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Optimizing Utility-Scale Solar Siting for Local Economic Benefits and Regional Decarbonization

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Corresponding Author:	Papa Yaw Owusu-obeng University of Michigan Ann Arbor, Michigan UNITED STATES
First Author:	Papa Yaw Owusu-obeng
Order of Authors:	Papa Yaw Owusu-obeng
	Steven R. Miller
	Sarah B. Mills
	Michael T. Craig
Abstract:	The Midwest’s agricultural lands are increasingly targeted for utility-scale solar development, but traditional power planning often overlooks local economic impacts and the opportunity costs of converting farmland. This study integrates local economic metrics into a power system planning model to assess how economic benefits and agricultural trade-offs influence solar siting decisions. Focusing on counties within the Great Lakes region, we develop localized supply and marginal benefit curves within a multi-objective optimization framework that minimizes system costs while maximizing community economic benefits. Results show that counties with larger economies and less productive farmland deliver the highest local economic benefit per megawatt (MW)—reaching $34,500 in Ohio due to property tax revenues—while smaller counties generate 31% less. Accounting for lost crop production reduces net benefits by up to 16%, depending on farmland quality. A scenario prioritizing solar deployment in high-economic-return counties boosts cumulative benefits by $1 billion (11%) by 2040, redirecting investment from Michigan and Wisconsin (down 39%) to Ohio and Indiana (up 75%), with only a marginal 0.5% increase in system-wide costs. These findings underscore the importance of integrating economic considerations into utility-scale solar planning to better align decarbonization goals with regional and local economic development.

SCHOOL FOR ENVIRONMENT & SUSTAINABILITY
UNIVERSITY OF MICHIGAN

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Dear Editorial Team:

I am pleased to submit the manuscript titled *"Optimizing Utility-Scale Solar Siting for Local Economic Benefits and Regional Decarbonization"* for consideration as a Research Article in Energy Policy. My co-authors on this work are Dr. Steven R. Miller, Dr. Sarah Banas Mills, and Dr. Michael T. Craig.

As utility-scale solar photovoltaics (PV) emerge as a critical driver of U.S. power sector decarbonization, siting strategies must increasingly balance cost efficiency, land use, and local economic outcomes. However, traditional capacity expansion planning neglects the localized economic impacts of solar deployment, limiting opportunities to align clean energy transitions with community development. In this study, we develop an integrated framework that endogenizes local economic impacts into a long-term capacity expansion model. Applying this framework across six Great Lakes states—Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin—we show that prioritizing counties with larger economies and lower farmland productivity significantly increases local economic benefits without meaningfully raising system-wide costs. Specifically, shifting solar investments toward high-benefit counties increases total economic value by $1 billion with less than a 0.5% increase in overall investment costs. Importantly, we find that state and local fiscal policies—particularly property tax regimes and payment-in-lieu-of-taxes (PILOT) programs—strongly mediate these gains, illustrating how targeted taxation policies can steer solar deployment toward communities that capture the greatest economic returns while advancing decarbonization goals.

Our findings provide critical insights for policymakers, planners, and developers seeking to advance renewable energy deployment while enhancing local economic resilience. By quantifying the trade-offs between cost minimization and economic benefit maximization, our work offers a replicable approach to more equitable and community-aligned decarbonization strategies.

We have no related manuscripts under consideration or in press elsewhere and disclose no conflicts of interest. Thank you for your consideration of our manuscript. We look forward to the opportunity to contribute to *Energy Policy*'s important discussions on clean energy transition and sustainable economic development.

Sincerely,

Papa Yaw Owusu-Obeng, Ph.D. Candidate
School for Environment and Sustainability
University of Michigan
owusup@umich.edu

Declaration of interests

☒The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

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Optimizing Utility-Scale Solar Siting for Local Economic Benefits and Regional Decarbonization

Papa Yaw Owusu-Obeng [a, *], Steven R. Miller [b], Sarah Banas Mills [c, d], Michael T. Craig [a, e]

[a] School for Environment and Sustainability, University of Michigan, Ann Arbor, MI 48109, USA
[b] Department of Agricultural, Food, and Resource Economics, Michigan State University, Lansing, USA
[c] Graham Sustainability Institute, University of Michigan, Ann Arbor, MI 48104
[d] A. Alfred Taubman College of Architecture and Urban Planning, University of Michigan, Ann Arbor, MI 48109
[e] Department of Industrial and Operations Engineering, University of Michigan, Ann Arbor, MI 48109, USA

*Corresponding author: Papa Yaw Owusu-Obeng
Email: owusup@umich.edu

Abstract

The Midwest's agricultural lands are increasingly targeted for utility-scale solar development, but traditional power planning often overlooks local economic impacts and the opportunity costs of converting farmland. This study integrates local economic metrics into a power system planning model to assess how economic benefits and agricultural trade-offs influence solar siting decisions. Focusing on counties within the Great Lakes region, we develop localized supply and marginal benefit curves within a multi-objective optimization framework that minimizes system costs while maximizing community economic benefits. Results show that counties with larger economies and less productive farmland deliver the highest local economic benefit per megawatt (MW)—reaching $34,500 in Ohio due to property tax revenues—while smaller counties generate 31% less. Accounting for lost crop production reduces net benefits by up to 16%, depending on farmland quality. A scenario prioritizing solar deployment in high-economic-return counties boosts cumulative benefits by $1 billion (11%) by 2040, redirecting investment from Michigan and Wisconsin (down 39%) to Ohio and Indiana (up 75%), with only a marginal 0.5% increase in system-wide costs. These findings underscore the importance of integrating economic considerations into utility-scale solar planning to better align decarbonization goals with regional and local economic development.

1 Introduction

Utility-scale solar photovoltaic (PV) is poised to become the largest contributor to power sector decarbonization, driven by technological advancements, cost reductions, and supportive policies such as the Inflation Reduction Act (IRA). In 2023, the United States added approximately 18.5 GW of utility-scale solar capacity—a 77% increase from the previous year—surpassing wind and other renewable energy technologies in new capacity additions. With over 1,000 GW of new capacity dominating the interconnection queue, utility-scale solar is set to maintain its trajectory of rapid growth in the coming decades. A notable trend in recent years is the surge of proposed projects in the Midwest [1], [2], particularly in states like Ohio and Wisconsin, as land availability and competition shifts deployments away from traditional solar hubs toward emerging energy communities [1]. This regional shift is underpinned by the Midwest's vast rural agricultural lands, characterized by flat terrain and large parcel sizes ideal for hosting utility-scale installations [3], [4], [5]. Notably, between 2012 and 2020, approximately 70% of solar projects in the Midwest were sited on agricultural land [6]. Owing to such land-use advantages the Midwest has emerged as a focal point for future solar development [7].

