Middleton—Cross Plains
Area School District
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Middleton-Cross Plains Area School District Energy Plan

December 31, 2023

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EXECUTIVE SUMMARY

Energy costs are often one of the largest operating costs for a school district. Implementing energy cost reduction strategies to lower operating costs and carbon emissions has long been a priority for Middleton-Cross Plains Area School District.

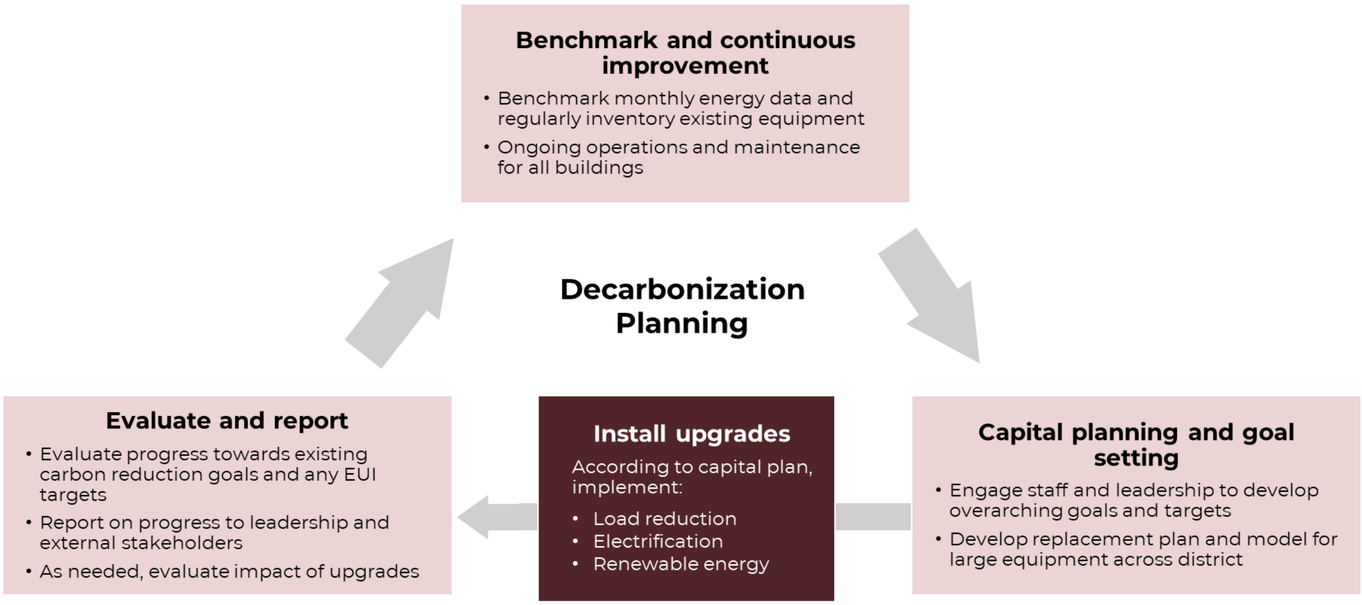
As a next step in its sustainability progress, Monona Grove School District (MGSD), Sun Prairie Area School District (SPASD), Oregon School District (OSD), and Middleton-Cross Plains School District (MCPASD) partnered to collaborate on a joint energy planning project. The project was funded by the Office of Energy Innovation and the goal of the collaborative project was to develop an actionable decarbonization framework while learning best practices from and alongside one another.

Over the last year, the school districts partnered with local nonprofit, Slipstream, to develop decarbonization plans for current school district operations. The joint energy planning project process included baseline data collection and benchmarking, analysis of energy efficiency, electrification, and renewable energy opportunities for the districts, development of recommendations for ongoing data tracking and reporting, and identification of funding sources for implementation.

As each of the school districts has already made significant strides in reducing energy use and started a transition to renewable energy, the planning process focused on full decarbonization, or elimination of carbon dioxide emissions, for buildings and fleet.

Figure 1 provides an overview of the decarbonization framework that guided the development of this plan for MCPASD. The framework includes a series of steps: benchmark energy data and continuous improvement, capital planning and goal setting, install projects, and evaluate and report. These steps work together as a phased implementation approach to decarbonization.

Figure 1. Overview of decarbonization pathway



Understanding current energy use, energy costs, and CO_2 emissions, as well as existing systems, and replacement ages is an important first step in decarbonizing school operations. Table 1 details the CO_2 emissions, energy costs, and total energy use for each of MCPASD's buildings. The costs are based on average energy use charges and do not represent exact 2021 costs.

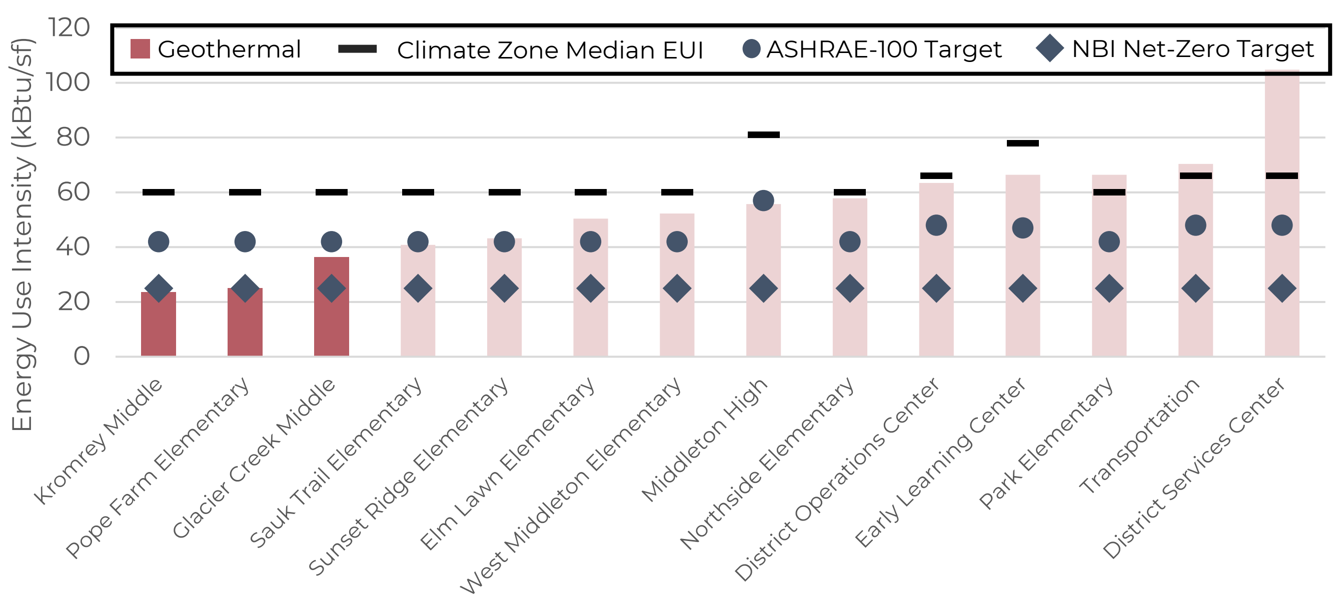
Table 1. Annual CO_2 emissions, energy costs, and energy use across MCPASD buildings (2021 data)

Building	CO_2 Emissions (MT)	Energy Costs	Energy Use (kBtu)
Middleton High School	3,092	$554,430	32,430,500
Kromrey Middle School	954	$180,930	5,956,550
Glacier Creek Middle School	683	$125,640	5,811,930
Pope Farm Elementary School	443	$83,900	2,822,120
Northside Elementary School	339	$60,740	3,556,760
Elm Lawn Elementary School	321	$57,710	3,293,040
Park Elementary School	307	$54,590	3,395,290
Sunset Ridge Elementary School	292	$52,520	2,989,320
West Middleton Elementary School	286	$51,180	3,038,320
Sauk Trail Elementary School	247	$44,630	2,473,660
District Services Center	211	$38,290	2,023,250
District Operations Center	146	$26,120	1,595,760
Transportation	98	$17,620	1,025,960
Early Learning Center	97	$17,120	1,092,110
Total	**7,516**	**$1,365,420**	**71,504,570**

Site energy use intensity (EUI) is a metric that shows the building's total energy use divided by square feet of the building and provides a standard approach to examine energy performance of a building. Figure 2 illustrates the site EUI of all MCPASD buildings compared to industry EUI targets schools in this climate zone. All MCPASD buildings currently perform better than median regional EUIs, so the graph also includes a high-performance target from ASHRAE-100[1] and a net-zero target developed by New Buildings Institute (NBI).[2]

The net-zero targets represent best-in-class buildings and establishes targets for all schools to strive for through energy efficiency and electrification. The intention is that buildings meeting the net-zero target could cover the remaining energy use with onsite renewable energy.

Figure 2. Weather-normalized site EUI compared to ASHRAE-100 target and NBI net-zero target

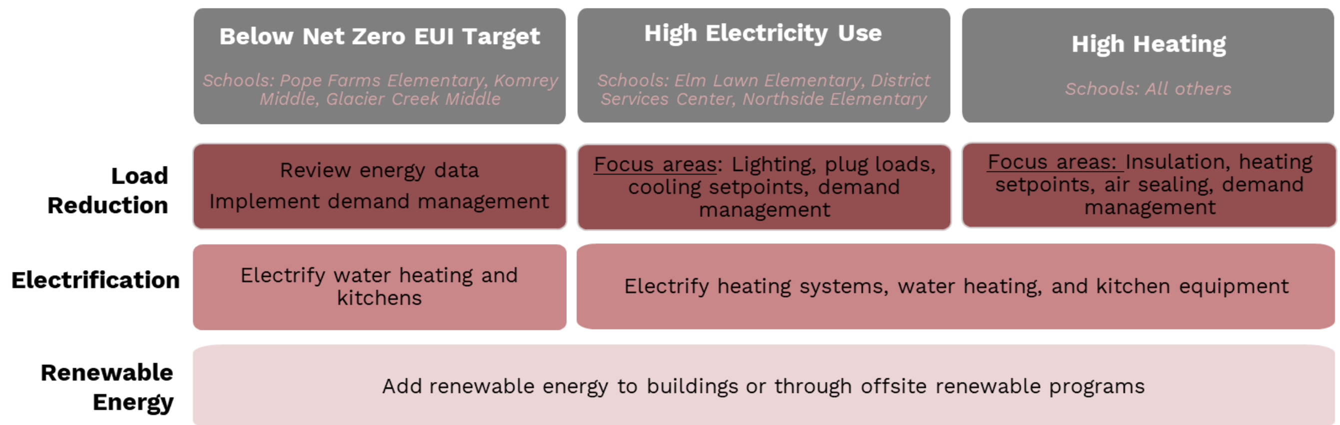


[1] The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) created Standard 100-2018 -Energy Efficiency in Existing Buildings that offers median EUI values as well as energy targets by building type. The energy targets represent the bottom (or best-performing) 25th percentile of energy use by building type. https://www.ashrae.org/news/esociety/updated-standard-100-published.

[2] New Buildings Institute, 2019, Zero Energy Commercial Building Targets, https://newbuildings.org/wp-content/uploads/2019/09/ZeroEnergyCommercialBuildingTargets.pdf

Informed by the baseline data and an inventory of current energy use intensity and equipment type and age, the team developed a decarbonization roadmap for the school districts' portfolio of buildings. Figure 3 summarizes the main three categories the team considered in decarbonizing buildings. Load reduction, or reducing overall energy use, is primarily achieved throuhg efficiency and demand management and leads to direct cost savings. Electrification, or transitioning from delivered fuels (e.g., natural gas or fuel oil) to high-efficiency options, is a key step in the process of decarbonizing. As evidence indicates that the electric grid will continue to add clean sources, electrification of key equipment ensures that energy use will be increasingly sourced from clean sources, whereas continuing to use delivered fuels will lead to the same amount of emissions per unit of energy used. Adding renewable energy can further offset emissions and lower energy costs.

Figure 3. Recommended measures for load reduction, electrification, and renewable energy



It is recommended that MCPASD plan for equipment replacements and renewable energy installations as part of its ongoing capital improvement process. As equipment upgrades are made, MCPASD should regularly assess their impact and report on the progress towards its goals. The evaluation of upgrades should consider progress against any goals previously set districtwide. When evaluating progress, it is important to calculate the actual impact by accounting for weather trends and comparing a full year of data prior to the upgrade to a full year after the upgrade. This process should also incorporate regular reporting (through presentations, reports, or dashboards) to external stakeholders to continually engage and inform the community and demonstrate the districts ongoing commitment the goals.

The timing for implementing a comprehensive decarbonization framework is opportune with an unprecedented amount of state and federal funding available to school districts for clean energy projects. The federal funding is available through 2032, emphasizing the importance of starting upgrades now to leverage the available funding. Funding opportunities include:

- **Leverage fuel and maintenance cost savings to fund capital expenses.** Energy efficiency upgrades and solar installations will save MGSD money on annual operating costs. MGSD could quantify avoided costs and use those avoided costs to implement other recommended actions.
- **Utilize existing Focus on Energy incentives.** Alliant Energy and MGE offer incentives through Focus on Energy for renewable energy installations and energy efficiency upgrades and installations.
- **Apply for federal tax credits.** The Inflation Reduction Act (IRA), a federal law passed in August 2022, represents an unprecedented amount of funding for energy and climate actions. Through this funding, it also includes a provision, direct or elective pay, that makes non-taxable entities eligible for the tax credits that can offset 30% of upfront costs.
- **Apply for other state, foundation, and federal grant and financing opportunities.** There are other grant programs and financing opportunities from the state, foundations, and federal grant programs that will fund these initiatives.

CONTENTS

GLOSSARY OF TERMS

Battery energy storage system (BESS): Equipment that is able to store energy and then release it when needed for use. Often lithium-ion batteries.

Decarbonization: Eliminating carbon dioxide emissions from operations of buildings, processes, and fleet. Switching from fossil-fuels to carbon-free sources.

Direct pay: A provision in the Inflation Reduction Act that makes non-taxable entities eligible for tax credits for clean energy items (including renewable energy and alternative vehicles).

eGauge monitors: Monitoring device that track energy use at a detailed time interval (down to 1 minute) that can be installed directly on electrical panels

Energy walkthrough: Assesses how a building currently uses energy and identifies opportunities to reduce the building's energy consumption.

Electric school buses (ESBs): School buses that are powered by a battery and electricity.

Electric vehicle (EV): vehicles; cars, trucks, and buses powered by a battery and electricity.

Electrification: Transitioning from fossil-fuel delivered fuels (such as natural gas or fuel oil) to electricity to lower carbon dioxide emissions, save money, and improve health. Transitioning to electricity is a benefit as the electric grid will continue to add clean sources while delivered fuels will maintain the same emissions rate.

Energy use intensity (EUI): Total energy use of a building divided by the total square feet of the building. Normalizes energy use across buildings of different sizes.

Focus on Energy: Wisconsin's statewide program to increase energy efficiency and renewable energy use among residents, businesses, and local governments.

Heat pump: Single heat pump replaces both furnace and an air conditioner; fueled only by electricity and very efficient.

Internal combustion engine (ICE): Conventional gasoline or diesel vehicles.

Inflation Reduction Act (IRA): Federal law passed in 2022 that directs significant funding to clean energy and climate solutions. A portion of funding is directed at local governments through rebates or grant programs.

Microgrid: A group of interconnected loads and energy resources that can connect and disconnect from the grid. Can operate as part of larger group or on its own.

Net metering: Billing mechanism that credits solar energy owners for electricity added to grid.

Non-taxable entity: An entity that is not required to pay income taxes. Includes nonprofits, local and state governments.

National Fenestration Rating Council (NFRC): Provides energy performance ratings for windows and doors.

PV: Photovoltaic solar energy; converts energy from the sun to electricity.

Renewable energy: Energy that is generated from a naturally replenishing resource that does not release carbon, such as solar energy, wind energy, or geothermal.

Retrocommissioning: A systematic process of investigating and analyzing existing building's systems for operational and maintenance improvements.

Solar heat gain coefficient (SHGC): A standard that estimates solar radiation that passes through a window compared to the amount of solar radiation that hits the window. The lower the number, the more efficient.

Total cost of ownership (TCO): Total cost of owning equipment, including upfront cost, any energy or maintenance costs, and resale forecast.

U-value: Performance rating for how well a window holds in heat or cool air. A lower number means less heat loss or higher efficiency.

Weather-normalized site EUI: The energy use a building would have consumed during 30-year average weather conditions. It can be helpful to use this weather normalized value to understand changes in energy when accounting for changes in weather. Energy use is divided by square feet.

INTRODUCTION

Energy use in schools is often at the top of operating cost for school districts and is the largest contributor of emissions. Significant cost savings from low-carbon and highly efficient schools can allow school districts to reallocate funding for use elsewhere. Over the last several years, Middleton-Cross Plains Area School District has invested in energy efficiency across its schools. The district also adopted a resolution to rely on 100% renewable electricity for district operations by 2035. To support this goal, the district has installed geothermal at new buildings and subscribed to a large offsite solar array for 1 megawatt (MW) of output.

