Microgrid Energy

Renewable Energy Feasibility Study

St. Louis County Public Facilities

Prepared for

St. Louis County

and the

Missouri Department of Natural Resources

Missouri State Energy Program

by

Microgrid Energy

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Executive Summary
As St. Louis County continues to develop and implement plans to reduce its overall energy consumption, they are in a good position to evaluate the incorporation of renewable energy into a number of facilities. It makes sense for improved energy efficiency to go hand-in-hand with renewable energy as strategies to improve overall energy performance. The purpose of Microgrid Energy's renewable energy feasibility assessment was to evaluate these opportunities at 15 sites owned by the County. During each of these site visits, Microgrid documented the potential for solar electric, solar thermal and geothermal heating and cooling¹, as well as recommendations for improved energy efficiency.

There are a number of common elements among most of the buildings in the study set:

- One or two story buildings.
- Adequate roof strength to support rooftop energy systems.
- Lack of available and unused ground space around the buildings.
- Room for temporary, onsite storage.
- Little public visibility.

The county seat complex in Clayton varies significantly from these generalizations. Specifically, those buildings are much larger and taller, have much greater public visibility, and have building automation systems. Nevertheless, those four buildings remain subject to many of the same recommendations and limitations.

This study focused on solar applications for general commercial use on the building-scale level.

- Solar electric (or solar photovoltaic, also referred to as solar PV or simply “PV”) generates electricity directly from sunlight.
- Solar thermal water heating collects the radiant energy from the sun to heat water, primarily for domestic uses such as cleaning, cooking, or bathing.

There are other solar technologies, such as using the solar radiation to convert water to steam to drive turbines to produce electricity or drive cooling processes. However, these are either large scale and not well adapted to single building scale, or they do not adapt well to the lower sunlight level here compared to the desert southwest, for instance.

Solar Electric
The St. Louis region overall has a good solar resource. This helps the business case for offsetting a portion of the electricity used in the County facilities by installing onsite PV, and also provides a hedge against rising energy costs.

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¹ Ground-source heating and cooling uses the ground as a heat reservoir, and is often called, “geothermal” heating and cooling. However, strictly speaking, geothermal is the process of using the heat in the earth’s core to generate electricity. That was not the focus of this study, but for the sake of brevity, we are referring to ground-source heating and cooling simply as “geothermal”.
This also is also an important posture of leadership for the County, and will serve to educate the public about the benefits and feasibility of renewable energy. The following sites are the best PV candidates:

- **Metropolitan Education and Training Center**: This seems like the best candidate overall, even though it is taller and installation would be more costly. The roof is well oriented, and the current use of the building makes it an ideal facility to train a potential workforce about solar. The facility has walkout access to facilitate observation and maintenance, and a variety of types of arrays could be installed. This would be an easy target for grant funds to demonstrate solar and prepare for green jobs.

- **Record Center**: The roof is in good condition with ample space, well oriented, easy connection, and an opportunity to develop a significant energy offset.

- **Courts Building**: Abundant roof space provides best opportunity for solar PV at the Clayton complex.

- **North County Community Health Center**: Abundant roof space in good condition, easy distribution connection, and good visibility.

- **Police & Fire Training**: Abundant, well oriented roof space which could be used to provide first responders an opportunity to learn about these systems as related to emergency or abnormal situations.

**Solar Thermal**

The County can also leverage solar water heating in several facilities. In order to be cost-effective and ensure long system viability, solar water heating is best targeted to buildings with a consistent demand for hot water. Only a few facilities require hot water beyond normal business hours. The best candidates include:

- **Justice Center**: High demand for hot water every day, all day, with great access to solar on the roof.

- **Police Headquarters**: Limited roof space on this building could be used to install a solar water heating system to serve the three-building complex (Admin, Police HQ and Courts).

- **Lakeside Center**: Good demand for hot water every day, but limited south-facing rooftops on which to mount collectors.

- **Baur Animal Shelter**: Laundry and showers provide consistent demand for hot water; flat roof has good southern exposure that could support collectors.

Given that detailed water usage was not available for these sites, this report only contains general design guidance for solar thermal systems. A standard rule of thumb is to allocate approximately 1/3 of the daily demand to the solar thermal system. Some additional guidelines to generate estimates are provided below:

- Housing: 15-20 gallons per day per bedroom
- Food service: 24 gallons per day and 10 full meals served
- Laundry: 20 gallons per day and 10 lb. of wash.
If desired, county staff can correlate the specific data for each candidate site using these figures to define the desired system size.

The findings show that most of the facilities visited could beneficially implement solar PV, some could benefit from solar thermal, and a few could benefit from geothermal. These differences are based on the operating conditions, building use, occupancy schedules, existing building systems, and other factors.

The analysis below lists a summary of pros and cons for solar electric vs. solar thermal.

**Solar Electric PV**

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ease of system design</td>
<td>Higher first cost</td>
</tr>
<tr>
<td>Electricity has universal usability</td>
<td>Lower efficiency</td>
</tr>
<tr>
<td>Low installation cost</td>
<td>Higher theft risk</td>
</tr>
<tr>
<td>Cash value of excess energy</td>
<td>More roof or ground space required</td>
</tr>
<tr>
<td>Low maintenance cost and effort</td>
<td></td>
</tr>
<tr>
<td>Financial incentives available</td>
<td></td>
</tr>
<tr>
<td>Greater contractor familiarity</td>
<td></td>
</tr>
</tbody>
</table>

**Solar Thermal Hot Water**

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher efficiency</td>
<td>System engineering more difficult</td>
</tr>
<tr>
<td>Lower first cost</td>
<td>No value to excess energy</td>
</tr>
<tr>
<td>Less mounting space required for collectors</td>
<td>Unused energy causes system degradation</td>
</tr>
<tr>
<td></td>
<td>Limited uses for hot water</td>
</tr>
<tr>
<td></td>
<td>Lower contractor familiarity</td>
</tr>
</tbody>
</table>

**Geothermal**

The potential for geothermal (ground-source) heating and cooling is even more limited. While a key consideration is the availability of space for geothermal loops, a more limiting factor is the extent to which existing systems need to be replaced. Finally, like solar thermal, geothermal heating & cooling requires a consistent demand, and most of the facilities are not occupied outside normal business hours and therefore don’t require space conditioning in the off hours on evenings and weekends. Given these considerations, there was only one facility that could benefit from geothermal.

- **Lakeside Center**: Consistent requirement for heating and cooling and ample access to unpaved ground surface make this the best candidate for a campus-wide ground source heating & cooling system.
- **Police & Fire Training**: The existing HVAC system is disjointed and inefficient, and ready to be replaced. The field inside of the track and other unpaved ground surface make this an attractive opportunity to leverage geothermal energy, but the lack of 24x7 demand lowers the payback considerably.

Appendix C presents an evaluation matrix developed in concert with County staff to evaluate the potential of these sites for the various renewable technologies. The matrix takes into consideration 22
factors, weighted by County staff, and scored based on site conditions. This provides a quantitative tool for future decision making.

**Energy Efficiency**

The County is also able to take advantage of a number of recommendations for lowering overall energy usage. While some of these require significant capital improvements, there are a number of recommendations that provide strong returns on investment, with paybacks in as little as 1-3 years. Other recommendations are low- or no-cost measures that may merely require minor operational changes.

Many of the buildings exhibit similar opportunities for improvement in energy efficiency:

- Inefficient lighting
- Low insulation characteristics of walls, ceiling, and windows
- Lack of procedures to manage energy use
- Lack of monitoring of energy consumption
- Lack of building automation.

The recommendations listed below are the most common.

**Lighting**

- Start by defining across the board what lighting levels the County wants to provide for different space usage. For instance, meetings rooms might be 50-70 foot candles, hallways might be 5-10 foot candles, etc. The IESNA and ASHRAE guidelines should be used to develop these standards.
- Replace T12 fluorescent lights and magnetic ballasts with more efficient T8 lights with electronic ballasts. Select the lamp wattage and ballast factors that will provide the defined lighting illumination level appropriate for the space, and explore improved fixture designs in addition to bulb and ballast replacements. Financial incentives from Ameren will be phased out after 2011 when T12 bulbs are no longer available, so this should probably be the County’s highest priority.
- Consider replacing 400W metal halide fixtures with more efficient T8 fluorescent fixtures, particularly where the lighting can be modulated with occupancy sensors or dimmable ballasts.
- Lighting loads could be reduced in a number of spaces. Consider installing bi-level switching on lights in classrooms and offices, as it is not always necessary to have them on full power.
- Install dimmable ballasts on fixtures located near windows or skylights to reduce artificial lighting loads during daylight hours. Photosensors and dimmable ballasts also work well in elevators, lobbies and large south-facing rooms.
- Replace incandescent exit signs with more efficient LED fixtures.
- Lights were observed on in unoccupied spaces. Install occupancy sensors in rooms to automatically turn off lights, and encourage employees to use task lighting and manually turn off lights when not in use.
- Skylights and solar tube lights could be used to increase the amount of daylight in single-story warehouse and garage spaces.
Equipment
- Non-essential computer equipment should be manually or programmatically powered down outside operating hours.
- As electrical appliances and equipment are replaced, ensure that Energy Star certified products are purchased as replacements.
- Install power management equipment on vending machines to reduce power consumption by 30-50%.
- Install timers on hot water recirculation pumps so that they only run during typical hours of operation. This will save energy used to pump the water, plus energy used to reheat the circulated water.
- Install insulating jackets on hot water tanks to reduce water heating costs, and insulation on hot water pipes to reduce energy loss.

HVAC
- Adjust temperature setbacks on HVAC controls to correspond to operating hours, and publish instructions for manual override to appropriate staff. Install programmable thermostats where applicable.
- More frequent replacement of air filters on HVAC equipment will increase the effectiveness of the system and extend the life of the equipment.
- Install ceiling fans to circulate warm air downward in high bay facilities.
- Retro-commissioning of existing systems or equipment upgrades may result in significant cost savings.
- Improve insulation where upgrades are feasible, and ensure that doors, windows, and other openings between conditioned areas and outdoors are well sealed.

Full investment-grade audits have been recommended on a number of facilities. The County’s maintenance staff is well aware of the benefits of this, and a collaborative effort between outside professionals and inside experts can produce strong energy savings.

Through the course of the project, Microgrid Energy personnel advised County staff when conditions were encountered that merited immediate action. These included potential plumbing failures and abnormally high levels of carbon dioxide in working areas. These ultimately would be addressed through remediying some of the EEMs, but it was felt these should be brought to the attention of County staff without waiting until the study was complete.
Project Overview
St. Louis County has demonstrated leadership in exploring new ways to reduce their energy consumption by implementing energy-saving technologies in a wide range of facilities throughout the county. Their strategic plan included the following items:

- Increase energy efficiency and conservation
- Promote transit investments to reduce auto dependence
- Increase recycling to reduce landfill use
- Invest in renewable energy resources
- Encourage residents and employees to reduce energy usage, greenhouse gas emissions and environmental degradation.

In recognition of their efforts, St. Louis County was recently awarded the Growing Green award by the Missouri Gateway Chapter of the U.S. Green Building Council. Anne Klein, the County’s Director of Energy Sustainability, understands the value and role of renewable energy in moving the county toward greater energy independence. Ms. Klein has enthusiastically embraced the opportunity to assess the potential and feasibility for renewable energy on county facilities, and secured the commitment and approval of the County Executive and key executive staff members to begin to plan for their next phase of facility improvements. The County would like to demonstrate leadership in the state among other counties and major municipalities. The findings in this report will provide a roadmap for their own investments, and enable them to demonstrate leadership for the 96 municipalities within the County.

A defined set of 15 County-owned facilities were assessed for feasibility to install onsite renewable energy systems, including solar electric photovoltaic (PV) systems, solar water heating, and ground source (geothermal) heating and cooling. This report includes the following:

- Overview of solar energy options to be considered including a short discussion of why small wind is not being considered;
- Background on the current state of the solar and geothermal technologies. This includes an analysis of facility conditions relevant to the installation of solar and geothermal equipment, and system integration requirements.
- A recommended plan for incorporating renewable energy into the County’s facilities, with suggested prioritization based on the findings of the feasibility studies. For each site, the following assessment is included:
  - Solar electric analysis that, if feasible, includes an overview of the system, the general concept and design, financial and energy performance, environmental performance, timeline for implementation, explanation of system monitoring, tracking of performance data;
  - Solar thermal analysis, if feasible, similar to the solar electric analysis;
  - Geothermal analysis, if feasible, similar to the solar electric analysis;
  - High level recommendations for cutting peak energy usage;
  - Financing options for project implementation;
- A “roadmap” for implementation, including a ranking of the 15 sites based on potential;
- Case studies of systems implemented by peer institutions;

In order to help other counties and municipalities learn how they can incorporate solar and geothermal technologies into their facilities, a summary suitable for web posting will be made available to share these findings with the broader audience.
Renewable Energy Technology Overview

The solar industry is showing significant growth despite the economic indicators in so many other areas. Fueled by concerns about rising energy costs, the environmental impacts of burning fossil fuels and the corresponding effects on global climate, solar energy is seen as a promising solution to many of the concerns about energy.

*In an hour, more sunlight falls on the earth than what is used by the entire population in a year.* This startling statistic gives us some sense of the immense capacity of this clean, natural source of energy. In fact, the sun is the ultimate source of all of our energy, making plants grow, winds blow and rivers run. Even our fossil fuels are merely decayed plant matter – energy originating from our sun.

*Wind energy* also originates from the sun, with energy generated by uneven temperatures that cause warm air to rise and cool air to sink. Wind was not considered for this study because of the lack of potential, which is documented in the section that follows.

**Wind Energy**

In order to assess the wind potential for a site, the first step is to review a map that shows average wind speeds for an area. The map below shows where the primary areas in the U.S. where the wind blows.

![Wind map](https://www.windnavigator.com/)

*Figure 1 Average wind speeds in continental U.S.*
Wind speed is determined by atmospheric conditions and terrain characteristics. Even in areas that are generally windy, local conditions may determine whether your wind resource is adequate or not. Wind speeds increase with increased height above the surface. In general, wind speeds are higher in wide open spaces, along ridgelines and near coastlines, where few obstructions interfere with air movement. Vegetation and land use also affect wind speed. For example, rough surfaces like forests reduce near-surface wind speed.

The amount of electricity that can be generated by a wind turbine is affected by wind speed, air density, diameter of the rotor, and efficiencies of the turbine and electrical system. Higher hub-height altitudes result in higher average wind speeds, along with higher overall cost of the wind turbine structure.

Figure 1 shows the wind speeds at higher altitudes (80M). On a broad scale, the areas shaded yellow, orange or red have excellent potential for wind. Missouri has some good, strong wind energy in the northwest corner of the state, but wind speeds taper off, particularly where the terrain of the Ozark Mountains meets the flatter plains in the state.

In order to cost-effectively produce energy from wind, 12 mph winds are typically sought as a minimum average wind speed. In the St. Louis area, wind speeds average only 8-11 mph. So at the high end, we usually don’t have adequate wind speeds to produce a satisfactory financial payback. Given this situation, wind energy was excluded from this study.

Local Solar Resource
The St. Louis area is an above-average location for solar irradiation. The National Renewable Energy Laboratory (NREL) in Golden, CO provides statistical data from 33 years of historical trends, and provides monthly radiation figures that are widely used for estimating solar energy production. The average annual hours of solar irradiance received in St Louis is approximately 4.85 kWh/m²/day. This is 92% of the solar irradiance in Miami, and about 74% of what is received in the Phoenix area, which has the highest irradiance in the continental U.S. The map in Figure 2 on the following page illustrates this well.

Solar irradiance also varies with the season. In the longer days of summer when the sun is higher in the sky, St. Louis receives over 5.8 kWh/m²/day, and in the winter, that drops to nearly 3.0 kWh/m²/day. By comparison, Germany, which has the greatest deployment of solar in the world, has an annual average irradiance of only about 3.0 kWh/m²/day. This is similar to Alaska and only about 60% of the irradiance in St. Louis.² See http://www.nrel.gov/rredc/pvwatts/ for more on their PV Watts tool.

² The solar irradiance at which solar modules are benchmarked is Standard Test Conditions (STC). The irradiance parameter in that criteria set is 1,000 W/m². The general translation from solar irradiance to STC is that 4.85 kWh/m²/day correlates to 4.85 hours per day with an irradiance of at least 1,000 W/m².
Types of Solar Energy
There are two primary forms of solar energy, solar electric (or photovoltaic) and solar thermal. Solar electric uses a photovoltaic process to convert light into electricity, whereas solar thermal is the simple transfer of heat. The vast majority of the sun’s energy is stored in the earth itself, and forms the basis for ground-source heating & cooling, which is sometimes referred to as geothermal. A summary of each of these technologies follows.

Solar Electric
Solar photovoltaic energy is sometimes referred to as solar electric. Solar PV modules are made of silicon semiconductors which convert the heat to electricity. The native output from a solar module is Direct Current or DC power, which is the type of power provided by batteries. This DC power is converted to AC (alternating current) with inverters, so it can feed into a grid-tied system to complement an existing energy from the local utility.

The primary components of a solar PV system are the set of solar modules, which collective make up an array, and the inverters, which convert the power to blend in with the grid-sourced electricity. The system also includes appropriate isolation (disconnect) switches to shut off power in an emergency. The

Figure 2 Solar Irradiation Map
existing electric meter is replaced with a bi-directional meter that enables the tracking of excess energy generated by system.

**Solar Modules**
There are three primary types of solar modules currently available on the commercial market. Listed in order of power density (watts per square foot of module surface area), they are: *monocrystalline silicon* (m-Si), *polycrystalline silicon* (p-Si), and *amorphous silicon* (a-Si), or *thin film*. There are other variants used in thin film, but a-Si is the most common.

Crystalline modules have been in general use around the world for over 30 years, so they have a long track record of success. Monocrystalline modules, which have a single layer of crystals, are the most efficient. Polycrystalline modules are less efficient and less expensive; they have multiple layers that enable modules to be manufactured in triangular shapes. If space is a constraint, monocrystalline modules are typically selected.

While thin film can also be manufactured as rigid panels, they commonly come in laminate form to adhere to standing-seam metal roofs or rubber membranes on flat roofs. The strips typically come in a standard (15.5”) width and a variety of lengths, and are flexible so that they can be wrapped around a curved surface. Thin film has a more limited track record, although deployment around the world has grown rapidly since 2005 and the performance of the a-Si variants is increasing over time. The power density of thin film is the lowest of the three alternatives, but the cost per watt is also the lowest. If space is not a constraint and the roof surface is appropriate, thin film may be the best choice. However, the life span of thin film is typically 20 years vs. 30+ years for polycrystalline.

Figure 4 below shows the relationship between cost and efficiency for each of the three types of modules:

![Figure 4 Price-Performance evaluation of various types of solar module]
Understanding that efficiencies are increasing slowly over time, the prospective owner should consider the alternative of installing now versus waiting a few years to get better performance. The financial performance, environmental benefits, and marketing/PR advantage all favor action in the near term rather than waiting. Since a solar-PV system usually is cash-flow positive, the present value is highest the sooner it is initiated.

The power ratings of the most common solar modules range from 150 to 250 watts, although there are modules that are capable of producing over 300 watts. Correspondingly, there are plenty of low-output solar modules for specialized applications. The typical size of a module is generally around 3’x5’, with higher power modules typically being bigger and lower power modules being smaller. In some cases the power rating selected is based on the optimal physical size of the module.

