DEPARTMENT OF TRANSPORTATION

Assessing a Solar Project and a Virtual Power Purchase Agreement Between the Red Lake Nation and the Minnesota Department of Transportation

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16. Abstract (Limit: 250 words)

In this report, we analyze the feasibility of a northern Minnesota solar project and accompanying Virtual Power Purchase Agreement (VPPA) between the Minnesota Department of Transportation (MnDOT) and the Red Lake Nation. We analyze three sets of benefits for MnDOT: government-to-government relations, environmental, and economic. In government-to-government relations, we find great potential for the VPPA to further a first-of-its-kind Tribal energy project and Tribal sovereignty. We also summarize lessons from other governmental entities in pursuing VPPAs. For environmental benefits, we find the array will avoid between 48,000 and 89,000 metric tons of carbon dioxide-equivalent gases, resulting in a monetized environmental value of between $1 million and $9.4 million in avoided emissions-related damages. Finally, for economic benefits while we find the array has a net present value (NPV) between a negative $5.5 million and negative $16.5 million to MnDOT, we identify several project adjustments that could increase the value to more than a positive $3 million in NPV. In conclusion, we recommend MnDOT form a “strike team” to develop the project further, communicate the project clearly, and consult with outside experts on further project opportunities.

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LIST OF ABBREVIATIONS

AC	Alternating Current
BIA	Bureau of Indian Affairs
BIL	Bipartisan Infrastructure Law
CO2	Carbon Dioxide
DC	Direct Current
DOE	Department of Energy
EPA	Environmental Protection Agency
FY	Fiscal Year
IRA	Inflation Reduction Act
IRS	Internal Revenue Service
ITC	Investment Tax Credit
kW	Kilowatt
kWh	Kilowatt-hour
MW	Megawatt
MWh	Megawatt-hour
MISO	Midcontinent Independent System Operator
MnDOT	Minnesota Department of Transportation
NREL	National Renewable Energy Laboratory
NPV	Net Present Value
PPPA	Physical Power Purchase Agreement
REC	Renewable Energy Certificate
SAM	System Advisor Model
TEDO	Tribal Energy Development Organization
VPPA	Virtual Power Purchase Agreement

EXECUTIVE SUMMARY

This research assesses a potential partnership between the Minnesota Department of Transportation and the Red Lake Nation to develop a Virtual Power Purchase Agreement (VPPA) for a Tribal-owned solar project.

Unlike other procurement contracts for renewable energy, a VPPA is a purely financial contract that provides the renewable energy project developer with a fixed-price cash flow and gives the energy consumer a variable-price cash flow (based on energy produced by the project and sold into the market) and the renewable energy certificates (RECs) associated with the project. VPPAs are unique in that they can meet the consumption of many distributed facilities under one contract and the consumption covered by a VPPA is not geographically tied to the project site. As a contract between the energy consumer (or offtaker) and project developer, a VPPA operates independently of local utilities.

Comparing a VPPA to other procurement options, such as community solar, we find that a VPPA maximizes opportunities for new Tribal-to-state government relations because projects can be located anywhere on an electric grid (in this case, supporting the benefits of government-to-government relations), provide RECs and greenhouse gas emission (GHG) reductions (environmental benefits) to the offtaker, and split economic risk and value with the offtaker bearing more economic risk in a VPPA and the developer more economic value. We identified only one existing VPPA with a government entity, Arlington County, Virginia, and no existing VPPAs between a U.S. government agency and a Tribal government. From our review of the Arlington, Virginia, VPPA and other sources, we found multiple strategies used to support the VPPA process. Much of the process of developing a VPPA falls into the "art" of a VPPA contract, which relies on developing goal-driven metrics based on stakeholder education and consensus-building.

Our project-specific techno-economic modeling found that MnDOT could offtake at least 60% of the proposed Red Lake Nation array. For emissions reductions, this VPPA would allow MnDOT to outpace the projected decarbonization of the electric grid in Minnesota while avoiding between $1 million and $9.4 million in cumulative emissions through this project. We estimated the base case of the solar project to present costs to MnDOT on an annual basis between $220,000 and $660,000 per year, but we also identified several adjustments that could help achieve a cost-neutral or economically beneficial project to MnDOT. After factoring in each of several adjustments, the project could save MnDOT $131,000 per year. We offer caution about our techno-economic analysis given market uncertainty and the uncertainty in our models themselves.

Our recommendations include creating a MnDOT-internal strike team to: work on the VPPA internally and with the external parties of Red Lake and Solar Bear; communicate the risk and uncertainty of the VPPA; and consult with outside legal and financial experts to take advantage of the project adjustments we modeled. This solar project has site control and interconnection queue placement, both of which are incredibly valuable in developing a VPPA. But more importantly, the project represents a first-of-its-kind opportunity to not only work with the Red Lake Nation, but also to provide a proof for other Tribal entities to increase their energy sovereignty going forward.

CHAPTER 1: INTRODUCTION

This report evaluates a proposed solar project for the Minnesota Department of Transportation (MnDOT). The project will be owned by the Red Lake Nation, which will also own the project site. The project is novel as a first-of-a-kind energy project, not only for Red Lake and other Tribal governments who want to engage in virtual power purchase agreements (VPPAs), but also as a model of shared energy governance between a state and Tribal government. Figure 1.1 shows one of two proposed locations for this project; a second proposed site lies a few miles south of this site and is also owned by the Red Lake Nation.

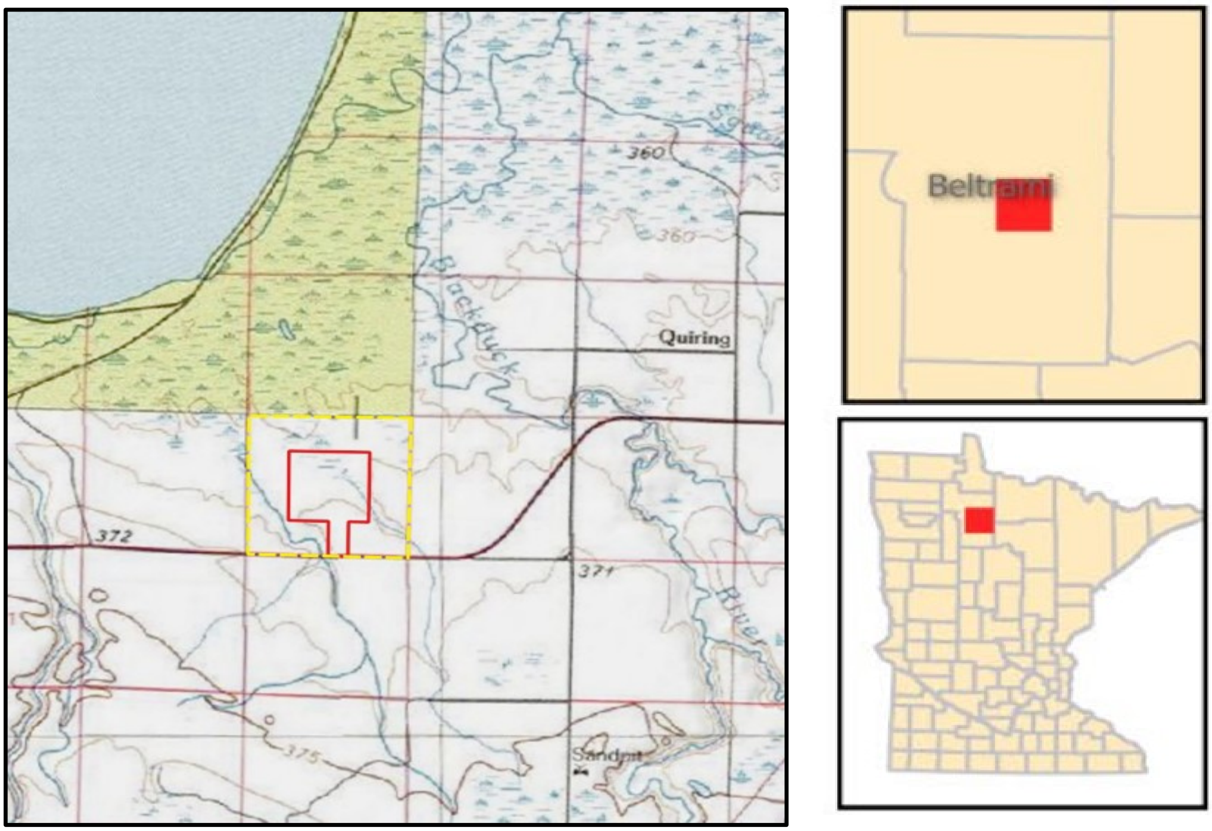

Figure 1.1: One of Two Proposed Locations for Solar Development. This site, the "Black Duck" site, totals about 178 acres and is owned by the Red Lake Nation. It lies just outside of Quiring, Minnesota, and the Red Lake Reservation, in Beltrami Electric Cooperative Territory.

