Darlington Community School District
Net Zero Energy School Feasibility Study

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Darlington Community School District (DCSD)
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The information presented here provides a feasibility study level estimates of solar PV and battery systems siting, sizing, generation, site electricity use offset, pricing and project economics. It should not be used as the only source of information in evaluating the feasibility of solar PV and battery systems for other schools and in other locations.

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Executive Summary

Main Findings

The central question of this feasibility study is whether it is financially feasible for the Darlington Community School District (DCSD or District), using solar photovoltaic (PV) systems and battery energy storage systems (BESS), to implement zero energy at the High School (HS) and/or the elementary and middle school (EMS) today or within the next few years. This question is of interest to the DCSD specifically but is of broad interest to other public and private schools in Wisconsin and beyond. The interest is being driven by the continued decline of PV system and BESS costs, the growing need to respond to climate change, and the interest in educating students in energy systems, climate change, and renewable energy systems.

Siting renewable energy systems at educational institutions also provides educational opportunities in STEM and other disciplines, thereby preparing students for the burgeoning job market in renewable energy. Adding renewable energy systems at schools must also reduce their operating costs (i.e., electricity costs), which in Wisconsin are capped by state law. Operating costs savings can be used in other needed areas such as teacher salaries.

A net zero energy commercial building, of which schools are one type, is a building that generates as much renewable energy on-site as the building requires over the course of the year. The building is connected to the utility electrical grid. At times it will export power while at other times it will import power. With a BESS it will also store power. Thus, it is a zero energy building on a net basis over a typical year. It can even be a net producer of energy or a net positive building. An inherent attribute of a net zero energy (net zero energy and zero energy are interchangeable terms in this report) building is that it is net zero carbon. To be truly net zero carbon requires that the building use no natural gas (or propane or fossil fuel fired electric power) for space or water heating. To provide heating needs, a zero energy building is very likely to adopt a ground-sourced heat pump (a.k.a. geothermal) or air-source heat pump system operating on renewable electric power. A zero net electricity building is defined here as a building meeting all of its annual electricity needs with renewable energy systems, but it may still use fossil fuels for heating.

The study's results, summarized in Tables 1 and 2, show the HS's net present value (NPV) for net zero energy for electricity only and for net zero for all energy use. The Tables show results for direct purchase by the District and with third party participant investors (TPP), with BESS and without BESS, and accounting for the District's pre-existing PV system and without the pre-existing PV system (which represents most existing schools).

When accounting for the pre-existing solar, the Darlington HS can directly purchase a solar PV system with and without BESS and the investment has a positive NPV for net zero electricity. Investing in the BESS results in a greater NPV. If the HS's pre-existing solar is ignored, only direct purchase with the BESS yields a positive NPV for net zero electricity. For net zero energy overall, none of the options provides a positive NPV.

For reasons described in this report, TPP does not yield a positive NPV in any cases, although TPP with BESS for net zero electricity when existing solar PV is recognized is only slightly negative.

These results are remarkable as some professionals in the solar and school building and operations field would not have anticipated that a positive NPV is currently attainable. The results suggest how far PV and BESS have come in being able to compete with the utility grid.

This finding comes with an important caveat. The caveat is that the cost analysis does not include the heating, ventilation and air conditioning (HVAC) retrofit costs in the situation where there is an existing school with a natural gas-fired HVAC system. This is the situation for the DCSD schools. In an existing school that uses natural gas for heating, a retrofit to a heat pump-based HVAC system is required if natural gas is to be displaced by renewable electricity. For a new school being designed with heat pumps, as is the case with a significant number of new schools in Wisconsin, including a zero energy elementary school currently under construction. A new zero energy school using direct purchase is at the threshold of being NPV positive. However, at the Darlington location, given the estimated energy use with geothermal and the utility rates, the NPV is a negative $80,463.

In the case of the Darlington HS, some HVAC updates were completed in 2018. Roof top units were installed, which provide air conditioning for much of the school. The existing boilers are half way through their anticipated life span. The EMS was built in 1996 and is being reviewed for HVAC updates. A building addition is under early consideration for one of the District's schools to accommodate growing enrollment.

The follow-on HVAC questions are:

- What is the cost of the HVAC retrofit if natural gas is kept as the fuel source for heating and air conditioning is added?
- What is the added cost if a geothermal or air sourced heat pump system is installed for the new addition and retrofitted at the EMS or HS?

The analysis baseline, used for comparison, is for the District to continuing purchasing power from the serving utility, Alliant Energy. The findings are based on conditions in 2019. The analysis focuses on the Darlington HS for reasons described in this report.

While the immediate focus of the feasibility study is the DCSD, the study has immediate implications for other schools in Wisconsin and in other states. The solar PV system costs used in the study are based on recent competitively bid pricing by solar PV system installers in Wisconsin. These costs are applicable with only slight variation across Wisconsin. What does vary from school to school includes:

- The serving utility and their respective electric rates and interpretation of rules with respect to third party investment and grid interconnection
- The electricity consumption profile of a school, especially the peak 15-minute demand levels and the building's summer electricity use
- The availability of suitable land for ground mounted solar PV systems for some or potentially all the solar array
- The age of and the suitability of the roof for siting PV
- The ability of a school district or private school to self-fund solar PV systems and the funding opportunities that support the project

Despite the variability in these five items, many schools in Wisconsin will have a reasonable probability of achieving a positive NPV in choosing to go to zero electricity and some could achieve net zero energy. This is a remarkable finding.

Methodology and Summary Numerical Results

The core modeling tool used for this feasibility study is the System Advisor Model (SAM) model. SAM was developed and is actively updated and supported by the National Renewable Energy Laboratory (NREL). It's a highly detailed representation of a solar PV and battery system applied to a specific building with an electric load profile at 15-minute intervals. The SAM was used to optimize the NPV (net present value), over a PV and battery system's first 25-years, for the building owner. The optimization accounts for ownership including direct purchase by the owner as well as ownership by third-party participant investors (TPP). It accounts for incentives, Internal Revenue Service (IRS) rules, and profits earned by the TPPs.

SAM was used to model the following conditions for the Darlington High School[1]:

- Zero electricity for the existing electricity load only
- Zero energy with conversion to geothermal
- With and without the pre-existing PV system
- Direct purchase by DCSD
- Use of TPP investors
- With and without a battery energy storage system (BESS)
- Without the announced 2020 Focus on Energy Incentives for TPP investors
- Battery operation assuming grid support revenue

The DCSD's NPVs for the mix of cases considered are summarized in Tables 1 and 2.

Table 1. DCSD's Economics for a Net Zero Electricity School (based on the Darlington High School). Assumes that the HVAC system is not converted to an air or ground-sourced heat pump.

High School with pre-existing 78 kilowatt (kW) direct current (dc) of PV	School District's NPV	Net Capital Cost
Direct Purchase Without BESS	$12,451	$389,732
Direct Purchase With BESS	$87,899	$564,287
TPP Without BESS	($27,355)	$473,897
TPP With BESS	($50,016)	$638,832
High School without pre-existing PV		
Direct Purchase Without BESS	($66,739)	$506,263
Direct Purchase With BESS	$22,651	$680,818
TPP Without BESS	($99,089)	$598,141
TPP With BESS	($115,176)	$763,076

Table 2. DCSD's Economics for a Net Zero Energy School (based on the Darlington High School). Does not include the cost of converting the HVAC system to an air or ground-sourced heat pump.

[1] The energy use at the HS is quite similar to energy use at the EMS.

High School with pre-existing 78 kW-dc PV	School District's NPV	Net Capital Cost
Direct Purchase Without BESS	($98,498)	$750,784
Direct Purchase With BESS	($15,933)	$1,080,442
TPP Without BESS	($134,229)	$868,132
TPP With BESS	($193,228)	$1,233,529
High School without pre-existing PV		
Direct Purchase Without BESS	($170,529)	$866,382
Direct Purchase With BESS	($80,463)	$1,197,991
TPP Without BESS	($208,953)	$993,462
TPP With BESS	($261,614)	$1,359,002

Discussion

The main conclusions are:
Project NPVs increase when:

- Capital cost is reduced because some of the PV is already purchased. This reflects the fact that 78 kilowatts (kW) direct current (dc) of solar PV is in place at the Darlington HS
- The project includes a BESS
- The project is directly purchased by the District
- The project's goal is limited to zero electricity rather than meeting all energy needs

The summary explanations for these conclusions are:

- Capital costs are reduced if some of the PV systems has already been purchased
- The BESS provides reduced demand charges, additional income from electrical grid support services and significantly reduces the amount of solar power delivered to the grid at avoided cost.
- When the District directly purchases the solar PV and BESS rather than use TPP, it can access Wisconsin Focus on Energy incentives and can more fully use the battery for arbitrage (that is buying utility power at night at low cost for limiting future peak demands and on-peak power costs the following day).
- Going to the larger PV and BESS to meet all energy needs results in a higher distribution grid interconnection cost due to having to purchase a limiter, that limits the export of power to the grid at 400 kW alternating current (ac). This is a situation particular to DCSD because it is served by a small distribution circuit. It

is for this reason that the EMS could not be simultaneously considered in this study.

Major Uncertainties and Key Assumptions

There are dozens of specific assumptions included in this study. These include electricity price escalation rates, discount rate, PV system cost, BESS cost, operation and maintenance (O&M) cost, battery life, etc. Of these assumptions, a few stand out as the most uncertain and critical to the study and its findings.

1. The revenue from grid support services provided by BESS. The Midcontinent Independent System Operator (MISO) rules for BESS grid support services were initially to be issued in December 2019 but have been delayed until December 2020. Lacking this guidance and how the FERC 841 rules will be implemented by MISO, this study used estimates provided by a battery installer working in the Commonwealth Edison service territory (i.e., Chicago, Il area), which operates within the Pennsylvania, New Jersey, Maryland Independent System Operator (PJM ISO). The sources of uncertainty include:
   a. Reliability of estimates
   b. Stability of estimates over time noting that the spot market for BESS grid support services will be dynamic
   c. Likelihood that Alliant/MISO payments will be similar to the PJM ISO payments
2. The cost of the BESS. The BESS price used in the study is based on recently priced battery systems in Wisconsin and a recent quote from a Wisconsin BESS provider. The literature suggests that battery prices are falling. Thus, the cost assumption used in this study could be higher than warranted for future installations.
3. The Alliant tariff schedule over the next 25 years. This is difficult to estimate, especially as utilities respond to large changes in the electricity market place including: increased generation from renewable resources, increased use of electric vehicles and electric heating, the adoption of electricity storage systems and climate change. Both the pricing and structure of electric rates may change dramatically.

Limitations Specific to DCSD

1. Grid Interconnection Costs. The DCSD is in a smaller town in rural SW Wisconsin. One of the limitations that this imposes on the study is the maximum amount of kW-ac that an on-site solar PV system can export to the distribution grid. Under Alliant Energy's use and interpretation of the standards regarding the amount of power that the DCSD can export onto the local distribution grid, the limit is 400 kW-ac. At DCSD, the limiter would not allow the PV system(s) on that distribution grid circuit to export more than 400 kW-ac. The implication of this limitation is that only one of the two DCSD schools can have solar with a positive NPV. Based on this, the study focuses on the HS.

2. Modeling only the High School (HS). The EMS has only modestly higher energy use, so the results from the HS are quite representative of what would be found for the EMS. The EMS is currently being evaluated for remodeling work. While the HS recently completed a remodeling phase. Thus, the HS has the most recent energy efficiency updates and its current energy use is most representative of an energy efficient Wisconsin school.

3. Existing HS HVAC System. If this were a new school being built with a heat pump HVAC system and a more efficient shell, the net zero energy case would be more attractive and is likely to have a positive NPV. Recall that a limiter is required at the Darlington HS. With the HS's existing HVAC system and shell, it may be that the incremental cost of geothermal system is a barrier to full zero energy. This will need to be studied within the context of other building plans and additions. If full net zero on all energy is determined not to be feasible, a financially stronger alternative is to pursue zero energy on the electrical side only, as summarized in Table 1.

4. Land Limitations for Array Siting. Open land adjacent to the DCSD schools is such that the PV array locations are 60% roof mounted and 40% ground mounted using a 70° tilt angle[2] for the ground arrays to optimize winter generation. For northern latitudes with snow cover and high winter electricity use (especially if geothermal systems are used for large space heating loads), higher percentages of ground-mounted steeply tilting PV arrays may yield higher NPV's.

[2] Ground-mounted PV racking systems offering this steep tilt angle are uncommon. A ground array using bifacial PV modules but a reduced tilt angle, could also be considered as a method of increasing winter generation.

1. Introduction

Overview of the Darlington Schools

The Darlington Community School District (DCSD or District) is a K-12 public school system located in Southwest Wisconsin. As of the fall of 2019, the District had 866 students enrolled in grades K through 12. The District has two schools along with athletic facilities located on the west edge of the city. The high school building dates back to the 1965 while the elementary and middle school was built in 1996.

The average income of a Darlington household was $47,287 in 2016, which is below the state average of $50,392. Darlington and Lafayette County are both rural. Southwest Wisconsin has one of the highest rates of farm foreclosures in the country.

The District has been proactive in maintaining its facilities, improving energy efficiency, and in adding solar energy. In 2016 and 2017, it added what was the largest on-site solar PV system for a school in Wisconsin. It financed the co-owned solar PV system in collaboration with third party investors in order to avoid the burden of upfront costs and to leverage tax incentives not available to non-profits such as a school district.

The development of 300 MW Badger Hollow solar farm located about 30 miles North of Darlington and the Quilt Block wind farm which can be seen from Darlington have added further impetus to the consideration of renewable energy.

Complementing the District's work in renewable energy, it has improved its energy efficiency over the past three years including replacing most of its lighting with LED fixtures and lamps and making improvements in some of its HVAC systems. With these improvements as a baseline, the District is now considering how to accommodate a growing enrollment and further reduce operating costs. Thus, it is considering a net zero energy approach at one or both of its schools for electricity and for all energy needs. The District is considering this as a responsible financial approach as well as platform for STEM and other education, especially as it sees quality jobs emerging in the area in renewable energy.

Although Darlington is in a rural area, the District has limitations in the amount of land it can dedicate to on-site solar. Thus, a feature of the study is to demonstrate that large empty school roofs can be used in combination with some ground based PV for generating solar power sufficient to meet all the needs of a school. If demonstrated to be financially advantageous for the District, the integration of on-site solar PV system and battery electricity storage system (BESS) can help the State of Wisconsin take a balanced approached to developing its solar PV generating and BESS resource with both customer-sited and utility-scale solar PV projects.

Solar Project in 2014-2016

This proposed effort is the natural next step after the DCSD added 156 kW-dc (77.775 kW-dc and 68.1 kW-ac at each school) of PV at its Elementary and Middle School (EMS), and High School (HS) in 2016. This was done through the District's Solar Education Project, described below. The solar project was implemented using third-party investors and reduces electricity costs for DSCD.

The Darlington Solar Education Project was established in late 2014 to explore renewable energy possibilities for the District. It was initiated by a group of students, community leaders, school board members, and staff that served as a think tank for creating a 21st century learning environment.

DCSD contracted with Hoffman Planning, Design & Construction, Inc. and its collaborating partner Madison Solar Consulting to assist them in attaining these objectives. The district won a Focus on Energy Grant for $63,000. The school board teamed with a group of "green-minded" community investors to support the project. The investors, who are now co-owners of the project, also helped secure a USDA grant for $61,000 that assisted with project funding.

After much thought, the District decided to pursue a solar PV system installation that ensures the responsible utilization of ecological, economic, and social resources. SunVest Solar, one of Wisconsin's most experienced solar energy installation companies, based in Pewaukee, won the competitive bidding for the final solar design and installation. The installation was completed in December 2015. SunVest partnered with Current Electric. Current Electric was the installation contractor and electrician.

The 156 kW-dc solar photovoltaic (PV) systems, both sited on the roof of the EMS, are generating almost 175,000 kWh per year, or about 20% of the District's needs. The systems are saving the District about $12,500 in usage (kWh) charges and roughly $3,250 in demand (kW) charges, or about 20% of their current electricity costs.

The third-party financed co-owned solar project provides a positive cash flow for the District. The financing structure provides the option for the District to buy-out the entire system, which the District plans to do.

Pending the results of this feasibility study, battery and PV system pricing and Wisconsin policy, the District is interested in considering options for going zero net electricity or zero net energy. One approach is to fund a solar PV system and BESS through a referendum possibly combined with other projects that may be required to address recent growth in enrollment. Self-funding the solar and BESS project (and not having to meet IRS requirements for the investment tax credit) would allow DCSD to use the BESS in a manner that would maximize the revenue to the District, including the use of arbitrage. Arbitrage includes buying inexpensive energy at off peak times for use during peak hours. The alternative to self-funding is to work with third party participant investors (TPP).

Many of the District's teachers are using solar system information and data within their ongoing curricula. Dr. Hanson and Mr. Wolter created a presentation about the existing PV systems for the District's students and community. That presentation and other information about the District's solar PV system can be found on the District's website.[3] That webpage includes a link to the live monitoring system. There are also public flat-screen kiosks in each building for students, staff, and community members to monitor the PV system's real-time energy production.

Feasibility Study Goals

DCSD would like to investigate the feasibility of becoming one of the state's first net zero energy schools. A net zero energy, also referred to as zero energy, building generates as much renewable carbon-free energy over the course of the year as it requires for operation. The financially optimal path to achieving zero net energy is a combination of high efficiency, to reduce energy requirements, and on-site renewable energy generation, in this case solar PV generation, to meet those energy requirements on an annual basis. A zero net energy school will generate excess energy at times and require energy beyond that being generated at times.

[3] Accessed on November 15, 2019; link: https://www.darlington.k12.wi.us/district/solarproject.cfm.

A zero net electricity building only meets its electric power needs with onsite renewable generation over a year but does not cover other energy needs (e.g., natural gas, primarily for space and water heating).

Since this project was initiated, the Oregon (Wisconsin) School District committed to building a net zero energy elementary school.[4] The project is expected to open in the summer of 2020. The school will include solar PV, a battery storage system and a ground-sourced heat pump for heating and cooling.

The Darlington Project Team considered both of the District's schools and the feasibility of both net zero energy, which would include converting the current natural gas space and water heating system to electricity, and net zero for electricity use only.

A central question in this feasibility study was to determine how much of the excess energy generated should be stored on site using a battery energy storage system (BESS). If no energy storage is provided, all excess solar generation would be exported to the grid and any energy needs beyond that available from the solar at any moment in time would be purchased from the grid. An on-site BESS enables power to be stored for later use and, if financially advantageous, for providing services to the Alliant and MISO grid.

The proposed DCSD feasibility study is particularly innovative as follows:

1. It is the first known financial analysis of net zero electricity and net zero energy for a Wisconsin school.
2. If implemented, it would be one of the first schools to attain a zero energy (i.e. net-zero) status in Wisconsin.
3. Given the Public Service Commission of Wisconsin's and utility's restrictions on net metering, it utilizes a BESS to improve the project's financial performance.
4. It evaluates the potential for utilizing an innovative TPP funding strategy so the District can avoid the project's up-front cost.
5. The study identifies both the technical and financial strategies, given current technologies, pricing and polices, that enables the project to be NPV positive for the District.

[4] Accessed on December 2, 2019; link: https://www.wortfm.org/oregon-school-district-to-build-a-net-zero-elementary-school/.

Study Team

The District's previous Administrator, Dr. Denise Wellnitz, the District's Head of Maintenance, Mr. Lee Black, Dr. Mark Hanson, and Mr. Niels Wolter worked together to successfully implement the solar PV projects on the District's schools. This study brings the same team together with the addition of Henry Hundt. During the summer of 2019, following the retirement of Dr. Wellnitz, Mr. Cale Jackson became the new District Administrator and a member of the project team.

Mark Hanson and Niels Wolter are at the forefront of solar planning and implementation in Wisconsin. They provided solar planning services for multiple sites in Wisconsin including 330 kW of solar implemented at the Northland Pines School District in 2017.

Mark Hanson, Director of Sustainable Services at Hoffman, and Niels Wolter, Principal at Madison Solar Consulting, led the energy efficiency and solar PV efforts at the District since 2014. They have in-depth understanding of the energy situation at the two schools from their studies and implementation activities over the past four years.

Mark Hanson is the former executive director of the Energy Center of Wisconsin (now Slipstream). Currently he leads the green building practice at Hoffman Planning Design and Construction. Mark recently published a book, titled "The Inevitable Solar School: Building the Sustainable Schools of the Future, Today" (Rowman & Littlefield, 2019).

Denise Wellnitz and Lee Black are champions for solar energy and energy efficiency in the DCSD and in the state in general. Denise Wellnitz and Mark Hanson have made presentations on the Darlington solar implementation at state level professional events, including the presentation to WASBO (Wisconsin Association of School Board Officials) in May of 2017.

Mr. Cale Jackson is a former math instructor and has spent the last 14-years as a school administrator (assistant principal, superintendent and district administrator). Mr. Jackson is focused on the potential of solar PV and BESS for cost savings for the District and new curriculum opportunities.

Niels Wolter is an active consultant in the solar PV and energy efficiency areas since 1991 working both in the Wisconsin and internationally. As his clients' solar project analyst and "solar agent" Niels has helped dozens of cities, counties, school districts, religious orders, not-for-profits and commercial businesses install larger PV systems (50 kW to 2.6 MW). For almost ten years, he managed the State of Wisconsin's Focus on Energy PV program. For the US DOE's Million Solar program he authored a study on Net Zero Energy Homes for the Northern Tier States – where PV systems where combined with highly efficient homes and ground-sourced heat pumps. Niels is a long-term board member of RENEW Wisconsin, where he heads the policy committee, and formerly of the Midwest Renewable Energy Association. He was also a founder and board member of the Wisconsin Distributed Resources Collaborative.