**Inverters**

As discussed above, inverters are used to convert the native DC power produced by the solar modules into AC power that can be blended with the grid-sourced electricity. Traditionally, string (or bulk) inverters have been used to tie a fixed set of modules to one or more inverters, with each inverter being calibrated to optimize the production of energy for that string of modules. Inverters come in a variety of sizes, so that the inverter is matched to the collective output of the string of modules. For large installations, multiple inverters are necessary because the largest inverter currently on the market is only capable of converting up to 8000 watts.

An alternative approach is to use microinverters, which are each paired up with a single module to produce AC power at the source.

3 Some newer microinverters are able to convert power from a pair of modules.

Microinverters enable each module to be optimized individually, so if one module is temporarily shaded by a tree, cloud, dirt or other object, only the power for that module is compromised. By contrast, the string inverter will lower the output of all of the modules to match the output of the compromised module.

4 Microinverters also enable the monitoring of performance of individual modules, so problems can be identified and corrected more quickly, limiting power production loss.

**Module Placement and Mounting**

To maximize energy production, solar modules are positioned in a shade-free south-facing location. As the sun “moves” from east to west daily and is higher in the sky in the summer and lower in the winter, energy production varies depending on how direct the sunlight is on the module. Ninety percent of the energy produced in a day is generated between 9 a.m. and 3 p.m. (standard time). As mentioned earlier in this section, more energy is produced daily in the longer summer days.

In assessing the optimal location for a system, several aspects are considered for the specific site in question:

4 There are other module-maximizing technologies available for use with string inverters such as DC-to-DC Optimizers.
- Effect of building orientation
- Obstructions on the site that would shade the desired area, including the building itself, trees and equipment
- Obstructions outside the site boundaries that would shade the desired area.

The azimuth, or angle of the module relative to the southern horizon, is typically optimal when the module is facing due south. However, buildings are not always lined up facing due-south, so roof-mounted modules tend to be aligned with the building. The overall energy production degrades as the cardinal angle of the building increases, as seen in the graph in Figure 5.

![Impact of Azimuth on Production](image)

**Figure 5 Impact of azimuth on energy production**

The tilt of the module also has an impact on its overall production. The figures above are based on modules tilted at the same degree as our latitude – 38.8°. The impact of the azimuth is less for modules that are tilted at a lower angle, with no impact on modules that are flat.

The optimal tilt is actually less than the default latitude angle if you want to maximize the annual energy production using a fixed tilt. A fixed 30-35° tilt yields the optimal production in the St. Louis area. On pitched roofs, the modules are typically installed parallel to the roof at the same angle as the roof. On flat roofs, the modules can be mounted flat or an angle, usually 10 or 20 degrees. The chart below shows the relative effect of the tilt on energy production.
Modules can be mounted with mechanical fasteners or with self-ballasted racks. On pitched roofs, the modules are typically mounted with mechanical fasteners that require roof penetrations. On flat roofs, self-ballasted racks are commonly used, and oftentimes do not require any roof penetrations. The typical load on a self-ballasted system is 5-8 pounds per square foot (psf), depending on the engineering of the racking system. For a mechanically fastened system, the dead load will be closer to 3 psf.

In determining the mounting options on flat roofs, the wind load must be taken into consideration. Taller buildings experience higher winds, and the modules must be mounted to withstand 90 mph winds in the St. Louis area. The height of parapet walls must be factored into the equation, as is distance from the edge of the building. Increasing the tilt also increases the potential wind uplift forces, the weight required for ballasting the system, and the number or size of roof penetrations for mechanically fastened racking systems. The table below shows a listing of the wind categories and a description of each.
When roof space is limited or the orientation is not well aligned with the southern exposure, ground mounted arrays are a feasible alternative. There are a variety of ground mounted solutions available, including single-pole mounted arrays, multi-leg arrays, and tracking systems. Single-pole arrays are more aesthetically pleasing and easier to maintain, but are slightly more expensive than arrays that are built on multiple legs. Either mounting option can be configured with adjustable tilts to modify the tilt to optimize for the seasonal variations in solar irradiation.

![Single-pole ground-mounted arrays](image1)

![Multi-leg ground mount with adjustable tilt](image2)

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>Buildings, forest, or surface irregularities covering &gt; 20% of the ground-level area within a mile of the site in all quadrants and taller than the subject building.</td>
</tr>
<tr>
<td>C</td>
<td>Generally flat terrain extending ½ mile or more from the site in any quadrant, or the terrain is not known.</td>
</tr>
<tr>
<td>D</td>
<td>Flat, unobstructed terrain or adjacent to large bodies of water. This area extends inland from the shore ¼ mile or 10 times the building height, whichever is greater.</td>
</tr>
</tbody>
</table>

Table 1 Wind Exposure Categories

In addition to having an adjustable tilt, dual-axis tracking systems track the sun daily as its position moves across the southern sky from east to west. These tracking systems can generate 30 percent or more power than a fixed array, with higher levels of efficiency at lower latitudes. However, since they have moving parts, they require more maintenance than fixed arrays. They are also more expensive, and as the cost of solar modules have come down, in many cases it’s more cost effective to simply add capacity if space is not limited.
Performance Monitoring
The power produced by the solar array is always tracked at a high level with a bi-directional meter installed to account for those times when the locally-produced energy exceeds demand (see Net Metering section on page 20.) String inverters often display performance metrics on the equipment, and the data can be web-enabled to publicize energy production metrics.

Microinverters optimize the output for individual modules, and performance monitoring can be provided down to the module level. The Enphase Enlighten program, shown in the figure below, enables system designers to graphically illustrate the layout of the modules in the web-based performance monitoring system. This provides insights into shading losses or product performance issues which can be corrected.

In addition to the benefits of monitoring energy production by maintenance staff, web-enabling this data also provides additional visibility to a larger audience. For example, a kiosk in the building lobby can be used to increase occupant and visitor awareness of the solar energy production. The data can also be displayed on a company website for additional marketing and PR exposure.

Web-based monitoring systems require a broadband connection to the internet. This connection typically must pass through the IT firewall, and protocols can be set and customized with the standard product documentation for most systems. The system integrator usually will coordinate with the system owner’s IT department to facilitate the desired level of system access and visibility.

The web interface may be provided by the inverter manufacturer or a third-party monitoring package. The cost for a monitoring system and hardware can range from zero dollars (manufacturer standard and displaying on existing hardware) to $20,000 (custom interface and touchscreen monitor in the building lobby).
Financial Incentives
There are a variety of financial incentives available to improve the financial viability of solar electric. The Database of State Incentives for Renewables and Efficiency is a great resource for financial incentives related to both renewable energy and efficiency. A comprehensive and continually updated listing of federal, state, local, and utility incentives for solar can be found at dsireusa.org/solar.

Federal Funding
Taxable entities, including commercial enterprises and individual taxpayers, can take advantage of federal tax credits that effectively reduce the total installed price of renewable energy systems by 30 percent. This incentive is available for solar electric, solar thermal, wind, and geothermal, with no cap. While this, along with the tax benefits of accelerated depreciation, make commercial investment in renewable energy a very attractive financial investment, public entities must rely more heavily on grants or other funding to recognize a reasonable payback on the investment. A possible alternative would be to partner with a for-profit entity to take advantage of the additional incentives.

Utility Rebate
An incentive available in Missouri for all Ameren customers is the result of the Renewable Electricity Standard that was passed by citizen initiative in 2008. This law requires all Missouri-based investor-owned utilities to produce 15% or more of their electricity from renewable resources like solar and wind. Additionally, 2% of this has to come from solar. To develop the market, Ameren will pay $2.00 per watt of installed solar power, up to $50,000 for a 25 kW system. This typically reduces the installed cost by about 30 percent. This rebate is typically received within 45-90 days of the installation.

Renewable Energy Credits
One additional incentive can be used to further improve the financial return on an investment in solar electric. Solar Renewable Energy Credits, or SRECs, are the environmental attribute of a megawatt hour (1000 kWh) of electricity produced. SRECs can be sold on an open market or through a Standard Offer Contract with Ameren. The approved tariff (active through 2011 and resubmitted annually for 10 years) currently offers a flat fee of $100 per SREC.

- For systems under 10 kW, the utility will offer to purchase 100% of the SRECs produced during the first 120 calendar months (10 years) following the execution of the agreement or the operational date of the solar PV system, whichever occurs later. The company will make a single payment up front for the value of the SRECs based on standard projections using NREL data in PV Watts.
- For systems 10 kW up to 100 kW, the utility will offer to purchase 100% of the SRECs produced during the first 60 calendar months (5 years) following the execution of the agreement or the operational date of the system, whichever occurs later. The solar PV owner must make provisions for the utility to meter all energy produced by the system, and the numbers of SRECs produced annually will be determined by those meter readings with total SRECs available for purchase being kWh energy divided by 1,000.
The funding for SRECs is limited, and credits were nearly exhausted at the time of publication, so this incentive may or may not be available. The SREC market is expected to change substantially and grow in Missouri over the next several years. Figure 10 shows the SREC values for other states with similar compliance markets. The SRECs can be sold on the spot market annually, or contracted with Ameren on a 5-10 year forward basis.

![SREC Pricing, US Compliance Markets](image)

**Figure 10 Spot Market Pricing for SRECs in US Compliance Markets**

While this increases the financial payback on the system, this is essentially selling the renewable attribute of the energy produced by the system. If the goal if the system owner is to make a “green claim,” then some consideration should be given to whether or not to sell or retire these credits. For specific guidelines, refer to the Federal Trade Commission’s *Green Guide* (see [ftc.gov/opa/2010/10/greenguide.shtml](http://ftc.gov/opa/2010/10/greenguide.shtml)).

**Net Metering**

In 2007, the Missouri General Assembly established the Easy Connection Act, which enabled all Missourians to interconnect solar and wind systems with existing grid-based systems.

All grid-tied systems must utilize interconnection standards established by the utility, which include a bi-directional electric meter. The energy produced by the solar PV system is metered and fed into the grid-tied system. Any energy generated in excess of that which is consumed is directed back onto the grid, during which time the bi-directional meter effectively spins backward. Depending on the size of the system, this may happen on sunny weekend days when a building is unoccupied and consumption is limited to base plug loads. In the event that, at the end of a monthly billing cycle, there is a net excess generation of electricity by the solar electric system, Ameren will credit the avoided cost to the customer, usually about one-third of the retail value. When financial returns are key, it is recommended that the system be sized to minimize situations when this occurs.
Financing Options
While paying cash for the system is an obvious option, a solar PV system can be cash flow positive after one year if the system is financed. There are a number of other programs available to consider.

Solar Leases
Using a leasing model is another option that has become increasing popular across the country. Standard equipment leases are available through a leasing company or bank, though terms are usually limited to five years. Typically the lease includes an agreement to purchase equipment at end of the lease. Third party leases are also available with extended terms of 15-25 years. Leases may also enable a nonprofit to partner with a for-profit to leverage all of the financial incentives. A lease may also be negotiated between a building owner and tenant. Power Purchase Agreements have been widely used across the country, but have the potential to be contested by a utility.

Energy Service Companies
ESCOs are commercial businesses that design and install a broad range of energy solutions, and use the energy savings to pay for the capital improvements, typically for larger enterprises, including businesses, hospitals, academic institutions and government bodies. This arrangement has been historically used to fund energy efficiency improvements, but renewable energy improvements can also be implemented using an ESCO. For more about ESCOs, see naesco.org.

New Market Tax Credits
A Community Development Entity can be established to leverage New Market Tax Credits to invest in low-income communities, with incentives totaling 39% of the investment. The program was designed to encourage private investors to revitalize distressed communities and inner cities. This can be a very complex and lengthy process involving large legal fees, so it typically only makes sense for larger scale projects. Additional information is available at info-inc.com.

Qualified Energy Conservation Bond
This is a special debt instrument that enables qualified state and local government issuers to borrow money to fund energy conservation projects. QECBs are subsidized by the US Department of Treasury, with a 3.5% direct subsidy on the interest rate. Bonds can have maturity dates up to 17 years. See http://www1.eere.energy.gov/wip/solutioncenter/financialproducts/qecb.html for more information.
Energy Costs

The combination of high production and financial incentives often make solar electricity cost less than or nearly the same as the utility service. As energy rates rise, energy from the grid will rise while the cost of the energy from an onsite solar array remains constant. Electric rates vary widely across the nation, ranging from a high of $0.24 in Hawaii and $0.14-$0.17 in New England and the Middle Atlantic states, where fuel oil is a major fuel source to $0.06-$0.07 in the Pacific Northwest where federally-funded dams provide a large share of the power.\(^5\) In the Midwest, rates tend to average around $0.08-$0.09. In Missouri, Ameren’s last two rate increases approved in 2010 have totaled 22%, and Ameren has stated publicly to expect double-digit rate increases for the next five years. Industry analysts project rates to increase between 4% and 10% annually over the next ten years.\(^6\)

The graph that follows shows the effect of different annual rate increases over a 30 year period from an initial average of 8 cents.

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Power is a measure of how fast the building is consuming electricity, and energy is how much electricity is consumed. A great analogy to help differentiate between power from energy is this: power is the speedometer on the building and energy is the odometer.

Improving energy performance and reducing energy costs have four overarching targets:

1. Reducing the amount of energy consumed;
2. Reducing the peak power demand;
3. Shifting the time of day the energy and power are consumed; and
4. Optimizing the tariff under which the utility is billed.

Not only does a solar array reduce energy costs by reducing consumption – it also can reduce the peak power and demand fees for the meter account based on the time of day the array generates electricity. The electrical power for a commercial office building usually peaks between noon and 2:30 p.m. local time (see Figure 12). This peak coincides with the maximum electricity production from a solar array oriented to the south. This daily usage peak may shift 1-2 hours later in the winter or hottest days of the summer. For buildings that use a non-electric heating source, a solar array will be most effective in offsetting summer peak power demand and providing the greatest reduction in energy expense.

![Figure 12 Typical Daily Electricity Use – Commercial Building, St Louis](image)

Ameren offers an energy tracking program to gain insights into energy usage patterns. The web-based Abacus™ program costs approximately $500/year, and provides valuable information to better manage electricity costs.
Solar Thermal

Solar thermal energy is the natural warmth of the sun, captured, condensed and converted to a usable form, like warm air or hot water. Solar air heating systems are designed to trap the radiant heat of the sun, and distribute it into an interior area using a small blower fan. Solar water heating is more common, and can be used year round for either domestic or industrial use. The feasibility assessment in this study was limited to solar water heating.

Solar thermal collectors for heating water are surprisingly efficient, but require consistent demand and strong, shade-free southern exposure in order to be cost effective. Residential applications are usually cost-justified by regular use of showers, laundry and cooking. Commercial and industrial processes, like hotels, restaurants, laundries, and food/beverage processors are great candidates for solar water heating.

Solar Thermal Components

There are two primary types of solar thermal collectors. Flat plate glazed panels, shown in Figure 13 to the right, look like traditional solar panels or skylights, and contain pre-assembled components to facilitate installation. They are durable and require little maintenance, and are often used in residential applications. Flat plate collectors are more easily installed, and tend to be a less expensive option.

Evacuated tubes (see Figure 14) have a vacuum seal that creates superior performance with no heat loss. They are lighter weight, and tend to work better in cold climates and on overcast days. They are also typically better for heavy-duty commercial or industrial applications.

Traditionally, solar water heating systems heated water directly in an open system, which typically used a passive method of siphoning water from a storage tank on the roof. However, open systems are only practical in warm climates that don't experience a hard freeze.

Closed systems are more widely used these days. In this approach, an anti-freeze solution like glycol is used to heat potable water in a storage tank through a heat exchange system. Closed systems require an active method of pumping the glycol solution from the rooftop collectors to the heat exchanger in the storage tank. Figure 15 shows a simple diagram of a closed-loop system.
Most closed loop systems use a sophisticated controller to run the system, so that you can program temperature controls and other variables into the system. Systems are sized based on demand for hot water, with the number of collectors related to the size of the storage tank. In smaller flat plate collector systems, a single collector might be used for a 50 gallon tank. Two collectors might be used for an 80 gallon tank, and 3 collectors for a 120 gallon tank. For larger systems, evacuated tubes are often used, with the number of tubes corresponding to the size of the tank.

In most cases, a backup water heating system is included in the design to accommodate high demand or extended cloudy, dark days. Backup heating systems can be electric, natural gas, or a boiler with a separate heat exchange loop.

**Financial Performance**

The financial incentives for solar thermal are more limited than solar electric, because there are no utility rebates or renewable energy credits available. Commercial enterprises and individuals can leverage the 30 percent federal tax credit, which has no cap on the incentive. In addition, businesses can take advantage of the additional cash flow benefits of the MACRS accelerated depreciation. Both of these, of course, require a sufficient tax appetite, but the benefits can be taken over multiple years if necessary.

With no tax incentives, the payback on solar water heating tends to be about 10-20 years, depending on energy source and utility rates. With incentives, payback periods typically range from 3-7 years.
Geothermal (Ground-Source) Heating & Cooling

The word *geothermal* comes from the Greek words *geo* (earth) and *therme* (heat), so it logically makes sense that geothermal is pulling heat from the earth. This heat can be internally generated from the molten magma beneath the earth’s crust. There are a number of places where naturally occurring steam or hot water is used to heat buildings or generate electricity. This form of geothermal energy is not being assessed in this study.

*Ground-source heat pumps* have been commonly referred to as *geothermal systems*, causing some confusion. These are similar to the electric *air-source heat pumps* that were popularized 20-30 years ago. But instead of using air as a source from which to extract or transfer heat, the ground is used. About half of the sun’s solar energy is stored in the earth, resulting in fairly stable temperatures ranging from 54-56 degrees six feet deep in the St. Louis area.

An air conditioner is actually an air-source heat pump. In the summer, warm, humid air is extracted from a conditioned space and “dumped” outside using a heat transfer fluid. Air-source heat pumps are relatively inefficient in the dog days of summer, because the hot fluid is not easily cooled by the warm outside air. However, the ground-source systems pump the coolant through a network of pipes in the earth, which quickly and efficiently absorb the unwanted heat. This method is 2-3 times more energy efficient than air conditioners or air-source heat pumps.

![Figure 16 Heating cycle of ground-source HVAC](image)

In the winter, traditional furnaces use some kind of fossil fuel (natural gas, propane or oil) to heat air to distribute throughout a building by a blower. An alternative is to heat water and distribute it through piping in concrete floors (radiant floor heating) or steam radiators. These systems rely on fuels which produce greenhouse gases at an ever-increasing cost. Electric furnaces are much cleaner, but using electricity to heat a building is usually much more expensive. Ground-source heat pumps, on the other hand, simply reverse the flow of the heat transfer fluid, and extract the heat from the ground. The only
energy required is electricity to run the system, primarily the pumps that circulate the coolant and fan to distribute warmed air throughout the building’s ductwork (or radiant floor heating).

A refrigerator is actually a small heat pump. Heat is extracted from the freezer, and blown out the back or bottom of the unit, and the cool air from the freezer keeps the refrigerator portion of the unit cold. It should be no surprise how much more easily heat is extracted from the ground, which averages 55 degrees. An added benefit to ground-source heat pumps is that excess heat, primarily in the summer, can be used to heat water, saving additional energy and money.

