District Use Case: University of Minnesota Twin-Cities

1. <u>Project Proposal</u>

Solar Commons Team

Team Members:

University of Minnesota - Twin Cities

Brooke Aschenbrener | Mechanical Eng.
Davis Bain | Mechanical Eng.
AJ Fundator | Mechanical Eng.
Ryan Geopfrich | Mechanical Eng.
Kate Huelskamp | Mechanical Eng.
Reese Peck Cowles | Mechanical Eng.
Rea Banerjee | Electrical Eng.
Robynn Hickmann | Environmental Engineering

University of Minnesota - Duluth

Adam Herman | Anthropology
Emilia Holstine | Anthropology
Jesse Krzyzaniak | Anthropology & Public Health
Davis Nelson | Anthropology
Noah Ruona | Anthropology & History

Mentors:

Professor Kathryn Milun | Ph.D.
- Department of Sociology, Anthropology and Criminology

Professor Uwe Kortshagen | Dr. rer. nat. (Ph.D.)
- Department of Mechanical Engineering

1.1 Executive Summary

For this project, University owned buildings located on the East Bank campus will be analyzed to determine if they are qualified for the installation of solar panels. From analysis of building load data, structural information, and financial modeling, our team will design a solar panel system on up to 20 buildings. The solar array system will solve two major problems. First, by motivating the University of Minnesota (UMN) decision makers to implement our solar system, they can generate savings on energy consumption as well as begin their transition to clean energy production and consumption. Additionally, a fixed portion of the generated savings will be deposited into a Solar Commons Trust with the purpose of funding an underserved community.

The project began by first receiving 15 minute interval electrical load data for every building on the East Bank campus from the Senior Energy Engineer at the University of Minnesota - Twin Cities. This data was then used to generate total monthly load data for each building in order for it to be utilized in the REopt® tool provided by the National Renewable Energy Laboratory(NREL). The entire consumption of the East Bank campus was also created to show the magnitude of total energy consumption of the campus per month (figure 1).

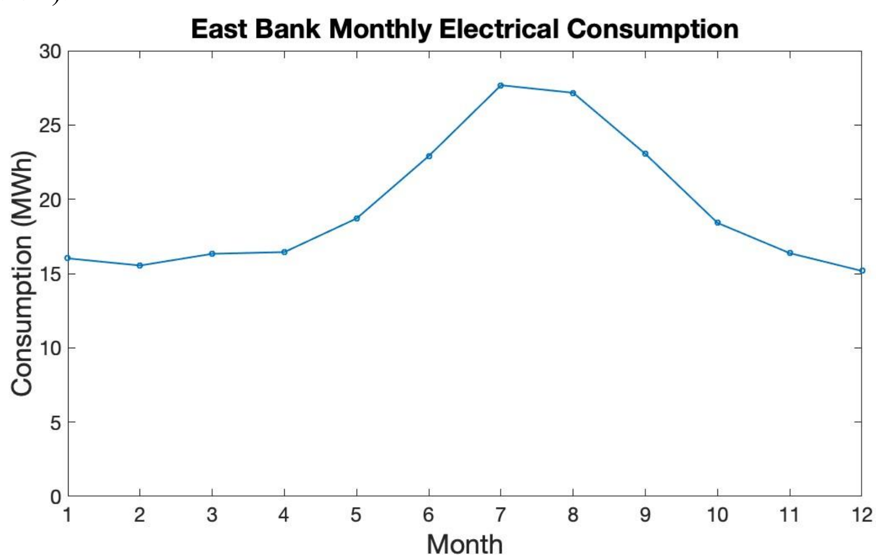


Figure 1: The entirety of the East Bank campus on the UMN - Twin Cities university campus. The Maximum electrical consumption peaks in the month of July at 27.67 MWh.

This tool then took inputs such as the types of energy that will be utilized, the electrical cost of energy, the building type, and the building location to then provide ideal Photovoltaic(PV) array size, battery capacity, and battery power for each building. After this was accomplished, the buildings in question were initially designed to see the maximum output of all buildings within Aurora Solar® using a Jinko Solar JKM410M-72HL-V panel as the UMN already has a small solar installation on Rapson Hall. The continued use of this panel allows for ease of maintenance and cost savings on the Operating and Maintenance portion of the financial analysis. Following the development of the arrays, the production numbers generated from Aurora were then put into a building selection matrix to find buildings with the best combination of roof space, exposure to sunlight and roof life. The selection matrix allowed the design team to focus on buildings that had the highest score for further modeling.

Following the selection of these initial buildings, it was determined that the roof space available was not adequate for the panels to meet 25% of any one building's electrical consumption. The utilization of a "clustering" method was then used to couple multiple buildings together to support a single building's consumption for larger cost savings through more effective peak shaving. The clustering of buildings resulted in 8 subsystems within the district with each cluster consisting of 2 to 3 buildings. Continuing on from the initial design of maximum production of all buildings, the selected buildings were then designed to comply with the International Fire Code (IFC) and the National Fire Protection Association (NFPA). The two major code sections to comply with for all selected buildings were that roof access needed to be prevalent with a 6 foot perimeter pathway on all edges of roofs and a 4 foot perimeter pathway around all roof equipment, ventilation hatches, & skylights (NFPA 1, Section 11.12.3.3.2).

With the panels selected, production numbers generated from Aurora, and all relevant building codes conformed to, the next step was the electrical design of the interconnections and battery storage of all possible electricity. First the panels and buildings need to be interconnected in order to properly provide the energy generated from the PV arrays. This can be seen in a representative one-line diagram(figure 2) of the Lind Hall building cluster which is made up of Lind Hall and Keller Hall.