Henry Hundt the primary modeler in this study effort, including serving as interface with the SAM modeling staff at NREL. He has experience in energy efficiency, energy analysis, renewable energy and sustainable building in Alaska while at Renewable Energy Alaska Project (REAP) and more recently at Hoffman as a member of the sustainable services team. While at Hoffman, Henry has worked on a wide variety of projects relating to building energy and economic performance, modeling, carbon sequestration and land use.

2. Energy Use and Cost in the Darlington Schools

Changes since 2013

In 2014, Hoffman Planning, Design & Construction, Inc. completed a building assessment for the DCSD, which includes a review of their energy systems and developed a list of recommended energy efficiency measures.[5] The District also has a three-year infrastructure plan that includes building energy efficiency improvements.[6] The DCSD competitively solicited professional services for remodeling, energy efficiency, and renewable energy in 2014 and contracted with Hoffman Planning Design & Construction, Inc. Hoffman contracted with Niels Wolter of Madison Solar Consulting to augment its service capabilities in solar planning.

Since 2014, Hoffman and Madison Solar Consulting have been undertaking studies, design, and construction of energy efficiency and renewable energy at the Darlington Elementary and Middle School (EMS) and the adjacent High School (HS).

This work includes:

- Ongoing energy efficiency upgrades, some of which have been implemented under an energy performance contract
- A 156 kW-dc solar PV installation was completed at the end of 2015 using TPP financing. The third party financing was critical at that time for the solar implementation, as it required no District funds to buy the system.

In the case of the 2015 solar project, the District was very limited for funds, and the school board believed that a referendum would not pass. Furthermore, the financial return to the District, under the rules at that time, was greater using TPP financing because the third party investors could take advantage of Federal Investment Tax Credits (ITC) and accelerated depreciation. The 156 kW-dc solar system was the largest public school solar installation in Wisconsin at the time of installation. Thus, it served as a pioneering example of solar in schools in Wisconsin.

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[5] Accessed on December 1, 2019; link: https://www.darlington.k12.wi.us/district/Facilities%20Assessment.pdf

[6] Accessed on December 1, 2019; link: https://www.darlington.k12.wi.us/district/DarlingtonCommunitySchoolDistrict3YearInfrastructurePlan.pdf.

The result of the efficiency and renewable energy improvements at the Darlington Schools since 2013 is evident in their performance data. Annual electricity purchases from Alliant at the High School declined from 559,000 kWh in 2014 to 306,000 kWh in 2018 declining by 45%. Natural gas purchases declined from over 52,000 therms to 40,000 therms declining by 23%.

A similar result is found at the EMS where annual electricity purchases dropped from 705,000 kWh in 2014 to 418,000 kWh in 2018 declining by 40%. Natural gas consumption fell from 42,000 therms to 30,000 therms declining by 29%.

Current Status

This feasibility study focuses on the HS for two reasons. First, due to the modest loads on the Alliant Energy Distribution Grid, as will be described later in this report, it was found that both schools could not be converted to net zero energy on a financially beneficial basis. Based on Alliant Energy's interpretation of IEEE standards and Alliant Energy's analysis, the Alliant distribution grid serving the DCSD cannot accept more than 400 kW-ac of distributed generation. Thus, any interconnected distributed generation requires a "limiter" to limit power delivered to the distribution grid to 400 kW-ac. The cost of the limiter, and any other distribution grid upgrades, is paid by the customer (in this case DCSD).

The second reason for focusing on the HS is that its future energy use level is better known. Thus, estimates of financial performance of solar PV and BESS can be estimated most accurately especially in the case of meeting all current electricity use. The EMS has modestly higher energy use. HVAC upgrades and other remodeling is under consideration at the EMS, thus its future energy use is less certain.

While many efficiency improvements were recently made at the HS. There is some prospect for further modification to the HS's HVAC system, which has conventional boilers that are half way through their lifespan. The conversion to a partial ground or air-sourced heat pump HVAC, in place of the boilers, and adding additional air conditioning could be considered, especially if a building addition is added. The Recently air conditioning was added to the HS, except for gym, locker rooms, shops and weight room, using rooftop units (RTUs). The new RTUs are natural gas-fire and temper the outside air fed to the fan coil units serving individual rooms. To meet the zero net energy requirement, this relatively small use of natural gas could be compensated for by the modest export of solar power. Both the ground or air-sourced heat pump conversion and the building addition could also be considered for the EMS.

As the HS and EMS are of similar size and have similar energy use levels, the results of this study for the HS are mostly transferable to the EMS. This is certainly true when pursuing net zero electricity.

In 2018 the HS used 395,000 kWh, of that 85,165 kWh was provided by the existing 77.8 kW-dc and 68.1 kW-ac PV system. The existing PV system uses:

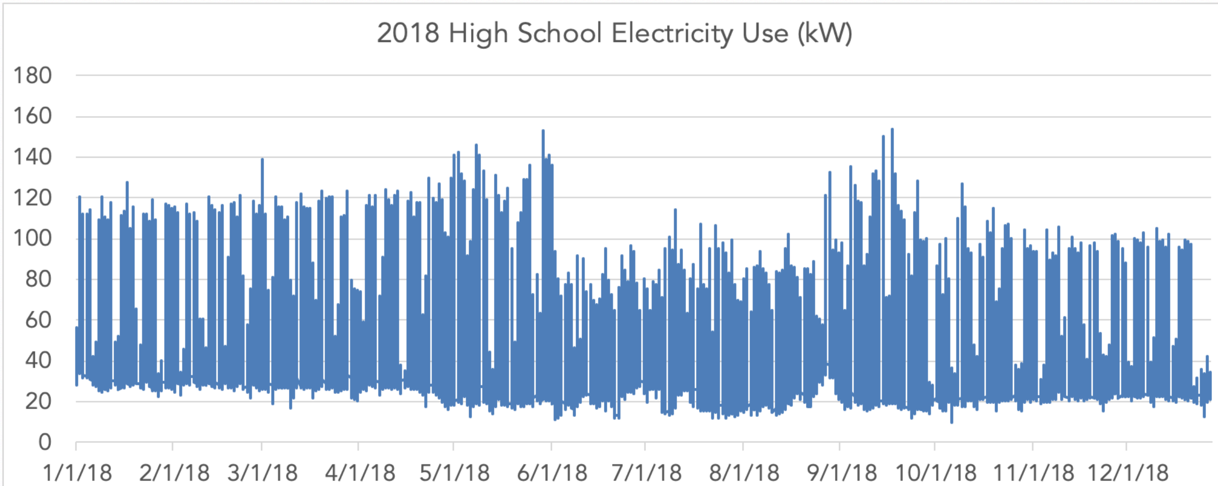
- 255 Canadian Solar 305-watt modules
- 3 Fronius SYMO 22.7 inverters
- UniRac racking

The HS PV array is oriented due south tilting between ~5° and ~15° from the horizontal (on average a 10° tilt). The low array tilt allows the array to be roof sited, as a higher tilt angle adds wind and snow drift loads. The low tilt angle is better for summer power generation than winter generation because the sun is higher in the summer (and shining more directly on the modules) and snow more easily covers and remains on low tilt angle PV arrays.

As shown in Figure 1, the HS has:

- Reduced power use during weekends and the summer (when school is not in session).
- Night-time demand of about 20 kW
- Weekend demand of about 50 kW
- School-day demand of about 100 kW
- Annual peak demands of almost 160 kW
- Peak demands occur just before classes end for the summer and after classes start again
    - Typically, the HS sets it annual peak demand charge during September due to air conditioning in the school's limited conditioned areas.
- Additional energy efficiency improvements were made during the summer of 2018. By comparing spring power use against fall power use, in Figure 1, the efficiency gains are easily noted.
    - High periods of electricity use decreased from about 120 kW in the spring to 100 kW in the fall.
    - While low periods of electricity use decreased from about 30 kW in the spring to 20 kW in the fall.

Figure 1. High School Power Use - January to December 2018.



Adding Electric Space and Water Heating

For the HS to be zero net energy, electric space and water heating need to replace the existing natural gas space and water heating systems. As noted above, the most likely option is an air or ground-sourced heat pump system (ground sourced heat pumps are also known as geothermal systems).

Converting the HVAC system to ground or air-sourced heat pumps would significantly increase the school's heating season electricity use with peak loads occurring in the winter.

Sample High School Load Shapes

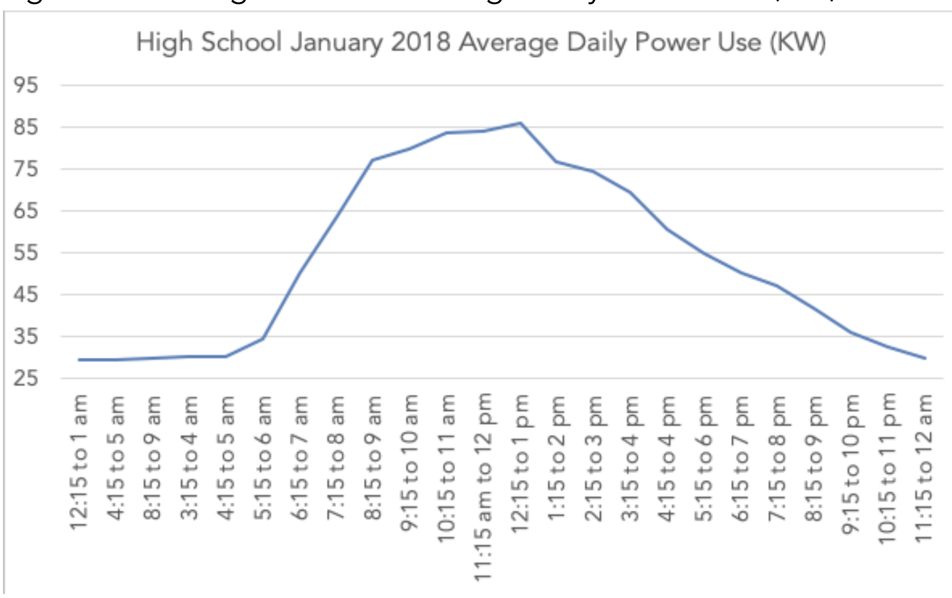
The four graphs below, Figures 2 to 5, show the HS's power use during the winter, spring, summer and fall. First, note again that summer power use (peaking at about 60 kW) is the lower than the rest of the year (while school is in session peak power use is between 100 and 120 kW). Fall, winter and spring solar generation is important to meeting the zero-energy goal in a cost-effective manner. Given Wisconsin's low winter solar resource, increasing winter solar generation is particularly important.

Also, note that power demand ramps up quickly in the morning, starting between 5 am and 6 am. Peak demands occur between 9 am and 3 pm and then drops off gradually. This suggests that early morning solar generation is more important than late afternoon generation. It also suggests that there is a need for energy at pre-solar (I.e., pre-dawn) hours during much of the school year.

Winter Power Use Darlington High School

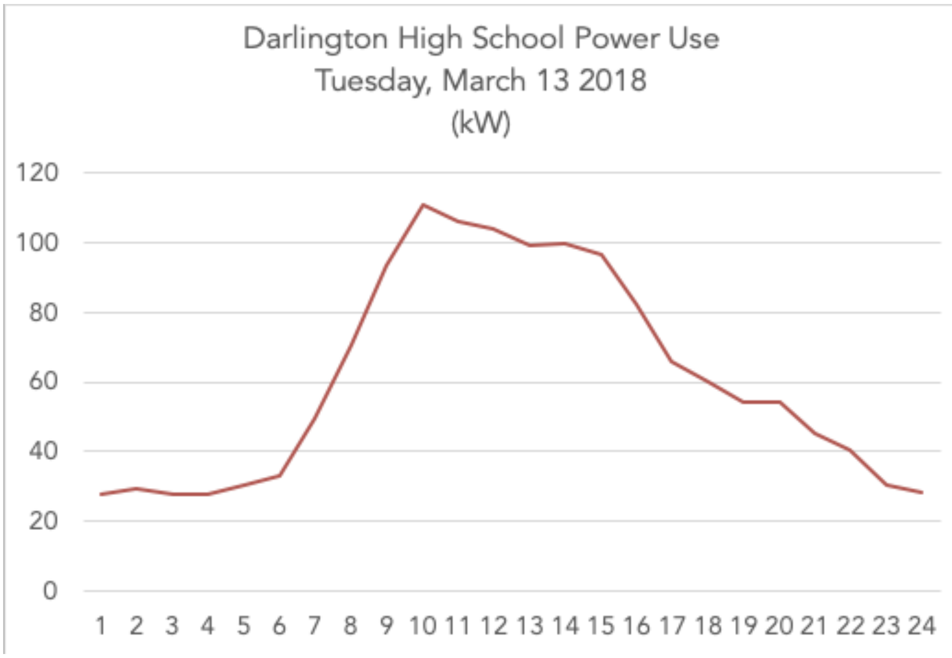
The HS's winter loads are the most difficult for PV to meet, so, understanding the school's winter usage characteristics is important. Figure 2, below, shows the average daily load shape for January 2018. The average load shape includes holidays and weekends (when the school's loads are reduced). The school's January load begins to increase sharply after 6 am, peaks between noon and 1 pm, steadily drops until midnight, and is stable and low between midnight and 5 am.

Figure 2. The High School's Average Daily Power Use (KW) in January 2018



Spring power use, Figure 3., also ramps quickly in the morning and tails off during the afternoon and into the late evening.

Figure 3. Spring Power Use Darlington High School



Summer power use, Figure 4, is similar to the solar generation curve on a decently sunny day with some clouds at mid-day. Note, how low the power use is compared to other times of the year.

Figure 4. Summer Power Use Darlington High School

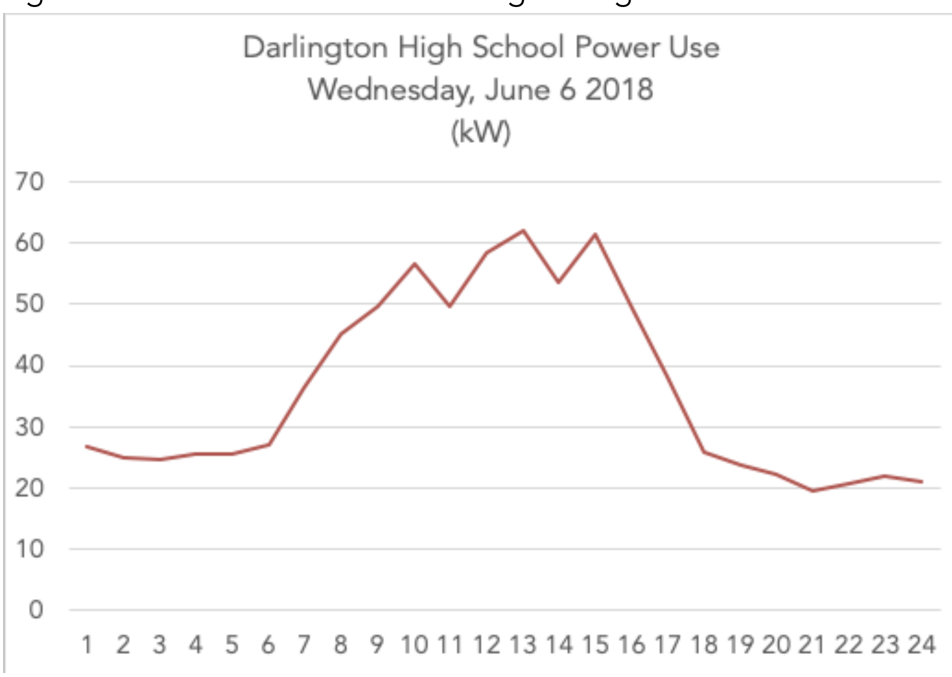
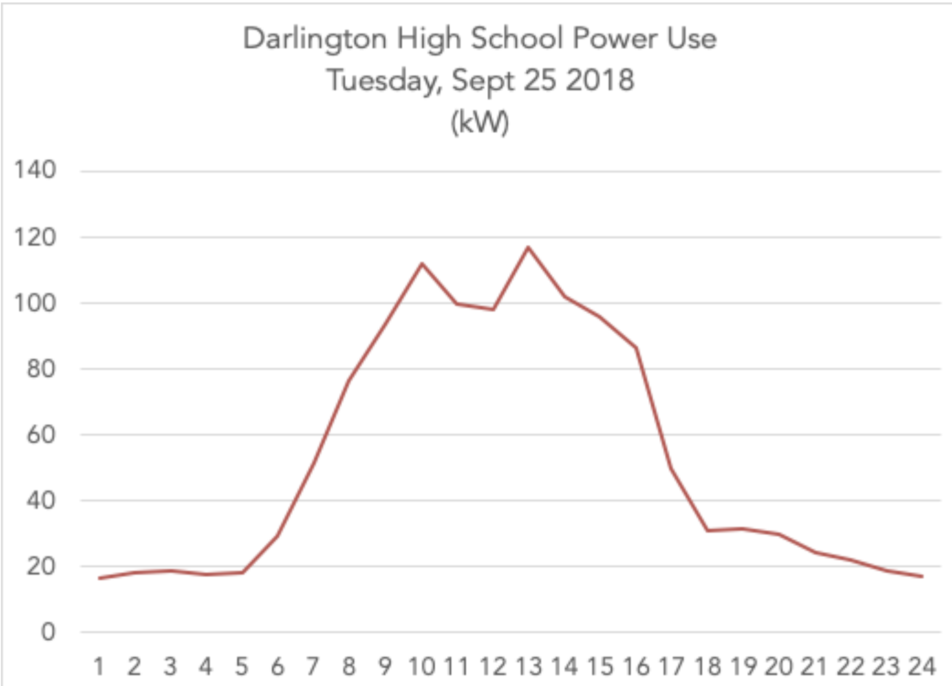


Figure 5. Fall Power Use Darlington High School



High School Solar Generation Characteristics

The HS's existing PV array was sized to provide very little power to the Alliant Energy grid. Alliant has a net metering billing cap of 20 kW-ac. Any solar power supplied to the grid, during any 15-minute interval of the year, is valued at the grid's avoided cost, which is about 1/2 the school's retail electric usage (kWh) cost and a small fraction of the school's demand (kW) costs (refer Figure 21 and accompanying text).

In Figure 6, below, note:

- PV capacity peaks at about 68 KW-ac
    - The PV system has an inverter rating of 68.1 kW-ac
- Generation is much reduced during the winter compared to summer
- The long period without significant generation in early 2018 is due to snow covering the PV array

Figure 6. Darlington High School Solar Generation 2018.