**Types of Loops**
A significant portion of the cost of a ground-source HVAC system is the installation of the underground piping to transfer heat to or from the home. When space is at a premium, wells can be drilled into the earth, usually 150 to 200 feet in depth, creating a vertical loop. A general rule of thumb is that for every ton of heating and cooling capacity, a 150’ deep well is required. So a 4-ton system could use either four 150’ wells or three 200’ wells. For optimal results, wells should be 10’ apart. Vertical loops are usually the most expensive option.

If space is abundant, a horizontal loop can be designed. In this case, trenches are dug, typically 6’ deep, with a total length similar to that required for the vertical loop. Again, horizontal pipe runs should be at least 10’ apart. Horizontal loops can be constructed in open fields or under parking lots.

If a water source – such as a lake or large pond – is available, a third option is to install a closed pond loop. The size and depth of the body of water is critical, and requires an engineering analysis to ensure that the water can handle the building loads. Open loop well water systems are also an option, but are relatively uncommon.

**Financial Considerations**
According to the EPA, geothermal systems are “the most energy efficient, environmentally clean and cost-effective space conditioning systems available today.”

For new buildings, the case can often be made to support ground-source heating and cooling. Construction of the wells can take place during initial excavation, or under...
parking lots before the surface is finished. Water features can sometimes be developed to support a pond loop.

In existing buildings, a retrofit can be cost-effective if both the heating and cooling systems need to be replaced, and there is suitable ground source available to construct the loops. Equipment life is typically 20 years or more, but once the investment is made in the loop, replacement of the equipment is comparable to the replacement of traditional equipment. However, the energy savings are dramatic.

The efficiency ratings for geothermal heat pumps are typically 300%-600%, which is much higher in comparison to a high-efficiency furnace (95%) or an air-source heat pump (175%-250%). Cooling efficiencies, measured by an Energy Efficiency Ratio typically range from 14-16 EER compared to traditional air conditioning efficiencies of 10-14. These efficiencies usually result in an annual energy savings of 30%-60%.

**Typical Operating Costs**

![Typical operating costs for geothermal](Source: heatcool2.com)
Renewable Energy Feasibility Assessments

A series of fifteen site surveys were performed from September through January to assess the selected facilities for their potential for the renewable energy technologies discussed in the first part of this document. These include solar electric (photovoltaic, or PV), solar water heating, and geothermal (ground source) heating and cooling. Observations were also made regarding any energy efficiency improvements that could be addressed. The results for each facility are documented in a separate section.

This section provides an overview of how each renewable energy technology can be deployed in various facilities.

Solar Electric

Almost all of the facilities are potential candidates for solar electric, though of course some are better suited for solar than others. Some of the primary considerations for solar include:

- Access to shade-free southern exposure
- Age, condition and orientation of roof
- Electricity demand, load factor and effective utility rate
- Visibility for public education
- Feasibility of electrical connection
- Ability to restrict access
- Financial payback.

The following list includes sites that are the best candidates

- **MET Center**: roof well oriented, great training opportunity
- **Record Center**: roof in good condition with ample space, well oriented, easy connection, opportunity to make significant offset
- **Courts Building**: abundant roof space provides best opportunity for solar PV on Clayton complex
- **North County Community Health Center**: abundant roof space in very good condition, easy connection, good visibility
- **Police & Fire Training**: abundant roof space, well oriented

The payback for tax-exempt government agencies is not as attractive as commercial or residential installations, but the County is still able to lock in a portion of their energy costs at a fixed rate by investing in their own renewable energy production. Given that financial incentives are limited to the utility rebate and potential sale of SRECs, we would recommend investing in the maximum 25 kW at several sites rather than investing in a larger system at one site.

Each of these, along with the good to marginal, will be discussed in more detail in the site summaries.
Solar Thermal
The primary consideration for solar thermal is a consistent demand for hot water. Of course, shade-free access to a southern sky is also important, and roof orientation and condition are also taken into consideration. Each of these play a role in the financial payback and cost-justification.

In most of the facilities surveyed, hot water is limited to rest rooms and light kitchen use. A second factor is that many of the buildings are unoccupied on evenings and weekends. Both of these situations eliminate most of the facilities as candidates. The following facilities could take advantage of solar water heating:

- **Justice Center**: High demand for hot water every day, all day, with great access to solar on the roof
- **Police Headquarters**: Limited roof space on this building could be used to install a solar water heating system to serve the three-building complex (Admin, Police HQ and Courts)
- **Lakeside Center**: Good demand for hot water every day, but limited south-facing rooftops on which to mount collectors
- **Baur Animal Shelter**: Laundry and showers provide consistent demand for hot water; flat roof has good southern exposure that could support collectors.

The rest of the facilities lack sufficient demand, as documented in the site summary.

Geothermal
Like solar thermal, the feasibility for ground-source heating and cooling is much less typical. A key consideration is the availability of space to drill wells. The second primary consideration is the age and design of the existing HVAC equipment, and how well or easily a ground-source heat pump could be integrated in with the existing system. A third component is the consistency of use; higher building occupation and corresponding demand for heating and cooling will provide a higher return on investment.

Given these considerations, there were only two facilities that could benefit from geothermal.

- **Lakeside Center**: Consistent requirement for heating and cooling and ample access to unpaved ground surface make this the best candidate for a campus-wide ground source heating & cooling system.
- **Police & Fire Training**: The existing HVAC system is disjointed and inefficient, and ready to be replaced. The field inside of the track and other unpaved ground surface make this an attractive opportunity to leverage geothermal energy.

Each of these situations will be discussed in more detail in the site summaries.
Record Center

A site survey was conducted on October 19, 2010 by Steve O’Rourke and Marc Lopata. Russ Schmidt provided an escort and background on the building. This section documents the specific findings and recommendations based on that visit and subsequent analysis.

Facility Description

The Record Center, located at 10275 Page Industrial Boulevard, is a 30,000 ft² facility situated in an industrial court in Olivette, MO. The building was originally built in 1960 and renovated in 1977.

Figure 21 County Record Center, from south (Image courtesy of Bing Maps)

The building houses a small staff of ten people in approximately 5,000 sq. ft. of office space in the front of the building. The operating hours are 7:30 to 5:30 Monday through Friday. The rest of the building is warehouse space divided into two sections. The first space just north of the office area is approximately
The building has 15,000 sq. ft. and has reached full storage capacity. The remaining space at the back of the building has been recently renovated to provide an additional 10,000 sq. ft. of storage space.

The office space has standard 10’ ceilings, with suspended acoustical tiles. The building walls are brick masonry, with an EPDM rubber membrane on a relatively flat roof. The warehouse area has approximately 20’ ceilings, and the rubber membrane roof there was replaced in 2009 and is in very good condition. There is virtually no parapet wall on all sides. The roof on the primary warehouse is a concrete deck, and the roof over the newer warehouse is a steel deck. Both the office and warehouse space are climate controlled.

**Solar Electric Assessment**

This site is a great location for a solar PV array. All three sections of roof have great southern exposure and have very little shade except from the HVAC equipment. There is no vacant land that could be developed that might result in shading of the areas of the site identified for system installation.

The building is situated about 7 degrees off a “cardinal square” orientation. This angular offset will have virtually on impact the solar production (0.3%). As a result, the optimum orientation will be parallel to the building outline.

![Figure 22 Array located over rear warehouse (image courtesy of Google Maps)](image)

**Mounting Options**

The roof has very few obstructions and appears to have sufficient structural capacity to support the PV array’s load of less than 5 pounds per square foot (psf). The roof has a rubber membrane, and a metal ballasted racking system will work well with this roofing. The roof is in good enough condition that it should not require replacement for at 15-20 years.

A 25 kW roof-mounted array would require approximately 3,000 sq. ft. The front roof over the office space would offer limited but better visibility, but may not be adequate to accommodate the entire array. The roof over the rear warehouse space is in close proximity to the electric meter, and the entire
system could be situated in contiguous arrays. To reduce wind lift, the modules are optimally installed at a 10° tilt.

![Figure 23 Proposed area for solar array](image-url)
System Configuration and Building Integration

**Modules**
Space is not at a premium, so the modules chosen could be selected strictly on a price/performance basis. Polycrystalline modules offer the better price performance for the price.

**Inverters**
Since there are no issues with shading, this array could use either micro-inverters installed on each module, or larger bulk inverters installed in the equipment room. Micro-inverters will provide better visibility into system performance than bulk inverters. However, the maintenance and replacement costs may be less for bulk inverters.

**Energy Systems and Distribution**
The Ameren service entrance and meter are on the north exterior wall and the distribution panels are immediately inside this location. Electrical service appears to have been originally located on the west wall but was moved or consolidated during the 1977 building renovation. The electrical service to the building includes a newer 480/277 service, plus an older 240/120 service. The building distribution includes 480/277 and 240/120. There is no surge suppression or lighting protection.

The building has natural gas utility service, which is used to heat the building. The natural gas service and performance is not part of the scope of this study, so no observations were made.

According to staff, the building can be de-energized to land the PV System breaker. That work would be done on the weekend to minimize impact to operations.

**Storage, Staging and Installation**
A 25kW system would require approximately 200 square feet for storage of 8-9 standard pallets, including modules, inverters, racking and ballast. Typically the solar installer will accept delivery of the equipment off site and deliver to the site when the timing is optimal for installation. If space permits, the warehouse could be used if the equipment would need to be stored prior to staging to the roof itself.

A small crane will be required to get the equipment up to the roof. The maximum pallet weight for equipment will be approximately 1,500 pounds, although ballast blocks may weight 3,000 per pallet. The lift height should be 40 feet or less, and the boom distance approximately 40 feet or less.

When the pallets are lifted to the roof (whether initially or after a delay), they will have to be placed directly on the structural columns or beams to ensure adequate long-term loading capacity. These locations should be physically confirmed and marked on the roof with spray paint to ensure accurate placement. The goal would be to install within a few days, but that could be delayed by weeks or months under worst-case conditions.
**Energy Production**

The proposed 25 kW system would produce approximately 30,800 kWh annually, with higher production in the longer days of summer (see Figure 24 below). The total energy produced over the expected 30 year life of the system is over 860,000 kWh, factoring in a typical annual degradation factor of 0.5%.

![Forecasted Energy Production](image)

*Figure 24  Estimated Annual Energy Production for 25 kW system at 10° tilt and 180° azimuth*
Financial Analysis
The turnkey cash installation cost for the 25 kW rooftop system using polycrystalline modules is estimated at $165,000 in 2011 dollars. That is calculated based on American-made components (complying with ARRA requirements) and prevailing or union labor rates. This should include design services, installation labor, materials, and equipment, including modules, inverters, and balance-of-system components necessary to comply with the local building code and Ameren interconnection requirements.

The PV system will require annual cleaning and inspection by building management personnel. Annual monitoring and maintenance contracts are available and would cost in the range of $600-700 per year. This is not included in the financial performance evaluation. Insurance is estimated at $600 per year for casualty loss coverage, and this cost is included in the financial performance model.

Applicable Incentives
The financial model to calculate the total value of the incentives includes the utility rebate, which is received within 90 days of the completed installation. Potential income from the sale of SRECs can also be factored in to maximize the payback. The net cost after these incentives are applied is shown below.

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Installed Cost</td>
<td>$165,000</td>
</tr>
<tr>
<td>Utility Rebate</td>
<td>$50,000</td>
</tr>
<tr>
<td>Sale of SRECs</td>
<td>$15,200</td>
</tr>
<tr>
<td>Net Cost After Incentives</td>
<td>$99,800</td>
</tr>
</tbody>
</table>

7 This value is an estimate of the sum of the first five annual payments from Ameren’s Standard Offer Contract. Cash flow projections in the financial model include additional SREC income for years 6-10.
Environmental Benefits
The electricity generated by this 25 kW system would result in reduced emissions from the coal-fired power plants that support the Ameren Missouri distribution region. This amounts to a reduction of 31 tons of carbon not polluting the atmosphere each year. This is equivalent to:

- The CO$_2$ absorbed by 28 acres of dense, hardwood forest (an area 1.4 times the size of Shaw Park in Clayton), or
- 2,500 gallons of gasoline not burned in automobiles each year.

The lifetime contribution of this system will effectively eliminate 790 tons of CO$_2$ from the atmosphere.

Implementation Schedule
Installing the solar-PV system would require approximately 10-11 weeks, depending primarily on equipment availability. The permitting task includes the following:

- Electrical permit issued by St Louis County;
- Approval from the Clayton Architectural Review Board;
- Interconnection and Net Metering Agreement from Ameren Missouri. By rulemaking, this is declared to be a 90-day or less interval. Typical approval period is 30-45 days.

![Figure 25 Typical Implementation Schedule](image)

Equipment lead times for the project as described above typically are 4-5 weeks, but this could vary significantly depending on project timing and conditions in the global markets. This should be reassessed at the time the project is planned.
Solar-Thermal Assessment
The demand for hot water in this facility does not warrant the use of solar thermal. Hot water is limited to hand washing in restrooms and light kitchen use, and there the operational hours are limited to 45 hours per week.

Geothermal Assessment
The building is not a good candidate for a geothermal HVAC system. The chillers on the roof of the larger warehouse space are scheduled to be replaced.
Energy Efficiency
During the site visit, a number of observations were made regarding the energy performance of the building.

- The primary lighting in the warehouse space consists of 400W metal halide fixtures. There are an estimated 146 fixtures, which are on 24x7, resulting in annual usage of nearly 150,000 kWh. This could be reduced significantly with more efficient lighting and occupancy sensors that only fully light up aisles that are occupied.
- Lights were on in unoccupied spaces. Occupancy sensors could reduce lighting load in areas that are intermittently occupied.
- T12 fluorescent lights should be replaced with more efficient T8 lights.
North County Community Health Center
A site survey was conducted on December 15, 2010 by Steve O’Rourke and Marc Lopata. Mark Fincher provided an escort and background on the building. The sky was overcast and the weather was cold, with snow present on the roof during the visit. This section documents the specific findings and recommendations based on that visit and subsequent analysis.

Facility Description
The North County Community Health Center (NCCHC) is a 36,000+ ft² facility located at 4000 Jennings Station Road in Jennings. The building was built in 2003.

Figure 26 North County Community Health Center, from west (Image courtesy of Bing Maps)

The center employs a staff of approximately 70 full-time employees, providing health services to lower income residents. The facility is open from 8:00 a.m. to 5:00 p.m. Monday, Tuesday and Friday, and is open until 9:00 p.m. on Wednesday and Thursday. The building is not open on weekends.
The building has a brick façade, and has double-pane windows with no thermal breaks. The built-up roof is mounted on a concrete/steel deck supported by structural steel trusses. The roof has a slight pitch with interior scuppers for drainage. There is a variety of HVAC equipment and exhaust vents on the roof deck, along with a number of skylights. The building’s parapet ranges from 12” to 24” around the building. There is no lightning protection.

The facility is burdened with a significant “plug load” from electrical equipment, including

- 70 computers and 20 laptops
- Three vending machines (2 refrigerated) and two refrigerators
- Ultrasound, sonogram, x-ray, and other lab equipment.

The facility is primarily lit with efficient T8 fluorescent lights with electronic ballasts. There are 124 fixtures that have a battery backed-up ballast, presumably installed before the emergency backup generator was installed. Emergency lights are on 24/7, and generate 50-80 foot candles (FC) of light. There were over 120 FC near windows.

The HVAC system is in average condition with constant volume heating and an R-22 cooling system. The CO₂ level inside was slightly higher (800-840) than the outside air (440).

The buildings domestic water supply is heated with natural gas, with hot water constantly recirculated throughout the building to provide hot water on demand. The pipes appeared to be well insulated.
Solar Electric Assessment
This site is a good location for a solar PV array. The roof has great southern exposure and has very little shade except from the HVAC equipment. The parking lot provides a good buffer to minimize the possibility of shading from a new development on an adjacent property.

The building is situated almost 30 degrees off a “cardinal square” orientation. This angular offset will have slight impact on the solar production (2-3%) if the array is installed parallel to the building outline. The blue shaded area in Figure 27 shows an approximate location of the best location for a 25 kW array, given the minimal roof obstructions in that area.

![Figure 27 Blue shaded area Array located on northwest corner of building (image courtesy of Google Maps)](image)

Mounting Options
The roof is in good condition, and appears to have sufficient structural capacity to support a ballasted PV array’s load of approximately 5 pounds per square foot (psf). A metal ballasted racking system will work well on the built-up roof.

A 25 kW roof-mounted array would require approximately 3,000 ft² of space. The array would be situated near the access hatch to facilitate monitoring and maintenance, but would provide limited visibility to the public. The array is also located in close proximity to the electric meter and equipment room. To reduce wind lift, the modules are optimally installed at a 10° tilt.
Figure 28 View of roof from northwest corner
System Configuration and Building Integration

**Modules**
Space is not at a premium, so the modules chosen could be selected strictly on a price/performance basis. Polycrystalline modules typically offer the best price performance.

**Inverters**
Though there are no issues with shading, this array could use microinverters to simplify installation and provide better visibility into system performance. Bulk inverters could alternatively be used, and may reduce maintenance and replacement costs.

**Energy Systems and Distribution**
The Ameren service entrance and meter are on the northwest exterior wall and the distribution panels are immediately inside this location. The electrical service to the building is 480A. The building distribution includes 480/277 and 240/120. There is no surge suppression or lighting protection.

According to staff, the building can be de-energized to complete the interconnection. That work would be done on the weekend to minimize impact to operations.

**Storage, Staging and Installation**
A 25kW system would require approximately 200 square feet for storage of 8-9 standard pallets, including modules, inverters, racking and ballast. Typically the solar installer will accept delivery of the equipment off site and deliver to the site when the timing is optimal for installation.

A small crane will be required to get the equipment up to the roof. The maximum pallet weight for equipment will be approximately 1,500 pounds, although ballast blocks may weight 3,000 per pallet. The lift height should be 30 feet or less, and the boom distance approximately 25 feet or less. The pallets would be staged to the southeast roof area and then components and parts carried to the installation location.

When the pallets are lifted to the roof (whether initially or after a delay), they will have to be placed directly on the structural columns or beams to ensure adequate long-term loading capacity. These locations should be physically confirmed and marked to ensure accurate placement. The goal would be to install within a few days, but that could be delayed by weeks or months under worst-case conditions.

**Energy Production**
The proposed 25 kW system would produce approximately 30,500 kWh annually, with higher production in the longer days of summer (see Figure 29 below). The total energy produced over the expected 30 year life of the system is approximately 852,000 kWh, factoring in a typical annual degradation factor of 0.5%.
Figure 29  Estimated Annual Energy Production for 25 kW system at 10° tilt and 219° azimuth
Financial Analysis
The turnkey cash installation cost for the 25 kW rooftop system using polycrystalline modules is estimated at $165,000 in 2011 dollars. That is calculated based on American-made components (complying with ARRA requirements) and prevailing or union labor rates. This should include design services, installation labor, materials, and equipment, including modules, inverters, and balance-of-system components necessary to comply with the local building code and Ameren interconnection requirements.

The PV system will require annual cleaning and inspection by building management personnel. Annual monitoring and maintenance contracts are available and would cost in the range of $600-700 per year. This is not included in the financial performance evaluation. Insurance is estimated at $600 per year for casualty loss coverage, and this cost is included in the financial performance model.

Applicable Incentives
The financial model to calculate the total value of the incentives includes the utility rebate, which is received within 90 days of the completed installation. Potential income from the sale of SRECs can also be factored in to maximize the payback. The net cost after these incentives are applied is shown below.