As a next step in its sustainability progress, Middleton-Cross Plains Area School District partnered with three other Dane County school districts in 2022 to collaborate on a joint energy planning project. The goal of the collaborative project was to develop an actionable decarbonization framework while learning best practices from and alongside one another. Together, Middleton-Cross Plains School District (MCPASD), Monona Grove School District (MGSD), Oregon School District (OSD), and Sun Prairie Area School District (SPASD) was awarded an energy planning grant from the Office of Energy Innovation in August 2022.

Over the last year, the school districts partnered with local nonprofit, Slipstream, to develop decarbonization plans for current school district operations. The decarbonization plan guides future actions and positions the school districts to apply for and access additional implementation funding from state and federal funding sources. Recognizing the value of collaboration, the school districts met regularly throughout the project period to share lessons learned and to discuss items to be included in the plan.

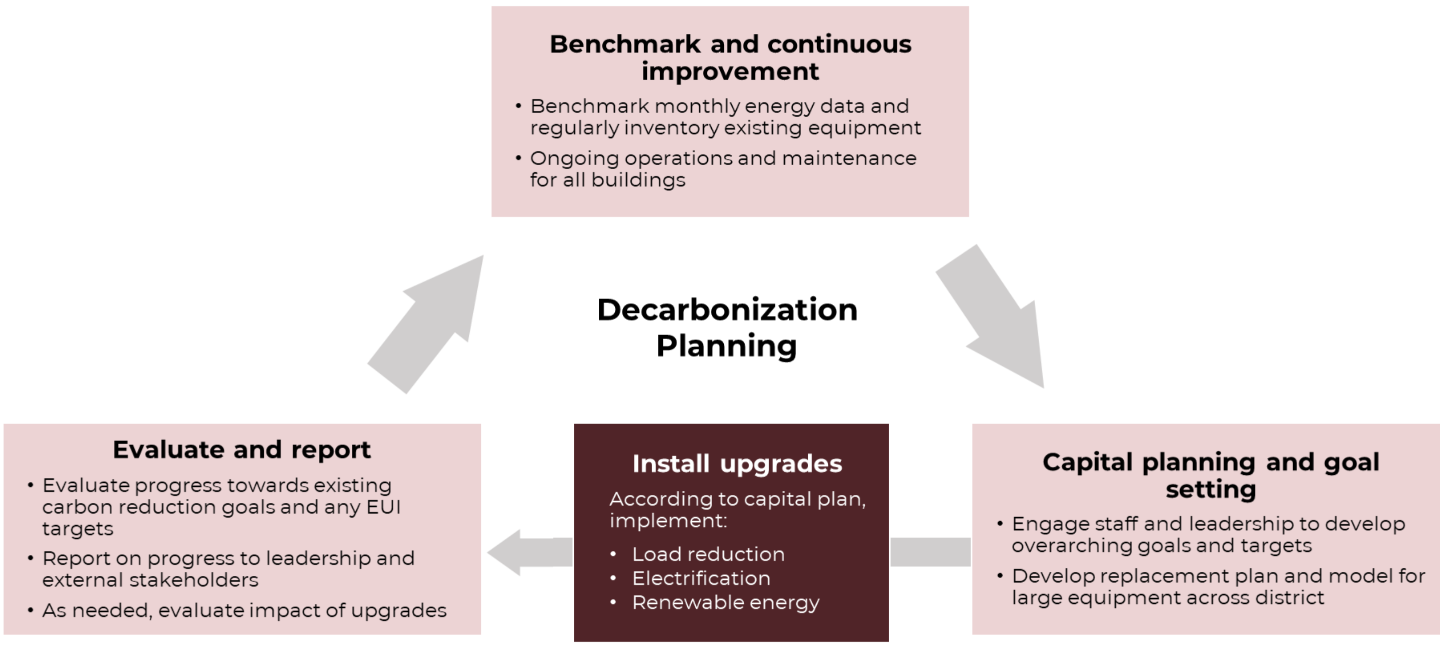
The joint energy planning project process included:

- **Data collection and benchmarking.** The team collected and compiled energy use data and information on current building systems to understand baseline conditions for each school district. The analysis included benchmarking current energy use and CO_2 emissions across buildings.
- **Building decarbonization planning.** An analysis of current building systems and research to identify pathways to reduce carbon emissions across the school districts' building portfolio. This includes energy efficiency, demand management, and electrification. The team also conducted an energy walkthrough assessment at one school building to develop a more detailed case study of the process and potential timeline for decarbonization.
- **Renewable energy analysis**. The team analyzed potential renewable energy installation opportunities for a select number of schools and researched potential opportunities for off-site renewable energy for the district.
- **Fleet case study research.** The team identified other school districts in the Midwest that have purchased electric school buses and discussed their experience with performance and charging to provide background information for the districts.
- **Ongoing data tracking and reporting exploration.** The team evaluated opportunities for ways to better track the impact year over year and how to report on progress to school leadership and external stakeholders.
- **Fact sheet development.** The school districts collaborated on creating fact sheets that describe some of the best practices they use in their schools. The goal is to share the fact sheets with other school districts across Wisconsin to share lessons learned.
- **Identification of funding sources for implementation.** The process also includes identification of funding opportunities for the school districts to implement recommended actions in the plan. These included rebates and federal grant and financing opportunities.

This document serves as the decarbonization roadmap for MCPASD's buildings. It provides high-level direction and recommended actions across the entire building portfolio. Additional engineering, design, and final pricing of all recommendations will be required prior to implementation.

Figure 4 provides an overview of the decarbonization framework that guided the development of this plan for MCPASD. The framework includes a series of steps: benchmark energy data and continuous improvement, capital planning and goal setting, install projects, and evaluate and report.

Figure 4. Decarbonization planning framework



Benchmarking and continuous improvement encourages ongoing benchmarking of monthly utility bills, inventorying of current equipment type, condition, and age, and ongoing operations and maintenance for all buildings. Benchmarking provides information on relative energy performance by comparing energy use over time to other buildings. Inventorying of systems informs the potential need for upgrades. Diligent operations and maintenance make larger upgrades and energy reductions more successful over time. MCPASD already engages in ongoing benchmarking. This report provides additional industry standard targets to aid in benchmarking and includes recommendations for inventorying of systems and provides suggestions for ongoing operations and maintenance improvements.

Capital planning and goal setting focuses on developing comprehensive goals and targets for overall MCPASD emissions and for individual buildings. With those goals in mind, the plan creates a capital improvement plan to map out when different equipment replacements will occur. Both steps should engage multiple internal stakeholders and should consider how to engage the community at large. Capital planning should consider the age and condition of equipment, overarching goals, and timelines of available funding such as federal tax rebates and grants.

As guided by the capital improvement plan, the school district should install upgrades as needed. The plan provides guiding information about how to prioritize projects and what to consider for energy efficiency, demand management, electrification, and renewable energy.

The last step is to evaluate annual progress and develop a process to report to stakeholders across the district. The roadmap includes an overview of tools and methods other school districts have used to both measure and validate savings, as well as develop a robust way to continuously report progress.

BENCHMARK AND INVENTORY

Understanding current energy use, energy costs, and CO_2 emissions as well as existing systems and replacement ages is an important first step in decarbonizing school operations. Table 2 details the CO_2 emissions, energy costs, and total energy use for each of MCPASD's buildings. The costs are based on average energy use charges and do not represent exact 2021 costs.

The high school and middle school buildings have higher annual emissions, costs and energy use, which is primarily linked to the size of the buildings.

Table 2. Annual CO_2 emissions, energy costs, and total energy across MCPASD buildings (2021 data)

Building	CO_2 Emissions (MT)	Energy Costs	Energy Use (kBtu)
Middleton High School	3,092	$554,430	32,430,500
Kromrey Middle School	954	$180,930	5,956,550
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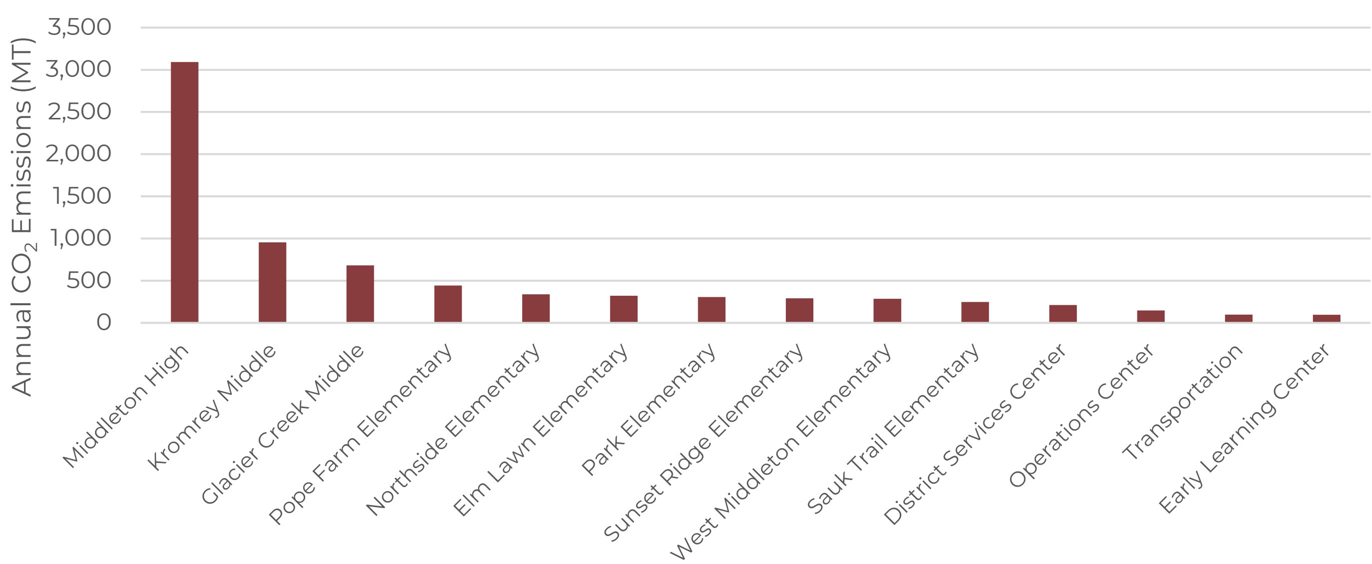
Figure 5illustrates the relative carbon impact of each MCPASD building.

Figure 5. MCPASD buildings CO_2 emissions inventory

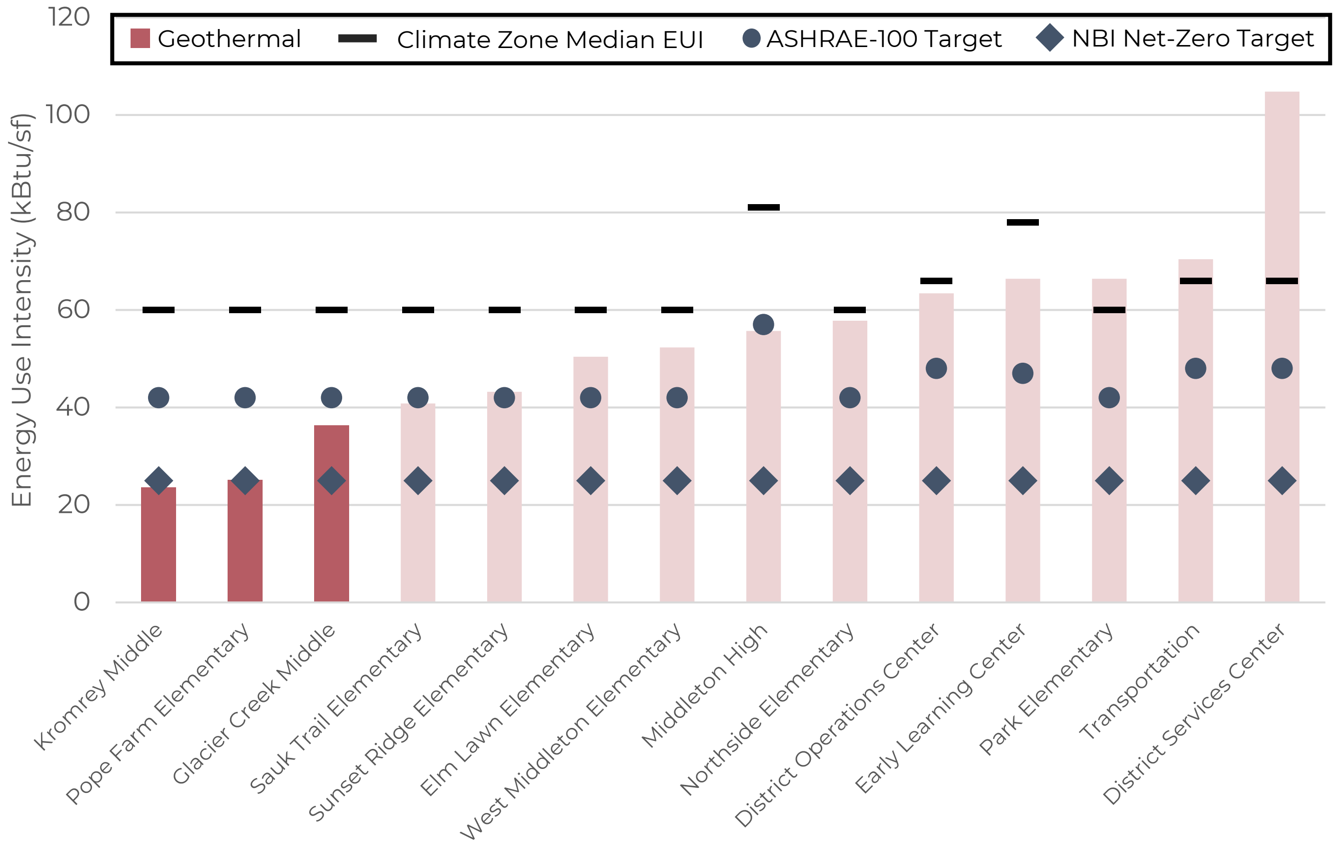


Site energy use intensity (EUI) is a metric that shows the building's total energy use divided by square feet of the building and provides a standard approach to examine energy performance of a building. Figure 6 illustrates the site EUI of all MCPASD buildings compared to industry EUI targets for primary and secondary schools in this climate zone. All MCPASD buildings currently perform better than median EUIs in the region, so the graph also includes a high-performance target from ASHRAE-100[3] and a net-zero target developed by New Buildings Institute (NBI).[4]

The net-zero targets represent best-in-class buildings and were developed to serve as a guide for new construction or as a goal for retrofits. The intention is that buildings meeting the net-zero target could cover the remaining energy use with onsite renewable energy. These targets are different for each building type, which is why the offices and Middleton High School have different targets.

The data illustrates those newer buildings with geothermal (Komrey Middle, Pope Farm Elementary) all have EUIs already below the net-zero target, and several other buildings are below or at the ASHRAE-100 target. This helps identify potential buildings to prioritize for energy efficiency upgrades and establishes targets for all schools to strive for through energy efficiency and electrification.

Figure 6. Weather-normalized site EUI compared to ASHRAE-100 target and NBI net-zero target



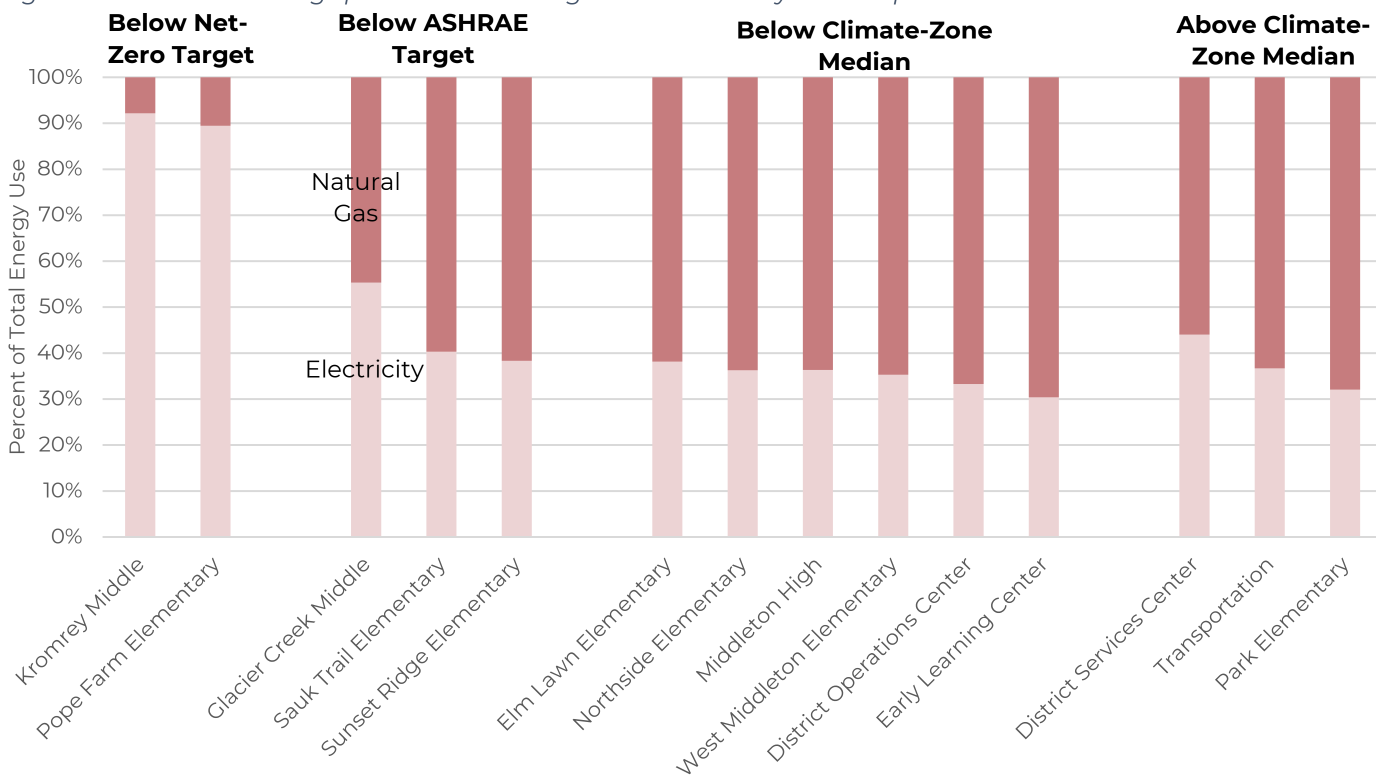
Another way to review energy use data and performance is to quantify the portion of electricity or natural gas consumption. This can help identify which efficiency items might be most relevant. Figure 7 illustrates the percent natural gas and electricity across buildings. It also separates the buildings into three groups: below net-zero and ASHRAE-100, above net-zero and below ASHRAE-100 and above ASHRAE-100 target.