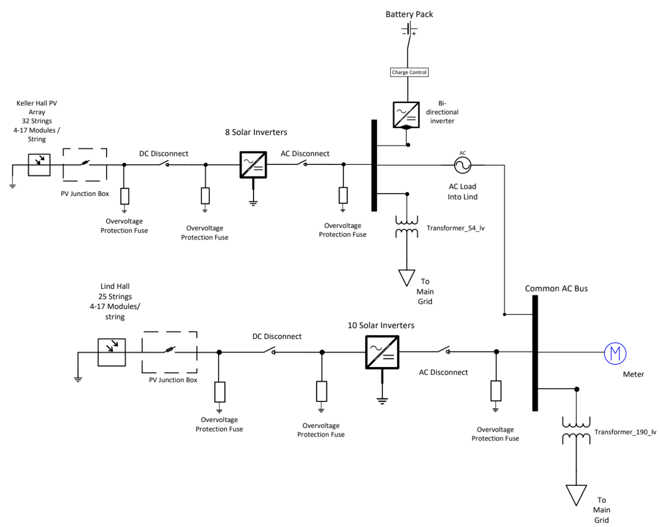


Figure 2: The Keller and Lind Hall cluster where the Keller and Lind Hall PV arrays support the Lind Hall electrical consumption.

After the wiring was laid out in Microsoft Visio®, the battery storage systems were then designed. As there is limited available data on the internet for large scale battery packs, the Evesco ES BESS Series was selected due to its highly modular and containerized design. This will allow for flexibility in battery capacity across all the clusters on the UMN campus.

After all the design work was done, the financial team used the model provided by NREL in order to model 30 year project finances. When modeling, simplifying assumptions needed to be made such as a construction cost of $1.57 per watt, roof structural capacity (to handle the additional load of panels/hardware), a PPA price of $0.13, and a system lifetime of 30 years. With all of this, a payback period of less than 12 years was achieved for all building clusters as well as for the entire district as a whole. The final system design has a size of 3.8 MW with an IRR of 9.7%. Another subsystem that was modeled was a Solar Commons Trust, which was created to have a total array size of 500kW as described by the Rocky Mountain Institute(RMI) (Brehm, 2018). This resulted in a total of $1,474,776 which will be sent to underserved communities over a 25 year period.

Our Solar Commons plan for the University of Minnesota campus system will benefit many underserved community partners, including the Stowe Elementary school neighborhood in West Duluth and the food sovereignty work on ancestral lands of the Ojibwe and Dakota peoples. These groups will have access to the trust align with not only the community engagement for the competition, but also with the University's mission of Outreach and Public Service by "applying scholarly expertise to community problems, … and by making the knowledge and resources created and preserved at the University accessible to the citizens of the state, the nation, and the world" (University of Minnesota, 2008).

1.2 Team Introductions

Students

Reese Peck Cowles

Mechanical Engineering student at the University of Minnesota - Twin Cities. Has been working as team lead as well as financial model advisor. Interested in renewable energy solutions and fundamental thermal science analysis.

Brooke Aschenbrener

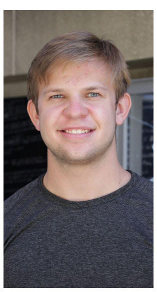
Mechanical Engineering student at the University of Minnesota - Twin Cities. Has been assisting design leads with equipment selection, complying with code, overall project organization. Interested in mechanical infrastructure solutions and analysis.

Davis Bain

Mechanical Engineering student at the University of Minnesota - Twin Cities. Has been in charge of project financial modeling and budgeting. Interested in building efficiency and sustainable power sourcing.

AJ Fundator

Mechanical Engineering student at the University of Minnesota - Twin Cities.He has been primarily working on the design team on panel layout and load analysis. Interested in manufacturing and optimization of manufacturing systems.



Ryan Goepfrich

Mechanical Engineering student at the University of Minnesota - Twin Cities. Has been working as lead on battery modeling and selection. Interested in energy efficiency analysis and renewable energy solutions.

Kate Huelskamp

Mechanical Engineering student at the University of Minnesota - Twin Cities. Has been working on panel layout design and district sizing. Interested in control design and implementation.

Rea Banerjee

Electrical Engineering student at the University of Minnesota - Twin Cities. Has been working on the electrical distribution impacts and wiring line diagrams. Interested in renewable energy solutions and power systems.

Adam Herman

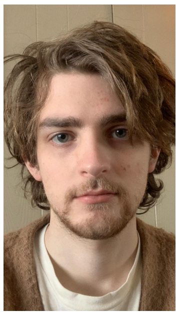
Anthropology major at the University of Minnesota Duluth. Work on the project includes design and community integration. I'm interested in how cosmology and our cultural systems have developed over time and where we are going from here.

Emilia Holstine

Anthropology student at the University of Minnesota Duluth. Working on the project as a community integration planner and communicator. Interested in reparative justice and how landscape shapes communities.

Jesse Krzyzaniak

Anthropology and public history major at University of Minnesota Duluth. Works in cultural resource management. Focus in archaeology and forming relationships with the past and present through presentation to the public.

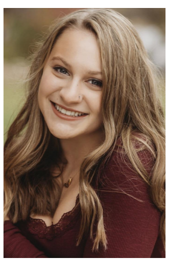


Noah Ruona

History and Anthropology student at the University of Minnesota-Duluth. Working on design work for the project. Interested in Russian history and holocaust studies.

Davis Nelson

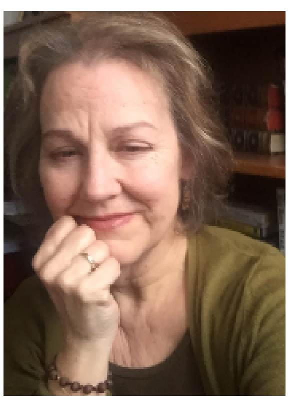
Anthropology major and history minor at the University of Minnesota Duluth. Working as a project designer and community coordinator. Interested in the energy transition and restoration of commons.



Robynn Hickmann

Environmental Engineering student at the University of Minnesota Twin Cities. Working on Dashboard design for the project. Interested in renewable energy sources and water treatment.

Mentors



Prof. Kathryn Milun

Assoc. Professor of Legal Anthropology at the University of Minnesota Duluth and Founder/Director of the Solar Commons Research Project at the MN Design Center of the University of Minnesota Twin Cities. Interested in energy democracy and the reparative justice potential of solar technology.

Prof. Uwe Kortshagen

Uwe Kortshagen's research is in the area of fundamental plasma manufacturing science and plasma materials science. Applications of his research span from renewable energy technologies to nanoscale plasma manufacturing, to new materials for bio-imaging and human health.