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<td>$15,200</td>
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<tr>
<td>Net Cost After Incentives</td>
<td>$99,800</td>
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This value is an estimate of the sum of the first five annual payments from Ameren’s Standard Offer Contract. Cash flow projections in the financial model include additional SREC income for years 6-10.
Environmental Benefits
The electricity generated by this 25 kW system would result in reduced emissions from the coal-fired power plants that support the Ameren Missouri distribution region. This amounts to a reduction of 31 tons of carbon not polluting the atmosphere each year. This is equivalent to:

- The CO₂ absorbed by 28 acres of dense, hardwood forest (an area 1.4 times the size of Shaw Park in Clayton), or
- 2,500 gallons of gasoline not burned in automobiles each year.

The lifetime contribution of this system will effectively eliminate 790 tons of CO₂ from the atmosphere.

Implementation Schedule
Installing the solar-PV system would require approximately 10-11 weeks, depending primarily on equipment availability. The permitting task includes the following:

- Electrical permit issued by St Louis County;
- Approval from the Clayton Architectural Review Board;
- Interconnection and Net Metering Agreement from Ameren Missouri. By rulemaking, this is declared to be a 90-day or less interval. Typical approval period is 30-45 days.

Equipment lead times for the project as described above typically are 4-5 weeks, but this could vary significantly depending on project timing and conditions in the global markets. This should be reassessed at the time the project is planned.
Solar-Thermal Assessment
The demand for hot water in this facility does not warrant the use of solar thermal. Hot water is limited to hand washing and light kitchen use, and the operational hours are limited to 53 hours per week.

Geothermal Assessment
The building is not a good candidate for a ground-source heat pump, as there is limited space available to drill wells, relatively new equipment, and limited occupancy.
Energy Efficiency
During the site visit, a number of observations were made regarding the energy performance of the building.

- Upgrade the R-22 cooling system to utilize a Variable Air Volume (VAV) distribution system.
- Occupancy sensors could be utilized in a number of areas, such as the break room, that do not require full lighting during operating hours.
- Non-essential computer equipment should be manually or programmatically powered down outside operating hours.
- Since there is an emergency backup generator for the entire building, there may be a more cost-effective plan to replace these $190 ballasts, and consider reducing the number of fixtures by 50%.
- Install dimmable ballasts on fixtures located near windows or skylights to reduce artificial lighting loads during daylight hours.
- Install a timer on hot water recirculation pump to only run during operating hours.
- Replace refrigerators with Energy Star certified appliances.
- Install power management equipment on vending machines to reduce power consumption by 30-50%.
- Program temperature setbacks on HVAC controls to correspond to operating hours, and publish instructions for manual override to appropriate staff.
- More frequent replacement of air filters on HVAC equipment will increase the effectiveness of the system and extend the life of the equipment.

A full audit will provide more detail analysis and recommendations, and a retro commissioning of the HVAC system will reduce energy consumption.
Baur Animal Health Center
This facility is currently under construction, so a review of drawings was conducted on October 7, 2010 by Steve O’Rourke and Marc Lopata in lieu of a site visit. Kevin Buckley and Russ Schmidt provided information and background on the building. This section documents the specific findings and recommendations based on that review and subsequent analysis.

Facility Description
The Baur Animal Health Center is a 27,000 ft² facility located at 10521 Baur Boulevard in Olivette. The building was constructed in 1968, and renovations began in September 2010.

![Baur Animal Health Center from south](image courtesy of Bing maps)

The plans include solar tube lighting and skylights to reduce the need for artificial lighting. The building plans specify 32W T8 lighting, but there is no definition on lighting levels. Outdoor lighting calls for high pressure sodium lights.

Solar Electric Assessment
This site is a good location for a solar PV array. The front of the roof has good southern exposure, with approximately 3,000 ft² of available space with limited shading. The trees between the parking lot and the street will need to be taken into consideration, when a site survey is conducted.
The building is situated approximately 16 degrees off a “cardinal square” orientation. This angular offset will have a minimal impact on the solar production (<1%) if the array is installed parallel to the building outline. The blue shaded area in Figure 27 shows an approximate location of the best location for a 25 kW array.

**Mounting Options**

The condition of the roof was not observed, but is assumed to be good. It is also expected that there is sufficient structural capacity to support a ballasted PV array’s load of approximately 5 pounds per square foot (psf). A metal ballasted racking system will work well on roof.

A 25 kW roof-mounted array would fit nicely into the 3,000 ft² of space available. It would provide limited visibility to the public. The array is also located in close proximity to the electric meter and equipment room. To reduce wind lift, the modules are optimally installed at a 10° tilt.
System Configuration and Building Integration

Modules
Space is not at a premium, so the modules chosen could be selected strictly on a price/performance basis. Polycrystalline modules typically offer the best price performance.

Inverters
Though there are no issues with shading, this array could use microinverters to simplify installation and provide better visibility into system performance. Bulk inverters could alternatively be used, and may reduce maintenance and replacement costs.

Energy Systems and Distribution
The Ameren service entrance and meter are on the northwest exterior wall and the distribution panels are immediately inside this location. The electrical service to the building is 480A. The building distribution includes 480/277 and 240/120. There is no surge suppression or lighting protection.

According to staff, the building can be de-energized to complete the interconnection. That work would be done on the weekend to minimize impact to operations.

Storage, Staging and Installation
A 25kW system would require approximately 200 square feet for storage of 8-9 standard pallets, including modules, inverters, racking and ballast. Typically the solar installer will accept delivery of the equipment off site and deliver to the site when the timing is optimal for installation.

A small crane will be required to get the equipment up to the roof. The maximum pallet weight for equipment will be approximately 1,500 pounds, although ballast blocks may weight 3,000 per pallet. The lift height should be 40 feet or less, and the boom distance approximately 30 feet or less, limited by the internal column bay spacing. The pallets can be lifted from the south parking lot area and placed in the immediate vicinity of the array as marked, allowing room to move and assemble the system.

When the pallets are lifted to the roof (whether initially or after a delay), they will have to be placed directly on the structural columns or beams to ensure adequate long-term loading capacity. These locations should be physically confirmed and marked to ensure accurate placement. The goal would be to install within a few days, but that could be delayed by weeks or months under worst-case conditions. The heaviest pallet for a system of this size usually is less than 2,000 pounds.
Energy Production
The proposed 25 kW system would produce approximately 30,700 kWh annually, with higher production in the longer days of summer (see chart below). The total energy produced over the expected 30 year life of the system is approximately 858,000 kWh, factoring in a typical annual degradation factor of 0.5%.

Figure 32 Estimated Annual Energy Production for 25 kW system at 10° tilt and 196° azimuth
Financial Analysis
The turnkey cash installation cost for the 25 kW rooftop system using polycrystalline modules is estimated at $165,000 in 2011 dollars. That is calculated based on American-made components (complying with ARRA requirements) and prevailing or union labor rates. This should include design services, installation labor, materials, and equipment, including modules, inverters, and balance-of-system components necessary to comply with the local building code and Ameren interconnection requirements.

The PV system will require annual cleaning and inspection by building management personnel. Annual monitoring and maintenance contracts are available and would cost in the range of $600-700 per year. This is not included in the financial performance evaluation. Insurance is estimated at $600 per year for casualty loss coverage, and this cost is included in the financial performance model.

Applicable Incentives
The financial model to calculate the total value of the incentives includes the utility rebate, which is received within 90 days of the completed installation. Potential income from the sale of SRECs can also be factored in to maximize the payback. The net cost after these incentives are applied is shown below.

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<tr>
<td>Initial Installed Cost</td>
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<td>Utility Rebate</td>
<td>$50,000</td>
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<tr>
<td>Sale of SRECs⁹</td>
<td>$15,200</td>
</tr>
<tr>
<td>Net Cost After Incentives</td>
<td>$99,800</td>
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</tbody>
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⁹ This value is an estimate of the sum of the first five annual payments from Ameren’s Standard Offer Contract. Cash flow projections in the financial model include additional SREC income for years 6-10.
**Environmental Benefits**

The electricity generated by this 25 kW system would result in reduced emissions from the coal-fired power plants that support the Ameren Missouri distribution region. This amounts to a reduction of 31 tons of carbon not polluting the atmosphere each year. This is equivalent to:

- The CO₂ absorbed by 28 acres of dense, hardwood forest (an area 1.4 times the size of Shaw Park in Clayton), or
- 2,500 gallons of gasoline not burned in automobiles each year.

The lifetime contribution of this system will effectively eliminate 790 tons of CO₂ from the atmosphere.

**Implementation Schedule**

Installing the solar-PV system would require approximately 10-11 weeks, depending primarily on equipment availability. The permitting task includes the following:

- Electrical permit issued by St Louis County;
- Approval from the Clayton Architectural Review Board;
- Interconnection and Net Metering Agreement from Ameren Missouri. By rulemaking, this is declared to be a 90-day or less interval. Typical approval period is 30-45 days.

![Figure 33 Typical Implementation Schedule](image-url)

Equipment lead times for the project as described above typically are 4-5 weeks, but this could vary significantly depending on project timing and conditions in the global markets. This should be reassessed at the time the project is planned.
Solar-Thermal Assessment
The demand for hot water in this facility likely is high enough and consistent enough to warrant the use of solar thermal for Domestic Hot Water (DHW). The primary DHW use is sanitation/cleaning for the animal areas, but additional uses include laundry, restroom, and light kitchen use.

The shelter is continuously operational around the calendar year. This makes it, like the Justice Center, an ideal target for solar thermal. However, there was no water-use data available for the facility, which is necessary to estimate system size and cost. As a result, general guidelines are provided below.

Mounting Options
The recommended solar thermal collectors would be the flat-plate configuration, 10’ tall and 4’ wide. They are mounted on racks at an angle of 45° to horizontal. One standard rack holds eight of the collectors, for 320 ft² of collector area.

Because of their high wind resistance, the racks and collectors are required to be mechanically fastened to the roof structure. However, the mounting systems are fully compatible with roof warranties and when installed correctly, pose a negligible risk of roof leakage. Based on the roof configuration, a good option might be to attach the collector racking to the roof wall that runs across the building. That wall will provide a wind break and an elevated connection point for the racking. This would decrease the installation cost and difficulty.

Potential Energy Production
The optimal application is to size the system to produce approximately 1/3 of the hot water demand for the facility. This will ensure the system is never producing too much energy or possibly going into a “stagnation” condition where the system is potentially overheating. When the sun is shining and the solar thermal system is transferring that energy to the DHW system, the existing DHW system will use significantly less natural gas. When the sun is not shining, the DHW system is already sized for peak demand, so there is no adverse impact to the solar thermal implementation.

Typical system sizing and costing for the St Louis area is as follows. These estimates are scalable.

- Standard rack is 8 collectors / 320 ft²
- Heats 600 gallons per day
- Annual system output of 33,000 kWh
- Assumes 80% efficiency of existing gas water heater
- Installed cost, including heat exchangers is $50,000

Building Interconnection
The piping would transition from the roof to the mechanical room where the existing water heater is located. A dedicated heat exchanger would be installed adjacent to the water heater, along with a supplemental storage tank.
Environmental Benefits
The energy generated by an 8-collector rack would offset 56,000 lbs. of CO₂ emissions annually, or 790 tons over the lifetime of the system. This is equivalent to:

- The CO₂ absorbed by 28 acres of dense, hardwood forest (an area 1.4 times the size of Shaw Park in Clayton), or
- 2,500 gallons of gasoline not burned in automobiles each year.

Financial Analysis
The financial performance of the solar thermal system is significantly improved by the Federal tax benefits and incentives. Specifically, were the system owned by a for-profit entity, a 30% credit or grant could be secured to offset the cost of the complete system installation. For a typical system with 16 collectors, and financed internally with a 4% cost of capital, the performance would look as shown in Figure 97 on page 155. The financial performance is as follows:

- Internal Rate of Return (IRR) of 76%
- Payback period of 1 year
- Net Present Value of $51,919

Geothermal Assessment
The building could possibly have been a candidate for a ground-source heat pump, as there is limited space available to drill wells and consistent demand for conditioned space. However, given the recent renovations including a new HVAC system, any opportunity that might have existed would be put off until the equipment is ready to be replaced.
Energy Efficiency

In reviewing the building plans, a number of observations were made regarding the energy performance of the building.

- Ceiling plenum does not appear to meet ASHRAE insulation standards. Consider a ducted return to HVAC.
- Suggest reviewing ASHRAE’s Advanced Energy Design Guide for Climate Zone 4 and check insulation and mechanical efficiencies.
- There appears to be significant opportunity to recover heat from crematory. This should be considered with the overall water heating capacity.
- The building plan calls for 32W T8 lighting, but includes no definition on lighting levels. Recommend defining a lighting level and design lighting to comply – may be able to use 28W.
- Recommend fluorescent or LED lighting instead of 250 W high pressure sodium in outdoor lighting.
- Use occupancy sensors in rooms with limited occupancy, and consider daylight-dimming ballasts in areas lit by natural lighting from windows and skylights.
- The Construction Drawings do not show any lightning protection or transient voltage surge suppression (TVSS) for the electrical system. At a minimum, consider adding TVSS, Class-C devices on the main switchgear and primary distribution panels.

An additional site survey once the building is completed may yield additional recommendations.
Highways & Traffic District #1

A site survey was conducted on January 26, 2011 by Steve O’Rourke and Marc Lopata. Ron Pflueger provided an escort and background on the building. The weather was partly cloudy and cold, with snow on the ground and roof of the building. This section documents the specific findings and recommendations based on that visit and subsequent analysis.

Facility Description

The District #1 facility is a 23,000+ ft$^2$ facility located at 4045 Seven Hills Drive in Florissant. The building was built in 1975.

The facility employs a staff of approximately 40 full-time employees, most of whom work in the field. Normal hours of operation are from 7:00 a.m. to 3:30 p.m. Monday through Friday, but the staff may work around the clock and on weekends to maintain roads during snow season or to address other traffic related issues.

The building has four sections. The western-most section is a high-bay area for vehicle maintenance, with a wash bay on the outside end. The second section is primarily office space and break/prep space for staff. The third section is another high-bay area for maintenance and repair, and the eastern-most section primarily houses parts.

The building has brick and concrete block façade, and has double-pane windows with no thermal breaks in the office area that appear to be in good condition. The built-up roof is mounted on a corrugated
steel deck supported by structural steel trusses. Though the age was undetermined, the roof is in fair condition, with a slight pitch that drains into exterior downspouts. The roof over the west bay (section 1) has six vent stacks for the heating units, and a 24” parapet around the roof. There is no lightning protection.

The office area is illuminated with T8 fluorescent lighting with electronic ballasts. A large skylight provides natural daylight into the central space. The office has a modest plug load, including computers, copiers, fax machines, vending machines, a refrigerator and a microwave.

Lighting in the west bay is primarily T12 fluorescent, with a single 400W metal halide light over the wash bay. The lighting in the north east bay is a combination of T12 fluorescent supplemented by seven 400W metal halide lights. The smaller third bay, which contains parts storage, also has T12 lighting.

The climate in each building section is controlled by separate HVAC systems, which were not analyzed in detail. The CO₂ level inside was significantly higher (1200) than the outside air (540), indicating a lack of ventilation. The building’s domestic water supply is heated with natural gas.

Figure 35 Interior of hi-bay area for vehicle maintenance
Solar Electric Assessment
This site is a reasonably good location for a solar PV array. The large roof over west bay would be the best location, with great southern exposure with very little shade from rooftop equipment.

The building is situated in a “cardinal square” orientation, facing due south. A 25 kW roof-mounted array typically requires approximately 3,000 ft² of space. Given the roof vents in the center of the roof, modules would have to be split into two sections, shown in Figure 36 below. In order to estimate conservatively, a 20 kW system is proposed.

![Figure 36 Blue shaded areas show proposed location for solar array over west bay (image courtesy of Google Maps)](image)

Mounting Options
The roof is in fair condition, and appears to have sufficient structural capacity to support a ballasted PV array’s load of approximately 5 pounds per square foot (psf). A metal ballasted racking system will work well on the built-up roof.

A 20 kW array could be installed using two sets of three rows, each made up of approximately 18-20 modules, depending on the size and power output. To minimize wind lift, the modules are optimally installed at a 10° tilt.
Figure 37 View of roof from the east
System Configuration and Building Integration

Modules
Given the shading from the parapet and roof vents, the roof area must be used effectively to create a 20 kW array. If the objective is to maximize energy production, monocrystalline modules might be used. However, if price/performance is the primary consideration, polycrystalline modules would be the better choice.

Inverters
Microinverters are recommended given the lack of mounting space in maintenance office and the somewhat dusty environment. This will also simplify installation, and minimize the effect of any temporary shading from the roof vents. Microinverters will also provide better visibility into system performance.

Energy Systems and Distribution
The Ameren service entrance and meter are on the north exterior wall and the distribution panels are immediately inside this location. The electrical service to the building was not documented.

According to staff, the building can be de-energized to complete the interconnection. That work would be done on the weekend to minimize impact to operations.

Storage, Staging and Installation
A 20kW system would require approximately 200 square feet for storage of 8-9 standard pallets, including modules, inverters, racking and ballast. Typically the solar installer will accept delivery of the equipment off site and deliver to the site when the timing is optimal for installation.

A small crane or boom-lift truck will be required to get the equipment up to the roof. The maximum pallet weight for equipment will be approximately 1,500 pounds, although ballast blocks may weight 3,000 per pallet. The lift height should be 30 feet or less, and the boom distance approximately 30 feet or less. It is possible at this location that the equipment could be stored on site and lifted to the roof using a county-owned fork truck or boom truck without the need for equipment rental.

When the pallets are lifted to the roof (whether initially or after a delay), they will have to be placed directly on the structural columns or beams to ensure adequate long-term loading capacity. These locations should be physically confirmed and marked on the roof with spray paint to
ensure accurate placement. The goal would be to install within a few days, but that could be delayed by weeks or months under worst-case conditions.

The electrical conduit would run across the roof and down the wall, connecting to the load side of the meter on the north wall. An Envoy box, which is used to distribute energy production data to computers across a local area network, could be mounted on the wall inside the maintenance office area.

When the pallets are lifted to the roof (whether initially or after a delay), they will have to be placed directly on the structural columns or beams to ensure adequate long-term loading capacity. These locations should be physically confirmed and marked to ensure accurate placement. The goal would be to install within a few days, but that could be delayed by weeks or months under worst-case conditions. The heaviest pallet for a system of this size usually is less than 2,000 pounds.

**Energy Production**

The proposed 20 kW system would produce approximately 24,600 kWh annually, with higher production in the longer days of summer (see Figure 39 below). The total energy produced over the expected 30 year life of the system is approximately 688,000 kWh, factoring in a typical annual degradation factor of 0.5%.

![Forecasted Energy Production](image)

*Figure 39 Estimated annual energy production for 20 kW system at 10° tilt and 180° azimuth*
Financial Analysis
The turnkey cash installation cost for the 20 kW rooftop system using polycrystalline modules is estimated at $135,000 in 2011 dollars. That is calculated based on American-made components (complying with ARRA requirements) and prevailing or union labor rates. This should include design services, installation labor, materials, and equipment, including modules, inverters, and balance-of-system components necessary to comply with the local building code and Ameren interconnection requirements.

The PV system will require annual cleaning and inspection by building management personnel. Annual monitoring and maintenance contracts are available and would cost in the range of $600-700 per year. This is not included in the financial performance evaluation. Insurance is estimated at $600 per year for casualty loss coverage, and this cost is included in the financial performance model.