To support this expansion, generation planning has leveraged optimal utility-scale PV siting that integrate technology potential [8], [9], [10], system cost efficiency [4], [8], [11], [12], [13], regulatory constraints [14], [15] and environmental considerations [16], [17], [18], [19]. More recently, attention has turned to the socio-economic dimensions of utility-scale solar siting, particularly the local economic impacts [5], [20], [21], [22], [23]. These impacts are becoming increasingly important as the growing footprint of solar projects displaces rural agricultural lands [24], [25], creating positive and negative economic spillover effects. On one hand, utility-scale solar can be highly lucrative for local economies. Solar development often provides landowners with significantly higher income through lease agreements compared to traditional agricultural uses. For example, in Michigan, typical solar leases offer landowners an average of $800 per acre annually for terms of 20 to 25 years, significantly exceeding farmland rental rates, which average around $127 per acre per year [26]. Beyond direct landowner benefits, solar installations can generate economic benefits for host communities, including job creation, increased property tax revenues, and long-term economic diversification [5], [20], [22], [23], [27], [28]. On the other hand, the conversion of agricultural lands to solar use can disrupt rural economies by affecting local agricultural supply chains, reducing agricultural employment, and diminishing ancillary industries[5], [29]. Recent studies highlight these nuanced local economic impacts and underscore the importance of evaluating the positive and negative dimensions of solar siting to enhance community acceptance and promote equitable solar deployment [5], [23], [29], [30].

The standard regional economic model for quantifying local economic impacts of new developments is the economic input-output (IO) model. Its development is largely attributed to the Nobel Prize winning economist Wassily Leontief, who developed the concept in the late 1920s and early 1930s [31], while Walter Isard extended its application to localized economic impact analysis [32]. An appropriately-specified IO model makes up the core of the National Renewable Energy Lab's Job and Economic Development Impact Model (JEDI) [33], allowing the user to apply their own region-specific IO model parameters derived from the commercial IO model developed by IMPLAN Group LLC [34] or that provided by the U.S. Department of Commerce's Bureau of Economic Analysis called the Regional Input-Output Modeling System (RIMS II) [35]. IO-based assessments track direct, indirect, and induced economic effects of solar projects, capturing changes in economic indicators such as employment, earnings, gross output, and value-added contributions throughout the project's lifecycle [23]. A growing body of literature documents positive economic outcomes of renewable energy investments at various scales—county [5], [36], [37], [38], [39], state [20], [40], [41], regional [22], [42] and national [28], [43], [44], [45], [46]. Yet, existing studies overlook the economic losses associated with converting farmland to solar. Some researchers argue that to provide a more balanced assessment, models must account for the direct economic effects of lost agricultural production [47]. Ignoring these costs risks overstating net benefits and could hinder efforts to align solar expansion with the long-term sustainability of rural agricultural economies [48].

Another limitation in the current literature is the narrow geographic scope of most economic impact studies. Few U.S.-based analyses of utility-scale solar compare economic outcomes across multiple potential installation sites. Instead, existing studies typically focus on individual projects within a targeted geographic area [21], [27], [49]. This narrow focus, combined with varied assumptions and modeling approaches, makes it difficult to generalize findings or inform broader decision-making. This gap limits our understanding of how economic benefits of utility-scale solar could be leveraged to advance decarbonization goals while enhancing local economic development.

Finally, the current literature also fails to integrate economic impact assessments directly into power system planning or capacity expansion models to guide optimal utility-scale siting. Capacity expansion models typically identify the least-cost mix of generation, storage, and transmission resources necessary to meet electricity demand reliably under various policy constraints. These models have improved spatial resolution to capture resource and technology cost variability, but they generally do not incorporate local economic impacts as endogenous optimization components [8], [14], [17], [50]. Instead, these models rely on a scenario based approach where power system plans are developed first, and only then are separate economic impact evaluations performed [44]. This post-hoc process fails to identify siting configurations that might optimize both technical and economic objectives simultaneously. Given the growing opposition to solar siting, which has led to project delays [51] and increased cost of decarbonization [14], several studies agree that large-scale deployment of utility-scale solar will require community support to ensure successful implementation and operation [52], [53]. Developing siting strategies that benefit rural communities is essential for fostering local acceptance and meeting both solar deployment and broader decarbonization goals.

In this study, we examine local economic effects from utility-solar solar deployment by developing an integrated modeling framework. Our framework is the first to endogenously incorporate local economic metrics into a capacity expansion model. Our analysis focuses on all 524 counties within the Great Lakes region—spanning Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin—and specifically considers photovoltaic (PV) deployment on rural agricultural lands. To quantify county-level economic impacts, we develop a regional economic simulation model employing a set of representative economic IO models. These models simulate how PV solar expenditures circulate through interconnected industries supporting the solar project to generate economic effects that are larger than the direct local expenditures by the PV solar project. The expected economic loss of forgone agricultural production is similarly modeled and subtracted from the positive effects of PV solar expenditures using stylized PV and agricultural expenditure profiles [54]. Therefore, the simulation model provides economy-wide economic impact estimates for each county in the six-state region, where the economic measure is the dollar value of annual transactions generated, the number jobs supported, earnings from those jobs and total regional income (sum of labor and proprietor income and net government revenues from taxes and fees). These estimates cover the full project lifecycle, including installation, operations and maintenance, and decommissioning phases. These net economic gains are represented as marginal benefit curves, detailing the incremental economic benefit per unit of PV capacity added. In parallel, we develop supply curves across counties, informed by earlier work [14], that capture the costs of capacity additions under land-use, zoning, and technoeconomic constraints. We then integrate these curves into a multi-objective capacity expansion (CE) model designed to minimize total annualized system costs while maximizing local economic benefits of utility-scale PV additions. To assess the trade-offs between system costs and economic benefits, we assign varying weights to these objectives and run the CE model from the present through 2040 in five-year increments. Across all scenarios, we implement an 80% CO_2 emission reduction target by 2040, aligning with state[55] and federal policies[56] as well as broader decarbonization goals [57].

2 Data and Methods

Our analytical framework is summarized in Fig. 1. First, we conduct site analysis that evaluates county-level land availability for utility-scale PV after applying zoning ordinances and land-use exclusions. We then develop supply curves based on solar resource quality, interconnection costs and land availability, and marginal benefit curves based on county-level economic impacts. These curves serve as inputs to a capacity expansion (CE) model, which optimizes generation and transmission investments.

