data source, Ohio currently has 195 solar-related O&M employees.[43] While we believe that there is enough labor in Ohio to meet the demand created by the *average individual project*, the state is currently experiencing a boom in utility-scale solar energy project proposals. Therefore, there is a need for a constant supply of skilled labor to meet this growing demand, with, as noted in Section 1, over 2.5 GW of capacity in the OPSB queue, and particularly to meet our moderate and aggressive deployment scenarios.

Table 4 includes estimates of the number of Ohio workers within each of the relevant solar energy occupations based on the Ohio Occupational Employment projections Report 2016–2026, provided by the Department of Job and Family Services.[44] The table includes the estimated Ohio workforce in 2020, and then the projected average annual increase in employment by occupation. The number of Ohio employees by occupation in 2020 is computed by assuming a constant yearly increase in employment equal to the projected annual average.

Table 4. *Ohio Solar Workforce by Occupation*

	Estimated Ohio Workforce in 2020	Projected Annual Increase in Ohio Workforce
A: Needed Across all Phases		
Electrical Engineers	6,422	41
Engineering Technicians	3,224	19
B: Manufacturing		
Advanced Manufacturing Technicians	3,382	26
Computer Control Operators	1,288	-36
Industrial Engineers	15,248	126
Mechanical Engineers	15,709	181
Environmental Engineers	1,242	6
Materials Scientists	669	7
C: Onsite Labor (Const. + O&M)		
Electricians (Solar PV Installers)	25,316	198
IT Specialists	19,017	70
Software Engineers	5,875	9
Structural Engineers	8,293	61

Note. Estimated Ohio workforce in 2020 and projected annual increase in employment is based on the Ohio Occupational Employment projections Report 2016–2026.

Given the relevant solar energy occupations in Table 4, we next reviewed community and technical colleges to identify programs in Ohio that are currently operating and able to train new labor force entrants, or even re-train displaced workers. When investigating these programs in Ohio, as shown below in Figure 10, we focused on occupations requiring an associate's degree, as those may be the fastest to provide skilled labor. As

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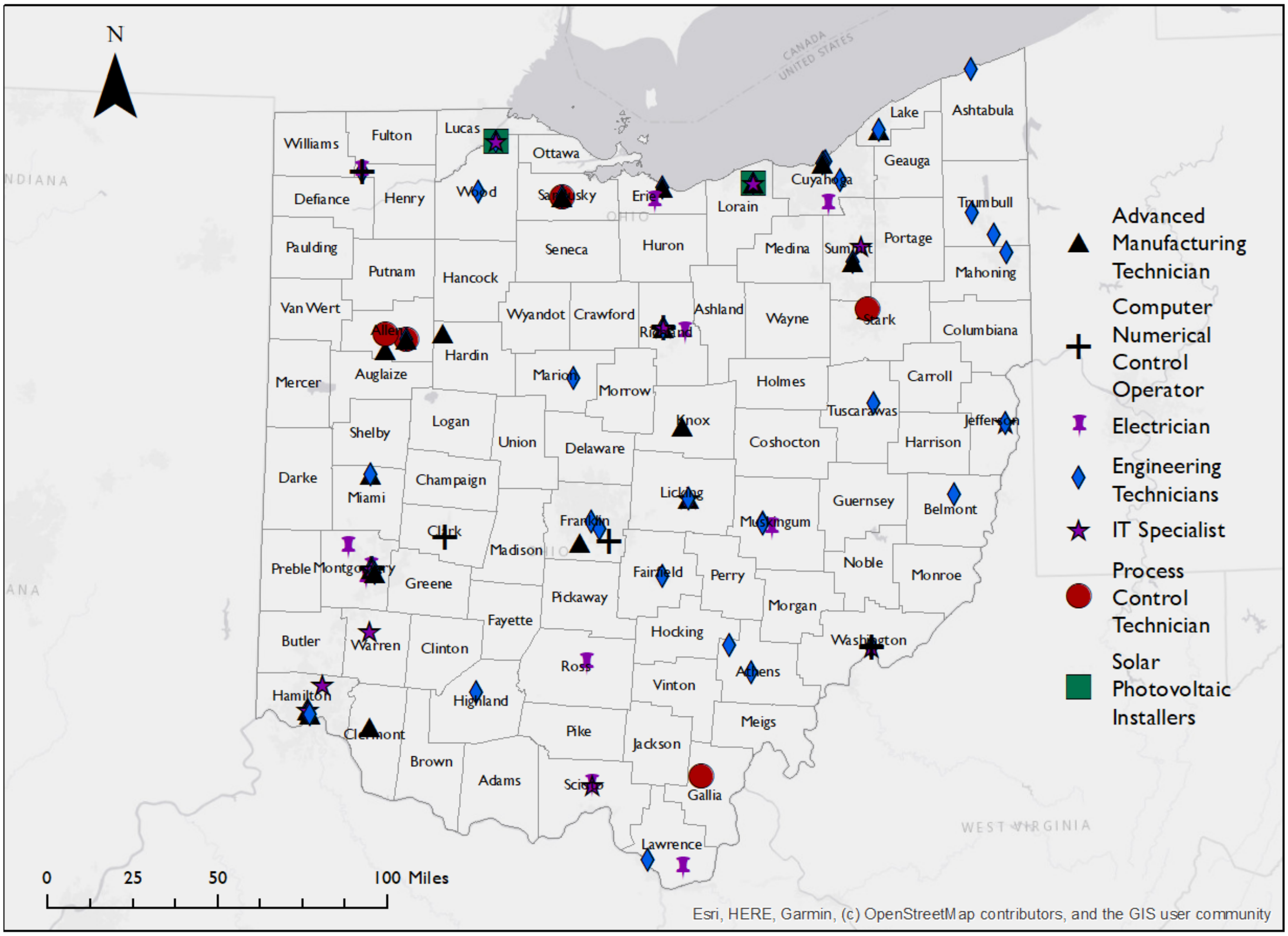
[42] The Solar Foundation. (2020). *Solar jobs census 2019: Ohio*. Retrieved from https://www.thesolarfoundation.org/solar-jobs-census/factsheet-2019-OH/.