1.3 Project Overview

1.3.1 System Sizing and Design Rationale

The goals of this project is to design and implement a solar photovoltaic system on the University of Minnesota Twin Cities campus and create a Solar Commons designated array that will be able to send its solar savings to underserved community partners. This is in accordance with UMN's Climate Action Committee which is in charge of providing a plan to reach net-zero carbon emissions by the year 2050 as well as their mission of outreach and public service. While the most ideal case of solar energy generation is to reach 100% of all electrical consumption demands, this was physically impossible due to the fact that the solar arrays needed to be designed for the East Bank campus location. All buildings located within the confines of the East Bank campus were then evaluated based on roof space, roof life, and annual production capabilities in order to focus on higher performance buildings. The buildings that were found to be acceptable through this selection process are shown in figure 2.

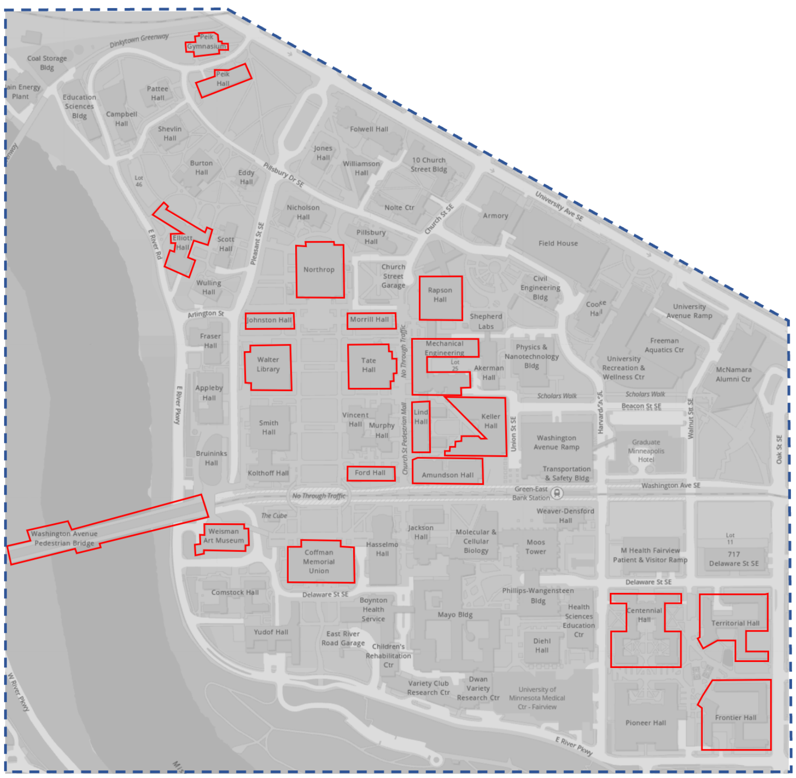


Figure 2: The buildings that were considered for further analysis are shown above outlined in red.

Through further analysis, it was found that no single building was able to support 25% of its own electrical load, so a clustering strategy was implemented in order to support more of a single building's load. This clustering method also allowed for decreased cost in battery and inverter purchasing as the number of buildings being supported is less, the electrical energy is able to be sent to the building before going through an inverter. One possible problem that arises from this clustering is the fact that many transmission lines need to be laid in order for the electricity to travel to buildings, but this is almost completely neglected for all but 2 clusters due to existing infrastructure underground that connects buildings. Panel and inverter selection was made through a precedent solar array already installed on

Rapson Hall and allows for a small reduction in Operations & Maintenance costs as the equipment is known.

The resulting final design of all these building-mounted solar arrays meet 19.82% of the University of Minnesota Twin Cities' annual electrical consumption. The overall solar design will produce around 3.83 GWh of electricity annually. This all resulted in a cost effective solution that minimizes the cost of battery storage systems, inverters, and O&M. The overall production vs. consumption can be seen in figure 3 and the location, size, and annual production of each cluster is shown in table 1.

Table 1: Size, location, and production of cluster systems.

Building Cluster #:	**Location of arrays:**	**Total size of Arrays (kW):**	**Annual Production of Arrays (kWh):**
1	Peik Hall, Peik Gym, Elliot Hall	493.7	463,306
2	Territorial Hall, Centennial Hall, Frontier Hall	685.1	662,013
3	Johnston Hall, Walter Library	326	322,346
4	Rapson Hall, Mechanical Engineering Building, Northrop Auditorium	843.4	892,029
5	Tate Hall, Morrill Hall	289.4	269,837
6	Lind Hall, Keller Hall	505.4	537,358
7	Ford Hall, Amundson Hall	225.1	248,686
8	Coffman Memorial Union, Weismann Art Museum, Washington Avenue Bridge	456	434,351