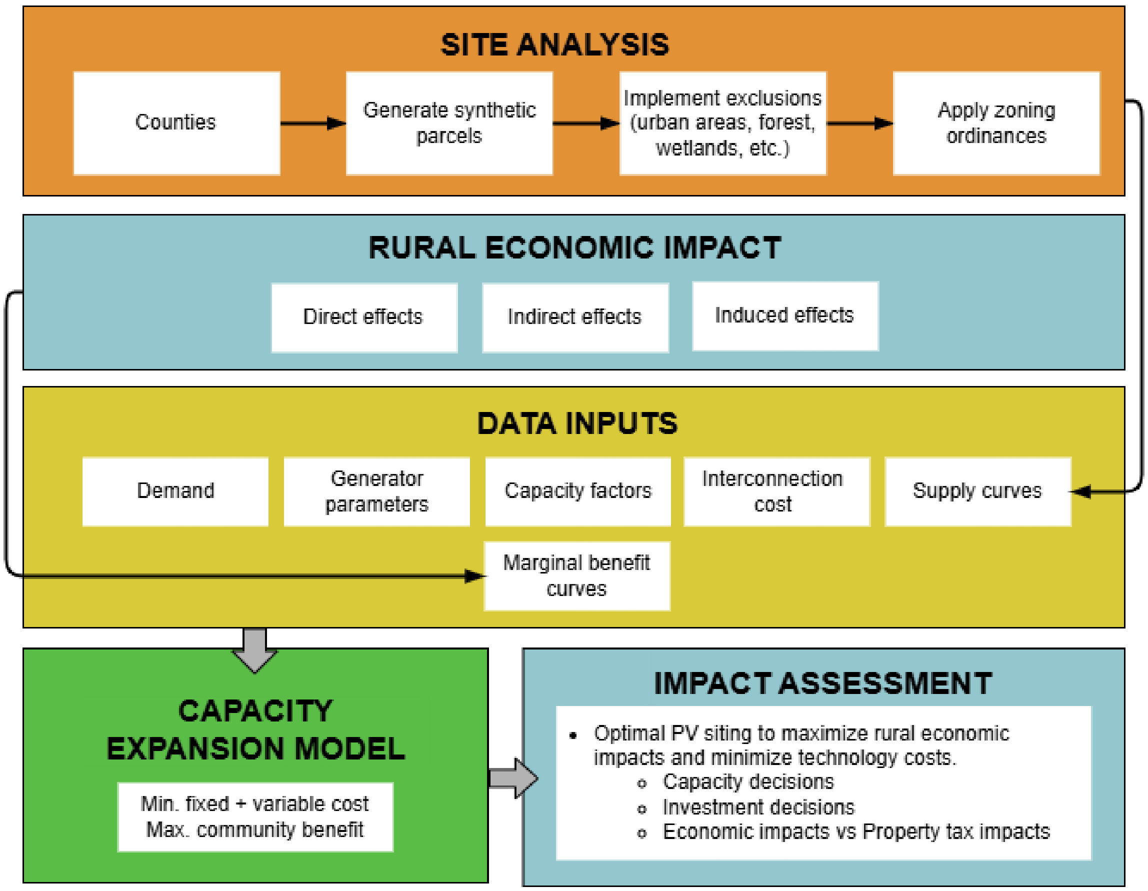

Fig. 1. Analytical framework used in this study.

2.1 Quantifying Land Area Available for Utility-Scale PV Development at the County Level

We quantify the land available for utility-scale PV development in each county by applying land-use exclusions and zoning ordinances to individual parcels, following the method outlined in Owusu-Obeng et al [14]. Due to the absence of comprehensive statewide parcel data, we use available parcel data from Wisconsin and Indiana to generate synthetic parcels through geospatial analysis in ArcGIS Pro and nearest neighbor analysis [58], [59] (SI 1, Section 1). We validate these synthetic parcels by comparing their size and distribution to those of actual parcels obtained from the Lawrence Berkeley National Laboratory (LBNL) dataset (SI 1, Fig. S1) [14].

To focus specifically on rural utility-scale PV potential, we exclude urban areas, urban buffers, and a range of non-agricultural land categories. These include developed lands as well as forested, wetland, and water-covered areas, which are generally unsuitable or restricted for solar development due to permitting barriers, ecological sensitivity, or conservation priorities. While not all land cover exclusions are explicitly listed, additional non-agricultural types, such as forest, are either implicitly excluded through the aforementioned filters or have negligible representation after zoning and slope constraints are applied. These exclusions are informed by datasets from the U.S. Census Bureau, the USDA Cropland Data Layer, and the USDA Natural Resources Conservation Service (NRCS) Prime Farmland dataset [60], [61], [62] (SI 1, Section 3). Our emphasis on agricultural lands reflects the dominant siting pattern for utility-scale PV in the Midwest, where croplands offer flat, accessible, and relatively unencumbered terrain. For example, USDA data show that 70% of Midwest utility-scale solar projects sited between 2012 and 2020 were located on croplands [6] (SI 1, Fig. S3). While solar projects can also occur on some non-agricultural lands, our model captures the primary siting landscape in the region. Therefore, we expect our agricultural land focus to lead to quantitative changes in the total available siting area, but not qualitative changes in the geographic patterns or conclusions drawn from our results.

We further exclude sites with slope unsuitable for wind or solar development, that is, at or above 10 degrees for solar and 19 degrees for wind [17], [50]. The remaining land parcels are mapped against a database of renewable energy zoning ordinances to evaluate land availability under various zoning regulations [14], [63]. We exclude parcels in zoning jurisdictions that prohibit utility-scale solar PV on agricultural lands. For jurisdictions that permit solar on agricultural lands, we apply road setbacks, participating property line setbacks, non-participating property line setbacks, and minimum and maximum lot size restrictions on individual parcels. We exclude jurisdictions whose zoning ordinances do not mention solar or are "silent" on solar development. In the states included in our study, these "silent" ordinances effectively operate as bans due to a permissive zoning framework, where land uses are prohibited unless explicitly allowed (SI 1, Section 2). Finally, all available land is aggregated at the county level. For additional modeling details, see SI 1: Site Analysis.

2.2 Assessing Solar Resource at the County Level

We determine the mean annual hourly capacity factors for each county by integrating meteorological data, such as hourly solar insolation, air temperatures, and other relevant meteorological variables, from the National Solar Radiation Data Base (NSRDB) [64] into the System Advisor Model (SAM) [65]. Furthermore, we estimate spatially explicit costs for connecting utility-scale PV facilities in each county to the bulk transmission grid by measuring the shortest straight-line distance. Our approach accounts for both electrical components and right-of-way costs from the Midcontinent Independent System Operator (MISO) [66], and transmission line data from the Homeland Infrastructure Foundation Level Database [67]. We then combine these interconnection costs with capital and operational cost parameters from the National Renewable Energy Laboratory's (NREL) 2021 Annual Technology Baseline (ATB) [68], using the "Market" case under a Mid cost scenario (SI 1, Table S1), which assumes a moderate pace of technological advancement and cost reduction. Based on these county-level capacity factors and cost estimates, we construct supply curves that serve as inputs to our capacity expansion model.

2.3 Determining the Economic Impact at the County Level

To estimate county-level economic impacts, we developed a publicly available, spreadsheet-based tool specifically for this study, designed to evaluate utility-scale solar projects across three distinct phases: (1) the short-term installation phase, (2) the long-term operations and maintenance (O&M) phase, and (3) the short-term decommissioning phase at the project's end-of-life. The tool and accompanying documentation are available at [69]. The installation phase is assumed to span 18 to 24 months, while the decommission phase is expected to span less than 12 months. The operating life of the projects is assumed to span 30 years. Key parameters for establishing baselines, such as the project timelines, land requirements, and cost structures are derived from NREL's ATB [68] and from survey-based economic impact estimates collected by Lawrence Berkeley National Laboratory [70]. For additional modeling details, see SI 2: PV Solar Net Economic Impact Estimation Model.

For each project phase, direct project expenditures drive economic impact estimates. For the installation phase, total installation expenditures are distributed to respective commodities based on ATB aggregates (e.g., land leases, site preparation, equipment procurement, installation, and grid interconnection). Because not all expenditures are captured within the county of installation, local purchase percentages (LPPs) are applied to each commodity to estimate the share of spending retained locally. For example, expenditures on solar panels are assumed to have no local capture, whereas most construction-related expenditures are retained within the local economy. Likewise, while electrical components and fixtures are sourced externally, services like ground maintenance (e.g., mowing) are assumed to be entirely local. During the O&M phase, all system administration and monitoring expenditures are assumed to occur outside the county, as are the purchases of replacement parts. Alternatively, ongoing facility services, like repair installations and grounds maintenance are mostly captured by the local economy. Because of wear and tear on the equipment, O&M expenditures are assumed to increase as equipment ages. To account for this, annual costs for depreciable O&M categories (e.g., equipment maintenance and repair) are modeled with a five percent annual escalation rate. Finally, the installation must be decommissioned at the end of the projects' 30-year life. The expected decommissioning costs, covering the removal of infrastructure and land restoration, are broken out by expenditure category for deconstruction, hauling and land restoration based on recent decommissioning plans [71], [72], [73]. All expenditures are measured in constant 2024 dollars to avoid inflation projections.

