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Technical and Financial Feasibility Study for Installation of Solar Panels at IDOT-owned Facilities

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16. Abstract

The Smart Energy Design Assistance Center assessed the administrative, technical, and economic aspects of feasibility related to the procurement and installation of photovoltaic solar systems on IDOT-owned buildings and lands. To address administrative feasibility, we explored three main ways in which IDOT could procure solar projects: power purchase agreement (PPA), direct purchase, and land lease development. Of the three methods, PPA and direct purchase are most applicable for IDOT. While solar development is not free of obstacles for IDOT, it is administratively feasible, and regulatory hurdles can be adequately met given suitable planning and implementation. To evaluate IDOT assets for solar feasibility, more than 1,000 IDOT sites were screened and narrowed using spatial analytic tools. A stakeholder feedback process was used to select five case study sites that allowed for a range of solar development types, from large utility-scale projects to small rooftop systems. To evaluate financial feasibility, discussions with developers and datapoints from the literature were used to create financial models. A large solar project request by IDOT can be expected to generate considerable attention from developers and potentially attractive PPA pricing that would generate immediate cash flow savings for IDOT. Procurement partnerships with other state agencies will create opportunities for even larger projects with better pricing. However, in the near term, it may be difficult for IDOT to identify small rooftop or other small on-site solar projects that are financially feasible. This project identified two especially promising solar sites so that IDOT can evaluate other solar site development opportunities in the future. This project also developed a web-based decision-support tool so IDOT can identify potential sites and develop preliminary indications of feasibility. We recommend that IDOT begin the process of developing at least one of their large sites to support solar electric power generation.

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EXECUTIVE SUMMARY

The State of Illinois has a stated goal to acquire 25% of its electricity from renewable sources by 2025. This project supports Illinois Department of Transportation (IDOT) in helping to achieve this goal by identifying and analyzing the potential for solar energy generation on IDOT lands. This work considers the procurement and economic ramification of solar energy generation on specific IDOT properties.

More specifically, in this report, the Smart Energy Design Assistance Center (SEDAC) assesses the administrative, technical, and economic aspects of feasibility related to the procurement and installation of photovoltaic solar systems on IDOT-owned buildings and lands.

Objectives

The main objectives of the research are to 1) determine the administrative feasibility of IDOT solar development; 2) determine the technical and economic feasibility of IDOT solar projects; 3) provide guidance on site selection for potential solar projects on IDOT lands; and 4) develop an overall strategy for moving forward with solar project development at IDOT. In the following sections, we summarize how we met each of the objectives.

Objective One. *Identify the applicable laws that affect the procurement, project development, and use of IDOT facilities and properties as host sites for solar energy generation.*

To address administrative feasibility, we explored three main ways in which IDOT could procure solar projects: power purchase agreement, direct purchase, and land lease development. Of the three methods, the first two are considered the primary means of solar development, while the third provides cash rent. A fourth possible method identified consists of a combination of the main three methods. We also identified issues associated with the use of IDOT rights-of-way and facilities in relation to potentially competing alternative uses, solar system interconnection and net metering, environmental protection objectives, and safety requirements. We find that the path forward is not free of obstacles and that the IDOT solar portfolio is likely to be affected by its regulatory environment. We conclude from this analysis, however, that solar development is indeed legally feasible, and regulatory challenges can be adequately met given suitable planning and implementation. Chapter 2 of this report details the nature of the ownership/agreement structures under consideration and evaluates the potential legal and administrative hurdles that may stand between IDOT and its renewable energy goals.

Objective Two. *Evaluate and prioritize IDOT-owned assets for solar production potential and develop cost-benefit estimates at a variety of specific IDOT sites.*

To evaluate IDOT assets for solar production, we compiled physical and locational data on IDOT sites in all nine IDOT districts (500 interchanges, more than 100 open land parcels, 50 rest areas, and more than 400 additional IDOT sites) and used spatial analytical tools to determine suitable places for solar production. The sites were narrowed through a manual review of each potential site. We then conducted a stakeholder feedback process to further narrow the sites to 40 and selected five case study sites based on suitability factors that cover a range of site types for detailed technical and economic review. Chapter 3 details our methodology and process for codifying unsuitability, exclusion, and selection. Of the 40 sites evaluated, five especially promising sites were identified and explored (Table 1) (see Chapter 4).

Table 1. Summary of IDOT Case Study Sites for Solar Feasibility Study

Site	Solar Type	District	Location	Site Area	Prelim Est. Solar Size	Utility
1	Large	3	I-80 Prairie Pkwy Corridor (near Minooka)	120 acres	Up to 25 MW solar; 35,000,000 kWh/yr	ComEd
2	Large	8	I-255 along Cahokia Creek (near Stallings)	68 acres	15 MW solar; 21,000,000 kWh/yr	Ameren
3	ROW	5	Bloomington Yard, I-55 @ I-74, south interchange	14,000 SF roof	68 kW (6,800 SF); 95,000 kWh/yr site electric	Ameren
			Towanda Yard, Old US-66	8,100 SF roof	36 kW (3,600 SF); 50,000 kWh/yr site electric	
4	ROW	5	I-57 & US-36 (near Tuscola)	12 acres	6 kW (700 SF); 8,000 kWh/yr site electric	Ameren
5	ROW	4	US-34 & IL-164 (near Monmouth)	9 acres	2 kW (200 SF); 3,000 kWh/yr site electric	McDonough Power

We explored the economics for direct purchase and a power purchase agreement (PPA) at each site (Table 2). The larger sites (1 and 2) are more economically attractive because they take advantage of economies of scale. We consulted with solar developers to refine the site economics and concluded that there is likely to be substantial developer interest in participation in the proposed case study projects. The availability of Illinois solar incentives changed drastically over the course of this study, and available incentives depleted late 2020, so the results of our economic model were not as economically attractive as earlier projections. In the near term, very large projects will get the best pricing, and small projects may be difficult to justify economically.

Table 2. Summary of Case Study Site Economics

Site	Solar System Size	Utility	Direct Purchase Option Cost ($)	PPA Option Cost ($/kWh)	Compare to: ($/kWh)
1	25 MW	ComEd	$30M	$0.05	$0.06
2	15 MW	Ameren Illinois	$18M	$0.06	$0.05
1&2	40 MW	ComEd/Ameren	$45M	$0.05	$0.05
3	108 kW	Ameren Illinois	$220k	$0.09	$0.08
4	6kW	Ameren Illinois	$15k	$0.14	$0.08
5	N/A	N/A	$210k	N/A	N/A

*"Compare to" rate is the value of the offset kWh; energy supply, capacity, and delivery, as appropriate.

Objective Three. *Develop a user-friendly decision-support tool to assess technical and financial feasibility of solar systems and any IDOT property.*

To intuitively assess the large portfolio of all IDOT-controlled properties statewide, a decision-support tool was developed that enhances decision-makers' ability to evaluate a wide range of potential sites.

The tool allows stakeholders to quickly evaluate the suitability of potential sites using an intuitive, familiar graphic user interface that describes address or location, district, utility, physical suitability, energy potential, and economics. Users can quickly scan areas within the state for potential suitable sites and zoom in to access more granular data. Chapter 5 explains how the system was developed and offers a demonstration of its use and efficacy.

Objective Four. *Develop an overall strategy for moving forward with solar project development at IDOT.*

Through the development of the case studies and the decision-support tool, SEDAC has offered a roadmap by which the most advantageous sites may be identified and developed to meet IDOT's renewable energy goals.

Characterization of IDOT's capacity for solar development projects. IDOT has substantial electricity demand across their portfolio. This makes for an attractive PPA contract of a scale that can entice solar developers to provide proposals at a competitive price. IDOT has at least two attractive sites that can support a large solar system and take advantage of economies of scale. IDOT also has several sites that are served by rural electric cooperatives and municipal utilities. These might be grouped to improve scale and viability (although not analyzed in this work).

Recommendations to achieve renewable energy goals. We recommend that IDOT consider at least two large projects be developed in collaboration with other state entities. This would provide substantial progress toward agency and state renewable energy goals. Additionally, this should be supplemented by a smaller grouping of project locations served by municipal utilities and/or rural electric cooperatives to enable IDOT to approach 100% renewable energy at their facilities.

Recommendations on financing and completing solar development projects. Because Illinois solar incentives were depleted in late 2020, large solar projects in collaboration with other state agencies currently offer the most attractive pricing. We recommend the use of PPAs for developing IDOT solar projects. This requires little or no out-of-pocket costs while also enabling IDOT to make use of the investment tax credit. Using PPAs also reduces IDOT's risk of deferred maintenance and other long-term costs. Available IDOT capital should be used to buy down the PPA rate. We do not recommend a direct purchase by the agency for maintenance and long-term culpability reasons.

As an agency of the State of Illinois, IDOT is permitted to install solar projects on agency facilities and land. We find solar project development to be administratively and economically feasible as well as environmentally desirable. The rules and required administrative procedures depend on case-by-case circumstances. The sites that present the most concern involve potential driver safety, including beyond the clear zone along high-speed areas of interstate routes, and where solar equipment may restrict visibility near intersecting or merging traffic. Although some locations are restrictive, there are many feasible locations for IDOT solar development projects, including maintenance yards, rest areas, and IDOT right-of-way parcels that can be accessed by local roads, US routes, or state routes.

We strongly recommend that IDOT begin the process of developing at least one of their large sites to support solar electric power generation.

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CHAPTER 1: INTRODUCTION

By the year 2050, solar energy generation is projected to climb to 48% of the total electrical energy produced in the US (up from 11% in 2017) (Smith, 2017). California is projected to increase its solar energy generation to 60% by 2030 (California Energy Commission, 2019). Illinois (in 2019), the fifth-largest energy-consuming state, produces only 10% of its electricity from renewable sources (primarily wind). In comparison, 53% is produced by nuclear power, 30% is coal fired, and 7% is from natural gas (US Energy Information Administration, 2019). When compared with other states or some European countries of similar size, it is apparent that the utilization of renewable energy in Illinois is still at the early stages of development. To begin to rectify this, the state seeks to increase the use of renewable energy, envisioning that it will play a vital role in climate mitigation, advancing the local economy, and improving public health (Illinois Environmental Council, 2019; Illinois Power Agency, 2019). An important consideration in these efforts is the identification of suitable places in the state for generating this type of energy.

The current Illinois renewable energy portfolio standard requires the State of Illinois to acquire 25% of energy from renewable sources by 2025, although projections show them falling short of that goal (NC Clean Energy Technology Center, 2018; Solar Energy Industries Association, 2019). A bill currently being debated, the Clean Energy Job Act, would require the state to obtain 100% of its electricity from renewable sources by 2050 (Illinois Clean Jobs Coalition, 2020). These legislative activities have prompted state agencies to take a more active role in renewable energy procurement. For example, the Illinois Department of Transportation (IDOT) is exploring an increase in in-state solar development activity by analyzing agency land assets compatible with renewable energy generation. The agency notes that to achieve ecologically and economically sustainable development, it is crucial to evaluate the potential for locating solar and other renewable energy resources on existing state assets. It is also important to engage and facilitate the decision-making process for the physical implementation of these resources at both the state and local level.

Toward these goals, the Smart Energy Design Assistance Center (SEDAC) is working with the Illinois Center for Transportation and IDOT, through project R27-207, to assess the feasibility of installing solar systems on IDOT facilities and rights-of-way and to provide guidance on site selection for future solar projects.

PROJECT RESEARCH QUESTIONS

To help guide this project, a series of research questions were defined. A summary of each research question, organized by objectives, is provided below:

Objective One: Identify applicable laws that could affect procurement, project development, and use of IDOT facilities and rights-of-way as host sites for solar systems.

- How will applicable laws and administrative rules affect solar project procurement and development at IDOT?

- What is the potential for using power purchase agreements to develop IDOT solar projects, where IDOT or other Illinois state agencies would be customers for the solar electricity?
- What are the solar project development issues associated with use of IDOT rights-of-way and facilities, in relation to potentially competing alternate uses, environmental protection objectives, and safety requirements?

Chapter 2 addresses these questions, presenting the administrative feasibility, barriers, and rationale for this work.

Objective Two: Evaluate and prioritize IDOT-owned assets for solar production potential and develop cost-benefit estimates at a variety of specific IDOT sites.

- What is the potential for leasing IDOT land assets and facilities to solar developers, where outside entities would be the customers for the solar electricity?
- Are there scenarios where IDOT should consider outright ownership as a means to procure and install solar systems?
- What are the cost estimates and revenue projections for solar projects at IDOT locations?
- What federal, state, and local incentives and programs are available to support solar project development on IDOT assets?
- What is the interest level and capacity of various solar project developers and operators to partner with IDOT on solar projects?

Objective Two is met in Chapters 3 and 4, the first of which provides detailed descriptions of our methods for evaluating and prioritizing sites for solar development. Chapter 4 provides results of this analysis.

Objective Three: Develop a user-friendly decision-support tool to assess technical and financial feasibility of solar systems and any IDOT property.

- In the future, how can IDOT personnel develop preliminary indications of feasibility of solar projects at any IDOT site?

This question is addressed in Chapter 5, which deals with the development of a decision-support tool.

Objective Four: Develop an overall strategy for moving forward with solar project development at IDOT.

Chapter 6 offers implications of the study, including major findings, suggestions, recommendations, and improvements. There is one appendix: Solar Suitability Analysis Details.

CHAPTER 2: ADMINISTRATIVE FEASIBILITY

This chapter seeks to determine whether solar development is administratively feasible by identifying applicable laws and issues that could affect procurement, project development, and use of IDOT sites for solar systems. We explore the use of power purchase agreements and other means to develop IDOT solar projects. We identify issues associated with the use of IDOT rights-of-way and facilities in relation to potentially competing alternative uses, solar system interconnection and net metering, environmental protection objectives, and safety requirements.

SOLAR PROCUREMENT AND LEASING

There are three ways IDOT could procure solar projects: power purchase agreement, direct installation, and land lease development. Of the three methods, the first two are considered the primary means of solar development. A fourth possible method consists of some combination of the first three methods.

First, a power purchase agreement (PPA) is an agreement by which IDOT would provide access to lands and/or facilities to a solar developer and then purchase the electricity from the developer at a contractually agreed-upon rate, typically for 10 to 25 years. The Illinois Procurement Code (30 ILCS 500/25-47) specifically allows Illinois state agencies to procure renewable energy in contracts of up to 25 years in duration, as in a PPA.

With PPAs, a private entity owns the solar system, and IDOT would be able to indirectly capture the value of federal solar tax credits in the agreement, for substantial cost savings. This is one important advantage of a PPA over direct ownership. An additional benefit of a PPA is that the developer is responsible for ensuring ongoing operation and maintenance throughout the duration of the contract. The operation and maintenance of large-scale solar systems is specialized, and maintenance shortfalls can seriously degrade the system performance. This degradation can reduce or eliminate the potential for cost savings and renewable energy generation.

Second, direct installation refers to a project in which IDOT would be responsible for purchasing, installing, and maintaining solar panels and managing the power they generate. This option requires considerable upfront capital investment and technical expertise but has the potential to be a more streamlined procurement process for on-site commercial-sized solar systems, when compared to a PPA. In a direct installation scenario, it is critical to allocate the necessary staffing and/or funding resources so that any IDOT-owned solar system receives adequate maintenance and repairs as needed and required.

Third, a land lease to a solar developer is also an option for developing solar on IDOT parcels. In this scenario, IDOT would not receive the energy benefits of the solar system but would benefit from revenue-generating lease payments. Typically, this type of agreement would involve a solar developer installing and maintaining a project that provides renewable energy to customers other than IDOT. In other words, a lease arrangement would not increase IDOT’s renewable energy consumption, although it could contribute to broader State of Illinois renewable energy goals. This option is viable only if developers are aware of the availability of a site and interested in developing it. Sites smaller than 10 to 12 acres are unlikely to attract interest; sites with hundreds of acres would be preferred for utility-scale developments.

Lease rates for recent solar developments in Illinois commonly range from $500 to $2,000 per year per acre with most leases in the $800 to $1,000 range. IDOT already has existing leases on certain right-of-way parcels for agricultural use, so IDOT could explore whether this mechanism, or a similar one, could be used to allow for leasing to solar developers. IDOT could also consider leasing of facilities and lands to a developer in return for regular lease payments.

Finally, a combination of these options is also possible. For instance, several of IDOT's parcels are larger than the area required to offset the agency's total annual electric consumption. It could be possible to rent the extra land for revenue-generating lease payments and let that renewable electricity serve the developer's other customers. Similarly, a PPA may be arranged at a more beneficial price per kWh with a certain upfront capital investment in the project. It is also common that PPAs include options to buy out the system during the project duration, combining direct ownership and PPA benefits.

Impact of Illinois Procurement Rules. Illinois procurement rules create special challenges for solar project development for state agencies. Solar pricing is sensitive to factors including project size, project location, and site-specific physical characteristics, and there can be significant variability in pricing between vendors. Typically, a buyer would call multiple vendors to discuss project specifics and obtain indicative pricing estimates before requesting proposals and moving forward with formal procurement actions. Solar procurement is still relatively new and complicated for government agency officials in Illinois, and the preliminary conversations provide information and vendor feedback that is an important foundation for a competent buyer. The state agencies are restricted from engaging in these important, informal conversations because of the risk of disqualifying potential bidders.

A request for information (RFI) is theoretically a useful mechanism for state agencies to obtain this type of information in advance of a request for proposals (RFP); however, conversations with personnel across multiple Illinois state agencies reveal an overall reluctance to engage the RFI process and skepticism that the results justify the effort. A streamlined process for obtaining feedback from developers and vendors, relating to pricing and other project development factors, would increase the competency of the state agencies as potential solar buyers and increase the likelihood of successful procurements through solar RFPs.

RIGHT-OF-WAY AGREEMENTS

As with other procurement contracts, solar development project work must be preceded by an agreement between IDOT and the vendor. Especially in the case of large projects and any projects located in areas where FHWA review is applicable, a right-of-way use agreement or license agreement may be required to address contractual provisions that include the following:

- A finding by IDOT that the project is in the public benefit
- Terms and conditions regarding installation, maintenance, operation, and removal
- A plan for safety and security, for items such as fencing and lighting
- An indication of IDOT's responsibility for obtaining FHWA approval of the agreement
- A vegetation plan
- An indication of what happens in case future road work affects the solar facilities
- Inclusion of design drawings and facilities specifications
- Inclusion of a plan for maintenance of traffic during construction

These provisions are based on land use agreement associated with a Georgia Department of Transportation solar project (Georgia DOT, 2019).

SOLAR SYSTEM INTERCONNECTION AND NET METERING

There are two typical arrangements for interconnecting solar systems to the electric utility grid: behind the meter and in front of the meter.

Behind-the-meter interconnection usually involves a system that serves a facility or group of facilities that are associated with a single electric utility account, and the system is normally located at or adjacent to the facility. The system is sized to generate a portion, not greater than 100%, of the electricity used at the site. Any electricity generated by the system offsets, or reduces, the amount of electricity billed by the electric utility by the amount of electricity produced and used on the site. Distributed generation behind the meter is favored by utilities as it reduces load on the grid.

Any additional electricity that is generated but not used on the site is fed back into the grid and is subject to "net metering" agreements. Up to net metering limits prescribed by the utility company, the utility will provide credit for overproduction (such as during the day) and trades them for electricity delivered at other times (such as overnight). This accounting process benefits the facility in that it reduces the amount of billable electricity consumption by the amount of electricity generated by the solar system. Generation in excess of consumption in one month can be carried as a credit in subsequent months. However, the net metering benefit does not extend to electricity generation beyond the facility's consumption of electricity over an annual period (for Ameren Illinois, ComEd, and MidAmerican Energy) or a quarterly period for some rural electric cooperatives. In practice this means that net-metered solar systems must be sized so that the generation does not exceed the site electricity consumption over the annual or quarterly period, depending on the utility territory.

Most electric utility companies in Illinois allow behind-the-meter interconnection and net metering, after processing customer applications and associated fees, which vary by utility company. The interconnection process is relatively simple. Some municipal electrical companies do not allow net metering. In addition to electricity generation limits, utility companies also limit the maximum solar system sizes allowed in net metering applications.

- In ComEd, Ameren Illinois, and MidAmerican Energy, the net metering size limit is 2 MW (2,000 kW). This is well beyond the annual electric use of almost all IDOT facilities. Therefore, the system could be sized up to the full annual electric use of the facility.

- Rural electric cooperatives generally have net metering limits around 10 kW. A 10 kW system would generate a roughly estimated 13,000 kWh of electricity per year, valued at approximately $1,300 per year, so facilities that use more than this amount of electricity in a year could apply for net metering for solar systems up to 10 kW. Based on past SEDAC evaluations of maintenance yards and sign shops, a 10 kW solar system would generate 10% to 25% of the electricity used at these sites.

- Alternatively, a system could be sized to provide only the electricity expected to be consumed during daytime generation times and no more. In that scenario, a net metering application would not be needed or applicable.

In 2016, IDOT procured a wind turbine with a capacity of 10 kW at the Krisdala Baka Rest Area, and it was installed behind the meter. Electric utility service at this location is provided by MidAmerican Energy.

In contrast, interconnecting in front of the meter typically provides electricity to multiple facilities that are located remotely from the solar system. These installations are typically large and are most commonly procured through a PPA due to the large capital investment and the complex installation and maintenance involved. These systems, typically referred to as "utility scale," are more economical to install due to economy of scale. However, the per kWh rate paid by the accounts served would be higher.

Because these types of systems rely upon the existing utility grid to deliver electricity to the accounts served, the utility company would continue to bill the associated electric accounts for distribution charges. The other portion—the supply charges—are paid through the PPA to the company that owns and operates the solar system. This type of arrangement is considered economically beneficial when the total electric cost (distribution and supply) is less than or equal to the baseline costs, before the solar installation. The interconnection processes are complex and normally mediated by a solar developer.

EXISTING ELECTRIC SUPPLY CONTRACTS

The State of Illinois, via the Illinois Department of Central Management Services (CMS), has entered into a contract for statewide electricity services with Constellation NewEnergy, Inc., which is in effect from January 1, 2020, until December 31, 2022. This includes IDOT facilities. The agreement provides fixed-rate electricity supply pricing for state facilities located in ComEd ($0.04117/kWh) and Ameren Illinois ($0.05102/kWh) service territories. As is typical, these facilities are also billed monthly for distribution charges associated with their electricity use by the electric utility (ComEd or Ameren Illinois), so the total cost of electricity use includes supply charges and distribution charges. IDOT and other state facilities located in territories served by rural electric cooperatives or municipal electric utilities are not covered under this contract.

It is likely that this electric supply contract would be impacted by a PPA or alternate electric supply agreement that becomes effective during the electric supply contract period. SEDAC has asked CMS for clarification on this point, and while the response was inconclusive, CMS did agree that future electric supply contracts should be negotiated to include flexibility to allow new solar projects. IDOT should coordinate in advance with CMS on any large solar project planning.

POLICIES AFFECTING SYSTEMS ON RIGHTS-OF-WAY ALONG HIGHWAYS

The following policies influence the development of solar systems on IDOT ROWs:

- **Non-highway Use of Interstate ROW**. Non-highway-use projects on interstate ROWs, including solar systems, must be approved by IDOT and then submitted to FHWA for review and approval. Per 23 CFR § 710.403, to be approved by FHWA, the project must be in the public interest and must not interfere with normal use, maintenance, operations, and safety of the highway. The IDOT *Land Acquisition Manual* provides the established process for review and approval of non-highway uses of IDOT ROW. This applies to ground- and building-mounted solar installations. Applicable regulations include 23 CFR § 1.23; 23 CFR § 710.403; and 23 CFR § 710.405.

- **Clear Zone Policies**. FHWA provides guidance as to where potential obstructions, such as solar installations, may be located along IDOT highway ROW. IDOT *Bureau of Design and Environment Manual*, Chapter 38 calls for clear zones of between 30 and 46 feet from the travel lane. The land that is outside of this clear zone may be available for solar projects mounted on the ground along IDOT highways.

- **Classification as a Utility**. Some members of the IDOT Technical Review Panel for this research project indicated that access requirements might be easier for solar installations on ROWs that can be classified as a utility. According to the Federal Energy Regulatory Commission, the utility classification is applied to generating facilities with a nameplate electrical capacity rating greater than 80 MW. An installation such as this would require an estimated 500 or more acres of roughly contiguous ROW land; therefore, the utility classification is most likely not applicable.