[43] Ibid.

[44] Ohio Department of Job and Family Services. (2018). *2026 Ohio job outlook employment projections*. Retrieved from https://ohiolmi.com/Portals/206/proj/ohio/Ohio_Job_Outlook_2016-2026.pdf.

perhaps expected, these colleges are geographically concentrated in Cleveland, Columbus, and Cincinnati. Beyond the formal education provided by community and technical colleges as shown here, solar developers, among other entities, often offer interested workers short-term training to provide basic solar project skills. While under pre COVID-19 economic conditions solar workers were in a shorter supply, the uncertainty created by the current health pandemic and the subsequent increase in unemployment has significantly increased the pool of displaced workers. These proposed solar projects as part of USSEC's efforts can provide a much-needed boost to Ohio's economy and help decrease unemployment.

Figure 10. *Solar-Related Associate's Degree Programs in Ohio*



Note. Figure developed by authors, with data from CareerOneStop, United States Department of Labor, Employment and Training Administration. (2020). *Find local training*. Retrieved from https://www.careeronestop.org/FindTraining/find-training.aspx.

5. Tax Impacts

Ohio's exemption on tangible personal property and real property of certain qualified energy projects was enacted with the passage of Ohio Senate Bill (SB) 232 in July of 2010.[45] This provision exempts qualified energy projects, as certified by the Director of Development Services, using renewable energy resources (such as solar PV) from taxation. To qualify for the exemption, the owner or lessee must submit an application to the OPSB by

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[45] Ohio Revised Code. (2019). *5727.75 Exemption on tangible personal property and real property of certain qualified energy projects*. Retrieved from http://codes.ohio.gov/orc/5727.75.

December 31, 2022, and the construction of the energy facility must begin before January 1, 2023.[46] For a qualified energy project with a nameplate capacity of 20 MW or greater, a Board of County Commissioners of an Ohio county, if the county has not been declared an alternative energy zone, has to approve the application to exempt the property located in that county from taxation. The tangible personal property of the qualified energy project is exempt from taxation for all ensuing tax years if the property was placed into service before January 1, 2024. The Board may require a service payment to be made in addition to the $7,000 per MW of nameplate capacity service payment required in lieu of property taxes. The sum of the service payments shall not exceed $9,000 per MW of nameplate capacity located in the county.[47] The Board shall specify the time and manner in which the payment(s) required by the resolution shall be paid to the county treasurer. The director certifies an energy project after the Board of County Commissioners of the county in which the project is located has adopted a resolution approving the application.