Applicable Incentives
The financial model to calculate the total value of the incentives includes the utility rebate, which is received within 90 days of the completed installation. Potential income from the sale of SRECs can also be factored in to maximize the payback. The net cost after these incentives are applied is shown below.

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<td>82,800</td>
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<sup>10</sup> This value is an estimate of the sum of the first five annual payments from Ameren’s Standard Offer Contract. Cash flow projections in the financial model include additional SREC income for years 6-10.
Environmental Benefits
The electricity generated by this 20 kW system would result in reduced emissions from the coal-fired power plants that support the Ameren Missouri distribution region. This amounts to a reduction of 31 tons of carbon not polluting the atmosphere each year. This is equivalent to:

- The CO₂ absorbed by 28 acres of dense, hardwood forest (an area 1.4 times the size of Shaw Park in Clayton), or
- 2,500 gallons of gasoline not burned in automobiles each year.

The lifetime contribution of this system will effectively eliminate 790 tons of CO₂ from the atmosphere.

Implementation Schedule
Installing the solar-PV system would require approximately 10-11 weeks, depending primarily on equipment availability. The permitting task includes the following:

- Electrical permit issued by St Louis County;
- Approval from the Clayton Architectural Review Board;
- Interconnection and Net Metering Agreement from Ameren Missouri. By rulemaking, this is declared to be a 90-day or less interval. Typical approval period is 30-45 days.

![Figure 40 Typical Implementation Schedule](image)

Equipment lead times for the project as described above typically are 4-5 weeks, but this could vary significantly depending on project timing and conditions in the global markets. This should be reassessed at the time the project is planned.
**Solar-Thermal Assessment**
The demand for hot water in this facility does not warrant the use of solar thermal. Hot water is limited to hand washing and light kitchen use, and the operational hours are typically limited to 45 hours per week.

**Geothermal Assessment**
The building is not a good candidate for a ground-source heat pump, given the type of operation. Geothermal heating & cooling is best applied in areas where a consistent temperature is maintained. Given the limited occupancy of the building and the dramatic swings in temperature when garage doors are opened, this is not a good application for ground source.
Energy Efficiency

During the site visit, a number of observations were made regarding the energy performance of the building.

- Replace the T12 fluorescent lamps and ballasts with T8 lamps with electronic ballast. Specify ballast factor based on desired lighting intensity at the working surface(s).
- Replace metal halide fixtures in both maintenance bays with hi-bay T5 fluorescent lights. This would enable the use of occupancy sensors in conjunction with the lighting controls, particularly in the west bay, to reduce usage significantly. Occupancy sensors would not work well with current metal halide lights because they need to warm up.
- Dimmable ballasts could be installed to reduce artificial lighting requirements in the large break area with skylight.
- The vending machines could be retrofitted with energy-saving occupancy sensors, which can reduce energy use by up to 50%.
- The office could benefit from additional ventilation. Using an energy recovery ventilator would minimize heat transfer while providing fresh air.
- Install an insulating jacket on the hot water tank to reduce water heating costs.
- Non-essential equipment should be manually or programmatically powered down outside operating hours.

A full audit will provide more detail analysis and recommendations, and a retro commissioning of the HVAC system will likely reduce energy consumption.

Figure 41 Metal halide and T12 fluorescent fixtures should be replaced with more energy efficient T5 fluorescent fixtures with occupancy sensors
Highways & Traffic District #2
A site survey was conducted on October 7, 2010 by Steve O’Rourke and Marc Lopata. Kevin Buckley and Russ Schmidt provided an escort and background on the building. Jeff Heine, the district manager, also provided information about the district operations. The weather was clear and mild. This section documents the specific findings and recommendations based on that visit and subsequent analysis.

Facility Description
The District #2 facility is a 30,600+ ft² facility located at 11201 Schaeffer Road in Maryland Heights. The building was built in 1998.

Like District #1, this facility is used to maintain a portion of the County’s highway maintenance fleet. The staff consists of approximately 40 full-time employees, most of whom work in the field. Normal hours of operation are from 7:00 a.m. to 3:30 p.m. Monday through Friday, but the field staff may be required to work around the clock and on weekends to maintain roads during snow season or to address other traffic related issues.

Figure 42 District #2 as seen from the south (image courtesy of Bing maps)

The facility includes two-story office area on the northwest side of the building (top left in the image above). The repair bay has closeable doors so that the space can be heated in the winter. Adjacent to this is the maintenance bay, which has no doors. At the end of the maintenance bay is a wash bay and shop.
The building walls are constructed of masonry with steel siding around the shop and maintenance garage. The roof of the office space is EPDM membrane on a steel deck with bar joist supports. The roof above the garage and shop is a standing seam metal roof. Both roofs are in good condition. The garage roof has a low pitch, with scuppers for drainage and a 24" parapet around the roof. There is no lightning protection.

The office space is primarily T8 fluorescent lighting with electronic ballasts. The plug load is typical, with typical office equipment like computers, fax machines, and copiers. The break room has vending machines, a refrigerator and microwave.

Lighting in the repair and maintenance bays is primarily 400 watt metal halide fixtures, with a string of fluorescent T12 fixtures down the center to provide minimal lighting when the metal halide fixtures are off or have not yet warmed up.

The repair bay, wash bay and shop are heated with ceiling-mounted gas heating units that are individually controlled. The office space is heated and cooled with a rooftop unit. A small gas-fired water heater supplies the building’s domestic hot water.
Solar Electric Assessment
This site is not a primary candidate for solar, but it could accommodate a small solar PV array. The roof over the office would be the best location, as it has adequate southern exposure with very little shade from rooftop equipment. The standing seam metal roof has a peak in the center, with the low pitch roof running to either side of the peak for drainage, so the rear section of the roof is actually angled away from the sun.

The building is situated approximately 33° off of due south, which will have a modest (3%) impact on energy production. A 20 kW roof-mounted array typically requires approximately 2,500 ft² of space. Given the roof vents in the center of the roof, modules would have to be split into two sections, shown below.

Figure 44 Blue shaded areas show proposed location for solar array over west bay (image courtesy of Google Maps)

Alternatively, the modules could be installed so that they are facing due-south to maximize energy production. This could be assessed at a later date if the decision is made to move forward on solar at this location.

Mounting Options
The roof is in good condition, and appears to have sufficient structural capacity to support a ballasted PV array’s load of approximately 5 pounds per square foot (psf). A metal ballasted racking system will work well on the EPDM membrane roof.
To minimize wind lift, the modules are optimally installed at a 10° tilt. A 15 kW array could be installed in the front half of the roof, and an additional 5 kW could be installed in the rear section.

Figure 45 View of proposed installation location from the southeast
System Configuration and Building Integration

Modules
Given the limited amount of available roof space, monocrystalline modules might be used to maximize energy production. However, if price/performance is the primary consideration, polycrystalline modules would be the better choice.

Inverters
Microinverters are recommended to simplify installation and minimize the effect of any temporary shading from the roof vents. This will also enable more detail monitoring of system performance.

Energy Systems and Distribution
The Ameren service entrance and meter are on the west wall and the distribution panels are immediately inside this location. The electrical service to the building is 480/277 and the building distribution is both 480/277 and 208/120.

According to staff, the building can be de-energized to complete the interconnection. That work would be done on the weekend to minimize impact to operations.

Storage, Staging and Installation
A 20kW system would require approximately 200 square feet for storage of 8-9 standard pallets, including modules, inverters, racking and ballast. Typically the solar installer will accept delivery of the equipment off site and deliver to the site when the timing is optimal for installation.

A small crane or boom-lift truck will be required to get the equipment up to the roof. The maximum pallet weight for equipment will be approximately 1,500 pounds, although ballast blocks may weight 3,000 per pallet. The lift height should be 40 feet or less, and the boom distance approximately 40 feet or less, depending on location of the crane/truck and the rooftop staging locations. There is ample access from both sides of the building, so the roof lift should be relatively easy.

When the pallets are lifted to the roof (whether initially or after a delay), they will have to be placed directly on the structural columns or beams to ensure adequate long-term loading capacity. These locations should be physically confirmed and marked on the roof with spray paint to ensure accurate placement. The goal would be to install within a few days, but that could be delayed by weeks or months under worst-case conditions.

The electrical conduit would run through roof into the maintenance bay, and connect into a 75 kVA 208V step-down transformer in the electrical room.

When the pallets are lifted to the roof (whether initially or after a delay), they will have to be placed directly on the structural columns or beams to ensure adequate long-term loading capacity. These locations should be physically confirmed and marked to ensure accurate placement. The goal would be to install within a few days, but that could be delayed by weeks or months under worst-case conditions. The heaviest pallet for a system of this size usually is less than 2,000 pounds.
Energy Production
The proposed 20 kW system would produce approximately 24,600 kWh annually, with higher production in the longer days of summer (see chart below). The total energy produced over the expected 30 year life of the system is approximately 688,000 kWh, factoring in a typical annual degradation factor of 0.5%.

![Forecasted Energy Production](image)

*Figure 46 Estimated annual energy production for 20 kW system at 10° tilt and 213° azimuth*
Financial Analysis
The turnkey cash installation cost for the 20 kW rooftop system using polycrystalline modules is estimated at $135,000 in 2011 dollars. That is calculated based on American-made components (complying with ARRA requirements) and prevailing or union labor rates. This should include design services, installation labor, materials, and equipment, including modules, inverters, and balance-of-system components necessary to comply with the local building code and Ameren interconnection requirements.

The PV system will require annual cleaning and inspection by building management personnel. Annual monitoring and maintenance contracts are available and would cost in the range of $600-700 per year. This is not included in the financial performance evaluation. Insurance is estimated at $600 per year for casualty loss coverage, and this cost is included in the financial performance model.

Applicable Incentives
The financial model to calculate the total value of the incentives includes the utility rebate, which is received within 90 days of the completed installation. Potential income from the sale of SRECs can also be factored in to maximize the payback. The net cost after these incentives are applied is shown below.

<table>
<thead>
<tr>
<th>Amount</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>$135,000</td>
<td>Initial Installed Cost</td>
</tr>
<tr>
<td>$ 40,000</td>
<td>Utility Rebate</td>
</tr>
<tr>
<td>$ 12,200</td>
<td>Sale of SRECs(^\text{11})</td>
</tr>
<tr>
<td>$ 82,800</td>
<td>Net Cost After Incentives</td>
</tr>
</tbody>
</table>

\(^{11}\) This value is an estimate of the sum of the first five annual payments from Ameren’s Standard Offer Contract. Cash flow projections in the financial model include additional SREC income for years 6-10.
Environmental Benefits
The electricity generated by this 20 kW system would result in reduced emissions from the coal-fired power plants that support the Ameren Missouri distribution region. This amounts to a reduction of 31 tons of carbon not polluting the atmosphere each year. This is equivalent to:

- The CO₂ absorbed by 28 acres of dense, hardwood forest (an area 1.4 times the size of Shaw Park in Clayton), or
- 2,500 gallons of gasoline not burned in automobiles each year.

The lifetime contribution of this system will effectively eliminate 790 tons of CO₂ from the atmosphere.

Implementation Schedule
Installing the solar-PV system would require approximately 10-11 weeks, depending primarily on equipment availability. The permitting task includes the following:

- Electrical permit issued by St Louis County;
- Approval from the Clayton Architectural Review Board;
- Interconnection and Net Metering Agreement from Ameren Missouri. By rulemaking, this is declared to be a 90-day or less interval. Typical approval period is 30-45 days.

![Figure 47 Typical Implementation Schedule](image)

Equipment lead times for the project as described above typically are 4-5 weeks, but this could vary significantly depending on project timing and conditions in the global markets. This should be reassessed at the time the project is planned.
Solar-Thermal Assessment
The demand for hot water in this facility does not warrant the use of solar thermal. Hot water is limited to hand washing and light kitchen use, and the operational hours are typically limited to 45 hours per week.

Geothermal Assessment
The building is not a good candidate for a ground-source heat pump, given the type of operation. Geothermal heating & cooling is best applied in areas where a consistent temperature is maintained. Given the limited occupancy of the building and the dramatic swings in temperature when garage doors are opened, this is not a good application for ground source.
**Energy Efficiency**

During the site visit, a number of observations were made regarding the energy performance of the building.

- Recommend replacing 400W metal halide fixtures in both maintenance bays with 6-lamp T8 or high-output T5 fixtures. Daylight sensors and dimmable ballasts could be installed in conjunction with this upgrade to not overlight the garage bays on bright sunny days.
- Solar tube lighting could be used to increase the amount of daylight in the vehicle maintenance and wash bays.
- Remove or upgrade the T12 fluorescent lighting fixtures to high-efficiency T8 fixtures with electronic ballast.
- Install photo electric sensor on outdoor lighting.
- Install ceiling fans in repair bay to circulate warm air downward.
- Install occupancy sensors in office space to turn off lighting in unoccupied rooms.
- Check lighting levels in office, and replace overhead lighting with task lighting where applicable.
- Suggest retro-commission or test and balance of the rooftop unit. The outside temperature was 50° F and the compressor was running with no outside air flow. Check set points and economizer.
- Vending machines could be retrofitted with energy-saving occupancy sensors, which can reduce energy use by up to 50%.
- Non-essential equipment should be manually or programmatically powered down outside operating hours.

A full audit will provide more detail analysis and recommendations.
Fleet Operations
A site survey was conducted on November 23, 2010 by Steve O’Rourke and Marc Lopata. Paul Brown provided an escort and background on the building. The weather was clear and mild. This section documents the specific findings and recommendations based on that visit and subsequent analysis.

Facility Description
The Fleet Operations facility consists primarily of two buildings, including a 21,000+ ft² garage facility and a 5,600 ft² office building located at 2480 Drilling Service Road in Maryland Heights. The facility was built in 1971.

This facility is used to maintain a portion of the County’s vehicle fleet. The office staff consists of approximately 10-15 full-time employees, and an additional 20 employees work in the garage. Normal hours of operation are from 7:00 a.m. to 3:30 p.m. Monday through Friday.

The office building has a flat built-up roof with a steel deck on bar joists. The age of roof is unknown, and is in fair condition with a coating. The roof has interior drainage scuppers, and there is no parapet or lightning protection on the building. The office building has a brick façade, with double pane windows that have no thermal breaks. There is only a very thin layer of roof insulation, so the building’s ductwork is housed in relatively uninsulated space.

Figure 48 District #2 as seen from the south (image courtesy of Bing maps)
The lighting in the office space is fluorescent T12 fixtures with magnetic ballasts. The office equipment is typical, including computers for each employee, three printers and a photocopier. The lighting levels are relatively high in the office.

The garage has a metal deck with a low pitch, with skylights spaced across the entire roof. The original roof is in average condition, and has no roof insulation. The wall construction is metal with panelized insulation on a concrete block knee wall. This building also has no lightning protection or parapet.

A combination of 400 watt metal halide and fluorescent T12 fixtures are used to light the garage. These lights are always on during operating hours, and there is no lighting automation.

Figure 49 Interior of maintenance garage with 400W MH lights supplementing natural light from rooftop.
**Solar Electric Assessment**
This site is not a particularly good site for solar. The office building could accommodate a small array, but the age and condition of the roof is such that it should be replaced before a solar array is installed. If a new roof were installed, the building could accommodate a 6-8 kW array.

The building is situated approximately 10° off a “cardinal square” orientation, slightly southeast, so modules could be installed in line with the building and have an insignificant impact on energy production.

![Figure 50 Blue shaded area shows potential location for solar array on office building (image courtesy of Google Maps)](image)

The garage is a less favorable location. The skylights limit the amount of available space, and the roof tilts to the west and east, so the best option would be to install modules flat on the roof. Given the much better alternatives for solar, this site is low on the list.

**Mounting Options**
The roof of the office building appears to have sufficient structural capacity to support a ballasted PV array’s load of approximately 5 pounds per square foot (psf). Since the building has no parapet, a hybrid racking system would be used that would include both ballast and mechanically fastened racking. This would require roof penetrations, so a new roof would be highly recommended before proceeding. The modules would be installed at a 10° tilt to minimize wind lift.
Figure 51 View of office building roof from the east
System Configuration and Building Integration

**Modules**
Given the limited amount of available roof space, monocrystalline modules might be used to maximize energy production. However, if price/performance is the primary consideration, polycrystalline modules would be the better choice.

**Inverters**
Microinverters are recommended to simplify installation and minimize the effect of any temporary shading from the roof vents. This will also enable more detail monitoring of system performance.

**Energy Systems and Distribution**
The Ameren service entrance and meter are on the north wall and the distribution panels are inside this location. The electrical service to the building is 480/277 and the building distribution includes 480/277 and 208/120.

According to staff, the building can be de-energized to complete the interconnection. That work would be done on the weekend to minimize impact to operations.

**Storage, Staging and Installation**
A 6kW system would require approximately 50 square feet for storage of 1-2 standard pallets, including modules, inverters, racking and ballast. Typically the solar installer will accept delivery of the equipment off site and deliver to the site when the timing is optimal for installation.

There are no suitable rooftop staging points on the west building due to its structural design and low strength. The east building could support equipment pallets but maybe not the pallets of ballast blocks – a structural certification would be necessary before finalizing this design. The lift height for a small crane or boom truck should be 60 feet or less, and the boom distance approximately 40 feet or less.

When the pallets are lifted to the roof (whether initially or after a delay), they will have to be placed directly on the structural columns or beams to ensure adequate long-term loading capacity. These locations should be physically confirmed and marked on the roof with spray paint to ensure accurate placement. The goal would be to install within a few days, but that could be delayed by weeks or months under worst-case conditions.

The electrical conduit would run through roof into the maintenance bay, and connect into a 75 kVA 208V step-down transformer in the electrical room.

When the pallets are lifted to the roof (whether initially or after a delay), they will have to be placed directly on the structural columns or beams to ensure adequate long-term loading capacity. These locations should be physically confirmed and marked to ensure accurate placement. The goal would be to install within a few days, but that could be delayed by weeks or months under worst-case conditions. The heaviest pallet for a system of this size usually is less than 2,000 pounds.
Energy Production
A 6 kW system would produce approximately 7,400 kWh annually, with higher production in the longer days of summer (see chart below). The total energy produced over the expected 30 year life of the system is approximately 206,300 kWh, factoring in a typical annual degradation factor of 0.5%.

Figure 52 Annual energy production for 6 kW array at 10° tilt and 170° azimuth
Financial Analysis
The turnkey cash installation cost for the 6 kW rooftop system using polycrystalline modules is estimated at $44,000 in 2011 dollars. That is calculated based on American-made components (complying with ARRA requirements) and prevailing or union labor rates. This should include design services, installation labor, materials, and equipment, including modules, inverters, and balance-of-system components necessary to comply with the local building code and Ameren interconnection requirements.

The PV system will require annual cleaning and inspection by building management personnel. Annual monitoring and maintenance contracts are available and would cost in the range of 200-300 per year. This is not included in the financial performance evaluation. Insurance is estimated at $200 per year for casualty loss coverage, and this cost is included in the financial performance model.

Applicable Incentives
The financial model to calculate the total value of the incentives includes the utility rebate, which is received within 90 days of the completed installation. Potential income from the sale of SRECs can also be factored in to maximize the payback. The net cost after these incentives are applied is shown below.