In conventional heating system buildings, most electricity use will be for cooling, plug loads, and lighting, while most natural gas use will be for space heating and water heating. Buildings with

[3] The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) created Standard 100-2018 -Energy Efficiency in Existing Buildings that offers median EUI values as well as energy targets by building type. The energy targets represent the bottom (or best-performing) 25th percentile of energy use by building type. https://www.ashrae.org/news/esociety/updated-standard-100-published.
[4] New Buildings Institute, 2019, Zero Energy Commercial Building Targets, https://newbuildings.org/wp-content/uploads/2019/09/ZeroEnergyCommercialBuildingTargets.pdf

geothermal will use electricity for both heating and cooling, and as a result have little to no annual natural gas consumption.

Figure 7. MCPASD buildings portion of natural gas and electricity consumption



In addition to benchmarking energy use data, inventorying existing building systems is an important step to understanding potential opportunities. A regular inventory of systems should identify several important characteristics, such as age of system, current fuel, efficiency of systems, and a replacement timeline and installation schedule. Table 3 details the inventory done during this project.

Table 3. MCPASD buildings heating system, cooling system, and lighting inventory

School	Heating system	Cooling system	Lighting
Kromrey Middle	Geothermal	Heat pumps	Most LEDs
Pope Farm Elementary	Geothermal	Heat pumps	Most LEDs
Glacier Creek Middle	Geothermal	Chiller/ HPs	Most LEDs
Sauk Trail Elementary	Boiler	Chiller	Most LEDs
Sunset Ridge Elementary	Boiler	Cooling tower	Most LEDs
Elm Lawn Elementary	Boiler	Chiller	Most LEDs
West Middleton Elementary	Boiler	Chiller	Most LEDs
Middleton High	Boiler	Chillers	Most LEDs
Northside Elementary	Boiler	RTU's	Most LEDs
District Operations Center	Boiler	DX	Most LEDs
Early Learning Center	Boiler	DX	Most LEDs
Park Elementary	Boiler	Chiller	Most LEDs
Transportation	RTU/ Oil burner	DX	Most LEDs
District Services Center	Boiler	RTU/ DX	Most LEDs

BUILDING PATHWAYS

Energy use in buildings is a sizable factor in annual operating costs and is the primary contributor to school district emissions. Significant decarbonization for the school district requires the implementation of load reduction and electrification measures as well as a transition to renewable energy sources. The implementation of these measures can lead to cost savings, CO_2 savings, and improved comfort in the district's buildings.

Figure 8 summarizes the main three categories to consider in decarbonizing buildings: load reduction through energy efficiency and demand management, electrification of heating systems, water heating, and kitchen equipment, and adding renewable energy to buildings. The figure highlights key considerations for three different sets of schools – 1) schools with an EUI below NBI net-zero EUI target, 2) schools with high electricity use, and 3) schools with high heating or natural gas use.

The schools with a low EUI all already have a geothermal heating system and operate very efficiently; the team recommends continuing to review energy data to ensure the maintenance of efficient operations, and electrifying water heating and kitchen equipment at their end-of-life. For schools with high electricity use, the priority efficiency items are lighting, plug loads, and cooling setpoints. For schools with high heating use, the focus areas include adding insulation, changing heating setpoints and air sealing. The project team recommends replacement of heating systems, water heating, and kitchen equipment with high efficiency electric options at end-of-life for those schools with both high electricity use and high heating use. For all schools, full decarbonization requires the addition of renewable energy to buildings or through offsite programs.

Figure 8. Recommended measures for load reduction, electrification, and renewable energy

	Below Net Zero EUI Target *Schools: Pope Farms Elementary, Komrey Middle, Glacier Creek Middle*	**High Electricity Use** *Schools: Elm Lawn Elementary, District Services Center, Northside Elementary*	**High Heating** *Schools: All others*
Load Reduction	Review energy data Implement demand management	Focus areas: Lighting, plug loads, cooling setpoints, demand management	Focus areas: Insulation, heating setpoints, air sealing, demand management
Electrification	Electrify water heating and kitchens	Electrify heating systems, water heating, and kitchen equipment	
Renewable Energy	Add renewable energy to buildings or through offsite renewable programs		

Load Reduction

Ongoing Operations and Maintenance

The operation of a building and the behavior of building occupants has a significant impact on building energy use. Operational guidelines can save energy without significant investment and have the potential to positively impact occupant comfort and productivity.

The Project Team recommends that MCPASD develop and continually refine a policy that defines clear guidelines for the operation of buildings. The guidelines should be flexible enough to reflect that each building has unique characteristics and should reflect a balance of energy use and comfort. Considerations should include ongoing maintenance practices, expectations for equipment and lighting shutdown at the end of the day, thermostat setpoints, guidance for when to use windows, and a communication method for building occupants to provide feedback on their comfort or the guidelines.

Energy Efficiency

Energy efficiency is an important step in reducing energy use, reducing costs, and improving comfort in buildings. The project team used utility bill analysis and a US Department of Energy tool, BETTER,[5] to evaluate energy efficiency and identify priority measures for buildings in the MCPASD portfolio. BETTER analyzes monthly billing data to determine how much energy use is weather-dependent versus baseload energy use. The total energy use, weather-dependent energy use, and baseload energy use is then compared to peers to help identify priority measures for the building.

To identify measures for each MCPASD building, an aggressive EUI target was selected, which is defined as one half of a standard deviation better than the median performance of the benchmarking peer group. As noted previously, many MCPASD buildings already perform better than the median, so this target represents a more ambitious target for the district.

Table 4 includes the recommended energy efficiency measures identified by BETTER for MCPASD schools. The schools below the NBI net-zero target, Komrey Middle and Pope Farms Elementary, are not included in the table as there were no recommended energy efficiency measures identified. Heating and water heating measures are not included in the table but are discussed in the electrification section.

Schools with high electricity use (Elm Lawn Elementary, District Services Center, and Northside Elementary) are highlighted for plug load, lighting, or cooling setpoint measures while most of the other schools have priority measures related to heating load, such as insulation, windows, and heating setpoints.

Table 4. Recommended energy efficiency measures for each school (as identified by BETTER tool analysis)

School	Reduce Equipment Schedules	Increase Cooling Setpoint	Lower plug load use	Tighten building envelope	Upgrade Windows	Decrease Heating Setpoint	Ensure Adequate Ventilation Rate
Glacier Creek Middle	x						
Sauk Trail Elementary		x		x	x	x	x
Sunset Ridge Elementary	x			x	x	x	x
Elm Lawn Elementary	x		x				
West Middleton Elementary	x	x		x	x	x	x
Middleton High	x			x	x	x	x
Northside Elementary	x		x	x	x		x
District Operations Center	X			x	x	x	x
Early Learning Center							
Park Elementary	x	x		x	x	x	x
Transportation				X	x	x	x
District Services Center	x		x	x	x	x	x

Reduce equipment schedules. This measure recommends looking for opportunities to turn off equipment during low occupancy or reduced building use. The measure is recommended for any building with a load higher than the target on either the heating or cooling side. This could include checking building automation systems (BAS) on a regular basis, reviewing schedules and adjusting the schedules to occupancy. It could also include implementing operating policies to ensure systems are shut down by occupants at the end of day.

Lower plug load use: There are a few buildings in MCPASD's portfolio with higher-than-expected plug loads. For plug loads, the school district can consider updating computers, printers, and other appliances to ENERGY STAR certified options and installation of advanced power strips to eliminate

[5] BETTER online tool is available here and is free for use: https://better.lbl.gov/

“vampire loads” consumed by electronic devices when they are turned off but still plugged in. MCPASD can also consider the implementation of an operational policy to set standard guidelines for turning off lights and appliances during unoccupied hours.

Increase cooling setpoints: An analysis of billing data shows that buildings recommended for this measure start cooling at a lower temperature than most buildings. Building energy use can be significantly reduced through the review and adjustment of cooling setpoints. This may include a chilled water temperature reset/increase or simply adjusting timing of cooling. Focus on Energy offers retrocommissioning or tune-up rebates that could cover this cost.

Insulation and air sealing: Sealing doors and windows and adding additional roof and wall insulation can lower heating and cooling load needs. This measure was highlighted for buildings with higher heating loads compared to high-efficiency schools. Air sealing can be done with caulk, spray foam, or weather-stripping materials. Basic air sealing can be done at a relatively low cost by facilities managers or a local contractor; however, insulation can be a significant investment and should be considered during the capital planning process and installed during comprehensive building or roof upgrades. The first step for both should be a discovery process to understand current installation and air sealing levels and determine the best approach to adding more.

Window replacement: Windows can impact comfort in the building, as well as cooling and heating loads. Windows should be upgraded at end-of-life or during major retrofits. When replacing windows, specify products certified by ENERGY STAR or by the National Fenestration Rating Council (NFRC) and look for products with a U-Value of less than 0.30 and a Solar Heat Gain Coefficient (SHGC) of less than 0.25.

Decrease heating setpoints: This measure is recommended for any school that has a higher heating setpoint than similar buildings. By lowering the heating setpoint, significant heating energy can be saved while still providing adequate comfort in the schools.

Ensure adequate ventilation rate: Ventilation into buildings maintains safe and comfortable environments for building occupants. However, providing more ventilation than is necessary could increase the buildings’ energy use. This measure is paired with all air sealing and insulation recommendations to ensure that adequate ventilation is provided as the building envelope becomes tighter.

Demand Management

Smoothing energy use across the day and month to avoid spikes in demand can lead to energy cost savings for the district. There are several actions the school districts can take to manage demand, explained below:

- **Granular or real-time monitoring:** Energy monitors, such as eGauge, can provide more granular data to help the district understand what time of day peak demand is occurring. Energy management tools, such as EnergyCAP Smart Analytics, can provide notifications when a school is approaching peak demand. Expansion of these tools at all schools can help the district to both examine demand spikes retroactively and monitor energy use in real-time.
- **Implementation of controls and sequences:** Demand management can best be implemented through control systems for heating, cooling, and lighting. This could include shifting equipment schedules and implementing pre-cooling or pre-heating to avoid high energy use for cooling or heating during peak times of the day. Controls also enable real-time adjustments if a school is getting close to peak demand, such as slightly lowering heating and cooling setpoints or dimming lights where possible. A complete analysis of current BAS sequences is

needed to develop specific recommendations for the control changes. Focus on Energy provides funding for retrocommissioning and building tune-ups.

- **Battery energy storage systems:** Battery energy storage systems can provide load management capabilities by storing energy when demand is low and then discharging energy when a school is close to peak demand. The system can also provide resiliency benefits and replace generators. The primary concern with Battery Energy Storage Systems (BESS) is cost. As costs continue to decline, BESS is becoming a viable option especially for new construction or generator replacement. From 2010 to 2018, battery prices fell by 85%, and costs are predicted to continue to decline at a rate of 18% each time cumulative volume installations doubles.[6] The U.S. National Renewable Energy Lab (NREL) estimates that a BESS costs $388 per kWh of energy and $775 per kW of capacity, compared to a diesel generator at $500 per kW of capacity.[7] For a BESS, the per kW and per kWh costs are additive– a one kW, one kWh battery would cost approximately $388 plus $775, or $1,063. As costs continue to decline, BESS with controls could be considered for both demand management and resiliency. New construction or time of generator replacement are especially opportune times to consider the addition of BESS.

Electrification

As explained earlier in this document, equipment electrification must be paired with efficiency to fully decarbonize buildings. Space heating, water heating, and commercial kitchens often use natural gas delivered directly to the school. The disadvantage of delivered natural gas is its constant emissions across time, while the carbon emissions intensity of electricity, or the amount of carbon released per unit of electricity generated, will continue to decrease in the future as the grid steadily transitions to cleaner sources.

Because equipment lasts for several decades, it is important to start electrification as soon as equipment fails to avoid locking in additional gas emissions for years to come. With high-efficiency electric options in the market, electrification becomes more feasible and allows for lower overall emissions over the lifetime of equipment and the potential to eventually emit zero carbon.

Heating Systems

Close to 40% of energy use in schools is from space heating and another 10% is from cooling. In Wisconsin, most schools are heated by the direct burning of natural gas. As the electric grid becomes increasingly renewable, the path to decarbonize these systems is electrification. For the most beneficial results, gas heating systems should be replaced with high-efficiency heat pumps, which output three to four units of heat for every unit of electricity used. This is compared to near one unit of heat for every unit of natural gas used by conventional gas heating systems.

Heating and cooling systems across MCPASD buildings primarily fall into one of four categories:

- Schools with variable-air-volume (VAV) systems with 4-pipe hydronic systems/boiler and chiller (ex: Middleton High School)
- Schools with packaged VAV rooftop units (RTUs) and boiler hot water reheat (ex: Northside Elementary)
- Schools and offices with single zone systems such as single zone packaged RTUs, steam/hot water radiators with individual A/C units, or central furnaces with A/C (ex: sections of schools, Early Learning Center)
- Schools that are already served by geothermal or other heat pumps (ex: Pope Farms Elementary)

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[6] Goldie-Scot, Behind the Scenes Take on Lithium-Ion Battery Prices." https://about.bnef.com/blog/behind-scenes-take-lithium-ion-battery-prices/
[7] S. Mishra et al., "The ReOpt Web Tool User Manual," 2021. https://reopt.nrel.gov/tool/reopt-user-manual.pdf

Three schools in MCPASD already have geothermal systems, however the remaining systems use natural gas heating systems. Several high-efficiency electric options exist to guide this replacement.

Table 5 provides an overview of the available heat pump systems that provide heating and cooling and key considerations for each. The comparisons in the table are relative to the other heat pump systems presented in the table and not to existing natural gas systems in the building. For example, an upfront cost of medium suggests that variable refrigerant flow falls in the middle of the range for other heat pump systems' upfront costs. Similarly, change to the building represents how disruptive an upgrade to each system would be, with dual-fuel RTUs and air-source heat pumps generally being the easiest to install. Lastly, energy efficiency indicates the relative efficiency across heat pump systems. It should be noted that all systems are high-efficiency systems, but a central heat pump system is the most efficient of the electrification technologies presented in the table.

It's valuable to note that geothermal systems are eligible for renewable energy tax credits (which are available for non-tax paying entities) until 2032 through the Inflation Reduction Act. A more complete description of the systems presented in the table are available in Appendix 1: HVAC System Electrification.