Land lease payments occur through all three project phases, based on project acreage. Interviews with lease holders for this project showed that actual land lease rates varied, $700 and $1250 per acre year. Approximately one-quarter of lease holders did not retain ownership in the affected region, indicating the local capture rate of about $580 per acre, measured in 2024 dollars. The model assigns 7.5 land-lease acres per MW of capacity. Land lease payments drive household spending and are modeled as induced effects using household expenditure distributions from the U.S. Department of Labor Consumer Expenditure Survey [74] and RIMS II multipliers [35]. For property tax modeling, we assume taxes are assessed based on the total project acreage. We assume that 80% of the acreage replaces agricultural use and therefore qualifies for agricultural tax treatment. State-specific property tax treatments for real and industrial property were applied, adjusted by average county millage rates where applicable. Because property tax rates in some states are determined by agricultural use value and in others by market value, we used soil productivity classifications—high-, medium-, and low-yield—to moderate per-acre tax estimates. All property tax revenues were modeled as government spending, and also as induced effects, following applicable depreciation rules for property taxation in each state. Similar to how household expenditures are distributed across multiple spending categories, changes in tax revenues are distributed based on state level expenditure shares, as reported by the U.S. Census [75].

Across all phases, agricultural production will be disrupted on the share of project acres expected to be converted to solar. Displaced agricultural production is only realized on 80 percent of total project acres, where the total project acres affected depends on the project size. The model makes the simplifying assumption that that the displaced agricultural acres would otherwise grow a rotation of corn, soybean or wheat, reflecting common three year-crop rotations in the Great Lakes Region. Recent Ohio State University Extension crop enterprise budgets [76] were used to develop a profile of per acre revenues and expenditures as baselines agricultural output that will be supplanted by the PV project, under each of the three crops. We assume that one-third of the impacted acreage would be assigned to each crop annually, allowing us to calculate a composite average annual loss in agricultural output. These values are assumed to be constant over time and measured in constant 2024-dollar values. To account for spatial differences in productivity, we classify counties into high-, medium-, or low-yield categories using 2017 USDA National Agricultural Statistics Services (NASS) county-level yield data for the three crops [54]. If at least two crop yields in a county exceed the six-state average, the county is deemed high-yield; if at least two fall below, it is low-yield; otherwise, it is categorized as average. Agricultural losses are adjusted accordingly: +10% for high-yield counties and –10% for low-yield ones.

Net macroeconomic effects of projects by county are estimated using representative RIMS II IO multipliers. Three sets of IO multipliers are made for each state, representing small (county population ≤ 15,000), medium (≤ 30,000), and large (≤ 50,000) counties and counties are categorized accordingly—excluding metropolitan areas (S2, Figure S1) [77]. This resulted in three representative county models per state (6 states × 3 sizes), providing 18 county profiles. Regional IO multipliers vary based on the lengths of local supply chains, which often reflect the size of the regional economy. Larger or more diverse economies tend to exhibit longer regional supply chains and therefore capture more internal transactions and larger multiplier effects.

RIMS II multipliers were acquired for each and mapped to 372 industry categories [78]. The economic effects of construction, O&M, and decommissioning expenditures, as well as that from supplanted agricultural production are modeled using the corresponding representative multipliers for the effected community, attributing the changes in business transactions, and all transactions throughout the supply chain via Type II multipliers. Household expenditures from lease revenues and changes in government expenditures from net tax changes are modeled as arising from induced effects only (S2) [35]. Collectively, the resulting estimates yield a net economic impact for each county profile over the full project lifecycle.

2.4 Capacity Expansion Model

We employ a long-term capacity expansion (CE) model to identify optimal utility-scale PV investment in each county. The CE model simultaneously optimizes investments in generation and transmission infrastructure, as well as hourly system operations. The model's objective is to minimize total annualized system costs while also maximizing net county-level economic impacts from utility-scale solar deployment. To balance these dual objectives, we apply a weighting factor ranging from 0 to 1, capturing the trade-offs between cost minimization and economic benefit. A higher weight on the cost objective results in the model prioritizing system cost reductions, while a lower weight places greater emphasis on maximizing local economic impacts. Intermediate weights balance both objectives equally.

Total system costs comprise the sum of annualized fixed investment and variable operating cost. Fixed costs account for capital and fixed O&M costs of new transmission lines, electricity generators, and energy storage systems. Variable costs account for fuel and variable O&M costs incurred by both new and existing units. To capture local economic benefits, we incorporate county-level metrics for the total value-added contributions from solar development (see Data and Methods: Determining the Economic Impact at the County Level and S1 2).

Following NREL's Regional Energy Deployment System (ReEDS) Model, our study region is subdivided into 24 subregions, between which limited transmission capacity exists [8]. At each time step, the model selects new investments from a portfolio that includes county-level solar PV and wind, as well as subregional investments in coal steam plants with carbon capture and sequestration (CCS), natural gas combined cycle (NGCC) facilities with and without CCS, nuclear power stations, battery storage systems, and transmission infrastructure. For solar capacity, we determine an upper bound in each county based on the extent of agricultural land available after the application of land exclusions and zoning ordinances. Similarly, wind is confined to agricultural lands. We convert land area to potential capacity for wind and solar using wind and solar power densities of 0.5 Wm^{-2} and 5.4 Wm^{-2}, respectively [79]. We obtain future capital and operational costs from NREL's Annual Technology Baseline, consistent with inputs used in our economic model (see prior section) [68]; interregional transmission capacity from ReEDS [8]; and future electricity demand profiles by subregion for a moderate electrification future [80]. We account for the Inflation Reduction Act by applying a 30% Investment Tax Credit (ITC) to the capital costs of solar and wind. We assume that all eligibility requirements for the 30% ITC, such as prevailing wage, project size and apprenticeship provisions, are fully met. While the IRA also provides tax credit adders or bonus incentives for projects sited in energy communities, we do not include these adders to maintain a conservative representation of capital costs across the study region. Wind, solar, and demand timeseries correspond to 2012 meteorology, capturing co-variability in these meteorologically-dependent variables. A list of our input datasets and assumptions is detailed in SI 1, Table S1. Our initial generation fleet is detailed in S1, Table S2.

The CE model enforces several system-level constraints, including balancing regional electricity and demand and meeting reserve requirements on an hourly basis (SI 3, Section 2). The model imposes unit-level constraints, such as upper limits on individual power plant capacities (SI 3, Section 3). Power flows between load regions are represented using a simple transport formulation, which determines optimal interregional energy transfers subject to maximum transmission capacities [12]. For computational tractability, each modeled year is condensed into two representative days per season plus the day of peak annual demand [81] (SI). The CE model is implemented in GAMS and solved with the CPLEX solver. For additional modeling information see SI 3 and SI 4.