This report includes an introduction, three chapters with analyses, and a conclusion. In the introduction, we provide background on VPPAs and how a VPPA compares to other renewable energy contracts. In our analyses, we provide a qualitative case study on the process and partnerships underpinning a VPPA and an example of how much renewable energy MnDOT might receive from the project, and we demonstrate early financial modeling of the project and potential returns to MnDOT. The purpose of this report is to provide preliminary results and recommend next steps for MnDOT regarding this opportunity to partner with the Red Lake Nation on a VPPA.

In conclusion, we provide a checklist of suggestions for MnDOT to engage with at this point in the project.

1.1 WHAT IS A VIRTUAL POWER PURCHASE AGREEMENT?

Energy consumers with renewable energy goals often are limited in how much renewable energy they can cost-effectively support on their own property. On-site limitations have supported a growing market for off-site renewable energy procurement, which comes in two flavors: physical power purchase agreements (PPPAs, or sometimes PPAs, for short) and virtual power purchase agreements (VPPAs).

With a PPPA, the energy consumer owns the electrons from a specific renewable energy project and is responsible for monetizing or selling those electrons, often through the retail electricity rates offered by the local electric utility. Often, the energy-consuming buyer in a PPPA also must consider costs associated with delivering the generated renewable energy to the grid.

In contrast, a VPPA is a financial contract associated with a specific renewable energy project, but the energy consumer does not own the electrons generated by the project. Instead, **a VPPA is a purely financial contract.** It provides the renewable energy project developer with a fixed-price cash flow and gives the energy consumer a variable-price cash flow (based on the energy produced by the project and sold into the market) and the renewable energy credits (RECs) associated with the project. Unlike PPPAs, VPPAs can be designed to match the energy consumption of many distributed facilities under one contract (e.g., many buildings located throughout a region or across the country), and the consumption covered by the contract does not need to be on the same grid or even state/region as the renewable energy project.

Off-site renewable energy projects, through either PPPAs and VPPAs, offer the potential to layer additional societal impact goals on top of the more traditional economic and environmental goals of conventional renewable energy projects. Relevant to this potential project between MnDOT and the Red Lake Nation, off-site renewable energy projects can uniquely support renewable energy development that aligns with goals such as supporting government-to-government relationships with Tribes, allowing for renewable energy development owned and controlled in a way that can maintain the sovereignty of the project owner, and promoting economic development in the area around the project.

A VPPA, unlike a PPPA, provides greater flexibility to direct these layered societal impact goals because a VPPA is not constrained by its physical placement on the grid. The flexibility of the VPPA model relative to the PPPA model could allow an offtaker, such as MnDOT, to partner with the Red Lake Nation to meet MnDOT's government-to-government relations goal without physical interties between the grid around Red Lake Nation and the broad geographic diversity of MnDOT's energy-consuming facilities across the state.

1.1.1 What does a VPPA look like?

Figure 1.2 provides a schematic representation of the relationships behind a VPPA. Of note in this contractual arrangement, MnDOT, as an "offtaker" or energy consumer on the project, continues to have the same arrangements with utility providers (point 1 in Figure 1.2). The VPPA will impact MnDOT through a contract with the Red Lake Nation (point 2 in Figure 1.2) that is separate from MnDOT's current utility payments or contracts. Red Lake Nation, in turn, sells energy generated by this project into the wholesale market, and the variable wholesale price will impact whether the offtaker or developer pays the difference between the contractual price and the market price.

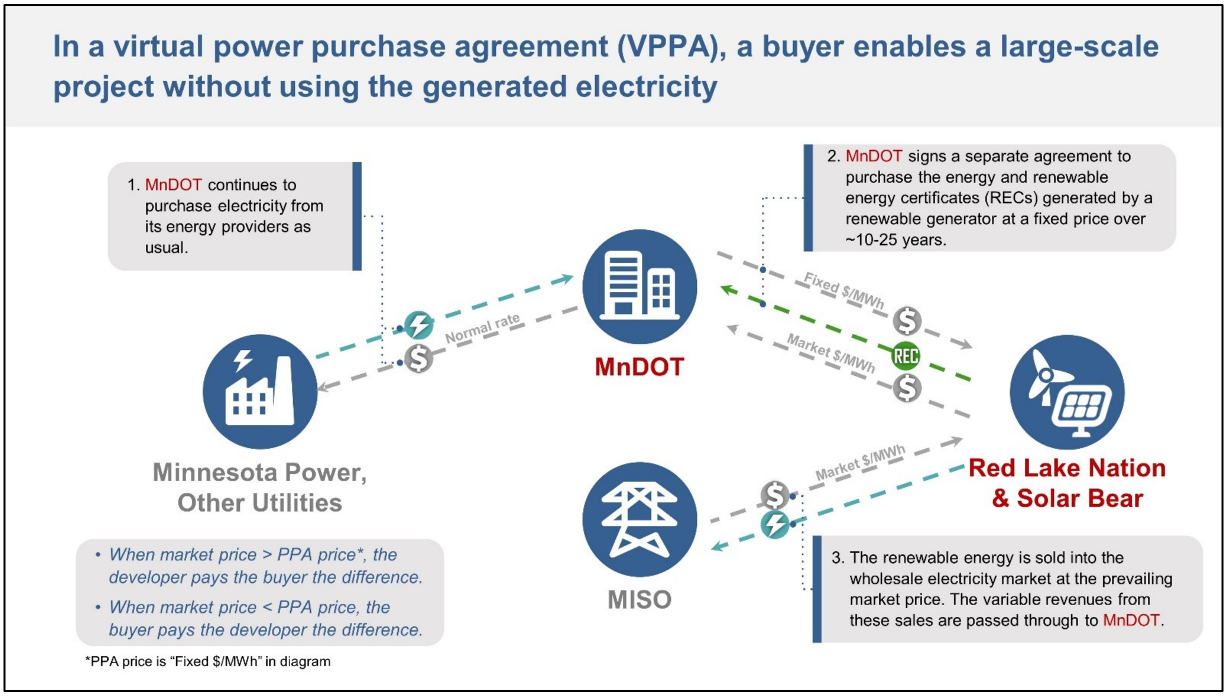

Figure 1.2: Schematic representation of the financial, REC, and energy flows in a VPPA between MnDOT and Red Lake Nation/Solar. The VPPA involves three relationships: 1. MnDOT and its electric utility providers see no change in their relationship; 2. MnDOT and Red Lake Nation/Solar Bear establish a VPPA contract whereby MnDOT pays a fixed price and receives a pass-through of the market price with RECs; 3. Red Lake Nation/Solar Bear agree with the grid operator (MISO) to sell all power to the grid at the market price. (Modified from American Cities Climate Challenge, 2020)

As financial agreements, VPPAs are often structured as a fixed-for-floating swap, known as a contract-for-differences, whereby an offtaker pays or receives benefits based on a fixed contract price and a floating wholesale price (see Figure 1.2). This differs from a PPPA where the project simply replaces electricity that an offtaker was already purchasing from a utility. In a typical VPPA structure, an offtaker, such as MnDOT, pays a pre-agreed upon fixed price and the project developer pays a market price based on the price of energy on the wholesale energy market at a point related to where the solar project injects energy onto the grid (either at the wholesale pricing node or hub, see Glossary for definitions). The project developer will calculate the difference between the floating market price and the fixed VPPA price in a set interval (typically every hour). Offtakers and developers can also agree to apply price collars, floors, inflators, and other terms to help hedge wholesale market price volatility (World Business Council for Sustainable Development, 2021).

The difference between these prices over time will be settled by the offtaker and the developer at agreed-upon times in the contract (monthly, quarterly, annually, etc.). If the market price is higher than the fixed price, the offtaker will receive the difference, but if the market price is lower, the offtaker will pay the developer to make up for the difference. Typically, this is aggregated over the agreed-upon time frame, so the settlement will reflect if the summed differences over time are positive (paid to the offtaker) or negative (paid to the developer). Figure 3 illustrates a scenario where the market price fluctuates over time, resulting in both payments to the offtaker (e.g., MnDOT) and payments from the offtaker to the developer.