Table 5. Available heating system electrification technologies: description and major considerations

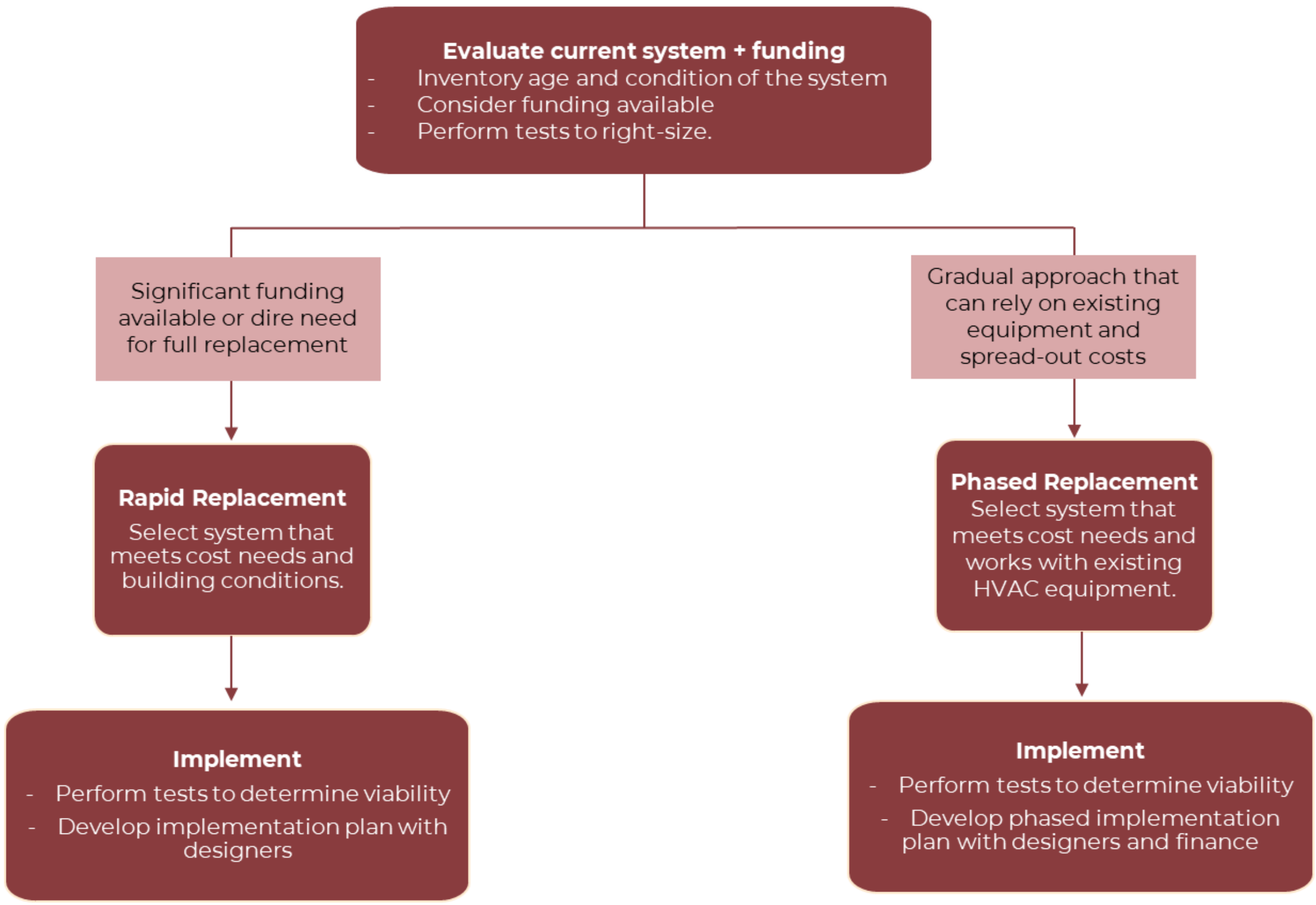
System	Variable Refrigerant Flow (VRF)	Air Source Heat Pumps	Distributed Water Source Heat Pumps	Central Heat Pump Plant	Heat Pump / Dual Fuel RTUs
Description	Air-source Variable Refrigerant Flow heat pump system with DOAS	Distributed single-zone mini-splits with DOAS	Single-zone Water-air heat pumps with condenser loop and DOAS	Central heat pump plant with condenser loop; either VAV or FCU+DOAS	Heat pump rooftop units with optional gas backup heat. Can be single-zone or part of a VAV system.
Upfront Cost	Medium	Low	Medium/High	Medium/High	Low
Funding Available	-	-	Geothermal eligible for up to 40% tax credits through direct pay	Geothermal eligible for up to 40% tax credits through direct pay	-
Change to Building	Medium	Low	High	Medium	Low
Energy Efficiency	Low to Medium	Medium	Medium to High	High	Low to Medium
Environmental Risk*	High	Medium	Low	Lowest	Medium

* Environmental risk refers to the risk of leaking HCFC- and HFC-based refrigerants. These substances are used in almost all HVAC systems and have a Global Warming Potential (GWP) up to several thousand times that of carbon dioxide.

Existing heating systems that are fueled by natural gas can be challenging to decarbonize and will take significant time and investment to convert to heat pumps. Figure 9 illustrates recommended steps as school districts start to consider decarbonization: (1) evaluate current HVAC system, (2) determine the replacement approach, (3) decide on the best replacement system, and (4) implement plan.

The evaluation of the current system and funding available directly informs the replacement approach. The two possibilities for replacement are rapid replacement and phased replacement. Rapid replacement removes all existing system equipment and completely replaces it with a new heating system. This approach requires significant upfront funding but provides flexibility in selecting any electrification technology. The phased approach is likely more common and retains equipment from the existing system while slowly replacing and building out the fully electric option. The phased approach spreads out cost but requires considerations of which electric options would work with existing HVAC equipment. Depending on the baseline HVAC system, there are specific electrification technologies and steps a district could take. Appendix 1: HVAC System Electrification includes more detailed information on how to evaluate the current system and how to determine the replacement approach and system based on existing HVAC technology.

Figure 9. HVAC system replacement recommended set of steps



Water Heating

In most schools, water heating accounts for a relatively small portion of total energy use, approximately 10% on average.[8] However, to fully electrify a school, water heating must also transition to electricity from traditional natural gas systems. The primary technology solution for central water heating electrification is heat pump water heaters. Small instantaneous electric resistance water heaters are options for specific schools or zones in schools with relatively low water loads.[9] For buildings with a central water heating plant, central or commercial heat pump water heaters with large hot water

[8] US Department of Energy & NREL, Advanced Energy Retrofit Guide: K-12 Schools. https://www.nrel.gov/docs/fy14osti/60913.pdf
[9] US Department of Energy Better Buildings, Low Carbon Technologies for Primary Schools. https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/Primary_School_BB_Carbon_Strategies.pdf; US Department of Energy, Low Carbon Technologies for Secondary Schools. https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/Secondary_School_BB_Carbon_Strategies.pdf

storage tanks are an emerging option. Air to water heat pumps can also provide domestic hot water as well as heating.[10]

A heat pump water heater is a high-efficiency option that uses electricity to move heat from one place to another instead of generating heat directly. Table 6 includes some considerations for heat pump water heaters, including current availability, efficiency, carbon savings, and cost. The systems are readily commercially available but do have a higher cost compared to conventional systems. The improved efficiency leads to significant emission savings. However, the operating cost savings depend heavily on local rates for natural gas and electricity.

It is recommended that any selected equipment is ENERGY STAR certified[11] or on Northwest Energy Efficiency Alliance's (NEEA) Qualified Products list for heat pump waters heaters.[12]

Table 6. Heat pump water heater main considerations[13]

Availability	Efficiency	Carbon Savings	Cost
• Commercially available in sizes between 40 and 120 gallons • Most require a 220-volt electrical line • New emerging technology for 120V HPWHs for 50-80 gallon systems	• Two to three times more efficient than conventional storage water heaters • Works well in cold-climates	• 50% or larger reduction in CO_2 emissions compared to conventional water heaters	• Incremental cost over conventional systems depends on size of water heater • Operating cost savings significant compared to electric resistance; mixed results compared to natural gas

Kitchens

Cooking equipment within school buildings accounts for a small percent of total energy use in school buildings, on average about 1 to 2% of total energy use.[14] Nonetheless, decisions when replacing kitchen equipment should consider CO_2 emissions and ongoing operating costs. Efficient and electric equipment should be installed to lower overall energy use and gradually eliminate natural gas.

The benefits of electric equipment include higher efficiency compared to gas stoves or kitchen equipment, improved indoor air quality from elimination of gas combustion, and in many cases improved cooking performance.

ENERGY STAR appliance lists should be consulted when replacing equipment, and MCPASD should consider replacing any existing cooktops with induction cooktops. The upfront cost for ENERGY STAR or induction equipment is often higher than conventional systems but operating cost for the equipment is often lower.[15]

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[10] NBI, 2023, The Building Electrification Technology Roadmap (BETR) for Schools, https://newbuildings.org/wp-content/uploads/2023/12/BETR-Roadmap-for-Schools_2023-12.pdf
[11] A list of ENERGYSTAR water heater products is available here: https://www.energystar.gov/productfinder/product/certified-water-heaters/results
[12] NEEA's qualified HPWH list is here: https://neea.org/resources/residential-hpwh-qualified-products-list
[13] Details from the following sources:
https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/Decarbonizing%20HVAC%20and%20Water%20Heating%20in%20Commercial%20Buildings%2011.21.pdf;
https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/Secondary_School_BB_Carbon_Strategies.pdf
[14] NBI, Key Measures about Carbon Neutral Schools, 2022, https://newbuildings.org/wp-content/uploads/2022/06/NBI_Key-Messages-About-Carbon-Neutral-Schools_June2022.pdf
[15] ENERGYSTAR, Guide for Cafes, Restaurants, and Commercial Kitchens
https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/ES%20Restaurant%20Guide%202017-2018%20v16.pdf

Renewable Energy

MCPASD does not currently have any solar arrays on its schools; however it has subscribed to an offsite solar array through MGE's Renewable Energy Rider program for 1 MW of output. The subscription covers roughly 15% of the school district's current electricity consumption. The district has a goal to reach 100% renewable electricity for school operations by 2035.

This report includes onsite renewable energy opportunities for a select set of schools and subsequent discussion of the offsite renewable programs through both MGE and Alliant Energy.

Onsite Renewable Energy Opportunities

The onsite renewable energy analysis evaluated five buildings for solar installations. The team excluded other buildings from this analysis due to concerns about space available on the roof or ground, condition of the roof, or other architectural considerations. The analysis incorporated available space at each school, monthly historical data for the building, and the actual utility rates. More detail on methodology is available in Appendix 2: Solar Results.

For each of the schools analyzed, the team developed a range of options for a solar installation. Table 7 includes a range for each metric to represent the high-end and low-end for the options analyzed. The options typically included an option that maximized the space available and a few that minimize the upfront cost. Installation of the arrays could cover roughly 10 to 30% of MCPASD current electricity use.

The table includes the solar array size, percent renewable electricity for each site, the simple payback period, and annual CO_2 and cost savings. The solar array size is determined by examining roof or ground space, monthly energy use of the building, and cost-effectiveness. The payback period is calculated by dividing yearly utility bill savings by the net upfront cost. The energy cost savings represent annual energy cost savings – after the payback year all of these will be direct savings for the district. The CO_2 savings represent annual emissions avoided. The full set of alternatives is available in Appendix 2: Solar Results.

Table 7. MCPASD onsite solar array performance metrics by building

School	Size (kW DC)	Percent Renewable Electricity	Payback (Years)	Annual CO_2 Savings (MT)	Annual Energy Cost Savings
Middleton High School	300-652	9-20%	14-15	254-552	$28,850 - $61,135
Komrey Middle School	100-500	7 – 35%	14-16	82-411	$9,405 - $43,145
Glacier Creek Middle School	100-614	12-75%	10-14	84-516	$12,915 - $59,410
Elm Lawn Elementary School	100-240	32-76%	14-16	85-203	$9,930 - $19,560
Sauk Trail Elementary School	100 – 190	40-76%	14-16	85-161	$9,925 - $15,550

Table 8 includes costs for each array. The estimated upfront cost is based on size and location on roof or ground. The Focus on Energy incentives represent local incentives available and are based on the size (generating capacity) of the array. Cities are also eligible for the Inflation Reduction Act's clean energy tax credits through elective pay, a provision that allows non-taxable entities to receive the credits (see Funding Opportunities). The credit is 30% of the upfront cost and is paid after the array is installed. Net cost represents total cost after the incentives and tax credit.

Table 8. MCPASD solar array cost details by building

School	Upfront Cost	Focus on Energy Incentives	IRA Tax Credit	Net Cost
Middleton High	$630,000-$1,369,200	$33,000 - $50,000	$189,000 - $410,760	$408,000 - $908,440
Komrey Middle	$210,000-$1,050,000	$13,000-$50,000	$63,000- $315,000	$134,000 - $685,000
Glacier Creek Middle	$210,000-$1,289,650	$13,000-$50,000	$63,000- $386,900	$134,000 - $852,750
Elm Lawn Elementary	$210,000-$504,000	$13,000-$27,000	$63,000 - $151,200	$134,000 - $325,800
Sauk Trail Elementary	$210,000-$399,000	$13,000-$22,000	$63,000- $119,700	$134,000 - $257,300

Offsite Renewable Energy

Onsite solar installations on school district facilities will only be able to cover a fraction of school operations electricity.

Offsite renewable energy is solar arrays or wind turbines that are installed on a plot of land (owned by the district or a third-party) not currently occupied by a school facility. The district purchases renewable electricity directly from the offsite array and can claim that electricity as offsetting grid energy use. Under current Wisconsin law, it is required that local customers primarily work with the utility on offsite renewable energy as developers are limited in ability to sell renewable energy to customers directly. Alliant Energy and Madison Gas and Electric, MCPASD's two electric utilities, have goals to transition to renewable electricity in the next decade and programs to help drive the transition. MCPASD has already partnered with MGE but could explore additional participation or a partnership with Alliant.

Alliant Energy

Alliant Energy has goals to reach a 50% reduction in greenhouse gas emissions compared to 2005 levels by 2030, 80% reduction by 2040, and have net-zero carbon dioxide emissions from its electricity by 2050. As part of these efforts, Alliant has programs available for offsite renewable energy.

MCPASD can engage with Alliant Energy to discuss their **customer-hosted renewable energy.** Under this program, a customer leases land or property to the utility and receives monthly lease payments. Alliant then builds and maintains a solar array and the energy helps power the nearby area. The program includes arrays as small as 200 kW or as large as 2.25 MW (15 acres) of solar on the ground or roof. The benefits of this program are that the district does not have to pay upfront costs, receives a lease payment for the use of land or property, and receives Renewable Energy Credits from Alliant.[16]

MGE

MGE has goals to reach an 80% reduction in CO_2 emissions compared to 2005 levels by 2030 and have net-zero carbon dioxide emissions from its electricity by 2050. As part of its goals, MGE gives customers the option to partner with the utility to identify a renewable energy solution. Under their **Renewable Energy Rider (RER) program**, the utility would partner with the school district to develop a contract to serve a portion of the district's electricity with renewable electricity. The customer pays for renewable electricity generation from a designated renewable facility owned by MGE or a third party.[17]

Purchasing Policy

One way to institutionalize decisions around new equipment and decisions at end of equipment life is to develop purchasing guidelines. By implementing a policy to ensure that sustainable decisions are being made at replacement, MCPASD can steadily work towards its goals, while making upgrades

[16] Customer hosted renewable information is available here: https://www.alliantenergy.com/cleanenergy/whatyoucando/customerhostedrenewables
[17] Renewable Energy Rider program information is available here: https://www.mge.com/customer-service/for-businesses/renewable-energy-rider

during the normal capital improvement process. This will minimize costs by limiting the need for early replacement, and ensure the equipment selected leads to lower operational costs.

Sustainable purchasing policies have been recognized in many areas as a best practice for meeting energy and carbon goals. The guidelines can be written to incorporate flexibility and to incorporate cost and performance considerations. For example, the policies could stipulate considerations of high-efficiency electric or ENERGY STAR appliances for any equipment replacement. It could require that total cost of ownership and CO_2 emissions comparisons between each are calculated to determine the final purchasing decision. Total cost of ownership would consider upfront cost differential, ongoing operating costs differential, and any changes in maintenance costs.

EVALUATION AND REPORTING

Evaluating and reporting on progress towards carbon reduction goals and EUI targets is a key step in a decarbonization framework and plan.

An evaluation approach should consist of assessing progress towards existing targets and goals, as well as analyzing impact of a major change or upgrade to a school. Reporting is also a critical tool in facilitating communication, engagement, and buy-in with stakeholders. Both efforts provide a way for school districts to celebrate successes along the decarbonization journey.

Evaluation and data tracking

Tracking facility energy consumption and emissions data is essential for enabling facility and energy manager to compare a building's current performance with baseline data for that facility. Tracking energy data is also needed to assess a facility's performance against relevant regional benchmark building performance levels. Additionally, energy and emissions tracking enables districts to assess their progress toward their efficiency and decarbonization goals.

Ongoing energy data tracking can quantify cost and CO_2 savings from past actions. The data can also guide priorities for future actions.

To analyze impacts of energy saving strategies over time, energy consumption data must be weather-normalized to eliminate the influence of different temperature patterns on consumption. At least a year's worth of energy use data prior to, and after a change is required to assess the impact.

Two strategies that enable facility managers to more quickly identify energy waste, maintenance concerns, and cost-effective upgrade opportunities are 1) monitor energy consumption in near real-time; and 2) collect sub-metered energy use. Sub-metering isolates energy use by load type and/or within different zones in a school. This more granular energy data can lead to prioritization for energy saving measures and analysis. Energy monitoring devices, such as eGauges, can be installed on submeters to provide energy data at frequent time intervals and by section of the school.[18]

Reporting

Providing regular updates on energy use and emissions through presentations, reports, or dashboards provides a way to inform all stakeholders on a district's progress toward its energy and/or decarbonization goals. Utilizing public data visualizations can help with clear communication to stakeholders, and these data can promote energy competitions amongst schools or can challenge schools to meet a specific energy consumption reduction goal.