2.5 Scenario Framework

To explore the tradeoffs between local economic benefits and system cost minimization in utility-scale solar deployment, we design a series of scenarios that adjust the relative weighting of our two objectives (minimizing total system costs and maximizing net county economic impacts). Specifically, we vary the importance placed on local economic outcomes and total system costs by applying a set of weights that range from 0 to 1 in increments of 0.2. At one extreme, the model prioritizes only economic benefits (100% weight on local benefits and 0% on cost), while at the other, it focuses on minimizing costs (0% weight on local benefits and 100% on cost). Intermediate scenarios allocate partial weights to each objective to balance local economic development with cost-effectiveness. All scenarios are evaluated under a consistent set of policy and decarbonization targets. We impose an 80% reduction in CO_2 emissions by 2040, aligned with state [55] and federal [56] policies, as well as broader decarbonization goals[57] to achieve net-zero emissions by 2050 [57]. The scenarios are run from present through 2040 in five-year increments, allowing us to track the evolution of generation portfolios, transmission infrastructure, and local economic outcomes over time.

3 Results

3.1 Drivers of local economic impact and effect of lost agricultural output

To quantify the extent, distribution, and drivers of local economic impacts, we first examine the annual net economic benefits from the value-added contributions per megawatt (MW) of installed solar capacity at the county level (Fig. 1), alongside the economic losses from farmland conversion. Figures 1c reveal substantial variation in value-added across and within states, driven primarily by the size of the local economy (Fig. 1a), and to a lesser extent by the productivity of the agricultural land converted to solar (Fig. 1b, SI-5 Fig. 1).

Regionally, the size of the local economy emerges as the dominant factor shaping net impacts, with counties in large, medium, and small economies experiencing average annual benefits ranging from $23,400–$34,600, $20,900–$29,700, and $18,500–$23,000 per MW, respectively. Firms and households in larger economies have more opportunities to transact with local businesses, enabling greater retention of economic activity. In contrast, smaller economies are more dependent on external supply chains, reducing local capture of expenditures. This regional pattern is also evident at the state level (Fig. 2). For example, Ohio shows the highest economic impacts, with average county-level values of $34,500, $29,700, and $20,000 per MW-year for large, medium, and small counties, respectively. By contrast, Indiana represents the lower bound, with corresponding values 31%, 18%, and 6% lower than those in Ohio.

Accounting for the loss in agricultural productivity from farmland conversion reduces economic benefits. Regionally, net economic impacts decline to $19,000-$30,600, $17,300-$25,700, and $14,500-$19,400 per MW-year for large, medium, and small counties, respectively. In Ohio, average reductions in value-added amount to 12%, 15%, and 16%—or $4,400, $4,500, and $3,200 per MW-year—for large, medium, and small economies, respectively (Fig. 2). The magnitude of reductions in large and medium counties is similar due to the predominance of land types with comparable average farmland productivity. When evaluating agricultural productivity losses independently of economic size, counties with "above average" productivity experience the highest reductions (averaging $4,700 per MW-year), compared to $4,200 and $3,500 for counties with average and below-average productivity, respectively.

The impact of net property tax revenue to local governments—reflecting the replacement of lost agricultural taxes with gained solar-related property taxes—varies by state (SI-5, Table S1). Ohio leads, with the highest net present value (NPV) of property tax revenues at $103,400 per MW, driven by its Payment In Lieu of Taxes (PILOT) program, which generates approximately $8,750 per MW annually and contributes to the state's overall highest economic impact (Fig. 1c). Wisconsin follows with an average NPV of $60,300 per MW, while Indiana and Michigan report more modest values of $39,400 and $38,800 per MW, respectively. Illinois yields $28,000 per MW, and Minnesota ranks lowest, with a property tax NPV of just $19,700 per MW.

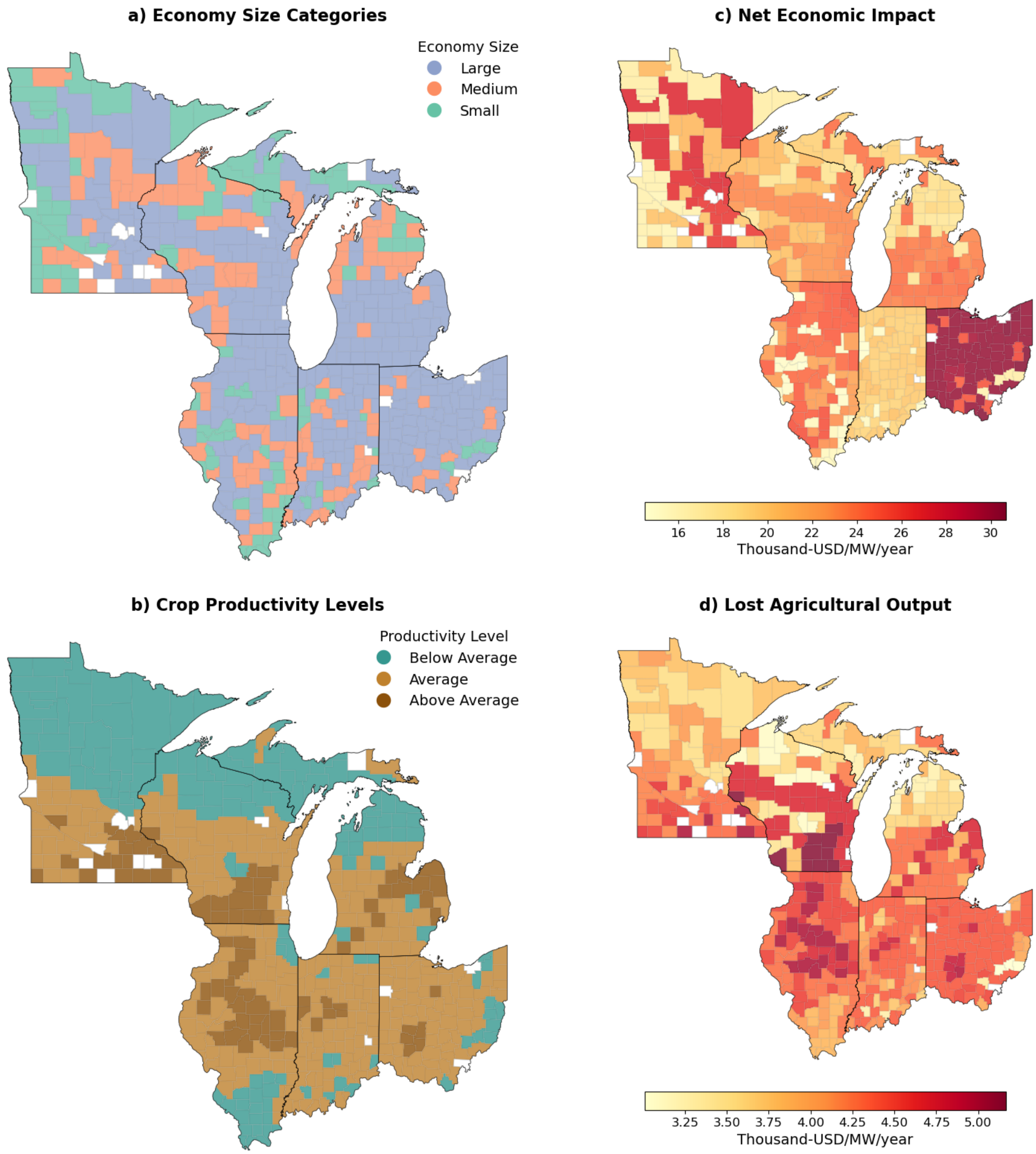

Fig. 1. County-level classification of (a) economy size (large, medium, small) and (b) crop productivity (below average, average, above average), along with (c) net economic impact per MW of installed solar capacity, accounting for the loss of agricultural output, and (d) annual economic losses from displaced farmland. Darker shades in (c) and (d) indicate higher value-added contributions and greater agricultural losses, respectively.