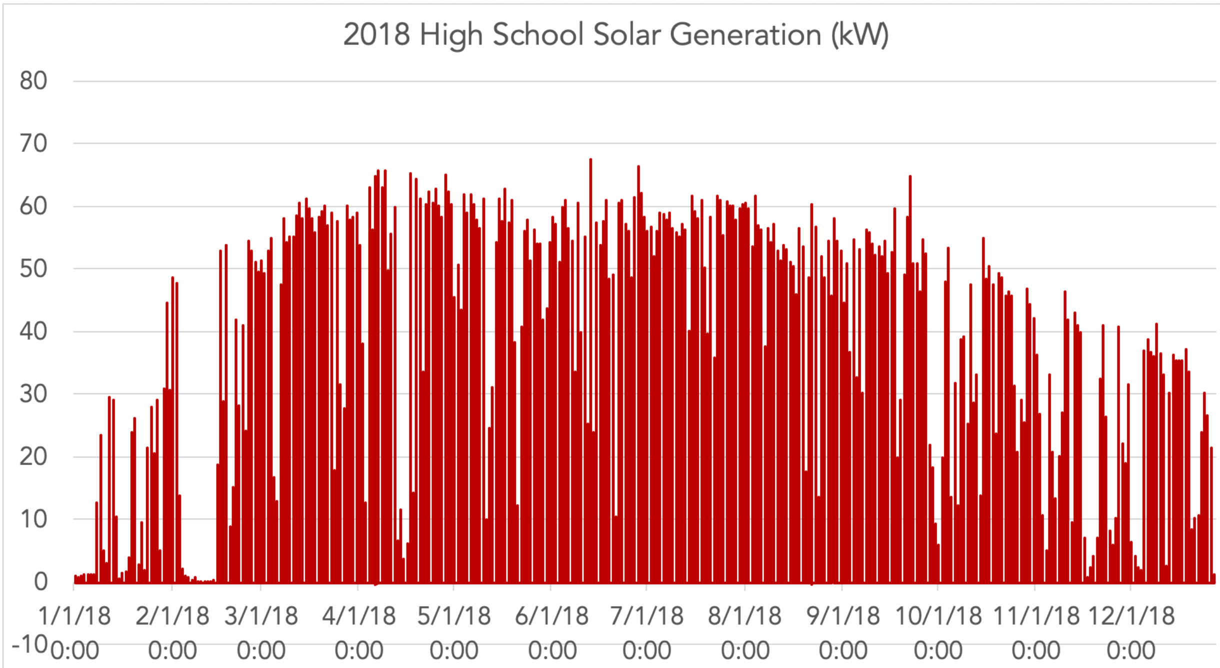
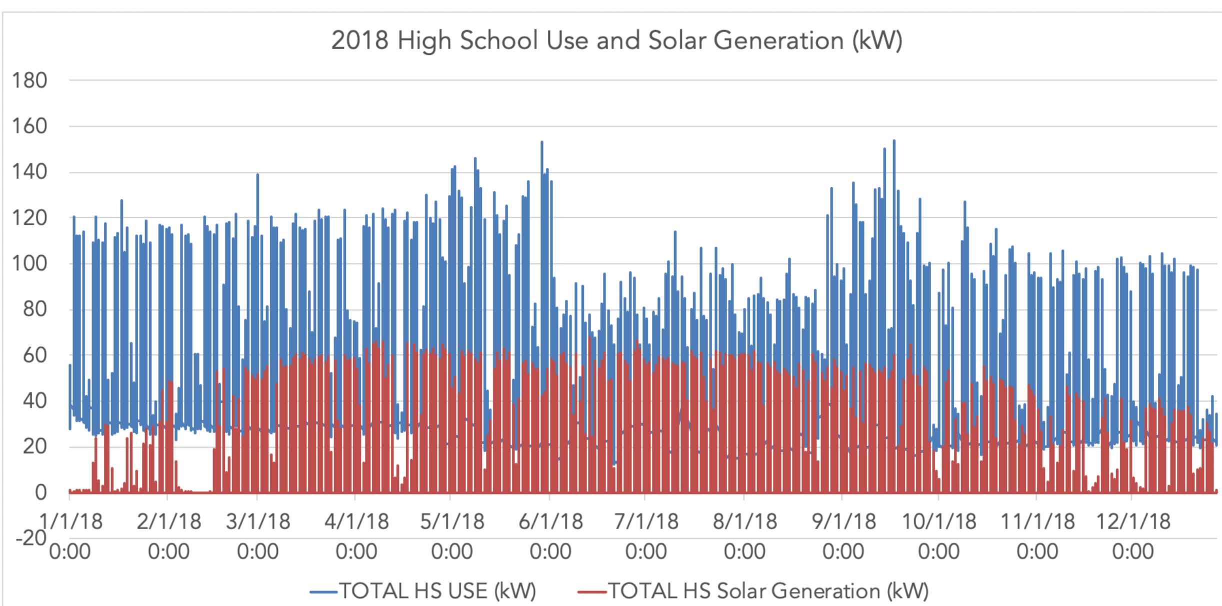


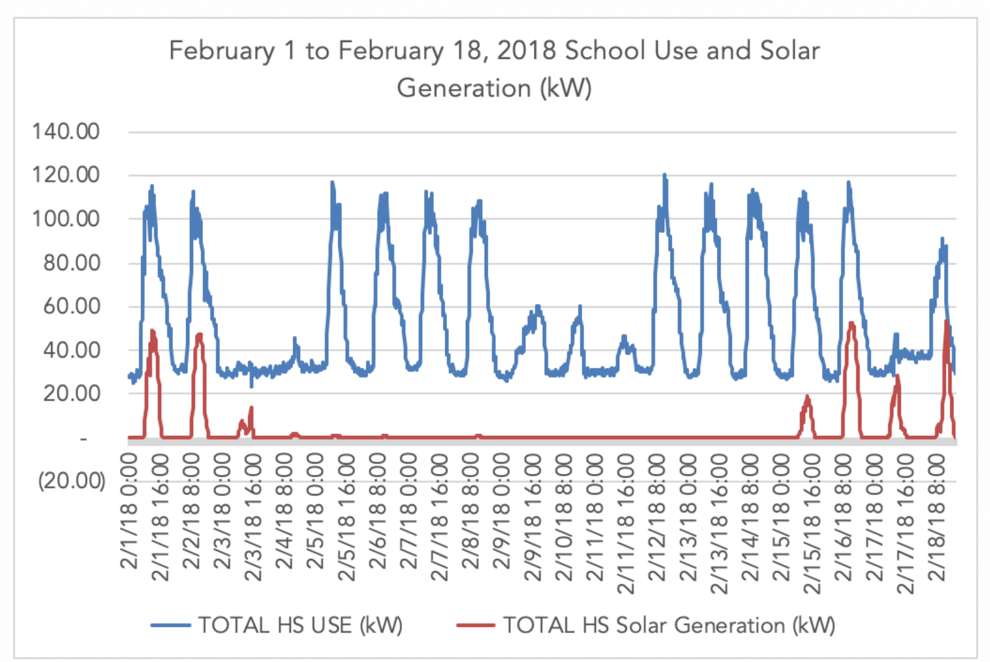
Figure 7 shows both the HS's power use (blue) the solar generation (red). Note that the existing PV system is on the EMS's roof has a low ~10° tilt angle (which optimizes for summer generation).

Figure 7. Darlington High School Solar Generation and Total Electricity Use 2018



During the winter, the PV system contributes very little to the HS building's power needs, as shown in Figure 8 below. However, when solar power is being generated it is often well matched to the HS's usage peaks.

Figure 8. Winter Detail of High School Power Use and Solar Generation



In the winter there are commonly periods of time (from hours to weeks) when the PV array is covered by snow and generating very little power. The PV array is on a flat roof with a tilt angle of ~10° from the horizontal, thus is easily snow covered. In the winter, the array's low tilt angle reduces solar generation as sunlight strikes the modules at an oblique angle. Also, in the winter the days are shorter, it is cloudier and the sun has a longer path through the atmosphere and is thus attenuated. Thus, winter solar generation declines sharply.

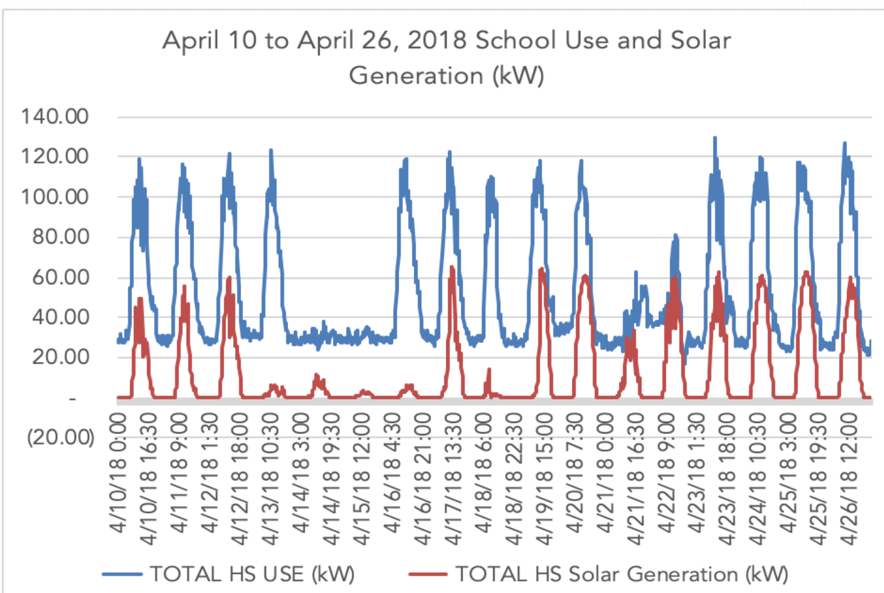
PV modules are the most efficient when they are cold - so on very cold clear sunny days PV arrays can be very efficient. If the array is at a higher tilt angle it is less likely to be covered by snow. Winter generation is maximized at a tilt angle of 60° to 70° degrees (see Figure 17).

It is also important that snow that slides off the array doesn't pile up at the base of the array and shade the bottom of the PV modules. This too can turn off or reduce the array's solar generation. To reduce the "snow pile shading effect" it is best to elevate the array some distance above the roof or ground surface. In the case of flat roofs, this adds cost and weight to manage wind and snow loading. Ground mounted PV panels will be more practical for higher angles.

The snow pile shading effect is reduced by installing the PV modules in a landscape orientation, which will allow part of the module to generate power when the bottom of the module is covered by snow. Landscape module orientation is the industry standard for roof-mounted PV arrays. Module level optimizers or inverters will also reduce the effects of snow partially covering a PV module or PV module string.

For ground-mounted arrays, snow slides off arrays sooner when using unframed PV modules. PV arrays with unframed modules present a smoother surface resulting in snow and ice sliding off more rapidly. Similarly, on sunny days ground mounted PV arrays using bifacial modules will absorb reflected solar energy on their undersides, heating up the modules, and shedding snow more quickly.

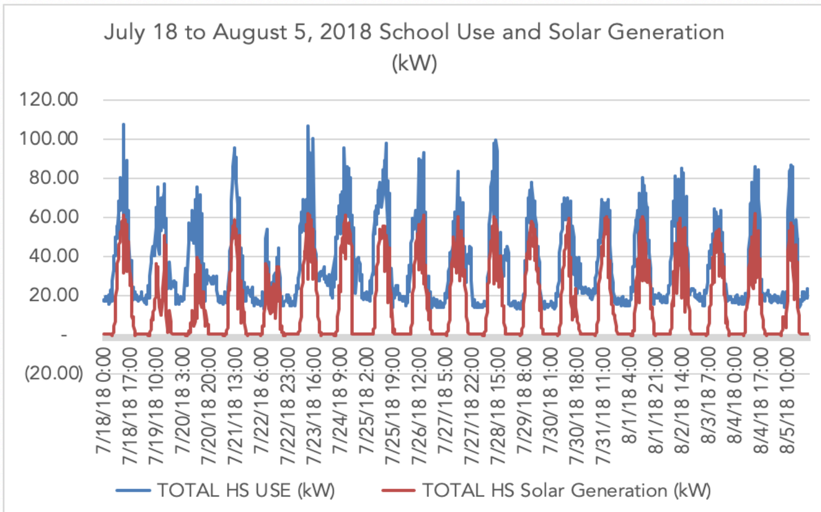
Figure 9. Spring Detail of High School Power Use and Solar Generation



During most of the year the solar generation matches nicely with the HS's load. The solar generation peaks match with the school's consumptions peaks. But the school's load ramps up before the PV is generating which could be addressed with a BESS.

If there is some flexibility in the school's electric loads, it could make sense to schedule them to be concurrent with the solar generation. This would have even more benefits if more solar generation were added. Scheduling loads is also part of the smart grid vision.

Figure 10. Summer Detail of HS Power Use and Solar Generation



On sunny summer days, 50% to 100% of HS's daytime electricity use is currently met by the solar generation, recalling that the HS's summer electricity demand is about half of the school-year demands. The school is only partially used in the summer. (A school used during the summer and air conditioning would have a very different summer load shape). There isn't much more room in the HS's current electricity usage profile to add low tilt south facing PV, unless batteries are added.

If the grid valued summer daytime generation or grid services, and reimbursed grid service providers, it could make sense to add additional south-facing low-tilt PV. But under current Alliant Energy policies and rates, there is no increased value for summer daytime power export. Under Alliant Energy's parallel generation rate the school's excess summer business day generation (i.e., power put onto the grid) is valued at 4.15 cents/kWh between 11 am and 7 pm (refer to Figure 21 and accompanying text). That power, even on Alliant's peak summer day, has almost no capacity value.

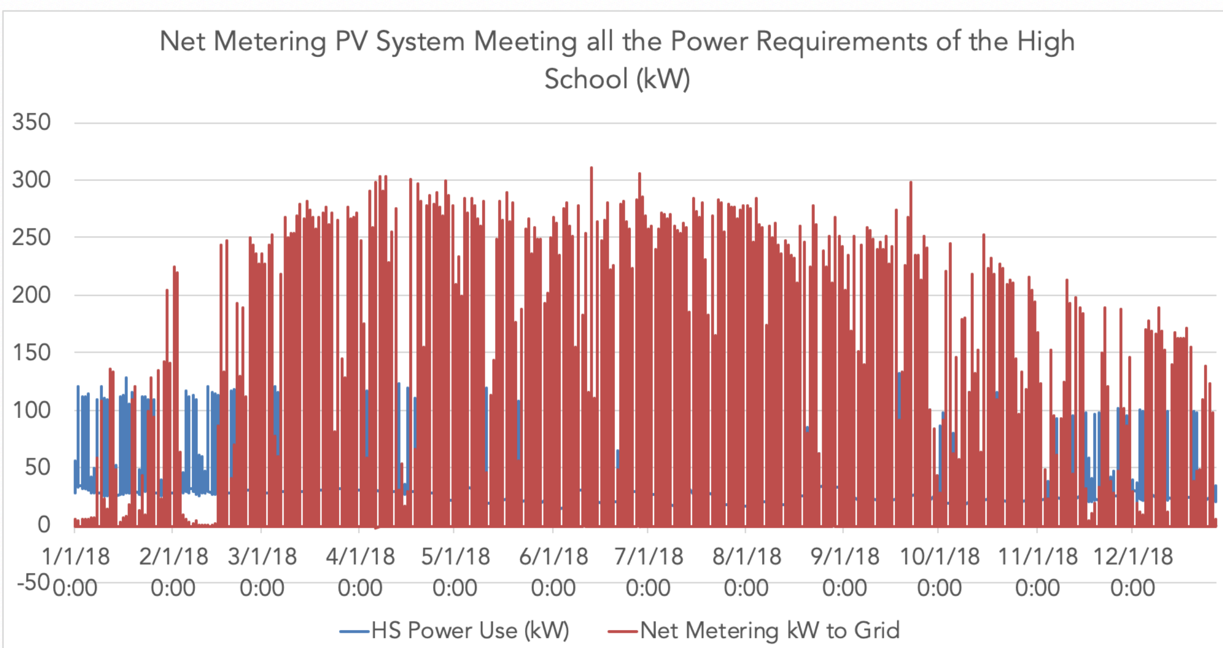
3. Potential for Achieving Zero Energy at the Darlington Schools

Building Designs and Technologies

In 22 states, including Indiana and Iowa, commercial building-sited PV systems of up to 500 kW-ac are allowed to net meter. If that were the case in Darlington, the easiest method of reaching net zero electricity would be to simply add PV to the High School's existing rooftop PV system.

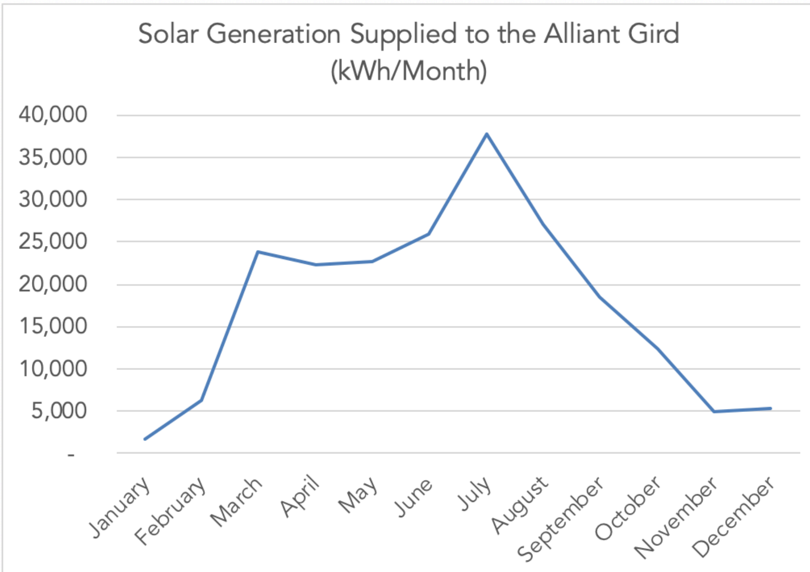
If the PV system were increased by 360% to 358 kW-dc (i.e., adding 280 kW-dc to the existing 77.8 kW-dc PV system), it would meet 100% of the school's annual power use. Assuming a PV system cost of $1.45/watt DC, this would cost $406,000. Figure 11 shows the total solar generation supplied to the grid from the 358 kW-dc array sited on the HS roof, assuming the same orientation as the existing array (i.e., due south facing with a 10° tilt) and the same production characteristics as the array and building power use as in 2018.

Figure 11. Solar Generation and Building Power Use if the HS's Existing PV System Was Increased 358 kW-dc, Meeting the Building's Annual Power Needs.



Much of the solar power would be delivered to the Alliant grid during the summer (see Figure 12). 58% percent of the solar generation (metered at 15-miute intervals) would go onto the Alliant distribution grid.

Figure 12. Solar Generation supplied to the grid each month if the HS's PV array was expanded to meet current electricity needs.



Alliant's net metering limit is 20 kW-ac. Under current Wisconsin policies this "excess solar" generation is paid by Alliant based on their PG-PgS-1 rate schedule (see Figure 21).

Without net metering, this suggests considering the following measures for the HS to financially benefit in achieving net zero electricity or energy:

- Installing additional energy efficiency measures
- Managing the school's electricity use to better utilize the solar generation profile
- Installing PV arrays at orientations that maximize winter generation
- Adding a BESS

Given that much of the excess solar power is generated on summer days, when the electric utility grid (i.e. Alliant's distribution grid or MISO's transmission grid) is often experiencing peak demands and high costs, the grid could compensate customers that provide excess solar power at these times.[7] For example, the grid could pay for the

[7] In Australia, the government has pledged 1 billion Australian to put solar and batteries (creating virtual power plants) on schools to provide grid reliability. Australian policy makers note that "schools are an excellent location for solar investment, and the creation of virtual power plants, because they often don't

grid support services provides by smart inverters and BESS at the HS. Although customer-sited and owned resources may be the least cost provider of these services, the current these services are not valued by the grid. With policy change, which is likely over the next five to ten years, the HS's PV system may be valued very differently. This suggests designing the flexibility for providing grid services within the District's PV/BESS systems.

The value of the grid services will generally be greatest during periods when the demand on the grid and the utility cost of meeting that demand is the highest. If in the coming years heat pumps are used for space and water heating, and wind, solar, and battery resources supply a large portion of the power on the grid, the greatest need for grid support may occur on calm, cold early winter mornings, before sunrise - particularly after a series of cloudy days.

Innovations in this Study

Optimizing Battery Size and Utilization for Financial Performance

The primary use for the battery electricity storage system (BESS) in a net zero-energy school is to capture some of the excess PV generation to offset power use during high cost periods when solar generation is insufficient. However, a BESS can also perform arbitrage (battery charging with low-cost off-peak power and using that power to offset high cost power and demand charges) and providing ancillary services to the distribution and transmission grids (please refer to Section 3 and Annex 1).

From a financial performance standpoint, a PV system at a net zero school without high net metering limits and without batteries will generate too much power —particularly during the summer daylight hours. The PV system will greatly over-produce what the facility needs, exporting large amount of solar power to the grid at avoided cost.[8] This is especially true for schools that are not in session during the summer. Without a BESS the net zero school would send significant amounts of electricity back to the grid (see Figure 12) at avoided costs and resulting in lower economic performance.

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use energy at times of peak demand and through a large portion of the summer." Accessed on November 2, 2019, link: pv-magazine-australia.com/2019/04/30/labor-to-connect-4000-schools-into-vpps-in-1-billion-solar-program/

[8] Avoided cost is the utility's cost to generate power, this is typically a third to a quarter of the retail electricity price. See Figure 21.

A BESS stores excess PV generation, which is then used to lower electricity costs and potentially produces added revenue by providing grid services. The four BESS services that provide income or savings to the District can be provided as follows:

1) By charging the BESS at times that the solar generation is more than the HS can use, the battery is charging rather than putting power on the grid, which is compensated at avoided cost.
2) By charging the BESS from the grid at off-peak low-costs times to offset high-cost peak-power needs. This is called arbitrage.
3) By discharging the BESS during peak demand periods, known as peak shaving, thereby reducing the District's demand charges.[9]
4) By using BESS to provide grid services, thereby providing added income to the District.

The Federal Investment Tax Credit (ITC) can be monetized through TPP investors. For the TPP to receive the ITC, the BESS must be charged with the school's solar power. Schools, other governmental organizations and not-for-profit 501(c)(3) organizations cannot directly utilize the ITC for PV systems or BESS, simply because they do not pay taxes. If the District directly owns the BESS rather than using TPP, the District is free to use it for arbitrage.

For the Darlington HS direct purchase scenario, under Alliant's current rates, the BESS is charged with approximately 30% solar power with the rest coming from the grid at low-cost off-peak hours. While for the TPP modeling scenarios, the battery is 100% charged with solar power.[10]

As Alliant's and MISO's rate structures and pricing changes, the BESS will adjust its operation to optimize income to the District. Possible rate changes include changing of the on-peak and off-peak periods, changing electricity use (kWh) and demand (kW) rates, and the changing compensation for grid services.

An important consideration for sizing the BESS is the grid support services market of the Independent system operator (ISO), in this case, the Midcontinent Independent

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[9] Resource for understanding behind the meter storage for demand reduction: Neubauer and Simpson. Deployment of Behind-The- Meter Energy Storage for Demand Charge Reduction. January 2015.
[10] For a breakdown of ITC application for storage, see NREL's guide compiled by Elgqvist, Anderson and Settle. Federal Tax Incentives for Energy Storage Systems. January 2018.

System Operator (MISO). Based on current information on this future market, participation requires a minimum of a two-hour battery (operating at peak power for two hours) with at least 100 kW-ac of power capacity.[11] This is not unreasonable for the Darlington HS, which sees monthly peak loads between 100 kW-ac and 200 kW-ac (and more with the addition of heat pumps). After a sunny day a 100 to 200 kW-ac battery can run the HS through summer evenings without power from the grid.

To optimize the PV/BESS's financial performance the BESS's operation software will consider each of the four potential areas of income (noted above) and optimize for the maximum net income to the District in real time.[12] The BESS will be regularly providing and deriving benefits from more than one savings and revenue source.

Batteries will need to be replaced when they are depleted. The primary factor determining battery life are the limits put on depth of charge/discharge and the average state of charge. This can be managed by setting limits on the battery's depth of discharge and limiting usage to only most profitable revenue and cost reduction opportunities. For the Darlington HS, using a gentle battery dispatch controller minimized the BESS capital costs. In this analysis, at the end of the 25-years the HS BESS still had 50% of its capacity.

The study team developed a BESS deployment schedule (or dispatch model) for Darlington based on the HS's schedule and Alliant's rate structures. However, the best performing dispatcher, of those the team built or tested, was SAM's pre-set peak-shaving, one-day look ahead dispatcher.[13] This assumes perfect knowledge of the coming day's solar resources.[14] Though this is impractical outside of modeling, it could be argued to be as effective as a real-time smart system controller that is considering

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[11] The study assumes that the BESS is AC-connected. This is based on conversations with battery installers. However, energy storage can also be DC-connected for greater PV to storage efficiency. For additional analysis, see: DiOrio, Freeman, and Blair. DC-connected Solar Plus Storage Modeling and Analysis for Behind-The-Meter Systems in the System Advisor Model. July 2018.