Annual reports or presentations can be simple and rely on data or graphs from existing reporting tools like ENERGY STAR Portfolio Manager. The annual reports can illustrate the year-over-year EUI and overall districtwide energy use trends and benchmark that against targets for buildings and overall goals.

Many schools and school districts have successfully employed various models for stakeholder engagement. Highlighted below are a few examples from school districts acrossthe country:

> **Seattle Public Schools:** Seattle Public Schools provides a public dashboard with energy use, cost, and greenhouse gas emissions data over time for the district overall and for each school.[19]

[18] Details on eGauges are available here: https://www.egauge.net/
[19] Seattle dashboard: https://app.powerbi.com/view?r=eyJrIjoiNGFlYWQ3OGQtNTAxNi00MWNmLThlZWMtOTM1ZGVjOTJhMzJiIiwidCI6ImQ0MzFkMTU4LTYwNzQtNDgzMi04NzgzLTUxZWE2ZjZkZDIyNyIsImMiOjZ9

Fairfax County Public Schools (VA): The district provides monthly energy use and cost data by school and across the school district for the last several years. The dashboard is available to the public and powered by EnergyCAP software.[20]

Orange Unified School District (Orange, CA): Provides solar information for each solar array on school buildings. Includes generation data and comparison points on the equivalent amount of trees or cars off the road the avoided energy emissions accounts for. [21]

Santa Monica School District (CA): Worked with a contractor to understand energy savings and develop an energy dashboard that shows energy costs and energy use by school. The dashboard helps identifies worst-performing schools and emissions.[22]

Energy Management Tools – Reporting and Evaluation

A number of advanced tools exist that allow for tracking, evaluation, and reporting of energy use across time. The tools integrate with existing eGauge or energy bill benchmarking programs, and can provide measurement and verification, cost tracking, real-time monitoring, alerts for peak demand, and public dashboard support. Examples of energy management software platforms that cater their services to school districts include EnergyCAP Smart Analytics, JadeTrack, Brightly Energy Manager, and Artis.[23] Middleton Cross Plains Area School District is currently piloting EnergyCAP Smart Analytics in their school district, and a number of the reporting examples above use the software for their dashboards. The tools provide some of the following functionality:

- **Performance metrics:** Includes tracking of energy use intensity, total energy use, total costs, and greenhouse gas emissions. Can help track progress towards goals. Often integrate directly with ENERGY STAR Portfolio Manager.

- **Dashboards (internal and external):** The energy management software platforms have dashboards for use by internal staff that allow for better analysis of energy use trends through built-in and custom visualizations. The software also often has the capability to build external dashboards that can be linked on school district websites.

- **Weather normalization and evaluation**: Many of the tools allow for setting a baseline period and then calculating savings according to standard measurement and verification methods. This includes weather-normalizing data and comparing baseline to current data to identify impact.

- **Real-time data tracking and demand alerts**: The tools track real-time data and send alerts when energy use is getting close to hitting peak demand. The tools detect outliers and send alerts via email and through the app.

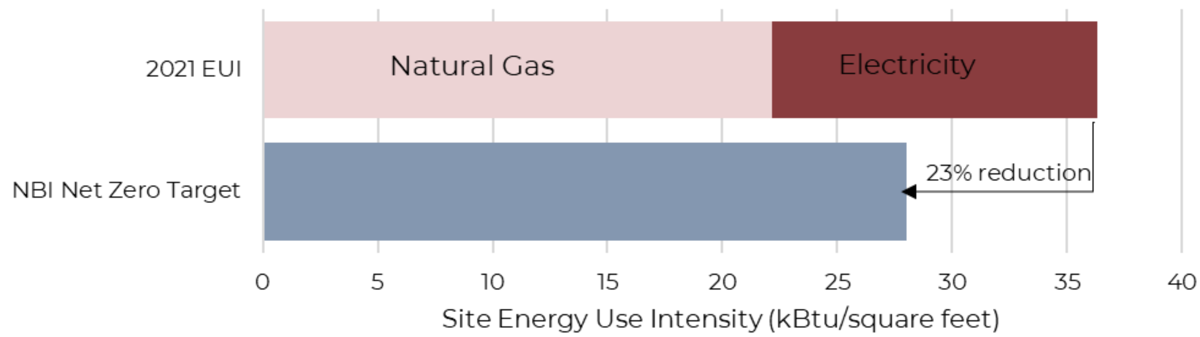
[20] Fairfax County Public Schools dashboard: https://get2green.fcps.edu/overview_db.html
[21] Orange Unified School District dashboard: https://www.orangeusd.org/departments/facilities-planning/energy-management
[22] Santa Monica School District dashboard: https://www.smmusd.org/EnergyDashboard
[23] Tool information is available here: https://www.jadetrack.com/, https://www.energycap.com/energy-monitoring-software/, https://www.brightlysoftware.com/products/energy-manager, https://www.artisenergy.com/

EXAMPLE ROADMAP: GLACIER CREEK

Benchmark and inventory

The team performed a walkthrough of Glacier Creek Middle School to inform an example roadmap for the school. Glacier Creek Middle School has the third lowest EUI of all schools in MCPASD's portfolio; however it has the second highest overall energy use across all district schools. It also was using significantly more energy than expected and compared to other geothermal schools at the time of the walkthrough. Figure 10 illustrates current EUI compared to two high-performance EUI targets.

Figure 10. Glacier Creek Middle School 2021 EUI compared to NBI net-zero target



The building was selected for a walkthrough as it was using more energy than expected for a geothermal building with all LED lighting and a relatively tight envelope. The building has natural gas boiler backup and natural gas water heating. The relatively high electricity use was linked to an energy recovery wheel that was not turning. With its low energy use, Glacier Creek is a good example of how to slowly electrify and how renewable energy systems can eventually make the building net-zero.

Capital planning and implement upgrades

Large-scale upgrades and reductions in energy use and carbon emissions will require a phased approach determined by capital planning. MCPASD should consider the recommended updates for Glacier Creek early, and integrate a phased replacement for a solar installation, and efficiency items into a multi-year capital plan. Figure 11 includes the general recommended timeline for items specific to Glacier Creek, and the following section provides additional detail on those items.

Figure 11. Recommended timeline for Glacier Creek Middle School efficiency, electrification, and renewable energy

	First 1- 3 years	3-5 years	5+ years
Load Reduction	Reduce equipment schedules. Review HVAC controls.	Continued review of EUI targets and data	
Electrification	Evaluate existing systems. Commission boiler system. Investigate technology options for replacing domestic hot water heaters. Consider utilizing solar hot water system more.	Begin replacement of older domestic hot water heaters with heat pump water heaters. Examine technology options for any gas-fired kitchen equipment.	Replace the newer domestic hot water heaters with new heat pump water heaters Replace remaining gas equipment with electrified equipment as technology is available.
Renewable Energy	Install up to 614-kW of solar arrays on school roof. Prioritize installation before 2032 to leverage direct pay tax credits. Explore programs with utility to source additional renewable electricity.		

Efficiency

Glacier Creek Middle School was identified with a higher-than-normal load. A portion of this was due to an energy recovery wheel not running; however, a few additional efficiency strategies can lower overall energy use. These energy efficiency upgrades could be eligible for retrocommissioning or building tune-ups rebates through Focus on Energy.

Reduce equipment schedules: This measure recommends looking for opportunities to turn off equipment during low occupancy or reduced building use. The measure is recommended for any building with a load higher than the target on either the heating or cooling side. This could include checking building automation systems (BAS) on a regular basis, reviewing schedules and adjusting the schedules to occupancy. It could also include implementing operating policies to ensure systems are shut down by occupants at the end of day.

Review HVAC controls: The heating load at the building is higher than target buildings. Our walkthrough showed boilers operating at high temperatures that are generally required for buildings where hot water heats the air directly, not geothermal heat pump systems. There is an outdoor reset system to bring the hot water temperature to 180°F in the winter. Although on very cold days that high temperature may be required, review controls so that boiler loop only turns on when the geothermal loop is below its low setpoint of 70°F. If the loop is meeting setpoint, the boilers should be off.

Electrification

As it is a relatively new building with a tight envelope, LED lighting, and heat pump heating systems, Glacier Creek is a prime candidate for full electrification. The first step to electrifying the remaining gas systems in a building is to evaluate the existing systems. Glacier Creek has a geothermal heat pump system with a backup boiler and cooling tower system. There are two natural gas domestic hot water heaters (one at 125 gallons and another at 120 gallons) tied to a solar hot water loop, although that solar hot water is not often used. The 120-gallon heater appears to have been installed in the last 5 years, while the 125-gallon heater appears to be older.

As the building already has an electrified heating system, we recommend the following steps to fully electrify the building:

1. Fine-tune controls to reduce boiler hot water consumption as much as possible.
2. Electrify domestic hot water heaters.
3. If possible, electrify remaining systems, such as kitchen equipment.

From there, begin to lay out a plan for equipment replacement and commissioning existing systems, while considering funding and incentive opportunities that are currently available.

Next 1-3 years:

- Evaluate existing systems, collect data on equipment models and sizes, and review control sequences.
- Commission the boiler system. As described in the efficiency section, the walkthrough showed boilers were operating at high temperatures that are generally required for buildings where hot water heats the air directly, not geothermal heat pump systems. Reviewing boiler controls to ensure the boilers turn on less frequently will help reduce natural gas use in the building and rely more heavily on electric systems.
- Investigate technology options for replacing the domestic hot water heaters with new heat pump water heaters. The older heater should be prioritized for replacement first. As it is 125 gallons, it is just beyond the 120-gallon limit for current heat pump water heater offerings.

Examine heating hot water usage data or trends to see if the storage tank size can be downsized or replace with multiple smaller heaters.

- Consider utilizing the solar hot water system more often or add new automatic controls.

3-5 years

- Begin replacement of older domestic hot water heater with new heat pump water heater or heaters.
- Examine technology options for any gas-fired kitchen equipment.

5+ years

- Replace the newer domestic hot water heater with a new heat pump water heater to fully electrify the domestic hot water system.
- Replace remaining gas equipment with electrified equipment if technology is available.

Renewable energy

As Glacier Creek Middle School is near the net-zero target set by NBI, a goal for renewable electricity could be to add enough to offset the majority of the school's consumption with clean sources. The building has around 61,000 square feet of roof space available, and most of the space is oriented in an ideal direction (southwest).

A system that uses all available space, sized at 614 kW, could replace 75% of current electricity use within the building. Paired with the renewable energy rider or a second offsite renewable program, this school could reach 100% of electricity use covered by renewable electricity. The 614-kW system would offset roughly 515 metric tons of CO_2 a year and generate cost savings of $20,000. The array would be eligible for Focus on Energy rebates and elective pay tax credits up to 30% of the upfront cost.

Reporting and evaluation

In annual reports and evaluation, consider the following:

- Compare EUI over time for Glacier Creek and in comparison, to the net-zero target.
- Break out natural gas vs electricity use over time to understand how updates to boiler controls are influencing how often the boiler is running.
- Report to stakeholders as part of a larger districtwide building energy progress update. Integrate Glacier Creek's performance into larger energy goals and targets.

SCHOOL BUS FLEET

School bus transportation contributes to overall CO_2 emissions for MCPASD operations. The current buses are diesel buses, which have significant CO2 and air quality emissions. To fully decarbonize school operations, a transition to low-carbon buses will be needed. The most-adopted low-carbon alternative is electric buses. There are currently electric models for various sizes of buses.

Important features of electric school buses include:

- Buses can drive 120 – 150 miles between charges, which could enable them to serve morning and afternoon routes without requiring mid-day charging.[24]
- Fleet managers may reduce fuel costs by over 70% per mile and reduce GHG emissions from buses by over 50%.[25]
- Electric school buses have fewer moving parts than diesel buses and may require less maintenance. For this reason, the cost of labor and supplies to maintain electric school buses is at least one-third less than equivalent costs to maintain diesel buses.[26]
- Electric buses reduce exposure of children to NO_x and other harmful emissions as they enter, exit, and ride the district's buses.

To reduce the district's indirect emissions produced by buses and improve air quality for students, MCPASD can develop a plan to transition the buses from diesel models to electric school buses. While the fuel and maintenance costs for electric school buses is currently lower, the purchase cost of an electric school bus is significantly higher than the purchase cost of an equivalent diesel bus. In addition to the purchase price, installing adequate EV charging equipment would add to the initial cost to incorporate electric school buses into its fleet.

Incorporating electric school buses requires consideration of several factors that may not be applicable to its diesel buses, including selecting vehicle charging equipment, anticipating effects of reduced vehicle range in cold weather, and staff training. Electric school bus manufacturers may provide data, guidance and support, which the district or its contractor may leverage for planning and implementation purposes. For example, one manufacturer, Blue Bird estimates cold weather vehicle range loss of 20%-25%. To minimize winter range loss, Blue Bird recommends starting to charge the electric school bus while it is still warm, immediately after it returns from its last route and, if possible, to install EV charging infrastructure in locations that offer some protection from the wind.[27]

Other school districts that have implemented electric school buses into their fleet can also provide relevant information and lessons learned. As one case study, the team discussed electric buses with the Cedar Rapids (IA) Community School District (CRCSD). CRCSD owns its bus fleet and added two electric buses to its bus fleet in August 2023. The district selected Blue Bird Vision Electric Buses with a battery size of 155 kW and a 120- mile range. In addition to the buses, the district installed two 60 kW fast chargers. Relevant considerations and lessons learned from CRCSD's initial experience are summarized below:

- **Cost and funding.** The total cost for each electric bus was approximately $500,000 and the installation cost of the two charging stations was $200,000. The district leveraged funding from Alliant Energy, its electric utility, as well as from Iowa's VW Settlement Funds to offset purchase

[24] Statement based on vehicle specifications provided by bus manufacturers.
[25] Based on an average cost of electricity in Wisconsin and historical data on the cost of diesel fuel,
[26] Levinson, M. Burgoyne-Allen, P. Huntington, A. and Hutchinson, N. *Recommended total cost of ownership parameters for electric school buses: Summary of methods and data.* WRI Technical Note. 2023
[27] Blue Bird Electric School Buses, July 2020. https://assets.ctfassets.net/ucu418cgcnau/362sQcGinJzFxVqFh0DBCr/cb2ee507e5c8f646ee133bfdabbccbfb/02_Blue_Bird_Electric_Bus_Presentation_Truck_and_Bus_NOTES_V2.pdf

and installation costs. CRCSD's net cost after applying grant funding was $87,000 per bus. The district currently pays $135,0000 per diesel bus that it purchases.

- **Vehicle charging plan and route selection.** CRCSD installed two Nuvee 60 KW fast charging stations in an unsheltered outdoor location at its primary garage to power the buses. It charges the buses overnight, as well as during the time between completing morning routes and starting afternoon routes. To reduce concerns about running out of charge mid-route, the ESBs currently serve some of the district's shorter routes.
- **Winter driving range reduction.** The fleet manager anticipates significant range reduction due to cold weather and snow. The district installed supplemental diesel-fueled space heaters on the buses to mitigate some of the range loss. Despite range loss, the district expects that it will continue to use the electric school buses to serve regular routes in the winter.
- **Staff training.** CRCSD maintenance staff are not certified to work on high voltage systems, so it has outsourced vehicle maintenance, as well as maintenance for charging stations. For the pilot, the district trained five drivers to run the electric school buses. These staff are the only drivers who operate the buses. The district limited operations to a sub-group of drivers so that these drivers can more easily provide feedback on bus operation and become comfortable with the electric buses.
- **Stakeholder feedback.** The district's fleet manager reports that its drivers love operating the electric buses. They have found that electric buses are much quieter than diesel buses and that the quieter interior environment supports improved behavior and reduced noise levels by riders. Drivers also enjoy finding ways to adjust driving habits as they attempt to minimize the amount of charge that the bus uses for each route.

A gradual transition to electric school buses is an important strategy as part of the district's decarbonization journey. Piloting EV buses in the next several years can also allow the district and its contractor to benefit from available funding through the U.S. Environmental Protection Agency (EPA)'s Clean School Bus Program and available vehicle tax credits. More information about the EPA's grant program and about the Clean Vehicle Tax Credit is available in the Funding Opportunities section below.

FUNDING OPPORTUNITIES

The cost of the upgrades identified in this plan is substantial and may be a barrier to implementation. This section is intended to provide an overview of potential funding opportunities for the upgrades identified in the report.

Leverage fuel and maintenance cost savings generated through solar energy and building energy efficiency to fund capital expenses.

As identified in the report, energy efficiency upgrades and solar installations will save MGSD money on annual operating costs. MGSD could quantify avoided energy and maintenance costs from solar and efficient buildings and use those avoided costs to implement other recommended actions during the subsequent budgeting cycle.

Utilize existing Focus on Energy incentives.

Alliant Energy and MGE offer incentives through Focus on Energy for renewable energy installations and energy efficiency upgrades and installations. It is recommended that MCPASD provide a copy of this report to its Energy Advisor and ask for assistance in identifying the best way to access rebates. The amount available is determined by each energy efficiency measure and often specific characteristics of the equipment, such as the size of the solar system or efficiency of the new equipment.

Apply for federal tax credits.