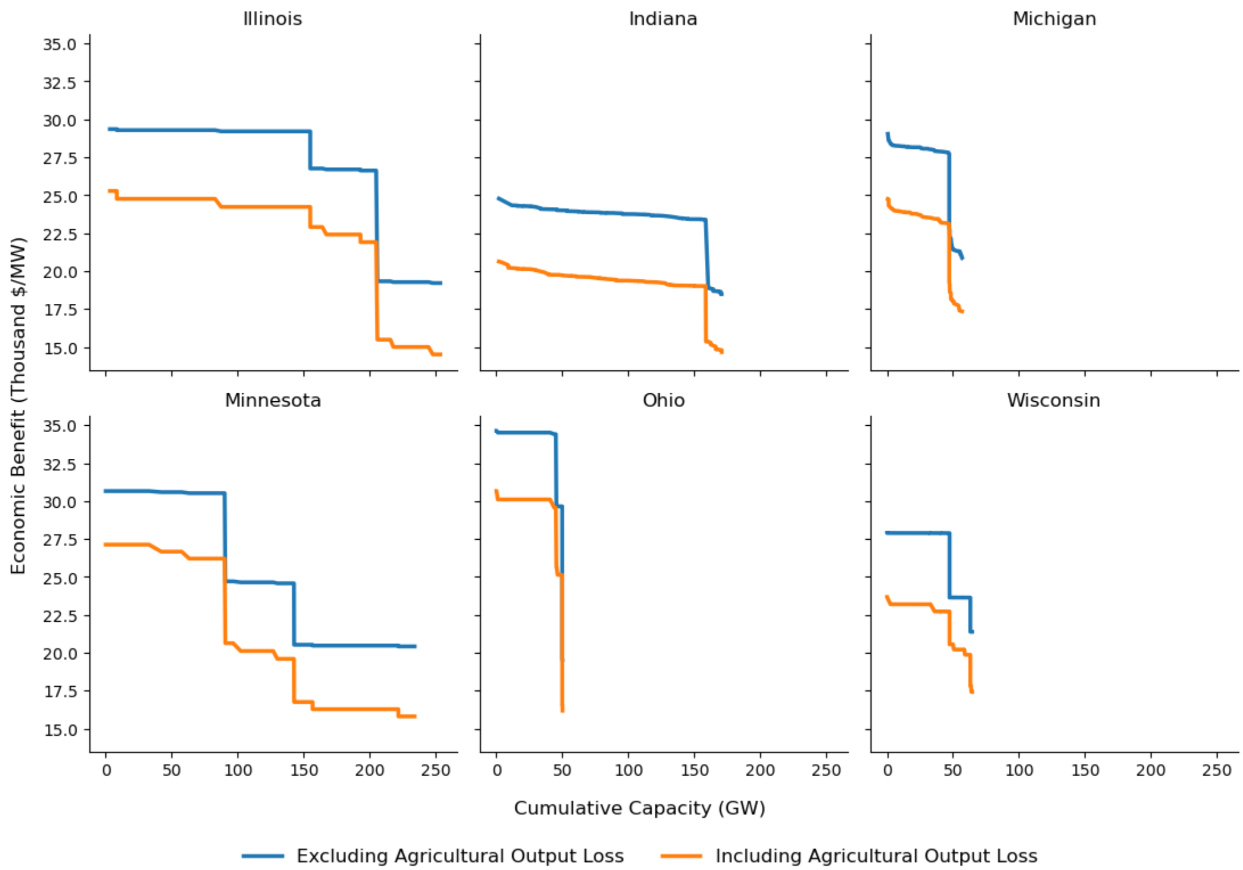

Fig. 2. Marginal benefit curves showing the value-added (thousand $/MW) as a function of cumulative solar capacity (GW). The blue line represents contributions to total state earnings, or value-added, without accounting for agricultural production losses, while the orange line measures the same accounting for agricultural production losses. The divergence between the blue and orange curves highlights the netting effect of accounting for supplanted agricultural production on economic benefits.

3.2 Effect of local economic impacts on utility-scale PV capacity investments

Fig. 3. illustrates investment decisions from our CE model by 2040 across the study region (3a) and their distribution by state (3b) under the base case scenario, which assumes a 100% weighting for minimizing system costs. Under this scenario, solar accounts for 37% (64 GW) of all new investments (Fig. 3a). These investments are driven primarily by zoning regulations, resource availability, and state-level minimum generation requirements. For instance, Ohio sees significant solar deployment in its eastern regions, despite lower solar capacity factors, largely due to the absence of restrictive zoning ordinances in these areas (SI-1 Fig. S4).

In Fig. 3c, we hold total investment capacity constant at the level observed in the base (100% cost) scenario and vary the weighting between cost minimization and community benefit maximization. This allows us to examine how capacity reallocates across counties with differing economic sizes and farmland productivity levels. Without imposing an upper limit on total buildout, the benefit-maximizing objective leads to unrealistically large solar investments (an infinite amount of investment, or an unbounded optimization problem, at the limit of only including maximizing community benefits in the objective via a weight of 1). Prioritizing community benefits shifts solar deployment to counties with larger economies and below-average farmland productivity. For instance, counties classified as large economies receive a total solar investment of 36, 41, and 52 GW when community benefit weight is 0%, 50%, and 80%, respectively. This increase in investment comes at the expense of declining investments in medium and small counties. Larger economies attract more investment because they yield higher local value-added impacts, due to their broader and more diverse industrial bases. From a system perspective, these locations may be less cost-effective in terms of resource quality, but the associated economic benefits more than offset the higher technology deployment costs under a community benefit–oriented objective. This shift is also influenced the availability of land, which is restricted by zoning regulations.

The influence of county farmland productivity plays a smaller role than county economy size. For example, solar investment in below-average productivity counties increases by 11%, from 16 GW under the 0% community benefit scenario to 19 GW under the 80% community benefit scenario, while investments in average and above-average productivity categories decline by 14% and 17%, respectively. This trend reflects the model's preference to avoid converting high-value farmlands when local economic benefits are prioritized.