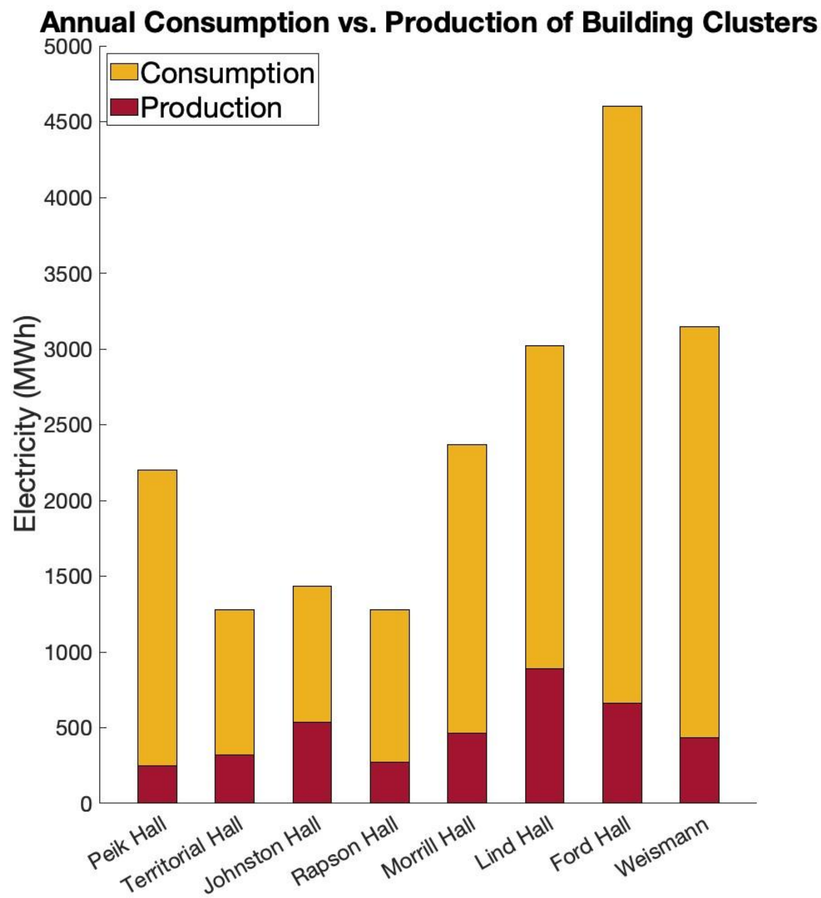


Figure 3: Annual production and consumption of each cluster graphed based on electricity in Megawatt-hours.

1.3.2 Distribution System Impact

The PV system is designed to reduce peak consumption of the University of Minnesota campus by clustering buildings into groups of two or three. Most building clusters are connected through tunnels, which can be used to interconnect the clusters without major construction. Feeder cables and low-voltage secondary cables can be routed through the tunnels. However there are exceptions, namely Peik Hall, Elliot Hall, Territorial Hall, and Frontier Hall. These buildings are not connected through tunnels and will require additional above ground interconnection construction. Our PV system is grid-tied, meaning on average, 20% of the load is met by solar, while the rest is met by the on-campus grid. This means a greater overall portion of the University's energy consumption can be met by renewable energy. In our initial model, each cluster was connected to a single transformer. This quickly proved unsuitable for the distribution system. Instead each building in a cluster is connected to one transformer. Clusters with buildings close to each other, like Morrill and Tate, Johnston and Walter, and Peik Hall and Peik Gym already share one transformer, so those connections remained in place, after ensuring no major overvoltages or overloading was taking place at those nodes. Through the use of overvoltage protection fuses and other network protection elements to reduce the amount of overvoltages in the system.

There are several limiting factors when connecting PV arrays to the on-campus grid. The major limiting factor is that most of the PVs are just above hosting capacity, leading to overvoltages and thermal violations. This can be remedied by improving hosting capacity. Such improvements include a battery storage system, which is already implemented. The battery can also be used for peak shaving within the system. Peak shaving techniques can reduce overall peak energy costs. Peak shaving requires managing energy demand in each cluster to predict when during the day the system should rely on battery storage. Smart inverter controls, upgrading equipment or potentially reducing and moving the PV system are also methods of improving hosting capacity. The second limiting factor is distance, as the battery pack must be closer to the distribution array than the supported array for maximum efficiency during charge. The longest distance between buildings in our design is Peik Hall and Elliot Hall at around 920 ft. This is a big limitation as the recommended distance between PV array and load does not exceed 500ft. Longer distances between the PV and the load results in greater power loss and voltage drop, which reduces the overall efficiency and output of the system. Reducing the power loss and voltage drop requires thicker, and more expensive cabling, or potentially adding relays to the interconnection, which can help keep the voltage stable.

1.3.3 Economic Analysis Summary

The financial system design must first begin with an understanding of how the University of Minnesota would interact with the PV system as they are the hosts. Due to the large energy demand of the East Bank Campus, for which we are designing, all of the generated solar energy would be used by the campus buildings, according to U of MN facilities management. When using the financial model, the following assumptions were made in knowledge of solar market data, U of MN energy usage data, and overall system capability. Based on conversations with U of MN facilities management and the U of MN Campus Sustainability Committee, the university is interested in purchasing the system incrementally over a series of years in upfront purchases. The next likely and best financial option is a one-time upfront purchase of the system. The third option for University project financing is using a Power Purchase Agreement (PPA). For conservative estimate purposes, each system was modeled for a PPA at a starting price of $0.13 per kWh and 2.5% annual escalator. The current (estimated and averaged, accounting for peak demand charge) utility rate that the university pays is $0.157 per kWh and utility escalation rate of 2.5%. The PPA price was chosen because it is a conservative estimate based on UMN's utility rate. The submitted Excel models account for both financing options.

The University of MN Twin-Cities, will likely do what makes the most financial sense. Thus, they will likely purchase the system upfront. This includes a 3rd party developer at a standard 10% developer margin. The overall system size is 3,824 kW. Given this, the safest, NREL published, guideline for overall construction cost is $1.59 per watt (for 2MW commercial rooftop systems). The closing costs for the system, from given assumptions about the system being part of a $50M development, is then $121,606. The total system proposed has 17 buildings divided into 8 sub-systems targeting the electric loads of 8 buildings. The overall consumption of the targeted buildings is 1,610,660 kWh/month. Using known production from all arrays, 20% of the total electrical load of the 8 buildings is met in the entire system's kWh production. With a margin of electrical load so low, Net Metering will not be applicable to this case. The construction loan amount equals the aggregate construction cost for the whole system, which is $4,696,263. The Project's sale price is modeled as the aggregate project cost, which is $5,541,177.

The University, being a non-profit organization, is a non-taxpayer who owns all of the land/buildings which would house solar projects. This means there is no purchase cost or additional taxes for site purchases. The IRA ITC benefits, having been recently made available to non-taxpayer universities, gives better financial benefit than PTC benefits so the 30% ITC is claimed in the model. Additionally, the partnership flip method is ignored in this model. In Minnesota, there are no SRECS to be taken advantage of, at least not now.

The entire system's displaced utility cost and project cash flow over time is shown in figure 4. The following figures will remain with the assumption that UMN will be developing the project themselves, not using a PPA.