- **FHWA Clarification on ROW Alternate Uses**. In a memo on April 27, 2021, FHWA (2021) clarified its policy position in support of the use of ROW for alternate uses including solar development projects, as long as the project does not adversely affect safety or the transportation purpose of the roadway.

SOLAR RIGHT-OF-WAY PROJECTS IN OTHER STATES

Several states have already developed solar right-of-way projects, including Georgia, Oregon, Massachusetts, Maryland, and Minnesota. Brief descriptions of these efforts are provided below.

- **Oregon**. On December 19, 2008, the nation's first solar highway project started feeding clean, renewable energy into the electricity grid, and the first Oregon Solar Highway project has been operating seamlessly ever since. The 104 kW (dc) ground-mounted solar system, made up of 594 solar panels, is situated at the interchange of Interstate 5 and Interstate 205 south of Portland, Oregon, and offsets more than one-third of the energy needed for freeway illumination at the site. Portland General Electric owns and operates this solar power plant. Solar energy produced by the system feeds into the grid during the day, in effect running the meter backwards for energy needed at night to light the interchange through a solar power purchase agreement. The project was developed through an innovative public-private partnership between the Oregon Department of Transportation and Portland General Electric, and US Bank as PGE's tax equity partner. The Renewable Energy Certificates are retired on behalf of PGE's customers, including the state and the Oregon Department of Transportation.

- **Massachusetts**. In the summer of 2013, the Massachusetts Department of Transportation (MassDOT) issued a Request for Response to install solar photovoltaic (PV) generating facilities at multiple parcels within the state highway layout with a minimal of 6 MW aggregated capacity. As of March 1, 2020, MassDOT-Highway has developed approximately 4.3 MW of PV at eight sites across the state. These sites combine to generate approximately 5,300,000 kWh of energy annually, which is equal to the average power consumption of 875 homes in Massachusetts. Replacing that amount of electricity in the current ISO-NE grid with solar power leads to 2.3 tons of carbon dioxide emission reduction annually. MassDOT-Highway saves approximately $600,000 annually or $12 million over the 20-year contract period at the sites.

- **Minnesota**. Minnesota Department of Transportation (MnDOT) is exploring how solar energy development on their rights-of-way can help meet MnDOT energy needs, reduce long-term operational costs, and reduce greenhouse gas emissions. In October of 2019, MnDOT completed its first right-of-way project with Cooperative Energy Futures for a solar project on Ramp A in downtown Minneapolis. The solar garden uses 3,760 panels and is expected to produce 1.4 MWh of electricity each year. The elevated solar panels function like a carport above the parked cars and cover more than half the parking spaces on the top deck of Ramp A. No parking spaces were lost during construction. Bill credits will offset MnDOT Metro District electricity costs for lighting on I-394 in Hennepin County.

- **Georgia**. In 2020, the Georgia Power Company commercialized a 1 MWh solar system at Exit 14 of The Ray Highway. The right-of-way solar project is a partnership between Georgia Department of Transportation, Georgia Public Service Commission, and Georgia Power, with support from its parent—Southern Company, the Electric Power Research Institute (EPRI) and The Ray. The solar energy produced and all associated renewable energy credits benefit Georgia Power's customers. The project also uses native, flowering plants as ground cover within the solar system, making Georgia the first in the nation to install pollinator-friendly ROW solar.

ENVIRONMENTAL LAWS AND POLICIES

Environmental laws and policies may impact where solar systems can be developed on IDOT lands and the administrative processes that would be required. These laws and policies require state agencies to consider the potential adverse effects of projects on the environment, and they typically involve application and review procedures. However, they do not necessarily prevent a solar installation at a given location.

The National Environmental Policy Act (42 U.S.C. §4321). This law requires federal agencies to consider impacts to the environment whenever a project uses federal funding or requires federal approval or permit. A National Environmental Policy Act (NEPA) review process may be required for solar development on interstate ROW, including building- or ground-mounted solar installations.

EcoCAT, the Ecological Compliance Assessment Tool of the Illinois Department of Natural Resources (DNR), can be used to help IDOT initiate a natural resource review of potential lands. This is a State of Illinois requirement that applies to ground-mounted solar installations, and the applicable laws include:

- The IL Endangered Species Protection Act (520 ILCS 10)
- The IL Natural Areas Preservation Act (525 ILCS 30)
- The Interagency Wetland Policy Act of 1989 (20 ILCS 830)

In addition to the environmental review requirements, SEDAC identified two laws regarding pollinator and prairie areas that may be applicable:

- **Pollinator Friendly Solar Site Act (525 ILCS 55)**. This act provides for an Illinois solar scorecard and a process for official recognition as a pollinator-friendly solar site. Participation and compliance with this act are voluntary.
- **IDOT Pollinator and Prairie Areas Policy**. IDOT has natural pollinator and prairie areas on IDOT rights-of-way that may need to be considered when evaluating potential solar installation sites. IDOT has been working with the University of Illinois at Chicago Energy Resources Center on these types of issues, including geospatial identification of these locations. The location information was not provided to SEDAC. However, the experience of conducting an IDOT stakeholder review process for solar site selection revealed that IDOT personnel are aware of the pollinator and prairie areas on IDOT ROW and prepared to provide feedback on sensitive locations when given the opportunity for input on potential solar development locations.

Industry-standard practices and the regulatory environment do pose some restrictions on IDOT development of solar projects. Fortunately, in general terms, these restrictions appear to be surmountable with sufficient care and oversight. In the following chapter, we incorporate this understanding of administrative feasibility into a method that can be applied to evaluate the feasibility of individual IDOT-controlled sites across Illinois.

CHAPTER 3: SOLAR SITE SCREENING AND SITE SELECTION

This chapter explains a method that was developed to screen potential IDOT solar sites for suitability for solar development and to narrow the list of potential sites through a stakeholder feedback process. Thus, this chapter is primarily concerned with the first portion of Objective Two, which deals with the evaluation and prioritization of IDOT-owned assets for solar production potential. The second portion of Objective Two, dealing with development of cost-benefit estimate of a variety of specifically selected sites, is treated in Chapter 4.

In general terms, the site selection approach was to compile IDOT sites, rapidly prescreen a large number of IDOT sites for a preliminary list of potentially suitable sites, and to narrow that preliminary site list through a manual review of each potential site. This was followed by a stakeholder feedback process. Finally, we selected five case study sites based on suitability factors and to cover a range of IDOT site types for detailed technical and economic review in Chapter 4.

SEDAC collected information on lands and sites that IDOT owns in all nine IDOT districts. This included nearly 500 interchanges, more than 100 open land parcels, 50 rest areas, and more than 400 additional IDOT sites. SEDAC used geographic information system (GIS) analysis to prescreen large sites and manual review for small sites, using technical selection criteria for ground-mounted solar systems, such as land use / land cover data, ground slope and solar directional aspect, proximity to transmission line or to direct point-of-use, status as an environmentally protected area, and 100-year floodplain status. These sites were also analyzed based on solar suitability criteria based on available load to be served by the solar systems.

For ground-mounted solar systems, the preliminary sites were identified by developing a method to rapidly prescreen lands for solar energy generation. We generated a solar site suitability map for the entire state of Illinois and applied it to IDOT lands to identify suitable sites. We divided the state into five IDOT regions and selected the IDOT sites with the highest scores in each IDOT district and location category. The top sites were provided to IDOT stakeholders for feedback and qualitative review. Site selection was narrowed based on this feedback and review. Screening and selection of potential roof-mounted solar systems was considered through a manual review process because the data-based rapid prescreening methods used do not apply to roof-mounted scenarios. Due to the preferences of key IDOT stakeholders, we chose to focus on rooftop solar at IDOT maintenance yards.

IDOT SITES REVIEWED

IDOT provided a database of locations that are owned by the Department. This included several different categories of parcel types. The data included 168 maintenance yards, 95 pump stations, 53 rest areas, 45 office buildings, 31 weigh stations, and 19 communication towers. The locations of these facilities are shown in Figure 1. Of these, maintenance yards, rest areas, and office buildings were determined to be potentially suitable for solar development. Pump stations and communication towers typically do not contain substantive land areas for solar development. IDOT had stated that weigh stations are under the control of the Illinois state police and therefore would not be considered under this project.

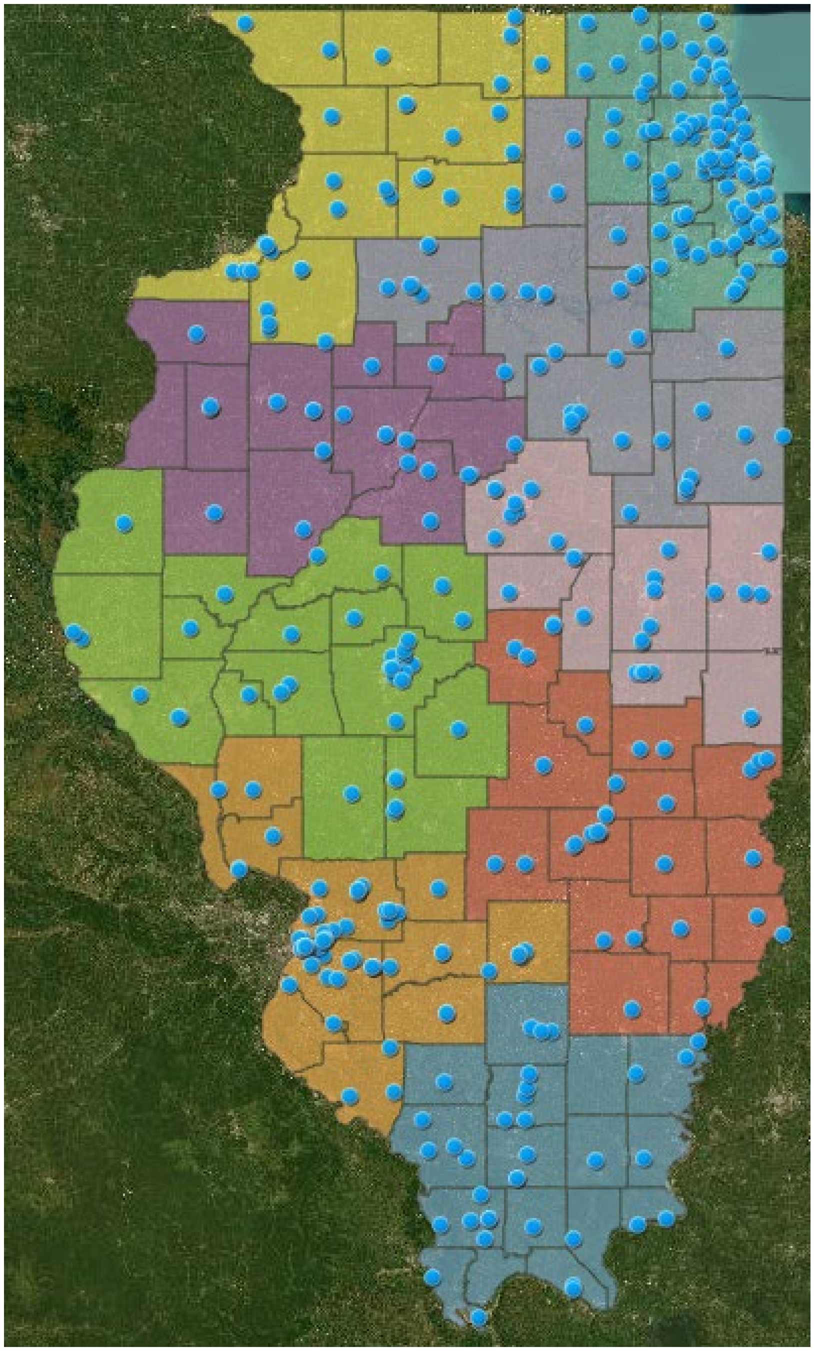

Figure 1. IDOT asset map. The map shows locations of IDOT facilities assets, including maintenance yards, pump stations, rest areas, office buildings, weigh stations, and communications towers.

IDOT also provided a shape file for open lands that were gathered for another project looking to add new truck parking facilities around the state, with locations indicated in Figure 2. SEDAC broke down the parcels by size. A shape file is a data file that is readable by a GIS and contains boundaries and locations along with associated data. The total area covered by these open land parcels is 978 acres across 95 parcels. The vast majority of these (84) are less than 20 acres. The remaining 11 parcels contain just less than 400 acres, or 41% of the total area.

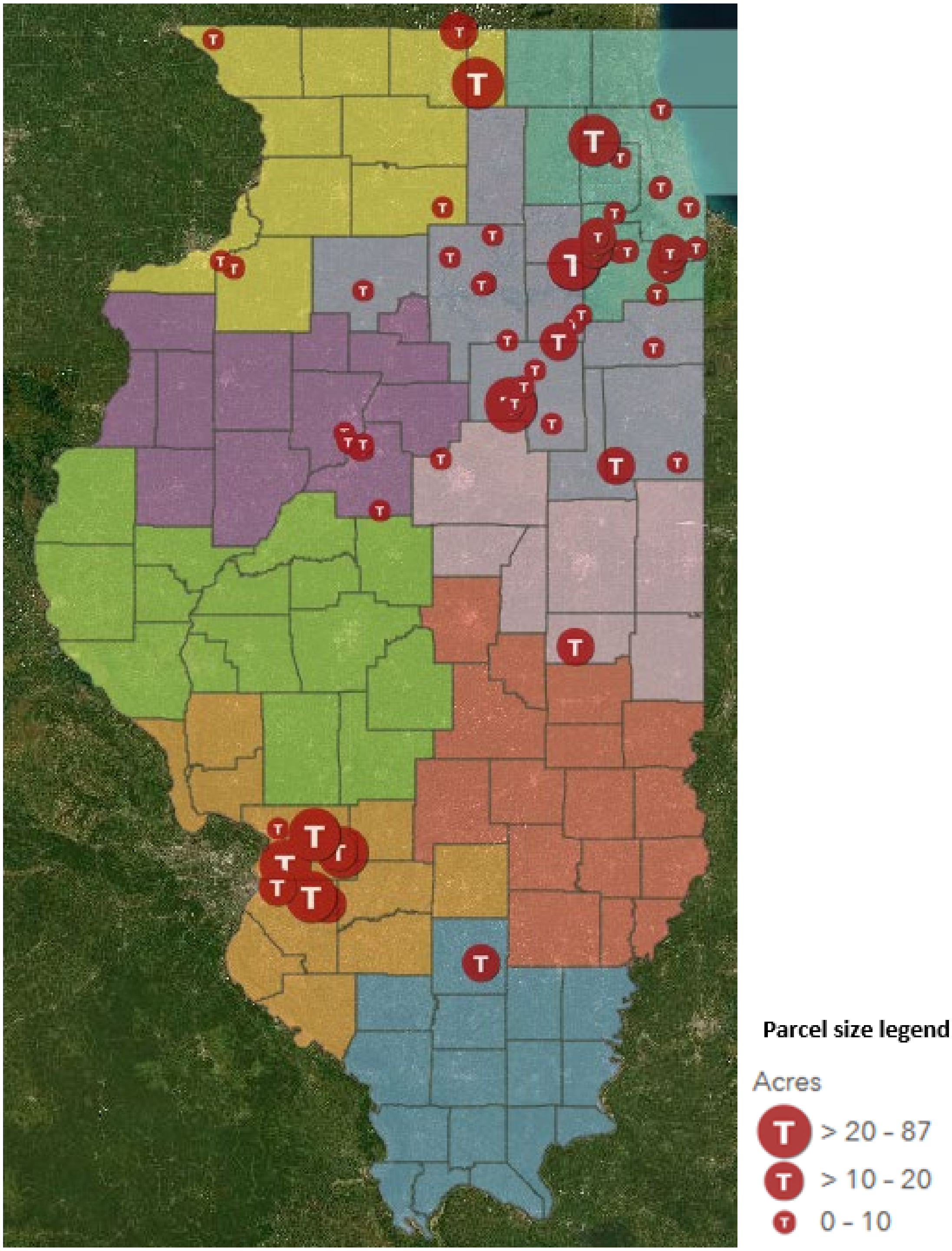

Figure 2. Excess lands map. The map shows excess land (T) locations for solar consideration. Larger circles are bigger sites.

SEDAC did a similar assessment of the 53 rest areas and welcome centers, which collectively comprise 1,500 acres of land area (Figure 3). Most locations (39) were between 13 and 39 acres. Six rest areas are smaller than 13 acres and nine rest areas are larger than 39.

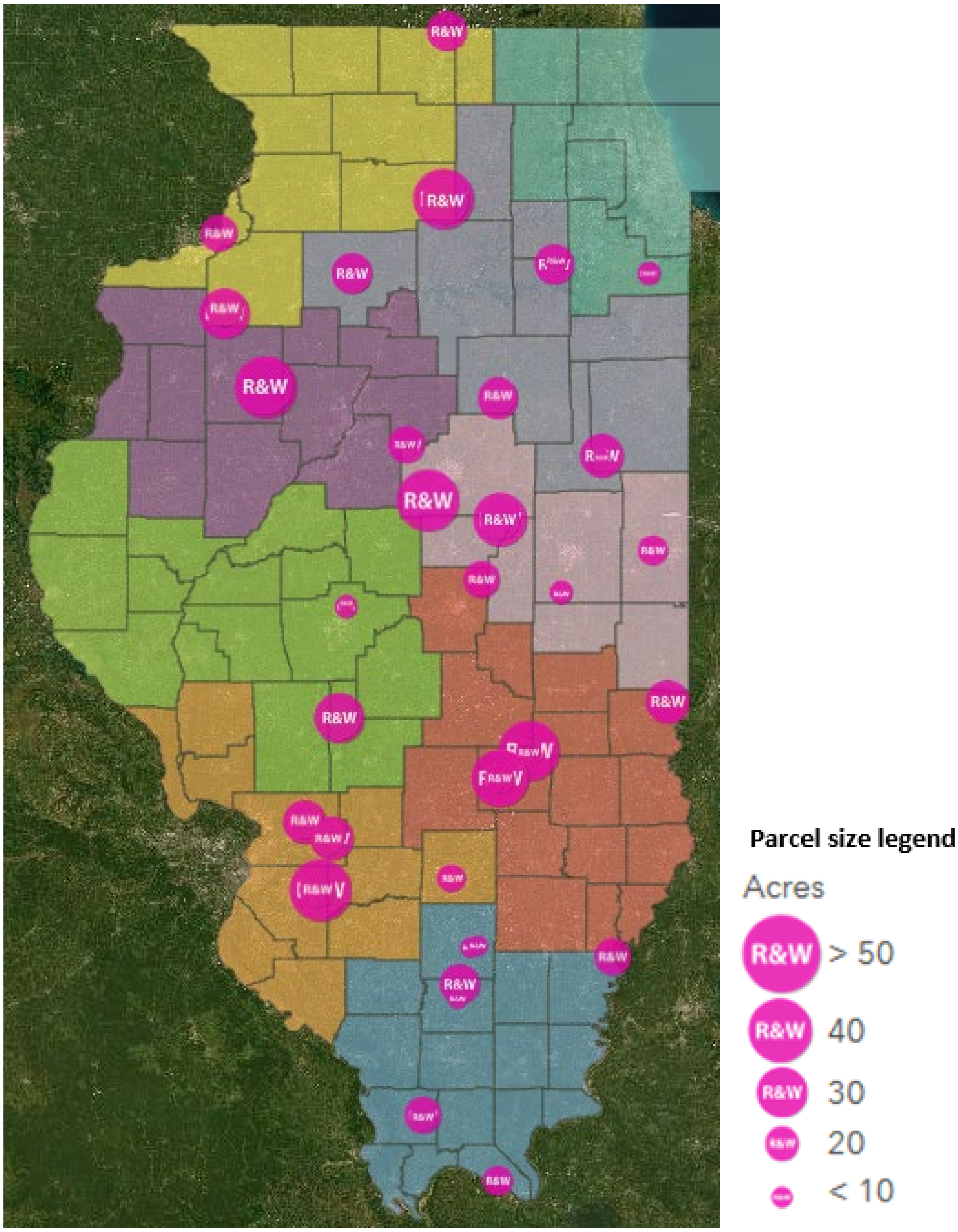

Figure 3. Rest areas map. The map indicates the areas of rest areas and welcome centers (R&W). Larger circles are bigger acreage sites.

SOLAR SUITABILITY ANALYSIS BACKGROUND

Site suitability criteria. SEDAC reviewed eight published solar suitability feasibility studies to determine site suitability criteria for solar development and to establish GIS methods for evaluating site suitability (Dahle et al., 2008; Zvolanek et al., 2013; Charabi & Gastli, 2011; Sánchez-Lozano et al., 2013; Wang et al., 2017; Majumdar & Pasqualetti, 2019; Janke, 2010; Li, 2013). Based on this review, SEDAC identified the following criteria for assessing the solar suitability of sites, shown in Table 3. These criteria address the environmental, economic, and social characteristics that influence the sustainability of the solar development at these potential sites. Also included in this table are exclusion criteria. Explanations of each type of criteria are provided in following subsections. Additional details on methods are included in the appendix.

Table 3. Site Selection Criteria by Category

Exclusion criteria	Environmental criteria	Social criteria	Economic criteria
• 100-year floodplains • Protected natural lands • Water bodies	• Solar radiation • Slope percentage • Aspect • Elevation	• Land use and land coverage • Population center density	• Distance to transmission lines • Access to roads • Crop productivity

Exclusion Criteria. Exclusion criteria represent constraint areas for solar development, so we began the site selection process by eliminating areas from consideration based on these criteria. In this study, they include 1) water bodies, 2) 100-year floodplains, and 3) ecologically sensitive or protected areas (US Geological Survey, 2019) that include conservation areas. It is worth mentioning that we include urban areas, forests, and parks in the analysis, which are typically designated as constraint areas in many studies (Al Garni & Awasthi, 2017; Watson & Hudson, 2015; Doorga et al., 2019; Zoghi et al., 2017; Doljak & Stanojević, 2017). We believe that the highest and best use criteria should be applied to all development decisions—determined by local stakeholders. Exclusion datasets were merged and rescaled using a binary scale, where 1 represents a viable location for development while 0 is a non-viable one.

The first exclusion criterion was met (i.e., a site was excluded) if the site was within a 100-year flood plain. The Midwest has experienced unprecedented flooding events in recent years. Because flooding can damage solar equipment and structures, including inverters, we excluded land within 100-year floodplains. The 100-year floodplain data was downloaded from the Illinois Geospatial Data Clearinghouse, which provides 100- and 500-year flood zones from 1986 (Illinois State Geological Survey, 2015).

Also excluded from consideration were protected natural lands. Due to state and federal laws, solar systems may not be developed on protected natural lands, including Illinois nature preserves. We used the Protected Areas Database from USGS to determine the protected natural lands in Illinois. USGS categorizes protected areas into four distinct gap analysis project (GAP) status codes ("PAD-US Data Download," 2019). GAP status codes 1 and 2 are protected areas where disturbances must be natural (or mimicking natural). These areas were excluded in our analysis.

Finally, bodies of water were considered unsuitable for solar development. While floating solar has become increasingly used overseas in countries such as China, it remains a specialty application that is outside the realm of plausibility within the present investigation.

Environmental Criteria. Once sites unsuitable for development had been excluded, an evaluation of sites based on environmental criteria was performed. These criteria included aspects that would positively contribute to solar development (e.g., high solar radiation) as well as detract from solar development (e.g., high slope percentage). Sites were evaluated for performance based on four environmental criteria.

First, sites were evaluated for suitably high levels of solar radiation. Most studies exploring the suitability of sites for solar development assign the greatest weight to this criterion. If the location is exposed to sufficient solar energy, electricity production will increase along with efficiency. Solar radiation was calculated using the direct, diffuse, and global insolation values from the Area Solar Radiation tool built into ArcGIS.

Second, sites were evaluated based on slope percentage. Flatland is generally required for solar development, as steep gradients increase construction and maintenance costs. Flat areas also experience less shade, which is important for receiving maximum solar radiation. We consider slopes greater than 10% to be the least suitable, and slopes less than 1% to be the most suitable. We measure slope using Digital Evaluation Models (DEM) from the US Geological Survey (USGS) 3D Elevation Program Illinois.

Third, aspect, which indicates the direction the topography is rising or falling, was considered. The orientation of the slope plays an essential role in determining the exposure to solar radiation. Using the degree system, aspect is calculated going clockwise starting north at 0°. Because Illinois is in the northern hemisphere, a southern-facing solar panel will face the sun more often than a northern-facing one. For this analysis we calculated the aspect for areas with slopes between 3° and 8°. Sites with a southeastern- (>112.5°) to southwestern-facing (<247.5°) aspect were considered suitable. It is not necessary to measure aspect for areas with slope less than 3° (USGS, "3D Elevation Program," 2019). A 0–3° slope or a 3–8° slope with a southeast to southwest aspect were generated using the spatial analysis tool in the ArcToolbox from ArcMap. These were generated by using the 1/3 arc second Digital Elevation Models from USGS ("3D Elevation Program," 2019).