The Inflation Reduction Act (IRA), a federal law passed in August 2022, represents an unprecedented amount of funding for energy and climate actions. The IRA channels a substantial amount of its funding through tax credits and rebates for renewable energy. Through this funding, it also includes a provision, direct or elective pay, that makes non-taxable entities eligible for the tax credits. The tax credits are available through 2032 and can be paired with other grants, forgivable loans, or tax-exempt bonds if the total funds do not exceed the total cost of the project. The tax credits have no cap on total amount a district can claim in a year.

Most notable for the school district is the availability of renewable energy tax credits for up to 30% of upfront cost. For any system under 1 megawatt (MW), 30% is the base amount, and if the installation meets domestic content requirements,[28] an additional 10% is available. For systems above 1 MW, additional restriction must be followed.[29] Geothermal, solar, and battery installations are all eligible items under the Investment Tax Credit for renewable energy. The credit is reduced by 15% for any project that is funded through tax-exempt bonds.

The school district could also work with its fleet contractor to encourage use of the Commercial Clean Vehicle Tax Credit for up to 30% of vehicle cost or a cap of $40,000 for vehicles over 14,000 pounds. Similarly, MCPASD could work with building contractors to claim the Energy Efficient Commercial Buildings Deduction (179D) for any building upgrades that reduce energy use by at least 25%. The credit is not available for elective pay and the school district's contractors would have to claim the credit and reduce the total cost to the school district.

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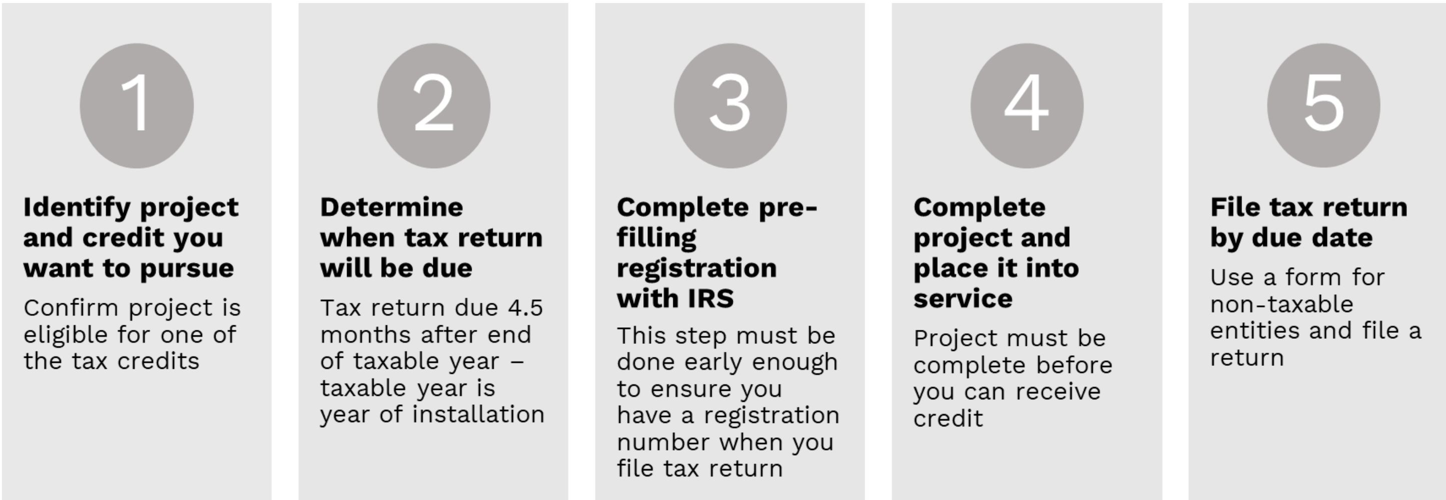
[28] Domestic content requirements apply to steel, iron or manufactured products. All steel and iron manufacturing must occur in the US. Manufactured products require that 40% of total costs of all materials are mined, produced, or manufactured in the United States.

[29] Prevailing wage requirements state that contractors Shall be paid wages at rates not less than the prevailing rates for construction, alteration, or repair of a similar character in the locality in which such facility is located as most recently determined by the Secretary of Labor. Registered apprenticeship requirements state that 15 percent of hours must be completed by a qualified apprentice (enrolled in registered apprenticeship program)

The IRS has released guidance on how entities can receive direct pay. The set of steps are listed in Figure 12.[30] The guidance for pre-filling registration was released in late December 2023.[31]

Figure 12. Inflation Reduction Act direct pay – steps for receiving credit



Apply for other state, foundation, and federal grant and financing opportunities.

There are other grant programs and financing opportunities from the state, foundations, and federal grant programs. A few programs are highlighted below:

- **Couillard Solar Foundation:** The program supports an in-kind solar module donation of 50 kW DC (valued at $20,000) to school districts. The foundation will support at least one installation per district.[32]
- **Renew America:** The Department of Energy's Renew America program funds energy efficiency and clean energy upgrades at schools. The grant is anticipated to open for a second round in spring 2024. The funding is flexible and covers HVAC, lighting, building envelope, and renewable energy technologies.[33]
- **Clean School Bus Program:** Through federal funding, the Environmental Protection Agency provides $5 billion over five years to transition school buses to low-carbon alternatives. The current round is open until January 31, 2024, and future rounds will open before 2026. School districts can apply and pass funding to a private contractor, or a private contractor could apply directly. The 2023 round allows for an application for up to 25 buses and will fund up to $200,000 of the cost depending on the bus size.[34]
- **State of Wisconsin Office of Energy Innovation:** The Energy Innovation Grant Program funds implementation of renewable energy and energy efficiency. The grant program usually opens annually in the fall with applications due in January.

[30] More information is available here: https://www.irs.gov/pub/irs-pdf/p5817.pdf
[31] Registration information is included here: https://www.irs.gov/credits-deductions/register-for-elective-payment-or-transfer-of-credits
[32] More information is available here: https://couillardsolarfoundation.org/solar-on-schools/
[33] More information is available here: https://www.energy.gov/scep/renew-americas-schools
[34] More information on the Clean School Bus Program is available here: https://www.epa.gov/cleanschoolbus

APPENDIX 1: HVAC SYSTEM ELECTRIFICATION

Electrification Replacement Process

Existing heating systems that are fueled by natural gas can be challenging to decarbonize and will take significant time and investment to convert to electric heat pumps. There are a series of recommended steps as school districts start to consider decarbonization: (1) evaluate current HVAC system, (2) determine the replacement approach, (3) decide on the best replacement system, and (4) implement plan. This section describes step two and three in more depth to help building operators

Evaluate the current HVAC system

Two possibilities should be considered when evaluating the existing HVAC system, reuse of system infrastructure or replacement of the entire system.

The first step, which is the same for every natural gas heating system, is to take inventory of all heating, cooling, and air handling unit equipment. This will help inform decisions about when and if equipment should be replaced, and which electrification systems are viable when reuse is desired over a need for replacement. It will also identify the starting point for sizing equipment and estimating building loads for the design and construction team.

One important item to inventory is the hot water temperature for buildings with boilers, the most common heating system for MCPASD buildings. Heat pump alternatives for boilers are being developed, but one barrier of adoption is that heat pumps can only heat water to around 130°F to 140°F, and ideally would heat at 110°F to 130°F for best efficiency. Most buildings using boiler systems were designed to use hot water that is 160°F to 180°F. Some systems do incorporate hot water reset which lowers supply water temperatures under conditions with lower heating loads.

Exploration of building heating demands and system limitations is critical for heat pumps to replace boiler hot water systems. Ideally a heat pump system could be retrofit to provide heating for most of the year allowing it to operate at higher efficiencies and utilize more readily available equipment. A supplemental heat source like an electric boiler and thermal storage could provide a additional capacity when needed. This holds true for both air-source and water-source (geothermal) heat pump equipment.

There are multiple ways to evaluate if a building can reduce the heating hot water temperature. It could be done through analyzing existing data from AMI gas meters or BAS to see if how often the building would be at risk if hot water temperature is not at design. Through this, an evaluation of equipment should be done to understand the limitations to coils sizes and equipment capacity at lower hot water temperature. And finally, an easy way to see if the building system hot water temperature can be lowered is to slowly lower the hot water temperature over a week or a month and see when students or teachers complain (don't lower the hot water temperature below 140 F if boilers are non-condensing boilers as that could damage the boilers).

It is also important to ensure that the building’s envelope and insulation are considered along with electrification. Electrifying a heating system in a building with high air leakage and poor insulation will result in large equipment and high electric bills. It would be a better investment to tighten up the building’s envelope and subsequently downsize the heating system to save energy in the meantime. Electric heat pumps will use more electricity than comparable air conditioning systems, so the size of electric service and electric switchgears and panels should be carefully evaluated to determine if they can handle additional electric capacity.

Determine the replacement approach and strategy

The next two steps in the process require determining if the district wants to pursue a rapid replacement of the current heating system by completely removing the current system, or a phased replacement in which the district slowly transitions from the existing system to a fully electric system. If resources are available or the need for replacing aging systems is dire, then rapid replacement may be the most practical. Any new electrified heating system could be used if the old systems are completely removed. In rapid replacement under certain scenarios, some existing infrastructure could be retained to reduce cost.

Advancements in technology is a factor to consider in electrification of heating systems. New systems that combine heat pumps and thermal energy storage are beginning to come to market, the ability for heat pumps deliver high supply water temperatures is starting to emerge with some limitations, and new low GWP refrigerants will be phased broadly into the market starting in 2025.

A more likely approach is the phased approach. The phased replacement would retain equipment from the existing system while slowly replacing and building out the fully electric option. This will spread costs and disruption over several years while taking advantage of existing equipment still in good condition. The new electrification systems may be limited by the existing building and should be chosen to take advantage of existing infrastructure and available funding.

The following sections go into more detail on three common types of existing systems and how different electrification heating systems could be implemented given the existing system.

4-pipe VAV (boiler + chiller)

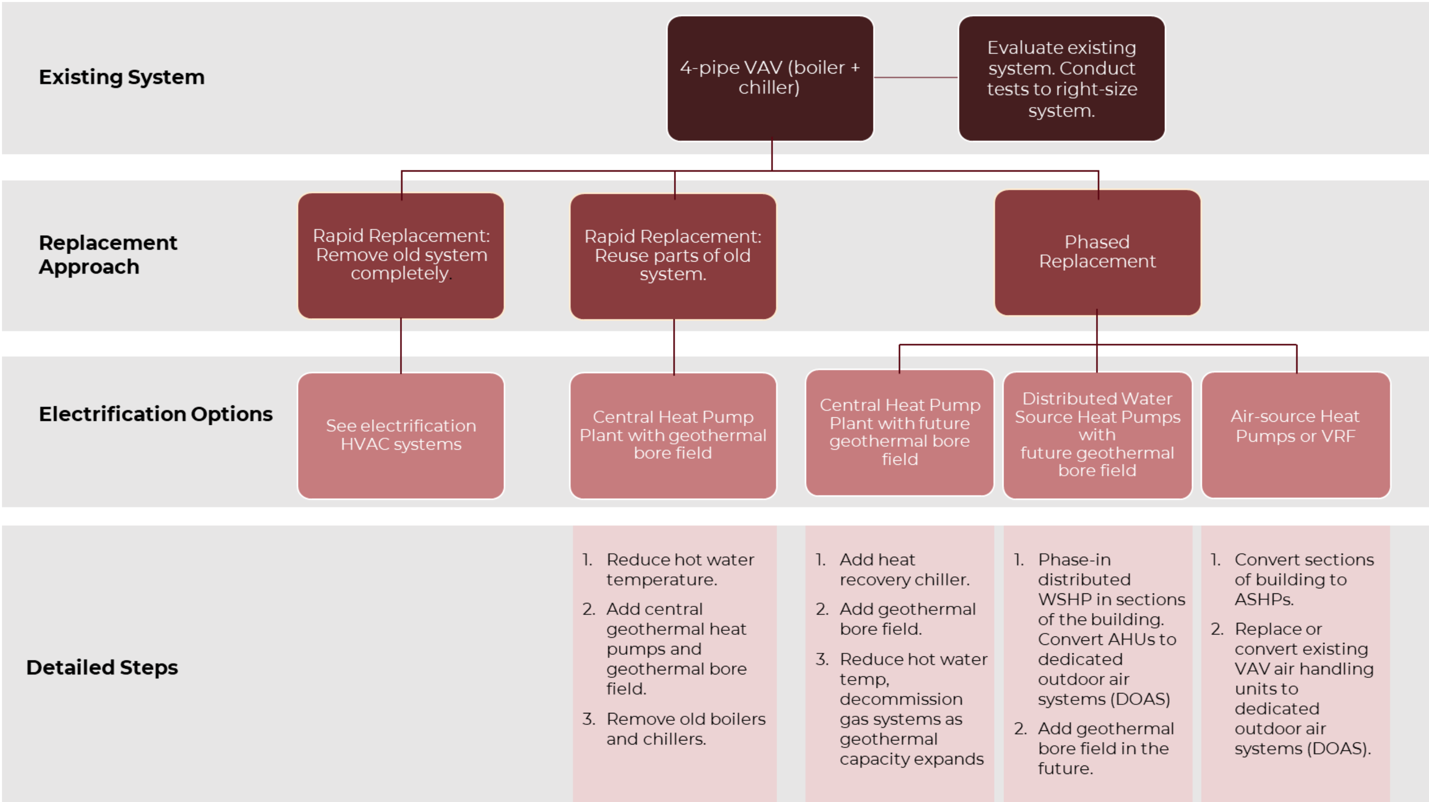
A common system in MCPASD schools is 4-pipe VAV or boiler and chiller systems. Figure 13 includes an overview of options for transitioning from a 4-pipe VAV system to a fully electrified system. The challenge that decarbonizing with these systems presents is reducing the hot water temperature to a temperature that can be produced by heat pumps. However, the existence of a central chiller and boiler plant also presents an opportunity for conversion to a geothermal heat pumps system.

If rapid replacement of systems is feasible and desirable, the existing system can be demolished and replaced with any electrified heating system. There is also an opportunity to reuse components of large central plants, such as piping and pumps, by converting these systems to a water-to-water central heat pump plant served by a geothermal field. This system will produce low temperature hot water (120°F) and chilled water to allow reuse of the VAV air system. Some heating coils may need to be replaced with equipment designed for 120°F hot water.

If phased replacement is selected, then the first step should be seeing if it is feasible to install a geothermal bore field. If there is room for a geothermal bore field, consider converting the boiler and chiller plant to a central heat pump plant. This will retain the building piping system and limit changes to just the water plant. A key step for this is making sure that the hot water coils can run at a lower hot water temperature from the water-to-water heat pumps. One way to phase this option is to add a water-to-water heat pump as a heat recovery chiller, add the geothermal bore field, and add more water-to-water heat pumps as geothermal expansion allows. Another option is to convert the building to distributed water source heat pumps, taking advantage of existing boilers and heat rejection equipment, and then converting to geothermal when feasible.

One other replacement option, particularly for smaller schools without the land for a geothermal field, would be to slowly convert to air-source heat pumps or VRF. The boilers can remain for back-up heat, if necessary, until those can be electrified.