[12] For a great a breakdown of economic analysis of storage using SAM: DiOrio, Dobos, and Janzou. Economic Analysis Case Studies of Battery Energy Storage with SAM. November 2015. And: DiOrio, Dobos, Janzou, Nelson, and Lundstrom. Technoeconomic Modeling of Battery Energy Storage in SAM. September, 2015.

[13] See SAM Help System, "Storage Dispatch Controller - Behind the Meter" in section 6.6.6 "Battery Storage." System accessed on October 25, 2019.

[14] For more on automated dispatch controllers in SAM, DiOrio, Nicholas. An Overview of the Automated Dispatch Controller Algorithms in SAM. November, 2017.

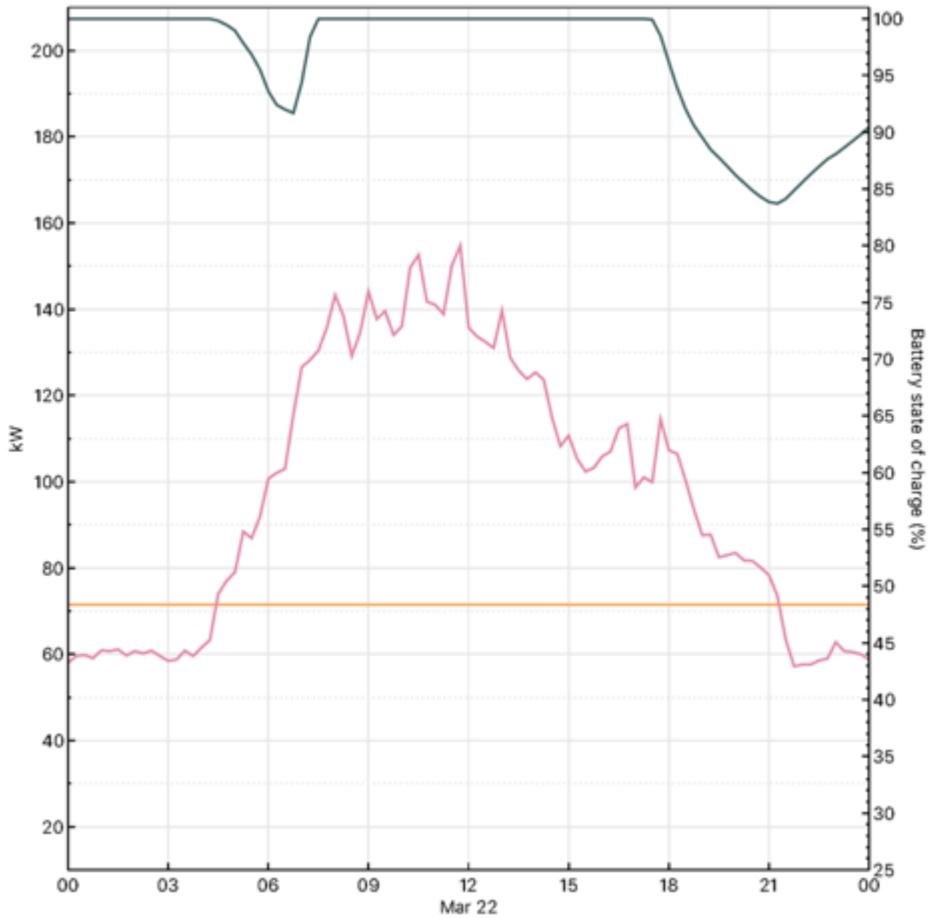
day ahead weather data (weather and building use) and adjusting operational behavior accordingly.

To illustrate how a PV and BESS system and battery dispatcher, in this case SAM's peak shaving dispatcher, performs at the HS, see Figures 13 to 16, below.

Each day's data was taken from the net zero energy direct purchase scenario. This means that the battery is not limited by needing to charge only from solar PV (for ITC reasons in the case of TPP), and the school's load includes a geothermal HVAC system. Each figure is a 24-hour snapshot of how each energy source (i.e., solar PV, grid and BESS) work together to meet the HS's load. The Figures do not show electricity flows from providing grid support services. Additionally, the "electricity to load from PV" only shows what the HS is using. It does not show how much is being exported to the grid. This is why, in Figure 16, the HS's load perfectly overlaps the line showing energy from PV to the HS.

Figure 13. Spring Day, Simple View w Building Load and Battery State of Charge.[15]

[15] Note that battery depth of discharge scale is on the right with kW shown on the left.

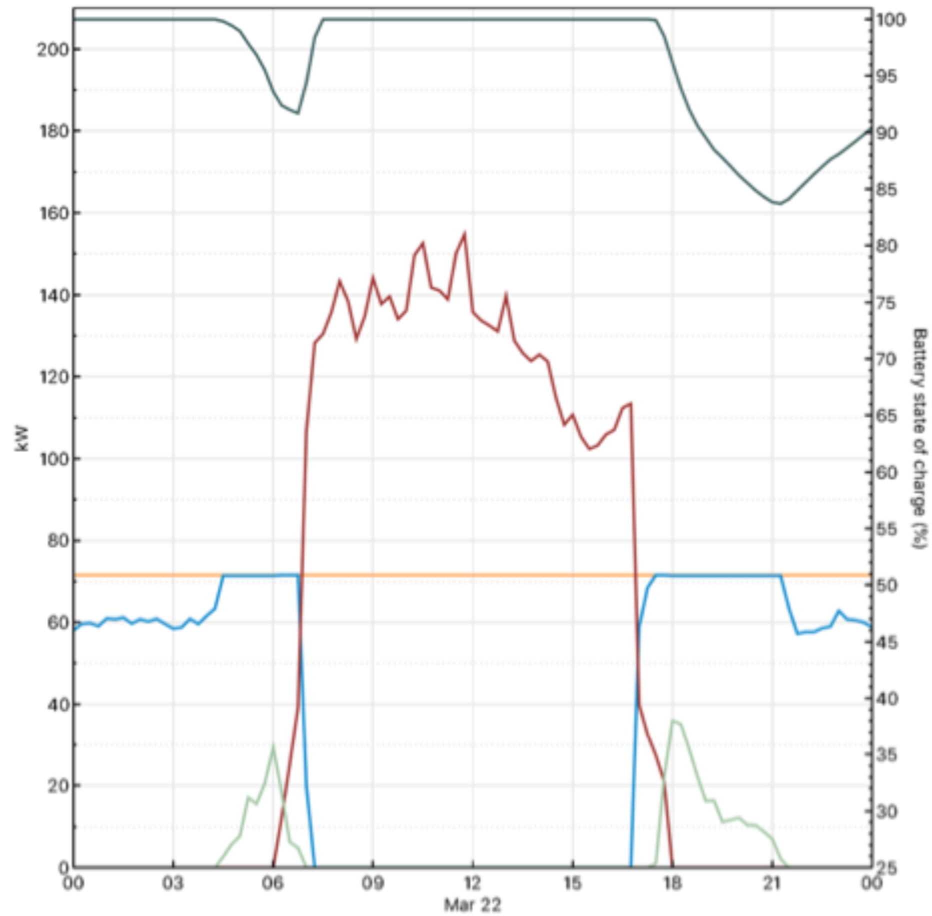


Dark Green line (top): Battery state of charge (%)
Red line (peak shaped): HS's electric load (kW)
Yellow line (straight): Electricity grid power target for automatic dispatch (kW)

Figures 13 to 14 are for the same spring day. Several of the following figures don't explicitly show the facility's load shape. Instead the HS's load is represented by the various power sources (PV, battery and grid supply). Figure 13 showing the facility's load (red line).

Figure 14. Spring Day, All Energy Sources (building load not shown).[16]

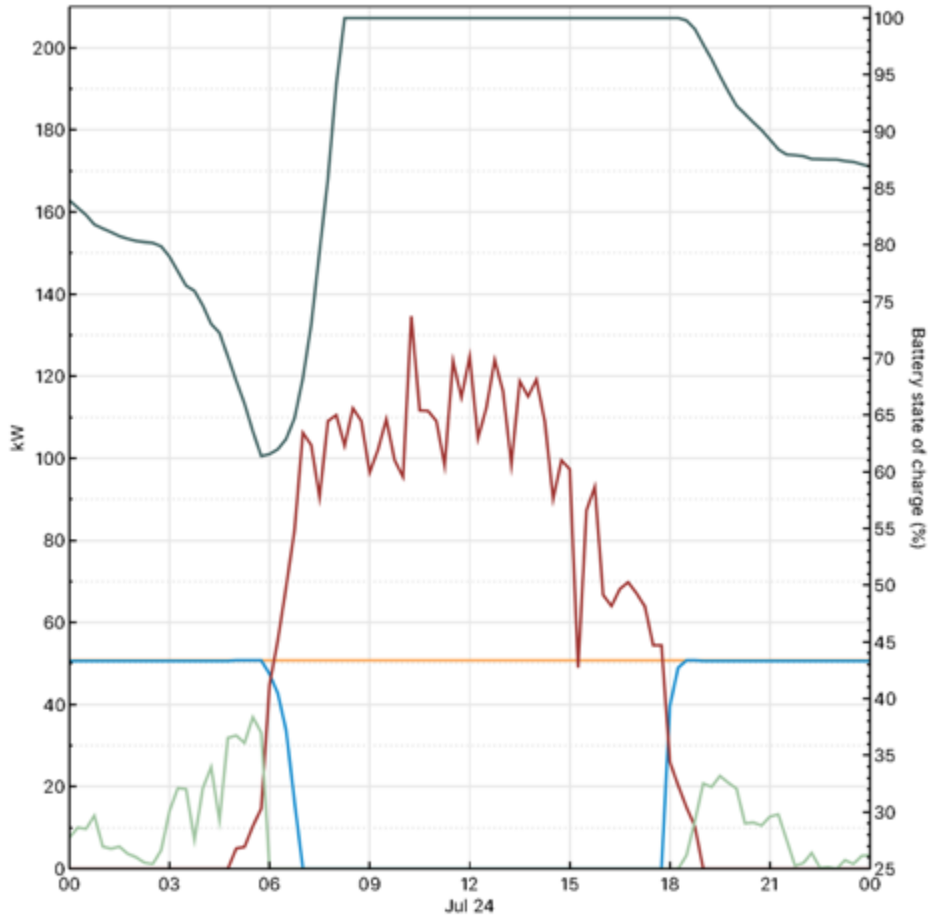
[16] Battery is shown in two different ways but both represent the same data: depth of discharge show at top and kW shown in green.



Dark Green line (top): Battery state of charge (%)
Red line (peak shaped): Electricity supply from PV array to HS (kW)
Yellow line (straight): Electricity grid power target for automatic dispatch (kW)
Blue line: Electric supply from grid to school (kW)
Green line: Electricity supply from battery to school (kW)

On a typical clear summer day, the PV generation meets the HS's load. Recall that the HS's summer loads are small. However, as the school's load starts to ramp up before the sun rises (i.e., PV generation is starting power up), the dispatcher has the BESS providing power, to minimize grid power use, until solar resource is available. Once the PV meets all the school's load the "excess" solar power is used to charge the BESS.

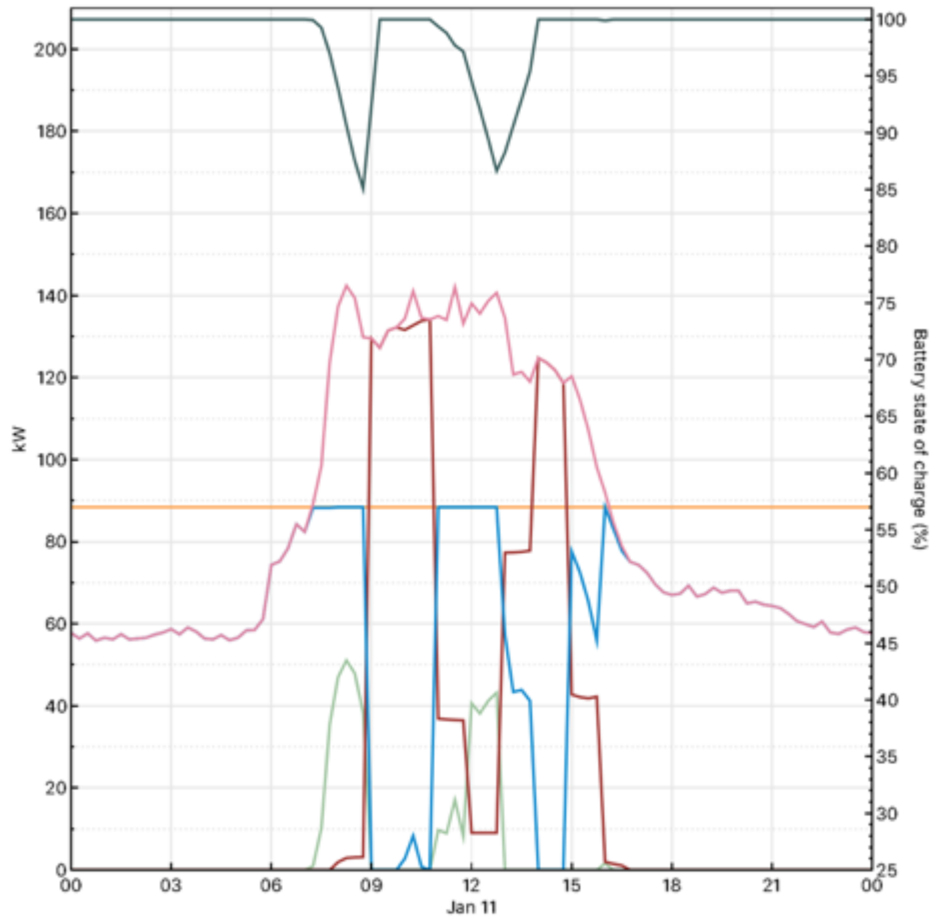
Figure 15. Summer Day, All Energy Sources (building load not shown).



Dark Green line (top): Battery state of charge (%)
Red line (peak shaped): Electricity supply from PV array to school (kW)
Yellow line (straight): Electricity grid power target for automatic dispatch (kW)
Blue line: Electric supply from grid to school (kW)
Green line: Electricity supply from battery to school (kW)

During the summer, the HS's low power load combined with higher solar insolation and PV generation, the dispatcher uses the stored electricity more aggressively during the night, impart because solar resource is available early and late enough to cover any school use during the shoulder hours. When there is excess PV generation, the BESS can charge while the school is having its load met by PV. This leaves the battery full during peak solar periods and when the grid support markets might offer high prices for BESS grid services.

Figure 16. Summer Day, All Energy Sources (building load not shown).



Dark Green line (top): Battery state of charge (%)
Light Red line (peak shaped): School's electric load (kW)
Dark Red line: Electricity supply from PV array to school (kW)
Yellow line (straight): Electricity grid power target for automatic dispatch (kW)
Blue line: Electric supply from grid to school (kW)
Green line: Electricity supply from battery to school (kW)

Figure 16 shows a winter day with mid-day clouds. At around 11 am, solar generation falls (dark red line) and BESS (top gray line) then meets the school's load.

What is not shown in any of these figures is the impact of participating in the ancillary grid service market. Depending on which service BESS is providing, the profiles could look very different. For example, the energy source distribution will be different if BESS capacity was held back to help reduce Alliant Energy's peak demand charges from MISO.

Ancillary Benefits from PV and Battery Systems

Both smart PV inverters and BESS can provide valuable services to Alliant's distribution grid and the MISO transmission grid. US distribution and transmission grid operators are beginning to pay third-party electricity storage system and inverter owners for these services.

BESS owners are being paid for providing grid services. FERC Order 841 on Participation of Electric Storage Resources in the Independent System Operator (ISO) Capacity, Energy and Ancillary Services Markets was issued in 2018. The ruling removes barriers to the participation of smaller non-utility owned electric storage resources in the capacity, energy and ancillary services markets operated by Regional Transmission Organizations or ISOs.[17]

In the PJM ISO the new FERC rules have been implemented for over a year while MISO implementation is being planned but is not yet operating.[18] The MISO ancillary service market is now anticipated to start mid-year in 2022. For more information regarding smart inverters and battery storage systems providing grid services please refer to Annex 1.

Third Party Investment to Reduce the First Cost Barrier for Schools

TTP Investors are outside investors that own, operate, maintain and insure the solar PV system. They receive the project's tax benefits and the payments for energy service from the site owner through the term of the Energy Services Agreement. The TPP often provides options for the site building owner options to purchase the system as fair market value under IRS rules between year 7 and 25. A major benefit of a TPP approach is that it enables a school to acquire solar PV and potentially battery systems without needing up front funds other than grant funds, which can provide its co-ownership share. If the school exercises the option to purchase the PV system in a future year, the cost is greatly reduced as it's based on market value at that time.

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[17] Source: https://www.ferc.gov/media/news-releases/2018/2018-1/02-15-18-E-1.asp#.XCU7Oc9KjUY

[18] MISO markets for storage will likely not be implemented until June, 2020. See link for FERC ruling on MISO requests: https://www.ferc.gov/whats-new/comm-meet/2019/112119/E-2.pdf; accessed on December 18, 2019.

Some Wisconsin utilities do not currently allow PV systems co-owned with TPP Investors. A docket open on this topic at the Public Service Commission of Wisconsin (PSCW) and an ongoing court case. As of 2019, Focus on Energy program (Wisconsin's energy efficiency and renewable energy incentive program) is unwilling to provide incentive for TPP financed or leased PV projects. Due to the Focus on Energy restriction and the limitation on battery use under ITC rules, the NPV with a TPP approach is reduced to less that the NPV for direct purchase. These rules are subject to change.

If the DCSD were to use a TPP approach similar to the existing DCSD agreement, it may be structured as follows:

- The District is the "Applicant" for purposes of the PSCW's Distributed Generation Application Form and Alliant Energy
- The project is largely owned by an LLC entity which is created solely for this project in order to monetize the tax benefits
- The District's co-ownership may be paid by the District or grant
- The District's co-ownership is typically between 10% and 25% of the PV/BESS system.
- The District is a party to a co-ownership agreement with the LLC entity and is a member of the board that manages the operation of the project
- The LLC Entity enters into a services agreement with the District that may provide:
    - The solar power: kWh, kW and grid support benefits from the PV/BESS system
    - The stored solar and grid power: kWh, kW and grid support benefits
    - Building energy and demand management services to increase the energy efficiency of the buildings
    - Solar energy and BESS services for design, installation, operation, and for delivery of solar and stored energy
    - Informational services, including real time and stored data accessed via a kiosk and the web
- The services agreement incorporates a fixed monthly service fee (with annual fee adjustments based on actual system performance)
- At the end of the contract term, the District may either purchase the solar PV/BESS system or ask it to be removed by the TTP (at the TPP's cost)
- The District is not required to purchase the PV/BESS system
- The District's purchase cost must be greater or equal to the residual value of the PV/BESS system (IRS requirement)
- It is recommended that the District entering a contract with a TPP has legal representation

PV Array Orientation

Another innovation is the evaluation of PV array orientation. PV systems are typically oriented for maximum annual solar production at whatever PV array orientations are easily available. The limitation of this approach is that the PV array may not deliver power when it's most financially beneficial. It may be more beneficial to give up a small amount of total annual power production to shift production to times of the year and times of day that yield better revenue. The following describes our methods and results, which guided the selection of the PV arrays used in this study.

South Facing Tilt Angles

The figure below summarizes the solar generation for a 1 kW-dc PV south-facing array tilted at different angles (sited in Darlington, WI) using PVWatts.[19] The areas in yellow show the maximum production for each month.

[19] Other assumptions include, 14.08% losses, premium modules, 96% inverter efficiency, no reflected light, 3% shading, no snow cover, 2% soiling, no reflected light, etc.

Figure 17. Monthly Power Generation for a 1 kW-dc South Facing Array at Tilt Angles (from the horizon) between 0° (horizontal) and 90° (vertical).

Tilt Angle (degrees)	0	10	20	30	40	50	60	70	80	90
Monthly Solar Generation	AC Energy Produced (kWh)									
January	45	58	70	79	86	90	91	91	90	86
February	61	73	83	91	95	98	98	96	93	86
March	100	111	118	122	124	123	120	114	105	93
April	116	123	127	128	125	120	113	102	90	75
May	143	146	146	142	136	127	115	101	85	67
June	149	150	148	143	135	124	110	95	77	59
July	152	155	153	149	142	131	118	103	85	66
August	134	140	143	142	138	132	122	109	94	76
September	106	117	125	129	131	129	124	116	105	92
October	75	89	101	109	115	118	117	114	108	99
November	48	62	75	85	93	98	100	100	97	92
December	36	49	59	68	75	79	81	81	80	77
Annual	1,165	1,273	1,348	1,387	1,395	1,369	1,309	1,222	1,109	968
Winter Generation										
November to March	290	353	405	445	473	488	490	482	465	434
December to February	142	180	212	238	256	267	270	268	263	249

The analysis does not include snow cover or reflected light. In winter, the more vertical the PV array will result in less snow cover and more reflected light (e.g., bouncing off the snow-covered ground). Snow has an albedo of 50% for old snow to 90% for fresh snow. Darlington has about two months of snow cover per year.[20] The increased output from reflected light is not analyzed in this study but for a vertical PV array it could be significant.[21]

In Darlington, winter generation is maximized by an array with a tilt angle of between 50° and 70° from the horizontal. Considering, qualitatively, the impact of reduced snow cover and reflected light, it is estimated that winter generation is maximized at tilt angles between 60° and 90°.