Finally, elevation was considered. Many studies have demonstrated a positive relationship between elevation and solar power generation. Under a clear sky, solar energy efficiency increases at higher elevations because energy harvesting is subject to atmospheric conditions, and the thickness of the atmosphere is inversely proportional to elevation. Elevation data is available from USGS and is measured in feet above sea level. There is very little difference in elevation in Illinois; therefore, we gave this criterion very little weight in our analysis. Elevation is included in our analysis to show the generalizability of our tool for other states.

Social Criteria. In addition to purely environmental properties, any investigation of potential development should include non-environmentally explicit social parameters to ensure site suitability. In this investigation, two social criteria were used.

First, land use and land cover (LULC), which represents the current developmental status of a site from a political, economic, and social perspective, was categorized. LULC can be used to project future solar potential, as it provides decision-makers with an understanding of the relationship between land use development and solar energy development. To calculate LULC, we first classified land use into eight categories: barren land, wetlands/waters, forest, urban areas, herbaceous uses, agricultural uses, shrubland, and open space. We then ranked and assigned them a score from one to five based on literature and feedback from IDOT.

For example, barren areas are considered highly suitable for solar development, while forested areas are considered suboptimal because foliage can obstruct solar radiation and development risks, damaging the environment. Acceptable land covers were agricultural uses, open space, and herbaceous uses. We used USGS GAP datasets, including the GAP/LANDFIRE National Terrestrial Ecosystems dataset, which details vegetation and land cover patterns across the US ("Gap Analysis Project," 2019).

Second, population center density was evaluated. As solar development may cause negative public reaction, sites in and around population centers are not considered preferable for community-scale or utility-scale solar development. This criterion is weighted in a way that would reduce the overall suitability score, but not eliminate from consideration a site that would otherwise be considered suitable.

Given that population density is an important measurement of socioeconomic activity, we assume that areas of lower population density are located farther from population centers. There is no consensus in maximum or minimum population density for solar development in the literature, but it is generally assumed that for sites in or near dense population centers, solar development is less suitable. We measure how densely populated centers are distributed with regard to population size. We visualize the distribution of population centers using kernel density estimation from datasets of 2018 census tracts.

Economic Criteria. In accordance with this investigation's stated purpose of identifying sites with preferable cost-benefit profiles, it was necessary to measure certain economic criteria as they relate to solar development. These three criteria were primarily practical in nature and are predicated on the understanding that certain proximities are required for economic development while other qualities make successful development less likely from a cost-benefit perspective.

First, distance to transmission lines was evaluated. The proximity of potential solar development sites to power transmission lines is a major factor in its economic viability, as accessibility to transmission lines is required for safety and maintenance, as well as to easily transfer the electricity generated. Distances of 1 to 3 miles are generally an acceptable range for solar development. National Renewable Energy Laboratory (NREL) suggests that solar development should be located within 0.5 miles from transmission lines, while other studies consider areas within 6 miles to be suitable.

At cost estimations of $300,000/mile for transmission lines (MISO, 2019), the closer the line, the better. For our study, we consider sites located less than 2 miles from a transmission line to be suitable and sites less than 1 mile from a transmission line to be very suitable. This criterion is weighted in a way that allows sites that are slightly suboptimal in distance to remain under consideration in case other factors would help to overcome any potential cost penalties.

Like proximity to transmission lines, connectivity to road networks is an essential economic factor for reducing the cost of construction and maintenance. Accessible wide, higher-speed road networks allow for easier transportation of large volumes of materials to solar sites. Sites that do not have access to these networks are less desirable and more costly for solar development. The ideal distance from solar sites to roads varies from 300 feet to 1.5 miles. Accessibility is also influenced by the speed and width of the nearby roads. To calculate the connectivity value of sites to primary routes, we adopt kernel density estimation with a weighted posted speed limit and road width.

Finally, areas characterized by high crop productivity were considered suboptimal. Agriculture is a critical component of Illinois' economy. About 75% of the state's lands are used as farmland, and about 89% of this land is considered prime farmland. Farmers are reluctant to displace high productivity farmland with solar but may be amenable to placing solar on low productivity cropland. Crop productivity was determined based on soil quality measures from the National Commodity Crop Productivity Index from Esri.

For each of the criteria identified (excluding the exclusion criteria), rankings were identified, with one being the most preferable and five being the least preferable. A summary of the ranking characteristics is shown in Table 4.

Table 4. Ranking for Site Evaluation Criteria

Criteria	**Rank***				
	1	**2**	**3**	**4**	**5**
Solar Rad. (kWhm-2yr-1)	<1,200	1,200–1,300	1,300–1,400	1,400–1,500	>1,500
Slope Percent (%)	>10	5–10	3–5	1–3	<1
Aspect	N	NE, NW	Flat, E, W	SW, SE	S
Elevation (ft)	<1,300	1,300–2,000	2,000–2,600	2,600–3,300	>3,300
LULC	Wetlands/waters, and forest	Urban areas	Herbaceous and agricultural uses	Shrubland and open space	Barren land
Population Density	Quantile method				
Road Networks	Quantile method				
Transmission Lines (miles)	>12	6–12	1–3	0.5–1	<0.5
Crop Productivity	Quantile method				

CRITERIA WEIGHT AND ANALYSIS

SEDAC assigned weights to the above criteria using Saaty's (1987) analytic hierarchy process, a comprehensive and flexible method to determine the relative weight of criteria that allows for quantitative and qualitative inputs. The relative importance and weight of each criteria was determined by reviewing existing studies. Further details on the process are in the appendix. As shown in Table 5, solar radiation and slope received the most weight, followed by distance from transmission lines.

SEDAC used the weighted site suitability criteria to complete a statewide solar suitability analysis. SEDAC analyzed 166 million points, each representing a 30-meter by 30-meter cell in Illinois. First, we used the exclusion criteria to eliminate points in 100-year flood plains, bodies of water, or in protected natural lands. All remaining points received a score of one to five for each of the nine criteria (higher scores indicated greater suitability). Using the weights described above, the individual attribute scores were combined into a combined suitability score for each point (also from one to five), and maps were created to represent the combined suitability scores for all cells in Illinois. SEDAC applied this statewide analysis to IDOT lands in five Illinois regions.

Table 5. Selection Criteria Weights

Criteria	Weight
Solar radiation	39.0%
Slope percentage	16.9%
Distance from transmission line	13.6%
Land use/land cover	9.8%
Elevation	5.7%
Aspect	5.4%
Accessibility to road networks	5.1%
Population center density	2.7%
Crop productivity	1.7%

RESULTS OF SITE SUITABILITY ANALYSIS

The map in Figure 4 summarizes the results of our statewide site suitability analysis, based on the combined suitability scores of each point. The gray areas indicate excluded points: bodies of water, areas in the 100-year floodplain, and protected areas. There are approximately 5.2 million acres of excluded area, representing about 14% of the entire state. The combined suitability scores for each point across the state ranged from a low of 1.08 to a high of 4.185. In the map below, green areas indicate points that are more suitable for solar development, and yellow and red areas indicate points that are less suitable. Some southern Illinois locations scored lower because of factors including higher amounts of exclusion areas, more sloped lands, and more tree cover.

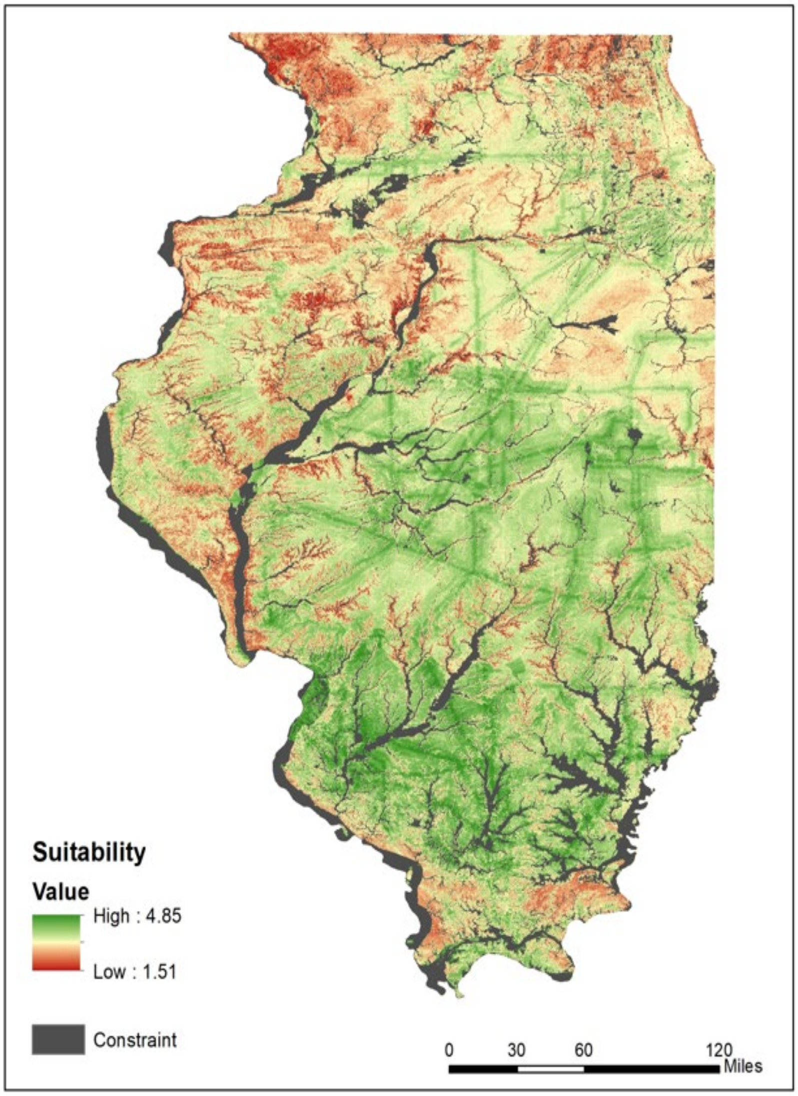

Figure 4. Illinois solar suitability map. Green areas are more suitable for solar development.

Environmental Criteria Results

Results of evaluations based on select environmental criteria, which include slope percentage and aspect, are shown in Figure 5 and Figure 6. Solar radiation and elevation were both found to vary relatively little across the state; thus, these criteria were not terribly significant in informing our findings.

For the slope percentage map in Figure 5, darker colors represent sites with less slope, indicating higher scores. Of the total state area, 38.5% has a slope less than 3%. Because much of Illinois is flat, there are many areas that have very little slope, making them more suitable for ground-mounted solar. For the aspect map in Figure 6, darker purple indicates a slope aspect (direction) that is more suitable for solar development. Based on our analysis, 35.6% of the state area faces a southeastern to southwestern direction, including south-facing slopes (approximately 12%), which are assigned a rank of five.

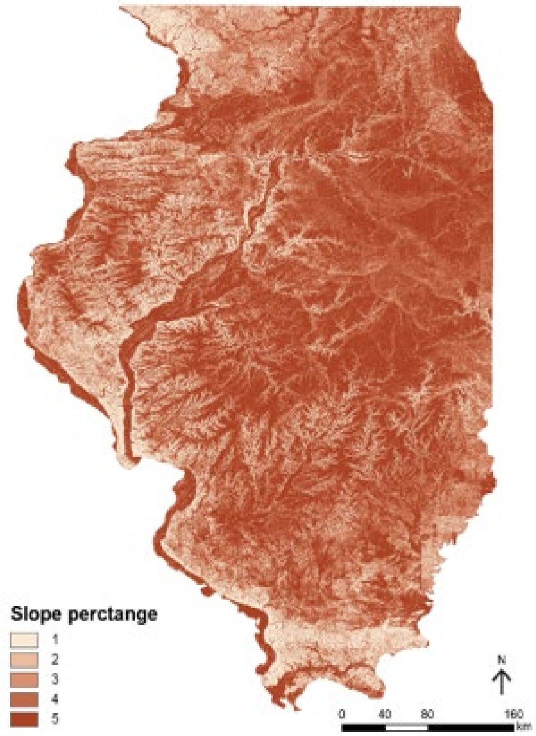

Figure 5. Slope percentage map. Darker areas are lower slope areas.

Figure 6. Aspect map. Darker purple indicates a slope aspect (direction) that is more suitable for solar development.

Social Criteria Results

Results from evaluations using the social criteria, which include land cover and population density, are shown in Figure 7 and Figure 8, respectively. For land use and land cover (Figure 7), the darker blue represents land use categories that are more suitable for solar, such as open space and barren land. Dark blue cells indicate sites with higher solar suitability. Conversely, population center density (Figure 8) is not a desirable trait, as this could lead to increased pushback from persons for a project as well as an increased likelihood for high land values. As such, the darker colors indicate lower population density and higher suitability scores.

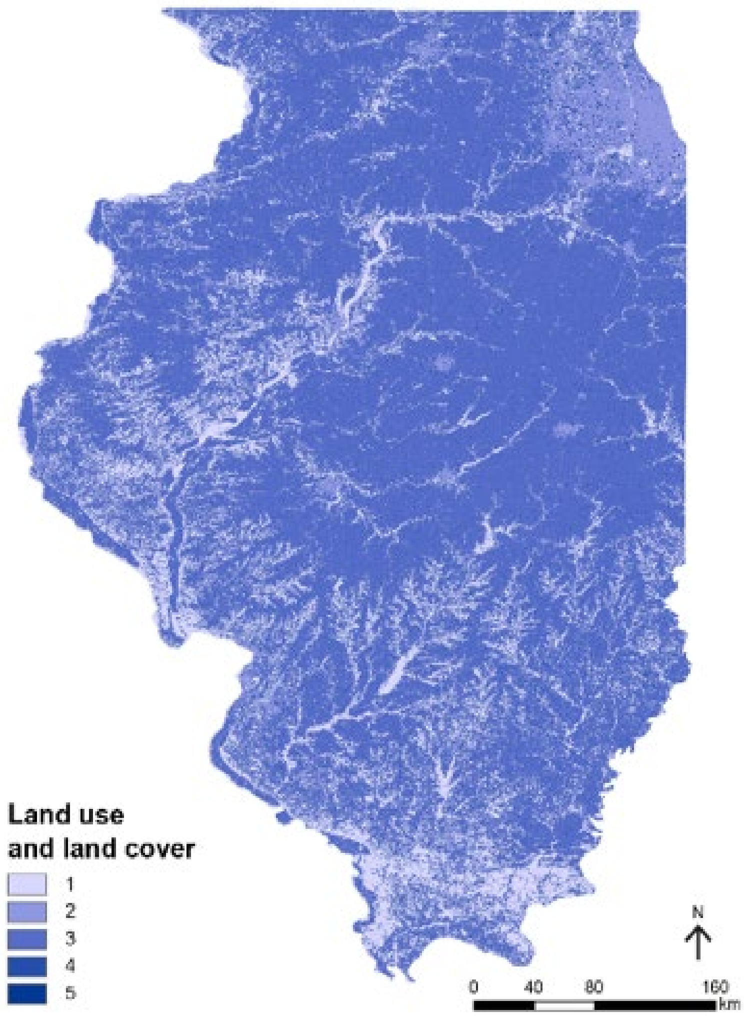

Figure 7. Land use and land cover map. Darker blue represents land use categories that are more suitable for solar, such as open space and barren land.

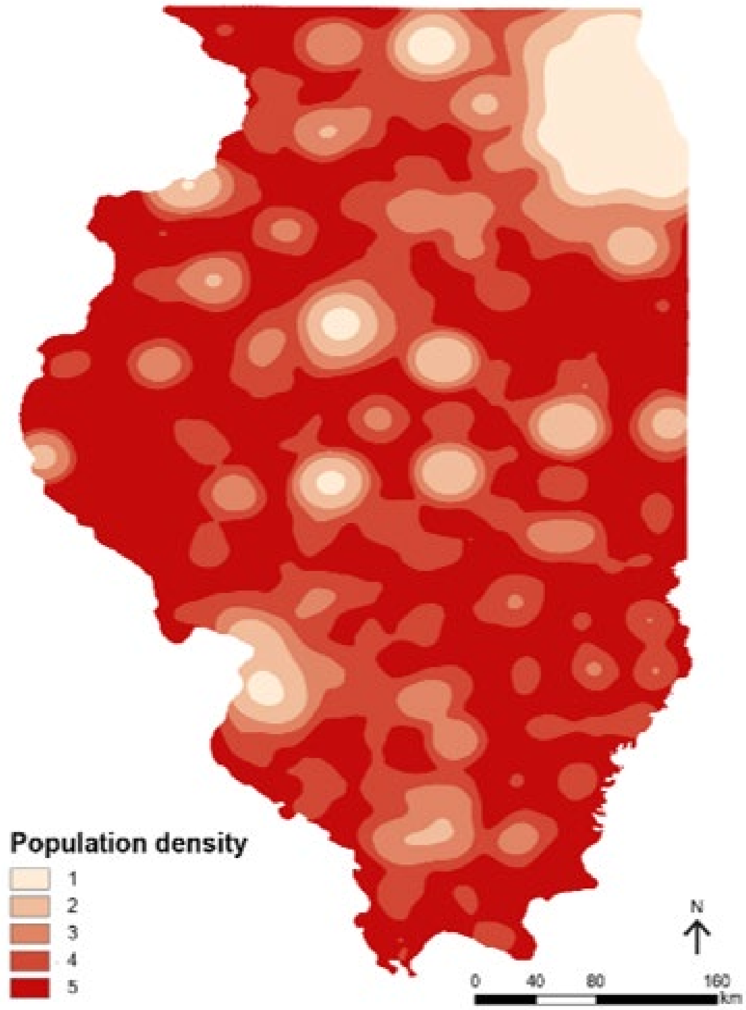

Figure 8. Population center density map. Darker colors indicate lower population density and higher suitability scores.

Economic Criteria Results

Results from evaluations using the economic criteria, which include accessibility to road networks, distance from transmission lines, and crop productivity, are shown in Figure 9, Figure 10, and Figure 11, respectively. Darker areas in the road and transmission line maps indicate areas that are closer to high-speed roads and transmission lines, making them more suitable for solar development. For the crop productivity map, the darker the color, the less productive the land, which makes it more suitable for solar development and reducing the competition between food and energy.

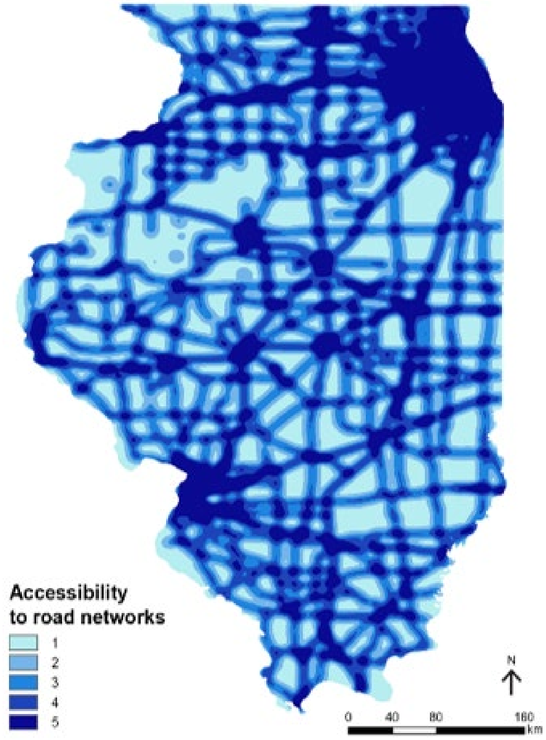

Figure 9. Accessibility to road map. Darker areas are areas that are closer to high-speed roads and more suitable for solar development.

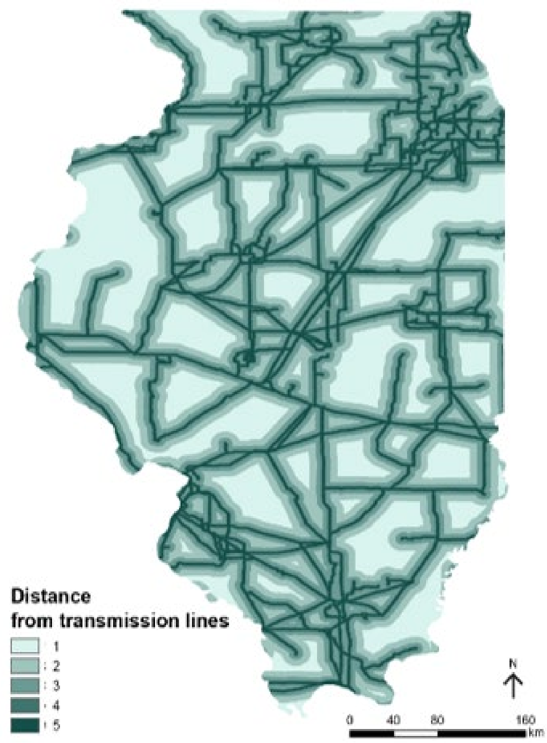

Figure 10. Distance to transmission line map. Darker areas are closer to high-speed roads and more suitable for solar development.

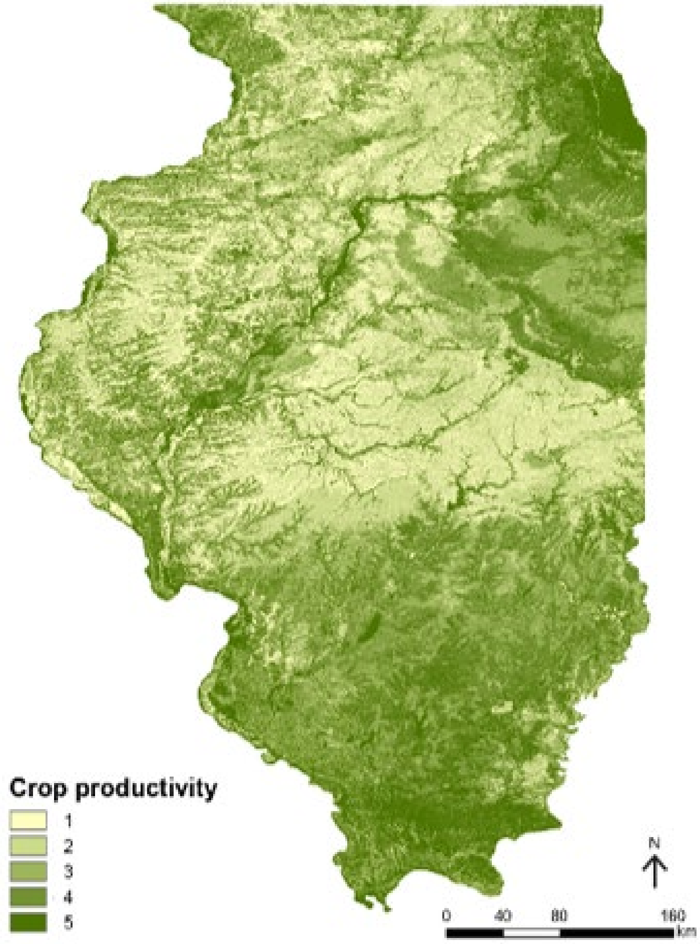

Figure 11. Crop productivity map. Darker areas are less productive farmland and more suitable for solar development.

PRELIMINARY SITES IDENTIFIED THROUGH RAPID PRESCREENING

Rest areas, welcome centers, right-of-way areas, and IDOT lands were prescreened as described above for a preliminary identification of the top sites for ground-mounted solar in each IDOT district. These sites selected had the highest solar suitability scores within each district, when compared to other known sites in the IDOT districts. The preliminary list included 48 potential sites. After a manual review to remove sites with too many trees, not enough distance from the roadway, inadequate proximity to appropriate utility connections, and other technical factors, the 40 sites shown in Table 6 and Table 7 were provided to IDOT staff to gather additional feedback and more local perspective.