Figure 13. 4-pipe VAV boiler and chiller system electrification replacement options



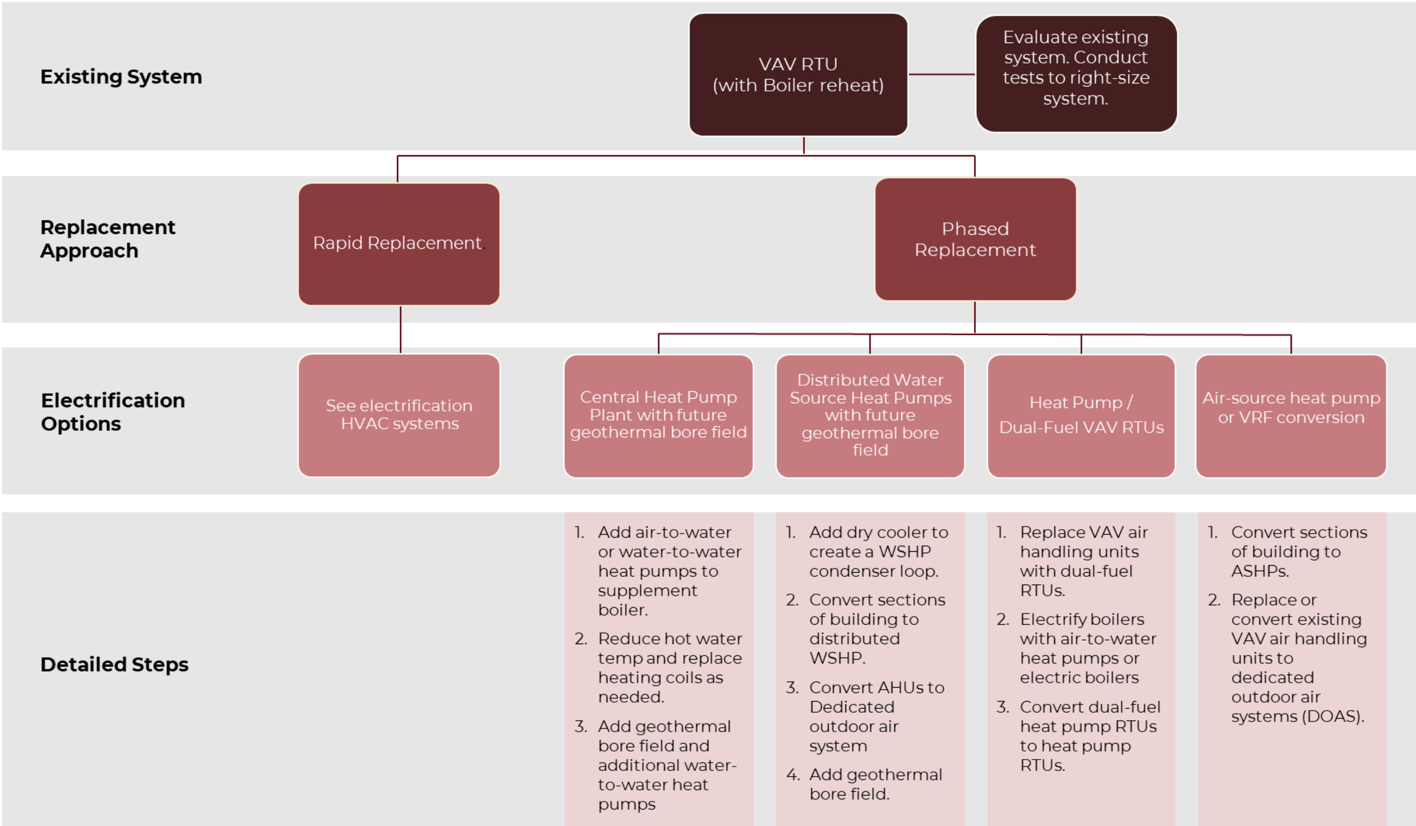
VAV RTU (with Boiler Reheat)

Another existing system for MCPASD schools is variable air volume (VAV) with a boiler and rooftop unit (RTU). Figure 14 includes an overview of options for transitioning from the existing system to a fully electrified system. The barrier to electrifying these systems is that heating is provided by both a gas boiler system and RTU preheat coils, requiring multiple points of electrification.

If rapid replacement of systems is feasible and desirable, the existing system can be demolished and replaced with any electrified heating system. One emerging technology to replace these units are dual-fuel RTUs, which uses both heat pump heating and gas heating depending on the outdoor air temperature. As heat pump RTU technology matures, fully electrified RTUs can replace the dual-fuel RTUs.

Converting to an electrified HVAC system in phases may be more involved if dual fuel RTUs are not used. If the boiler system is sufficiently large, it can be converted to a central heat pump plant by adding a dry cooler for rejection, and slowly converted to water-source heat pumps or geothermal system. Adding distributed heat pumps when adding a geothermal field or water-to-air rejection (later converted to geothermal) would also be an option. A final opportunity would be to replace or convert the RTUs to dedicated outdoor air systems (DOAS) and add air-source heat pumps or VRF heat pumps to heat and cool the building.

Figure 14. VAV RTU (with boiler reheat) electrification replacement options



Single-zone RTUs, steam/hot water radiators, central furnaces with ACs

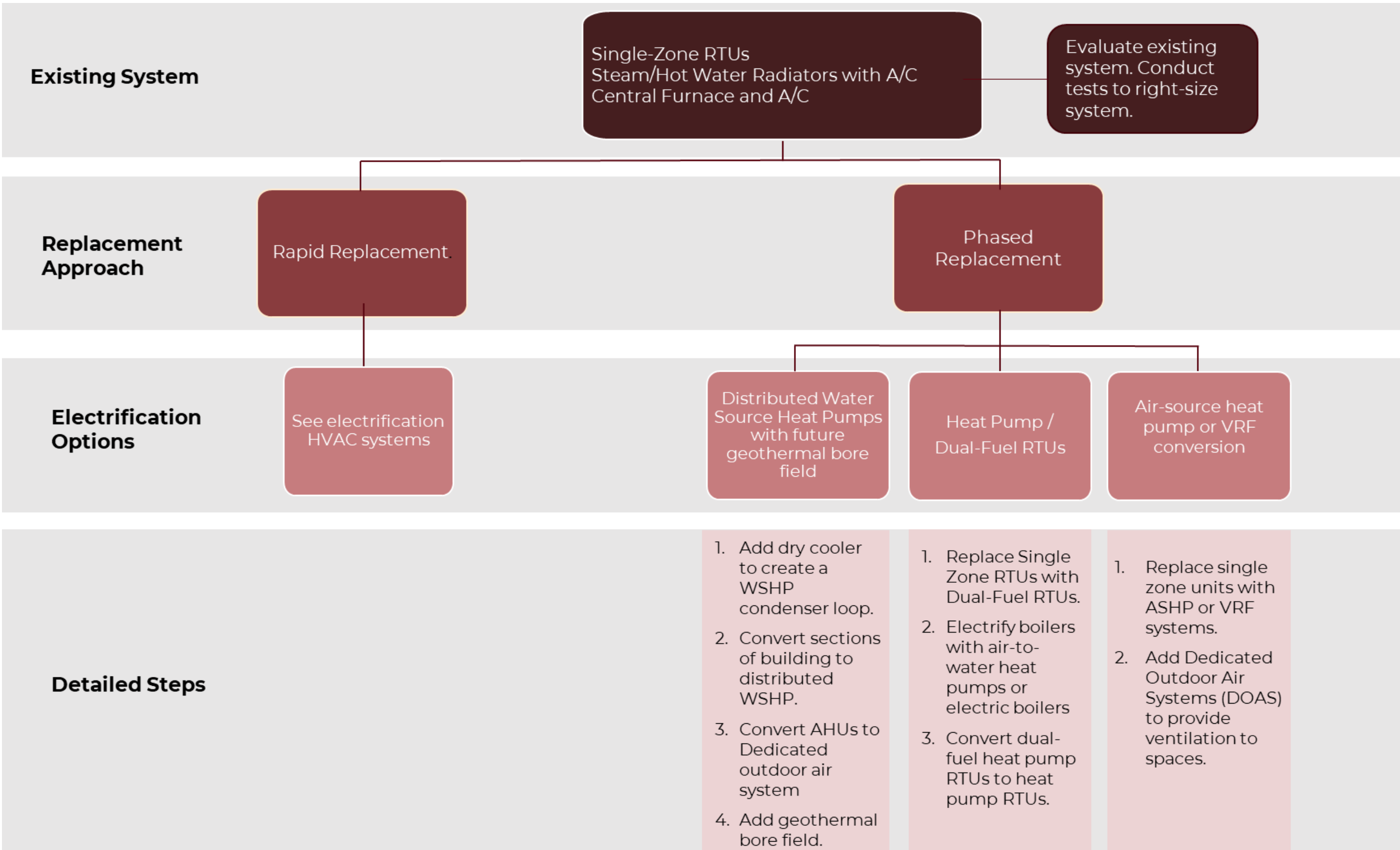
A less common existing heating system is single-zone units. These include single-zone RTUs, steam/hot water radiators, and central furnaces with ACs. Single-zone RTUs are still common for large open spaces like gymnasiums, cafeterias, and auditoriums. Steam/hot water radiators are common in older school buildings, which often were served by unit ventilators or similar units. A furnace and AC/unit system are common in offices.

Figure 15 includes an overview of options for transitioning from the existing system to a fully electrified system. Like the previous systems, evaluating the system and determining if rapid replacement is an option is the first step. Given that these are generally smaller systems, rapid replacement may be easier.

Where radiators or unit ventilator style systems are the prominent heating system, consider converting to air-source heat pumps or VRF, or using distributed water source heat pumps. The latter two options have indoor unit options that are designed to retrofit into radiator or unit ventilator equipment. The water-source heat pump option can be converted to geothermal in the future. A central heat pump plant could also be feasible with careful study, though the smaller distributed systems are likely more cost effective.

For single zone equipment serving specialty areas or sections of building, first consider if they can be added to the primary system (e.g., determine if a geothermal system could cover a RTU covering the gym). Otherwise, single-zone RTUs should be converted to dual-fuel RTUs and later heat pump RTUs as the technology becomes more widely available. Furnaces could be converted to residential dual-fuel heat pumps and later heat pumps.

Figure 15. Single-zone RTUs, steam/hot water radiators, central furnaces with ACs electrification replacement options



Electrification Technologies

Variable Refrigerant Flow (VRF)

Variable Refrigerant Flow (VRF) systems consist of multiple fan coil units (known as “indoor units”) in different rooms attached to a central compressor and outdoor heat exchanger (known as an “outdoor unit”). In buildings where different rooms need heating and cooling at the same time, some “heat recovery” VRF systems can recycle thermal energy used for cooling to heat other rooms. Most VRF systems use a dedicated outdoor air system (DOAS) to provide ventilation, which can use the same heat pump technology as the outdoor units. While VRF systems can come in water-source or geothermal configurations, most VRF installations are air-source.

Most VRF systems are very efficient because they use the most advanced heat pump technology. Some VRF manufacturers have “cold-climate” models which overcome the capacity limitations of other air-source heat pumps at low outdoor temperatures. Cold-climate VRF systems avoid the need for any backup heat. VRF systems are relatively easy to install in retrofit applications because the refrigerant lines connecting the system are small compared to pipes or ductwork, and existing ductwork can be reused to provide ventilation air from the DOAS. However, designers can encounter difficulties related to code requirements for refrigerant safety. Additionally, VRF systems are at an elevated risk for leaking refrigerant compared to other systems because they require a larger refrigerant charge and because running the refrigerant lines requires numerous field connections, which are more prone to leakage than factory-installed piping.

Opportunities

- VRF systems with optional heat recovery feature can reduce power requirements when there are simultaneous heating and cooling loads
- High operating efficiencies at non-peak loads

Risks

- Increased risk of refrigerant leakage compared to other systems
- System can experience extensive maintenance issues if improperly installed

Ideal systems to replace

- Any

Recommendations

- Make sure to specifically name a cold-climate VRF system in any owner’s project requirements or specification documents. Require that the system be able to maintain 100% of its AHRI rated heating capacity at an outdoor temperature of -4 F.
- Require that contractors bidding on installing a VRF system provide documentation that their staff performing the work have received the proper training for installing the manufacturer’s specific system, as well as prior experience with VRF installation.

Air Source Heat Pumps (ASHPs)

A new generation of air source heat pumps, often referred to as "mini-split heat pumps," are small air-source heat pumps which consist of a single indoor unit paired with a single outdoor unit. An ASHP heats and cools a single room, so buildings typically install multiple units. Each ASHP can provide its own ventilation air individually with a matched outdoor air intake, or multiple ASHPs can be paired with a DOAS.

Most ASHPs are very efficient because they use the most advanced heat pump technology; and most are made by the same manufacturers that produce VRF systems. Like VRFs, most manufacturers have "cold-climate" model options which enable them to provide sufficient heat even at low outdoor temperatures. ASHPs are simple and easy to install and maintain compared to other systems, although the large number of compressors can require substantial maintenance time. In larger buildings, an ASHP can be used to condition a single room or specialized space where it is difficult or impractical to extend the main HVAC system.

Opportunities

- Simple and easy to maintain
- Easy to deploy in small, specialized applications

Risks

- Large number of heat pump units can lead to substantial maintenance time

Ideal systems to replace

- Furnace and A/C units
- Single Zone RTUs

Recommendations

- Make sure to specifically name cold-climate heat pumps in any owner's project requirements or specification documents. Require that the system be able to maintain 100% of its AHRI rated heating capacity at an outdoor temperature of -4 F.

Distributed Water-Source Heat Pumps (WSHPs)

A distributed water-source heat pump system consists of multiple heat pumps distributed throughout a building and connected to a common condenser loop. The condenser loop can be attached to a geothermal borefield, or to boilers and a cooling tower to supply and remove heat from the building. The system provides ventilation through a DOAS, which is also a water-source heat pump connected to the condenser loop.

A key advantage of this system is that it can be used as a “bridge” between an existing system and a geothermal system: if a building’s existing boilers are relatively new, they can supply heat to the water-source heat pumps and be removed when a geothermal borefield is installed later. The building could also retain the boilers as a backup heat source. This reduces the risk of the boilers becoming a stranded asset. Furthermore, since the system does not use air-source condensers, more room is left on a building’s roof for installing solar panels. When the system is installed with a geothermal borefield, its efficiency is extremely high.

A drawback to this system is that its installation costs are likely high relative to VRF or air-source heat pump systems, both because of geothermal costs and new piping has to be run to all the water-source heat pumps. There is federal funding through a tax credit under the Inflation Reduction Act that can lower the cost of the systems. Also, reduced costs related to refrigerant safety compliance may make this less of an issue when compared to VRF systems.

Opportunities

- Can be a “bridge” system in a phased conversion of a building to fully electrified HVAC

Risks

- Potentially high installation costs compared to other systems

Ideal systems to replace

- 4-pipe VAV
- Single-Zone RTUs
- VAV RTUs
- Steam/Hot Water Radiators with A/C

Recommendations

- During conceptual design, determine whether to install a geothermal borefield immediately or wait until existing equipment has depreciated further. Take into account the age of existing boilers and chillers and the additional cost of installing a geothermal field.

APPENDIX 2: SOLAR RESULTS

Solar Methodology

The project team identified solar opportunities by reviewing energy use profiles and roof and ground space available by building. Certain schools were excluded due to roof constraints or architectural requirements, or ones that already had solar panels and used the majority of their roof capacity.

For the rest of the buildings, the team started by identifying the space available by reviewing the buildings with Google satellite mapping. The satellite images provide an idea of the amount of space available, the direction the array could face, and degree tilt. South-facing arrays offer the most cost-effective opportunities, followed by east or west facing arrays. The degree tilt represents how angled the panels. On average, matching the degrees of tilt for the panels to the degrees latitude of the solar array will produce the most electricity over the course of a year. If a building's roof is not tilted at this angle, panel mounting can apply a tilt. However, the amount of tilt must be balanced against shading effects created between rows of panels.

The roof space available was combined with monthly energy data and utility rates and entered into the technoeconomic tool, ReOpt, to find the most cost-effective solution. ReOpt takes inputs of a building's energy loads, utility rate, and based on user inputs and constraints, optimizes the sizing of solar PV.

The analysis assumes that the net metering limit is 20 kW DC for Alliant Energy and 100 kW for MGE. This is the current limit set by the utility and any solar installations below this size receive the full utility retail rate for any overproduction of solar that is sent back to the grid. Any solar size above 20 kW DC receives the buyback rate (or wholesale rate) instead. The buyback rate is lower than the retail rate and changes yearly. Both rates are only applicable when the amount of solar produced at a certain time is higher than the building's consumption. The remainder of the time the solar array is saving money as no energy must be purchased from the grid.

Other assumptions include:

- The lifetime of the system is 25 years. This is a conservative value; estimates range from 25 to 50 years.
- The upfront cost of the system is $2,500/kW for roof systems below 75 kW and $2,100/kW for systems above 75 kW. Ground systems are assumed to be 30% more expensive than roof systems. These costs are based on market research and similar quotes in Wisconsin.
- Roof loading and electrical panel space needs to be verified by a trained design professional.
- Operations and maintenance costs are low per year. Inverters need to be replaced at year 15.

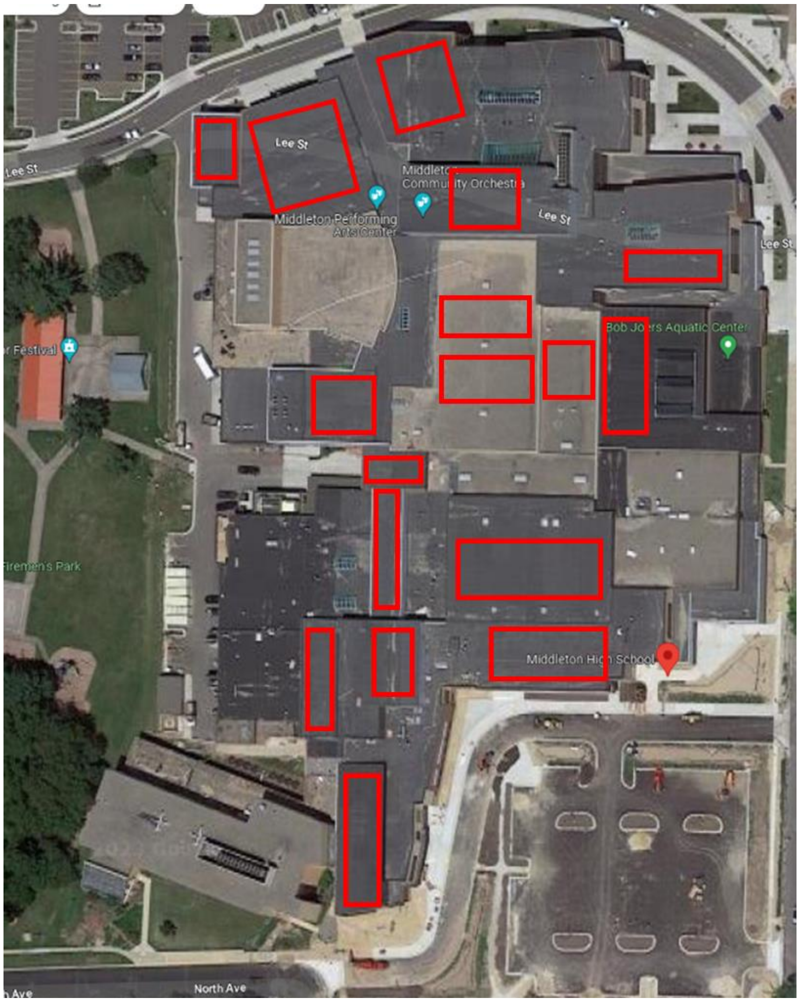
Table 9 below includes a definition for each output.