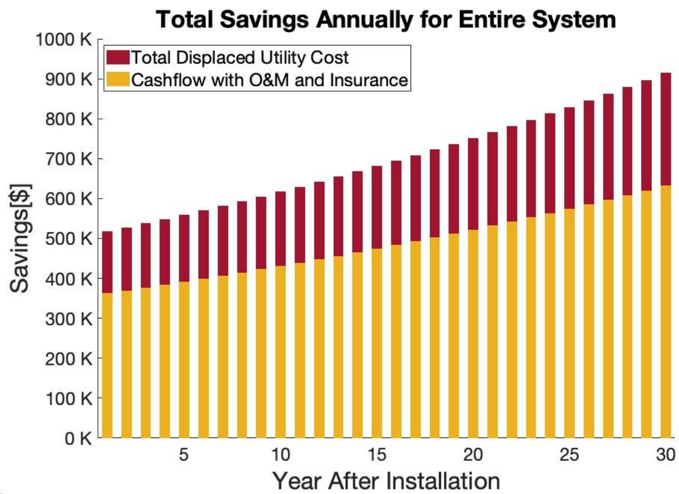


Figure 4: The total savings of the University of Minnesota shown after the year of installation. A significant portion of the solar savings goes toward Operations & Maintenance as well as Insurance.

As mentioned above, the project could be financed through a PPA or upfront purchase. Both options are displayed(figure 5& 6) showing the cumulative project cash/tax benefits at PPA price or UMN direct return price.

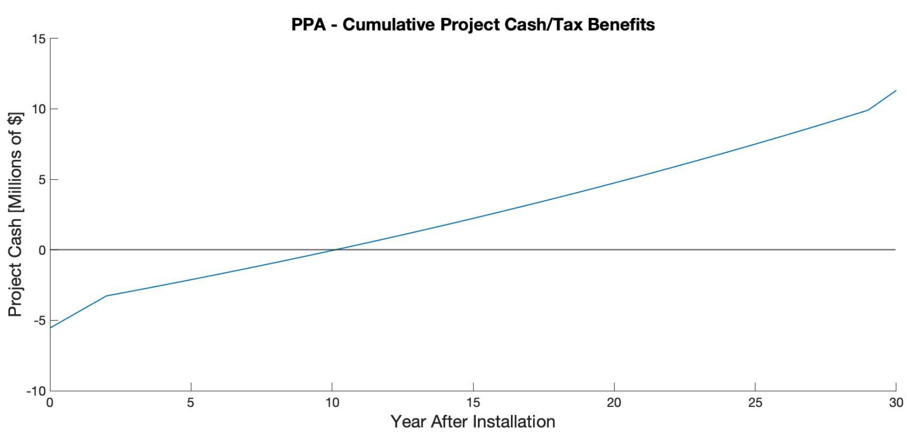


*Figure 5:*Using a PPA price set at $0.13/kWh, the end revenue after 30 years is $11,314,784.

To model the system as developed by the university, the PPA price is set to the utility cost of $0.157 per kWh, if the system is financed through a PPA, the PPA price remains at $0.13 per kWh.

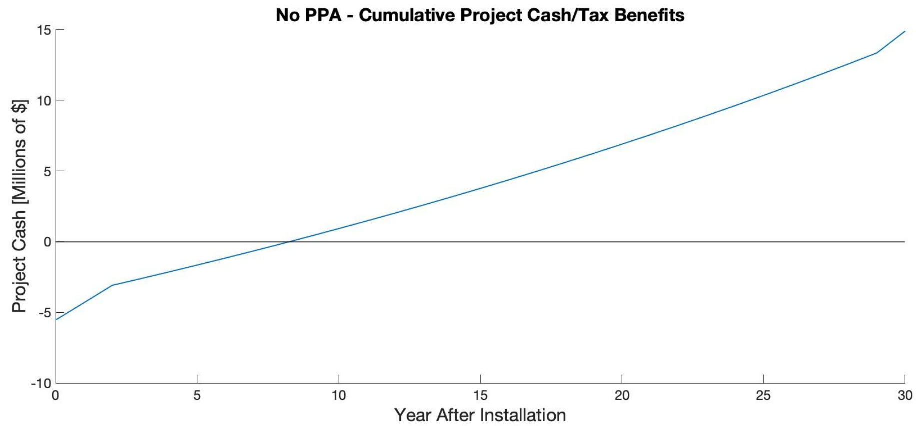


Figure 6: When not considering a PPA, the end revenue after 30 years is $14,895,609.

Table 2 below gives the summary data for all 8 subsystems, the whole system and the solar commons portion. This is the list that will be given to the U of MN authorities for evaluation of installing solar on campus, incrementally if they so choose. It must also be noted that the construction cost increases as the project size decreases.

Table 2: Financial Summary Data from all Sub-Systems

Sub-system	Buildings	Syst. Size (W)	Yield (kWh/ kW)	Consumption (kWh/mon)	Closing Costs	Approx. Payback (Yrs)	IRR %	Cost
1:	Peik, Peik Gym, Elliot	493,700	938.4	197362	$ 15,699.66	10.8	8.91	$ 838,922
2:	Territorial, Centennial, Frontier	685,100	966.3	383600	$ 21,786.18	10.4	9.27	$ 1,160,283
3:	Johnston, Walter	326,000	988.8	106395	$ 10,366.80	10.2	9.45	$ 557,354
4:	Northrop, Rapson, Mech E	843,400	1,057.7	251534	$ 26,820.12	9.3	10.34	$ 1,426,069
5:	Tate, Morrill	289,400	932.4	106395	$ 9,202.92	11.1	8.76	$ 495,903
6:	Lind, Keller	505,400	1,063.2	119576	$ 16,071.72	9.4	10.35	$ 858,567
7:	Ford, Amundson	225,100	1,104.8	183387	$ 7,158.18	9.1	10.67	$ 387,943
8:	Weisman, Wash Bridge, Coffman	456,000	952.5	262411	$ 14,500.80	10.5	9.07	$ 775,624
	Whole System	3,824,100	1,001.5	1610661	$ 121,606.38	9.6	9.71	$ 5,541,177
	Solar Commons	500,000	1,057.7	149119	$ 15,900	9.4	10.30	$ 849,500

1.3.4 Solar Commons Trust Economic Analysis

Given the project's dual purpose of bringing solar energy savings to the U of MN campus and benefiting a local community, as discussed above, the following section analyzes the economics specific to the Solar Commons Trust (SCT). Much of the engineering assumptions made for the system apply for the solar commons trust as it is part of the larger system and not its own system. Additionally, connections are being made with possible donors for the project's high cost, principally, the McKnight Foundation is promising. While nothing is certain, the following analysis assumes no grants or donations will be acquired for the project.