Table 6. List of Potential Sites Selected for IDOT Stakeholder Feedback, IDOT Districts 1–4

District	Location	Route	Acres	Solar Suitability Score
1	I-57 @ Stuenkel Rd (Near University Park)—interchange infield	I-57	13	3.63
1	I-55 @ US 30 (Lincoln Hwy)—interchange infield	I-55	8.6	3.63
1	I-55 @ US 30 (Lincoln Hwy)—interchange infield	I-55	7.4	3.60
1	I-57 @ US 30 (Lincoln Hwy)—interchange infield	I-57	9.8	3.57
1	I-57 @ US 30 (Lincoln Hwy)—interchange infield	I-57	12	3.57
2	Newburg Rd to State Street (Near Belvidere)—excess land		45	3.58
2	Turtle Creek SB Rest Area (Near State Line)	I-90	30	3.45
2	IL-75 and I-39 (At State Line)—excess land	IL-75	3.1	3.31
2	I-39 and Manchester Rd (At State Line)—excess land	I-90	19	3.30
3	I-57 @ US 45 (Near Loda)—at rest area	I-57	15	3.63
3	I-55 (Near Ocoya)—at rest area	I-55	3.9	3.59
3	I-80 @ Columbus St (Near Ottawa)—ROW at interchange	I-80	3.9	3.57
3	Great Sauk Trail WB Rest Area (Near Princeton)	I-80	32	3.56
3	Interchange w/ Prairie Pkwy Corridor (Near Minooka)—excess land	I-80	83	3.41
3	Interchange w/ Prairie Pkwy Corridor (Near Minooka)—excess land	I-80	38	3.41
4	Mackinaw Dells EB Rest Area (Near Goodfield)	I-74	18	2.89

Table 7. List of Potential Sites Selected for IDOT Stakeholder Feedback, IDOT Districts 5–9

District	Location	Route	Acres	Solar Suitability Score
5	Salt Kettle WB Rest Area (Near Danville)	I-74	23	3.71
5	Illini Prairie SB Rest Area (Near Pesotum)	I-57	15	3.59
5	Illini Prairie NB Rest Area (Near Pesotum)	I-57	14	3.48
5	Farmland EB Rest Area (Near Farmer City)	I-74	32	3.45
6	Rail Splitter SB Rest Area (Near Springfield)	I-55	6.8	3.72
6	Coalfield NB Rest Area (Near Litchfield)	I-55	34	3.51
6	Coalfield SB Rest Area (Near Litchfield)	I-55	40	3.48
6	Rail Splitter NB Rest Area (Near Springfield)	I-55	15	3.38
7	Pride of the Prairie WB Rest Area (Near Decatur)	I-72	28	3.38
7	Green Creek NB Rest Area (Near Effingham)	I-57	18	3.36
7	National Trail EB Rest Area (Near Effingham)	I-70	21	3.33
7	Pride of the Prairie EB Rest Area (Near Decatur)	I-72	24	3.25
7	Green Creek SB Rest Area (Near Effingham)	I-57	50	3.15
7	Former Janvrin Interchange (Near Decatur)	I-72	35	(not scored)
8	I-255 along Cahokia Creek (Near Stallings)—excess land	I-255	7.2	4.18
8	I-255 along Cahokia Creek (Near Stallings)—excess land	I-255	58	4.15
8	I-255 along Cahokia Creek (Near Stallings)—excess land	I-255	3.6	4.07
8	Gateway EB Rest Area (Near O'Fallon)	I-64	27	3.96
8	Gateway EB Rest Area Infield Area (Near O'Fallon)	I-64	12	3.95
9	Rend Lake NB Rest Area (Near Benton)	I-57	12	3.90
9	Rend Lake SB Rest Area (Near Benton)	I-57	31	3.66
9	Goshen Rd EB Rest Area (Near Mt. Vernon)	I-64	13	3.65
9	Goshen Rd WB Rest Area (Near Mt. Vernon)	I-64	13	3.56
9	Fort Massac Rest Area (Near Metropolis)	I-24	21	3.51

Most of the sites (21 out of 40) in this list were rest areas with on-site loads that could be served by solar development. Some of these sites were also large enough to host larger installations that could serve off-site loads. Eighteen of the sites were located on IDOT excess lands that were under review by IDOT for potential use as additional truck parking. One of the sites, the former Janvrin interchange in District 7, is a large right-of-way area in the median of I-72 near Decatur. This site was not identified in the prescreening process, but it was nominated by a member of the Technical Review Panel.

PRELIMINARY SITES REVIEW WITH IDOT STAKEHOLDER FEEDBACK

SEDAC divided the lands by district and presented them for discussion with district personnel. These discussions provided a local perspective regarding the current or future land use development at these sites, which may inform how much land might be considered for solar development. With solar system life spans of 20 years or more, it is not desirable to locate solar in sites that are likely to be developed for alternative uses in the near future. These discussions helped SEDAC to identify and narrow a list of potentially suitable sites for detailed case study evaluation. Stakeholder feedback on potential solar sites is summarized in Table 8.

Table 8. Summary of IDOT Stakeholder Feedback on Identified Potential Solar Sites

District #	Site	Desirable?	Justification/considerations
District 1	All sites	No	Future growth and interchange reconfiguration
District 3	Prairie Parkway All other sites	Yes No	Interested in solar, no other transportation use for the land. (Note: per TRP April 2021, truck parking in consideration) Planned development or prairie restoration projects
District 4	Mackinaw Dells EB Rest Area The intersection of US-34 & IL164	Maybe Maybe	Consider integrating with pollinator habitat, and solar with storage to address local power reliability issues Lighting desired but no electricity at site. Consider new utility service or off-grid solar with battery for lighting.
District 5	Rest areas ROW corridor around Bloomington/Normal Intersection of I-57 & US-36 (near Tuscola)	No Maybe Yes	Established prairies, pollinator areas, and sanitary systems may be disrupted by ground-mounted solar systems. Two maintenance yards (Bloomington, Towanda) are good. ROW areas of interest for lighting but construction and maintenance access is restricted along ROW. Would be ok to locate in the interchange infield near the electric meter.
District 7	Pride of the Prairie Rest Areas	Maybe	Potentially compatible. Scenic easements could limit solar development—there may be restrictions for building mounted systems. Some parcels are shaded, which may limit building mounted systems.
District 8	Large parcel I-255 along Cahokia Creek (Near Stallings)	Yes	No known operational need for site, no slated plans. May be considered for sale if they don’t develop solar there. The parcel is protected by a berm and had been purchased for flood control, but no known flooding issues.

During this feedback process, there was an overall decision by IDOT that rest areas would not be considered further for evaluation during this project. If stakeholder concerns can be addressed, many rest areas have enough open land for solar systems that could supply electricity for the rest area facilities and connected roadway lighting loads. Solar development on rest areas could be a productive topic for the future.

IDOT District 2 personnel did not respond to the inquiry, so their feedback was not collected. Feedback from the IDOT district stakeholders is summarized in Table 8. Likewise, we did not receive feedback from Districts 6 or 9; however, the identified potential sites were all rest areas, and the decision to remove rest areas from consideration in this project may have contributed to the non-responsiveness.

Personnel from IDOT Districts 4 and 5 elected to nominate additional parcels for consideration during the feedback process. These personnel were highly engaged and interested in the process of feedback, discussion, and review. Stakeholder interest is an important factor in the success of solar installation and, especially for potential on-site behind-the-meter solar projects, selecting from within suitable locations in Districts 4 or 5 would be recommended for initial experience with smaller solar projects.

Based on this feedback and our site suitability analysis, SEDAC narrowed our list of 40 sites to five sites that represented three different site types as well as different solar strategies IDOT could pursue. In the following section, we describe these sites and explore the development potential and cost-benefit analysis for each site.

CHAPTER 4: CASE STUDY SITES

This chapter explores the potential for solar development on five potential case study sites, considering the administrative requirements and conducting a cost-benefit analysis. This work, along with the work in the previous chapter, helps to satisfy Objective Two. Specifically, Chapter 4 deals with the selection of a variety of specific IDOT sites and evaluation of their solar energy potential, installation costs, potential leasing revenue, and cost-benefit analysis.

NARROWED LIST OF SITES SELECTED FOR CASE STUDY REVIEW

Based on the broad technical feasibility study and the input from IDOT personnel, the list of sites was narrowed from 40 to five pilot sites, representing three different site types for three kinds of solar systems.

1. **Large Sites (two)**. We selected the two large sites that received enthusiastic support from IDOT staff: The I-255 site along Cahokia Creek, east of Granite City (68 acres by combining three adjacent suitable parcels), and the I-80 Prairie Parkway site near Minooka (120 acres by combining two adjacent suitable parcels). These two sites could be suitable for utility-scale solar systems and could tap into economies of scale.

2. **Maintenance Yards (one set of two maintenance yards)**. There was substantial interest in maintenance yards. These maintenance yards may be considered for roof- or ground-mounted solar systems, sized to meet the load on the site. We selected two maintenance yards in District 5 (Bloomington and Towanda) because district staff were supportive, and offices were near the sites for direct supervision. The Bloomington maintenance yard has available ground space near a roadway lighting controller that might provide an opportunity to add roadway lighting loads to a solar system within the fence of the yard.

3. **Interchanges (two)**. With the substantial quantity of interchanges, there was the desire to include at least one interchange in the selected sites. IDOT recommended selecting interchanges with ramps that come to a 90-degree controlled intersection. An interchange near Tuscola was found to fit this profile and had recently been upgraded to LED, which reduced the amount of solar needed to satisfy the load, reducing project costs. Finally, we selected a site near Monmouth, where an off-grid system may be desirable, as IDOT may want to locate several interchanges in locations that are not in close proximity to the electrical grid.

The five sites are summarized in Table 9. Sites 1 and 2 are meant to be utility-scale solar systems that could meet or exceed IDOT's entire electric load. Sites 3 through 5 are sized to meet the electrical demand on the site. The sites are all suitable for ground-mounted systems, and site 3 also allows for roof-mounted systems on the maintenance facilities.

Table 9. Summary of IDOT Case Study Sites for Solar Feasibility Study

Site	Solar Type	District	Location	Site Area	Preliminary Solar Sizing Estimate	Utility Territory
1	Large	3	I-80 Prairie Pkwy Corridor (near Minooka)	120 acres	Up to 25 MW solar; 44,000,000 kWh per year of generation	ComEd
2	Large	8	I-255 along Cahokia Creek (near Stallings)	68 acres	Up to 15 MW solar; 26,000,000 kWh per year of generation	Ameren
3	ROW Corridor	5	I-55 & I-74 through Bloomington/Normal Bloomington Yard, I-55 @ 1-74, south interchange Towanda Yard, Old US-66	 14,000SF roof 8,100SF roof	 68 kW (6800SF); for 95,000 kWh/yr site electric use 36 kW (3600SF); for 50,000 kWh/yr site electric use	Ameren
4	ROW, for lighting	5	I-57 & US-36 (near Tuscola)	12 acres	6 kW (700 sf); 8,000 kWh/yr	Ameren
5	ROW, for lighting	4	US-34 & IL-164 (near Monmouth)	9 acres	2 kW (200 sf); 3,000 kWh/yr; 100% of site electric	McDonough Power

SOLAR SYSTEM SIZING

For the feasibility analysis at each case study site, the solar system size and electricity generation output must be estimated. For utility-scaled sites (sites 1 and 2, as shown above), we estimated the approximate upper limit of solar system capacity that could be installed on the sites at five acres per MW of solar capacity (Day, 2018). In Illinois, ground-mounted systems can be initially estimated to generate 1,750 kWh per year of electricity per kW of capacity, and rooftop-mounted systems can be initially estimated to generate 1,300 kWh per year of electricity per kW of capacity, based on inputs in a variety of Illinois locations in the NREL PVWatts Calculator.

IDOT AGENCY-WIDE ELECTRICITY USE

For the feasibility assessment of utility-scale solar at large sites (1 and 2), the solar electricity generation should not be greater than the annual electricity use of IDOT accounts receiving the solar electric supply. IDOT electric accounts served by ComEd and Ameren Illinois can be connected to utility-scale solar projects via PPA. IDOT accounts served by other electric utilities might in some cases be able to remotely purchase solar power; in many cases they will not. For this study we focus on the use of large solar PPA for electric supply to IDOT accounts in ComEd and Ameren. In 2019, there were approximately 350 of these accounts, with a total annual electric use of 23,000,000 kWh. It is roughly estimated that 160 accounts using 13,000,000 kWh/yr are located in ComEd territory, and 190 accounts using 10,000,000 kWh/yr are located in Ameren Illinois territory. The electric account and electricity use information is based on a download of Illinois state agency energy use data from the CMS "State Utility Database Management System" (accessed from a computer at the IDOT Champaign Sign Shop in September 2019). Access to IDOT energy use data in other utility territories is not readily available and was not collected.

DEVELOPER PRICING ESTIMATES

The feasibility analysis included input from developers on their interest in the types of projects and sites that IDOT could pursue. Separate discussions were held with five national and regional solar developers for third-party construction, financing, and ownership of solar energy generation projects on anonymized, generalized descriptions of the five case study sites. There was no disclosure that IDOT was the site owner or power purchaser, and the site information provided to the developers was not sufficiently detailed to allow developers to identify the case study site locations. Below is a summary of key issues for IDOT to consider prior to proceeding with the RFP.

Ownership Entities. The successful bidder (developer) will establish an acquisition entity for each project. As detailed below, solar projects are structured to include tax equity investors, equity investors, and debt providers. Lenders typically have security interests in the systems.

Developer Financial Considerations. Owners of solar generation assets receive revenue from the sale of power during the operating life of the assets, investment tax credits, and accelerated depreciation. During the development process, developers use solar insolation tables and production projections to determine the estimated kWh generated by the system over the course of the asset life.

The tax benefits of these projects also drive investment. This includes the federal investment tax credit, which allows investors to deduct 26% of the cost of projects. Construction must commence in accordance with IRS regulations to establish eligibility for the investment tax credit. For the case study sites, developer PPA estimates assumed that construction would commence while the 26% federal investment tax credit is in effect. There is no cap on the solar investment tax credit. Federal law also allows qualifying solar energy equipment to be depreciated over five years, which reduces tax liability and increases the rate of return.

Financial Structuring. Developers and investors in solar projects often do not have sufficient tax liability to benefit from the significant investment tax credit and accelerated depreciation benefits. To address this, these projects use tax equity financing where investors with significant tax liability receive the tax benefits of the solar project to reduce their overall federal tax burden. There are also traditional equity investors. These projects include a significant amount of debt during both the construction and operational phases.

Ongoing Costs of Operations. As discussed, the owners (developers) bear the risk of loss of anticipated revenue due to inaccurate insolation projections or operations and maintenance disruptions. The solar resource is variable and cannot be predicted with complete certainty for any particular project or location. There is also the risk of increased costs from rising property taxes or other state and local regulatory requirements. These risks are borne solely by the project owners.

Developer Indicative Pricing Estimates. National and regional solar energy developers were engaged in discussions about pricing, pricing factors, and developer interest. Each of the developers expressed interest in bidding on the projects should IDOT issue an RFP. Indicative bids were requested for the entire package of sites indicated in Table 9 with the following assumptions:

- 25-year PPA term
- Investment grade power purchaser (IDOT)
- IDOT purchases 100% of power at PPA rate
- 1-year development timeline from award
- Investment Tax Credit of 26%
- 0% annual escalator
- $0.05/Wdc for interconnection costs
- Construction start date of March 31, 2022
- No lease revenue for IDOT
- No solar renewable energy credit (SREC) revenue
- Package does not include battery backup or off-grid solar for site 5

Table 10. Developer PPA Pricing Estimates for Case Study Site Bundles

Developer	PPA Price ($/kWh)
A	$0.047–$0.049
B	$0.060
C	$0.074–$0.75
D	$0.071–$0.074
E	$0.081–$0.084

The range of prices is great. Developers A, B, and E are national solar developers while C and D are regional, which may partly explain the pricing differential. Note that PPA kWh rates will change to reflect changes in the assumptions or actual conditions (e.g., increases in panel costs, property taxes, and construction costs).

Investment Grade Power Purchaser. From recent bond issuances, credit rating agencies issued the State of Illinois a BBB credit rating, which is one notch above the speculative rating of BB. The proposed PPA pricing assumes that the State of Illinois will maintain investment grade ratings. If the state falls below investment grade, IDOT may need to provide credit enhancement or an alternative structure to secure a competitive long-term PPA rate. Certain developers may require credit enhancement in their PPAs, and the RFP should inquire whether under any circumstances credit enhancement will be required. This will impact the PPA kWh rate offered by developers.

PPA Expiration. At the end of the PPA term, there are several options, including: (i) entering into a new PPA with IDOT (PPAs typically have two five-year extensions); (ii) selling the systems to IDOT at fair market value (estimated at 20%–25% of the original installed cost at the end of the 25th year); or (iii) removing the systems and returning the property to its original condition (less wear and tear). Most often, the power purchaser extends the PPAs.

Renewable Energy Credits. IDOT will retain the solar renewable energy credits (SRECs) rather than monetizing through the Illinois Power Agency programs to meet the state's renewable portfolio standard. Illinois solar incentive programs have provided the SREC payments that significantly improved the economics of installed systems; however, as of late 2020 the funds have been depleted and Illinois SRECs are unavailable, pending Illinois legislative action to allocate new funding. This has significantly impacted the results of our model, making the economics less attractive than earlier projections.

IDOT Lease. Developers assume no lease payment to IDOT for the 25 MW and 15 MW systems. These projects exclude lease costs to avoid a circular cash flow: an increase in operating expenses (e.g., lease payments) are added to the system cost and may increase the PPA kWh rate. If IDOT requires a lease payment, developers will likely adjust the PPA kWh rate.

PPA Price Escalator. IDOT will pay a fixed PPA kWh rate for the entire PPA term. There will be no increase (or decrease) in kWh rate due to extraneous factors, such as inflation or increased cost of operations and maintenance. In contrast to power purchased from utilities or alternative energy suppliers, IDOT will receive a guaranteed fixed cost for electricity from these projects for 25 years. Depending upon the comparable energy supplier rates, this can generate significant financial savings over the PPA term.

Equipment Warranty. There are several safeguards to ensure consistent performance of the systems to contracted expectations. Equipment failures and other factors could increase projected operations and maintenance expenses and reduce anticipated energy production, each of which adversely effects profitability of the assets. This risk is borne solely by the developers.

It is important for IDOT that the systems maintain consistent operation. Developers are required to provide for operations and maintenance on the systems during the PPA terms. In addition, the solar equipment (panels and inverters) will be covered by warranties meeting the standards set out in IDOT's RFP. IDOT should secure a developer commitment to warranties meeting IDOT expectations before award issuance. Solar panel suppliers provide warranties for performance and equipment. The solar panel performance warranty guarantees a certain level of production throughout the warranty term (e.g., 90% at 10 years and 80% at 25 years). The equipment warranty guarantees operation for 10 or more years.

Project Bundling. Given that small streetlight projects are not as beneficial to investors as the large ground-mounted systems, developers recommended that IDOT bundle the projects into a portfolio of projects for a single developer. Developers cited the small size and higher relative operations and maintenance costs of the proposed streetlight projects. The assumption is that a small ground-mounted solar system would power the streetlights in each area.

Bundling the projects allows the developers to spread the cost of streetlight projects across the larger ground-mounted systems. The developers surveyed estimated between $40 to $50 million to construct the 40 MW of utility-scale solar projects and an additional $600,000 for the approximate 400 kW of smaller projects. If the IDOT projects are bundled, the developer will be able to use the 40 MW of utility-scale solar projects to absorb the increased per kW development cost of the 400 kW of smaller projects. Because the streetlight projects comprise just greater than 1% of the total portfolio, IDOT should consider requesting that the 411 kW of small projects be provided free or as a donation as part of the award of the entire portfolio.

Developer Input Summary. Given that there is currently no funding for SRECs in the state, Illinois projects that offer a competitive rate of return without monetization of SRECs are rare and in demand. There is expected to be significant interest in large-scale IDOT projects. Small projects such as for roadway lighting or maintenance yards are not expected to attract developers unless packaged with much larger projects.

SOLAR SYSTEM COST-ESTIMATING

As noted, solar project costs and PPA pricing are highly sensitive to system size, developer-to-developer variations, and other site-specific factors. However, we relied on industry pricing data analyses to develop preliminary cost estimates for cost-benefit analysis of the case study scenarios. Based on available recent pricing data for solar systems in the literature (Feldman & Margolis, 2020; (Bolinger et al., 2020) and from the developer pricing information discussed above, we developed logarithmic trend equations to estimate total installed cost of a solar system ($) and the PPA price ($/kWh), as shown in Figure 12. Solar electricity project pricing benefits from economies of scale, as shown in the chart.

While the developers' indicative pricing estimates varied significantly, they are close enough to the model equations in Figure 12 to justify the use of the model equations for the purposes of this economic feasibility analysis. Compared to nationwide utility-scale PPA pricing data (Bolinger et al., 2020), which converges in the range $0.03–$0.05 per kWh for projects sized 10 MW (equal to 10,000 kW) and greater in the years 2019–2020, our pricing model for this project is conservative and predicts pricing in the range $0.04–$0.06 per kWh for projects sized 10 MW and greater.

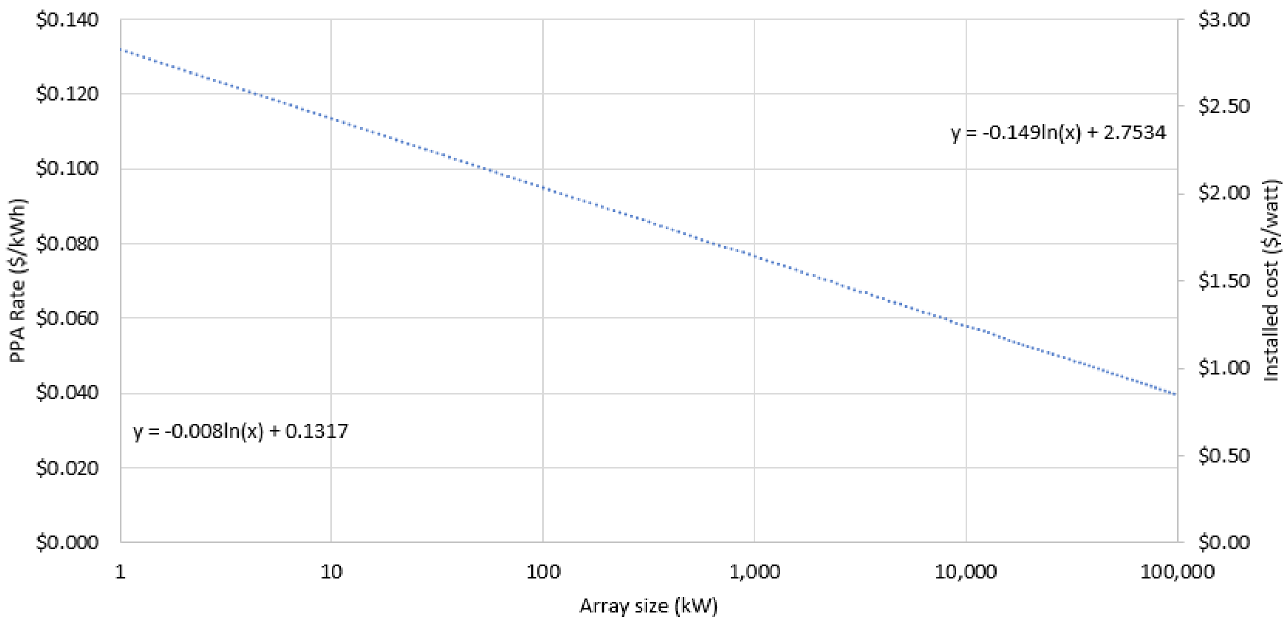

Figure 12. Installed solar costs. Model equations for preliminary estimates of the installed cost of solar ($) or the PPA price ($/kWh) for solar, across a range of scales from small rooftop to large utility scale.

SOLAR PPA PRICING FEASIBILITY FOR UTILITY-SCALE SOLAR PROJECTS

IDOT electric accounts located within the service territories of ComEd and Ameren Illinois are the accounts that would most feasibly be served by a solar PPA, and they are currently covered by a master contract for electricity supply services through CMS. Under this contract, the electric supply price for accounts in ComEd is $0.041 per kWh (down from $0.048/kWh in the previous contract), and it is $0.051 (down from $0.058/kWh in the previous contract) for accounts in Ameren Illinois. However, this does not account for the capacity fees that the supplier must pay for and pass onto IDOT. These fees are $195/MW-Day for ComEd accounts and $5/MW-Day for Ameren Illinois accounts, which equates to an additional $0.016/kWh and $0.001/kWh, respectively. This equates to an all-in effective electric supply rate of $0.057/kWh in ComEd and $0.052/kWh in Ameren Illinois.