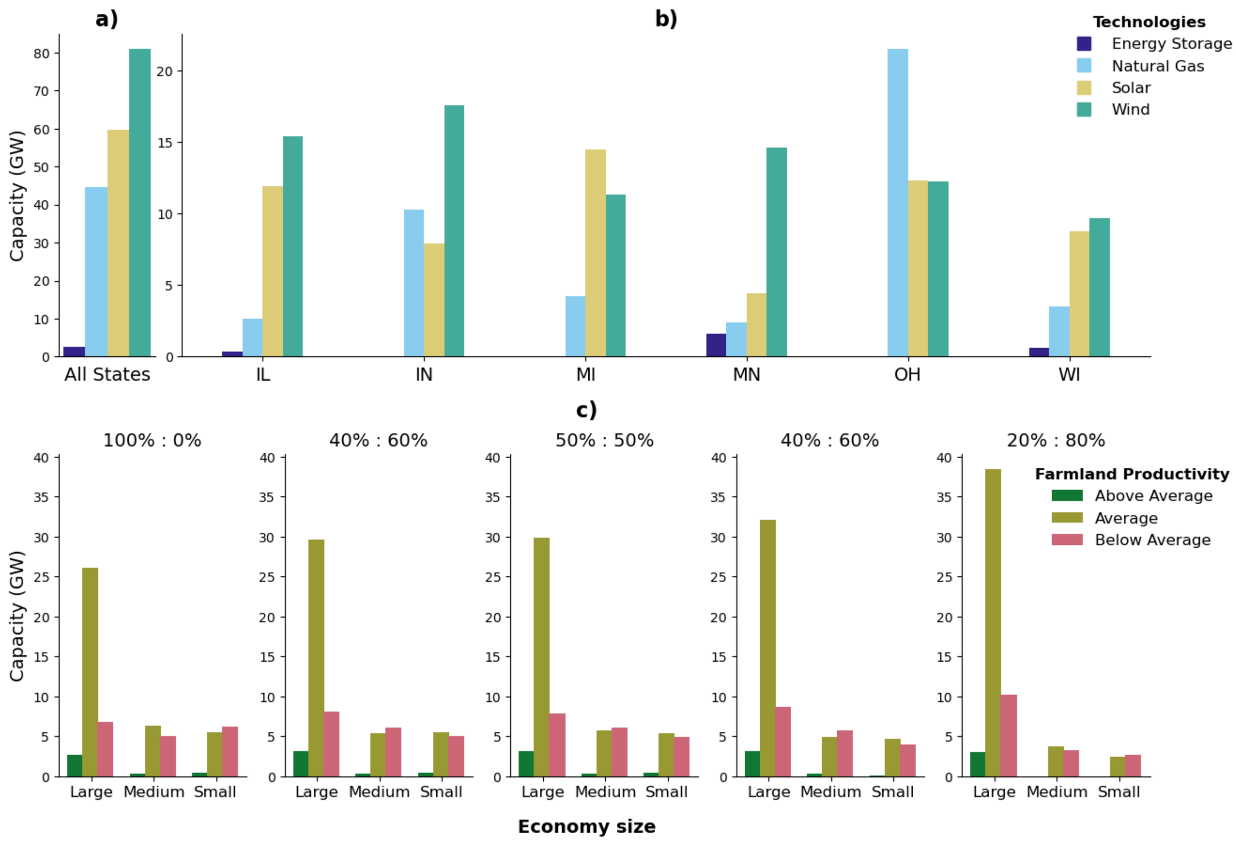

Fig. 3: Allocation of new technology investments by 2040 across the study area and states, and their distribution by economic and farmland productivity categories. (a) Total capacity additions by technology type across all states under the cost-minimization-only scenario (100% weighting of costs). (b) Distribution of investments across individual states under the same scenario. (c) Reallocation of solar capacity investments across county economy size and soil productivity categories for varying weighting ratio of cost minimization to community benefit maximization (written as cost minimization weight: community benefit weight).

3.3 Effect of local economic impacts on geographical distribution of new utility-scale solar

Fig. 4 illustrates the geographic distribution of new utility-scale solar deployments as community benefit weighting increases. Capacity shifts within and across states are influenced by economy size and farmland productivity categories. Comparing the base (100% cost) scenario to the 80% benefit scenario, new solar investments shift from Michigan (down 5.8 GW or 39%) and Wisconsin (down 2.7 GW or 31%) to states with a higher prevalence of counties characterized by large economies and lower soil productivity, increasing investments in Ohio (up 9 GW or 75%), Illinois (up 2.4 GW or 20%), Indiana (up 780 MW or 10%), and Minnesota (up 380 MW or 6%) (Fig. 4). These shifts also lead to the emergence of new counties with solar investments, including 9 additional counties in Ohio (18% increase), 8 in Illinois (35% increase), 2 in Indiana (14% increase), and 1 in Minnesota (8% increase).

Accompanying these shifts is a complementary increase in wind capacity and a decline in natural gas capacity. In the 80% benefit scenario, wind capacity grows significantly in Minnesota (by 6.9 GW or 45%) and Wisconsin (by 2.3 GW or 23%) (refer to Fig. 4 color bar). This growth is attributed to changes in solar generation profiles at new sites, requiring additional investment to ensure continued balance between electricity demand and supply. Conversely, total natural gas capacity decreases marginally by 2.1 GW (5%), with 2 GW occurring in Ohio.

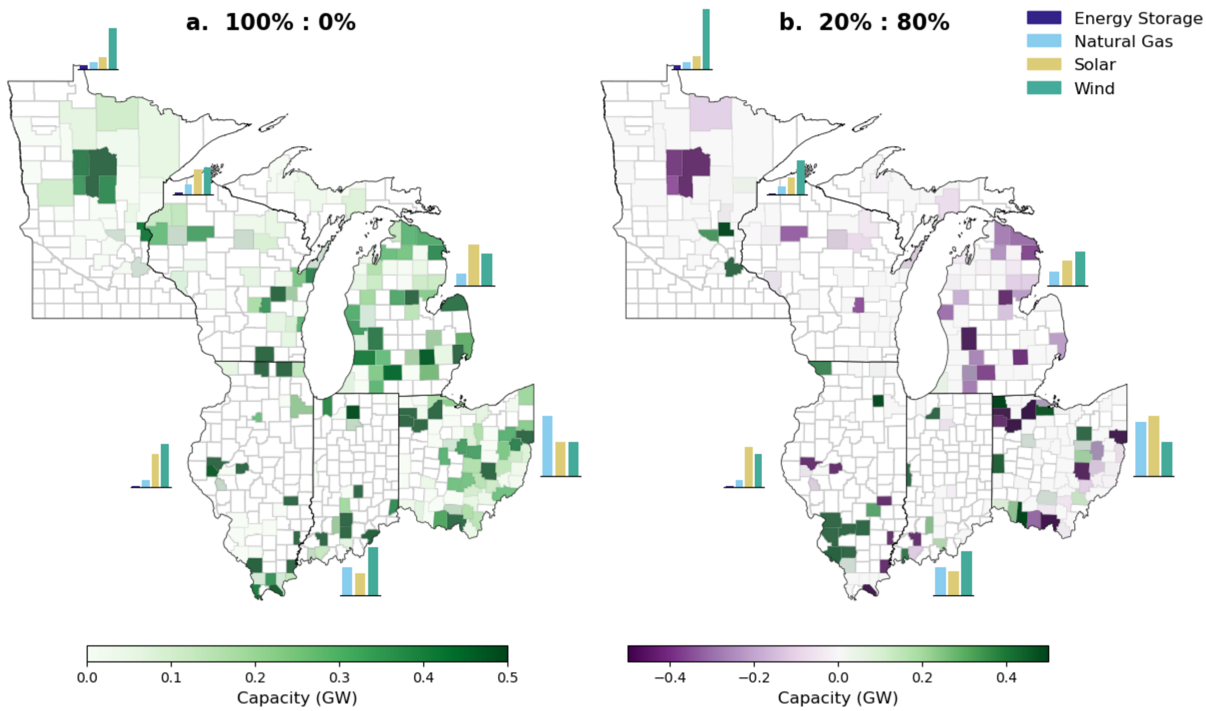

Fig. 4. Geographic shifts in new utility-scale solar as the weighting ratio between cost to local economic benefit is adjusted. (a) Is the represent the 100% cost scenario and (b) represents the 100% benefit scenario. Positive values on the scale (green) represent capacity additions, while negative values (purple) indicate capacity reductions. Color bars indicate the total capacity investment for each technology, with yellow for solar, green for wind, purple for energy storage, and blue for natural gas.