<table>
<thead>
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<th>Category</th>
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<td>Initial Installed Cost</td>
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<td>Utility Rebate</td>
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<td>Sale of SRECs</td>
<td>$4,300</td>
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<tr>
<td>Net Cost After Incentives</td>
<td>$27,700</td>
</tr>
</tbody>
</table>

12 This value is an estimate of the sum of the first five annual payments from Ameren’s Standard Offer Contract. Cash flow projections in the financial model include additional SREC income for years 6-10.
**Environmental Benefits**

The electricity generated by this 6 kW system would result in reduced emissions from the coal-fired power plants that support the Ameren Missouri distribution region. This amounts to a reduction of 7 tons of carbon not polluting the atmosphere each year. This is equivalent to:

- The CO$_2$ absorbed by 7 acres of dense, hardwood forest (an area 1/3 the size of Shaw Park in Clayton), or
- 600 gallons of gasoline not burned in automobiles each year.

The lifetime contribution of this system will effectively eliminate 189 tons of CO$_2$ from the atmosphere.

**Implementation Schedule**

Installing the solar-PV system would require approximately 10-11 weeks, depending primarily on equipment availability. The permitting task includes the following:

- Electrical permit issued by St Louis County;
- Approval from the Clayton Architectural Review Board;
- Interconnection and Net Metering Agreement from Ameren Missouri. By rulemaking, this is declared to be a 90-day or less interval. Typical approval period is 30-45 days.

![Figure 53 Typical Implementation Schedule](image-url)

Equipment lead times for the project as described above typically are 4-5 weeks, but this could vary significantly depending on project timing and conditions in the global markets. This should be reassessed at the time the project is planned.
Solar-Thermal Assessment
The demand for hot water in this facility does not warrant the use of solar thermal. Hot water is limited to hand washing and light kitchen use, and the operational hours are typically limited to 45 hours per week.

Geothermal Assessment
While there is ground area suitable for vertical wells, the building is not a good candidate for geothermal given the type of operation. Given the limited occupancy of the building, the payback on geothermal would be marginal at best.
Energy Efficiency
During the site visit, a number of observations were made regarding the energy performance of the building.

- Recommend retrofitting the T12 fluorescent lighting fixtures with T8 fixtures with electronic ballast.
- Replace metal halide fixtures in the maintenance garage with hi-bay T5 fluorescent lights. This would enable the use of daylight sensors and dimmable ballasts to significantly reduce the need for artificial lighting.
- Occupancy sensors could be used to automatically switch off lighting in unoccupied rooms.
- Non-essential equipment should be manually or programmatically powered down outside operating hours.
- The office building could benefit from additional insulation.
- A programmable thermostat could be used to automatically set back the temperature controls outside of normal operating hours in both buildings.
- Install an insulating jacket on the hot water tank and wrap pipes to reduce water heating costs.
- Increasing the frequency of filter changes on HVAC units will prolong the life of the equipment and reduce energy consumption.

A full audit will provide more detail analysis and recommendations, and a retro commissioning of the HVAC system will likely reduce energy consumption.
Traffic Operations
A site survey was conducted on November 23, 2010 by Steve O’Rourke and Marc Lopata. Paul Brown provided an escort and background on the building. The weather was clear and mild. This section documents the specific findings and recommendations based on that visit and subsequent analysis.

Facility Description
The Traffic Operations facility is a 30,900 ft² facility located at 2688 Adie Road in Maryland Heights. The facility, built in 2006, consists of office space and high bay warehouse and garage space, used to monitor and maintain traffic equipment and vehicles. The office staff consists of approximately 7-8 full-time employees, and an additional 40-50 employees work in shop or the field. Normal hours of operation are from 7:00 a.m. to 3:30 p.m. Monday through Friday.

As seen in the image above, the facility is primarily garage and warehouse space, with a small 3,000 ft² office in the front of the building. The white standing-seam metal roof is in good condition, with typical HVAC components penetrating the surface and 3” of roof blanket insulation to minimize heat transfer. Of course, the white surface reflects light and heat rather than absorb it, so the high-bay area is naturally cooler in the summer. The roof has a low pitch with interior gutters, and the parapet ranges from 18” on the northeast to 36” on southwest. The building has no lightning protection.

The building has a Trane building management system, but the programmed set points did not appear to correspond to the hours of operation. Thermostat set points were 76° for cooling and 65° for heat, which are modest. The HVAC system is relatively efficient with variable air volume blowers and 85.5%
efficient rooftop unit motors. The building has a 100 gallon gas water heater with a pump to continuously circulate hot water to faucets in the building. The temperature was set at 140°, but the actual temperature of the water was 115°.

The office is primarily lit with efficient T8 fluorescent fixtures with electronic ballasts. The observed lighting levels were relatively high, and lights appeared to be always on, even in unoccupied rooms. The lighting in the garage and warehouse/shop areas is primarily 400 watt metal halide fixtures.

The office has typical office equipment, including computers, printers and fax machines. A traffic monitoring station was equipped with six computers with 24” flat screen monitors, and five additional 42” wall-mounted television monitors. The stations were unmanned but operational.

Figure 55 Traffic monitoring station
Solar Electric Assessment
This site has abundant rooftop space that could be used to effectively harvest solar energy. There is very little shade except from a few rooftop components of the HVAC system. There is little risk of any other development that might result in shading on the roof. The roof could support up to 100 kW of power capacity if modules were installed at a 0° tilt (flat) on the roof.

Figure 56 Blue shaded area shows potential location for solar array on office building (image courtesy of Google Maps)

The building’s standing seam metal roof would require the use of a special racking system (see Figure 57 on the following page) that would require the modules to be fixed in line with the building. The building is situated approximately 48° off a “cardinal square” orientation, but if modules are installed at a 0° tilt this will have no impact on energy production.

Alternatively, if modules are installed in line with the building at 10°, there would be an increase in the efficiency of the power production, but fewer modules could be installed to eliminate or minimize shading between rows of modules. Capacity would be reduced by approximately 50%, but this would still enable the County to install up to 50 kW of power.
**Mounting Options**

The structural capacity of the roof should easily accommodate the PV array’s load of approximately 3 pounds per square foot (psf). A specialty racking system for standing-seam metal roofs would be used to mount the modules flush with the roof. A sample racking system is shown below.

*Figure 57 Specialty racking for standing seam metal roof*

The modules would have to be installed in a somewhat irregular fashion to accommodate the roof penetrations of the HVAC equipment.

*Figure 58 Modules would have to be installed around roof equipment on standing seam metal roof*
System Configuration and Building Integration

Modules
Given the abundant space available, polycrystalline modules can be used to maximize price/performance. While thin film laminate PV modules are often applied to standing seam metal roofs, the 2” height of the seams would cast shade on a portion of the module. Further analysis would have to be done to determine if this would be a viable option.

Inverters
Bulk inverters could be installed on the parapet wall. The wall on the southwest building line is 36” and would provide adequate space to consolidate power production before penetrating the roof.

Energy Systems and Distribution
The Ameren service entrance and meter are on the east exterior wall and the building electrical distribution panels are inside this location. The electrical service to the building is 480/277 and the building distribution includes 480/277 and 208/120.

According to staff, the building can be de-energized to complete the interconnection. That work would be done on the weekend to minimize impact to operations.

Storage, Staging and Installation
A 50 kW system would require approximately 400 square feet for storage of 16-18 standard pallets, including modules, inverters, racking and ballast. Typically the solar installer will accept delivery of the equipment off site and deliver to the site when the timing is optimal for installation.

The equipment probably would have to be lifted to the lower roof at the north end of the building, because the metal roof doesn’t appear to be strong enough to support the concentrated load. The equipment and materials would have to be carried by hand to the southern roof area for installation. This represents a small additional labor cost.

When the pallets are lifted to the roof (whether initially or after a delay), they will have to be placed directly on the structural columns or beams to ensure adequate long-term loading capacity. These locations should be physically confirmed and marked on the roof with spray paint to ensure accurate placement. The goal would be to install within a few days, but that could be delayed by weeks or months under worst-case conditions.
The electrical conduit would run through roof into the maintenance bay, and connect into a 75 kVA 208V step-down transformer in the electrical room.

When the pallets are lifted to the roof (whether initially or after a delay), they will have to be placed directly on the structural columns or beams to ensure adequate long-term loading capacity. These locations should be physically confirmed and marked to ensure accurate placement. The goal would be to install within a few days, but that could be delayed by weeks or months under worst-case conditions. The heaviest pallet for a system of this size usually is less than 2,000 pounds.
**Energy Production**

A 100 kW system would produce approximately 113,800 kWh annually, with higher production in the longer days of summer (see chart below). The total energy produced over the expected 30 year life of the system is approximately 3,179,000 kWh, factoring in a typical annual degradation factor of 0.5%. The estimated value of this energy is $533,300.

![Forecasted Energy Production](image)

*Figure 60 Estimated annual energy production for 100 kW system at 0° tilt and 238° azimuth*

A smaller 50 kW system would produce 59,200 kWh annually, with a total lifetime production of 1,650,000 kWh, conservatively valued at $288,000.

![Forecasted Energy Production](image)

*Figure 61 Estimated annual energy production for 50 kW system at 0° tilt and 238° azimuth*
**Financial Analysis**

The turnkey cash installation cost for the 50kW rooftop system using polycrystalline modules is estimated at $300,000 in 2011 dollars. That is calculated based on American-made components (complying with ARRA requirements) and prevailing or union labor rates. This should include design services, installation labor, materials, and equipment, including modules, inverters, and balance-of-system components necessary to comply with the local building code and Ameren interconnection requirements.

The PV system will require annual cleaning and inspection by building management personnel. Annual monitoring and maintenance contracts are available and would cost in the range of $1,000-1,200 per year. This is not included in the financial performance evaluation. Insurance is estimated at $1,000 per year for casualty loss coverage, and this cost is included in the financial performance model.

**Applicable Incentives**

The financial model to calculate the total value of the incentives includes the utility rebate, which is received within 90 days of the completed installation. Potential income from the sale of SRECs can also be factored in to maximize the payback. The net cost after these incentives are applied is shown below.

<table>
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<th>Amount</th>
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</thead>
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<td>Utility Rebate</td>
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<td>Sale of SRECs(^{13})</td>
<td>$30,000</td>
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<td>Net Cost After Incentives</td>
<td>$220,000</td>
</tr>
</tbody>
</table>

\(^{13}\) This value is an estimate of the sum of the first five annual payments from Ameren’s Standard Offer Contract. Cash flow projections in the financial model include additional SREC income for years 6-10.
Environmental Benefits
The electricity generated by a 50 kW system would result in reduced emissions from the coal-fired power plants that support the Ameren Missouri distribution region. This amounts to a reduction of 52 tons of carbon not polluting the atmosphere each year. This is equivalent to:

- The CO$_2$ absorbed by 52 acres of dense, hardwood forest, or
- 4,600 gallons of gasoline not burned in automobiles each year.

The lifetime contribution of this system will effectively eliminate 1,459 tons of CO$_2$ from the atmosphere.

Implementation Schedule
Installing the solar-PV system would require approximately 10-11 weeks, depending primarily on equipment availability. The permitting task includes the following:

- Electrical permit issued by St Louis County;
- Approval from the Clayton Architectural Review Board;
- Interconnection and Net Metering Agreement from Ameren Missouri. By rulemaking, this is declared to be a 90-day or less interval. Typical approval period is 30-45 days.

![Figure 62 Typical Implementation Schedule](image)

Equipment lead times for the project as described above typically are 4-5 weeks, but this could vary significantly depending on project timing and conditions in the global markets. This should be reassessed at the time the project is planned.
Solar-Thermal Assessment
The demand for hot water in this facility does not warrant the use of solar thermal. Hot water is limited to hand washing and light kitchen use, and the operational hours are typically limited to 45 hours per week.

Geothermal Assessment
While there is ample unpaved ground area for to create a vertical loop, this building is not a good candidate for a ground-source heat pump. The systems are new, and will not need replacement for some time. A second reason why it is not recommended is the type of operation. Geothermal heating & cooling systems are best applied in areas where a consistent temperature is maintained. Given the limited occupancy of the building and the dramatic swings in temperature when garage doors are opened, this is not a good application for ground source.
Energy Efficiency

During the site visit, a number of observations were made regarding the energy performance of the building.

- Adjust temperature set points in building management system to correspond to typical hours of operation, and provide guidelines for manual override when necessary. Consider lowering set points for heat from 65° to 62° and from 76° to 82° for cooling.
- Change set point for cooling in data center from 75° to 80°
- Investigate short cycling of one of the cooling fans in the high-bay garage.
- Install occupancy sensors in rooms to automatically turn off lights, and encourage employees to use task lighting and manually turn off lights when not in use.
- Lighting levels in the office were relatively high; consider the installation of dimmable ballasts in lights to reduce artificial light on bright sunny days.
- Replace 400 watt metal halide lights in high-bay with more efficient T5 fluorescent fixtures with dimmable ballasts to lower artificial lighting when garage doors are open.
- Install central power switch on flat screen monitors in the traffic monitoring room so that monitors can be powered off when not in use.
- Replace incandescent bulbs with LED indicators in signal monitoring equipment.
- Install timer on hot water recirculation pump so that it only runs during typical hours of operation. This will save energy used to pump the water, plus energy used to reheat the circulated water.
- Implement automated power management capabilities of computers to reduce power consumption using sleep/hibernate modes.
MET Center
A site survey was conducted on February 10, 2011 by Steve O’Rourke and Marc Lopata. James Prader and Fred Geldmacher provided an escort and background on the building. Lee Brotherton, executive director for the Met Center, provided additional information about the facility’s operations and history. The weather was clear and very cold, with snow and ice on the parking lot and building roof. This section documents the specific findings and recommendations based on that visit and subsequent analysis.

Facility Description
The Metropolitan Education and Training Center is located in Wellston just east of the Wellston MetroLink stop at 6347 Plymouth Avenue. The original Wagner Electric building, which was built around 1930, is a 129,440 ft² facility on a brownfield site that was renovated in the early 1990s to provide education and training services to county residents. The St. Louis County Economic Council oversaw the renovation.

Figure 63 MET Center as seen from the south (image courtesy of Bing maps)
The building is occupied primarily by tenants, including Better Family Life, St. Louis Community College, East-West Gateway, St. Louis Agency for Training and Employment, and St. Louis County. Classes are held regularly, with 200-300 visitors each week taking advantage of various programs. Approximately 75-100 staff workers from the various tenant agencies work in the building, which is open Monday through Thursday from 7:00 a.m. to 10:00 p.m. The building is closed at 5:00 p.m. on Friday.

The building is constructed of brick and concrete, with 5” thick concrete floors. In the front of the building, the bottom four of six stories have been renovated. The larger portion of the building in the rear consists of a high-bay area used for construction training, and a low-bay area on the east side of the building is used for additional training.

![Figure 64 View of MET Center from the east, with low-bay in the foreground and hi-bay area behind (image courtesy of Bing maps)](image)

The ground floor of the front office portion of the building consists primarily of administrative offices, classrooms, and a break room. Levels 2 and 3 house additional offices, classrooms and conference rooms. Level 4 is used primarily for nursing classrooms, with additional office space. A portion of the floor on the east side of the floor remains unfinished. Level 5 and 6 have also been stripped and ready for renovation, with new windows on south and west side to match the windows on the first four floors. Both floors are currently used for storage.

The roof deck is constructed of bar joists with steel deck. The composite roof is old and in average condition with an approximately four foot parapet and no lightning protection.
The lighting in the renovated office area is high efficiency T8 fluorescent fixtures with electronic ballasts. Both large bays have a combination of 400 watt metal halide and T12 fluorescent fixtures, which are relatively inefficient. There are not automated controls in the building, and the lighting is always on during operating hours. The security guard that closes the building is expected to turn off lights in the evening, but this manual process is prone to omissions.

The classrooms contain a significant number of computers, with 30 or more computers on in each room. The computers are not on an automated power plan, and thus run 24x7 unless they are manually powered down. There are no standard operating procedures for the building, and no evidence that the computers were manually powered down. Since tenants do not bare their share of energy costs, there is no incentive in place to adopt such measures.

The building is heated with five rooftop units, with additional electric heat registers in the classrooms. The cooling system is a variable air volume unit with electric re-heat. CO\textsubscript{2} levels in the executive offices were relatively high (1400) compared to outside levels (550), indicating a need for additional makeup air. The hot water tanks are heated with electric energy.
Solar Electric Assessment
This site is an excellent candidate for solar. The building has good southern exposure, with little risk of development of a taller building on adjacent property to impact the solar resource. Given that the building is used for construction training, this would be a great way to educate trainees about solar energy and how it is installed. The roof has a full stairwell to provide easy walk-out access, and the 4’ parapet provides adequate safety for visitors. This would likely be a great candidate for a grant to fund the system.

The roof of the office building could accommodate a moderate 25 kW array. The age and condition of the roof is unknown, as snow was covering most of the roof surface. The building is situated approximately 6° off a “cardinal square” orientation, facing slightly southwest, so modules could be installed in line with the building and have an insignificant impact on energy production.

![Figure 66 Proposed area for mounting 25 kW solar array](image-url)
Mounting Options
As mentioned earlier in this section, the age and condition of the composite roof is average at best, and should probably be replaced before a solar PV system is installed. The image below shows the snow-covered area.

The roof appears to have sufficient structural capacity to support a ballasted PV array’s load of approximately 5 pounds per square foot (psf). A metal ballasted racking system would work well.

System Configuration and Building Integration

Modules
Given the nature of the facility, a number of different types of modules might be installed to demonstrate the variety of modules available. One array might use monocrystalline modules, while another might use identical watt polycrystalline modules to illustrate the difference in power production. A string along the north wall might be installed at an optimal 30° tilt to demonstrate the effect on energy production.
A new white reflective roof might be installed to reflect heat, and translucent modules could be installed to absorb light on both sides of the solar module. Additionally, cylindrical solar modules could be installed, which might enable the white roof to be eligible for additional incentives. A tracking system could potentially be installed on the steel beam platform that presumably was originally designed to hold HVAC equipment (see below.)

![Steel beam platform could potentially be used to install multi-axis solar tracking system](image)

**Inverters**

Given the potential variety of modules that might be installed, microinverters would be well suited to simplify the installation and demonstrate power production for each module. However, bulk inverters might also be installed on some arrays for demonstration purposes...

**Energy Systems and Distribution**

The Ameren service entrance and meter are on the east exterior wall and the distribution panels are immediately inside this location. The electrical service to the building is 480/277 and the building distribution includes 480/277 and 208/120.

- Either string or microinverters, connect into building system on 4\textsuperscript{th} floor
- Utility service 480, meter outside on east side of building
- Building distribution 480/277 and 208/120
- No surge suppression
- Building can be de-energized

According to staff, the building can be de-energized to complete the interconnection. That work would be done on the weekend to minimize impact to operations.

**Storage, Staging and Installation**
A 25kW system would require approximately 200 square feet for storage of 8-9 standard pallets, including modules, inverters, racking and ballast. Typically the solar installer will accept delivery of the equipment off site and deliver to the site when the timing is optimal for installation. A crane would be required to lift the pallets to the roof.

The electrical conduit would run through roof into the maintenance bay, and connect into a 75 kVA 208V step-down transformer in the electrical room.

When the pallets are lifted to the roof (whether initially or after a delay), they will have to be placed directly on the structural columns or beams to ensure adequate long-term loading capacity. These locations should be physically confirmed and marked to ensure accurate placement. The goal would be to install within a few days, but that could be delayed by weeks or months under worst-case conditions. The heaviest pallet for a system of this size usually is less than 2,000 pounds.
Energy Production
Given the different types of modules, mounting options, and potentially the use of a tracking system, an accurate estimate of energy production is not realistic to present. However, a typical 25 kW system installed on a roof at 10° would produce approximately 30,800 kWh annually, with higher production in the longer days of summer (see chart below).