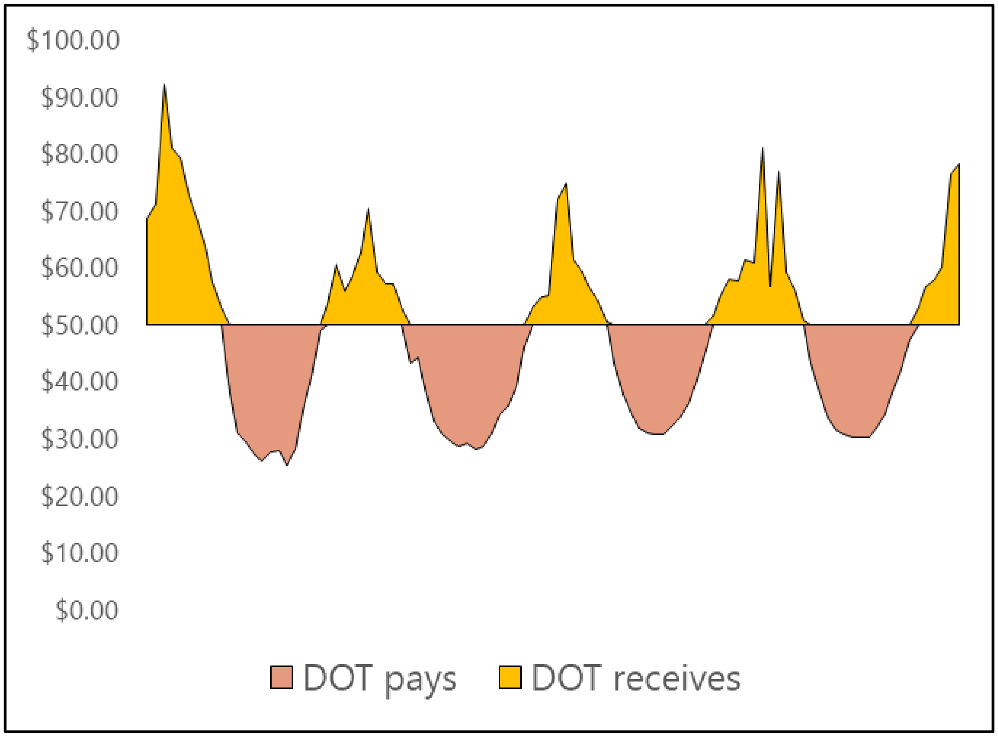

Figure 1.3: Sample VPPA Costs and Benefits. With a VPPA's strike price set at $50/MWh, the daily marginal energy price fluctuates between roughly $70 to $90/MWh and $30/MWh. When the price goes below $50/MWh, the offtaker of the VPPA (in this case, MnDOT), pays the owner of the project, as indicated by the valleys in red. When the price goes above $50/MWh, the owner pays the offtaker, as indicated by the hills in yellow.

1.1.2 How does a VPPA compare to PPPAS and Community Solar?

Given that MnDOT has previous experience with other contracts for renewable energy, namely community solar, we provide a simple comparison between a VPPA, PPPA, and Community Solar, along social, environmental, and economic considerations. We focus on social benefits embedded within the government-to-government partnership in this project, environmental benefits from RECs, and economic benefits related to risk and value. We find that a VPPA's social and environmental benefits are more conducive to MnDOT than community solar. Table 1.1 compares the benefits associated with a PPPA, VPPA, and community solar.

Table 1.1: Comparing a PPPA, VPPA, and Community Solar.

BENEFITS AREA	QUESTION	VIRTUAL PPA (VPPA)	PHYSICAL PPA (PPPA)	COMMUNITY SOLAR
SOCIAL	**Opportunity for government-to-government relations?**	Yes, most flexible opportunity to support new partnerships because projects can be located anywhere on an electric grid	Maybe, if there is an existing grid connection (and policy allows)	Limited by current program offerings to opportunities in Xcel Energy territory
ENVIRONMENTAL	**Who gets the Renewable Energy Credits?**	Offtaker receives the RECs	Offtaker receives the RECs	Utility or developer (typically the utility retains the RECs due to economic incentive)
ECONOMIC	**Who takes the economic risk?**	Split between the developer and the offtaker; can often involve more offtaker risk (depending on the contract)	Split between the developer and the offtaker; can often involve more developer risk (depending on contract)	Utility or developer (depending on contract, there can be risk to both)
	Who gets the economic value?	Split between the developer and the offtaker; can often involve more developer risk (depending on the contract)	Split between the developer and the offtaker; can often involve more offtaker value (depending on contract)	Utility or developer (depending on contract, there can be value to both)

1.1.3 What are key considerations (risks and benefits) of a VPPA?

A VPPA offtaker, like MnDOT, has a range of variables to consider for the structure and construct of a VPPA. Typical considerations for an offtaker include location, term length, long-term price forecasts, credit, seller/developer experience or capacity, accounting, risk management (performance security, locational basis risk, wholesale market risk), and additionality (Duke Energy Sustainable Solutions 2021; Susman 2017). As a financial transaction, VPPAs allow offtakers to procure renewable energy (and receive RECs) without any disruption to their existing utility, with no capital investment, cover a larger number of distributed facilities, and have the potential to be cost neutral or even net positive depending on the market price. The structure of a VPPA allows an organization to hedge against future costs of electricity while contributing to its sustainability goals. Additionally, universities that have pursued VPPAs also point to the benefits of creating a sustainability-centered image, building relationships and a coalition with others working on common goals, and the opportunity to extend this into partnerships and curriculum opportunities to support university goals (Second Nature 2019).

1.1.4 Who is doing VPPAs?

To date, VPPAs are more common with corporate offtakers than with the public sector, but many of the involved parties are consistent across VPPA agreements. In the next chapter, we provide a case study of Arlington County, Virginia, the only government VPPA offtaker identified in our research as of December 2022. For corporate projects, the actors involved in a VPPA typically include the treasurer or CFO, accounting (accountants or auditors), legal counsel, facilities/operations (those currently responsible for managing energy and utility billing), procurement, sustainability (those involved in establishing and tracking greenhouse gas emissions reduction or renewable energy goals), public relations (communication with stakeholders), and the executive sponsor (support leading to implementation) (Duke Energy Sustainable Solutions 2021). Some public universities are taking advantage of VPPAs to meet their goals and hedge against future costs; the decision processes for universities may be strong comparisons to public agencies like MnDOT.

1.1.5 What is the process for entering into a VPPA?

Getting support for a VPPA is a process that requires multiple stages of assessment and education, both related to the project itself and also how a VPPA project may support organizational goals. Best practices suggest engaging stakeholders in careful processes to identify this alignment with organizational goals, support a common understanding across parties, and identify pathways to align goals and address concerns in a procurement strategy. Figure 1.4 presents an example timeline to develop and execute a VPPA from the American Cities Climate Challenge (2020). Given some of the unique considerations for the MnDOT-Red Lake Nation VPPA project, the timeline and tasks for this project may differ, but the time and effort required for team building, assessment, and contract negotiation may be broadly applicable to the project at hand.

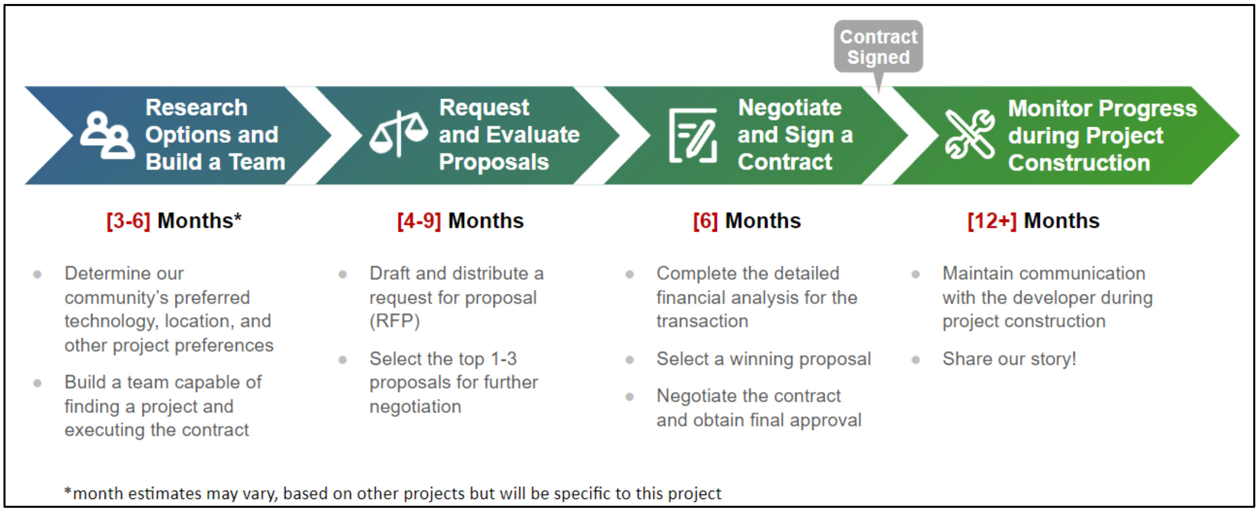

Figure 1.4: Example timeline of developing and executing a VPPA contract. Image from American Cities Climate Challenge, 2020.

Much of the process of developing a VPPA falls into the "art" of a VPPA contract, which relies on building goal-driven metrics based on stakeholder education and discussion. Such activities may include:

- Supporting stakeholder discovery (understanding what is most important to an organization and its stakeholders),
- Stakeholder education (workshops, answering questions, bringing market insights into conversation)
- Alignment of stakeholders (to help reach a consensus on what is important)

This process of education and consensus-building can help determine a procurement strategy and path forward for a VPPA. Level Ten Energy recommends stakeholder education and processes to facilitate alignment early in the process as critical activities to mitigate unforeseen barriers (Level Ten and 3Degrees 2021).