[20] Accessed on November 16, 2019; link: http://ak-wx.blogspot.com/2014/04/length-of-snow-cover.html

[21] I.e., 10% to 20% of increased output on a sunny day with fresh snow on the ground

PV arrays with 60° to 90° tilt angles are uncommon and racking for them is also uncommon. Due to wind loading, they and even much lower angles cannot be sited on rooftops due to structural requirements. Due to the limitations of using PV modules at higher angles on roofs, ground-mounted panels at steeper angles are considered. As noted, angles at 60° to 80° are uncommon, however, vertical surfaces such as fences and the sides of a building are common. Thus, vertical and steeply tilting PV arrays should be considered to increase winter solar generation.

The PV racking industry should consider developing more ground-mounted racking options that tilt arrays at 60° to 80°. Given their increased area perpendicular to horizontal winds, they may require more structural strength and perhaps a larger foundation and higher costs.

PV Arrays Tilting at 70°

Arrays with a 70° tilt angle:

- Have very good winter solar generation characteristics
- Shed snow well
- Capture reflected light

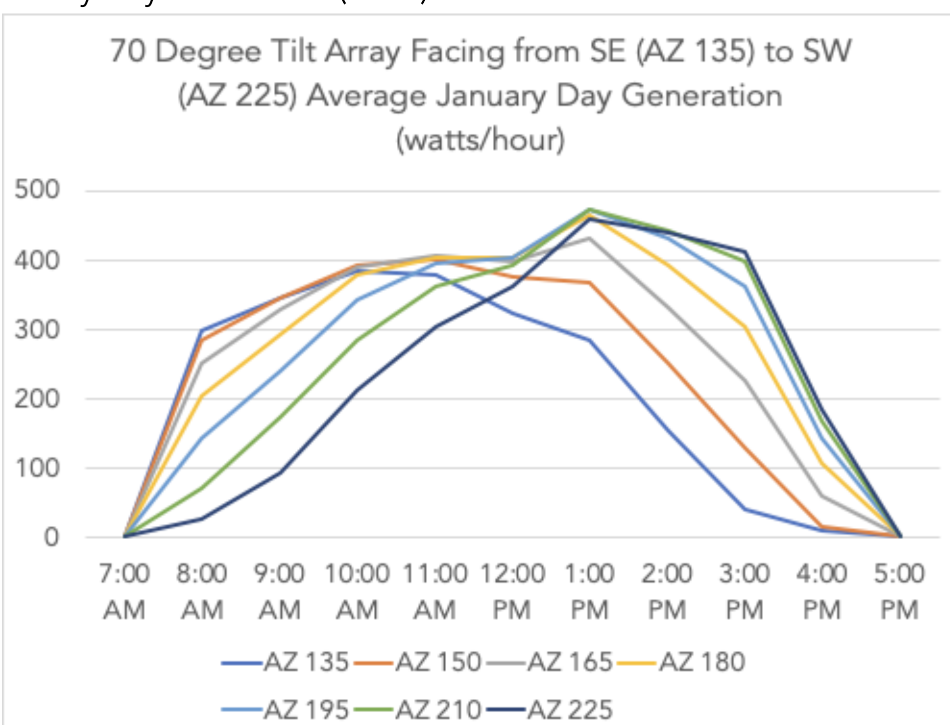
Figure 18. Monthly Generation of a 1 kW-dc PV array Tilting at 70° at Different Azimuths from East (90°) to West (270°). Yellow highlights the maximum generation for each month. Generation, including winter generation, is maximized by the south-facing array.

	East			South East			South			South West			West
Orientation	90	105	120	135	150	165	180	195	210	225	240	255	270
January	37	47	58	69	79	87	91	91	86	77	67	56	44
February	52	62	72	81	88	94	96	94	88	80	71	61	51
March	78	88	96	103	108	112	114	112	108	102	94	86	76
April	86	93	98	101	102	103	102	103	102	100	97	92	86
May	105	109	111	110	107	104	101	101	103	104	104	102	98

June	104	106	106	103	99	95	95	97	103	108	112	112	111
July	106	109	110	109	106	103	103	106	111	116	118	118	115
August	99	105	109	111	111	110	109	110	111	110	108	104	98
September	81	91	99	106	111	115	116	116	113	109	103	95	85
October	62	74	85	95	105	111	114	112	105	96	86	75	63
November	43	55	67	79	90	97	100	97	89	79	67	55	42
December	33	43	54	65	74	80	81	79	73	63	53	42	32
Total	886	982	1,065	1,132	1,180	1,211	1,222	1,218	1,192	1,144	1,080	998	901

PV Array Tilting at 70° – Maximizing Winter Morning Generation

Figure 19. 1 kW-dc Array with a 70° tilt and at varying azimuths (from 135° to 225°) Average January Day Generation (watts).



The morning ramp rate for the azimuth 135°, 150° and 165° arrays are all about the same. Daily generation is maximized by the array facing due south (180°). This suggests that a 70° tilt array that is slightly SE facing (around 165°) optimizes both morning and total winter day generation.

Grid Interconnection Issues

A net zero electricity or a net zero energy building results in a large export of solar power to the grid. Typically, when an electric utility does an interconnection study it will assume that the building has no power use and 100% of the solar generation is supplied to the grid. The customer pays for any grid upgrades, if any, that the utility determines need to be completed. Buildings considering larger PV systems, must then consider the interconnection costs.

The District's PV/BESS system would to be connected to the Alliant distribution grid. There are limits regarding how much PV can be interconnected based on Alliant's existing distribution system. Alliant uses and interprets the Institute of Electrical and Electronics Engineers (IEEE) Standard 1547 to limit the export of power for a customer sited distributed energy resource (DER) to the distribution grid to be more than 33.3% of the distribution grid's minimum day time circuit load. Alliant's distribution system serving the Darlington School's and other customers has a minimum daytime circuit load of 1200 kW-ac. One-third of that, or the amount of DER that can be connected, is 400 KW-ac.

The capacity of the PV system needed to take one of the schools to net zero electricity, plus the existing PV on the other school, requires less than 400 kW-ac of PV. If one school is net zero energy (i.e., which includes a heat pump HVAC system) the interconnected PV will be significantly greater than 400 kW-ac.

If the total PV on the District's Alliant distribution grid is greater than 400 KW-ac, a significant cost, paid by the customer, is required to provide a limiter on the export of DER power to the grid. If the battery discharges into the grid, then its discharge capacity is included in the 400 kW-ac limit.

The Darlington study team met with and had conference calls with Alliant Energy staff (Troy Pitts, Key Account Manager, Jason Nelson, Regulatory Affairs and Jim Krier PE, Lead Engineer – Power Quality & Distributed Generation Engineering) to discuss the interconnection issues.

Jim Krier at Alliant Energy/Wisconsin Power and Light recommended the following interconnection options.

Alliant Energy[22]'s Darlington Interconnection Scenario Options:

Existing Distribution System Conditions:
Existing Solar PV = 136.2 kW-ac (Both Schools) - 68.1-ac kW at each school
Minimum Daytime Circuit Load: 1200 kW-ac
1/3 Minimum Daytime Circuit Load: 400 kW-ac
Direct Transfer Trip (DTT) Threshold for Circuit: 400 kW-ac

Scenario 1: Solar PV system greater than 400 kW-ac Total (Exporting to the distribution system)

The DCSD could install any size solar PV system, but they must limit the total amount exported to the Wisconsin Power and Light (WPL)[23] distribution system to 400 kW-ac between the two schools. Example: (68.1 kW-ac at school 1 with no additional equipment required. 331.9 kW-ac export limitation at school 2, thus meeting requirements set forth). To accomplish the limited export at school 2, the District would need to install a SEL (Schweitzer Engineering Labs) 700GT intertie relay with specific ANSI functions (See Drawing A1.6) and an intertie breaker that shall interrupt all three phases simultaneously and shall have a separate tripping control independent of the AC source, i.e., DC battery (24, 48 or 125 VDC) and charger. This will also require a SEL-2401 GPS clock. The clock's battery shall have an 8-hour runtime. The District (via the project's engineer) will need to determine the relay settings (Requires a Protection Study by an Engineering Firm), program the settings and have the relay tested. This will also require PTs (potential transformers) and CTs (current transformers) for the intertie relay as well as test switches. The CTs and PTs will have to be tested too. The SEL 700GT relay and SEL 735 Revenue meter needs to be in a climate-controlled enclosure (inside the school building). See the attached drawing A1.6. (Note: Relay, intertie breaker, Interconnection Disconnect switch, and Revenue meter would be on the secondary side of the transformer – this drawing is for a primary metered installation, but the equipment still applies).

[22] Also known as Wisconsin Power and Light
[23] Also known and Aliant Energy

Scenario 2: Solar PV system at both schools totaling 400 kW-ac
Darlington Schools could add 263.8 kW-ac between the two schools, noting that each school already has 68.1 kW-ac of solar in place. WPL would have to make sure of transformer sizes, fuse sizes, etc. to see if any upgrades would be required.

Scenario 3: Solar PV system greater than 400 kW-ac (Exporting to the distribution system)
This is similar to scenario 1 but uses a different control approach. This requires an Engineering Review and Distribution System Study (Fees apply) to determine system upgrades and costs which would include a DTT (Direct Transfer Trip Scheme). The DTT would require the installation of fiber-optic cable that runs from the RDB sub to the customer-owned SEL 700GT intertie relay (i.e., running from the Alliant Energy substation, that the school is fed from, to the intertie relay at the point of interconnection (at the school)). It would include the addition of relays, RTUs (remote terminal units), Line-sensing PT, etc., on the utility system as well as other customer equipment. See Drawing A1.5 (Note: Relay, intertie breaker, Interconnection Disconnect switch, and Revenue meter would be on the secondary side of the transformer – this drawing is for a primary metered installation, but the equipment still applies). The District would need to install at school 1 and/ or school 2 (Depending upon size of PV system at each school) a SEL (Schweitzer Engineering Labs) 700GT intertie relay with specific ANSI functions (See Drawing A1.6) and an intertie breaker that shall interrupt all three phases simultaneously and shall have a separate tripping control independent of the AC source, i.e., DC battery (24, 48 or 125 VDC) and charger. This will also require a SEL-2401 GPS clock. The intertie breaker clock's battery shall have an 8-hour runtime. The District (via the project's engineer) will need to determine the relay settings (Requires a Protection Study by an Engineering Firm), program the settings and have the relay tested. This will also require PTs and CTs for the intertie relay as well as test switches. The CTs and PTs will have to be tested too. The SEL 700GT relay and SEL 735 Revenue meter needs to be in a climate-controlled enclosure (inside the school building). Provisions for a grounding transformer need to be incorporated into the design of the system in case it is needed. If the system is greater than 1.0 MW, four-second scan data is required to be sent to the WPL GDC in Madison.

Note: Since all of this equipment resides on the customer side of the meter, I have no estimated costs for the equipment or for the services required. The aforementioned scenarios do not necessarily depict all of the details of the interconnection.[24]

The interconnection is likely to require two studies completed by Alliant Energy. The engineering review (estimated to cost $5,000 to $6,000) and the distribution study (estimated to cost $5,000).

Alliant Energy's scenario 3 requires the installation of a fiber optic communications line from the substation serving the District to the HS. That substation is estimated to be ¾ to 1 mile from the school. Fiber optic lines cost roughly $30.30/ft. to $44.33/ft. (source: Alliant Energy), or for this project roughly $120,000 to $235,000.

If the fiber optic line enables Alliant and MISO to better use the BESS, resulting in more income to the District, this benefit should be considered. Currently, Alliant Energy does not have an ADMS (advanced distribution system management system) that could interact with a BESS.

Alliant Energy's scenario 1 uses an intertie relay set at 400 kW-ac, that would limit the PV/BESS system's export to 400 kW-ac. Alliant has limited the export on solar PV systems three times in Wisconsin. One such project is at the Deerfield School District[25] done in 2018/2019 at a cost of about $25,000 for a 450 kW-ac PV system (no batteries). This cost is very site specific and may not be applicable to the DCSD.

Alliant is concerned about system islanding.[26] This would increase risk to utility personnel and the public who think the grid is down and not energized. Alliant would prefer that the PV systems use the same inverters.

Conversion to Heat Pump HVAC and Water Heating Systems

The innovative aspect of heat pump systems for HVAC and domestic water heating is that they are highly efficient and provide a pathway for curtailing the use of natural gas

[24] Jim Krier on August 27, 2019
[25] Source: Cal Couillard, personal communication.
[26] I.e., the PV system unexpectedly continuing to operate when the grid goes down.

and its associated carbon emissions.[27] Heat pump systems are run on electricity, which can be supplied by the grid or in the case of net zero energy schools by on-site solar PV or from the BESS. While the US DOE provides a definition of zero energy that would allow for natural gas use, if that use is all off-set by on-site renewable export of energy[28], as a practical matter that is unlikely to be possible in Wisconsin. Serving electrical utilities in many cases would object to significant net annual electricity exports from a customer. Furthermore, other zero energy building programs such as the New Buildings Institute and the Living Building Challenge do not allow natural gas or other fossil use in their zero energy certification programs.

There is a recent trend towards geothermal (aka ground sourced heat pump) systems in new K-12 Schools in Wisconsin. This is particularly evident in the Madison area considering recent or current construction in the Sun Prairie, Verona, Oregon, and Middleton School Districts. The existing Madison West High School was recently converted to geothermal. Attention is also being given to high efficiency air sourced heat pump systems because they provide a lower first cost for a heat pump system because a well field or pond loop is not required. Air sourced heat pumps are not as efficient in severely cold temperatures as geothermal systems, perhaps below 10° F, resulting in higher electricity use and operating costs in the coldest weather. It is unknown if air sourced heat pumps have yet been applied to larger new schools in Wisconsin.

If an existing school has geothermal or air-sourced heat pump systems, it would be a natural candidate for the addition of PV and BESS to achieve zero energy. The potential impediments to the zero energy goal include if the existing roofs are aged and would need replacement within say 10 years and if there is not enough land available for ground-mounted PV arrays.

The Darlington HS and EMS present a challenge common to many existing schools in Wisconsin. They need to convert to geothermal (aka air source heat pumps) if they are to be fully zero energy under the New Buildings Institute definition. The conversion to a geothermal system will come at a cost. The other choice is to continue natural gas heating and implement zero energy on the electric side only, noting that electricity use is the majority of energy operation cost and carbon emissions. This would achieve a

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27 Hanson, Mark. The Inevitable Solar School: Building the Sustainable Schools of the Future, Today, Rowman & Littlefield, 2019.

28 USDOE-EERE, A Common Definition of Zero Energy Buildings, September 2015.

considerable reduction in carbon emissions, but would not bring the schools to net zero energy and net zero carbon.

At the HS, the conversion to geothermal is possible, but the question is at what additional cost. And will the additional cost offset the potential NPV of adding zero energy solar PV and batteries? It is beyond the scope of this study to estimate the cost of a geothermal conversion. There are, however, some general observations that can be provided that inform this question.

- The age and condition of the existing HVAC systems impacts how the cost of the geothermal conversion is assessed. If an existing HVAC system is relatively old and uses a non-condensing boiler, then the school will be facing a partial system replacement in any event.

- If the existing HVAC system does not provide air conditioning, then the cost of including air conditioning is added to the renovation cost (if air conditioning is desired). Air conditioning is a feature of a geothermal system as it provides both heating and cooling. It is worth noting that the percentage of Wisconsin schools with air conditioning continues to increase over time, with most new schools and additions include air conditioning.

- If there is both the need to update the HVAC system and the desire to include air conditioning in a school, the incremental cost of conversion to geothermal relative to a system renovation cost with air conditioning provided with a chiller will be less than in the cases where no replacement was needed or where replacement is needed but air conditioning is not chosen.

- Another consideration that alters the incremental cost of adding geothermal is whether the school needs an addition. Due to enrollment increases, the DCSD is beginning the planning for a potential addition. This may provide an opportunity to consider a geothermal system for a new addition, and expand the system sizing to serve the existing High School.

All of these conditions will have an impact on the cost of upgrading a schools HVAC system to geothermal. Under the most favorable conditions including:

- An HVAC renovation is required
- Air conditioning is included
- An addition will be built

The incremental cost of including geothermal will be minimized or eliminated.

For a broad context on cost, the cost of a new 100,000 square foot school in Wisconsin in on the order of $25 to $30 million. The approximate cost of a geothermal HVAC system for a new 100,000 square foot school is approximately $4.5 to $5.0 million. Of this cost, the well field cost is about $600,000 to $1,000,000.

The retrofit cost of an existing HVAC system depends on the type and condition of the existing HVAC system, and which elements need to be addressed.

4. Methodology

"Prediction is very difficult, especially if it's about the future." - Niels Bohr
And even more difficult if the prediction looks forward 25 years.

This analysis uses realistic assumptions. All assumptions are clearly presented. The assumptions are critical to and determine the results. Thus, please review and consider them carefully.

Assumptions such as the PV and BESS price, amount of the Focus on Energy grant, year-one insurance costs, year-one generation, and utility interconnection costs can be more precisely determined after bidding and design of the PV and BESS, and the interconnection studies are completed.

Perhaps the largest unknowns are:

- The future value of the solar energy produced and demand savings
- The future value to the electric grid of the BESS
- The BESS's capital cost

Sensitivity and Scenario Analysis are provided to show the impact of changes to the single key assumptions (Sensitivity analysis) and a group of assumptions (Scenario analysis) on the project's financial metrics.

Computer models calculate numbers to many decimal points. In reality, many of the assumptions used here have uncertainty ranges.

Models

Helioscope

Helioscope is a model provided by the private sector and used by many PV project developers. It was used to determine array obstacle shading and self-shading estimates, do the preliminary physical design and the preliminary array siting on the

DCSD campus. Helioscope was also used to checking some of SAM's solar PV assumptions, and SAM's annual PV system performance estimates.

System Advisor Model (SAM) and PV Watts Calculator

SAM is the primary modeling tool used for this feasibility study. SAM was developed by the National Renewable Energy Laboratory (NREL) to perform technology and economic modeling to help facilitate decision-making across the renewable energy field.[29] It combines the latest data from databases such as California Energy Commission (CEC) list of approved solar equipment, NREL's National Solar Radiation Database (NSRDB) for potential solar resources and weather files among others and has been updated regularly to include new technologies. SAM is also capable of pre-determined or custom system controls and battery dispatch tools, which is key for understanding the proportional sizing of each component of a zero-energy building while still using actual 15-min load data from the existing facility. SAM was also our primary tool for checking variations in physical design, sizing and financial arrangement. Solar sizing and performance were checked and adjusted using Helioscope, although it is possible to have done this in SAM. SAM comes with default values for all inputs but can be adjusted for the specific characteristics of the project being modeled.

A key part of the decision to use SAM, in addition to its source at NREL, was that it is free to use. This means that any school district, municipality or other entity can model their own scenarios using the parameters outlined in this report or with other variations in technology or economic approaches. Ultimately, professionals will determine the final designs and sizing for any given project, but for initial analysis, it is possible to get useful estimates.

PV Watts Calculator is another NREL tool developed to provide solar professionals an easy way to estimate possible solar resources for a given site and array type and size. Because all of the calculator's functionality is built into SAM already, PVWatts was primarily used as a quick estimator during initial setup of our model and as a reference tool throughout.

[29] The feasibility study would not have been possible without the help the SAM team and SAM forum moderators.

Darlington High School Options

Base Conditions

Net Zero Electric School

The HS currently uses approximately 400,000 kWh/year including power provided by its on-site solar PV system. The peak demand is approximately 165 kW.

Net Zero Energy School

Assuming the HVAC is converted to a ground-sourced heat pump, to meeting space heating, water heating and air conditioning needs, electricity needs increase to approximately 660,000 kWh/year with peak demands of 200 kW.

Adding batteries results in conversion losses of about 4.8% per year for all of the power stored by the battery. The operation of the BESS uses approximately 2,500-3,000 kWh annually. This is the standard assumption used by SAM.

Scenarios and Assumptions

The input assumptions, data and parameters are described generally for all model runs and then by the financial approach: direct purchase or TPP. System parameters and SAM inputs are combined below. Additional detail is provided for year-one and ongoing indirect costs as well as solar PV modeling variables.

Primary Model Inputs and Parameters

	Darlington High School Existing System and Use	
Solar	78	kW-dc
Annual Building Load	400,000	kWh
Grid Dependent Load	316,000	kWh
Peak Demand	165	kW

	Net Zero Energy HS		
Zero Energy Building Load	660,000	kWh	
Geothermal HVAC Peak Demand	200	kW	
	Physical Design		
Location	42.65 Lat, 90.14 Long		
Module	Canadian Solar 370 Watt DC		
Inverter	SolarEdge 100 kW-ac		
Orientation	1. Due south facing 10° tilt angle, EMS roof mount 2. Due south 70° tilt, ground mount 3. south 20° east facing with 70° tilt, ground mount		
Battery			
	Round-trip Efficiency: 90%		
	Losses	Ground Mount	Roof Mount
	Tilt angle	10°	70°
Soiling/snow[30]	Jan	40%	10%
	Feb	40%	10%
	Mar	10%	2%
	Apr	2%	2%
	May	2%	2%
	Jun	2%	2%
	Jul	2%	2%
	Aug	2%	2%
	Sep	2%	2%
	Oct	2%	2%
	Nov	10%	2%

[30] Monthly snow-cover and soiling loss estimates (estimated by the study team). Shown as the share of the month the array is 100% covered by snow/soiling. Based on combination of SAM model and Darlington performance data from existing array.