Table 9. Solar output definitions

Output	Definition
System Size	Total solar photovoltaics size in kW dc
Payback (years)	Calculated as net upfront cost divided by first year cost savings
Percent Renewable Electricity	Total electricity produced divided by total energy consumption
Lifetime CO_2 Savings (MT)	Avoided grid electricity use multiplied by a grid emissions factor
Lifetime Energy Savings	Total energy bill savings over the lifetime of the solar panels (25-years)
Upfront Cost	Total initial upfront cost ($/kW multiplied by system size). Assumed flat utility rate across time.
Focus on Energy Incentives	Focus on Energy Business rebates[35]
IRA Tax Credit	30% direct pay through Inflation Reduction Act
Net Upfront Cost	Total initial upfront cost minus rebates and tax incentives

[35] Solar incentive information is available here: https://assets.focusonenergy.com/production/inline-files/2023/RR-Solar-PV-APL.pdf

Middleton High School



Available roof space: ~65,000 square feet

Utility rates: Time-of-use rate with 7 periods: \$0.06894/kWh - \$0.09997/kWh; demand charge: \$0.498-\$0.581/kW/day

Wholesale (buyback) energy rate: \$0.034/kWh on-peak and \$0.047 off-peak

Orientation: South facing at 20-degree tilt

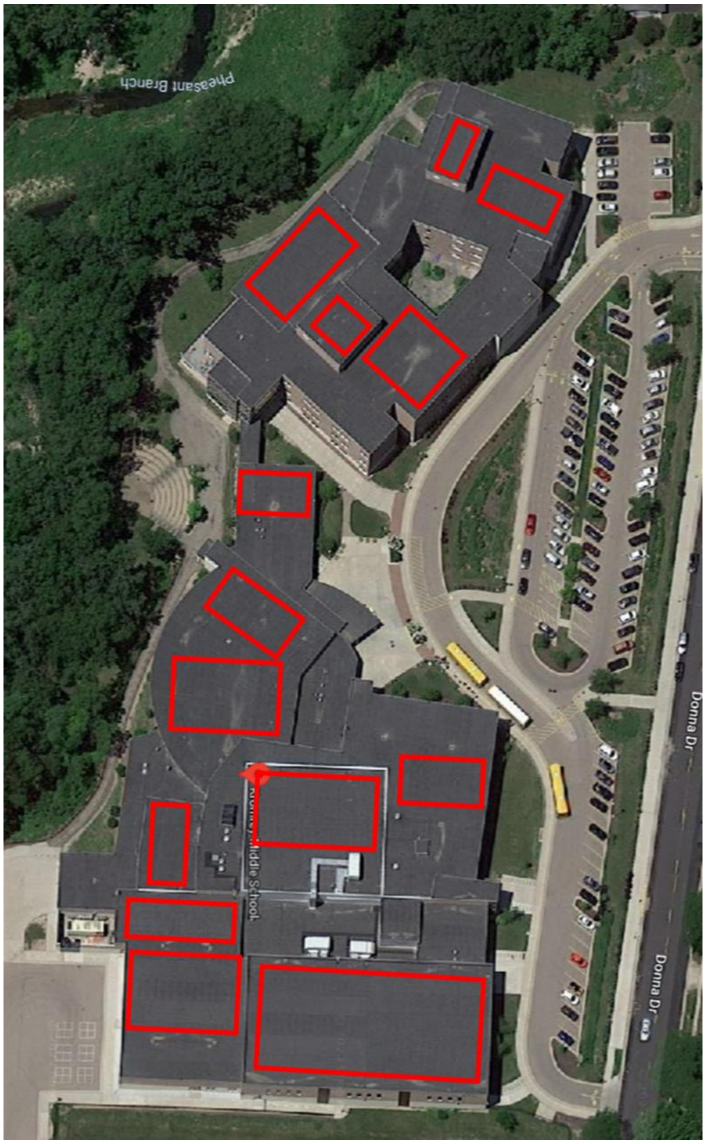
Annual energy use: ~ 3,863,000 kWh

Table 10 presents the options for solar arrays on the Middelton High School roof. The options include one that maximizes the roof space available and a second option that minimize upfront costs. The percent of electricity covered is lower for Middleton High as it's a large electricity consumer; however, the overall impact on CO_2 emissions is significant for either size of array.

Table 10. Middleton High School solar array options

Metric	**Maximized System**	**Cost Optimized**
System Size (kW DC)	652	300
Payback (years)	14.9	14.1
Percent Renewable Electricity	20%	9%
Lifetime CO_2 Savings (metric tons)	13,791	6,345
Lifetime Energy Savings	\$1,528,385	\$721,180
Total Upfront Cost	\$1,369,200	\$630,000
Focus on Energy Incentives	-\$50,000	-\$33,000
IRA Tax Credit	-\$410,760	-\$189,000
Net Cost	\$908,440	\$408,000

Komrey Middle School



Available roof space: ~50,000 square feet

Utility rates: Time-of-use rate with 7 periods: $0.06894/kWh - $0.09997/kWh; demand charge: $0.498-$0.581/kW/day

Wholesale (buyback) energy rate: $0.034/kWh on-peak and $0.047 off-peak

Orientation: Southwest facing at 20-degree tilt

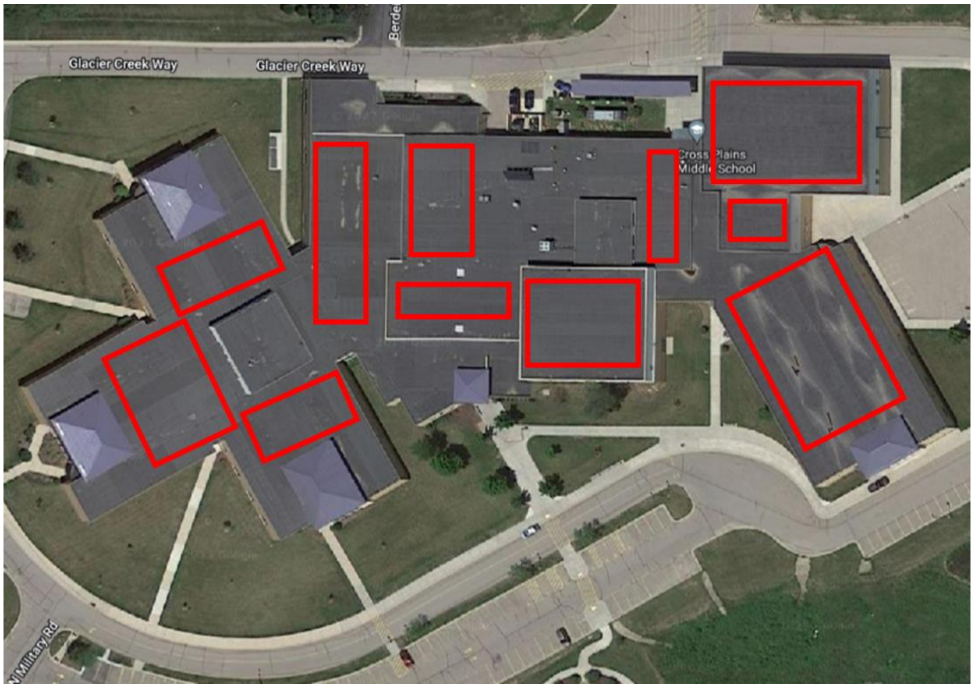
Annual energy use: ~ 1,602,000 kWh

Table 11 presents the options for solar arrays on the Komrey Middle School roof. The options include one that maximizes the roof space available and two option that minimize upfront costs.

Table 11. Komrey Middle School solar array options

Metric	Maximized System	250-kW	100-kW
System Size (kW DC)	500	250	100
Payback (years)	15.9	14.9	14.2
Percent Renewable Electricity	35%	18%	7%
Lifetime CO_2 Savings (metric tons)	10,282	5,141	2,056
Lifetime Energy Savings	$1,078,580	$570,000	$235,140
Total Upfront Cost	$1,050,000	$525,000	$210,000
Focus on Energy Incentives	-$50,000	-$28,000	-$13,000
IRA Tax Credit	-$315,000	-$157,500	-$63,000
Net Cost	$685,000	$339,500	$134,000

Glacier Creek Middle School



Available roof space: ~61,400 square feet

Utility rates: $0.073/kWh high, $0.0552 regular, $0.044/kWh off-peak; $14.02 demand charge

Wholesale (buyback) energy rate: $0.0599/kWh off-peak, $0.0768/kWh regular, $0.1028/kWh on-peak

Orientation: Southwest facing at 20-degree tilt

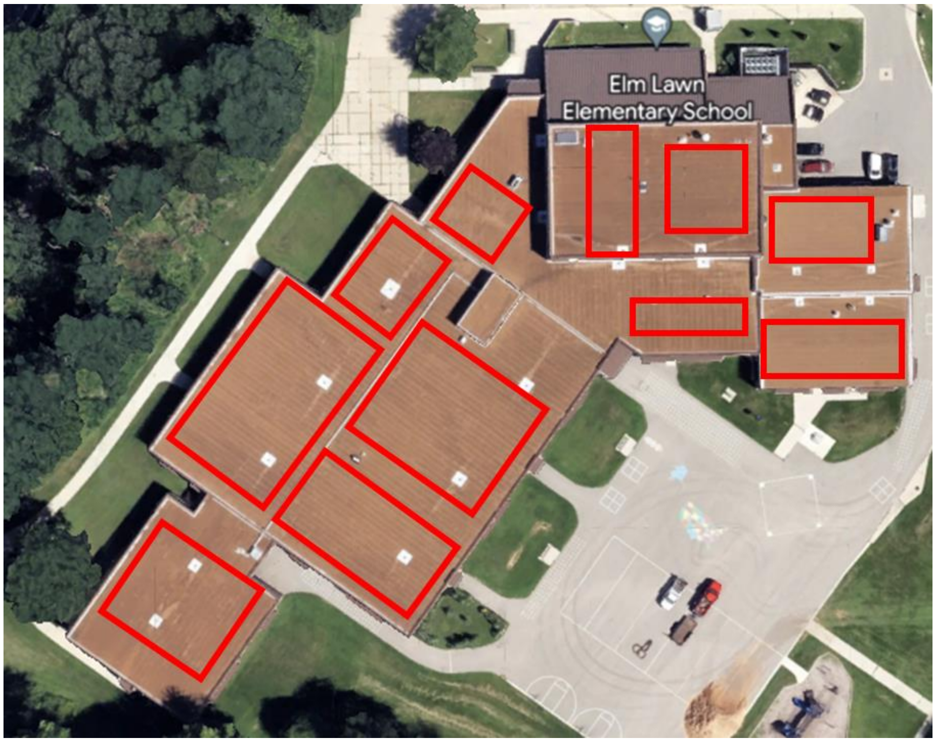
Annual energy use: ~ 938,500 kWh

Table 12 presents the options for solar arrays on the Glacier Creek Middle School roof. The options include one that maximizes the roof space available and two options that minimize upfront costs.

Table 12. Glacier Creek Middle School solar array options

Metric	Maximized System	300-kW	100-kW
System Size (kW DC)	614	300	100
Payback (years)	14.4	13.0	10.4
Percent Renewable Electricity	75%	37%	12%
Lifetime CO_2 Savings (metric tons)	12,899	6,301	2,100
Lifetime Energy Savings	$1,485,285	$783,430	$322,880
Total Upfront Cost	$1,289,650	$630,000	$210,000
Focus on Energy Incentives	-$50,000	-$33,000	-$13,000
IRA Tax Credit	-$386,895	-$189,000	-$63,000
Net Cost	$852,755	$408,000	$134,000

Elm Lawn Elementary School



Available roof space: ~24,000 square feet

Utility rates: Time-of-use: seven periods, \$0.074/kWh - \$0.102/kWh; demand charge: \$0.0.848/kW/day for maximum 15-minute demand

Wholesale (buyback) energy rate: \$0.034/kWh on-peak and \$0.047 off-peak

Orientation: South and southeast facing at 20-degree tilt

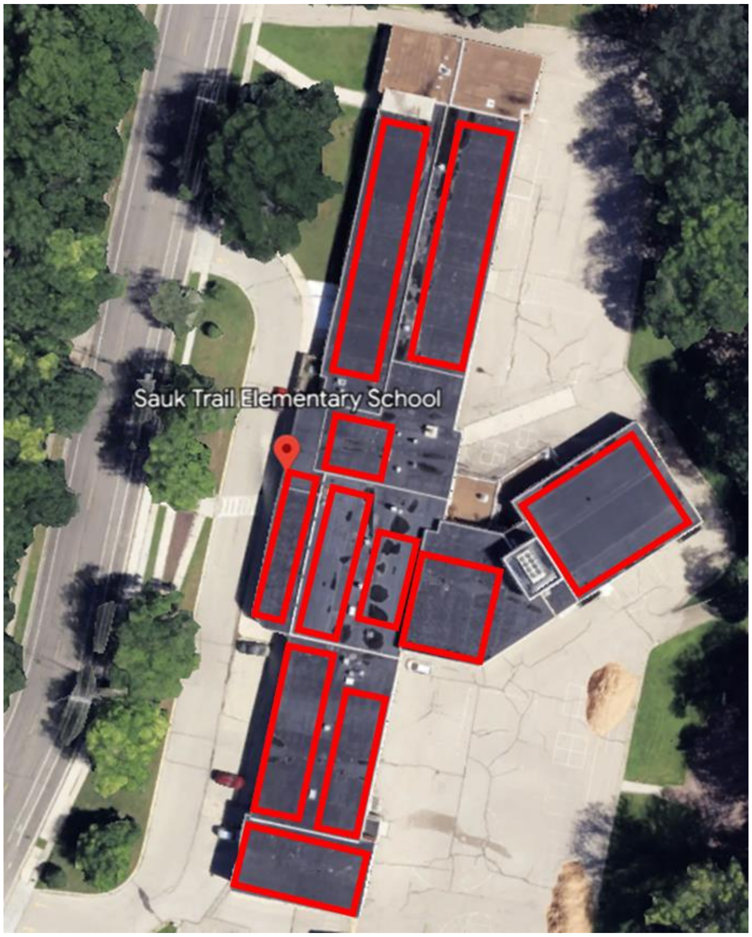
Annual energy use: ~ 367,000 kWh

Table 13 presents the options for solar arrays on the Elm Lawn Elementary School roof. The first option maximizes the space available and the other two options minimize upfront costs. The 100-kW system is the most cost-effective as the net-metering limit is 100 kW, meaning that the system receives the full retail rate for any electricity sent back to the grid.

Table 13. Elm Lawn Elementary School solar array options

Metric	Maximized System	150-kW	100-kW
System Size (kW DC)	240	150	100
Payback (years)	16.7	14.9	13.5
Percent Renewable Electricity	76%	48%	32%
Lifetime CO_2 Savings (metric tons)	5,076	3,173	2,115
Lifetime Energy Savings	\$488,930	\$339,920	\$248,315
Total Upfront Cost	\$504,000	\$315,000	\$210,000
Focus on Energy Incentives	-\$27,000	-\$18,000	-\$13,000
IRA Tax Credit	-\$151,200	-\$94,500	-\$63,000
Net Cost	\$325,800	\$202,500	\$134,000

Sauk Trail Elementary School



Available roof space: ~19,000 square feet

Utility rates: Time-of-use: seven periods, \$0.074/kWh - \$0.102/kWh; demand charge: \$0.0.848/kW/day for maximum 15-minute demand

Wholesale (buyback) energy rate: \$0.034/kWh on-peak and \$0.047 off-peak

Orientation: South facing at 20-degree tilt

Annual energy use: ~ 292,000 kWh

Table 14 presents the options for solar arrays on the Sauk Trail Elementary School roof. The first option maximizes the space available and the second option minimizes upfront costs. The second option is the most cost-effective solution as any electricity sent back to the grid receives the full retail rate.

Table 14. Sauk Trail Elementary School solar array options

Metric	Maximized System	100-kW
System Size (kW DC)	190	100
Payback (years)	16.5	13.5
Percent Renewable Electricity	76%	40%
Lifetime CO_2 Savings (metric tons)	4,019	2,115
Lifetime Energy Savings	\$388,735	\$248,130
Total Upfront Cost	\$399,000	\$210,000
Focus on Energy Incentives	-\$22,000	-\$13,000
IRA Tax Credit	-\$119,700	-\$63,000
Net Cost	\$257,300	\$134,000