Given the above, we calculated the potential tax revenues paid using $7,000 per MW as our lower bound and $9,000 as our upper bound. Table 5 shows that our three solar deployment scenarios would result in annual tax revenues between $17.5 million and $22.5 million in the low scenario, $35 million and $45 million in the moderate scenario, and between $52.5 and $67.5 million in the aggressive scenario, depending on the service payment required by any potential resolution passed by the Board of County Commissioners.[48] Taken together, this tax revenue, presumably paid into general funds, will benefit local schools, health systems, senior citizens, and many other aspects of rural Ohio counties and communities.

Table 5. *Potential Tax Revenues from Utility-Scale Solar in Ohio*

	(1) Low: 2.5 GW	(2) Moderate: 5 GW	(3) Aggressive: 7.5 GW
Minimum Tax Revenue	$17,500,000	$35,000,000	$52,500,000
Maximum Tax Revenue	$22,500,000	$45,000,000	$67,500,000

6. Solar Production Estimates

In this section, our research team calculated energy produced (in megawatt hours (MWh)/year) and number of homes powered, using input data and assumptions from the U.S. Energy Information Administration (EIA) and other sources. Estimates were produced using direct current (DC) converted capacities, assuming a de-rating factor of 0.75.[49]

First, we assumed all solar projects to be single-axis (east-west) tracking, which was the predominant form of utility-scale solar per a Lawrence Berkeley National Laboratory (LBNL) 2019 utility-scale solar report.[50] This also aligns with our supplied inputs, methods, and results for the economic impact analysis results detailed above. We made solar energy production assumptions based on NREL's Annual Technology Baseline data 2020

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[46] Ibid.

[47] Ibid.

[48] Our analysis assumes that all project developers will enter into the PILOT agreement, which will abate real property and tangible personal property taxes and replace them with the payments as depicted above. We use the projected installed capacities of 2.5 GW, 5 GW, and 7.5 GW, and multiply by $7,000/MW as our lower bound, and $9,000/MW as our upper bound.

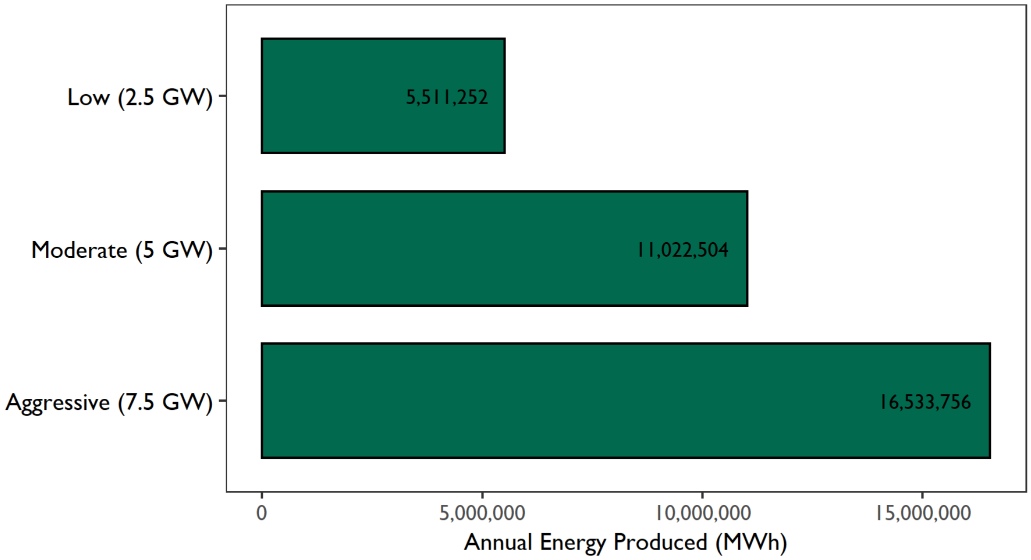
[49] Randolph, J., & Masters, G. M. (2008). *Energy for sustainability: Technology, planning, policy*. Washington, DC: Island Press.

[50] Bolinger, M., Seel, J., & Robson, D. Lawrence Berkeley National Laboratory. (2019). *Utility-scale solar: Empirical trends in project technology, cost, performance, and PPA pricing in the United States - 2019 edition*. Retrieved from https://emp.lbl.gov/sites/default/files/lbnl_utility_scale_solar_2019_edition_final.pdf.

spreadsheet, which shows annual capacity factors for five sample locations.[51] The best comparison for Ohio is Chicago, with a capacity factor of 25.2%. Chicago and the Columbus Metropolitan Statistical Area (as a proxy geography for the rest of the state) both have average solar irradiance in the range of 4.0–4.4 kWh/m^2/day, per the standard NREL maps. At the assumed ~25% capacity factor, the NREL spreadsheet shows an estimated annual electricity production of 2.205 MWh per MW of capacity, using the constant estimation. We then determined the average household energy consumption in Ohio to discern the equivalent homes powered.