Given by market data suggested by the Rocky Mountain Institute (RMI) (Brehm, 2018), the ideal size for a community focused Solar Commons Trust PV array is 500 kW. With this, 500 kW of subsystem 4 will be dedicated to this purpose. This subsystem was chosen for its high yield of 1058 kWh/kW and its large size of 843 kW. This means the 500kW portion could always be supplied from a consistent source and the benefits of the high yield system can be seen in the Solar Commons Trust financing. As seen in table 1.3.3.1, the system has an aggregate cost of $849,500. It has a 9.4 year payback period and a project IRR of 10.3%, exceeding national averages.

The exact finance structure is not yet known but we have a theoretical model for the relationship between the U of MN and the Solar Commons Trust: The U of MN will build and maintain all of the panels with proportional financial help from the Solar Commons Trust fund. The U of MN will use all generated electricity from the SCT portion and donate the cash flow to a needy indigenous Minnesotan community. The SCT fund will not begin receiving financial support until the system is paid off (breakeven). Any Solar Commons Trust donations from the U of MN will cease at year 25 at which time all financial gains from the 500 kW SCT portion can go to the U of MN directly for proper panel recycling costs and system upgrades. This accounts for the additional cost of recycling solar panels instead of tossing them at a landfill. Over 25 years, the project will generate $1,474,776 for underserved tribal communities; this factors in the full project cost, which the system will pay itself.

1.3.5 Development Plan

The development plan consists of applicable zoning codes, permits, a detailed construction schedule, and how our proposal can engage the local student community on campus. The State of Minnesota and Hennepin county have no major zoning laws or codes to follow for all buildings except the Territorial Hall cluster. The buildings in this cluster are classified as residential buildings and are subject to stricter zoning law and code. Solar systems in Minnesota require permits and inspections for both structural and electrical construction. Non-residential buildings need to be assessed by a structural engineer. Electrical designs must conform to the National Electrical Code 2008 Edition. Permits are procured through the City of Minneapolis' Department of Labor and Industry. Additionally, The International Fire Code (IFC) and the National Fire Protection Association (NFPA) are the codes most relevant in this proposal. Aurora software was used to optimize the panel layouts and walkways along the rooftops up to code.

The construction schedule will depend on the U of MN's plan for financing and building. Very likely, they will build all subsystems at once as it is the most financially viable but they have indicated interest in building the system incrementally over a series of years. The construction pre screening process is estimated to take around 10 days, due to the amount of stakeholders involved. Stakeholders include University of Minnesota, Xcel Energy, and the Solar Commons trust. The design process includes structural and civil engineers inspecting each building cluster to ensure they are able to hold the weight of panels, inverters, battery packs and other electrical components. Previous issues with rooftops must also be taken into account. Additionally, the tunnel systems must be fitted with power lines and have a high safety standard due to the large amount of foot traffic through the tunnels every day. The team of engineers will also inspect the overall system design to ensure structural, electrical and fire safety requirements are not violated. All inspections will follow the NFPA codes adopted by Minnesota. Permit applications will also need to be filled out with the City of Minneapolis Department of Labor and Industry, as well as with Xcel Energy, the local utility company. The permit with Xcel will act as an interconnection agreement between Xcel and the University. The material arrival process will occur simultaneously and is estimated to take 3 months depending on supply chains. The actual construction phase will include civil, system and electrical construction. System construction will take the longest time, approximately two months. The following electrical construction will take around twenty one days to complete. Following construction, each cluster will be tested to ensure proper installation. The final phase of construction is the interconnection of the grid to the PV arrays and any final inspections.

In order to facilitate greater community engagement with this proposal, students at the University of Minnesota Duluth and UMN Twin Cities have created a dashboard to share information about the solar project. They connected with people from across the country to gain a better understanding of solar installations and the needs of each stakeholder. The 500kW Solar Commons carve out costs $849,500 and the University's Solar Commons Research Project suggests seeking a donor or grant funding to pay for it. This project can be funded through tax incentives and multiple funding sources, and will benefit underserved community partners. It aligns with the University of Minnesota campus mission of making knowledge and resources accessible to citizens of the state, nation, and world.

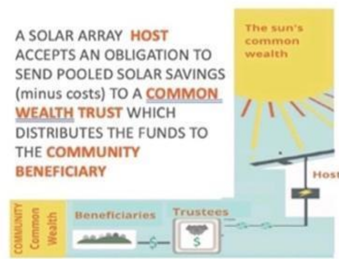
1.3.6 Social Rules, Tools, and Community Benefits of a 500kW University Solar Commons

This section, created by social anthropology undergraduate students at the University of Minnesota Duluth (UMD) and an environmental engineering student at UM Twin Cities, describes the social rules, peer governance tools, and community benefits of the proposed 500kW Solar Commons carve out for the proposed University of Minnesota campus solar design.

Introduction and Background. Solar Commons are a new type of community solar that uses community trust ownership to enable underserved communities to receive financial benefit from a host institution's solar energy savings. Solar Commons partners follow general guiding principles of the Solar Commons Community Trust Ownership Model™ to direct solar savings to a community trust.[1] For as long as the sun shines, the trust will provide steady revenue for the community beneficiary to do reparative justice work and build local community wealth.

Solar savings on a typical electric bill.


Neighbors partner with a local building owner who agrees to share their free solar savings.



Neighbors use a community trust to share the solar savings.


Neighbors use a digital dashboard to transparently govern how the solar savings are used in their neighborhood.

This design for a 500kW Solar Commons on the University of Minnesota campus is based on a smaller Solar Commons prototype (14.5kW) interconnected to the grid in Tucson, AZ in 2018. The Rocky Mountain Institute (RMI) did a financial and scalability analysis of that prototype and proposed that the sweet spot for a Solar Commons, the size at which it could provide the most benefit to its community trust beneficiary would be 500kW (after which administrative costs would subtract from the trust) (Brehm, 2018). According to RMI, Solar Commons are economically feasible and scalable. Over the coming decade of urgent energy transition, RMI predicts that solar arrays owned as "Solar Commons" could iterate to ten gigawatts in the US. This would result in billions of dollars of long-term economic benefit flowing to underserved US communities.