While economic feasibility can be defined in many ways, depending on the circumstances and preferences of the power purchaser, for this context we define a solar PPA to be economically feasible if the PPA price is less than or equal to the current electric supply price. For IDOT, a PPA price of $0.05/kWh or less is economically feasible for all accounts under the current master supply contract, and a PPA price of $0.055/kWh or less is economically feasible for all ComEd accounts.

Given the pricing variability and uncertainties noted above in the literature, our developer discussions, and our pricing model in Figure 12, economic feasibility for an IDOT utility-scale solar PPA is possible but not certain. To resolve the uncertainty and evaluate firm pricing, IDOT would need to issue an RFP. To improve pricing and increase the likelihood of economic feasibility, IDOT would need to solicit a larger solar project in coordination with an additional set of solar PPA customers. Most likely this would be other Illinois state agencies. Illinois Department of Natural Resources is currently engaged in a similar review of solar feasibility and potentially interested in moving forward with an RFP. Illinois Department of Corrections has informally expressed interest during related discussions.

SOLAR PRICING FEASIBILITY FOR BEHIND-THE-METER SOLAR PROJECTS

Economic feasibility of on-site solar projects connected behind the meter is evaluated differently than an off-site project in front of the meter. As described above, pricing for a remotely located off-site project will compete with the existing effective electric supply price. Pricing for an on-site project connected behind the meter, if sized appropriately, will compete against the existing cost for supply and delivery. Electric delivery costs are charged by the utility providing service to the electric account, independently of supply pricing. Case study sites 3, 4, and 5 could host on-site solar projects, and they are in Ameren Illinois territory, where the estimated cost for electric supply and delivery combined is $0.074/kWh.

For these sites, solar project pricing is economically feasible: a) if, in the case of procurement through PPA, the pricing is less than or equal to $0.074/kWh or b) if, in the case of direct purchase, the annual energy cost savings at $0.074/kWh result in a simple payback of the total installed cost within approximately 10–15 years or less, depending on IDOT's rate of return expectations and requirements.

CASE STUDY SITE DESCRIPTIONS

Site 1

Site 1 contains a pair of large parcels near Minooka, which were purchased with the intent of constructing an interchange for the Prairie Parkway Corridor. This site has the capability to provide more electricity from solar than IDOT consumes per the CMS utility database and would generate energy beyond IDOT use. IDOT could coordinate on a joint development with another state agency to maximize the benefits of this site, or it could specify a smaller solar project.

In April 2021, IDOT stakeholders provided an update that the site is being evaluated for an alternate use. Therefore, the actual acreage available for solar development may be less than is indicated in the descriptions below.

Figure 13. Site 1. Satellite view of the area around Site 1.

Figure 14. Site 1. Zoom-in view of Site 1.

Site 1 Sizing and Economics. As summarized in Table 9, this site can host an estimated maximum 25 MW of solar capacity, with an estimated 44,000,000 kWh per year. This location is well suited to supply solar electricity for the approximately 160 IDOT accounts in ComEd, which collectively consume an estimated 13,000,000 kWh per year.

PPA for IDOT Only. We recommend sizing a solar system to meet 70% of this annual electric consumption to allow room for energy efficiency and conservation improvements. To meet this criterion, a 5.5 MW system with annual generation of 9,600,000 kWh is specified. The PPA price would need to be less than the current supply price ($0.057/kWh) to be economically feasible. While a developer might provide better PPA pricing than our model, Figure 15 shows that the modeled PPA price ($0.063/kWh) generates a negative cash flow, averaging −$53,000 per year over the 25-year term, and is not economically feasible. This figure also shows an alternative scenario, assuming that a developer provides a price slightly better ($0.055/kWh) than the existing supply price, which would generate positive cash flow savings, averaging $18,000 per year over the 25-year term.

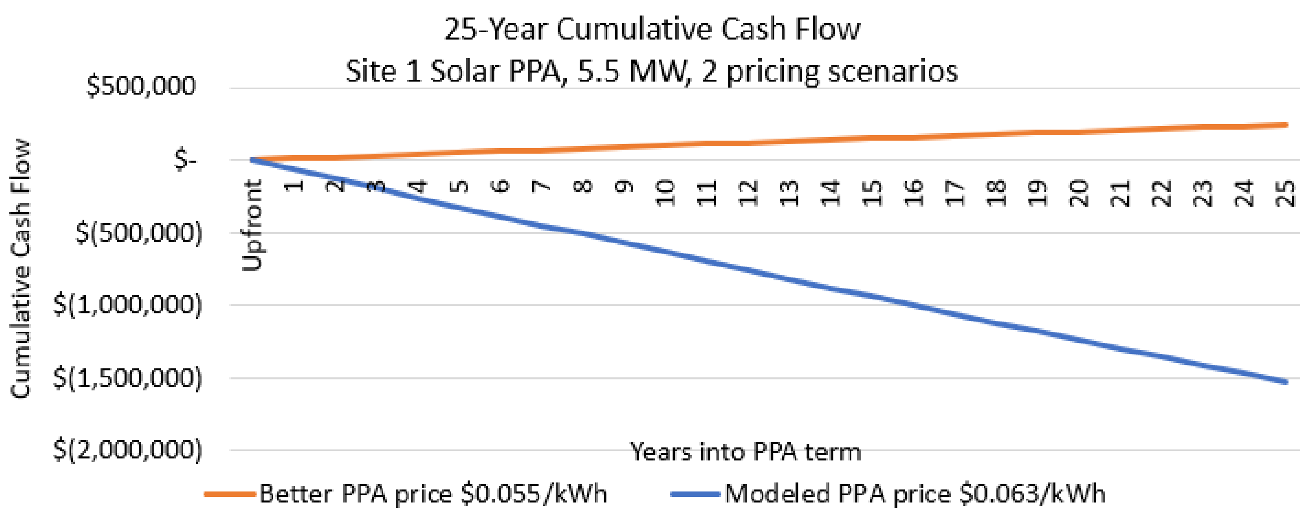

Figure 15. Life cycle analysis high scenario. Life cycle cash flow analysis for Site 1 PPA serving only IDOT ComEd accounts, comparing the base modeled PPA price vs. an optimistic pricing scenario.

PPA contracts often provide provisions for an early buyout of the solar system, which can improve the economics in some cases. If IDOT secures capital to buy out the system at the fair market value of the solar system (not sooner than seven years due to IRS tax regulations that apply to developers) and if IDOT contracts with a third-party company for operation and maintenance services, then IDOT may be able to capture more electricity cost savings value. We assumed operation and maintenance (O&M) costs to be $15 per year per kW of system capacity (Walker et al., 2020). PPA requests for proposals will commonly ask bidders to include an annual schedule of buyout values, starting with year seven, so that the buyout values are known and agreed to at the start of the contract. Buyout valuation is highly variable from one developer to the next and from one project to the next. A buyout is typically structured as an option that can be exercised if desired.

Figure 16 shows the cash flow analysis for a scenario involving a seven-year buyout assuming a fair market value of 50% of the original $8 million installed cost, and further assuming the modeled PPA price ($0.063/kWh). This scenario becomes cash flow positive in year 17, at which point the system will deliver positive cash flow savings averaging $400,000 per year ($490,000/year energy cost savings; $90,000/year O&M costs). In this case the buyout scenario improved the economic feasibility, compared to the economically unfeasible 25-year PPA scenario in Figure 15. Setting other sensitivity factors aside, the buyout scenario results are contingent on two key assumptions: 1) IDOT will have $4 million of capital to invest in year 7, and 2) IDOT will, as mentioned above, be responsible for continuous operations and maintenance of the system or for continuously contracting out the operations and maintenance services. The expense categories involved in solar system operations and maintenance include solar panel cleaning, vegetation management, system inspection and monitoring, replacement parts, solar panel replacement, inverter replacement, and operations administration. Lack of maintenance results in serious degradation of system performance and economic feasibility. End of life decommissioning and removal is an additional expense for system owners, estimated at $100,000 per MW of system capacity (NYSERDA, 2020).

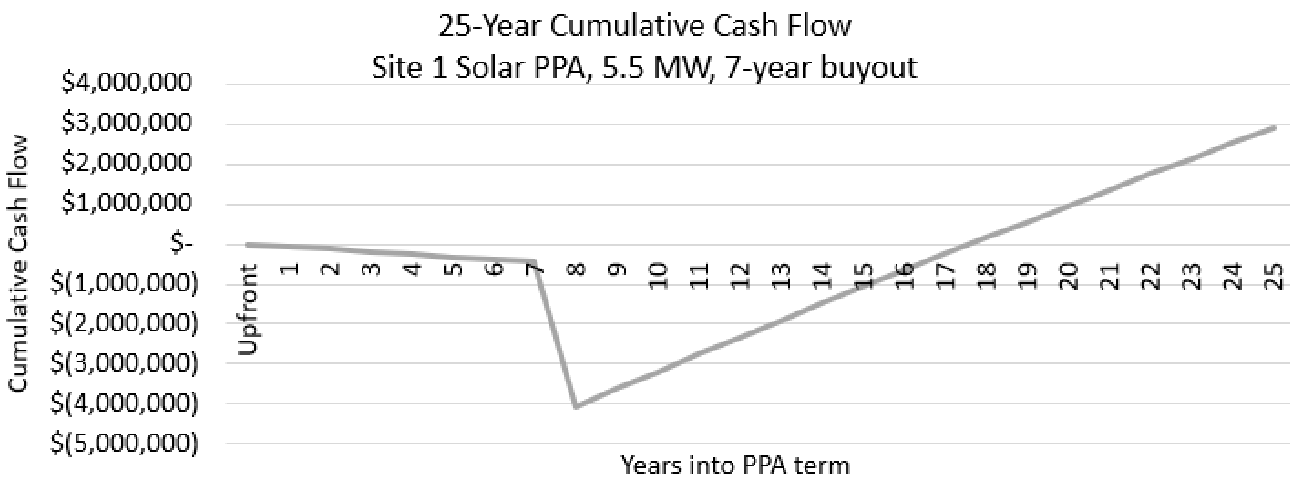

Figure 16. Life cycle analysis 50% fair market value. Life cycle cash flow analysis for Site 1 PPA serving only IDOT ComEd accounts, assuming the base modeled PPA price ($0.063/kWh) and a seven-year buyout scenario at 50% fair market value.

Due to the correlation between project costs and the PPA rate, it is possible to get a better PPA price by investing capital up front. This buy-down of the PPA contract allows IDOT to offset some of the up-front system costs and reduce the amount of cost that needs to be financed by the developer over the life of the system. Figure 17 shows the cash flow analysis for a scenario involving an initial investment of $4 million (50% of the original $8 million installed cost) to buy down the PPA price. The graph shows that the modeled PPA price ($0.031 /kWh) generates a positive cash flow, averaging $224,000 per year over the 25-year term, and it becomes cash flow positive in year 18. In this case the buy-down scenario improved the economic feasibility, compared to the economically unfeasible 25-year PPA scenario in Figure 15.

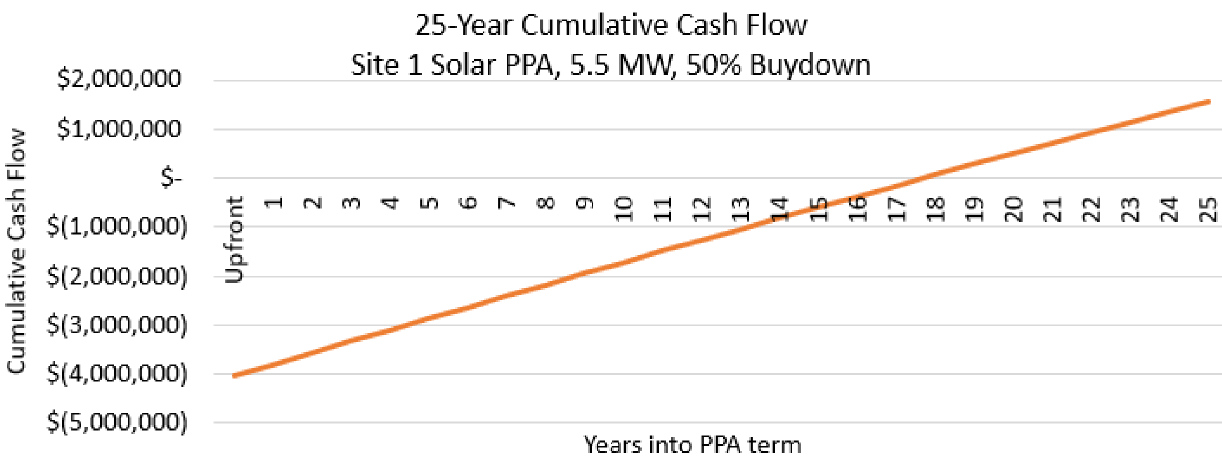

Figure 17. Life cycle analysis of a PPA buy-down scenario. Life cycle cash flow analysis for Site 1 PPA serving only IDOT ComEd accounts, assuming the modeled buy-down PPA price ($0.031/kWh) and a 50% upfront investment in the cost of the solar system.

Direct Purchase for IDOT Only. This scenario involves the same system as described above (5.5 MW capacity and 9,600,000 kWh in the first year). However, the procurement method is direct purchase and ownership by IDOT, rather than by PPA. As shown in Figure 18, IDOT would invest approximately $8 million upfront, and the system would become cash flow positive in year 18, at which point the system will deliver positive cash flow savings averaging $400,000 per year ($490,000/year energy cost savings; $90,000/year O&M cost). Like the description of the buyout scenario above, IDOT would be responsible for continuous operations and maintenance of the system or for continuously contracting out the operations and maintenance services, as well as decommissioning at system end of life. Interestingly, a direct purchase is slower to become cash flow positive, when compared to the seven-year buyout scenario above. The cost of the developer overhead and profit is outweighed by the benefit of the investment tax credit that the developer can claim in the PPA. In a direct purchase, IDOT does not benefit from the investment tax credit, resulting in a higher net installation cost.

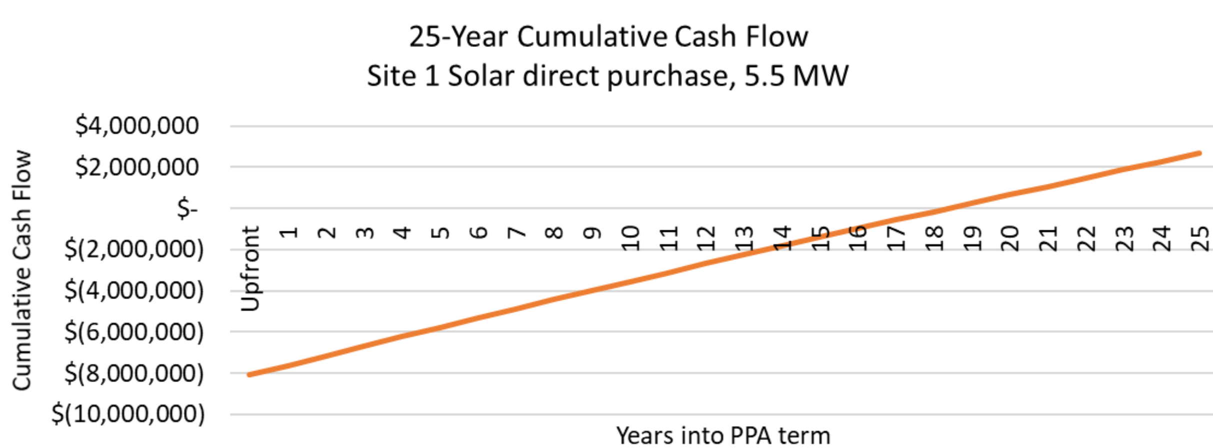

Figure 18. Life cycle analysis of direct purchase scenario. Life cycle cash flow analysis for Site 1 direct purchase serving only IDOT ComEd accounts.

IDOT and Other State Agencies for Maximum Site Build Out, PPA. For better economic feasibility this scenario assumes that IDOT will coordinate with other state agencies with sufficient annual electricity use for a 25 MW solar system with annual generation of 44,000,000 kWh. Figure 19 shows that the modeled PPA price ($0.051/kWh) immediately generates a positive cash flow, averaging $260,000 per year over the 25-year term, and is economically feasible. The figure also shows an alternative pessimistic scenario assuming that a developer provides a price slightly worse ($0.06/kWh) than the existing supply price, which would generate negative cash flow, averaging −$120,000 per year over the 25-year term.

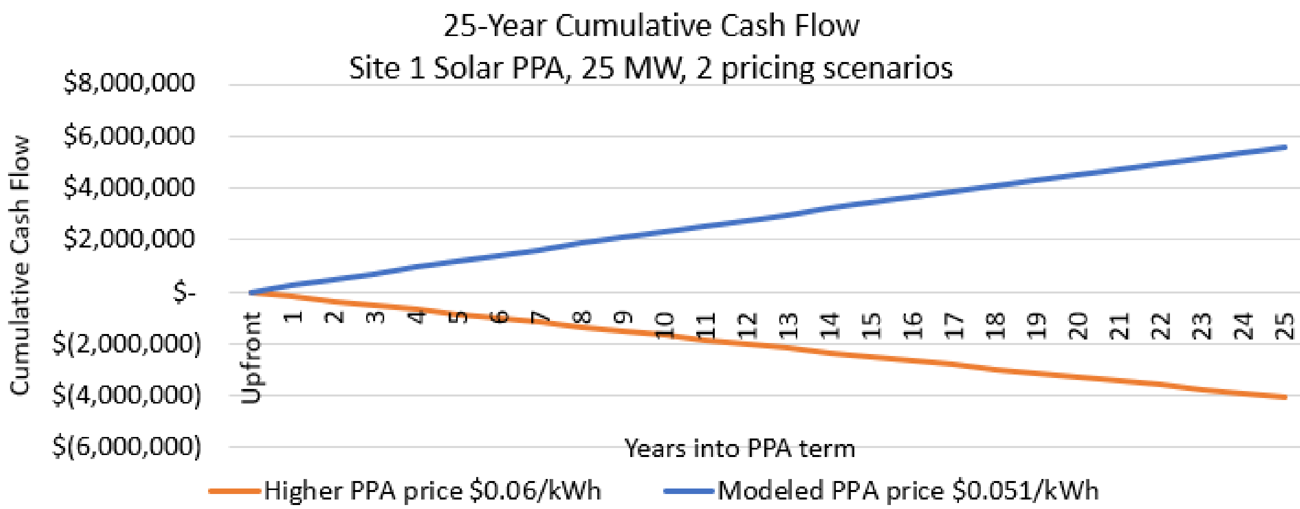

Figure 19. Life cycle analysis low scenario. Life cycle cash flow analysis for Site 1 PPA serving IDOT and other state agency ComEd accounts, comparing the base modeled PPA price vs. a pessimistic pricing scenario.

Site 2

Site 2 has a single, large parcel near Stallings, which was purchased for flood control near St. Louis. The site is protected by a berm and is not located in the flood plain. This site has the capability to provide more electricity from solar than IDOT consumes in the Ameren territory per the CMS utility database. IDOT could coordinate on a joint development with another state agency to maximize the benefits of this site, or it could specify a smaller solar project.

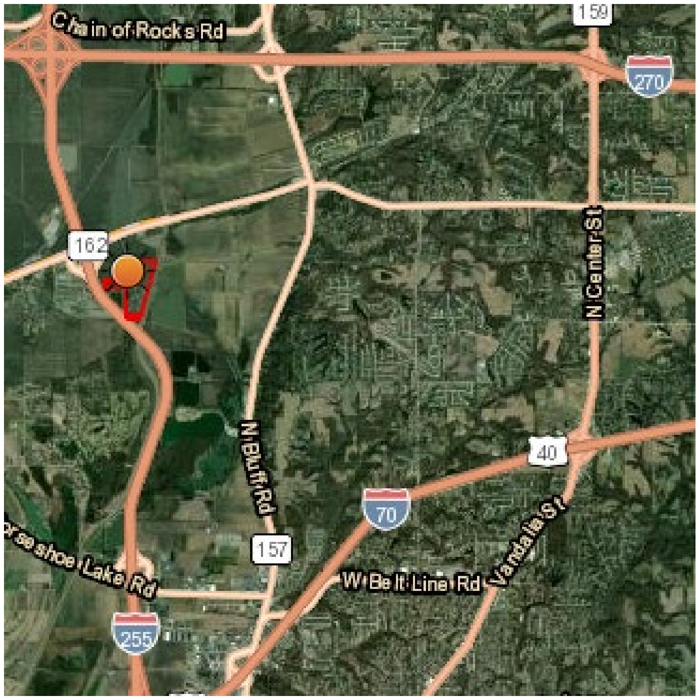

Figure 20. Site 2. Satellite view of the area around Site 2.

Figure 21. Site 2. Zoom-in view of Site 2.

Site 2 Sizing and Economics. As summarized in Table 9, this site can host an estimated maximum 15 MW of solar capacity, with an estimated 21,000,000 kWh per year. This location is well suited to supply solar electricity for the approximately 190 IDOT accounts in Ameren Illinois, which collectively consume an estimated 10,000,000 kWh per year.

PPA for IDOT Only. We recommend sizing a solar system to meet 70% of this annual electric consumption to allow room for energy efficiency and conservation improvements. To meet this criterion, a 4 MW system with annual generation of 7,000,000 kWh is specified. The PPA price would need to be less than the current supply price ($0.052/kWh) to be economically feasible. While a developer might provide better PPA pricing than our model, Figure 22 shows that the modeled PPA price ($0.065/kWh) generates a negative cash flow, averaging −$88,000 per year over the 25-year term, and is not economically feasible. The figure also shows an alternative scenario assuming that a developer provides a price slightly better ($0.050/kWh) than the existing supply price, which would generate a positive cash flow savings, averaging $13,000 per year over the 25-year term.

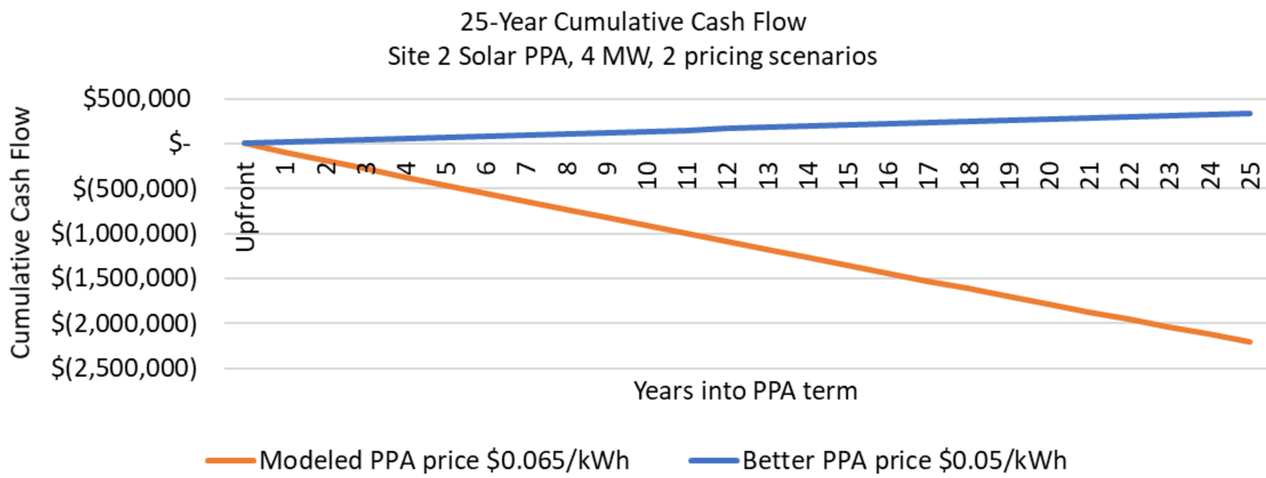

Figure 22. Life cycle analysis high scenario. Life cycle cash flow analysis for Site 2 PPA serving only IDOT Ameren Illinois accounts, comparing the base modeled PPA price vs. an optimistic pricing scenario.

If IDOT secures capital to buy out the system at the fair market value of the solar system (not sooner than seven years due to IRS tax regulations that apply to developers) and if IDOT contracts with a third-party company for operation and maintenance services, then IDOT may be able to capture more electricity cost savings value. As with the analysis in Case Study Site 1 above, we assumed operation and maintenance costs to be $15 per year per kW of system capacity. Figure 23 shows the cash flow analysis for a scenario involving a seven-year buyout assuming a fair market value of 50% of the original $6 million installed cost, and further assuming the modeled PPA price ($0.065/kWh). This scenario becomes cash-flow positive in year 20, at which point the system will deliver positive cash flow savings averaging $260,000 per year ($330,000/year energy cost savings; $70,000/year O&M costs). It involves an IDOT capital investment of approximately $3 million in year 7 and IDOT taking responsibility for O&M for the life of the system and decommissioning.