As a part of this process, an organization, like MnDOT, may identify ways to build internal project buy-in through adaptable processes that can support MnDOT's overall renewable energy goals. Further, this process may highlight common and diverging interests across the agency, ways to bring those differences closer together, and who within MnDOT might be internal project champions that will garner broader support for the project (Second Nature 2019). Other developers, like Geronimo Energy (now National Grid Renewables), reiterate the importance of stakeholder engagement and devoting the necessary time to gather needed internal and external expertise to support the decision process.

CHAPTER 2: BENEFITS OF ENABLING GOVERNMENT TO GOVERNMENT RELATIONSHIPS

This project creates the opportunity to align with MnDOT's Vision and Mission, enhance existing cooperation between MnDOT and the Red Lake Band of Chippewa, and bolster the Red Lake Nation's pursuit of Tribal energy sovereignty.

A solar project such as this creates broader MnDOT benefits in sustainability, public health, and diversity and inclusion, along with environmental and economic benefits previously described (see Table 1.1). MnDOT's guiding principles for solar projects emphasize that solar projects should support "equity and diversity in contracting," and that the agency may "pursue solar projects with higher costs if the project supports our broad agency Vision." How these considerations are operationalized related to this project may be a core component of the internal process outlined in the previous section.

Honoring Tribal sovereignty, MnDOT regularly consults, collaborates, and coordinates with Tribal Nations. MnDOT "seeks to foster and facilitate positive government-to-government relations between MnDOT and all federally recognized Minnesota Tribal Nations." This project could innovate another type of strategic partnership for MnDOT (and other state agencies) to work with Tribal Nations.

2.1 INNOVATION AND SOVEREIGNTY IN A FIRST-OF-ITS-KIND PROJECT

Based on our review of renewable energy projects, this VPPA would be the first Tribally owned VPPA project in the nation and the first Tribe-to-state agency project (to our knowledge) in the nation. It may also be the first of its kind to utilize the U.S. Department of Energy's Tribal Energy Loan Program Office.

More importantly, the project would also create meaningful Tribal energy sovereignty benefits for the Red Lake Nation while providing an example for other state agencies and Tribes around the nation to replicate in their environmental and climate actions. Home to more than 14,000 Tribal members, the Red Lake Nation has begun to form its own Tribal energy utility and first-ever Tribal Energy Development Organization (TEDO). With help from Solar Bear, the Tribe has begun to construct solar projects on its schools and government buildings. This project supports the next phase of energy development and sovereignty for the Tribe, which includes doing business on the wholesale market and to, as Tribal chairman Darrell Seki says, "provide all the energy for our membership free so they don't have to pay nothing, so they don't have to worry about getting disconnected." Red Lake Nation is also currently in the process of working with a team from the Massachusetts Institute of Technology on a community benefits agreement for this project, so that it can return benefits back to the Tribe and community.

2.2 CASE STUDY: ARLINGTON COUNTY, VA'S VPPA WITH DOMINION ENERGY, AMAZON

VPPAs for government agencies in general are nascent, as noted in Section 1.1.3, and the private sector is moving much more quickly to achieve renewable energy goals using VPPAs. To the best of our knowledge, Arlington, VA is the only widely known case of a public entity as a VPPA offtaker. Therefore, in this section we detail lessons learned from the VPPA Arlington County, VA has with Dominion Energy.

Arlington County's experience highlights the social and organizational benefits that are more difficult to quantify and offers guidance for next steps. The case is summarized in Table 2.1 and supporting material is available in Appendix A.

Table 2.1: Summary, Takeaways, and Lessons from Arlington, VA. Data from Arlington Virginia Department of Environmental Services 2020.

SUMMARY	● Project Capacity: 120 megawatts ● Arlington County Share: up to 38 MW (~79,000,000 kWh/year); 31.7% of energy produced by project. ● Owner: Dominion Energy ● Term: 17 years ● Land: 1500 acres ● Portion of Arlington County's Use: over 80% ● Operational Date: 84% system capacity operational on September 15th, 2022, rider added to electricity bills November 1st, 2022. System completed in December 2022. ● Net Electrical Energy Output (NEEO) price $33.50/MWh (see contract)
TAKEAWAYS	● Engaging in careful analysis of market risk (fluctuations that may result in payments or costs) can support the decision process to help identify fixed rates that are reasonable given potential risk. ● Aggregation with multiple offtakers may help make a project feasible, this case demonstrated the opportunities in cross-sector partnerships with an experienced corporate partner. Aggregation may have benefits for all parties involved, including the public entity, the corporation, and the solar developer. Aggregation may be easier if the RFP is for one primary entity with opportunities for others to join, rather than trying to establish a joint RFP as consensus on joint terms may be complex. ● Staff in Arlington County were learning quickly, and as they went, they did not consider options such as capacity payments and Dominion kept capacity. Nevertheless, the county believes they received a good deal with this project.
RECOMMENDATIONS	● Include legal counsel early in discussions. ● Reinforce the stability of MnDOT as an offtaker and bond rating to reduce perceptions of risk. ● Proactively discuss environmental criteria and impact on surrounding communities. ● Identify key assessments and points of discussion that examine VPPAs in the context of public goals.

2.2.1 Developing VPPA project support

Arlington County, Virginia has a long history of support for renewable energy, beginning at least two decades ago. This VPPA built on past work and county goals in the Arlington Community Energy Plan (2019) to achieve 100% renewable electricity by 2025. After reviewing options for on-site solar, the county determined that this would not be feasible without off-site procurement given the available rooftops on county buildings. Once this was realized, staff at the county began working with senior management to socialize and build comfort with the idea of off-site solar and to garner support and momentum.

The scale needed for an off-site project was challenging for Arlington County. The timing of the Amazon HQ2 provided an opportunity for Amazon to use this VPPA to build a positive relationship with local government, support county climate goals, and their own corporate climate goals. Additionally, given the expected size of HQ2, Dominion Energy (the local utility) also wanted a strong relationship with Amazon. Amazon brought their corporate experience and capacity related to renewable energy procurement to this opportunity.

Even with Arlington County, Amazon, and Dominion on board, issues emerged throughout the process, such as the impact on tree cover and agricultural land. Ultimately, the required tree removal for the project was modest and the farmers received more from leasing the land to Dominion than using it for agriculture. Yet the issue of agricultural land continues to persist in the area as other places in the region consider renewable energy projects. Discussions of environmental criteria, the impact on surrounding communities, and what benefits rural areas receive for these projects may continue to influence like projects in the future.

For Arlington County, this project aligned with their commitment to additionality (American Cities Climate Challenge 2020) and paying for high-quality RECs. The framing related to ensuring high-quality RECs, since the county was already buying RECs, was also helpful for county staff to get support for the project. To support the decision process, a 'proprietary forecast' for wholesale electricity prices was purchased by the county (see Appendix A). This forecast was informative to the county but not publicly available. The county also found it helpful to discuss worst-case or extreme scenarios related to estimated additional costs to the county, they estimated a realistic worst-case scenario would not cost the county more than \$100K/year, and if wholesale prices really plummet it could be up to \$250K.

2.2.2 Negotiating the VPPA design

The deal was signed in 2020 with different agreements for Arlington County and Amazon – we focus here only on the Arlington County experience and contract. Dominion Energy served as both the developer and the utility of this project (this was a unique configuration and differs from Figure 1.2 in that Dominion plays multiple roles). Perhaps different from a private sector offtaker, Arlington County relied on its AAA bond rating to demonstrate creditworthiness and on the assumption that as a county government they are a stable, durable, and reliable entity.

The county employed multiple strategies to manage risk on the offtaker side of the project. **First**, they acknowledged that given the county's policy goals, staff already knew that the county would have to pay something to achieve their goals, but this VPPA also offers a chance of being paid to meet their goals. **Second**, their negotiated fixed price is low enough that the practical floor for the county was such that if the wholesale price dropped dramatically, it would still be an acceptable price to pay for the RECs. The negotiation of this fixed rate over the life of the contract was supported by a third-party analyst.

Settling for differences in this project is simple for the county and Dominion. Since the county already receives utility bills from Dominion, a charge or credit is added to the bill annually. As detailed in Appendix A, the rider rate is calculated annually, and a rider is added to the County's monthly utility bill. As of February 2023, Arlington County expects a positive credit for FY23.

CHAPTER 3: BENEFITS OF CREATING GREENHOUSE GAS EMISSION REDUCTIONS

In this section, we estimate the environmental benefits from the array. To do so, we use two sources from the National Renewable Energy Laboratory (NREL). The first is the System Advisor Model (SAM), which models solar project production and techno-economics. The second are Cambium annual data, which offer possible scenarios for emissions, costs, and operational wholesale energy market data through 2050. See Appendix B for modeling assumptions. These two sources allow us to estimate the costs, output, and emissions likely for this project under different scenarios. We explain our models' functionality more in Chapter 4.