Our estimates show that, in our low scenario, 5,511,252 MWh of energy will be added to the grid in Ohio, the equivalent of powering 502,791 households. The moderate and aggressive scenarios produce 11,022,504 MWh and 16,533,756 MWh of energy, powering 1,005,582 and 1,508,374 homes, respectively. As a point of reference, this most aggressive scenario would power all of the households in Ohio's largest city, Columbus, roughly four times over.[52]

Figure 11. *Energy Produced in MWh*



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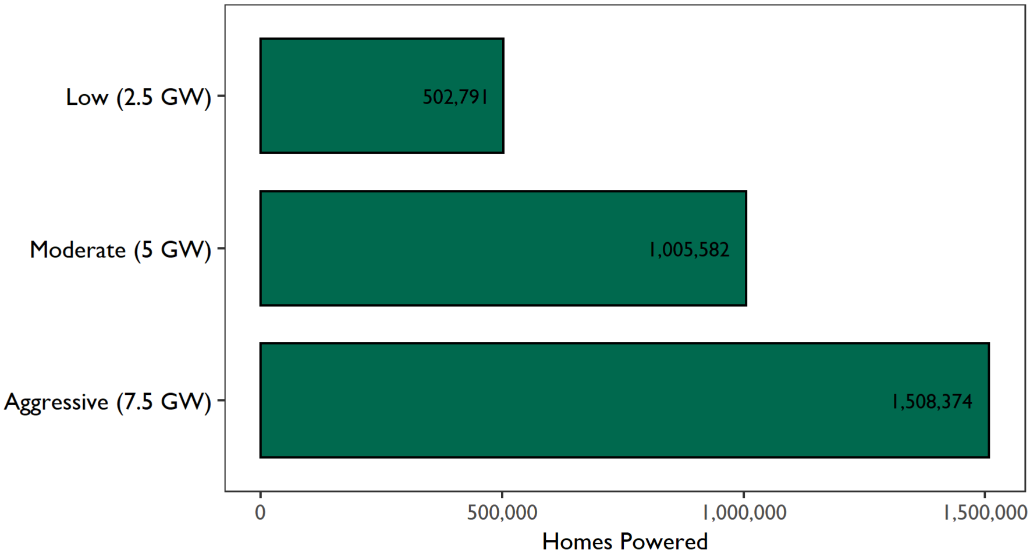
[51] National Renewable Energy Laboratory. (2020). *Annual Technology Baseline (ATB) data*. Retrieved from https://atb.nrel.gov/electricity/data.html.

[52] United States Census Bureau. (2019). *QuickFacts: Columbus city, Ohio*. Retrieved from https://www.census.gov/quickfacts/columbuscityohio. Columbus has an estimated 352,543 households.

Figure 12. *Equivalent Number of Homes Powered*



7. Conclusions

This study's aim was to better comprehend the key economic, workforce, and tax-related metrics for USSEC's current and future efforts in the State of Ohio. Across all of our modeling and work tasks, we found a multitude of positive benefits that utility-scale solar energy projects would bring, such as the projected annual tax revenues of over $67M per year in our most aggressive deployment scenario. Our economic impact modeling shows that 2.5 GW of utility-scale solar projects would bring 18,039 construction jobs to the state, and 207 annual O&M jobs. At 5 GW and 7.5 GW, these numbers jump to 36,074 and 54,113 (construction phase), and 413 and 618 (O&M phase), respectively. We also calculated $3.2B (construction phase) and $54M of annual O&M economic impacts in our low scenario, followed by $6.4B and $107M, as well as $9.6B and $160M, respectively across our moderate and aggressive deployment scenarios. These solar projects will also produce millions of MWh annually, and power between 500,000 and 1.5M homes in Ohio, depending on deployment scenario. Taken as a whole, these projects bring high value to Ohio, such as in avoiding electricity imports coming from the grid, and instead using local annual electricity production, keeping many millions of dollars within the state.