3.4 Effect of local economic impacts on the costs of utility-scale solar investments.

Prioritizing community benefits in siting decisions significantly increases local economic impacts with minimal effect on system-wide costs. As shown in Table S2 (SI-5), shifting from 0% to 80% community benefit weighting raises total value-added from $8.7 billion to $9.7 billion—a 11% or $1 billion gain—while system-wide investment rises by less than 0.5%. The magnitude of these local economic benefits varies widely across states. Minnesota experiences the largest percentage increase (41%, $442 million), followed by Ohio (24%, or $520 million), Indiana (5%, $75 million), Illinois (3%, $44 million), and

Wisconsin (1%, $16 million). In contrast, Michigan experiences a reduction of 7% ($100 million). These reductions reflect their lower value-added contributions per unit of installed capacity (Fig. 1d).

4 Discussion

This study quantifies the effect of local economic impacts on utility-solar investment and power sector decarbonization in the Great Lakes region of Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin. We develop and integrate marginal benefit curves of installing solar alongside supply curves for each county into a power system planning (or capacity expansion) model to simultaneously minimize system costs and maximize local economic benefits. We explore various weighting scenarios to assess the trade-offs between cost minimization and benefit maximization.

Our analysis reveals that relocating solar investments towards counties offering higher net economic benefits does not increase the total cost of decarbonization. Across our region, prioritizing local solar economic benefits increases aggregate economic impact by up to 11% ($1 billion) while total decarbonization costs increases by less than 0.5%. This finding challenges the conventional assumption that maximizing local economic benefits from renewable energy projects necessitates significantly higher overall system costs. This result aligns with emerging research on spatially explicit renewable energy planning [82], [83], demonstrating that strategic siting can unlock co-benefits without compromising cost-effectiveness. By adopting targeted planning guidelines, developers can prioritize counties with higher net economic benefits, fostering community acceptance and reducing local opposition or delays associated with permitting.

We also find that counties with robust local economies and lower farmland productivity deliver the highest value-added per megawatt (MW) of installed capacity. For example, large economies in Ohio generate an average of $34,500 per MW-year, a value that is 42% higher than that observed in smaller economies within the same state. Accounting for the opportunity cost of agricultural losses reduces these value-added contributions by up to 16% in some counties, depending on farmland productivity. This correlation between economic size and impact, while varying in magnitude across counties and states due to differing economic multipliers, remains consistent. This is expected, as previous studies using IO economic multipliers [5], [36], [39], also demonstrate a proportional scaling of economic impact with economy size. However, these prior studies often present an overoptimistic view by capturing solely positive economic benefits. Our findings highlight the critical importance of incorporating the opportunity cost of agricultural land into local economic assessments of solar development. Local governments should recognize that these costs can offset the perceived benefits, particularly in counties where agriculture contributes significantly to local revenues. While policies like agrivoltaics may reduce these opportunity costs, the required investment in specialized racking and mounting increases system costs relative to traditional utility-scale solar [84]. By explicitly weighing foregone agricultural revenues against projected economic gains, policymakers and community stakeholders can better target solar investments to regions where total net benefits are maximized.

Further, prioritizing locations with higher economic impacts leads to shifts in utility-scale solar capacity within and across states, resulting in a net reduction in natural gas capacity and a corresponding increase in wind capacity. Specifically, shifting 8.5 GW of solar investment from Wisconsin and Michigan to the remaining states increases wind capacity in the recipient states and concurrently reduces natural gas generation across the system. This technology substitution highlights the interconnected nature of renewable energy resource planning and the importance of system-wide coordination when evaluating local economic benefits. A regionally coordinated approach to solar deployment, where states collaborate to identify optimal siting locations based on both local economic and system-wide criteria, could diversify renewable energy resources, enhance grid reliability, and reduce reliance on fossil fuels.

Finally, we find that net property tax payments and payments in lieu of taxes (PILOT) are among the most influential drivers of local economic impact that are directly controllable by local governments. Our results show that Ohio's PILOT program, which provides relatively higher payments, correlates with a 75% increase in solar investment under scenarios that prioritize local economic benefits. While such payments can generate substantial revenue for local jurisdictions [85], excessively high or poorly structured tax rates may deter solar development. Previous studies have highlighted this trade-off, noting that elevated local tax burdens can raise project costs, reduce the net present value for investors, and shift development to neighboring areas with more favorable tax policies [86]. Therefore, local governments must strike a balance between maximizing public revenue and maintaining tax structures that remain attractive to private investment.

Our study has several limitations that future research could examine. First, due to the complexity and variability of county-level tax structures, we compiled property tax data at the state level rather than the county level. This aggregation may mask important local variations and potentially lead to under- or overestimation of property taxes in specific counties. Future research incorporating more granular, county-specific property tax data would provide a more precise assessment of local economic impacts. Second, while grouping counties under broad categories of economy size and agricultural productivity allowed us to assess the influence of these factors on local economic impacts and enabled generalization of our results, this categorization could obscure finer-scale relationships that might emerge from a more disaggregated analysis. Third, although our model integrates zoning and economic impact data for solar development, we lack comparable data for wind and other technologies. As a result, scenarios that optimize solely for cost may underestimate the siting challenges associated with wind or storage, while scenarios that prioritize local economic benefits may inadvertently favor more solar buildouts. To mitigate this bias, we hold solar capacity constant in scenarios that prioritize economic impacts, fixing it at the levels identified under cost-only optimization. Nonetheless, future work should seek to develop comparable zoning and local economic impact data for all technologies to enable a more balanced and comprehensive planning framework.

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6 Data Availability Statement

The data used in this study, including the Solar Economic Model, the Energy Zoning Database, and the input datasets for the capacity expansion model, are available from publicly accessible repositories. The Energy Zoning Database, which provides information on zoning ordinances relevant to renewable energy deployment, is accessible at https://energyzoning.org/ [83]. Other datasets supporting the analysis presented in this paper are available at https://doi.org/10.5281/zenodo.14983655 [84]. The Solar Economic Model developed for the study is available at https://doi.org/10.5281/zenodo.15231344 [69]. The Python code used for the capacity expansion model, which integrates the economic model and zoning regulations to assess solar deployment feasibility, is archived on Zenodo at https://doi.org/10.5281/zenodo.14983951 [85]. All datasets and software are released under open-access licenses to facilitate transparency and reproducibility.

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