	Dec	30%	10%

Total System Losses[31]	17%
Module Degradation	0.5%/year
Limiter[32]	$20,000
Analysis Period	25 years
Solar PV Installed Cost $/kW-dc	$1,450
BESS Installed Cost $/kWh	$800
O&M Price	Solar: 0.45% of installed cost/year Battery: $3/kWh of installed cost/year
PV System Direct Cost	Included in the $1,450/ kW-dc price: $140/kW-dc Labor $300/kW-dc Balance of System $700/kW-dc Installer Margin and Overhead 4% for contingency
BESS Replacement Costs	
Total Indirect Costs	

Financial Parameters

Inflation Rate	2.5%	
Host Real Discount	2%	nominal: 4.55%
Insurance	0.35% of installed PV and BESS cost	
Tenure	25 Years	
PV Equipment Replacement Reserve	$0.0033/watt-year	
Rate Schedule	Alliant Energy Commercial Time-of-Use Cg-2 TOD (Three Phase)	
Energy cost inflation (kWh and kW)	2.5%/year	

[31] Includes all soil, snow and shading loss including electronics and standard system losses from SAM and Helioscope.

[32] Only for Net Zero Energy scenarios.

	Battery Operation
Storage Dispatch Controller	Peak Shaving 1-Day look ahead
Charge Limits	Maximum 100%
	Minimum 25%
Replacement Schedule	N/A
Battery Efficiency	90%
	Revenue
Average kWh sell rate	$0.035/kWh
Grid support (frequency)	$18/MW per hour availability

Additional Inputs Direct Purchase by the District

Inflation Rate	2.5%		
Host Real Discount	2%	Nominal: 4.55%	
Bonds	3.0% Range: 1.5% to 3%		
Approx. Debt Percentage	90%		
Tenor	25 Years		
Cost of Acquiring Financing	Included in the Total Indirect Cost		
PV Focus Incentive	$50,050 - $73,500[33] Focus on Energy does not provide incentives for BESS		
	BESS Storage Operation and Revenue		
Grid Support Availability	92% average availability		
Battery Charging	PV & Grid		
Year 1 Battery Revenue:	Direct	92% of $1.8/100 kW/hr=	$ 14,542
		92% of $3.6/200 kW/hr=	$ 28,996

[33] Focus on Energy Prescribed Incentive Program as expected. Currently the exact details of the new (2020) incentive program are not known. It is likely to use a sliding scale depending on PV system's size, and cover 10% to 12% of PV system's cost, which this study assumes.

Additional Inputs TPP

Inflation Rate	2.5%		
PPA Price Escalation[34]	2.5%		
Project (developer) Real Discount	3%	nominal: 5.57%	
Host Real Discount	2%	nominal: 4.55%	
State income tax rate	5%		
Federal Income tax rate	27%		
Debt service coverage ratio	1.3		
Annual Interest Rate	5.5%		
Cost of Acquiring Financing	Included in Indirect Costs		

Tax Benefits

Fed Investment tax credit		26%
Depreciation Treatment[35]	Fed: 5-yr MACRS State: 5-yr MACRS	
Depreciable Allocation	98%	
Bonus Depreciation	100% of 5-yr MACRS	

Storage Operation and Revenue

Average Grid Support Availability	84%
Battery Charging	PV Only

Battery Operation and Revenue

Grid Support Availability	84% average availability		
Grid Charging	No		
Year 1 Battery Revenue:[36]	TPP	84% of $1.8/100kW/hr=	$13,228
		84% of	$ 26,455

[34] Inflation does not apply to PPA price.

[35] Though the treatment is noted in SAM as 5-yr MACRS, all of it qualifies for bonus appreciation of 100% in the first year.

[36] TPP grid support revenue is considered taxed at normal rates.

$3.6/200kW/hr=

Upfront and Ongoing Costs

Costs determined by a percentage of project costs are based on total project cost without contingency. Where noted, costs apply to only TPP. Otherwise they apply to both financial approaches. Some costs only apply to scenarios that include BESS.

Indirect Upfront Cost		
Legal	$5,000	TPP only
Accounting	$750	TPP only
General liability insurance	0.46%	
Construction loan	1%	
Permits	$1,000	Fixed
Prop insurance	0.30%	
Utility Fee	$250	Fixed
Development fee	7%	TPP only
Consulting grants, RFP	$10,000	Fixed
Consulting battery	$5,000	BESS only
Limiter	$20,000	Net Zero Energy Scenarios only

Ongoing System Costs		
Year 1-2		
O&M PV	0.45%	
O&M Battery	$3/kWh Size	BESS only
Insurance Prop and GL	0.08%	
Tax Prep	$2,500	TPP only
Other Years		
O&M PV	0.45%	
O&M Battery	$3/kWh Size	BESS only
Insurance Prop and GL	$1,000	
Tax Prep	$1,050	TPP only

Costs Not Considered:

- Extended warranty for inverters
- Unusual Alliant interconnection costs beyond limiter
- Local government costs including staff, consultants, legal review, etc.
- Large unforeseen site expenses (e.g., electrical panel/system upgrade, remedying roof structural issues, etc.)

Note: Contingency is not included in calculating percentage-based cost items (e.g., insurance costs).

Additional Rate and Tariff Detail

Alliant Electric Rates [37]

Current Rate Structure: CG-2 TOD Commercial Service – Time of Day, three phase service. For customers with a maximum demand greater than 75 kW (but less than 200 kW) 8 out of 12 months or whose annual energy use exceeds 250,000 kWh.

Customer Charge: $1.15 per day.

Figure 20: Electricity Rates for Electricity Usage (kWh)

Rate	($/kWh)		
High Rate	0.082	Business days	Summer: 11 am to 7 pm Winter: 5 pm to 9 pm
Regular Rate	0.060	Business days	all other business day hours
Low Rate	0.0471	Business days	11 pm to 6 am
		Weekends and holidays	All day

Demand (kW) Charges

[37] Accessed on December 10, 2019; Comments and reformatting included by authors; Link: https://www.alliantenergy.com/-/media/Alliant/Documents/CustomerService/AlliantEnergyService/RatesandTariffs/WisconsinElectricRates/Wisconsinelectricscheduleofrates.pdf

- On-peak Demand Charge: $11.42/kW during on peak period from On-peak: 10 am to 10 pm on business days (highest on peak demand in pervious billing cycle)
- Customer (or Annual) Demand Charge: $2.20/kW (highest demand in previous 11 billing cycles)

There are two components of an electric bill that vary with a site's power use:

- Electricity usage charge—measured in kilowatt hours (kWh), which is the amount of electricity used over the billing period
- Electricity demand charge—measured in kilowatts (kW), which is the site's peak electricity use during any 15-minute period over the last month (during on peak periods) and during the last year during (during on and off-peak periods)
- The demand charges can account for 25% to 40% of the total electric bill.

Parallel generation rate: Parallel generation in excess of 100 kW-ac - PgS-1

Facilities charge

- Systems rated between 20 and 200 kW-ac: $0.3205/day
- Systems rated 200 kW (AC) or greater: $0.6411/day

Figure 21. Electricity Rates at Secondary Voltage for Solar Power Generation Delivered to the Alliant Grid (what the customer is paid for power put onto the grid during any 15-minute period

	($/kWh)		
High Rate	0.0415	Business days	Summer: 11 am to 7 pm Winter: 5 pm to 9 pm
Regular Rate	0.0314	Business days	all other business day hours
Low Rate	0.0247	Business days	11 pm to 6 am
Low Rate	0.0247	Weekends and holidays	All day

Capacity Credit equals (X *365)/4342

- Where X is the most recent year's MISO capacity auction results for the relevant load zone on a kW cost per day basis for the high, and regular rate periods
- The capacity credit is calculated each year. Its future value is unknown.
- The 2019 capacity credit was 0.1 cents/kWh

Darlington High School Net Zero Electric Array Scenarios

Figure 22. Share of the High School's PV System in Each Orientation (Share of total generation kWh) for a Net Zero Electricity School.

Array Racking and Orientation	Share of Total kWh Generated
Flat Roof Sited, Due South 10° Tilt	60%
Ground Mounted, South 10° East 70° Tilt	19%
Ground Mounted, Due South 70° Tilt	21%
Total	100%

Figure 23. Capacity (kW-dc) of the PV Arrays. Based on annual generation values shown above (Figure 22) for a Net Zero Electricity School.

Array Racking and Orientation	Total Module Rated Capacity (KW-dc)
Flat Roof Sited, Due South 10° Tilt	214.6
Ground Mounted, South 10° East 70° Tilt	66.6
Ground Mounted, Due South 70° Tilt	74.4
Total	355.6

PV Array Siting Options

Figures 24 and 25, present two very preliminary array-siting options. Both options site the HS's roof mounted PV array on the flat unobstructed roof of the EMS. The EMS roof is relatively new, flat and easily accessible, while the HS roof is complex and with limited flat areas. Note, that each of the ground arrays are composed of two rows of PV modules, each row is two PV modules wide in portrait orientation, and the rows are 50 feet apart. The 50-foot row spacing reduces row-on row shading in the winter and late and early in the day when the sun is low on the horizon (and solar power is expected to have higher value).

Figure 24. High School PV arrays all sited on EMS roof and northeast of HS building.

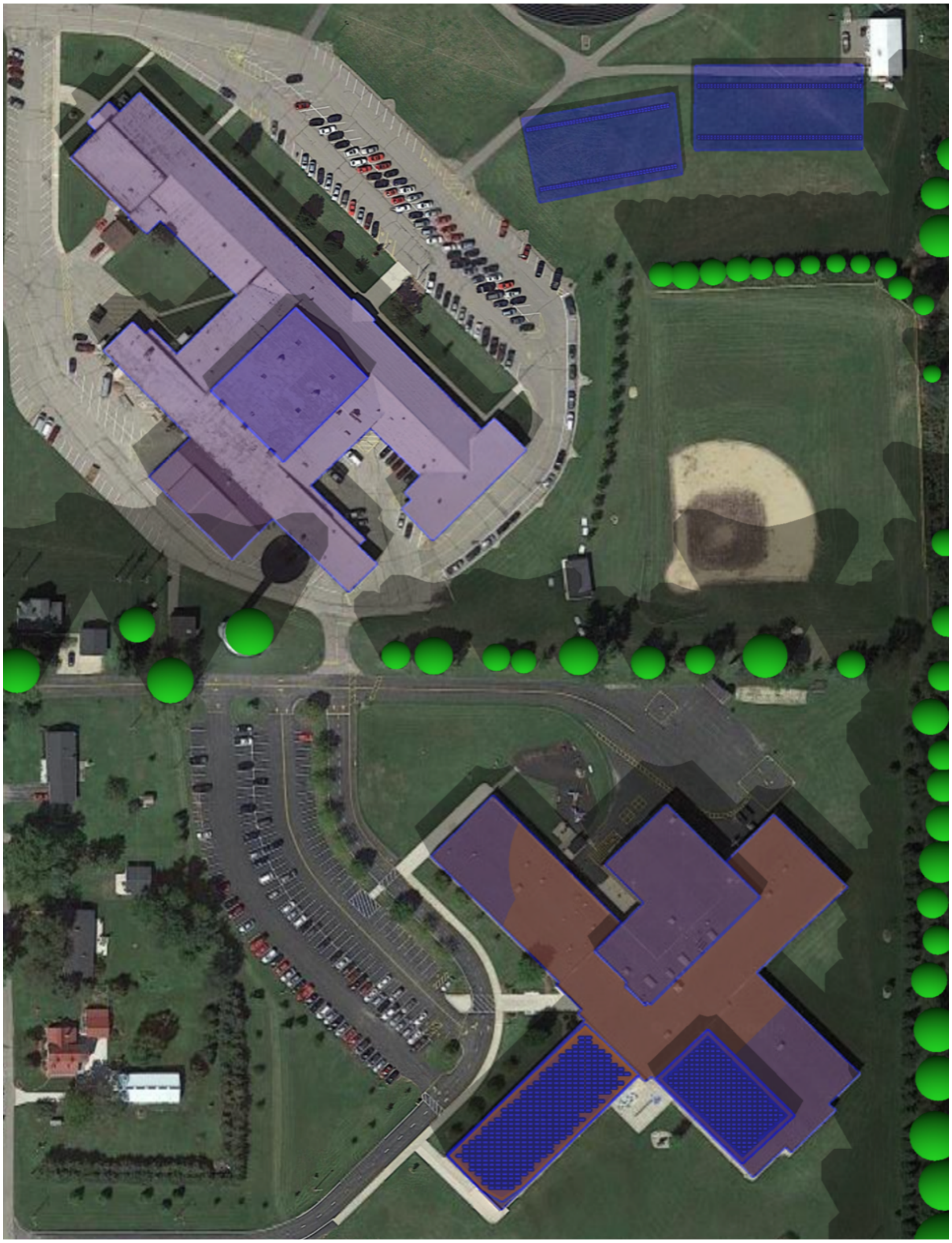
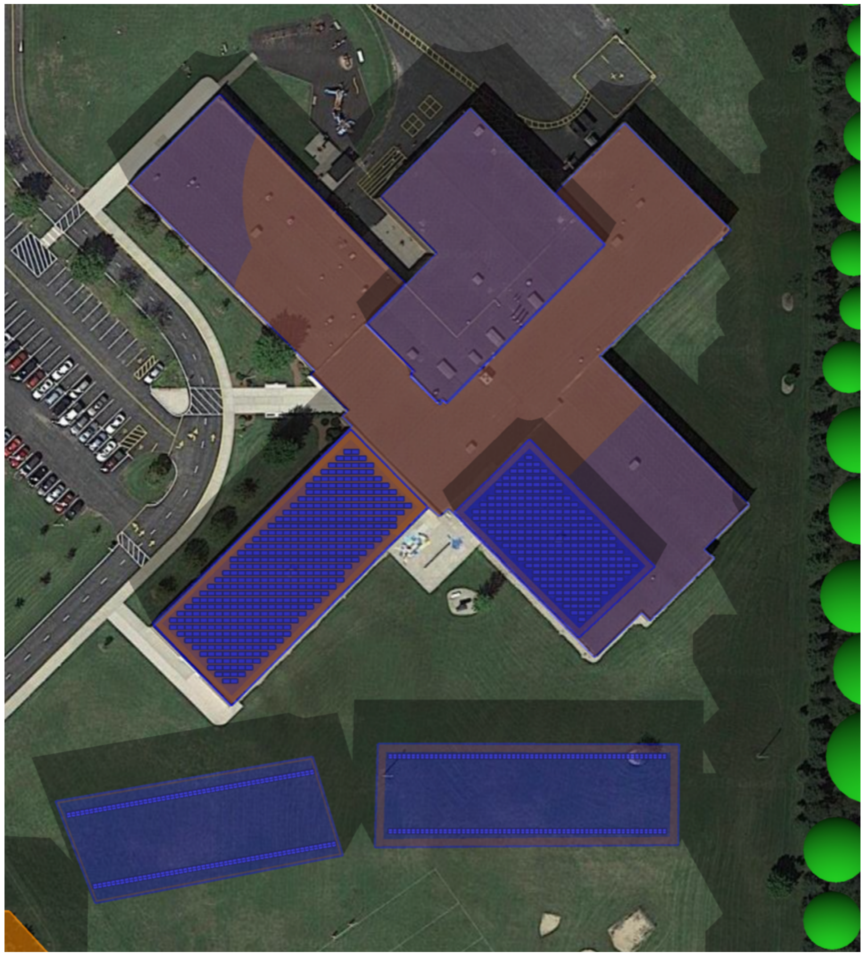


Figure 25. High School PV arrays all sited on and around the EMS. The new rooftop PV array is sited on the SW portion of the EMS roof.[38]



- PV System Components Used in Modeling
    - Roof arrays
        - Modules: Canadian Solar 370 Watts-dc
        - Inverters: SolarEdge 99.9 kW-ac
            - Optimizers: SolarEdge P370I
        - Orientation: due south facing, 10° tilt from the horizontal
        - Ground coverage ratio: 0.67
    - Ground arrays
        - Modules: Canadian Solar 370 Watts-dc
        - Inverters: SolarEdge 99.9 kW-ac
            - Optimizers: SolarEdge P370I

[38] Orientation is with due north at top for all top down images.

- Orientation:
  - Due south facing, 70° tilt from horizontal
  - South 20° east, 70° tilt from horizontal
- Ground coverage ratio: 0.20

- Shading estimates from Helioscope
  - Existing roof array
    - Row on row shading and obstacle shading: 1.2%
    - Snow cover and soiling: 7.2%
    - Total shading: 8.1%
  - New roof array
    - Row on row shading and obstacle shading: 0.9%
    - Snow cover and soiling: 7.2%
    - Total shading: 8.4%
  - South facing ground array
    - Row on row shading and obstacle shading: 5.4%
    - Snow cover and soiling: 3.5%
    - Total shading: 8.9%
  - Southeast facing ground array
    - Row on row shading and obstacle shading: 4.8%
    - Snow cover and soiling: 3.5%
    - Total shading: 8.3%
- PV System output degradation: .05%/year

Helioscope estimate of kWh/kW-dc for each array type, assuming 100 kW-ac inverter.

- Existing roof array: 1290.9 kWh/kW-dc
- New roof array: 1292.8 kWh/kW-dc
- South facing array: 1221.6 kWh/kW-dc
- Southeast facing array: 1215.7 kWh/kW-dc

- Solar resource data - Used in SAM
  - National Solar Radiation Database (NSRDB) Physical Solar Model (PSM) version 3, Typical Meteorological year (TMY)3 data solar radiation data.[39] Data from 20-year period from 1998-2017.[40]

[39] Accessed on December 1, 2019; Link: https://nsrdb.nrel.gov/about/u-s-data.html

- Using NSRDB database, solar and weather files were pulled from DCSD location

Discussion of Critical Parameters

Revenues and Incentives

Direct Purchase by the District and TPP ownership are different primarily in the areas of incentives and revenues. At the time of this report, only the direct purchase scenarios include Focus on Energy grant. The impact of the grants has a significant positive impact on the results.

Ownership also impacts how the BESS is operated. Under TPP, it is more beneficial to charge the battery only with the PV system, thus qualifying all BESS costs for the 26% tax credit in 2020 but not allowing for energy arbitrage. While under direct ownership the BESS system can be used for arbitrage (generating additional savings). Note that under TPP ownership, after the 5-year ITC vesting period, the BESS can be used for arbitrage however this was not modeled but would positively impact NPV.

TPP ownership also impacts the performance of the BESS, as it will have fewer charging cycles, resulting in a decreased average state of charge, from 92% (with direct ownership with PV and grid charging) to 84% (with TPP ownership with only PV charging). This means a decrease in possible grid support revenue and a shorter battery life. However, receiving the ITC on the battery provides better NPV for TPP scenarios.

Limiter/Direct Transfer Trip

The limiter's upfront capital cost impacts net zero energy scenarios' economics. The limiter is not required for school's net zero electric scenarios because the sizing of the PV system is below the threshold determined by Alliant for DCSD. Alliant determines restriction by the local distribution grid's capacity. In the future, there may be lower

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[40] More on using solar resource data for solar energy application: Sengupta, Habte, S.Kurtz, A.Dobos. Best Practices Handbook for the Collection and Use of Solar Resource Data for Solar Energy Applications. February, 2015.

cost solutions to limiting a PV system's output to the grid as behind the meter applications grow in number and capacity.

Critical Assumptions

BESS Revenue Sources

Revenue from grid support services is crucial for positive economic returns. A net positive NPV can be achieved for a direct purchase of PV without BESS. The NPV is much larger if a BESS is included with grid support revenue. A positive NPV can only be reached for a direct purchase net zero energy school if BESS with grid support revenue is included.

The assumed $18/MW per hour revenue for the BESS is assumed to be eligible by increments of 100 kW-ac of BESS storage. It is also assumed that the battery can be optimized for multiple revenue sources at once. Grid support revenue must be re-evaluated for each project as revenues are clearly defined by the BESS capacity and availability.

Grid support revenue is modeled to decline with battery degradation by 2.5% per year.

Wisconsin Regulatory Conditions regarding Third Party Investment

The legality of TPP is currently in limbo in Wisconsin. As noted elsewhere, TPP acceptance is currently determined on a utility-by-utility basis. Because of the proliferation of TPP across the US, and its established use at DCSD, we included it in the modeled scenarios[41]. If TPP grows in availability and flexibility in Wisconsin, it should result in the increased adoption of solar PV and BESS systems. However, its popularity will also depend on the future ITC level. Current system costs cannot be support by TPP at a 10% ITC level, which is the level under the existing IRS rules in 2022. As the ITC has been extended numerous times. Its future level is to be determined.

[41] Accessed on December 12, 2019; link: https://www.seia.org/initiatives/third-party-solar-financing.

Alliant Energy Distribution Feeder Limitations

Feeder limitations will vary depending on geographic location of the school. Darlington's schools are located in an area with limited feeder capacity for distributed energy resources (DER) and thus are confronted with the need for limiters or communication system upgrades. In other locations around the state, schools will be able to add sufficient PV capacity needed to reach net zero electric/energy levels without needing expensive grid upgrades or system limiters.

A difficulty in modeling PV/BESS systems that require a limiter is the lack of established precedents in Wisconsin. The $20,000 limiter cost estimate used in this study is based on a previous non-publicly disclosed limiter installation, and conversations with Alliant. The cost estimate is uncertain. Each zero energy project needs to determine if a limiter is needed, if other options are available, and what the interconnection costs are.

5. Findings

Model Results

Results are presented for both net zero electric school and a net zero energy school. The results are broken down by two primary factors:

- Storage: with and without the BESS
- Financing: direct purchase or TPP

Because DCSD HS already has 78-dc kW of solar, each scenario is also presented with existing PV system as well as if the school had no existing PV system.

For the modeling that includes the existing 78 kW-dc PV system, the impact on the HS's demand is left as is and the existing PV system's cost is removed. The existing PV system is included in the model to ensure that the batteries are appropriately modeled and scheduled. For modeling the HS power use that does not include the existing PV system, the PV system's generation is netted out leaving the HS's true use and load.