Our cumulative findings suggest that the low, moderate, and aggressive solar deployment scenarios will work to promote economic growth, diversification, durable job creation, new economic clusters, and stable income generation across the state. Purchasers of this solar energy output will receive fuel diversification and a pricing hedge at a valuable price against a historical reliance on fossil fuels. Moreover, advancing a clean energy economy in Ohio may help attract additional businesses to the state. Ohio currently has nearly 250 Fortune 500 companies seeking, or investing in, the outputs of renewable energy projects, with 61% having some form of business operations in the state.[53] The state's growing solar industry is an increasingly important factor in corporate location or expansion decisions, procurement planning, foreign investment, and particularly for facilities like research laboratories, data centers, server farms, warehouse and logistics, government and community facilities, and our military.

Finally, these large solar energy facilities may be a strategy to replace historical generation from coal and nuclear that have reached the end of their useful lives. Local energy assets also strengthen the state economy, use

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[53] See: Kowalski, K. M. (2020, January 9). *Appalachian Ohio solar projects are moving forward, but jobs impact unclear*. Energy News Network. Retrieved from https://energynews.us/2020/01/09/midwest/appalachian-ohio-solar-projects-are-moving-forward-but-jobs-impact-unclear/ & Michaud, G., & Zimmer, M. (2020, April 13). *Ohio University's letter to the OPSB for the 2020 Rule Review*. Retrieved from https://www.opsb.ohio.gov/rules/ohio-university/.

cleaner resources, and help expand research and interest in grid modernization, energy storage, and other advanced clean technologies. Investments in infrastructure and the electric system (and its modernization) are assuming the spotlight in Ohio through discussions advanced by the state's PowerForward initiative.[54] Solar energy offers an important asset to the growing modernization, upgrading, and deployment of advanced and electric vehicles transportation solutions in the state. Comprehensively, this will include critical consideration of energy storage, electric vehicles, microgrids, new nanotechnology and materials science, and demand-side and energy management companies in Ohio that are designing, producing, and manufacturing these clean tech products as important tools for the future. From a workforce perspective, large solar energy projects in Ohio will foster growth as part of the post-COVID recovery, as well as the formation of a supply chain for parts and materials, O&M services, and future research and development. In the current, pandemic-driven recession, solar energy can be a low-cost to government solution to boost the economy through short-term construction jobs, as well as enhancing tax revenues to geographies that would greatly benefit from such dollars.

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[54] For our take on this initiative, see: Zimmer, M., & Michaud, G. (2018). *What are the implications of the Public Utilities Commission of Ohio's recent PowerForward report?* Blog post for the Consortium for Energy, Economics & the Environment (CE3) at Ohio University's Voinovich School of Leadership and Public Affairs. Retrieved from https://ce3comprehensive.wordpress.com/2018/10/24/what-are-the-implications-of-the-public-utilities-commission-of-ohios-recent-powerforward-report/.

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Appendix A. Full Economic Impact Results

Table A.1. *Low (2.5 GW): Manufacturing Economic Impacts [30% Ohio Materials]*

	Employment	Labor Income	Value Added	Output
Direct Effect	1,609	$151,136,310	$217,298,917	$731,513,342
Indirect Effect	1,965	$131,360,795	$201,746,727	$370,054,065
Induced Effect	1,782	$86,457,304	$153,462,521	$270,567,754
Total Effect	**5,356**	**$368,954,409**	**$572,508,165**	**$1,372,135,161**
Multiplier	**3.33**	**2.44**	**2.63**	**1.88**

Note. Values may not directly add up due to rounding.

Table A.2. *Low (2.5 GW): Onsite Labor Economic Impacts [80% Ohio Labor]*

	Employment	Labor Income	Value Added	Output
Direct Effect	6,927	$432,199,590	$523,523,284	$923,052,105
Indirect Effect	2,231	$126,306,463	$207,010,438	$366,920,141
Induced Effect	3,525	$171,021,925	$303,500,371	$535,061,373
Total Effect	**12,683**	**$729,527,978**	**$1,034,034,093**	**$1,825,033,619**
Multiplier	**1.83**	**1.69**	**1.98**	**1.98**

Table A.3. *Low (2.5 GW): O&M Phase Economic Impacts [80% Ohio Labor & 30% Ohio Materials]*