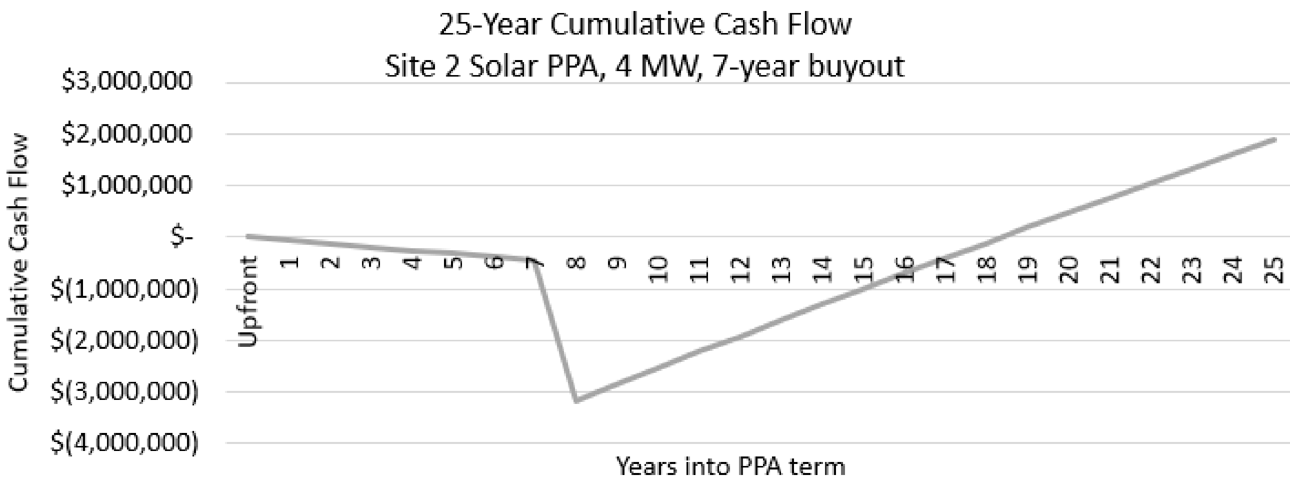

Figure 23. Life cycle analysis 50% fair market value. Life cycle cash flow analysis for Site 2 PPA serving only IDOT Ameren Illinois accounts, assuming the base modeled PPA price ($0.065/kWh) and a seven-year buyout scenario at 50% FMV.

If IDOT can invest capital up front, then it is possible to get a better PPA price. This buy-down of the PPA contract allows IDOT to offset some of the up-front system costs and reduce the amount of cost that needs to be financed by the developer over the life of the system. Figure 24 shows the cash flow analysis for a scenario involving an initial investment of $3 million (50% of the original $6 million installed cost) to buy down the PPA price. The graph shows that the modeled PPA price ($0.033/kWh) generates a positive cash flow, averaging $155,000 per year over the 25-year term, and it becomes cash flow positive in year 20. In this case the buy-down scenario improved the economic feasibility, compared to the economically unfeasible 25-year PPA scenario in Figure 22.

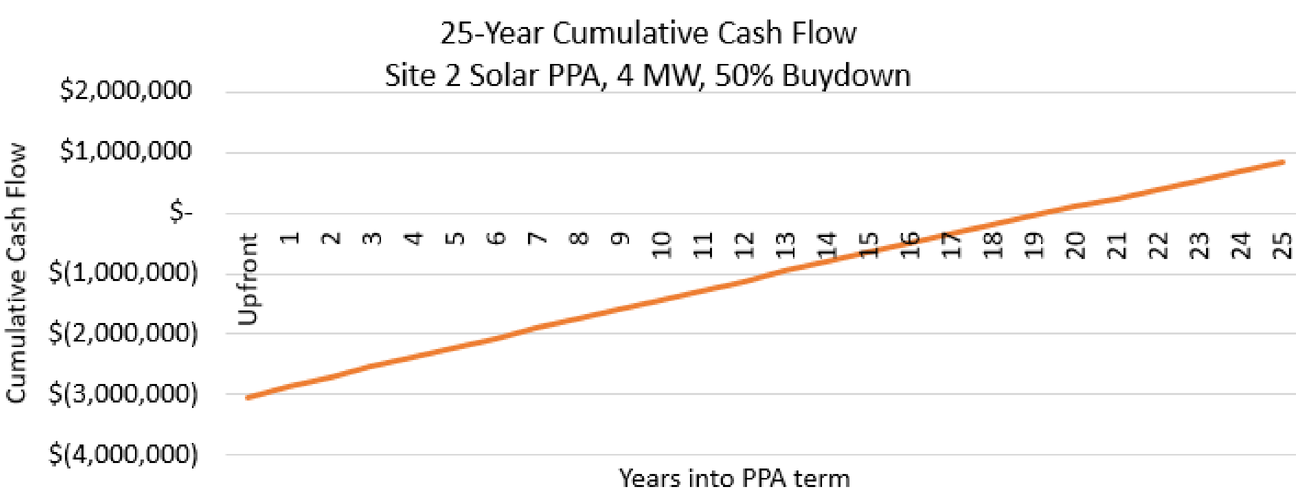

Figure 24. Life cycle analysis of a PPA buy-down scenario. Life cycle cash flow analysis for Site 1 PPA serving only IDOT ComEd accounts, assuming the modeled buy-down PPA price ($0.033/kWh) and a 50% upfront investment in the cost of the solar system.

Direct Purchase for IDOT Only. This scenario involves the same system as described above (4 MW capacity and 7,000,000 kWh in the first year). However, the procurement method is direct purchase and ownership by IDOT, rather than by PPA. As shown in Figure 25, IDOT would invest approximately $6 million upfront, and the system would become cash flow positive in year 21, at which point the system will deliver positive cash flow savings averaging $260,000 per year ($330,000/year energy cost savings; $70,000/year O&M costs). IDOT would be responsible for continuous operations and maintenance of the system or for continuously contracting out the operations and maintenance services, as well as decommissioning at system end of life. Compared to the seven-year buyout scenario in Figure 23 above, the direct purchase procurement method is slower to become cash flow positive because IDOT cannot capture the value of the investment tax credit, resulting in a higher net installation cost.

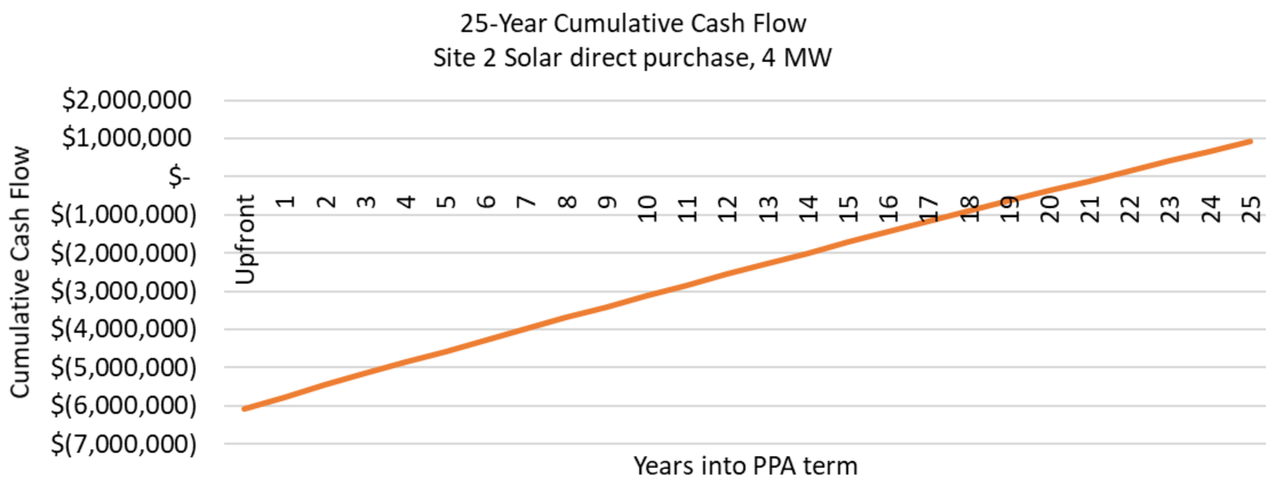

Figure 25. Life cycle analysis of direct purchase scenario. Life cycle cash flow analysis for Site 2 direct purchase serving only IDOT Ameren Illinois accounts.

IDOT and Other State Agencies for Maximum Site Build Out, PPA. For better economic feasibility, this scenario assumes that IDOT will coordinate with other state agencies with sufficient annual electricity use for a 15 MW solar system with annual generation of 26,000,000 kWh. Figure 26 shows that the modeled PPA price ($0.055/kWh) generates a negative cash flow, averaging −$69,000 per year throughout the 25-year term, and is not economically feasible. The figure also shows an alternative scenario, assuming that a developer provides a price slightly better ($0.050/kWh) than the existing supply price, which would generate positive cash flow savings, averaging $50,000 per year over the 25-year term. The graph also shows the cash-flow analysis for a scenario involving a seven-year buyout, assuming a fair market value of 50% of the original $20 million installed cost, and further assuming the modeled PPA price ($0.055/kWh). This scenario becomes cash-flow positive in year 17, at which point the system will deliver positive cash flow savings averaging $1 million per year ($1.2 million/year energy cost savings; $200,000/year O&M costs). It involves an IDOT or State of Illinois capital investment of approximately $10 million in year 7 and IDOT taking responsibility for O&M for the life of the system and decommissioning.

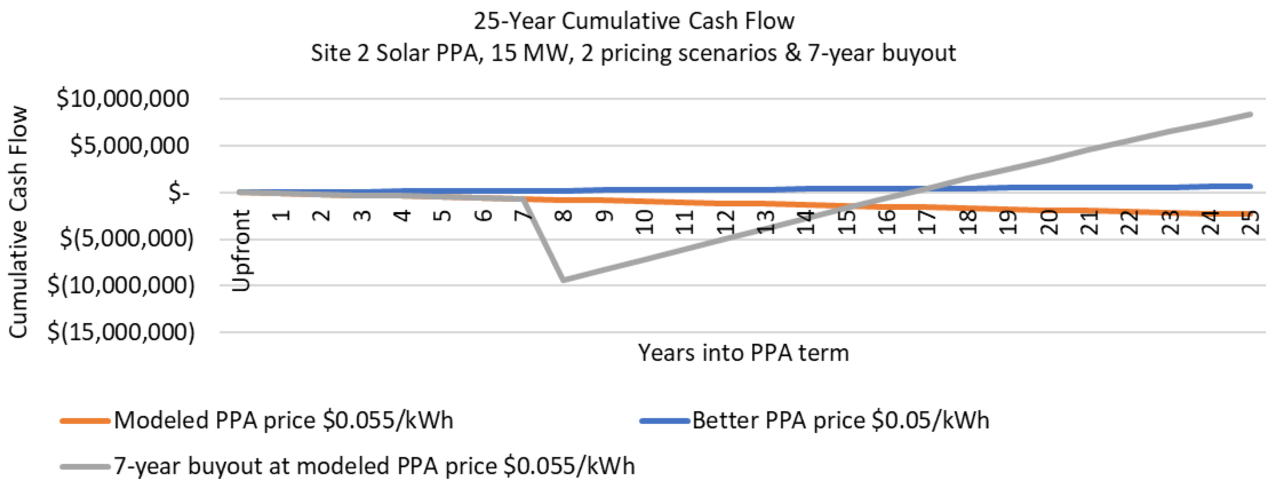

Figure 26. Life cycle analysis high and buyout scenario. Life cycle cash flow analysis for Site 2 PPA serving IDOT and other state agency Ameren Illinois accounts, comparing the base modeled PPA price vs. an optimistic pricing scenario and a seven-year buyout option.

Site 1 + Site 2 Sizing and Economics. As summarized in Table 9, these sites combined can host an estimated maximum 40 MW of solar capacity, with an estimated 70,000,000 kWh per year. This location is well suited to supply solar electricity for the approximately 350 IDOT accounts in ComEd and Ameren Illinois, which collectively consume an estimated 23,000,000 kWh per year.

PPA for IDOT Only. We recommend sizing a solar system to meet 70% of this annual electric consumption to allow room for energy efficiency and conservation improvements. To meet this criterion, a 9 MW system with annual generation of 16,000,000 kWh is specified. The PPA price would need to be less than the current blended average supply price ($0.056/kWh) to be economically feasible. While a developer might provide better PPA pricing than our model, Figure 27 shows that the modeled PPA price ($0.059/kWh) generates a negative cash flow, averaging −$41,000 over the 25-year term, and is not economically feasible. This figure also shows an alternative scenario, assuming that a developer provides a price slightly better ($0.054/kWh) than the existing supply price, which would generate positive cash flow savings, averaging $31,000 per year over the 25-year term.

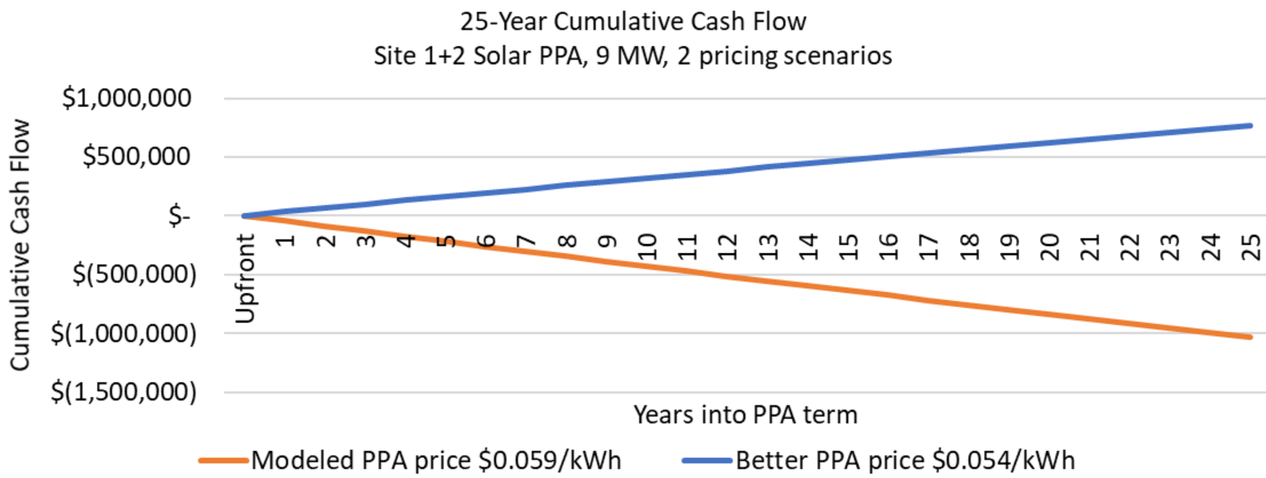

Figure 27. Life cycle analysis 1 and 2. Life cycle cash flow analysis for Site 1+2 PPA serving only IDOT ComEd and Ameren Illinois accounts, comparing the base modeled PPA price vs. an optimistic pricing scenario.

If IDOT secures capital to buy out the system at the fair market value of the solar system (not sooner than seven years due to IRS tax regulations that apply to developers) and if IDOT contracts with a third-party company for operation and maintenance services, then IDOT may be able to capture more electricity cost savings value. Figure 28 shows the cash flow analysis for a scenario involving a seven-year buyout, assuming a fair market value of 50% of the original $13 million installed cost, and further assuming the modeled PPA price ($0.059/kWh). This scenario becomes cash-flow positive in year 17, at which point the system will deliver positive cash flow savings averaging $650,000 per year ($800,000/year energy cost savings; $150,000/year O&M costs). It involves an IDOT capital investment of approximately $6.5 million in year 7 and IDOT taking responsibility for O&M for the life of the system and decommissioning.

If IDOT can invest capital up front, then it is possible to get a better PPA. This buy-down of the PPA contract allows IDOT to offset some of the up-front system costs and reduce the amount of cost that needs to be financed by the developer over the life of the system. Figure 29 shows the cash flow analysis for a scenario involving an initial investment of $6.5 million (50% of the original $13 million installed cost) to buy down the PPA price. The graph shows that the modeled PPA price ($0.029 /kWh) generates a positive cash flow, averaging $400,000 per year over the 25-year term, and it becomes cash flow positive in year 16. In this case the buy-down scenario improved the economic feasibility, compared to the economically unfeasible 25-year PPA scenario in Figure 27.

Direct Purchase for IDOT Only. This scenario involves the same system as described above (9 MW capacity and 16,000,000 kWh in the first year). However, the procurement method is direct purchase and ownership by IDOT, rather than by PPA. As shown in Figure 29, IDOT would invest approximately $13 million upfront, and the system would become cash flow positive in year 18, at which point the system will deliver positive cash flow savings averaging $650,000 per year ($800,000/year energy cost savings; $150,000/year O&M costs). IDOT would be responsible for continuous operations and maintenance of the system or for continuously contracting out the operations and maintenance services, as well as decommissioning at system end of life. Compared to the seven-year buyout scenario in Figure 28, the direct purchase procurement method is slower to become cash flow positive because IDOT cannot capture the value of the investment tax credit, resulting in a higher net installation cost.

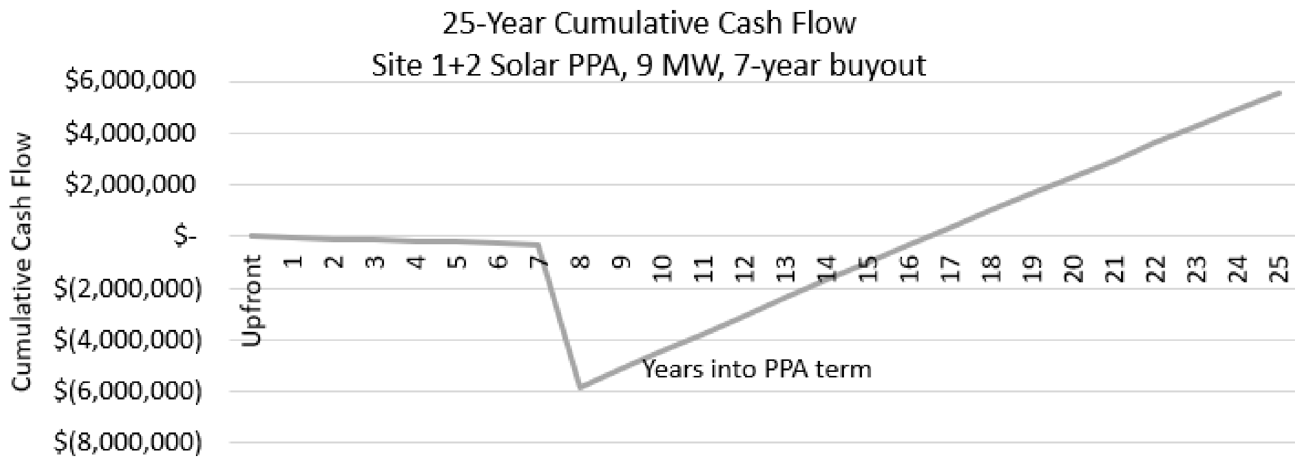

Figure 28. Life cycle analysis 1 and 2 buyout and 50% fair market value. Life cycle cash flow analysis for Site 1+2 PPA serving only IDOT ComEd and Ameren Illinois accounts, assuming the base modeled PPA price ($0.059/kWh) and a seven-year buyout scenario at 50% FMV.

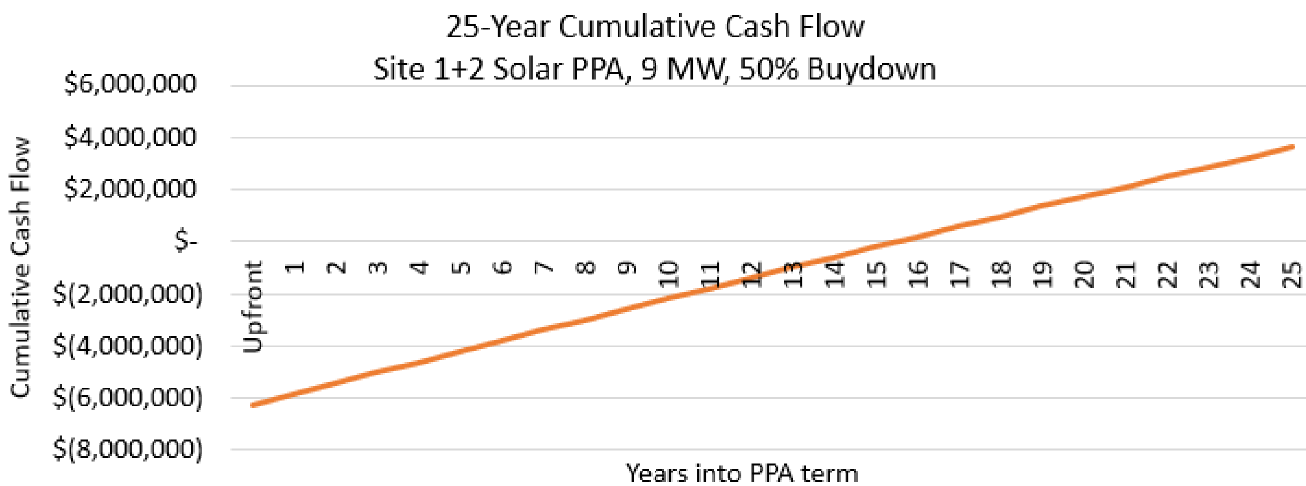

Figure 29. Life cycle analysis of a PPA buy-down scenario. Life cycle cash flow analysis for Site 1 and 2 PPA serving only IDOT ComEd accounts, assuming the modeled buy-down PPA price ($0.029/kWh) and a 50% upfront investment in the cost of the solar system.

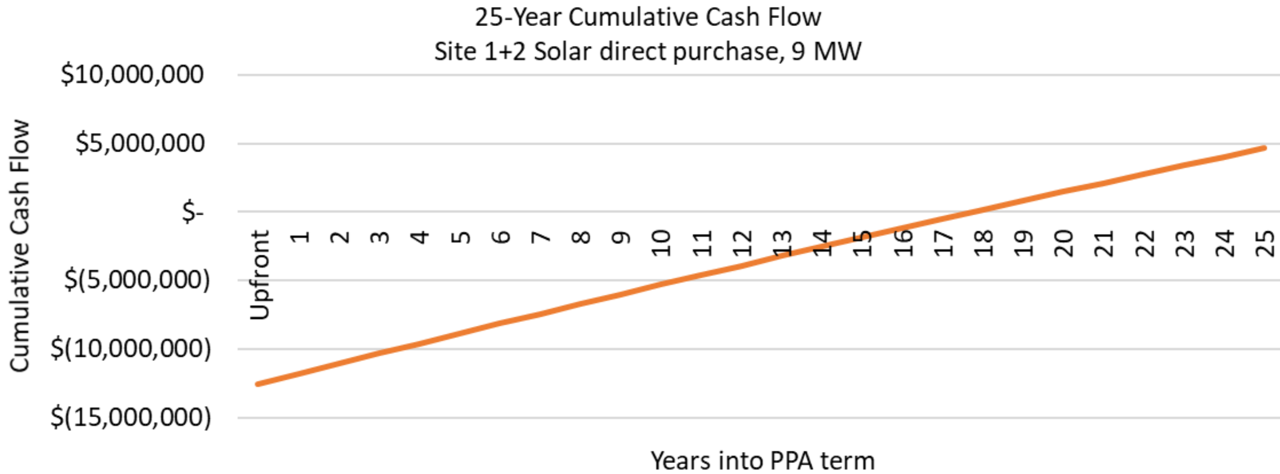

Figure 30. Life cycle analysis of direct purchase scenario. Life cycle cash flow analysis for Site 1+2 direct purchase serving only IDOT ComEd and Ameren Illinois accounts.