3.1 HOW MUCH ENERGY CAN MNDOT OFFTAKE?

Our estimates, based on 2021 MnDOT usage data from B3 Benchmarking, suggest that the solar array could easily serve renewable energy to all MnDOT's electricity load outside of Xcel Energy service territory.

In Figure 3.1, we demonstrate that MnDOT load in Minnesota Power's service territory takes up only a small percentage of the array's first year's solar production. Outside of Minnesota Power territory and subtracting in MnDOT's community solar garden-subscribed load in Xcel Energy's service areas, there is enough MnDOT load to offtake **at least 60% of the array** (Figure 3.1).

The remainder of the array may be met by bringing on additional offtakers (see discussion of aggregation in Table 2.1). With 60% of the array, MnDOT's role would at the least allow it to claim additionality and enable outside participation that would not happen without MnDOT's leadership and majority offtaking role.

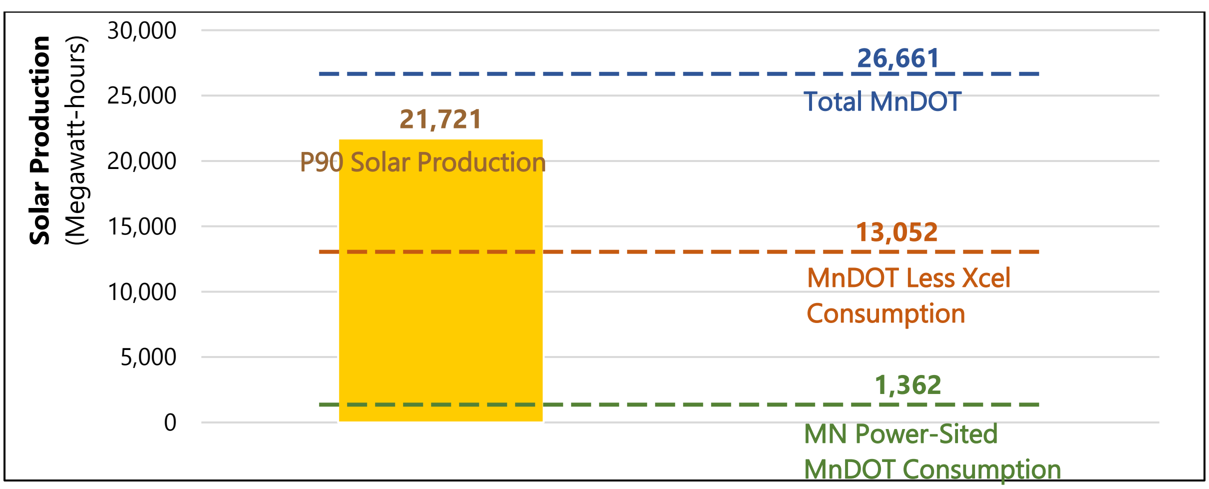

Figure 3.1: Comparison of MnDOT Electricity Consumption in 2021 to Project Solar Array Output. Solar production can vary on an annual basis. Our analysis tries to account for this by using a P90 solar production value from the System Advisor Model. P90 means there's a 90% chance that the solar array will produce more than 21,721 megawatt-hours of production in the above instance.

3.2 HOW MUCH GREENHOUSE GAS EMISSIONS WILL BE AVOIDED?

We use the National Renewable Energy Laboratory's Cambium model (both its 2021 and 2022 vintages) to estimate the project's long-run emissions reductions. **Over a 25-year lifetime, and accounting for both post-combustion and pre-combustion CO2 and CO2-equivalent emissions, the solar project is anticipated to help avoid between 48,122 and 88,554 metric tons of carbon and carbon-equivalent greenhouse gas emissions**. **Using a $37 per metric ton social cost of carbon, with a 5% discount rate, that means between $997,762 and $1,836,087 in present value.** Using other higher prices for the social cost of carbon creates even greater estimates of the value of this project's carbon reduction (Table 3.1).

Table 3.1: Red Lake Solar Project's Emissions Reduction Values Across Social Cost of Carbon Scenarios. Values represented as net present values. Data taken from MnDOT and U.S. Environmental Protection Agency's recent call to update the federal social cost of carbon from $51 per metric ton to $190.

	$37/METRIC TON	$51/METRIC TON	$190/METRIC TON
CAMBIUM 2021 ESTIMATE (88,554 METRIC TONS)	$ 1,836,087.20	$ 2,530,822.90	$ 9,428,555.89
CAMBIUM 2022 ESTIMATE (48,122 METRIC TONS)	$ 997,761.76	$ 1,375,293.23	$ 5,123,641.45

The Cambium model also shows that Minnesota's electricity grid will have half the emissions in 2050 than it does in 2022 (see orange line in Figure 3.2). In this scenario, a solar project would avoid less emissions as the decades pass. Still, it would allow MnDOT to claim additionality with the solar project and to greatly outpace (see yellow line in Figure 3.2) the projected decarbonization of the electric grid and contribute to long-term structural change in the energy system.

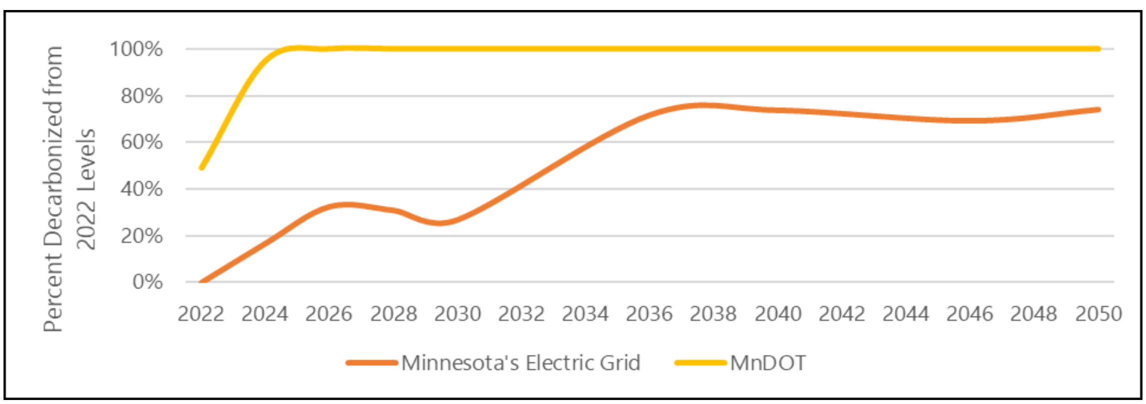

Figure 3.2: Percent Decarbonized from 2022 Totals, MnDOT Versus Minnesota's Electric Grid. Because MnDOT already has community solar subscriptions for a little more than half its load, the VPPA in 2024 would completely decarbonize MnDOT's energy consumption well ahead of Minnesota's electric grid. Forecasts of Minnesota electric grid carbon intensity derived from Cambium 2021 model's Mid case, representing a conservative forecast of decarbonization in the state.

CHAPTER 4: BENEFITS OF EXPECTED ECONOMIC SAVINGS

4.1 HOW DO WE CALCULATE SAVINGS WITH OUR MODELS?

Solar project cost and wholesale market prices drive the economic value of the project to MnDOT.

For project cost, we ran the National Renewable Energy Laboratory's System Advisor Model (SAM) based on a range of assumptions described in Appendix B, which are drawn from Solar Bear's preliminary engineering estimates and project designs. **We found that the cost of the solar project itself, without factoring in wholesale market gains, will be about $0.073/kilowatt-hour.** As the project is still being developed, we anticipate future refinements to this cost number. For now, this cost number represents our base estimate using a P90 value, or the expectation that the solar production of the project (and thus cost) will be better in 90% of potential years in our analysis. P90 values are often used by solar developers when seeking to finance a solar project.

4.1.1 How does the Cambium model predict wholesale energy and capacity prices?

We used the National Renewable Energy Laboratory's Cambium model for wholesale market prices. The Cambium model is a capacity expansion model, meaning it simulates generation and transmission capacity investment given a set of assumptions (fuel prices, technology costs, electricity demand, policy). It forecasts electric grid technology and system changes out to 2050, providing estimated hourly wholesale energy and capacity prices in the process. Capacity expansion models, like Cambium, are often used to support long-term resource planning with utilities like Xcel Energy or Minnesota Power (Chernyakhovskiy, Joshi, and Rose 2021). Although VPPAs mostly participate in real-time energy markets, as modeled by Cambium's energy prices, we also use Cambium's capacity prices to demonstrate potential gains from participating in both the energy and capacity markets.

To create a range of potential wholesale market gains, we used the Cambium 2022 and 2021 vintages to pick seven modeled scenarios, representing a range of potential futures in the wholesale energy and capacity markets. From Cambium 2022, we selected the more conservative Mid and High Natural Gas Prices cases, alongside the more progressive scenarios of 100% Decarbonization by 2035 and 95% Decarbonization by 2050. From Cambium 2021, we selected the more conservative Mid case, the more progressive 95% Decarbonization by 2035, and 95% Decarbonization by 2050. Appendix B includes more details about these cases, and their assumptions and drawbacks.