	Employment	Labor Income	Value Added	Output
Direct Effect	103	$5,733,827	$14,478,811	$28,000,000
Indirect Effect	45	$3,310,236	$8,239,622	$16,572,738
Induced Effect	59	$2,766,476	$5,015,033	$8,751,684
Total Effect	**207**	**$11,810,539**	**$27,733,466**	**$53,324,422**
Multiplier	**2.01**	**2.06**	**1.92**	**1.90**

Table A.4. *Moderate (5 GW): Manufacturing Economic Impacts [30% Ohio Materials]*

	Employment	Labor Income	Value Added	Output
Direct Effect	3,217	$302,272,620	$434,597,834	$1,463,026,683
Indirect Effect	3,929	$262,721,589	$403,493,455	$740,108,130
Induced Effect	3,564	$172,914,607	$306,925,041	$541,135,507
Total Effect	**10,710**	**$737,908,817**	**$1,145,016,330**	**$2,744,270,320**
Multiplier	**3.33**	**2.44**	**2.63**	**1.88**

Table A.5. *Moderate (5 GW): Onsite Labor Economic Impacts [80% Ohio Labor]*

	Employment	Labor Income	Value Added	Output
Direct Effect	13,854	$864,399,182	$1,047,046,570	$1,846,104,212
Indirect Effect	4,461	$252,612,927	$414,020,876	$733,840,282
Induced Effect	7,049	$342,043,851	$607,000,742	$1,070,122,747
Total Effect	**25,364**	**$1,459,055,959**	**$2,068,068,188**	**$3,650,067,241**
Multiplier	**1.83**	**1.69**	**1.98**	**1.98**

Table A.6. *Moderate (5 GW): O&M Phase Economic Impacts [80% Ohio Labor & 30% Ohio Materials]*

	Employment	Labor Income	Value Added	Output
Direct Effect	205	$11,467,655	$28,957,623	$56,000,000
Indirect Effect	91	$6,620,472	$16,479,243	$33,145,476
Induced Effect	117	$5,532,952	$10,030,066	$17,503,368
Total Effect	**413**	**$23,621,079**	**$55,466,932**	**$106,648,845**
Multiplier	**2.01**	**2.06**	**1.92**	**1.90**

Table A.7. *Aggressive (7.5 GW): Manufacturing Economic Impacts [30% Ohio Materials]*

	Employment	Labor Income	Value Added	Output
Direct Effect	4,826	$453,408,931	$651,896,751	$2,194,540,025
Indirect Effect	5,894	$394,082,384	$605,240,182	$1,110,162,195
Induced Effect	5,346	$259,371,911	$460,387,562	$811,703,261
Total Effect	**16,066**	**$1,106,863,225**	**$1,717,524,495**	**$4,116,405,481**
Multiplier	**3.33**	**2.44**	**2.63**	**1.88**

Table A.8. *Aggressive (7.5 GW): Onsite Labor Economic Impacts [80% Ohio Labor]*

	Employment	Labor Income	Value Added	Output
Direct Effect	20,781	$1,296,598,772	$1,570,569,855	$2,769,156,317
Indirect Effect	6,692	$378,919,390	$621,031,314	$1,100,760,423
Induced Effect	10,574	$513,065,776	$910,501,113	$1,605,184,120
Total Effect	**38,047**	**$2,188,583,938**	**$3,102,102,282**	**$5,475,100,860**
Multiplier	**1.83**	**1.69**	**1.98**	**1.98**

Table A.9. *Aggressive (7.5 GW): O&M Phase Economic Impacts [80% Ohio Labor & 30% Ohio Materials]*

	Employment	Labor Income	Value Added	Output
Direct Effect	307	$17,201,482	$43,436,434	$84,000,000
Indirect Effect	136	$9,930,707	$24,718,865	$49,718,215
Induced Effect	175	$8,299,429	$15,045,098	$26,255,053
Total Effect	**618**	**$35,431,618**	**$83,200,398**	**$159,973,267**
Multiplier	**2.01**	**2.06**	**1.92**	**1.90**

Appendix B. Author Biographies

Gilbert Michaud, Assistant Professor of Practice, Ohio University (Principal Investigator)

Dr. Gilbert Michaud is an Assistant Professor of Practice at the George V. Voinovich School of Leadership and Public Affairs at Ohio University, where he primarily teaches courses in the school's Master of Public Administration (MPA) program. His applied research portfolio focuses on renewable energy policy, electric utilities, state politics, and economic and workforce development. Dr. Michaud also serves as a Faculty Affiliate with the Gerald R. Ford School of Public Policy at the University of Michigan.