IDOT and Other State Agencies for Maximum Site Build Out. For better economic feasibility this scenario assumes that IDOT will coordinate with other state agencies with sufficient annual electricity use for a 40 MW solar system with annual generation of 70,000,000 kWh. Figure 30 shows that the modeled PPA price ($0.047/kWh) generates a positive cash flow immediately, averaging $600,000 per year throughout the 25-year term, and is economically feasible. The figure also shows an alternative pessimistic scenario assuming that a developer provides a price slightly worse ($0.058/kWh) than the existing average blended supply price, which would generate negative cash flow, averaging −$130,000 per year over the 25-year term. The graph also shows the cash-flow analysis for a scenario involving a seven-year buyout, assuming a fair market value of 50% of the original $47 million installed cost, and further assuming the modeled PPA price ($0.047/kWh). This scenario becomes cash-flow positive in year 13, at which point the system will deliver positive cash flow savings averaging $2.9 million per year ($3.6 million/year energy cost savings; $700,000/year O&M costs). It involves an IDOT or State of Illinois capital investment of approximately $23 million in year 7 and IDOT taking responsibility for O&M for the life of the system and decommissioning.

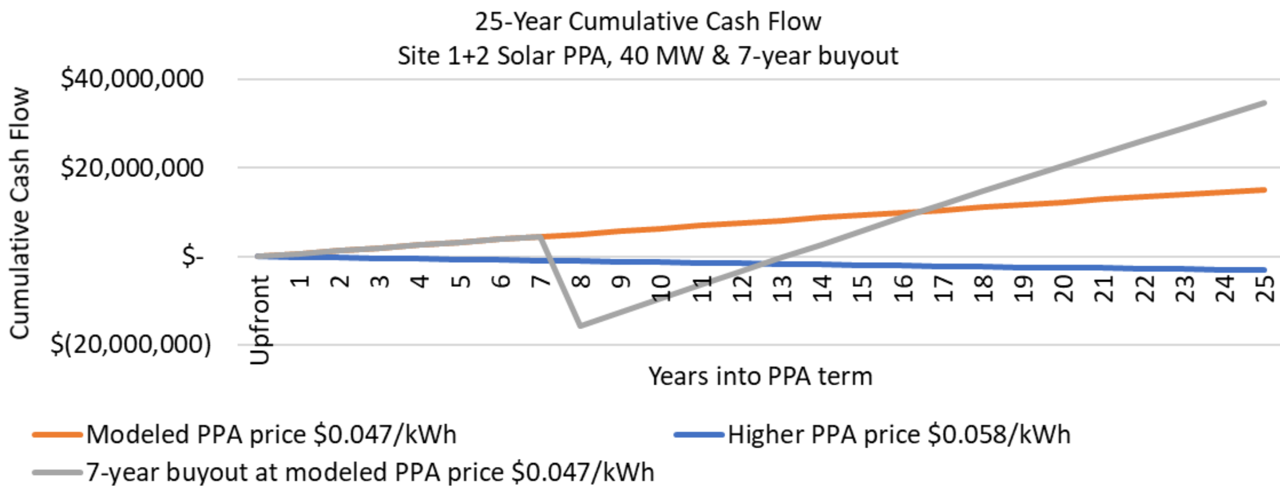

Figure 31. Life cycle analysis 1 and 2 low buyout. Life cycle cash flow analysis for Site 1+2 PPA serving IDOT and other state agency ComEd and Ameren Illinois accounts, comparing the base modeled PPA price vs. a pessimistic pricing scenario and a seven-year buyout option.

Sites 3 and 4

Site 3 consists of a set of sites in the Bloomington/Normal area and includes two maintenance yards in Ameren territory. Both yards, in Bloomington and in Towanda, have enough roof space for solar systems that could supply all the site electricity. Roof conditions in Bloomington are reported to be in good shape. In Towanda, there is an old building needing a new roof in five years and a large new building with a good roof. A solar system at the Bloomington Yard could potentially connect to a lighting system whose controller is located near the south end of the yard. The District 5 personnel discussing this site expressed interest in direct ownership and maintenance of small systems such as these.

Figure 32. Site 3. Satellite view of the area around Site 3.

Site 4 is at an interchange near Tuscola. Because IDOT replaced the old high-pressure sodium lighting with new LED lighting, this substantially reduced the size of the solar system required to provide the electricity needed for the lighting. Therefore, the size of the solar system required to offset the power consumed at Site 4 is only 6 kW. Similar to Site 3, the District 5 personnel discussing this site expressed interest in direct ownership and maintenance of a small system like this.

Figure 33. Site 4. Satellite view of the area around Site 4.

Figure 34. Site 4. Zoom-in view of Site 4.

Site 3 and Site 4 Economics. Sites 3 and 4 have less attractive economics as they are not able to take advantage of the economies of scale that sites 1 and 2 do. Site 3 would have an estimated direct purchase cost of $220,000 providing a simple payback of 20 years or provide a PPA rate of 9.4 cents per kWh. Site 4 would have an estimated direct purchase cost of $15,000 with a simple payback of 24 years. Alternatively, a PPA rate of 14 cents per kWh might be anticipated. Table 11 summarizes the economics for Site 3 and Site 4.

Table 11. Summary of Case Study Site Economics

Site	Solar System Size	Utility	Direct Purchase Option Cost ($)	Simple Payback (Years)
3—Maintenance/ Lighting	108 kW	Ameren	$220k	20
4—Interchange	6 kW	Ameren	$15k	24

Site 5

Site 5 is an intersection near Monmouth. This is a site that IDOT had investigated around a decade ago to provide lighting. At the time there was no development nearby. Since that time, the Cooperative has extended their system closer to the intersection and the estimated cost to connect has decreased.

Figure 35. Site 5. Satellite view of the area around Site 5.

Figure 36. Site 5. Zoom-in view of Site 5.

With LEDs and solar panels improving their performance, integrated products are now on the market that include solar panels, LED fixtures, and batteries in one package. An integrated system would cost around $210,000. This is for 24 fixtures, which would be on a 33-foot pole and provide 3,000 lumens each. They also contain a battery cabinet and would require periodic maintenance, including battery replacement. This scenario is not economically feasible based on energy cost factors alone.

Alternatively, IDOT might consider having the cooperative bring electricity to the site to avoid the cost and maintenance of a system requiring batteries. The cooperative now estimates the cost to bring power to the site at around $5,000 now that there is power nearby.

CHAPTER 5: DECISION-SUPPORT TOOL

This chapter discusses the development of the long-term decision-support tool. This tool sought to bring together a number of different data streams regarding site suitability and overlay them for dissemination within a single, spatially oriented framework. The challenge of creating such a framework was being able to successfully overlay spatial, locational data with information about solar suitability and input from stakeholders regarding the most desirable sites.

To meet these goals, a web-based decision-support tool was created that would allow stakeholders to quickly evaluate the suitability of potential sites using an intuitive, familiar graphic user interface. Users would be able to quickly scan areas within the state for potential suitable sites, "zooming in" to access more granular data as necessary. In this chapter, we first explore how new tools are helping decision-makers to make informed choices in matters related to land use. Second, we discuss the development of the decision-support tool utilized in our specific case. We then offer a graphical "demonstration" of the functioning of the tool. Finally, we review the tool's features and set up a roadmap for future tool improvements.

PLANNING SUPPORT SYSTEMS

Since Ian McHarg (1971) first introduced large-scaled scientific approaches (i.e., overlay methods), planners have strived to provide tools that allow for the simultaneous consideration of spatial data from a number of streams. Beginning in the latter half of the twentieth century, the creation of tools that could allow for decision-makers to quickly understand and act on quantitative data became more common. Such tools were often called planning support systems (PSSs).

Planning support systems are spatial, data-driven tools, which have shown an ability to enhance environmental outcomes by offering decision-makers the ability to measure, scenario test, and visualize potential outcomes (Deal & Pan, 2016; Geertman et al., 2013). Use of such tools allows for decision-makers to analyze complex environmental systems, identify potential problems, and respond to such problems in a data-driven way. At their best, PSSs are designed with simple user interfaces that enable nontechnical users to navigate data analysis and evaluate potential solutions independent of direct support from technical experts (Geertman et al., 2013). Traditionally, PSSs use GIS to analyze and visualize spatial data, especially as such data relate to scenario planning.

The literature on PSSs suggests that large-scale analysis should incorporate contextually explicit information that allows policymakers to determine suitability, project relevant demands, and inform localized decisions (Klosterman & Pettit, 2005). These tools are typically asked to help facilitate a consensus-driven decision-making process (Waddell, 2001). According to Geertman (2008), this is highly dependent on the ability of the PSS tools to represent the specific context of the application. He notes that this ability to contextualize information influences how and to what degree the tool will be used. Similarly, Andrews (2002) argues that effective planning models must be locally credible to successfully support decisions. Good PSS tools, therefore, should be capable of contextualizing the characteristics and demands of specific sites as part of a larger analytical or planning process (Andrews, 2002; Deal et al., 2017a).

Highly scalable PSS modeling systems can convey spatially explicit information from a variety of sources in a readily understandable and contextual form that enables decision-making based on site conditions (Klosterman, 1997). They enable a fine-grained spatial assessment, comparison, and site identification in support of very local decision-making. This allows, with visual representation functions, an ability to govern multi-scalar systems collectively (Norberg & Cumming, 2008); suitable locations for development activities (e.g., solar development), for example; and other planning suitability questions (Steel et al., 2008).

PSS usefulness is a topic of note in the current literature. Pan and Deal (2020) note that a credible PSS requires objectiveness, reasonableness, and understandability to be classified as "useful." PSS operationalization, according to Brömmelstroet (2013), is a function of the quality of analytic outcomes and quality of communicative processes in operationalizing a PSS. Generally, a credible PSS must produce quality analyses, effectively communicate outcomes to nonexperts (e.g., stakeholders) in understandable manners, and well account for the local condition (Andrews, 2002; Pan & Deal, 2020). Decisions made through a credible PSS with explicit contextual information are more understandable to the user, more easily replicable, and quicker to track and manage (Bach et al., 2020; Marimbaldo et al., 2018).

In recent years, advances in computational technology have allowed for PSSs to evolve through the use of new spatial methods and software technologies (Geertman et al., 2017). These advanced technologies and tools have enabled a new generation of PSSs that are capable of performing more complex tasks through their ability to evaluate complex algorithms in relatively little time (Widjaja et al., 2015). Perhaps the greatest value of these tools is that they allow for esoteric and opaque datasets to be infused in decision-making in an understandable way (Pan & Deal, 2020). In doing so, these systems are capable of conveying complex computational outcomes to decision-makers who are not experts in model generation (Deal et al., 2017b). Various PSSs have been used successfully to measure the suitability of different areas for renewable energy (Flacke & DeBoer, 2017; Deal et al., 2017c).

TOOL DEVELOPMENT

The planning support system-like tool that was developed for this project is, like many such tools, underpinned by data available through GIS. Such spatially explicit data was processed and analyzed using ArcGIS, an industry-standard GIS software system. Encoded within this system were data involving the location, size, and physical characteristics of potential sites under consideration for solar development.

Once data analysis was complete, it was necessary to devise a method by which spatial information from ArcGIS and non-spatially explicit information could be harmonized. This represented an iterative process in which graphical "mock ups" of web pages were produced and reviewed by staff. Each page that was necessary to the web-based tool was designed via a graphical mock-up and changed through the design process based on user feedback. Once the mock-ups were suitably complete, it became possible to begin with the digital construction process of the tool.

An interactive data visualization software, Tableau, was used to begin to display the spatial data on reactive maps. Using this system, end users can “navigate around” the entire stock of potential sites around the state of Illinois by zooming in and out. The devised solution also allowed for individual sites to be selected, which afforded an opportunity to display the properties of each site by selecting it in the graphic user interface.

The tool reacts to a number of different user inputs that are not directly related to navigating around the map or displaying site properties. For example, users can toggle between different maps of relevance by selecting the appropriate button from the user interface. This non-map-based reactive functionality was implemented using novel HTML and JavaScript coding solutions.

Display of the map tool in a web-based format made further use of HTML coding, allowing the tool to be displayed on most common web browsers and devices. Finally, CSS was used to provide a graphically consistent and aesthetically suitable user experience.

In the final developed solution, users are able to intuitively navigate between various maps of relevance, viewing the state at the scale that is most useful for their analysis. All sites considered can be visualized collectively, with additional information available on each site. The model is also sophisticated enough to evaluate potential sites in different ways, considering variables that may be impactful to one type of property, but not to others.

Open lands, for example, are rated on their available land size. Because they do not have the ability to benefit from net metering, the primary factor dictating their suitability is their ability to benefit from economies of scale. Such economies are *prima facie* easier to realize on a larger site. Interchanges, conversely, were rated based on if they had a controlled intersection present. Conversations with FHWA raised substantial concerns about maintenance of solar systems and possible hazards to motorists at uncontrolled intersections. Therefore, for interchange sites, one measure of suitability is the presence of a controlled intersection. Meanwhile, one limiting factor in solar productivity in rest areas was their tree canopy, the shade from which could be detrimental to solar generation. For the purpose of the tool developed, rest areas are considered more suitable for solar development if they have little shade.

Of course, even the most robust tool is not without its limitations. Some site-specific factors may not be apparent from the general datasets that were analyzed. For example, the condition of an existing roof or the ease of accessibility between solar systems and interconnection points could both be important factors to a decision-maker, yet such granular information is not captured by the model. The decision-support tool, then, is best used alongside the contextual expertise of decision-makers.

PRESENTATION OF THE TOOL

In this section, explanations and screenshots from within the tool demonstrate its operation and functionality. Figure 36, for example, displays a map of the entire state in the tool’s viewer window. The blue dots visible at various locations throughout the state represent IDOT’s existing office and maintenance yard.

Below each displayed map is a text explanation of the map. In Figure 37, this expository text states that the map is displaying offices and maintenance yards and provides a "key" for reading the color of the dots. Blue dots represent sites that show promise for implementing solar installations. As evidenced in this image, offices and maintenance yards in general tend to be strong candidates for solar implementation due to minimal conflicts and a large roof area available for solar relative to the amount required to serve the on-site load. Maintenance yards also do not have substantial shade that would conflict with the solar systems, and they are generally secured with fencing and other security features.

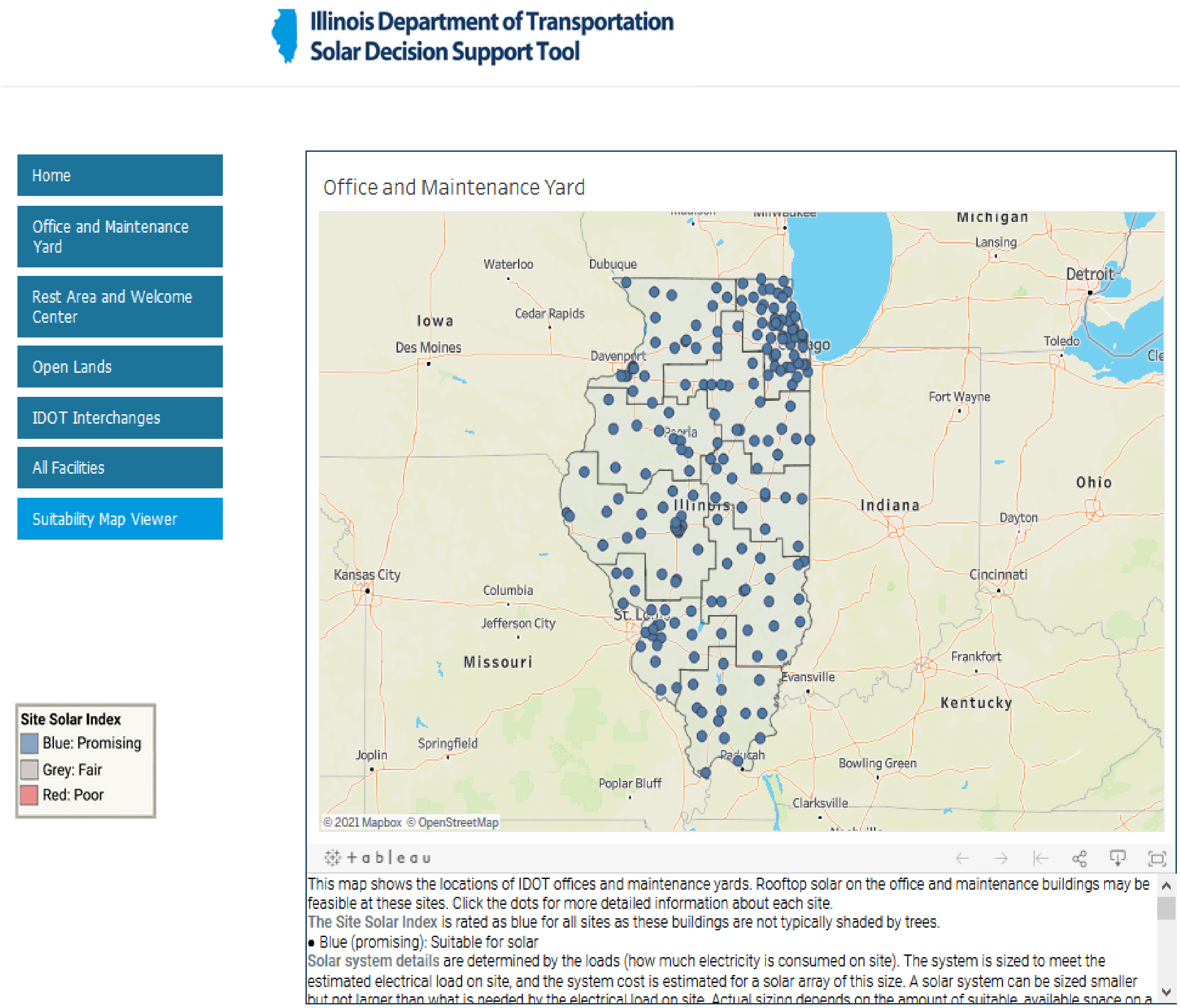

Figure 37. IDOT solar decision-support tool. A screenshot of the display of IDOT DST. Office and maintenance yards are shown in blue dots. Land menu is to the left.

As shown in Figure 38, each “dot” on the map can convey a much greater degree of information than just the degree of promise for future solar installation. In this image, a single point has been selected, which has caused information about this particular site to be displayed. In this case, the site selected is at 4142 North Westlawn Avenue in Decatur, Illinois.

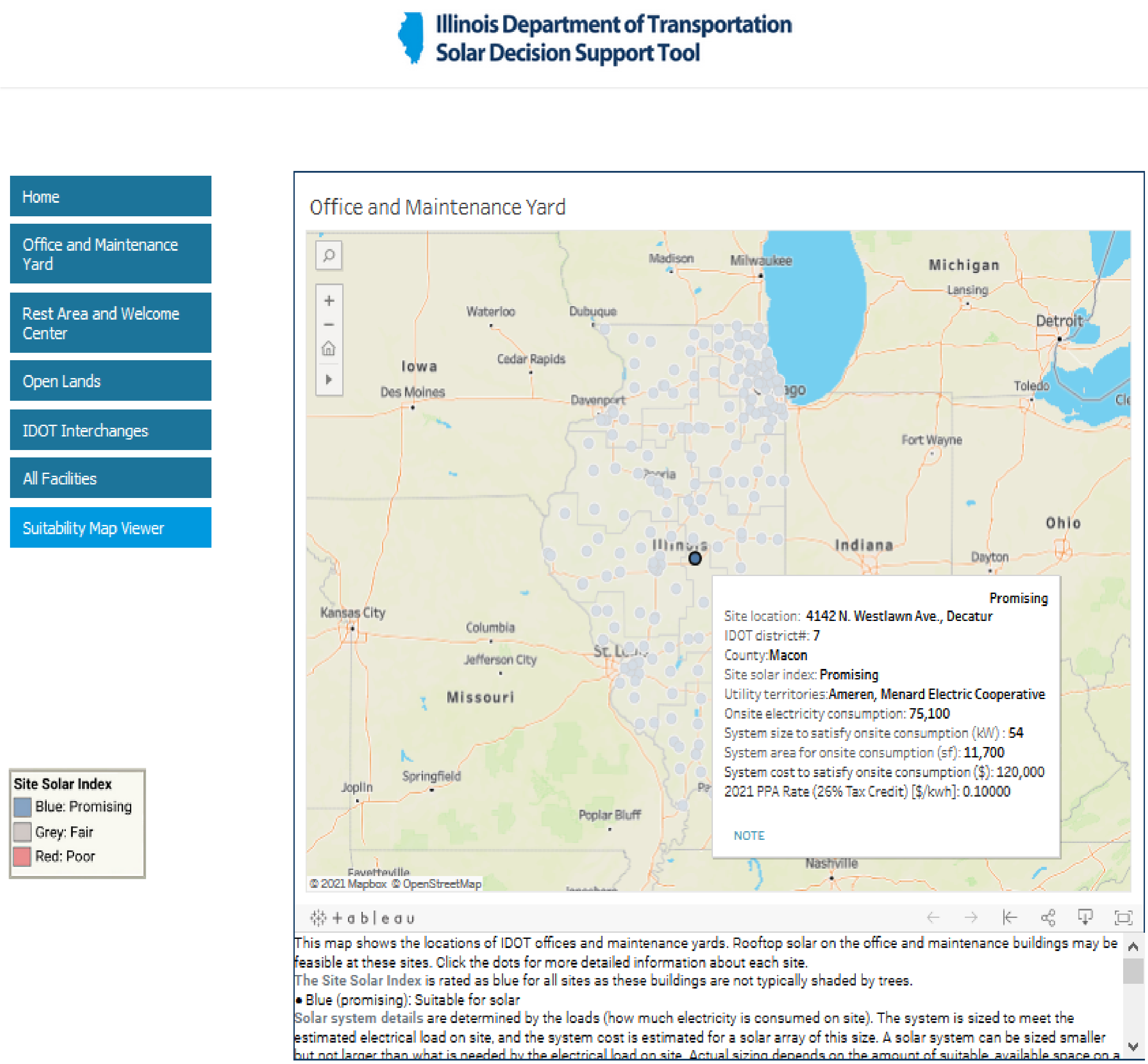

Figure 38. IDOT solar decision-support tool. Office and maintenance yards. Selection of a single site with suitability, locational, economic, and energy data pop-up.

The dialog box that appears upon selection provides a range of information. Location information in terms of street address, county, and IDOT district is provided first. Then, the classification of the site's suitability. We also see which utility companies operate in the area of the site, the site's annual electric consumption, the size of solar system necessary to satisfy on-site consumption, and the amount of area required to install a system of that size. Finally, the tool provides some financial parameters related to a system of the prescribed size.

The on-site electricity consumption was determined based on the approximate square footage of office areas for offices and maintenance yards and applying a kWh metric per square foot. A similar metric of kWh per square foot was applied for rest areas. The kWh per square foot was based on SEDAC's previous experience through the energy assessment programs for maintenance yards and rest areas. The system size was based on NREL data through their PV watts program to determine the size that would provide the kWh determined as the load. The system area has been calculated through data from NREL and developers. This includes that roof-mounted systems require around 100 square feet per kW and that ground-mounted systems require 5 acres to fit 1,000kW or around 218 square feet per kW. This is due to roof-mounted systems requiring minimal space between panels. It was anticipated that systems smaller than 10 kW and where buildings are present would be roof mounted and systems larger than 10 kW or without buildings would be ground mounted. The system costs were based on data from the Department of Energy through their benchmarking surveys. Power purchase agreement rates were based on discussions with solar energy developers and previous projects that SEDAC staff had involvement with and correlated to cost data.

To determine energy consumption for interchanges, SEDAC used satellite and street view images to determine the quantity of fixtures and if the fixtures were traditional high-pressure sodium or LED. IDOT indicated that they use 10 watts per traffic signal light, 300 watts for lower streetlights, 465 watts for higher streetlights, 100 watts for lower LED streetlights, and 200 watts for higher LED streetlights. The streetlights were assumed to operate 12 hours per day and traffic signals operate 24 hours per day.

In Figure 39, the number of facilities being shown has been expanded. Instead of seeing only office and maintenance facilities as in the previous images, now all IDOT facilities are displayed, including rest areas, welcome centers, interchanges, and open lands. Because many of the sites represent interchanges, there is a concentration of sites along interstate highways that makes an instantly recognizable pattern.

Note that when only maintenance yards and offices were selected, all dots were blue, suggesting promising opportunities for solar installation. On this map, with all property types shown, colors are more diverse. Promising sites are still abundant, but so too are marginal (gray) and poor (red) sites. Viewing all property types simultaneously may be advantageous in identifying synergies between sites or areas in which developing multiple sites could benefit from economies of scale.