The total energy produced over the expected 30 year life of a generic 25 kW system would be approximately 860,000 kWh, factoring in a typical annual degradation factor of 0.5%. The estimated value of this energy is $150,000.

![Forecasted Energy Production](image)

*Figure 69 Estimated annual energy production for 25 kW system at 10° tilt and 186° azimuth*
Financial Analysis
The turnkey cash installation cost for the 25 kW rooftop system using polycrystalline modules is estimated at $170,000 in 2011 dollars. The increased cost is due to the longer conduit runs inside the building and the age of the electrical distribution panels.

That estimate is based on using American-made components (complying with ARRA requirements) and prevailing or union labor rates. This should include design services, installation labor, materials, and equipment, including modules, inverters, and balance-of-system components necessary to comply with the local building code and Ameren interconnection requirements.

The PV system will require annual cleaning and inspection by building management personnel. Annual monitoring and maintenance contracts are available and would cost in the range of $600-700 per year. This is not included in the financial performance evaluation. Insurance is estimated at $600 per year for casualty loss coverage, and this cost is included in the financial performance model.

Applicable Incentives
The financial model to calculate the total value of the incentives includes the utility rebate, which is received within 90 days of the completed installation. Potential income from the sale of SRECs can also be factored in to maximize the payback. The net cost after these incentives are applied is shown below.

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Installed Cost</td>
<td>$170,000</td>
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<tr>
<td>Utility Rebate</td>
<td>$50,000</td>
</tr>
<tr>
<td>Sale of SRECs(^{14})</td>
<td>$15,200</td>
</tr>
<tr>
<td>Net Cost After Incentives</td>
<td>$104,800</td>
</tr>
</tbody>
</table>

\(^{14}\) This value is an estimate of the sum of the first five annual payments from Ameren’s Standard Offer Contract. Cash flow projections in the financial model include additional SREC income for years 6-10.
Environmental Benefits
The electricity generated by a 25 kW system would result in reduced emissions from the coal-fired power plants that support the Ameren Missouri distribution region. This amounts to a reduction of 28 tons of carbon not polluting the atmosphere each year. This is equivalent to:

- The CO₂ absorbed by 28 acres of dense, hardwood forest (an area about 1.4 times the size of Shaw Park in Clayton), or
- 2,500 gallons of gasoline not burned in automobiles each year.

The lifetime contribution of this system will effectively eliminate 790 tons of CO₂ from the atmosphere.

Implementation Schedule
Installing the solar-PV system would require approximately 10-11 weeks, depending primarily on equipment availability. The permitting task includes the following:

- Electrical permit issued by St Louis County;
- Approval from the Clayton Architectural Review Board;
- Interconnection and Net Metering Agreement from Ameren Missouri. By rulemaking, this is declared to be a 90-day or less interval. Typical approval period is 30-45 days.

Equipment lead times for the project as described above typically are 4-5 weeks, but this could vary significantly depending on project timing and conditions in the global markets. This should be reassessed at the time the project is planned.
Solar-Thermal Assessment
The demand for hot water in this facility does not warrant the use of solar thermal. Hot water is primarily limited to hand washing and light kitchen use, and the operational hours are typically limited to 50 hours per week.

Geothermal Assessment
The building site is a delisted superfund site, so no soil disturbance is allowed, eliminating the possibility of installing geothermal heating and cooling. However, if this was not a limiting factor, the operational characteristics of the building make it a relatively poor candidate as well, because the occupancy of the building is limited to 50 hours/week.
Energy Efficiency
During the site visit, a number of observations were made regarding the energy performance of the building.

- Replace 400 watt metal halide fixtures in the high-bay area to high-output fluorescent T5 fixtures with dimmable ballasts and daylight sensors to reduce energy usage on bright days.
- Replace metal halide and T12 fluorescent lighting fixtures in low-bay area with more efficient T8 or high-output T5 fluorescent fixtures.
- Install occupancy sensors in classrooms and hallways to reduce energy consumption from unnecessary lighting.
- Install photosensors and dimmable ballasts for elevator, lobbies and large south-facing rooms.
- Implement automated power management capabilities of computers to reduce power consumption using sleep/hibernate modes. With 30+ computers in each computer lab, this represents a significant energy savings opportunity.
- Install vending machine energy misers on three vending machines in first floor break room.
- Provide training and signage for lighting and thermostat control, and establish general guidelines and expectations for tenants to reduce energy consumption. Formalize procedure to ensure that security personnel turn off lights when closing the building at night.
- The air handler in 4th floor unfinished space is drawing air into VAV from unconditioned space. This should be ducted to the return plenum.
- Add insulation jacket to electric water heaters, and add timer to turn off recirculation pump on unit between high-bay and low-bay areas.
- Turn off bathroom vent fans after hours, or install occupancy sensors that operate both lights and fans.

A full audit is strongly recommended to provide more detail analysis and recommendations, and a retro commissioning of the HVAC system will likely result in a significant reduction in overall energy consumption.
Lakeside Juvenile Center

A site survey was conducted on December 1, 2011 by Steve O’Rourke and Marc Lopata. Bill Warner of the Missouri Department of Natural Resources attended the visit to observe the process. Nigeria King provided an escort and background on the facility, and Rich Swinger, Director of Treatment Services at the Lakeside Center, provided additional information about the facility’s operations and history. The weather was sunny and cold. While the entire campus operations were considered in the analysis, the primary observations in this report are limited to the main school and administration building on the campus.

Facility Description

The Lakeside Center is located at 13044 Marine Avenue in Maryland Heights. The campus houses a school with administrative offices, a police substation and five residential buildings, totaling over 60,000 ft² of space. The center operates 24 hours a day, 365 days a year, and is staffed by the St. Louis County Special School District, including 70 teachers, administrators and other specialists. The school/administration building, shown in the bottom left of the image below, is open Monday, Tuesday and Friday from 8:00 a.m. to 5:00 p.m., and Wednesday and Thursday until 9:00 p.m.

![Lakeside Center as seen from the east](image courtesy of Bing maps)

The original school building, built in 1955, included classrooms, office space and a gymnasium on the southwest corner of the original structure. A second wing was built in 1974, and a third expansion took place in the late 1980s. Figure 73 on the following page shows the original structure and the additions.
The school building has a largely flat membrane roof with exterior gutters. The gymnasium has a bow truss with a slight (15°) pitch on roof facing slightly southeast. There are a number of roof penetrations, including HVAC equipment and vents. There is no parapet, but the building does have lightning protection. The building has a brick façade, and double-pane windows with no thermal breaks on the newest portion of the building. The windows in the original structure and the 1974 addition are single pane, and very drafty.

The lighting in the building is primarily T12 fluorescent lighting with magnetic ballast in classrooms and offices. The gym has 20 400 watt metal halide lights. The building is heated by a gas boiler, and cooled with an R-22 cooling system. Both systems are in old and good candidates for replacement or upgrades. The CO2 levels inside the building were slightly higher than normal, with 830 ppm inside vs. 525 ppm outside, indicating a need for improved ventilation.

Domestic hot water is heated in two 80 gallon gas-fired tanks. The supply/return pipes appear to be reversed and should be addressed. It was also observed that pressure regulator is bypassed and should be closed. These tanks are supplemented by an additional 40 gallon hot water tank and a 120 gallon tank in the boiler room.
Solar Electric Assessment
This site is a relatively good site for solar. The administration building could benefit from the additional power generated during peak consumption, and has adequate space on the roof to install a modest array. The membrane roof is in relatively good condition, and the structure appears sufficient to support the system.

The gym roof could be used to install a 12 kW array, and additional modules could be installed on a flat roof to create a total of 25 kW of solar power capacity on the roof. The building is approximately 24° off cardinal south, which would only have a minor impact on solar production.
Mounting Options
As illustrated in Figure 74, a portion of the total array could be mounted flush on the pitched roof of the gym. The pitch was estimated at 15°, which would provide slightly better production efficiency than the modules installed at 10° on the flat roof. The image below shows the gym roof in the background, with two different levels of flat roof in the foreground.

![Image of gym roof with pitched and flat sections](image)

Figure 75 Flat roof in foreground, with pitched roof in the background

System Configuration and Building Integration

**Modules**
Given the available roof space, polycrystalline modules might be used to maximize the price/performance balance. The gym roof could support approximately 60 modules, mounted in a contiguous fashion because there would be no shading from adjacent modules. Modules mounted on the flat roof would be installed at 10° tilt in rows with space between to minimize shading.

**Inverters**
Microinverters would simplify installation given the two different tilts used on the pitched vs. flat roof, and minimize the effects of temporary shading from the higher flat roof. Alternatively, separate bulk
inverters could be used for the different arrays to optimize power production for the tilt of each array. This will also enable more detail monitoring of system performance.

**Energy Systems and Distribution**
The Ameren service entrance and meter are on the east exterior wall and the distribution panels are immediately inside this location. The electrical service to the building is 208/120 and the building distribution is 208/120.

- Main Service Disconnect is 1200A
- 208V panel targeted for connection
- Penetrate into electrical room through roof or wall, install new 208V breaker in the 1200A main board, then new 208Y/120VAC distribution panel
- Stage equipment in various storage rooms, including outbuilding and basement area adjacent to boiler room

According to staff, the building can be de-energized to complete the interconnection. That work would be done on the weekend to minimize impact to operations.

**Storage, Staging and Installation**
A 25kW system would require approximately 200 square feet for storage of 8-9 standard pallets, including modules, inverters, racking and ballast. Typically the solar installer will accept delivery of the equipment off site and deliver to the site when the timing is optimal for installation.

A boom truck or small crane will be required to lift the equipment to the roof. The maximum pallet weight for equipment will be approximately 1,500 pounds, although ballast blocks may weight 3,000 per pallet. The lift height should be 20 feet or less, and the boom distance approximately 30 feet or less.

When the pallets are lifted to the roof (whether initially or after a delay), they will have to be placed directly on the structural columns or beams to ensure adequate long-term loading capacity. These locations should be physically confirmed and marked on the roof with spray paint to ensure accurate placement. The goal would be to install within a few days, but that could be delayed by weeks or months under worst-case conditions.

The electrical conduit would run through roof into the maintenance
bay, and connect into a 75 kVA 208V step-down transformer in the electrical room.

When the pallets are lifted to the roof (whether initially or after a delay), they will have to be placed directly on the structural columns or beams to ensure adequate long-term loading capacity. These locations should be physically confirmed and marked to ensure accurate placement. The goal would be to install within a few days, but that could be delayed by weeks or months under worst-case conditions. The heaviest pallet for a system of this size usually is less than 2,000 pounds.

Energy Production
The proposed 25 kW system would produce approximately 30,800 kWh annually, with higher production in the longer days of summer (see bar chart below). The total energy produced over the expected 30 year life of the system is approximately 860,000 kWh, factoring in a typical annual degradation factor of 0.5%. The estimated value of this energy is $150,000.

![Forecasted Energy Production](image)

**Figure 77** Estimated annual energy production for 25 kW system at 10° tilt and 186° azimuth
Financial Analysis
The turnkey cash installation cost for the 25 kW rooftop system using polycrystalline modules is estimated at $155,000 in 2011 dollars. That is calculated based on American-made components (complying with ARRA requirements) and prevailing or union labor rates. This should include design services, installation labor, materials, and equipment, including modules, inverters, and balance-of-system components necessary to comply with the local building code and Ameren interconnection requirements.

The PV system will require annual cleaning and inspection by building management personnel. Annual monitoring and maintenance contracts are available and would cost in the range of $600-700 per year. This is not included in the financial performance evaluation. Insurance is estimated at $600 per year for casualty loss coverage, and this cost is included in the financial performance model.

Applicable Incentives
The financial model to calculate the total value of the incentives includes the utility rebate, which is received within 90 days of the completed installation. Potential income from the sale of SRECs can also be factored in to maximize the payback. The net cost after these incentives are applied is shown below.

<table>
<thead>
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<th>Description</th>
<th>Amount</th>
</tr>
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<td>Utility Rebate</td>
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<td>Sale of SRECs$^{15}</td>
<td>$15,200</td>
</tr>
<tr>
<td>Net Cost After Incentives</td>
<td>$89,800</td>
</tr>
</tbody>
</table>

$^{15}$ This value is an estimate of the sum of the first five annual payments from Ameren’s Standard Offer Contract. Cash flow projections in the financial model include additional SREC income for years 6-10.
Environmental Benefits
The electricity generated by a 25 kW system would result in reduced emissions from the coal-fired power plants that support the Ameren Missouri distribution region. This amounts to a reduction of 28 tons of carbon not polluting the atmosphere each year. This is equivalent to:

- The CO₂ absorbed by 28 acres of dense, hardwood forest (an area about 1.4 times the size of Shaw Park in Clayton), or
- 2,500 gallons of gasoline not burned in automobiles each year.

The lifetime contribution of this system will effectively eliminate 790 tons of CO₂ from the atmosphere.

Implementation Schedule
Installing the solar-PV system would require approximately 10-11 weeks, depending primarily on equipment availability. The permitting task includes the following:

- Electrical permit issued by St Louis County;
- Approval from the Clayton Architectural Review Board;
- Interconnection and Net Metering Agreement from Ameren Missouri. By rulemaking, this is declared to be a 90-day or less interval. Typical approval period is 30-45 days.

Equipment lead times for the project as described above typically are 4-5 weeks, but this could vary significantly depending on project timing and conditions in the global markets. This should be reassessed at the time the project is planned.
**Solar-Thermal Assessment**

The demand for Domestic Hot Water (DHW) is moderate to high and consistent, due to the residential usage of the buildings. Should that usage change, or if it has been mistakenly characterized as being consistent around the calendar year, solar thermal may not be as feasible as it is considered at this time.

The primary challenges relate to the lack of central hot water boiler capabilities combined with the lack of good locations for installation of the collectors. Each building heats water separately, which will make it somewhat difficult to implement solar thermal. Additionally, only one of the five residential buildings has a south-facing roof, so the installations would have to be either ground-mounted or installed at a high and difficult angle on the roof. Building G (as seen in Figure 72 on page 112) is the only building that has a portion of roof that is well-oriented for solar.

The school and administration buildings are not good candidates for solar thermal, given the limited use of hot water in the facility.

**Mounting Options**

The recommended solar collectors would be the flat-plate configuration, 10’ tall and 4’ wide. They are mounted on racks at an angle of 45° to horizontal. One standard rack holds eight collectors, for a total of 320 ft² of collector area.

Because of their high wind resistance, the racks and collectors are required to be mechanically fastened to the roof structure. However, the mounting systems are fully compatible with roof warranties and when installed correctly, pose a negligible risk of roof leakage.

Based on the roof configuration, a good option might be to attach the collector racking to the roof wall that runs across the building. That wall will provide a wind break and an elevated connection point for the racking. This would decrease the installation cost and difficulty.

**Potential Energy Production**

The optimal application is to size the system to produce approximately 1/3 of the hot water demand for the facility. This will ensure the solar thermal system is never producing too much energy or possibly going into a “stagnation” condition where the system is potentially overheating. When the sun is shining and the solar thermal system is transferring that energy to the DHW system, the existing DHW system will use significantly less natural gas. When the sun is not shining, the DHW system is already sized for peak demand, so there is no adverse impact to the solar thermal implementation.

Typical system sizing and costing for the St Louis area is as follows. These estimates are scalable.

- Standard rack is 8 collectors / 320 ft²
- Heats 600 gallons per day
- Annual system output of 33,000 kWh
- Assumes 80% efficiency of existing gas water heater
- Installed cost, including heat exchangers is $50,000.
Building Interconnection
The solar thermal piping would transition from the roof to the mechanical room where the existing water heater is located. A dedicated heat exchanger would be installed adjacent to the water heater, along with a supplemental storage tank.

Environmental Benefits
The energy generated by an 8-collector rack would offset 56,000 lbs. of CO₂ emissions annually, or 790 tons over the lifetime of the system. This is equivalent to:

- The CO₂ absorbed by 28 acres of dense, hardwood forest (an area 1.4 times the size of Shaw Park in Clayton), or
- 2,500 gallons of gasoline not burned in automobiles each year.

Financial Analysis
The financial performance of the solar thermal system is significantly improved by the Federal tax benefits and incentives. Specifically, were the system owned by a for-profit entity, a 30% credit or grant could be secured to offset the cost of the complete system installation. For a typical system with 16 collectors, and financed internally with a 4% cost of capital, the performance would look as shown in the graph below.

The financial performance is as follows:
- Internal Rate of Return (IRR) of 76%
- Payback period of 1 year
- Net Present Value of $51,919.
**Geothermal Assessment**
There is good potential for geothermal on the Lakeside Center campus. There is plenty of open ground available to drill wells to provide campus-wide heating and cooling. This would afford an opportunity for the HVAC equipment in the school/admin building to be replaced for more efficient heating and cooling. Given the number of buildings and diverse hourly loading, a campus approach may make sense for this property.

**HVAC Coordination**
Ground source would require the complete replacement of the HVAC system for each building where it is used. The air-side ducts can be re-used, provided they are sized correctly and not oversized (a common problem with design-build mechanical contractors).

**First Cost and Operating Cost Expectations**
The well-field installation capacities and cost are as follows:

- Well field area ~ 50 ft²/ton
- Each 200’ well has a 1 ton capacity.
- Estimated 12 wells, based on utilizing current sizing.
- Bids should range from $75-90,000 depending on COP and other performance factors chosen.
- Federal tax credit (or Treasury Grant) of 10%, and accelerated depreciation available to taxable entities.
- Recommend upgrading controls at the time of installation
- Operating cost reduction should be 30-50%. Estimated payback of 5-6 years (without capturing federal incentives)
- Maintenance costs are typically the same or lower than standard system costs.
Energy Efficiency
During the site visit, a number of observations were made regarding the energy performance of the building.

- Replace the 400 watt metal halide lights in gym with high-output fluorescent T5 fixtures with dimmable ballasts and daylight sensors to lower artificial lighting requirements during the daytime.
- Install occupancy sensors in restrooms where lights always on. Occupancy sensors could be installed in a number of other rooms to automatically shut lights off when the room is not in use.
- Install bi-level switching on lights in classrooms, as it is now always necessary to have them on full power.
- Replace incandescent exit signs with more efficient LED fixtures.
- Create schedule for heating and cooling that fits with the building’s operational schedule. It was observed that the programmable thermostat was set to hold the temperature at 75°F rather than let the building cool down in the evening and warm back up in time for operations in the morning.
- Thermostats should be installed away from doors and windows to a place where ambient temperatures don’t skew temperature readings.
- Get rid of R-22 cooling system and upgrade to VAV if geothermal is not implemented.
- Heating is boiler – old – replace w/ high efficiency, install VFD
- Investigate the supply/return pipes and bypassed pressure regulator to improve performance of water heating, and add timer to recirculation pump to reduce energy consumption.

A full audit is strongly recommended to provide more detail analysis and recommendations. If there is no desire or capacity to further explore the geothermal option, a retro commissioning of the HVAC system will likely result in a significant reduction in overall energy consumption.
Police & Fire Training Academy
A site survey was conducted on November 17, 2010 by Steve O’Rourke and Marc Lopata. Ron Pflueger provided an escort and background on the building. Kevin Lawson, director of the academy and Dave Schmalzer, chief instructor for the St. Louis County Fire Academy, provided additional information about the building operations. The weather was cool and partly cloudy. This section documents the specific findings and recommendations based on that visit and subsequent analysis.