Previously, Dr. Michaud served as principal investigator on an American Electric Power (AEP) grant project to evaluate the economic impacts of solar energy deployment in Ohio. Other funded research activities have included economic impact studies for utility-scale solar developers, an Ohio energy job trends report, and several other projects funded by the U.S. Department of Energy, U.S. Small Business Administration, and U.S. Economic Development Administration. For his applied research portfolio, Dr. Michaud was awarded a faculty sustainability research award from Ohio University's Office of Sustainability, as well as a Midwest Energy News 40 Under 40 award, both in 2018. In 2019, he won the "Best Article of the Year" award from the Association of Energy Engineers (AEE) for his peer-reviewed paper: "Non-Utility Photovoltaic Deployment: Evaluation of U.S. State-Level Policy Drivers."

Dr. Michaud has published numerous academic articles in journals such as the *International Journal of Energy Research*, *Journal of Environmental Planning and Management*, *The Electricity Journal*, and *Renewable Energy Focus*, among many other scholarly venues. He is author or co-author of over 80 technical, white paper reports and commentary articles, including ones for Solar United Neighbors, the Virginia Department of Environmental Quality, and Appalachian Partnership, Inc., and has been quoted in several national news media outlets, including *NPR*, *Bloomberg Law*, and *S&P Global*. He serves as a board member for both Solar United Neighbors of Ohio and Virginia, as well as on multiple committees for the American Solar Energy Society. Dr. Michaud has also served as a guest editor for a special issue of *Solar Energy* Journal focused on solar economics and policy for climate action.

Prior to his academic career, Dr. Michaud worked as an economics content author for Sapling Learning, Inc., as well as the lead researcher for the Energy & Power segment of U.S. Business Executive Journal. He holds a Ph.D. in Public Policy & Administration from the L. Douglas Wilder School of Government and Public Affairs at Virginia Commonwealth University (VCU), as well as an advanced certificate in Data Analytics from Cornell University.

Christelle Khalaf, Economist, Ohio University

Dr. Christelle Khalaf is an Economist at the George V. Voinovich School of Leadership and Public Affairs at Ohio University. Her initial research at the Voinovich School was a U.S. EDA funded project mapping the occupational skills of displaced coal mining and coal-fired power plant workers to emerging occupations, such as renewable energy, in the Appalachian Ohio region. Currently, she continues to work on economic development, workforce transitions, and solar energy projects, as well as COVID-19 related health and economic ramifications. Dr. Khalaf has published peer-reviewed papers in journals such as *Economic Inquiry*, *Journal of Labor Research*, and *Regional Science Policy & Practice*, among others. She holds a Ph.D. in Economics from North Carolina State University (NCSU), where she received the Jenkins Dissertation Fellowship in recognition of the quality of her research. She was part of a team at NCSU studying challenges to retirement readiness in the North Carolina public sector workforce. The project, funded by a Sloan Foundation grant, was in partnership with the North Carolina Retirement Systems Division (a division of the Department of State Treasurer).

Michael Zimmer, Executive-in-Residence, Ohio University

Michael Zimmer, J.D. is an Executive-in-Residence at the George V. Voinovich School of Leadership and Public Affairs at Ohio University, where he works on a wide range of energy and water research issues. A longtime attorney based in Washington, D.C., he is a national expert on energy policy, corporate sustainability, clean tech transactions, and finance. Zimmer has been at the forefront of public policy changes since serving as Vice President and Assistant General Counsel of the American Gas Association to the National Energy Plan and advanced natural gas technologies and liquefied natural gas in the late 1970s. He led the American Bar Association's (ABA) Renewables and Distributed Energy Committee from 2008 to 2010, and led the ABA Energy and Environmental Markets and Finance Committee from 2010 to 2012. Zimmer has been educated at Providence College and University of Baltimore School of Law.

David Jenkins, Research Associate, Ohio University

David Jenkins is a Research Associate at the George V. Voinovich School of Leadership and Public Affairs at Ohio University. In this role, he focuses on energy policy and economic development studies, largely related to renewables, climate, and sustainability. Previously, he conducted research on public health data and program evaluation, as well as ecological and environmental modeling and related research for The U.S. Army Corps of Engineers and the Maryland Environmental Service. He holds a bachelor's degree in Applied Mathematics from the University of Akron, and a master's degree in Ecology and Evolutionary Biology from Ohio University.