4.1.2 What are the energy and capacity markets?

The energy market incentivizes actual electricity production of kilowatt-hours, operating in both day-ahead and real-time markets. The capacity market, on the other hand, compensates producers for the ability to meet future peak electricity demand in kilowatts. The purpose of the capacity market is to ensure future bulk reliability and sufficient resource capacity in the geographic locations where and when capacity is needed most. In the Midcontinent Independent System Operator (MISO) region, which includes Minnesota, there is a voluntary annual capacity auction called Planning Resource Auction. For this project, if the developer wanted to benefit from the capacity market, it would require bidding into the MISO capacity market. This is not pictured in Figure 1.2 but would be another transaction with MISO as pictured for the wholesale energy market.

4.2 WHAT ARE THE POTENTIAL COSTS OR SAVINGS?

Using P90 values for solar production (where solar production is higher than our estimates 90% of the time), we created a base case of a solar project that is nontaxable (being Tribally-owned), obtaining a 40% investment tax credit, and having fixed panels. Putting together cost from SAM and value from Cambium, we create a base range of costs and benefits that MnDOT could see from a potential project (Table 4.1). The total NPV of the project ranges from negative $5.5 million to negative $16.5 million. As compared to Cambium 2021 values, the Cambium 2022 model sees a marked decrease in energy values generally, and capacity values for solar in particular. This represents a conservative business model design and a potentially worst-case scenario. In Section 4.3, we offer ways to increase the viability of this model.

Table 4.1: Potential Range of Costs and Benefits Across Cambium Scenarios to MnDOT from VPPA Solar Project. All values are represented as "P90" values, or the probability of exceeding a certain value 90 percent of the time.

COST/BENEFIT	CAMBIUM 2022 MODELS	CAMBIUM 2021 MODELS
POTENTIAL PROJECT COST	7.3 cents/kWh	
ENERGY VALUES	1.6 to 2.6 cents/kWh	2.8 to 3.2 cents/kWh
ENERGY+CAPACITY VALUES	1.8 to 3.3 cents/kWh	4.8 to 5.4 cents/kWh
TOTAL (COST)/BENEFIT TO MNDOT PER KWH	(4 to 5.7 cents/kWh)	(1.9 to 4.5 cents/kWh)
AVERAGE NPV PER YEAR	$ (464,120) to $ (660,440)	$ (221,203) to $ (523,176)
TOTAL NPV	$ (11,603,000) to $ (16,511,000)	$ (5,530,070) to $ (13,079,400)

4.3 WHAT ARE THE WAYS TO BREAK EVEN?

There are additional adjustments that may greatly increase this solar project's economic value to MnDOT. These adjustments could include technological choices (such as changing the project from fixed to tracking panels) and business model innovations (such as making the project into a taxable entity). We present these scenarios in Table 4.2.

Table 4.2: Potential Adjustments to the Base Case Business Model.

ADJUSTMENT	EXPLANATION
PARTICIPATE IN ENERGY AND CAPACITY MARKETS	VPPA's regularly participate in wholesale energy markets, but this one could also participate in MISO's capacity market through its auction process. Last year, for instance, 2.1 gigawatts of solar cleared the MISO auction, an increase of 48% from the prior year.

USE A TAXABLE PROJECT	Tribal governments are not taxed at the state or federal level. New incentives from the Inflation Reduction Act make the investment tax credit for solar directly refundable to Tribes and other nontaxable entities, but that still leaves accelerated depreciation benefits on the table for this project. However, if Red Lake were to partner with a taxable entity, or create its own taxable subsidiary, it could take advantage of tax benefits like depreciation through the life of this project. Conversations with Red Lake Nation staff have confirmed the feasibility of this approach.
USE TRACKING PANELS	The Base Case of this project uses fixed panels, but the project could also use one-axis tracking panels. For the purposes of simplicity, the same project size is applied to the analysis, although its anticipated that tracking panels could reduce the project's size (and thus output) if there are land constraints.
INCREASE THE INVESTMENT TAX CREDIT	The Inflation Reduction Act extended the base Investment Tax Credit for Solar into the 2030s. With the base 30%, we assumed that our Base Case would take a 40% ITC in total. Here we assume it could take an additional 10%, totaling up to 50% in this analysis. More is described about the tax credits in Table 4.3.
MAKE THE PROJECT CHEAPER	We assume that the project could become about 10% cheaper in its upfront cost, resulting in a price decrease of about $0.11/watt-DC. This is potentially feasible if the project achieves more economies of scale or achieves supply chain cost decreases.
APPLY GRANTS TO THE PROJECT	As explored in Table 4.3, below, there are numerous federal grants available for Tribes and Tribal energy projects as part of recent federal legislation. We assume that a $1 million dollar grant could be obtained by this project.

In Figure 4.1, we illustrate how this solar project could potentially stack adjustments (included in Table 4.2) to create a cost-neutral or cost-saving project for MnDOT. We present our values with Cambium 2021's Mid case, a conservative but more optimistic scenario than Cambium 2022, to highlight what could be the project's upside. Once all adjustments are added in Figure 4.1, a negative $13.1 million net present value becomes a positive $3.3 million in net present value, equivalent to about $131,000 per year.

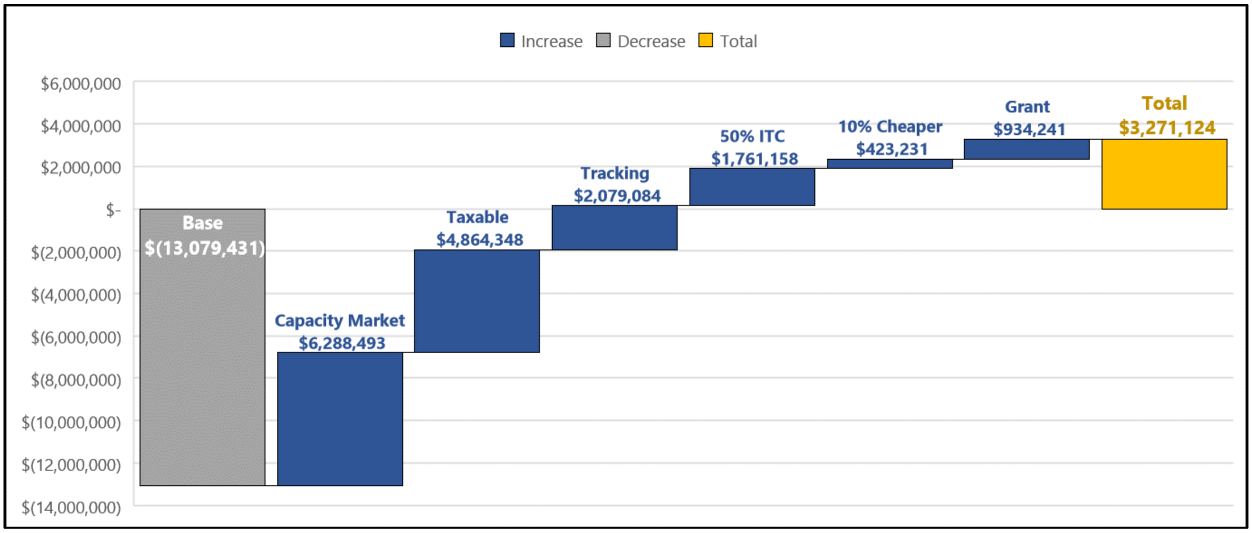

Figure 4.1: Cost Saving Technological and Business Model Adjustments to the Solar Base Case. All values represented as net present value.

We see particular benefits from participating in the capacity market and incorporating as a taxable entity, both of which contribute to making the project operate at a -$1.9 million NPV, translating to a additional cost to MnDOT of only 0.7 cents/kWh. Adding tracking arrays to this set-up makes the NPV then positive, creating potential savings for MnDOT. In all, MnDOT could consider that any number of these and other adjustments, in combination with each other, since they may help create a more cost-neutral project.

We can also account for the value of carbon avoided in our Base Case. With the range we presented in Chapter 3, we depict a solar model that participates in the capacity market with a taxable incorporation status in Figure 4.2 to illustrate how different social values of carbon create an economic benefit in the project. A $37 per metric ton value, for instance, creates a net present value that is nearly positive, while updating to the EPA's latest proposed social cost of carbon at $190 per metric ton, creates a net present value of $3.2 million or higher. Accounting for environmental benefits, along with project-level adjustments, has potentially great value to MnDOT.