Scenarios

The NPV's for the mix of cases considered are summarized in Tables 1 and 2.

Table 1. DCSD School District's Economics for a Net Zero Electricity School (based on the Darlington High School). Assumes HVAC system is not converted to and electric geothermal (aka heat pump) system.
The detailed results of each scenario are provided in Annex 3.

High School with pre-existing 78 kilowatt (kW) direct current (dc) of PV	School District's NPV	Net Capital Cost
Direct Purchase Without BESS	$12,451	$389,732
Direct Purchase With BESS	$87,899	$564,287
TPP Without BESS	($27,355)	$473,897
TPP With BESS	($50,016)	$638,832
High School without pre-existing PV		
Direct Purchase Without BESS	($66,739)	$506,263
Direct Purchase With BESS	$22,651	$680,818
TPP Without BESS	($99,089)	$598,141
TPP With BESS	($115,176)	$763,076

Table 2.[42] A School District's Economics for a Net Zero Energy School (based on the Darlington High School). Does not include the cost of the electric geothermal (or heat pump) HVAC system.

High School with pre-existing 78 kW-dc PV	School District's NPV	Net Capital Cost
Direct Purchase Without BESS	($98,498)	$750,784
Direct Purchase With BESS	($15,933)	$1,080,442
TPP Without BESS	($134,229)	$868,132
TPP With BESS	($193,228)	$1,233,529
High School without pre-existing PV		
Direct Purchase Without BESS	($170,529)	$866,382
Direct Purchase With BESS	($80,463)	$1,197,991
TPP Without BESS	($208,953)	$993,462
TPP With BESS	($261,614)	$1,359,002

The detailed results of each scenario are provided in Annex 4.

Further Discussion

A few conclusions can be drawn from the analysis results. Project economics are improved for the Darlington HS's particular situation when:

- Some of the PV is already purchased
- The project includes a BESS
- The project is owned by the school district (i.e., direct ownership)
- The project's goal is zero net electricity rather than extending to zero net energy

The main reasons for these findings are:

- The BESS provides real savings, some income, and significantly reduces the amount of power delivered to the grid at avoided cost
- When the district owns the project, interest rates are lower, the battery is used for arbitrage, the project qualifies for the Focus on Energy grant, and the TPP fees/costs are avoided
- Going large, for the zero net energy project, incurs a higher interconnection cost related to the necessity of the limiter. Note this is very site specific as it depends on the local distribution grid's capacity

[42] Both tables also appear in executive summary.

Impact of Direct Purchase and TPP on Financial Return

TPPs cannot use the full functionality of the BESS. A TPP owned BESS can charge only from solar (if they want the full ITC for the BESS). This results in less grid support revenue due to the different use of the battery and reduced average state of battery charge. Also, TPP ownership has other costs including legal costs, accounting fees, the TPPs profit and fees, etc., which are not incurred by direct PV system owners. The TPPs financing interest rate is also typically higher. And as noted, TPP's are not eligible for the Focus on Energy incentive under the 2019 rules.

6. Conclusions and Recommendations

The central question of the feasibility study is whether it is financially feasible for the DCSD to implement zero energy at the HS and/or the EMS at the present time or within the next few years. This question is of interest to the DCSD specifically but is of broader interest to other public and private schools in Wisconsin and beyond. For schools such as the HS and EMS, this is both a matter of education in STEM and other disciplines, as well as preparing students for the burgeoning job market in renewable energy. It may also be a means of reducing cost of operation.

As discussed below, the answer to the central question is "yes" for net zero electricity and not quite for net zero energy based on the assumptions used.

There are dozens of specific assumptions, as described in this report, that form the basis of this study. They include inflation rates, discount rates, interest rates on school bonds, PV system costs, battery costs, O&M costs, battery life, etc. Of these assumptions, a few stood out to us as uncertain and critical to these findings. These are as follows:

- The revenue under MISO rules from grid support services provided by the battery. The MISO rules were initially to be issued in December 2019 but have since been delayed until December 2020. Lacking this guidance and how it is implemented by Alliant Energy and MISO, this study used estimates based on information provided by a BESS currently operating in the Commonwealth Edison service territory, which operates within the PJM ISO. The sources of uncertainty include:
    - Reliability of estimates
    - Stability of estimates over time noting how dynamic the market is anticipated to be
    - Likelihood that Alliant/MISO payments will be similar to PJM ISO payments
- The cost of BESS. The BESS price used in the study was based on a recently priced BESS in Wisconsin and a recent estimate from a Wisconsin battery source. Battery prices are falling. Thus, the cost assumption used in this study could be higher than warranted.

- The Alliant tariff schedule over the next 25 years. This is difficult to estimate, especially as utilities respond to large changes in the electricity market place including: increased generation from renewable resources, increased use of electric vehicles and electric heating, the adoption of electricity storage systems and climate change. Both the pricing and structure of electric rates may change dramatically.
- Interest rates on school bonds. Interest rates are at very low levels approaching 2.5%.

In each of these areas of uncertainty, conservative assumptions are used to provide a sober rather than an optimistic assessment. For example, while interest rates for school bonds have been recently been close to 2.5%, this study assumes 3.0%. Similarly, while battery costs are declining based on market reports and discussion with two providers, the BESS costs used in this study are on based on experience with BESS orders or quotes in the later months of 2019. Finally, NPV values are calculated for a 25-year life-cycle analysis although the PV and BESS systems are anticipated to be in operation longer than that.

Darlington Community Schools

The study estimates that the HS can invest in a solar system including BESS that will result in a positive NPV using a 25-year lifecycle analysis. The highest NPV is provided for the net zero electricity scenario with BESS when recognizing the existing solar PV system. The baseline used for comparison is continuing to purchase power from Alliant Energy. This finding is based on conditions and assumptions of 2019.

In the case of net zero energy (rather than net zero electricity), the NPV is slightly negative even without costs associated with conversion of the HVAC system to geothermal (aka, ground sourced heat pump system). The DCSD will want to compare the incremental cost of a geothermal system to serve a potential new addition and the existing HS (or the EMS), relative to the cost of a more standard HVAC system upgrade. It can then weigh the incremental cost of geothermal systems versus a natural gas HVAC upgrade along with the NPV estimates in this study.

The NPV estimates for the solar PV systems with and without the BESS are summarized in Tables 1 and 2. As noted in the tables, the NPVs assume 1) the existing 78 kW-dc solar PV is in place, or 2) the entire PV system is purchased. The purchase of the entire PV system (ie.no existing system is in place) case is presented to be representative of schools considering solar PV and batteries without any pre-existing PV investments, which represents most Wisconsin schools.

As can be seen in the tables, the best financial results for DCSD for obtaining net zero are the options with the direct purchase of the combined solar PV and BESS systems. The NPV value, in the case of net zero energy with the geothermal conversion, is just below a positive NPV when the value of the existing 78 kW-dc of solar PV is accounted for. In the case where all the PV system is purchased for this school (i.e. the existing 78 kW-dc is purchased), the NPV drops to negative $80,463.

Using TPP investors substantially reduces the estimated NPV. This reflects two current issues with TPP investors. First, as of 2019, the Wisconsin Focus on Energy RECIP program does not provide PV system incentives if TPP investors are used. Second, the third party investment would restrict the use of BESS for arbitrage such as buying low cost power overnight to store in the BESS and use that power during the next day to limit peak demands. For the current federal tax credit of 30% (2019) and 26% (2020) to apply to the BESS at the full credit, the BESS must be charged with the solar power. As Wisconsin Focus on Energy as well as federal tax credit rules continue to change, the rules need to be monitored to determine the best approach for school to implement solar and battery systems.

A similar result with respect to direct purchase relative to TPP investors is found for the cases where net zero electricity is the goal (i.e., meeting the existing electrical use only). In other words, the HS remains with natural gas for heating. This results in a smaller solar PV and BESS system. The NPV in the case of direct purchase with a BESS exceeds $87,000. Without BESS, the direct purchase NPV is reduced to $12,000. If the existing 78 kW of solar was not in place, the direct purchase NPV for solar and battery is about $22,600.

The financial advantage of direct purchase rather than TPP is shown by the NPV estimates with TPP investors for solar and BESS for meeting existing annual electrical use and recognizing the existing 78 kW-dc of solar. The NPV falls to negative $27,000. If all new solar was included in the costs, the NPV drops to almost negative $99,000.

In summary, DCSD has options for the HS for net zero electricity with positive NPV for meeting the current electrical demand. There are no NPV positive options at net zero energy size of solar PV and BESS systems using third party investors. The results indicate that including batteries in a direct purchase provides higher NPV values.

A direct purchase by the District eliminates all but the final technical and cost issues related to the grid interconnection. The value of grid support services and income should become clearer when FERC rules are announced and implemented by MISO. Other solar PV/BESS options exist at levels short of net zero electricity and should also be considered.

Wisconsin Schools

The study results for the Darlington High School have broad implications for other public and private schools in Wisconsin. Many energy efficient new schools in Wisconsin built with a geothermal HVAC system will be able to include solar PV and BESS to achieve net zero energy performance at a positive NPV over a 25-year life-cycle analysis. These schools will likely be more efficient than an existing school and will not typically face the limiter requirement at Darlington HS. A financial assessment is required in each case to provide a more site and situation specific estimates. The positive NPV values are small, but are expected to increase in the future especially as the cost of batteries decline (as anticipated). Grid support revenue trends should also be watched closely. The positive NPV's do not account for the educational benefits of having solar PV and BESS systems at a school. No accounting is made for reducing externality costs. As evidence of the emerging interest in zero energy, a new zero energy elementary school is currently being constructed by the Oregon School District in Fitchburg, WI.

Existing schools present a more complicated situation with respect to achieving zero energy on a positive financial basis using NPV as the measure. The example of Darlington High School suggests that many existing schools could at least provide for net zero in meeting their electrical needs while remaining with a natural gas fired HVAC system. The main question is the availability of roof and/or land for ground mounted solar PV. If the roof on an existing school is aging (I.e., over ten years old), then it does not make financial sense to locate solar on the roof until the roof is replaced. For some schools, the path forward will be to wait until a new roof is installed. The added weight of a roof mounted solar PV system is typically less than 5 pounds per square foot and therefore rarely a structural issue. A structural engineer should always verify this. If land is not available, and the school does not want to consider solar covered parking, which adds to the PV system cost (but does provide other benefits), then zero energy solar with a positive NPV is unlikely.

Darlington High School has the benefit of large available new roof area (on the adjacent EMS) as well as some land area for ground mounted PV arrays.

Considering these general conclusions for Wisconsin schools, it is important that each school evaluate their specific energy use data, plans for changes in energy use patterns due to planned efficiency improvements and school additions if any, roof and site conditions, specific utility rules and rate schedules, and available incentives. Seemingly small changes to one or more of these conditions may make zero energy a possibility. These conditions continually change and evolve.

There are a few patterns that are notable with respect to zero energy school prospects.

Although TPP investment approaches resulted in negative NPV's in the cases considered here, it could play an important role if Wisconsin Focus on Energy incentives were equally available to TPP investment, if the 30% ITC is extended, and as other costs drop. At the present time, TPP investment in the form of energy service agreements is not feasible in WE Energies service territory. They have been approved in the last few years with Municipal Utilities in the WPPI network, Alliant Energy, and MGE. While leases have been approved in the Xcel service territory, current rules for public school districts appear to restrict schools from the lease approach. The ability to use energy service agreements in the WPS service territory is not known. Policy recommendations for TPP are provided in the next section.

This is an important topic as direct purchase is not possible in many school districts given debt ceilings or what voters are willing to fund. TPP investment enables the monetization of tax credits available to for profit entities. The use of TPP investment continues to be a changing landscape and needs to be ascertained for each site.

Direct solar PV and BESS purchases are currently allowed in all of Wisconsin for schools. With low financing costs hovering around 2.5%, this is an attractive time to consider financing solar and BESS projects. Schools will have to verify their bonding capacity and the interest of voters in supporting referendums when required. The challenges of going to tax payers for permission to investment in PV and BESS are a major barrier for many school districts. Wisconsin Focus on Energy grants are available for direct purchase situations. Grants were not available for third party funded systems in 2019.

For the most part, Wisconsin has very low net metering thresholds for commercial customers including schools. Somewhat of an exception, however, is WE Energies with a 300 kW-ac threshold.[43] This threshold may enable mid-sized and large schools to invest in solar on quite financially attractive terms, but monthly rules regarding load input and building usage, block small schools from approaching zero energy and still net meter.

National/International

Many states and other countries are more accommodating of on-site solar and batteries for schools than Wisconsin. If net zero energy schools are feasible for some schools in Wisconsin, prospects are even better in many other states and nations. The main factors to consider include:

TPP Investment

Many states such as California support TPP investment in a variety of forms such as PPA (power purchase agreements), leases, and energy service agreements. Increasing numbers of schools are employing this tool to reduce their energy costs and to avoid borrowing for direct purchase. Third party options also allow the ability to outsource ongoing solar and battery operations for a period of time (until purchase or transfer of ownership) or permanently.

High Net Metering Limits

Some states have high net metering limits. Discovery Elementary School in Virginia for example is a net zero energy school using geothermal HVAC systems and on-site solar of almost 500 kW-dc. The net metering thresholds and rules need to be verified for each location, but usually provide considerable financial advantage. In some instances, it will alter the value of having BESS.

Grid Support Payments

[43] We Energies' 300 kW-ac net metering tariff does not share any of the demand benefits of PV system with the customer rather only the kWh savings are valued at the customer's retail rate.

One element of this study is assessing the grid support service revenue from the battery. The model used is based on PJM ISO, which covers a large portion of the east coast and the Chicago area. Revenue from grid support is an important option to consider in battery decisions as it provides revenue beyond the simple storing of solar power for later use and arbitrage.

Utility Rates and Incentives

Utility rates vary widely across the US and internationally. The higher the electric rates, the more attractive solar PV and battery systems become. Areas with particularly low rates perhaps due to large hydro in the region will reduce the financial performance of solar and battery systems unless there are incentives to overcome this barrier.

Insolation and Weather

The solar resource varies considerably across the US and globally. Modeling tools account for geographic location, and varying snow cover, and obviously need to be modeled for the school location.

7. Wisconsin Policy Recommendations

Schools are a great place to install solar PV and BESS because:

- With reduced electricity costs (i.e., operating costs) additional funds are available for other operating cost needs, such as teacher salaries and building maintenance
- Schools are full of Wisconsin's future leaders, tax-payers and hardworking citizens
- The school's curriculum can leverage the school's PV/BESS system by educating students about energy, environment, technology, financing, climate, etc. There are and will be many business opportunities and jobs in the renewable energy sector.
- During the summer when schools tend to be less used, school sited PV and BESS can generate power and grid services to support the utility grid when it is most needed.
- School serve as community centers and often serve as shelters in times of crisis, so increasing their energy reliability is beneficial

If Wisconsin wants to emphasize solar PV at schools and net zero schools, a few policy changes would make siting and investing in PV and BESS at schools easier:

State support to school districts for implementing solar PV, BESS and net zero schools

Wisconsin could develop a road map, goals and perhaps requirements for schools to adopt PV and BESS systems. The Office of Sustainability and Clean Energy and other state offices, institutions and organizations could provide technical assistance. The State could also provide co-funding through the Focus on Energy program and other resources such as the Energy Innovation Grant Program

Raising the net metering/net energy billing caps

About half of the states allow net metering of 500 kW-ac PV systems at commercial buildings. A 200 kW-ac to 600 kW-ac PV system (depending on the school's size and use) is likely to meet all the power needs of most Wisconsin schools. Simply allowing school PV systems to net meter would avoid the need for and cost of the BESS, and unusual PV array orientations.

At schools, which commonly have limited summer use, much of the excess solar generation would be delivered to the grid during summer days. Today, this is also when Wisconsin's electric utility grid is experiencing peak demands and the highest cost to provide electricity service. The excess solar from a net metering school PV system could be of significant value to the grid (as well as auxiliary services provided by smart PV inverters).

Allowing aggregated (also known as community or virtual) Net Metering

With aggregated net metering all of a school district's electric meters could be aggregated (i.e. combined) and their use offset by one or more net metering renewable energy systems. This, for example, allows a school district to site solar PV or wind at one site, and use that generation to offset the electricity use of other meters. This would work particularly well for school districts with multiple sites, some of which are constrained and some open. Constrained sites include schools that have two or more stories, busy or complicated roof, or other issues that limit siting solar directly on school buildings or their grounds.

Valuing grid services provided by BESS and smart inverters

School PV and BESS systems can provide high value grid services. FERC Order 841 could be implemented by MISO, and Wisconsin utilities, as soon as possible and in a fair manner that recognizes the value of grid services provided. This would be for all grid services provided by BESS and smart inverters. The Wisconsin PSC could encourage this market by requiring that Wisconsin electric utilities fully support FERC Order 841 and the MISO Rules.

In addition, the PSC could require that the electric utilities develop rates that pay the owners of smart inverters for providing grid services. This also includes using electric utility's advanced distribution management systems (ADMS) to manage, operate and optimize the BESS and smart inverter provided grid services.

Third party completing the interconnection and distribution studies, and determining the interconnection requirements and costs

For new PV and BESS systems, standardized rules and procedures are needed for completing the interconnection and distribution system studies. The studies should be done by a third party in a consistent manner and overseen by the PSCW. Currently, each utility company does the studies or an engineering firm hired by the utility. It is not clear what the procedures and rules are used and to what extent they are consistent and self-serving.

To project developers, grid upgrades required by utilities to interconnect PV and BESS projects can often seem unreasonable and costly. Some customers are disappointed that they pay for grid upgrades when the utility then often owns the upgrades.

Utility interconnection costs are typically determined relatively late in the project development process. A method of estimating these costs early in the process would be helpful, along with an explanation of why the grid upgrade was necessary.

The capacity value of utility-owned solar generation should be the same or similar to the capacity value of customer-owned/sited solar generation

Currently the capacity value of solar PV if owned by an electric utility is 36 times greater than the capacity value of the DCSD's PV system. MISO's estimate of the long-term capacity value of solar PV generation is referred to as Cost of New Energy or "CONE" and was recently $87,000 MW/year.[44]

On a per kWh of solar generation basis this is $0.03625/kW-hr. (Based on the MISO's 50% capacity factor for PV systems[1] and assuming PV annual generation of 1200 kWh/kW-dc).

Meanwhile, under the Alliant Energy PgS-1 rate capacity valued is based on the annual average capacity value for the high and regular rate periods during the previous year. In 2019 value is 0.1 cents/kWh and is adjusted each year, so its future value is unknown. This is Alliant's estimate of the short-term capacity value of solar PV generation.

[44] Accessed on December 8, 2019; links: https://cdn.misoenergy.org/2019%20Wind%20and%20Solar%20Capacity%20Credit%20Report303063.pdf; https://cdn.misoenergy.org/20190412_PRA_Results_Posting336165.pdf

PV systems are a long-term technology, with an expected life of at least 25 years, customer sited PV and utility owned PV should be treated similarly using long-term capacity values (i.e., CONE values).

Allowing Third Party Ownership

The Federal ITC and State and Federal accelerated depreciation can reduce the cost of a PV system by 50% to 60%. Since school districts do not pay taxes, they can't avail themselves of these benefits. In a sense a school district has to pay almost three times more for the PV system than a for profit business.

However, when a tax paying third party owns the PV system at a school district, it can receive the tax benefits and pass them on to the district. This financing structure is known as third party financing or ownership. Third party ownership is not currently clearly legal in Wisconsin.

Allowing Leases

Wisconsin electric utilities seem to be OK with leases (a form of third party ownership) for PV/BESS systems. However, not for profit organizations and public institutions, such as a school district, IRS rules and Wisconsin regulations make leases very difficult, if not impossible. To meet IRS requirements the school district would likely need to form a for-profit limited liability corporation. This has not been done in Wisconsin and may not be legal. If the PSCW is unwilling to allow simple third party ownership at Wisconsin school districts, then State including the DPI (Department of Public Instruction) it could investigate the IRS's leasing requirements to identify a clear path for school districts to lease PV/BESS systems.

Increasing Focus on Energy funding

The Focus on Energy incentive budget and incentive levels are declining and increasingly difficult to obtain. Given that schools, and other not for profit owners, cannot used the available tax benefits, Focus on Energy should consider funding schools separately and at a higher level than for-profit owned PV/BESS systems which have significant tax advantages.

When Focus on Energy determines the value of PV and BESS systems and determines the funding levels for Focus on Energy, the grid benefits of smart inverters and paired BESS should be considered.

8. Annexes

Annex 1. Smart Inverters, Energy Storage and Grid Services

In past the "grid" wanted PV systems to trip out during grid events, now the grid increasingly wants them to stay online and provide support services.

Smart Inverters

Almost all of the inverters sold today are "smart inverters" but the standards for smart inverters are still evolving. Smart inverters can provide grid support services including[45]:

- Anti-Islanding Protection
- Low and High Voltage Ride-Through
- Low and High Frequency Ride-Through
- Dynamic Volt-Var Operation
- Ramp Rates
- Fixed Power Factor
- Soft Start Reconnection

When providing these services, the kWh output of the PV system is reduced, so PV system owners should be compensated.

In recognition of the potential grid benefits, in 2018, Illinois offered a $250/kW incentive for new PV projects that use smart inverters. Some utilities are beginning to develop special smart inverter rates (e.g., Pennsylvania).

In the near future, smart inverter owners could be compensated for the grid support services provided by their inverters and for allowing the utility to control their inverters.

One of the main technical barriers to the utilities' use of smart inverters is the required smart and secure communications and control protocol.