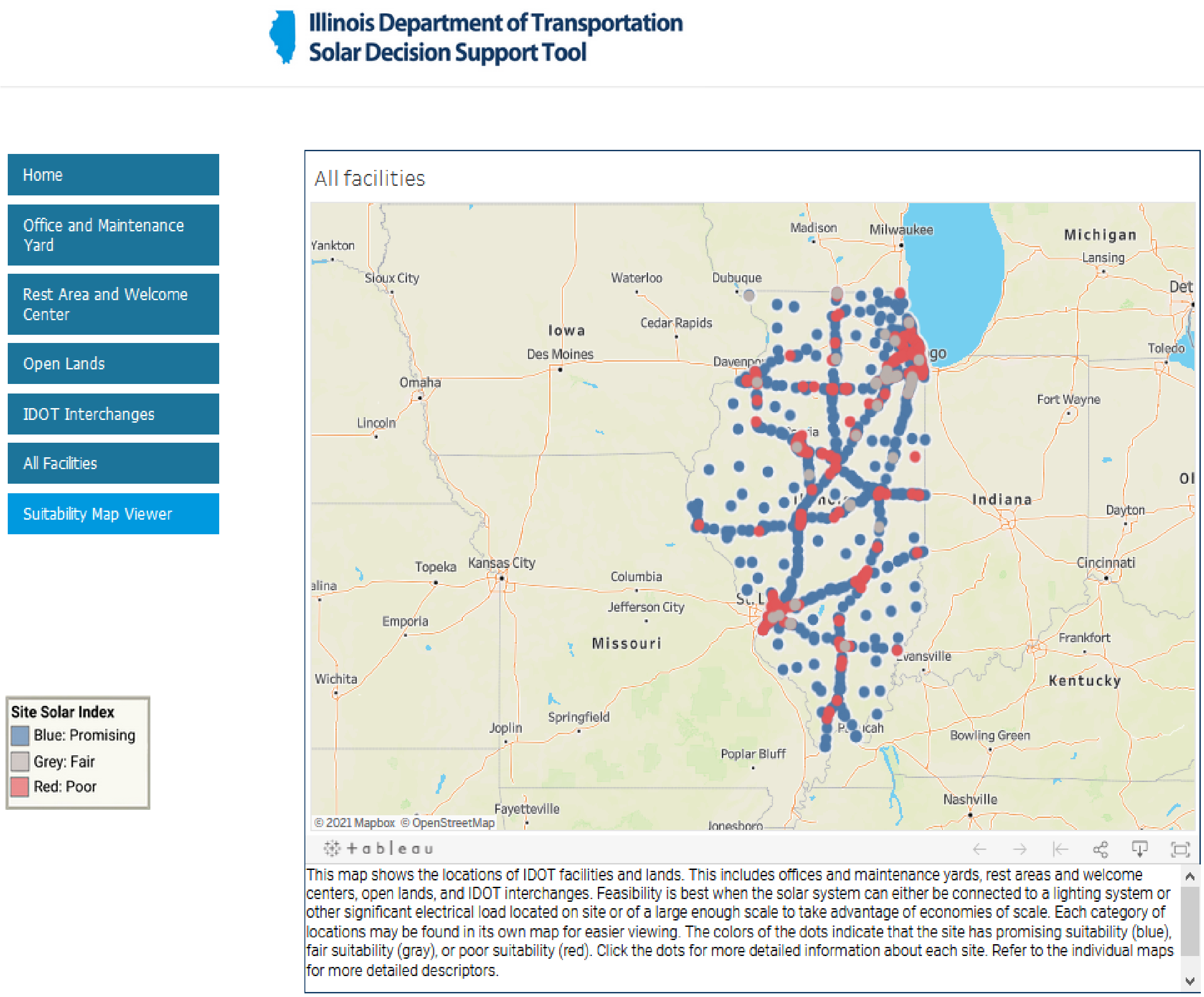

Figure 39. IDOT solar decision-support tool. Office and maintenance yards. Statewide rendering of IDOT sites. Color denotes suitability—blue is suitable, and red is less suitable.

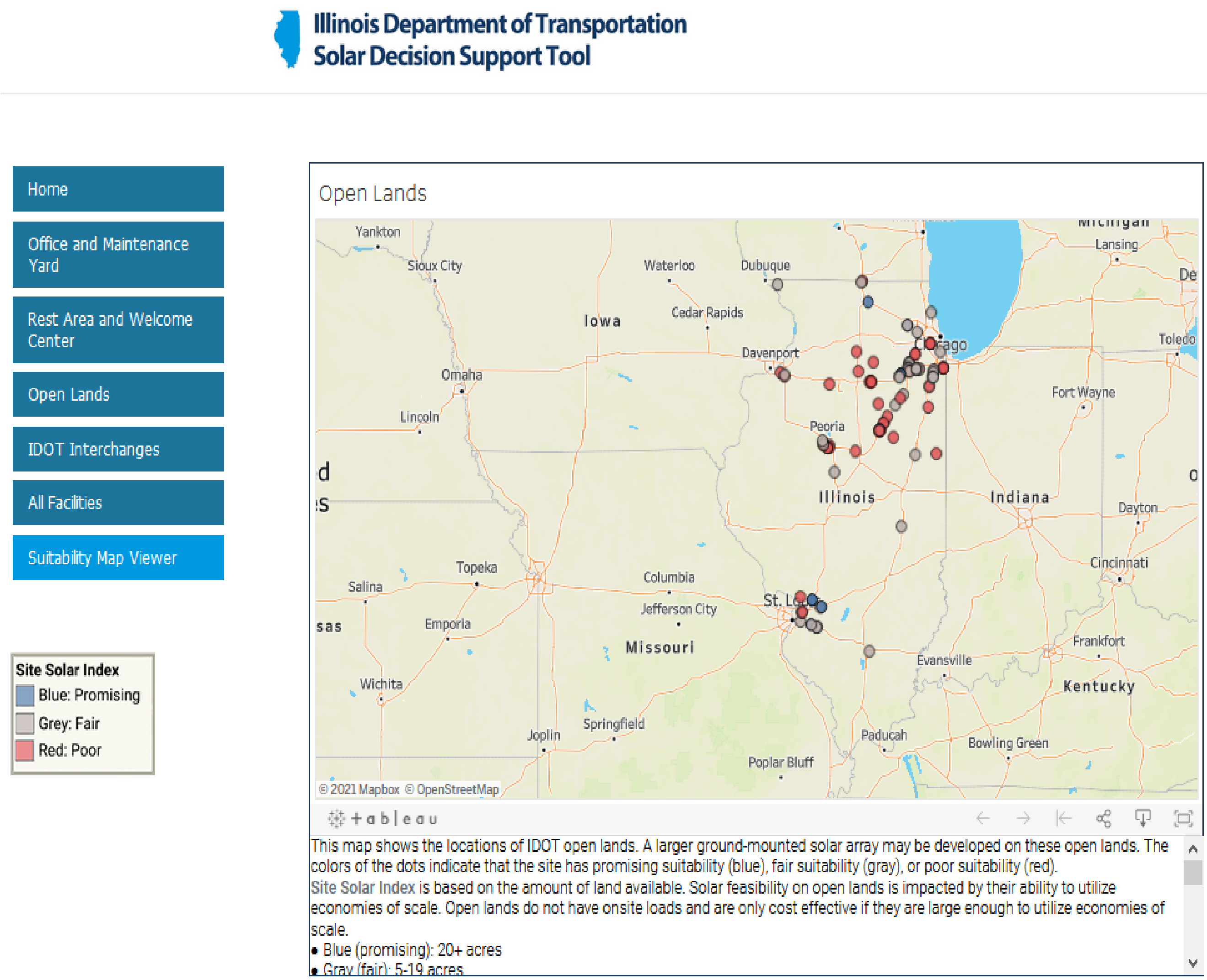

Figure 40. IDOT solar decision-support tool. IDOT open lands.
Blue denotes suitable, grey moderate, and red less suitable areas.

Figure 40 shows an example of the suitability map feature. By selecting the suitability map from the left on-screen menu, users are shown projects of at least 20 acres evaluated in a manner incorporating the nine different site selection factors discussed in Chapter 3. This allows users to quickly evaluate the most suitable solar development sites.

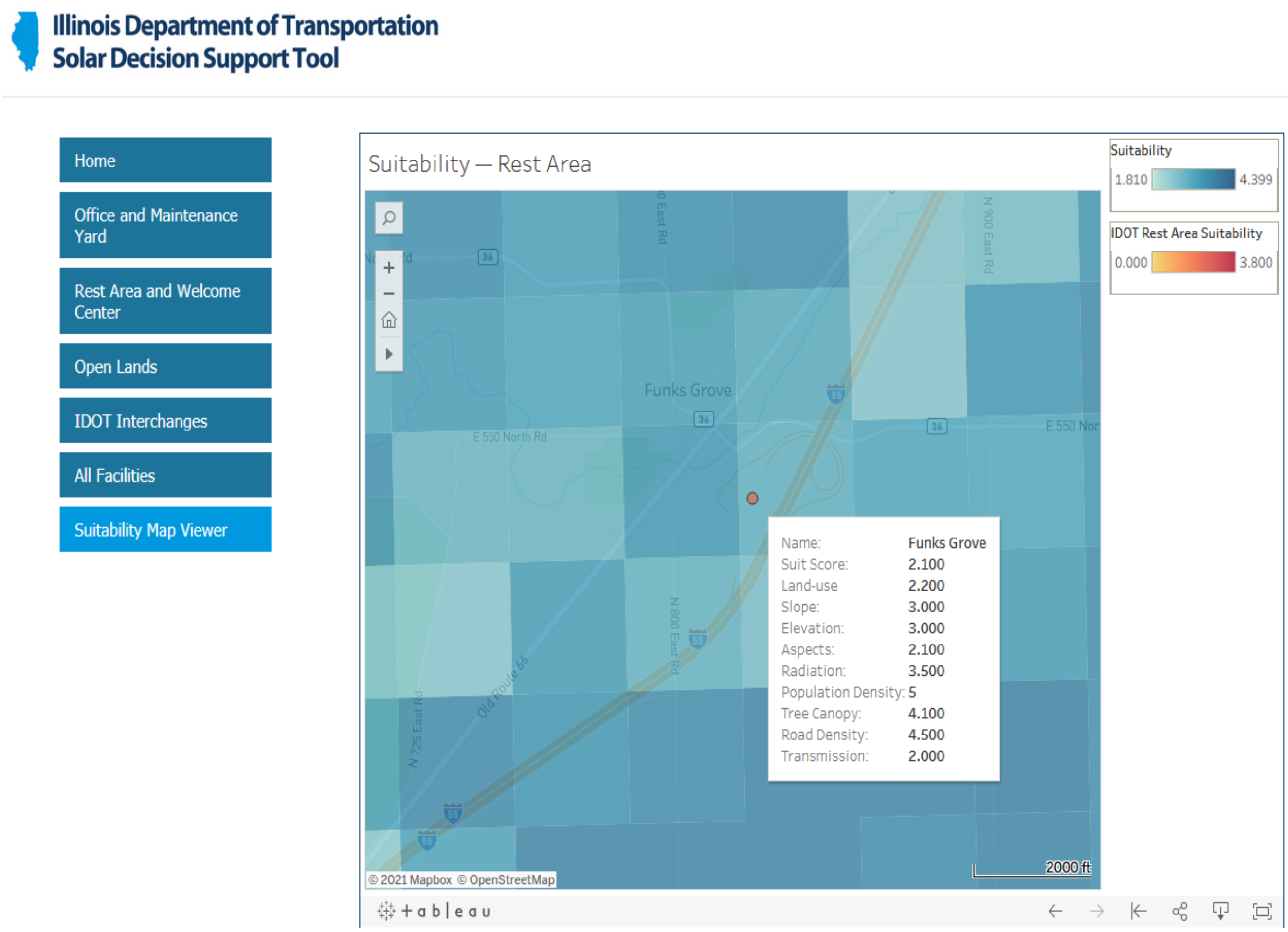

Figure 41. IDOT solar decision-support tool.
Suitability map zoom-in showing data granularity limitations.

As shown in Figure 41, the suitability mapping and general mapping tools are not without their limitations. For sites of less than 20 acres, the suitability data can be clouded by the lack of granularity in the dataset. Because much of the data is available only down to 30 m square blocks, confidence in site suitability ratings have the highest confidence when sites of at least 20 acres are evaluated. Even a 20-acre site contains only approximately 80 “pixels” of data. Even within the one-quarter acre “pixel,” there can be variability.

REVIEW OF FEATURES

The tool provides a visual representation at a glance of solar development attractiveness from promising to poor. It has the data broken into four groups (office and maintenance yards, open lands, rest areas, and interchanges) as well as a single comprehensive map. Selecting any of the points will provide additional details, including which utilities are in the area, estimated electricity consumption for a site, how large of an system would it take to produce that much, the amount of land or roof area that an system would require, the cost of such an system, and an estimated PPA rate for an equivalent system.

The tool also allows for a space for users to leave notes, which may be used either to pass institutional knowledge to other users or to administrators for updating the database. Some of these could be roof conditions, reasons that may make a site more or less suitable than the index would lead one to believe, or updated information such as narrowing down the utility provider from the multiple listed to the one that is known to serve the site.

FUTURE UPDATES

One of the virtues of the dynamic planning support system is that it need not represent a static point in time permanently. As better data or changing data becomes available, the model can be updated to reflect the most current and accurate information. For example, at present, some sites are within a territory served by more than one utility provider. In this case, the model displays all possible utility providers. If better data should become available (i.e., if the utility meters at each site were checked to verify provider), then the correct utility provider could be provided for each site.

Many of the administrative regulations identified in Chapter 2, the site selection criteria in Chapter 3, and the site cost information in Chapter 4 is predicated on data that represents a single point in time. At any time, any number of input variables, from the regulatory environment to the estimated financial parameters of a PSS, is subject to political and market fluctuations. The proposed tool is able to easily account for such changes without “reinventing the wheel.” As long as the tool is updated and maintained, it can continue to provide useful information as underlying data changes.

One dynamic factor not accounted for above is the changes to IDOT’s portfolio of sites and solar assets. One of the sites evaluated, for example, the proposed Prairie State Parkway interchange, was likely acquired for an expressway project that did not materialize. As IDOT is forced to meet the challenges of a changing transportation environment, it is likely that the use of currently considered parcels may change, or that entirely new parcels may be acquired or sold. The tool developed allows for continued updating of the inventory of sites.

CHAPTER 6: CONCLUSION/FUTURE IDOT STRATEGY

This chapter is focused on the take-aways from the analysis described above. In summary, the proposed evaluation of IDOT sites for the implementation of solar energy generation addresses four main elements: 1) administrative hurdles are present but not a barrier to IDOT solar development; 2) it is technically and economically feasible to develop IDOT solar projects; 3) IDOT has a large selection of appropriate lands for good (feasible) solar development projects; and 4) we strongly recommend that IDOT begin the process of developing sites to support solar electric power generation.

Procurement and Administrative Barriers. The development of an IDOT solar portfolio is likely to be affected by industry standard practices for solar development as well as by the regulatory environment in which IDOT operates. This report details the nature of the ownership/agreement structures under consideration and evaluates the potential legal and administrative hurdles that may stand between IDOT and its renewable energy goals. While the path forward is not free of obstacles, solar development is indeed legally feasible and regulatory challenges can be adequately met given suitable planning and implementation.

We explored three main ways in which IDOT could procure solar projects: power purchase agreement, direct installation, and land lease development. Of the three methods, the first two are considered the primary means of solar development, while the third provides cash rent. A fourth possible method identified is a combination of approaches. We also identified issues associated with the use of IDOT rights-of-way and facilities in relation to potentially competing alternative uses, solar system interconnection and net metering, environmental protection objectives, and safety requirements.

Priority Assets, Technical and Economic Viability. Drawing on the literature on solar suitability analysis, we identified a set of evaluation criteria based on environmental, social, and economic performance. We compiled physical and locational data on IDOT sites in all nine districts (500 interchanges, more than 100 open land parcels, 50 rest areas, and more than 400 additional IDOT sites); used spatial analytical tools to determine suitable places for solar production, the sites were narrowed through a manual review of each potential site; conducted a stakeholder feedback process to further narrow the sites to 40; and, finally, selected five case study sites based on suitability factors that cover a range of site types for detailed technical and economic review. Larger sites are economically attractive because they take advantage of economies of scale. We consulted with solar developers to refine the site economics and conclude that there is likely to be substantial developer interest in participation in the proposed case study projects. While some of the modeled case study results for the larger sites indicated potentially unattractive PPA pricing, they are close enough to the threshold of financial feasibility that a formal request for proposals may reasonably be expected to generate attractive pricing responses.

An IDOT Solar Suitability Decision-Support Tool. To intuitively assess the large portfolio of all IDOT-controlled properties statewide, a decision-support tool was developed that enhances evaluation on a wide range of potential sites. The tool allows stakeholders to quickly evaluate the suitability of potential sites using an intuitive, familiar graphic user interface that describes address or location, district, utility, physical suitability, energy potential, and economics for each site.

Overall Strategy. An overall strategy for moving forward with solar project development at IDOT consists of three main components: capacity, goals, and financing.

Capacity for solar development projects. IDOT has substantial electricity demand across their portfolio. This makes for an attractive PPA contract of a scale that would entice solar developers to provide proposals at a competitive price. IDOT has at least two attractive sites that can support a large solar system and take advantage of economies of scale. IDOT also has several sites that are served by rural electric cooperatives and municipal utilities. These might be grouped to improve scale and viability (although not analyzed in this work).

Renewable energy goals. We recommend that IDOT consider at least two large projects be developed in collaboration with other state entities. This would provide substantial progress toward agency and state renewable energy goals. Additionally, this should be supplemented by a smaller grouping of project sites served by municipal utilities and/or rural electric cooperatives to enable IDOT to approach 100% renewable energy at their facilities.

Financing. We recommend the use of PPAs for developing IDOT solar projects. This requires little or no out-of-pocket costs while also enabling IDOT to make use of the investment tax credit. Using PPAs also reduces IDOT's risk of deferred maintenance and other long-term costs. Any available IDOT capital should be used to buy down the PPA rate. We do not recommend a direct purchase by the agency for maintenance and long-term culpability reasons.

Conclusions. As an agency of the State of Illinois, IDOT is permitted to install solar projects on agency facilities and land. We find solar project development to be administratively and economically feasible as well as environmentally desirable. The rules and required administrative procedures depend on case-by-case circumstances. The sites that present the most concern involve potential driver safety, including beyond the clear zone along high-speed areas of interstate routes, and where solar equipment may restrict visibility near intersecting or merging traffic. Although some locations are restrictive, there are many feasible locations for IDOT solar development projects, including maintenance yards, rest areas, and IDOT right-of-way parcels that can be accessed by local roads, US routes, or state routes.

We strongly recommend that IDOT begin the process of developing at least one of their sites to support solar electric power generation.

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APPENDIX: SOLAR SUITABILITY ANALYSIS DETAILS

Various GIS-based MCDA methods have been deployed and visualized to select development locations in the energy literature. Choudhary and Shankar (2012) adopted Technique for Order Preference by Similarity to Ideal Solution (TOPSI) to rank the alternative locations for thermal power plants, Sánchez-Lozano et al. (2013) combined GIS and the Elimination and Choice Translating Reality (ELECTRE-TRI) for solar farms site selection, Szurek et al. (2014) used Weighted Linear Combination (WLC) to develop a wind farm suitability map. Charabi and Gastli (2011) applied Fuzzy Logic Ordered Weight Averaging (FLOWA) to photovoltaic site suitability analysis.

Of the variations of MCDA, AHP is an extensively used, robust approach in energy decision-making (Firozjaei et al., 2019. AHP weighs the MCDA variable and enables a reliable evaluation of the complex MCDA data for producing reasonable outcomes (Malczewski, 2004; Saaty, 1987). GIS-based AHP offers an important advantage over other methods, especially for spatial decisions, to easily obtain the relative importance weights of a large number of criteria through pair-wise comparison. (Charabi & Gastli, 2011 Chen & Khan, 2010). This study employs AHP, and spatially presents the results using geospatial technologies.

In the study of solar energy development using MCDA, it is critical to optimize the analysis process for given study areas because the energy potential is subject to different environmental, economic, and social settings (Watson & Hudson, 2017; Charabi & Gastli, 2011; Majumdar & Pasqualetti, 2019; Doorga et al., 2019; Noorollahi et al., 2019; Zoghi et al., 2017; Doljak & Stanojević, 2017; Suh & Bownson, 2016). Different contexts, such as available natural resources, cultural assets, and developmental statuses, necessitate different optimizations in the criteria setting process. Majumdar and Pasqualetti (2019) select nine evaluation criteria for solar development in Arizona. In their MCDA process, five distance criteria, such as distance from recreational areas, are selected based on the public opinion survey, and different combinations of the criteria are used to establish multiple scenarios. Noorollahi et al. (2016) use 11 criteria, including solar radiation and distance from transmission lines, for identifying suitable development locations in Iran. They especially include average dusty days as a criterion with respect to the metrological conditions of Iran. Both Watson and Hudson (2015) and Doorga et al. (2019) highlight the importance of solar radiation in identifying the suitability for solar development in south-central England and Mauritius, respectively. Both assign more than 40% of the total weights to a criterion of solar radiation.

The ability of the method to flexibly reflect diverse contextual settings in the optimization process makes the method still useful in decision-making. Table 12 summarizes the top three highly rated criteria used in select previous studies. Drawing on these examples, we propose a set of suitability criteria which are of unique importance to the inventory of land available to IDOT. Information on these specific criteria is provided in the following subsection.

Table 12. Top Three Criteria Weights Used in Previous Studies

Literature	Top 3 Evaluation Criteria	Weights	Exclusion Criteria	Study Area
Watson and Hudson (2015)	Solar radiation	0.49	Historical areas, residential areas, wildlife designations, etc.	South Central England
	Distance from transmission lines	0.26		
	Distance from roads and train lines	0.07		
Doorga et al (2019)	Solar radiation	0.23	Residential areas, reservoirs, national parks, etc.	Mauritius
	Sunshine duration	0.07		
	Slope	0.05		
Uyan (2013)	Land use	0.41	Private lands	Karapinar region, Turkey
	Distance from transmission lines	0.37		
	Distance from residential areas	0.14		
Al Garni and Awasthi (2017)	Solar radiation	0.35	Protected areas, high slope area, urban areas, and major roads	Saudi Arabia
	Temperature	0.24		
	Slope	0.16		
Janke (2010)	Solar radiation	0.3	–	Colorado, US
	Distance from transmission lines	0.2		
	Distance from roads	0.1		
Suh and Bownson (2016)	Solar radiation	0.39	Residential areas, conservation areas, water bodies, etc.	Ulleung Island, Korea
	Sunshine duration	0.27		
	Distance from transmission lines	0.16		
Doljak and Stanojević (2017)	Solar radiation	0.32	Forests, water bodies, protected areas, road networks, etc.	Serbia
	Sunshine duration	0.18		
	Slope	0.15		

Identification of Solar Suitability Criteria Weights: The Analytic Hierarchy Process. We use Saaty's (1987) AHP method to estimate the weights of the criteria for suitability evaluation. AHP operates through pairwise comparison within a reciprocal matrix that uses a scale of absolute judgment representing how much one criterion dominates another (Parry et al., 2018). The process involves two stages: 1) determining the relative importance of each criterion, and 2) calculating the relative weight. In performing a pairwise comparison matrix, the relative importance values are ranked from 1 to 9. Once weights are computed based on relative importance, a consistency ratio (CR) is calculated to check the degree of consistency.

The relative importance values were established based on the literature at the initial stage of the process. The final decisions are presented in Table 13. The fractions refer to the relative importance of criterion over criterion and should be equal to 1. For example, 9 signifies that solar radiation is judged to be much more important than crop productivity in determining the suitability of solar development.

Table 13. Pairwise Comparisons of the Evaluation Criteria

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9
Solar Rad. (C1)	1	5	8	7	5	9	7	5	9
Slope (C2)	1/5	1	5	3	3	7	5	1	7
Aspect (C3)	1/8	1/5	1	1	1/2	3	1	1/3	5
Elevation (C4)	1/7	1/3	1	1	1/2	3	1	1/3	5
LULC (C5)	1/5	1/3	2	2	1	5	3	1/2	7
Pop. Den. (C6)	1/9	1/7	1/3	1/3	1/5	1	1/3	1/5	3
Road Net. (C7)	1/7	1/5	1	1	1/3	3	1	1/3	4
Trans. Lines (C8)	1/5	1	3	3	2	5	3	1	8
Crop Prod. (C9)	1/9	1/7	1/5	1/5	1/7	1/3	1/4	1/8	1

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