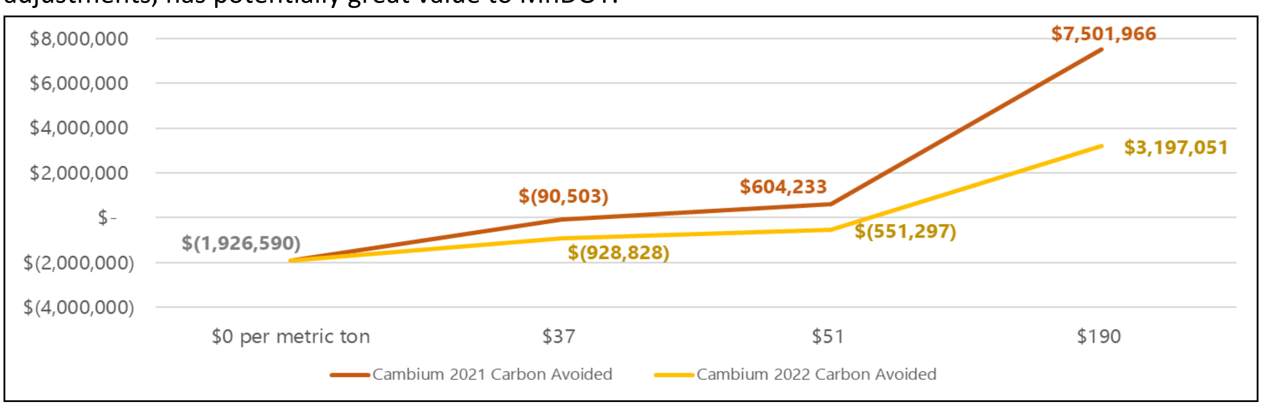

Figure 4.2: Social Costs of Carbon Within the Net Present Value of the Adjusted Solar Project. All values represented as net present value.

4.4 WHAT ARE THE CAVEATS?

There are several assumptions our analysis takes, particularly regarding the Cambium model. As noted in NREL's technical documentation, the Cambium model "should not be the sole basis for decisions." The Cambium model's outputs are based on cost-minimizing, system-wide models, and have several structural features that make the model an imperfect representation of market prices. Those features include an inability to capture a full range of uncertainty (for instance, it cannot predict economic downturns). Among other factors, the Cambium model also lacks spatial and temporal resolution that leads to the model underestimating transmission congestion and buildouts (which, in reality, severely distort market prices across wholesale energy market balancing areas).

In addition, actual wholesale market values may be greater or less than our forecasts. Actual real-time energy prices in the wholesale market have, especially recently, been volatile and higher than the Cambium forecast. For example, in 2022 through September, a 19.6 MW-DC solar project would have captured 30% more income on the real-time energy market in MISO than in the Cambium model, leading to more than $190,000 more income than what our modeling estimates for this nine-month span (Figure 7). With inflation affecting energy inputs such as fuel, steel, and minerals, it is anticipated that wholesale market prices may continue to be inflated for the next few years, making our analysis conservative in this regard.

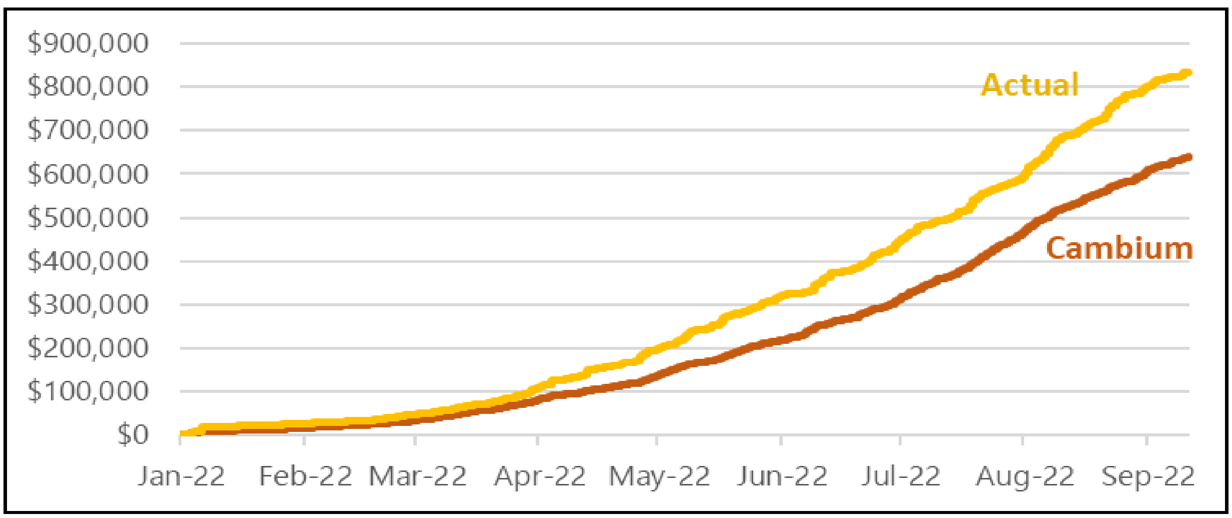

Figure 4.3: Cumulative Revenue from Actual Real-time Energy Market Versus Cambium Forecasts. Data through September 2022. "Actual" data from LCG Consulting.

4.5 WHAT ADDITIONAL RESOURCES ARE AVAILABLE FOR THE PROJECT?

To bring the project cost down and support a strong partnership and working relationship, MnDOT could work with Solar Bear and the Red Lake Nation to identify additional funding opportunities and incentives from state and federal government to help cover the upfront and ongoing costs of the project. For instance, recent funding calls under the Inflation Reduction Act (IRA) and the Bipartisan Infrastructure Law (BIL) could help provide grants and increased incentives (in the form of enhanced investment tax credits) to the project (Table 4.3). Incentives from the IRA and BIL could help drive down the cost of the project while ensuring potential revenues and savings to all parties in the deal.

Table 4.3: Programs from Inflation Reduction Act (IRA), Bipartisan Infrastructure Law (BIL), and Others, for Tribal Energy Projects. Sourced from Biden Administration (2022) and U.S. Department of Energy (2022). Other ongoing funding opportunities on the DOE's Office of Indian Energy Policy and Program's website.

PROGRAM	LAW	AGENCY	FUNDING	NOTES
TRIBAL ENERGY LOAN GUARANTEE PROGRAM	IRA	DOE	$75 million	Loan authority raised to $20 billion. Loan guarantee may now cover 100% of debt.
TRIBAL CLIMATE RESILIENCE	IRA	BIA	$220 million	No cost-sharing or matching requirements
ENERGY INFRASTRUCTURE REINVESTMENT FINANCING	IRA	DOE	$27 billion	Tribal governments eligible to apply. FY 2024 expiration.
CLIMATE POLLUTION REDUCTION GRANTS	IRA	EPA	$5 billion	Tribal governments eligible to apply. Guidance for eligible activities and projects is yet to be released. FY 2026 expiration.
ENVIRONMENTAL AND CLIMATE JUSTICE BLOCK GRANTS	IRA	EPA	$3 billion	Tribal governments in partnership with non-profits eligible to apply. Provides 3-year grants for a range of pollution and carbon emission reduction projects. FY 2026 expiration.
INVESTMENT TAX CREDIT ENHANCEMENTS	IRA	IRS	NA	Tribal governments eligible for direct payment of clean energy tax credits. Stackable 10% increases in ITC available for projects located in "energy communities" and/or made with American materials; and for projects less than 5 MW in size located on Indian land, and less than 5 MW and delivering benefits to low-income communities
ENERGY IMPROVEMENT IN RURAL AND REMOTE AREAS	BIL	DOE	$1 billion	Coming in Spring 2023. For addressing innovative business models in rural and remote communities. Money currently involved in prizes for developing applications.
CLEAN ENERGY DEPLOYMENT ON TRIBAL LANDS - 2023	Energy Policy Act 2005	DOE	$50 million	Coming in Spring 2023 and forward on an annual basis. For deploying community-scale clean energy among other topics.

CHAPTER 5: CONCLUSION

Developing a solar project is an iterative process. A development team gathers information, measures the financial impact, evaluates, and makes incremental investments in a continuous cycle until the project is complete (Springer, 2013). Our report is meant to aid the pre-development stage of that process, helping to define and motivate the project for Solar Bear, the Red Lake Nation, and MnDOT before the group engages in development.

With pre-development in mind, our conclusion includes recommendations for the development process of this project. The project has key advantages so far: it has site control on Red Lake land, a place in the interconnection queue (which is extremely unique and valuable for a VPPA), and a business case that is founded on the unique partnership between MnDOT, the Red Lake Nation, and Solar Bear. The project is a chance to fortify government-to-government relations, expand environmental benefits, and provide a first-of-its-kind opportunity in the United States to fortify the Red Lake Nation's Tribal sovereignty and provide a model of energy development that Red Lake and other Tribes can follow in the future.

Our recommendations build on the strengths of the project and hopefully provide guidance for MnDOT on procedural and project considerations.

1. **Assemble a strike team and involve financial experts, lawyers, and the Red Lake Nation early.** Our conversations with industry experts and the Arlington County case indicate that it was important to involve the different parties early in the process to highlight common and diverging interests across the offtaking agency. It's important that MnDOT further conversations, especially with members of the Red Lake Nation, so that the project can help to protect and enhance Tribal sovereignty.