The University of Minnesota Solar Commons Design: Cost and Funding. The engineering students' design estimates that a 500kW Solar Commons carve out would cost approximately **$849,500**. We suggest that the University's Solar Commons Research Project at the MN Design Center seek donor or grant funding to pay for this. As the first 500kW Solar Commons project in the US and as a prototype for iteration on campuses across the US, we believe it is a fully fundable project. We looked into the mission statements and annual distributions of several local charitable foundations and feel that the McKnight Foundation, newly redirecting its funds to climate mitigation, community wealth-building and economic justice, would be a likely sponsor for the University's Solar Commons. The Bush Foundation, promoting equitable and sustainable communities in Minnesota, and the Otto Bremer Trust, supporting economic

[1] Solar Commons uses a Creative Commons License that lays out the guiding principles for using Solar Commons legal and peer governance tools. During its research and development stage, Solar Commons researchers at the University of Minnesota are co-creating the tools and standards with community partners with the goal of releasing a well-tested, open-source toolkit that will enable Solar Commons to iterate across the United States.

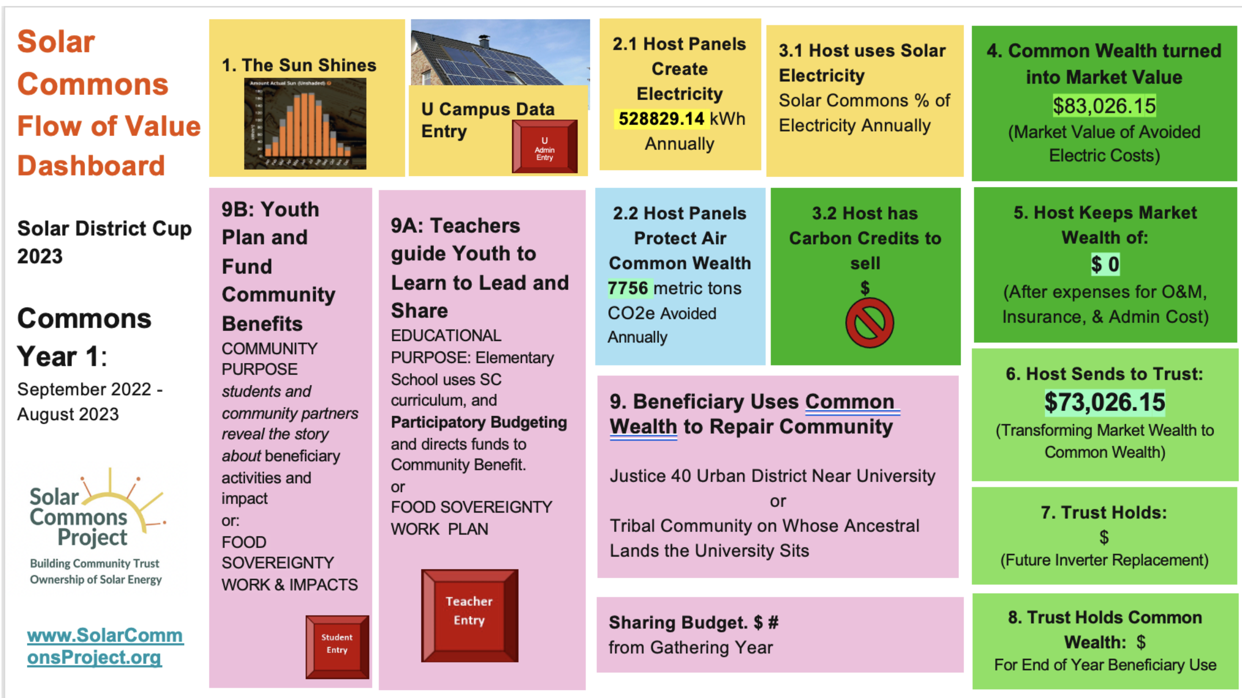
opportunity and self-sufficiency, are also potential donors that align with Solar Commons' goals. These foundations have histories of supporting social and environmental justice initiatives and may be strong partners for the University's campus SC project. Also, because the University Solar Commons would direct benefits to underserved communities, this project meets funding criteria from federal agencies (EPA and DoE) who are administering the US Inflation Reduction Act (for energy transition infrastructure) using Justice 40 Census Tract data(Justice). (Of course, Solar Commons arrays, like any arrays, can also be financed and pay for themselves from electric bill solar savings.)

Social Rules for University Solar Commons. The diagram below illustrates our proposal for a campus-wide Solar Commons initiative at the University of Minnesota.

As the University complies with Minnesota's Sustainable Buildings 2030 energy standard requiring government buildings to generate at least 3% of their electric load with rooftop solar by 2030(Minnesota Building), university administrators can seize this opportunity to design campus solar systems that include 500kW Solar Commons carve outs on each campus. In our design, each campus would have a Solar Commons Trust Agreement (SCTA) with their local underserved community partners acting as the trust beneficiaries. Like standard Power Purchase Agreements (PPA) that are well known in the solar industry, a SCTA is a long-term agreement (25 years). The SCTA sets legal terms for how to calculate the host's solar savings (set, with no accelerator, at the rate of electricity on the day the agreement is signed) in order to maximize economic benefits to the trust and incentivize the host's participation. SCTA's are five years shorter than PPAs in order to leave funds for the host to pay for equipment and decommissioning costs.

We propose two ways for University of Minnesota campuses to share the financial benefits of solar energy. First, support food sovereignty work by Indigenous groups on whose ancestral lands the campus sits. Second, support the community wealth-building efforts of a neighboring underserved community by having their local elementary school use a School Participatory Budgeting process to disburse Solar Commons Trust funds (PB in Schools,2022).[2] The diagram outlines the parties and the general terms of a twenty-five-year Solar Commons Trust Agreement.[3]

Peer-Governance of the University Solar Commons: The Dashboard Tool. Our final diagram is of the Solar Commons dashboard.