[45] Source: https://smartgrid.ieee.org/newsletters/june-2019/california-utilities-define-new-smart-inverter-capabilities

Customer Sited Electricity Storage Systems

Similarly, electricity storage systems can provide many services that are of value to the electric grid. These services include[46]:

- Transmission and Distribution Infrastructure Services
  - Transmission upgrade deferral
  - Distribution upgrade deferral
- Bulk Energy Services
  - Arbitrage
  - Peak shaving
- Ancillary Services
  - Voltage control
  - Voltage rise mitigation
  - Black start
  - Voltage flicker mitigation
  - Frequency regulation
  - Frequency response
  - Spinning reserve
- Renewable Integration
  - Ramp rate control
  - Export limiting
  - Renewable firming
- Customer energy management services
  - Retail energy time shift
  - Power quality
  - Demand charge management
  - Demand peak lopping
  - Islanding

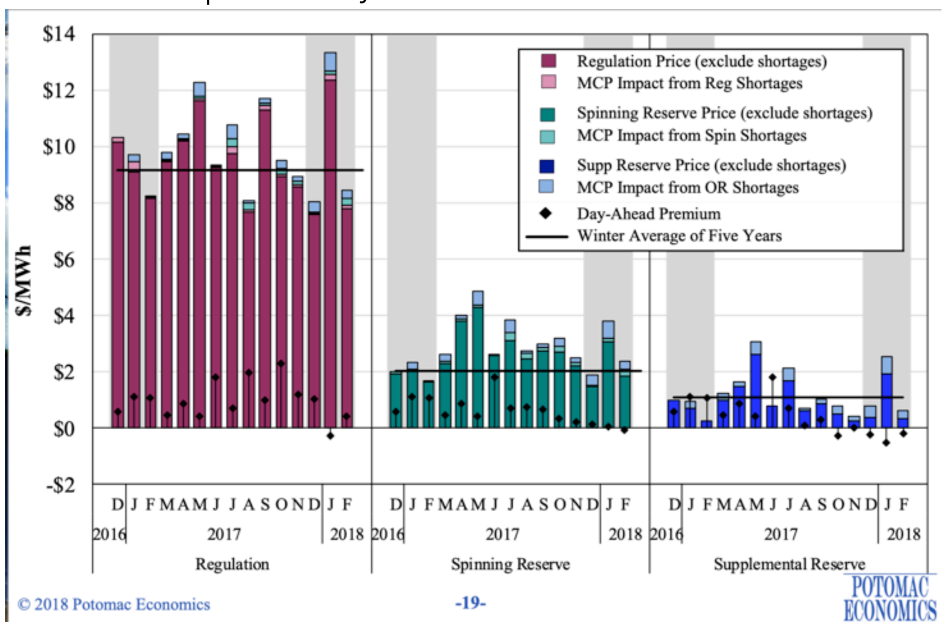
In the PJM transmission grid (which include parts of Illinois) electricity storage system owners are being paid for:

- Reducing PJM's peak demand charges
  - The battery system provides power to PJM during the few days and hours each year that the PJM determines their demand charges for the utility company (e.g., Commonwealth Edison)
  - The battery owner is paid by their local distribution utility (e.g., Commonwealth Edison) to reduce their demand charges from PJM
- Frequency regulation services

[46] Accessed on December 10, 2019; link: https://rules.dnvgl.com/docs/pdf/DNVGL/RP/2015-12/DNVGL-RP-0043.pdf

Before the FERC rules implementation, MISO's Values for Ancillary Services from December 2016 to February 2018[47] are: Regulation: ~$9/MWh, Spinning Reserve: ~$2/MWh, Supplemental Reserve: ~$1/MWh.

Figure A1.1 Example ancillary service values. Source Potomac Economics



These prices are before the implementation of FERC' 841. MISO should compensate storage at higher levels than shown above because of its fast response (compared to natural gas generation and other "slow" assets).

By Providing Grid Support Services, Battery Systems Can Make Economic Sense

Early indicators of the economics of customer-sited grid-interactive battery systems, include:

- In the PJM ISO, customer-sited battery systems are getting income from multiple income streams[48]:
  - Transmission (PJM) peak demand savings
  - Peak capacity savings
  - Solar REC credits
  - Usage (kWh) offset
  - PJM frequency regulation services

[47] Accessed on November 15, 2019: https://cdn.misoenergy.org/2018%20IMM%20Quarterly%20Report%20Winter162312.pdf
[48] Source: John Kivlin and Steve Johnson, Convergence Energy

    - Resulting in payback periods of about 4 years
- Similar customer-sited battery systems, that provide and monetizing some of these services, are now being developed in Wisconsin (e.g., at a school, clinic, factory, and brewery)
- "Their (i.e., battery system) economics pencil out" with Federal incentives – but require income from providing grid services[49]
- Micro-grids can also be viable for resilience[50]:
    - Providing a Wisconsin health clinic two hours of time to wind down their patient services and keeping their refrigerators operating
    - Providing backup power to a brewery that could lose $250,000/event from a power outage

Risks of Customer-Sited, Grid-Interactive Battery Systems

Storage systems and grid service markets are new and thus have significant risks, including.

- Financial: The estimated value of many services is based on either not yet operating or very new spot markets. Thus, making both financing projects and forecasting income difficult
- Financial: Spot markets prices can change very quickly, particularly for new markets using rapidly improving technologies with high or uncertain adoption rates
- Technology: Storage/battery systems are still new, and changing quickly
- Technology: Communication and control systems and proto calls, linking the battery systems to the local utility and MISO, are new and may change
- Policy: MISO, and Wisconsin utilities seem to be slow to embrace the FERC rules on electric storage participation in regional ISO ancillary service markets
- Policy: MISO and utility policies/rules can change and may adversely affect the project's income

[49] Ibid.

[50] Ibid.; A backup generator could also provide these services.

Annex 2. Bifacial PV Modules on a Vertical PV Fence

Bifacial PV modules have a clear back (either glass or polymer) and are able to generate power on both their front and backsides. They typically have longer, 30-year, production guarantees and are made by dozens of manufacturers. They are expected to meet 10% of the market's needs in 2020.

The backside commonly generates about 80% of the front side under optimal conditions (the ratio between the maximum back and front generation is called the "bifaciality factor"). The backside's actual generation is dependent on how:

- The back of the PV module is shaded by the racking
- The junction boxes on the back of the module are sized and positioned
- Open the back of the racking system and site is, to allow reflected light to strike the back of the PV module
- The albedo (aka reflectivity) the surface (roof or the ground) is. Example albedos include:
    - New snow: 90%
    - Old snow: 60%
    - White roof: up to 90%
    - Green grass: 25%
    - Dry grass: 33%
    - Humid soil: 15%

Recent studies have found that standard array designs with bifacial modules increase the output by only 1.7% and at a maximum 3% to 7%.

This study considered bifacial arrays that are vertical, run east west, and widely spaced, and thus not shading each other early and late in the day, on school grounds. They can be called PV fences. A vertical bifacial array/fence is not limited by being under a PV array facing downwards, and thus albedo of the ground surface, and the openness of the racking system. This study is most interested in winter generation PV generation when there may be snow on the ground and the vertical array is unlikely to be snow covered.

The table below shows the annual generation, as modeled by PVWatts, of different array orientations sited in Darlington WI. Note, that the bifacial fence has high annual power generation but low winter generation when compared to steeply tilting or vertical southeast, south and southwest facing arrays. Thus, it was not considered for further analysis.

Table A2.1. Monthly and annual solar generation for one kW-dc of PV modules sited in Darlington WI., sited at different orientations Source PVWatts, assumptions: no soiling, no shading, no reflection, premium PV modules, 14.08% losses.

	Flat Roof Due South 10° Tilt	North-South Fence Bifacial	South 15° East 70° Tilt	South 15° West 70° Tilt	Due South 70 ° Tilt	Due South 90° Tilt
January	35	63	87	91	91	86
February	44	79	94	94	96	86
March	100	117	112	112	114	93
April	123	128	103	103	102	75
May	146	150	104	101	101	67
June	150	158	95	97	95	59
July	155	164	103	106	103	66
August	140	147	110	110	109	76
September	117	126	115	116	116	92
October	89	97	111	112	114	99
November	56	66	97	97	100	92
December	34	52	80	79	81	77
Annual	1189	1347	1211	1218	1222	968

Annex 3. Analysis Results for a Net Zero Electric School

Darlington High School with pre-existing PV

Direct Purchase Without Battery	
Metric	Value
Annual energy (year 1)	448,458 kWh
Capacity factor (year 1)	14.4%
Energy yield (year 1)	1,262 kWh/kW
Performance ratio (year 1)	0.80
Levelized COE (nominal)	6.53 ¢/kWh
Levelized COE (real)	4.96 ¢/kWh
Electricity bill without system (year 1)	$35,840
Electricity bill with system (year 1)	$12,675
Net savings with system (year 1)	$23,165
Net present value	$12,451
Simple payback period	17.4 years
Discounted payback period	NaN
Net capital cost	$389,732
Equity	$0
Debt	$389,732

Direct Purchase with Battery	
Metric	Value
Annual energy (year 1)	446,662 kWh
Capacity factor (year 1)	14.3%
Energy yield (year 1)	1,257 kWh/kW
Performance ratio (year 1)	0.79
Battery efficiency (incl. converter + ancillary)	92.61%
Levelized COE (nominal)	6.79 ¢/kWh
Levelized COE (real)	5.16 ¢/kWh
Electricity bill without system (year 1)	$35,840
Electricity bill with system (year 1)	$7,068
Net savings with system (year 1)	$28,771
Net present value	$87,899
Simple payback period	15.1 years
Discounted payback period	23.2 years
Net capital cost	$564,287

Equity	$0
Debt	$564,287

TPP Without Battery	
Metric	Value
Annual energy (year 1)	448,458 kWh
Capacity factor (year 1)	14.4%
Energy yield (year 1)	1,262 kWh/kW
Performance ratio (year 1)	0.80
PPA price (year 1)	5.58 ¢/kWh
Levelized PPA price (nominal)	7.08 ¢/kWh
Levelized PPA price (real)	5.44 ¢/kWh
Levelized COE (nominal)	6.83 ¢/kWh
Levelized COE (real)	5.25 ¢/kWh
Developer net present value	$14,099
Host net present value	$-27,355
Host indifference point (year 1)	5.17¢/kWh
Levelized host indifference point (nominal)	6.73¢/kWh
Levelized host indifference point (real)	5.11¢/kWh

TPP with Battery	
Metric	Value
Annual energy (year 1)	446,722 kWh
Capacity factor (year 1)	14.3%
Energy yield (year 1)	1,257 kWh/kW
Performance ratio (year 1)	0.79
Battery efficiency (incl. converter + ancillary)	91.48%
PPA price (year 1)	6.59 ¢/kWh
Levelized PPA price (nominal)	8.35 ¢/kWh
Levelized PPA price (real)	6.42 ¢/kWh
Levelized COE (nominal)	7.52 ¢/kWh
Levelized COE (real)	5.78 ¢/kWh
Developer net present value	$47,417
Host net present value	$-50,016
Host indifference point (year 1)	5.97¢/kWh
Levelized host indifference point	7.66¢/kWh

(nominal)	
Levelized host indifference point (real)	5.82¢/kWh

Net Zero Electric School without pre-existing PV or BESS

Direct Purchase Without Battery	
Metric	Value
Annual energy (year 1)	448,458 kWh
Capacity factor (year 1)	14.4%
Energy yield (year 1)	1,262 kWh/kW
Performance ratio (year 1)	0.80
Levelized COE (nominal)	8.22 ¢/kWh
Levelized COE (real)	6.25 ¢/kWh
Electricity bill without system (year 1)	$44,636
Electricity bill with system (year 1)	$19,979
Net savings with system (year 1)	$24,657
Net present value	$-66,739
Simple payback period	20.6 years
Discounted payback period	NaN
Net capital cost	$506,263
Equity	$0
Debt	$506,263

Direct Purchase With Storage	
Metric	Value
Annual energy (year 1)	446,743 kWh
Capacity factor (year 1)	14.3%
Energy yield (year 1)	1,257 kWh/kW
Performance ratio (year 1)	0.79
Battery efficiency (incl. converter + ancillary)	92.43%
Levelized COE (nominal)	8.48 ¢/kWh
Levelized COE (real)	6.45 ¢/kWh
Electricity bill without system (year 1)	$44,636
Electricity bill with system (year 1)	$14,235
Net savings with system (year 1)	$30,402
Net present value	$22,651
Simple payback period	17.0 years

Discounted payback period	NaN
Net capital cost	$680,818
Equity	$0
Debt	$680,818

TPP Without Storage	
Metric	Value
Annual energy (year 1)	448,458 kWh
Capacity factor (year 1)	14.4%
Energy yield (year 1)	1,262 kWh/kW
Performance ratio (year 1)	0.80
PPA price (year 1)	6.80 ¢/kWh
Levelized PPA price (nominal)	8.63 ¢/kWh
Levelized PPA price (real)	6.64 ¢/kWh
Levelized COE (nominal)	8.32 ¢/kWh
Levelized COE (real)	6.40 ¢/kWh
Developer net present value	$17,824
Host net present value	$-99,089
Host indifference point (year 1)	5.50¢/kWh
Levelized host indifference point (nominal)	7.16¢/kWh
Levelized host indifference point (real)	5.44¢/kWh

TPP With Storage	
Metric	Value
Annual energy (year 1)	447,057 kWh
Capacity factor (year 1)	14.4%
Energy yield (year 1)	1,258 kWh/kW
Performance ratio (year 1)	0.79
Battery efficiency (incl. converter + ancillary)	91.83%
PPA price (year 1)	7.81 ¢/kWh
Levelized PPA price (nominal)	9.90 ¢/kWh
Levelized PPA price (real)	7.62 ¢/kWh
Levelized COE (nominal)	9.00 ¢/kWh
Levelized COE (real)	6.93 ¢/kWh
Developer net present value	$51,151

Host net present value	$-115,176
Host indifference point (year 1)	6.27¢/kWh
Levelized host indifference point (nominal)	8.19¢/kWh
Levelized host indifference point (real)	6.23¢/kWh

Annex 4. Analysis Results for a Net Zero Energy School

Darlington High School with pre-existing PV

Direct Purchase Without Battery	
Metric	Value
Annual energy (year 1)	738,223 kWh
Capacity factor (year 1)	14.4%
Energy yield (year 1)	1,262 kWh/kW
Performance ratio (year 1)	0.80
Levelized COE (nominal)	7.44 ¢/kWh
Levelized COE (real)	5.73 ¢/kWh
Electricity bill without system (year 1)	$56,661
Electricity bill with system (year 1)	$19,957
Net savings with system (year 1)	$36,704
Net present value	$-98,498
Simple payback period	20.8 years
Discounted payback period	NaN
Net capital cost	$750,784
Equity	$0
Debt	$750,784

Direct Purchase with Battery	
Metric	Value
Annual energy (year 1)	729,264 kWh
Capacity factor (year 1)	14.2%
Energy yield (year 1)	1,247 kWh/kW
Performance ratio (year 1)	0.79
Battery efficiency (incl. converter + ancillary)	82.13%
Levelized COE (nominal)	7.73 ¢/kWh
Levelized COE (real)	5.95 ¢/kWh
Electricity bill without system (year 1)	$56,661
Electricity bill with system (year 1)	$13,388
Net savings with system (year 1)	$43,273
Net present value	$-15,933
Simple payback period	17.9 years
Discounted payback period	NaN

Net capital cost	$1,080,442
Equity	$0
Debt	$1,080,442

Third Party Purchase Without Battery	
Metric	Value
Annual energy (year 1)	738,223 kWh
Capacity factor (year 1)	14.4%
Energy yield (year 1)	1,262 kWh/kW
Performance ratio (year 1)	0.80
PPA price (year 1)	6.05 ¢/kWh
Levelized PPA price (nominal)	7.68 ¢/kWh
Levelized PPA price (real)	5.90 ¢/kWh
Levelized COE (nominal)	7.40 ¢/kWh
Levelized COE (real)	5.69 ¢/kWh
Developer net present value	$25,758
Host net present value	$-134,229
Host indifference point (year 1)	4.97¢/kWh
Levelized host indifference point (nominal)	6.47¢/kWh
Levelized host indifference point (real)	4.92¢/kWh

TPP with Battery	
Metric	Value
Annual energy (year 1)	731,086 kWh
Capacity factor (year 1)	14.3%
Energy yield (year 1)	1,250 kWh/kW
Performance ratio (year 1)	0.79
Battery efficiency (incl. converter + ancillary)	86.05%
PPA price (year 1)	7.26 ¢/kWh
Levelized PPA price (nominal)	9.20 ¢/kWh
Levelized PPA price (real)	7.08 ¢/kWh
Levelized COE (nominal)	8.24 ¢/kWh
Levelized COE (real)	6.34 ¢/kWh
Developer net present value	$89,388
Host net present value	$-193,228

Host indifference point (year 1)	5.84¢/kWh
Levelized host indifference point (nominal)	7.44¢/kWh
Levelized host indifference point (real)	5.65¢/kWh

Net Zero Energy School
Darlington High School without pre-existing PV

Direct Purchase Without Battery	
Metric	Value
Annual energy (year 1)	738,223 kWh
Capacity factor (year 1)	14.4%
Energy yield (year 1)	1,262 kWh/kW
Performance ratio (year 1)	0.80
Levelized COE (nominal)	8.46 ¢/kWh
Levelized COE (real)	6.51 ¢/kWh
Electricity bill without system (year 1)	$64,814
Electricity bill with system (year 1)	$26,694
Net savings with system (year 1)	$38,120
Net present value	$-170,529
Simple payback period	22.7 years
Discounted payback period	NaN
Net capital cost	$866,382
Equity	$0
Debt	$866,382

Direct Purchase With Battery	
Metric	Value
Annual energy (year 1)	729,512 kWh
Capacity factor (year 1)	14.2%
Energy yield (year 1)	1,247 kWh/kW
Performance ratio (year 1)	0.79
Battery efficiency (incl. converter + ancillary)	82.16%
Levelized COE (nominal)	8.77 ¢/kWh
Levelized COE (real)	6.75 ¢/kWh
Electricity bill without system (year 1)	$64,814
Electricity bill with system (year 1)	$19,317

Net savings with system (year 1)	$45,497
Net present value	$-80,463
Simple payback period	19.2 years
Discounted payback period	NaN
Net capital cost	$1,197,991
Equity	$0
Debt	$1,197,991

Third Party Purchase Without Battery	
Metric	Value
Annual energy (year 1)	738,223 kWh
Capacity factor (year 1)	14.4%
Energy yield (year 1)	1,262 kWh/kW
Performance ratio (year 1)	0.80
PPA price (year 1)	6.81 ¢/kWh
Levelized PPA price (nominal)	8.63 ¢/kWh
Levelized PPA price (real)	6.64 ¢/kWh
Levelized COE (nominal)	8.32 ¢/kWh
Levelized COE (real)	6.40 ¢/kWh
Developer net present value	$29,502
Host net present value	$-208,953
Host indifference point (year 1)	5.16¢/kWh
Levelized host indifference point (nominal)	6.72¢/kWh
Levelized host indifference point (real)	5.11¢/kWh

Third Party Purchase With Battery	
Metric	Value
Annual energy (year 1)	731,838 kWh
Capacity factor (year 1)	14.3%
Energy yield (year 1)	1,251 kWh/kW
Performance ratio (year 1)	0.79
Battery efficiency (incl. converter + ancillary)	86.97%
PPA price (year 1)	8.01 ¢/kWh
Levelized PPA price (nominal)	10.15 ¢/kWh
Levelized PPA price (real)	7.81 ¢/kWh
Levelized COE (nominal)	9.15 ¢/kWh

Levelized COE (real)	7.04 ¢/kWh
Developer net present value	$93,179
Host net present value	$-261,614
Host indifference point (year 1)	6.05¢/kWh
Levelized host indifference point (nominal)	7.74¢/kWh
Levelized host indifference point (real)	5.88¢/kWh

Annex 5. Financial Analysis Definitions

Simple Payback Period

- Defined as: The system cost less all incentives, including depreciation benefits, divided by year one bill savings
- Does not include maintenance, insurance, output degradation, increased value of power production, etc.

Years to Cost Recovery

- The year the system's cumulative cash flow goes positive
- Includes: electric price changes, output degradation, maintenance and insurance costs, etc.

Internal Rate of Return (IRR)

- Definition 1: The actual return provided by the project's cash flows
- Definition 2: The interest rate at which the net present value of all the cash flows (both positive and negative) from a project or investment equal zero
- Can be used to compare other investment returns

Discounted Net Present Value (NPV)

- The difference between the discounted value of cash inflows and the discounted value of cash outflows
- Discounting uses the discount rate, the discount rate is
    - The percentage that each future year's cash inflows and outflow are reduced to reflect the time value of money

Annex 6. Additional Technology Information

Solar Photovoltaic (PV) Systems - Basic Information

- No moving parts and low maintenance needs
- Modules have a 25-year warranty (to produce 80% of their rated capacity)
- Inverters typically have a 10 or 15-year warranty
- Racking systems typically have a 15 to 25-year warranty
- With regular maintenance and as needed inverter replacements solar PV system should have a 30 to 40-year life
- The National Electric Code includes solar PV systems
- All key components are UL certified
- Many highly qualified licensed electricians with PV certification are available to design, specify, and install solar PV systems to code
- Solar modules are made of the high-strength glass and are rated for hail
- Property insurance policies cover solar PV systems

Battery Systems – Basic Information

- No moving parts and low maintenance needs
- Battery chemistry modeled: lithium ion: nickel magnesium cobalt oxide
- AC connected for greater utility in grid support services
- DC connected can be used if prioritizing PV-battery charging
- 88% round-trip efficiency
- Enclosed and minimal footprint
- -22oF to 122F operating temperatures