   Recommendation: Begin having conversations within MnDOT early in project development, socialize the idea, bring together different perspectives, and identify core MnDOT values related to this project that may be represented by financial and non-financial value. It is important that the project also be coordinated with Solar Bear and the Red Lake Nation.

2. **Communicate the VPPA.** A VPPA is not a PPA, first. A VPPA operates as a financial contract that can act as an incentive for new, additional clean energy projects that meet environmental and cost-saving goals. Because VPPAs can provide the necessary financial guarantees to incentivize new renewable energy projects that would not otherwise be built, VPPAs are well suited to meet other policy objectives (such as building government-to-government relations with Tribes). There is also an inherent uncertainty to VPPAs that needs to be communicated well.

   Recommendation: Communication for this project will require internal and external efforts to both familiarize MnDOT staff with a VPPA while identifying ways to leverage the opportunities outlined in Tables 4.2 and 4.3

3. **Further analysis should be performed by qualified parties while accounting for uncertainty, qualitative benefits.** Our analysis was holistic, but in background conversations with VPPA developers and offtakers, it was stressed that operational and financial consultants play a large role in the final price setting of the VPPA itself. For offtakers like MnDOT, it is important to assess the uncertainty of cash flows and assess the most likely and worst-case scenarios, while understanding that the uncertainty of the VPPA is a key feature but can be mitigated by proper assessment, contract design, and communication.

   Recommendations: The team should work with outside legal and financial teams to assess possible financial risk and determine what threshold may be acceptable (see Arlington Case for their approach). There is also a need to work with energy experts to understand how to participate in the capacity market of MISO and properly evaluate the uncertainty of the wholesale market. The team should probably expect to work with an outside vendor to purchase a proprietary forecast of wholesale prices for this purpose. In addition, the team could consider different contractual pricing floors and collars that might keep risk more palatable in the project. Our team made several connections with outside parties during this project and would be happy to connect the MnDOT team with them to help further this recommendation.

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GLOSSARY

Additionality: when a power purchase agreement/contract has the direct effect of adding new renewable energy generation to the grid that would otherwise not have happened.

Aggregation: allows for access to benefits of a larger project at scale by partnering with other organizations (universities, companies, government entities) to aggregate demand; different parties that come together under an aggregation do not necessarily have the same contract.

Energy and capacity markets: An energy market provides per-kilowatt-hour payments for energy in short intervals in the near future. A capacity market provides per-kilowatt payments for power to ensure reliability in the year or seasons ahead. In MISO (the wholesale market applicable for Minnesota), the energy market sets prices for energy in real-time and the capacity market prepares for the future. MISO operates two interrelated energy markets, the real-time market (that prices energy every five minutes at specific locations on the grid) and a day-ahead market (that prices energy hourly for the next day). MISO's capacity market (called the "resource adequacy market") ensures that there is sufficient capacity on the grid one to two years into the future. MISO uses the analogy that the capacity market ensures that there are enough parking spots at the shopping mall to handle the Christmas holiday period when demand for parking spots is the highest. Understanding the impacts of variable generation sources (like solar energy) on long-run resource needs is continuously evolving.

Hub price: aggregated price across multiple nodes via a weighted average formula, as an aggregated price hub prices are usually more stable over time.

Node price: prices in the wholesale electricity market are set at nodes, often electrical buses in specific locations in the transmission system.

Offtaker: the buyer in a physical or virtual PPA.

Physical Power Purchase Agreement (PPA or PPPA): A power purchase agreement where the seller delivers electricity to the customer at their facilities, or a predetermined delivery point within their local electricity markets where the customer then takes legal title to the energy.

Renewable Energy Certificates (RECs): Certificates associated with units of energy from the production of a renewable energy facility.

Strike price: price is the price at which the project owner can meet their investment return goals, for a VPPA this is an agreed upon fixed and known price.

Virtual Power Purchase Agreement (VPPA): a financial agreement in which a customer agrees to pay a project owner a predetermined price per unit of energy and, typically, the associated RECs from a renewable energy project. Instead of physically delivering the electricity to the customer, the project owner sells the energy into the local organized wholesale market; for each MWh, the buyer then pays or receives the difference between the wholesale market revenue and the predetermined PPA price.

APPENDIX A
ELECTRICITY FORECAST EXAMPLES FROM ARLINGTON COUNTY, VA

The following slides are from a February 2023 presentation by Arlington County to the Arlington Initiative to Rethink Energy. The slides briefly overview the County's VPPA and its projected cost and savings over the coming year.

Maplewood VPPA Overview

Arlington Initiative to Rethink Energy | CARBON 2050 NEUTRAL

- Dominion developed the project in partnership with Amazon and Arlington County
- 120 MW capacity facility in Pittsylvania County, with Arlington off taking 31.7% of electricity produced
- Output is approximately 79,000,000 kWh annually, about 83% of County operations annual consumption
- Project was approved by County Board at the January 25, 2020 Board Meeting

One of the 4 blocks at Maplewood Solar facility, Pittsylvania County

Maplewood Implementation

Arlington Initiative to Rethink Energy | CARBON 2050 NEUTRAL

- Initial 84% system capacity operational on September 15th 2022, rider added to electricity bills November 1st, 2022. System completed in December 2022.

$$\text{Rider Rate} = \frac{(\text{System Production}) \times (\text{Forecasted Wholesale Electricity Price} - \text{Contracted Price})}{\text{Volumetric Use of Accounts}}$$

- FY23 credit based on hourly wholesale electricity markets
  - Anticipated rider: $.050 - $.054 $/kWh
  - Current electricity rates: $.07- $.13 $/kWh
- Anticipated total credits for FY23 = **$2.2M-$2.7M**
- Annual surcharge reconciliation (true-up) process with Dominion to reset rider rate each contract year

APPENDIX B
FINANCIAL MODEL ASSUMPTIONS

Base costs: Drawing from the Lawrence Berkeley National Laboratory (LBNL), we assume that a ~20 MW-DC project will be more cost effective than a 5 MW-DC project, so we use the 20th percentile costs of 5 to 20 MW solar projects from LBNL and inflate their cost to $2024 dollars. Our 19609 kW-DC project is estimated to cost $1.1/W-DC, as is reported in the LBNL data, without factoring in the project-specific costs described below. Assumed $15/kW-DC in operational costs, consistent with LBNL data.

Weather data: We use the uncertainty function in SAM to identify the P90 value for first year solar energy production in Quiring, Minnesota. We then use a 2016 weather file for Quiring, Minnesota, to simulate P90 values for solar production from the array for Chapter 4's economic analysis.

Financing: The project team validated SAM solar outputs with real solar production from the U.S. Energy Information Administration 923 reports. While initially the team used a 13% snow cover reduction for fixed panels, that snow loss number was lowered to 3% to account for real-life efficiency improvements in panels and actual solar production data in Minnesota.

Financing: We assume the base project will be Tribally owned, nontaxable, with a composite federal and private loan for 100% of the capital stack at 4% interest for a tenor of 25 years, the life of the project.

Taxes: Assumed the project was nontaxable, as Tribal governments and enterprises are not subject to state or federal taxes.

Investment tax credit: We assume the array is sized to achieve the 30% ITC plus a 10% bonus ITC, per new Inflation Reduction Act rules.

Project-specific Costs: A wheeling charge of $5.5/MWh was added (as a negative performance-based incentive), per our interviews with ACE, as was a $667,405 transmission upgrade fee.

Cambium model: We used publicly available energy forecasts from the National Renewable Energy Laboratory's Cambium model. As all model costs are inflated from $2020 to their nominal years with a 2% inflation rate for the p42 balancing area in Cambium, which is located around the project's proposed siting area near Quiring, MN. While the energy and capacity markets in the Cambium model are like the real-time energy and capacity markets in MISO, they are not perfect replications. To hedge the wholesale cost estimate difference, we used seven cases across the Cambium 2021 and 2022 vintages. From Cambium 2022, we selected the more conservative Mid and High Natural Gas Prices cases, alongside the more progressive scenarios of 100% Decarbonization by 2035 and 95% Decarbonization by 2050. From Cambium 2021, we selected the more conservative Mid case, alongside the more progressive 95% Decarbonization by 2035 and 95% Decarbonization by 2050.

The Cambium model documentation is available online: https://scenarioviewer.nrel.gov/.

Emissions estimates: We use long-run CO2-equivalent emissions reduction estimates from the Cambium 2021 and 2022 models. We model the array at the Minnesota state level, using both pre- and post-combustion emissions, Fifth Assessment Report values for the emissions, and averaged out over a 25 year basis. In consultation with Cambium modelers at NREL, we averaged out solar production over a 25 year basis and multiplied it by the long-run hourly values offered by the Cambium workbooks. Other estimates from sources such as the U.S. Environmental Protection Agency's AVERT model might model the emission reductions higher, but the Cambium model's long-run estimates include the growing decarbonization of the electric grid. See the Cambium technical guides for more information: https://scenarioviewer.nrel.gov/.