This real time digital tool is currently being prototyped for SC1.0, the Tucson Solar Commons. We have redesigned it here to demonstrate flows of wealth **for one year of the 500kW campus Solar Commons**. All parties to the Solar Commons Trust Agreement use this dashboard to peer-govern their funds. The University of Minnesota (solar host) would use it to calculate how much solar savings on their electric bill will be passed on to the trust. Once the host enters specific requested data from their monthly electric bill (see the red U Admin Entry button), the dashboard updates to show how much solar energy was generated by the Solar Commons arrays that month (2.1) and how much C02 the University avoided putting into the air (2.2). The dashboard shows how much solar savings the University would see on its electric bill (4) and how much it passes on to the Solar Commons trust after subtracting standard O&M costs (6). Box #5 shows how much savings the University host keeps for itself.[4] The dashboard shows how much the SC

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[2] Participatory budgeting is a well-tested, democracy-enhancing social process. It fits well with Solar Commons aims of being a "bottom-up" community economy tool supporting civic engagement and social-ecological responsibility. The Solar Commons Project is currently creating a Solar Commons curriculum with School Participatory Budgeting experts in Tucson, AZ, the site of the first Solar Commons (SC1.0).

[3] Note that the beneficiaries in our diagram are for the University of Minnesota Duluth campus. Our campus is on ancestral lands of the Ojibwe tribes. The Twin Cities campus is on the ancestral lands of the Dakota who have many important food sovereignty initiatives that the University could support.

[4] The Solar Commons Trust Agreement (SCTA) takes the current utility price of electricity (~$.15/kWh) and keeps the same rate for the duration of the agreement. As noted above, unlike a Power Purchase Agreement (PPA), SCTA does NOT use an accelerator. This means that as the utility's electric rates increase each year, the SCTA will allow the University host to keep more and more of its solar savings. The dashboard shows this value in box #5. In year

trust sets aside for equipment repairs such as inverter replacement in year ten (7) and how much common wealth remains for the beneficiary to use (8). Finally, the pink area is where beneficiaries record what common good they create for their community with the trust funds.

The SC online dashboard brings a Solar Commons Trust Agreement to life. It becomes part of what anthropologists call the "lifeworld" of all participants. For this reason, we recommend that University Administrators display a live version of the SC dashboard at the student center or library on campus. Passers-by could then experience how solar energy can be related to reparative justice, how earth values and technical realities are related to market values and common wealth economics. Beneficiaries will showcase the value gained from the trust funds in their own ways. Indigenous food sovereignty workers may frame value in traditional terms relevant to their communities. School kids may use the dashboard to show the educational merit of solar commoning. They will record how their choices in participatory budgeting came to be, and what the results of those choices look like. Overall, the dashboard serves as a bridge between the technical complexities of solar energy, the abstractions of numerically defined wealth and the practical benefits experienced by the community.

Concluding Note on the Community Benefit of Solar Commons Solar technology has enormous potential to be shaped by social systems tuned to economic democracy. As the Solar Commons model demonstrates, when we create a way to share the economic benefits of solar technology, community partners themselves will demonstrate all sorts of new, meaningful benefits of solar. Solar technology can make decades-long contributions to reparative justice projects on Indigenous lands; it can provide benefits to economically devastated areas within our societies; and it can create a community space that contains recreational and educational possibilities to unite our communities. We are excited to note that in Fall of 2022, University of Minnesota undergraduate students on the Twin Cities campus passed a “Resolution on Rooftop Solar” for the campus. They called on UM administrators to increase the amount of rooftop solar on campus and “to adopt a Solar Commons model whenever possible”(O’Connell, 2022).

In this design proposal, we offer a vision of what a campus Solar Commons might look like for all five campuses. Engineering students have designed the technical systems and demonstrated the economic values. Anthropology students have shown how Solar Commons tools can further shape those technical and economic values to create new kinds of solar benefits such as community wealth-building and reparative justice. Solar Commons projects do more than simply generate green energy or create and direct wealth within a community; they provide an opportunity to unite communities around the common resource of the sun. Communities connected through Solar Commons can grow, heal, and strive for a future that thrives on renewable energy and favors justice and equality.

one, this value is of course zero. But after five years of electricity rates increasing by the standard 3%, the University will start to see how much of the solar savings it is keeping. Solar Commons financial model thus incentivizes and rewards hosts for their Solar Commoning.

1.4 Conclusion

To recap, the team developed this model utilizing an in depth analysis of the solar potential of all building candidates on UMN campus. Furthermore, the team utilized Aurora® modeling software to analyze the production capabilities of each building. Using this data, buildings were selected to house PV panels using a building selection matrix that assessed each building on its production capabilities, roof space, sunlight exposure, and roof age. During these analyses, it was determined that the best course of action was to supply energy to 8 separate buildings utilizing the roof space of 17 buildings. This method was seen as beneficial to maximize the percentage of solar energy used compared to classical grid energy and to gain more control over peak shaving and financial savings. The result is a system that generates over 19% of the 20 eligible buildings electrical loads from purely solar energy. The system generates 3.8 MWh of clean energy for the UMN East Bank Campus.

The system was modeled for both a PPA agreement and a direct ownership/development by the U of MN using NREL's Excel Financial model. The final design has an entire system size of 3.8 MW and a project IRR of 9.7% The cost of the system is $5.5M which will be paid back in 9.6 years. The assumed system lifetime is 30 years for all components. The parent system was divided into 8 optimal subsystems to target the electrical loads of 8 campus buildings. Each of these subsystems performs very well with IRRs of greater than 8.5% and payback periods of less than 12 years. 500 kW of subsystem 4 was taken as a portion dedicated to the upstanding of a solar commons trust, owned by and benefitting an underserved indigenous community. The total capital provided to the community over 25 years will be $1,474,776.

In summary, the University of Minnesota, Twin Cities/Duluth 'bring your own district' case design for the U of MN, East Bank campus is an innovative and effective system design that embodies maximum system performance, effective project financing, and financial utility bill mitigation while bringing clean energy generation directly to campus. The design and financial structure bring an extremely high performing 3.8MW system with a payback period of 9.6 years and IRR of 9.7%. The project additionally serves a greater purpose of building consistent community income for an underserved indigenous Minnesotan community on whose land the University of MN sits. Over 25 years, the 500 kW Solar Commons portion will generate a total of $1,474,776 in usable income.

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