Facility Description
The Police & Fire Training Academy is a 41,000+ ft² facility located at 1266 Sutter in St. Louis. The building was built in 1988, and is used to train police and fire department staff in both classroom and field exercises. The building is staffed by approximately 15 full-time employees, and is used by an average of 200 trainees each week. Normal hours of operation are from 8:00 a.m. to 4:30 p.m. Monday through Friday.

Figure 79 View of the front of training academy from the west (image courtesy of Bing maps)

The building includes office space, classrooms, and a gymnasium on the far east side of the facility. A portion of the building has two levels, with locker rooms on the lower level adjacent to the gym.
The building has a built-up roof with a coating that is in fair condition; the age is unknown. The walls are constructed of concrete block with double-pane windows.

The facility has a Johnson Controls building management system, but no documented operating procedures. The original HVAC system, now 22 years old, is still in use, and is somewhat disjointed in its design. An electric baseboard heating system was added to the classrooms to supplement the existing system, but there was a general lack of knowledge about the system and how to control it.

The building's hot water supply is heated with natural gas, with insulated pipes. The system has recirculation pumps running 24/7, but the pumps not configured well, as it takes ~20 seconds for hot water to reach the shower and 10 seconds to reach sinks. The return pipe only ½", and may be too small.

The classrooms and locker rooms are lit by T12 fluorescent fixtures with manual controls. The lighting level in the computer room was high, given that students are looking at illuminated displays. The garage and gymnasium are lit with 400W metal halide fixtures.

Figure 80 Typical classroom in training center
Solar Electric Assessment
This site is a relatively good site for solar. There is abundant space on the rooftop to support a 25 kW array. Rooftop-mounted HVAC equipment provides the only unnatural shade on the building. The building is well-oriented, only a few degrees (5°) off due south.

The building has a number of visitors, with police and firefighters from all over St. Louis County making occasional use of the building. This would provide educational opportunities for trainees, but would provide limited exposure to the general public. However, the energy production would coincide well with peak energy demand in the building.

The image below shows the ideal location for a 25 kW array to avoid shade from rooftop equipment.

![Figure 81 Blue shaded area is proposed location for 25 kW array (image courtesy of Google maps)](image)

Mounting Options
The building’s roof appears adequate to support the weight of a ballasted array. The modules would be installed in south-facing rows at a 10° tilt with spacing between each row to eliminate or minimize shading from adjacent modules. Figure 82 shows a different perspective on the rooftop and equipment.
Figure 82 View of roof from the southeast shows rooftop equipment and potential for shading

System Configuration and Building Integration

**Modules**
Given the available roof space, polycrystalline modules are recommended to maximize the price/performance balance. The designated area on the roof could support approximately 110-120 modules, depending on the size.

**Inverters**
Microinverters would simplify installation and minimize any production losses from temporary shading of rooftop equipment. Alternatively, bulk inverters may be less expensive to replace and maintain.

**Energy Systems and Distribution**
The Ameren service entrance and meter are on the east exterior wall and the distribution panels are immediately inside this location. The electrical service to the building is and the building distribution were not documented.

According to staff, the building can be de-energized to complete the interconnection. That work would be done on the weekend to minimize impact to operations.
Storage, Staging and Installation
A 25kW system would require approximately 200 square feet for storage of 6-8 standard pallets, including modules, inverters, racking and ballast. Typically the solar installer will accept delivery of the equipment off site and deliver to the site when the timing is optimal for installation.

A crane will be required to get the equipment up to the roof. The maximum pallet weight for equipment will be approximately 1,500 pounds, although ballast blocks may weight 3,000 per pallet. The lift height is not excessive – about 30 feet. However, the boom distance from the west parking lot is approximately 40-50 feet. This will require a moderately sized crane.

When the pallets are lifted to the roof (whether initially or after a delay), they will have to be placed directly on the structural columns or beams to ensure adequate long-term loading capacity. These locations should be physically confirmed and marked on the roof with spray paint to ensure accurate placement. The goal would be to install within a few days, but that could be delayed by weeks or months under worst-case conditions.

The electrical conduit would run through roof into the maintenance bay, and connect into a 75 kVA 208V step-down transformer in the electrical room.

When the pallets are lifted to the roof (whether initially or after a delay), they will have to be placed directly on the structural columns or beams to ensure adequate long-term loading capacity. These locations should be physically confirmed and marked to ensure accurate placement. The goal would be to install within a few days, but that could be delayed by weeks or months under worst-case conditions. The heaviest pallet for a system of this size usually is less than 2,000 pounds.
Energy Production
The proposed 25 kW system would produce approximately 30,800 kWh annually, with higher production in the longer days of summer (see bar chart below). The total energy produced over the expected 30 year life of the system is approximately 860,000 kWh, factoring in a typical annual degradation factor of 0.5%. The estimated value of this energy is $150,000.

Figure 83 Estimated annual energy production for 25 kW system at 10° tilt and 185° azimuth
Financial Analysis
The turnkey cash installation cost for the 25 kW rooftop system using polycrystalline modules is estimated at $155,000 in 2011 dollars. That is calculated based on American-made components (complying with ARRA requirements) and prevailing or union labor rates. This should include design services, installation labor, materials, and equipment, including modules, inverters, and balance-of-system components necessary to comply with the local building code and Ameren interconnection requirements.

The PV system will require annual cleaning and inspection by building management personnel. Annual monitoring and maintenance contracts are available and would cost in the range of $600-700 per year. This is not included in the financial performance evaluation. Insurance is estimated at $600 per year for casualty loss coverage, and this cost is included in the financial performance model.

Applicable Incentives
The financial model to calculate the total value of the incentives includes the utility rebate, which is received within 90 days of the completed installation. Potential income from the sale of SRECs can also be factored in to maximize the payback. The net cost after these incentives are applied is shown below.

- $155,000 Initial Installed Cost
- $50,000 Utility Rebate
- $15,200 Sale of SRECs\(^{16}\)
- $89,800 Net Cost After Incentives

\(^{16}\) This value is an estimate of the sum of the first five annual payments from Ameren’s Standard Offer Contract. Cash flow projections in the financial model include additional SREC income for years 6-10.
**Environmental Benefits**

The electricity generated by a 25 kW system would result in reduced emissions from the coal-fired power plants that support the Ameren Missouri distribution region. This amounts to a reduction of 28 tons of carbon not polluting the atmosphere each year. This is equivalent to:

- The CO₂ absorbed by 28 acres of dense, hardwood forest (an area about 1.4 times the size of Shaw Park in Clayton), or
- 2,500 gallons of gasoline not burned in automobiles each year.

The lifetime contribution of this system will effectively eliminate 790 tons of CO₂ from the atmosphere.

**Implementation Schedule**

Installing the solar-PV system would require approximately 10-11 weeks, depending primarily on equipment availability. The permitting task includes the following:

- Electrical permit issued by St Louis County;
- Approval from the Clayton Architectural Review Board;
- Interconnection and Net Metering Agreement from Ameren Missouri. By rulemaking, this is declared to be a 90-day or less interval. Typical approval period is 30-45 days.

![Figure 84 Typical Implementation Schedule](image_url)

Equipment lead times for the project as described above typically are 4-5 weeks, but this could vary significantly depending on project timing and conditions in the global markets. This should be reassessed at the time the project is planned.
Solar-Thermal Assessment
The demand for hot water in this facility is marginal. While showers do require a heavier load for hot water, the fact that the operation is limited to weekdays will not provide a very attractive payback.

Geothermal Assessment
As noted earlier in the Facility Description portion of this section, the majority of the HVAC system, including heating and cooling units, is original equipment and could be replaced with much more efficient equipment. The currently disjointed systems could be consolidated to take advantage of a central ground-source heat pump system.

It should be noted that, while there is potential here, this building is not an ideal facility. The occupancy of the building is largely limited to business hours during the week, so the building does not need to be heated overnight or on weekends. There is plenty of ground available to drill wells, though it is unknown if there are any restrictions on soil disturbance. The primary drawback is the many rooftop HVAC units – ground source would require that these be replaced with a central plant. Retrofitting the refrigerant side with a chilled- and hot-water loop would be cost prohibitive.
Energy Efficiency
During the site visit, a number of observations were made regarding the energy performance of the building.

- Replace the 400 watt metal halide lights in gym and garage with high-output fluorescent T5 fixtures with dimmable ballasts and daylight sensors to lower artificial lighting requirements during the daytime.
- Install occupancy sensors in restrooms where lights always on. Occupancy sensors could be installed in a number of other rooms to automatically shut lights off when the room is not in use.
- Install bi-level switching on lights in classrooms, as it is now always necessary to have them on full power.
- Implement automated power management capabilities of computers to reduce power consumption using sleep/hibernate modes. With 30+ computers in each computer lab, this represents a significant energy savings opportunity.
- Create schedule for heating and cooling that fits with the building’s operational schedule.
- Install timer on hot water recirculation pump.

A full audit is strongly recommended to provide more detail analysis and recommendations. If there is no desire or capacity to further explore the geothermal option, a retro commissioning of the HVAC system will likely result in a significant reduction in overall energy consumption.
Administration Building
A site survey was conducted on September 22, 2010 by Steve O’Rourke and Marc Lopata. The facility manager, Jim Koch, provided an escort and information about the building. This section documents the specific findings and recommendations based on that visit and subsequent analysis.

Facility Description
The St. Louis County Administration Building is a 178,000 ft² facility located in the heart of downtown Clayton on 41 S. Central. The nine-story building was originally built in 1968, and houses a number of county agencies. The County Executive offices are located on the ninth floor.

Figure 86 View of the Administration Building from the east (Image courtesy of Bing Maps)
The building forms a hub for the neighboring Police Headquarters to the north, the Courts Building to the south, and the Justice Center is just west of the Courts Building. The electricity for all four buildings is supplied through the Admin Building. The building also serves as a distribution source for gas for the Courts and Police HQ. The Justice Center has its own gas meter.

Figure 87 Clayton County Seat Complex

The building serves as office space for approximately 750 employees, with operating hours from 7:30 to 5:30 Monday through Friday. Only a sampling of floors were visited given the similar characteristics of each floor.

The brick building has a flat roof that is divided into three sections. The center section above the ninth floor holds two large cooling towers. The southern section contains a penthouse that houses the elevator equipment, and is surrounded by additional equipment on the roof. The north section also
contains additional equipment. The built-up roof is over 20 years of age, and the condition of the roof is below average. The roof has a 30” parapet with lightning protection installed.

Nine stories of the building are dedicated to office space, with a basement and top level containing HVAC equipment. It was reported that approximately 80 percent of the lighting in the building is T12 fluorescent lamps with magnetic ballasts, and that all floors above street level have asbestos above lamps where the ballasts are. As a result, a lighting upgrade will require special handling. Spaces with access to exterior windows have ample daylight, depending on the time of day.

Lighting controls in the building are limited. The facility utilizes a MetaSys building management system which is programmed to turn lights on at 6:00 a.m. on weekdays until 10:00 p.m. Observed lighting levels in offices were relatively high at 60-65 FC, compared to 25 FC in hallways.

The HVAC system is a central-plant configuration consisting of the following equipment:

- Two 750 ton chillers, installed in 2003
- Three rooftop cooling towers
- Two hot water boilers, being replaced in 2011.

The system is configured for air-side and water-side economizing. The air-side configuration is Variable Air Volume (VAV) with hot-water reheat. The makeup water for the cooling towers is separately metered, which is a good management measure to reduce water and sewage disposal costs.

The Domestic Hot Water (DHW) system also is a central boiler. This boiler supplies hot water to the Administrative Building, the Courts Building, and the County Police Headquarters building. There is no metering on this system. As a result, it is impossible to know the water usage for any one building in the complex. There are recirculating and boost pumps for each building in the complex.
Solar Electric Assessment
This building is not a good candidate for solar-electric PV system installation. The center section of the roof is roof is largely occupied by the cooling towers, and is heavily shaded by the southern section of the roof because of its lower height. The northern section of the roof has very limited capacity as a result of the distribution of the mechanical equipment.

In addition, there is no vacant land suitable for a ground-mounted array. The large grass circle west of the building is designated for another purpose, and is largely shaded by the building in the morning. The multitude of trees planted throughout the park-like setting also reduce the value of the ground for solar.

Solar Thermal
The demand for hot water in this facility alone does not warrant the use of solar thermal for water heating. The best applications for solar thermal are a high demand for hot water every day of the year for a significant portion of the day. While hot water is distributed throughout the complex for both heating and domestic hot water, potable water use is limited to hand washing in restrooms and light kitchen use. In addition, the operational hours are limited to 45 hours per week.

However, since the DHW central boiler in this building also serves the Courts building and the County Police Headquarters, it is possible that a central or distributed solar-thermal system could be beneficial for the system taken as a whole. The most feasible place to put such a plant would be the roof of the County Police Headquarters, since it has the fewest number of floors and would result in the shortest pipe runs. This is discussed further in the following sections addressing the County Police Headquarters.

A thorough hot water demand study would be required to ascertain whether there is sufficient consistent demand to warrant this system – again focusing on the desire for consistent demand every day of the week and the year. Ideally a level could be defined where the solar thermal system could be fully utilized among the usage in the three buildings.

Ground Source Heating and Cooling
The building is not a candidate for a geothermal HVAC system. The size of the building would require significantly more space for wells than is available.
Energy Efficiency
During the site visit, a number of observations were made regarding the energy performance of the building.

- The primary lighting in the office space consists of T12 fluorescent fixtures with magnetic ballasts. Unfortunately, there is asbestos above the lighting on all but the street level, which would likely need to be mitigated as part of the lighting upgrade.
- Many of the rooms are over-lighted, and do not take daylight into consideration. Dimmable ballasts with daylight sensors could reduce lighting loads, and occupancy sensors could further reduce energy use.
- A Metasys Building Automation System is used to control the lighting, with lights scheduled to be on from 6:00 a.m. until 10 p.m. We recommend turning off lights earlier, and enable cleaning crew and staff to override the schedule as needed.
- A number of conference rooms and offices do not have lighting controls, so the lights cannot be turned off except by the Metasys building automation system. Switches or occupancy sensors would save energy here.
- Incandescent bulbs in elevator are very inefficient and create excess heat which requires additional cooling in summer season

A full audit would provide more detail analysis and recommendations, and a retro commissioning of the HVAC system will reduce energy consumption.
Police Headquarters
A site survey was conducted on September 22, 2010 by Steve O’Rourke and Marc Lopata. Ernie Zimmerman provided an escort and information about the building. This section documents the specific findings and recommendations based on that visit and subsequent analysis.

Facility Description
The St. Louis Police Headquarters is a 150,000 ft$^2$ facility located on the southwest corner of Forsyth Boulevard and South Central Avenue. The five-story building was built in 1950, and consists primarily of office space. There are about 300 employees in the building.

![Police Headquarters](image)

Figure 89 Police Headquarters as seen from the east *(image courtesy of Bing maps)*

The brick building has a built-up roof that has been replaced in sections at different times. Overall it is in good condition. There is a 48” parapet on the building, which also has lightning protection installed.
Solar Electric Assessment
As seen in Figure 89 and Figure 87 on page 135, this building sits in the shadow of the neighboring Administration Building, and therefore has limited space available for solar, particularly during the times of the year when the sun is lower in the sky. The building’s penthouse casts an additional shadow on a portion of the roof. The roof could potentially house a small solar PV array, but the limited space on the western portion of the roof might be more effectively used for solar water heating.

Solar Thermal
As noted earlier, this building gets its hot water from the Administration Building central plant. The demand for hot water in this facility is limited to restroom and light kitchen use, although the load is significant given the size of the buildings. However, the hours of operation are limited and the building is not normally occupied on weekends.

This building in and of itself is probably not a good candidate for solar hot water. But combined into a “campus” approach with the Admin and Courts buildings, as noted in the previous section, there could be a very efficient and effective application possible. There is no water metering in any of the buildings, so designing a solar thermal system would require either comprehensive estimates or the installation of building-specific water meters in the distribution lines going between the buildings.

There is a wiring and pipe chase that could be used for conduit from the basement electrical room to the roof. That goes from the C-Level to the basement. The building is fairly old, and installation could be difficult, which would increase the installation cost.

Mounting Options
A solar-thermal array could be installed against the north parapet wall on the roof. Depending on the time-of-day demand for hot water, it should be possible to place the collectors in such a way that they receive abundant solar irradiation during the hours when the energy can be effectively managed and used. For instance, if the demand was during the morning, the collectors could be on the east end of the wall to receive morning sun, and vice versa for afternoon demand and solar access.

The collectors as recommended for the Justice Center would be the flat-plate configuration, 10’ tall and 4’ wide. They are mounted on racks at an angle of 45° to horizontal. One standard rack holds eight of the collectors, for a total of 320 ft² of collector area.

At a 45° angle, the collectors stand about 7 feet above the mounting surface. Since the parapet wall is 4 feet tall, the collectors would extend about 3 feet above the parapet. If that is visually undesirable, the collectors could be mounted on the south side of the penthouse wall. This would introduce additional shading, but would render them not visible from the street.

Because of their high wind resistance, the racks and collectors are required to be mechanically fastened to the roof structure. However, the mounting systems are fully compatible with roof warranties and when installed correctly, pose a negligible risk of roof leakage.
Potential Energy Production
The energy generation from the solar thermal collectors would be tailored to the demand on the three-building campus. Estimation is not possible without detailed usage data.

Building Interconnection
The connection to the building hot-water loop would be done in the basement mechanical room. There already is a complex network of water piping there that conveys hot water from the Admin building into the police building. The return line (back to Admin) could be tapped in this space to move the heated water back to the central storage tank. This would require the installation of a new heat exchanger in the mechanical room, probably a plate-and-frame with a footprint of 4’x4’. Exact dimensions could be determined through a detailed design study for this concept.

Ground Source Heating and Cooling
The building is not a candidate for a geothermal HVAC system. The size of the building would require significantly more space for wells than is available.

Figure 90 Police Headquarters building as seen from the Administration Building roof. Solar collectors could be mounted on the western portion of the roof seen on the left portion of the image.
Energy Efficiency
During the site visit, a number of observations were made regarding the energy performance of the building.

- We recommend replacing the remaining T12 fluorescent fixtures with more efficient T8 lamps with electronic ballasts. Financial incentives to do this will no longer be available after this year, so there is limited time to act.
- Add insulation to hot water pipes near pump.
- Upgrade incandescent exit signs with LED fixtures.
- Install occupancy sensors to automatically turn off lights in unoccupied spaces.

A full audit will provide more detail analysis and recommendations, and a retro commissioning of the HVAC system will reduce energy consumption.
Courts Building
A site survey was conducted on September 22, 2010 by Steve O’Rourke and Marc Lopata. Charlie Morgan and Ernie Zimmerman provided an escort and information about the building. This section documents the specific findings and recommendations based on that visit and subsequent analysis.

Facility Description
The St. Louis Police Headquarters is a 244,000 ft$^2$ facility located at 7900 Carondelet, between South Central and South Meramec Avenues north of Bonhomme Avenue. The building was built in 1972, and consists primarily of office and courtroom space. There are approximately 450 employees that work in the building.

The six-story brick and concrete building has a parking garage located on the south side of the building. The membrane roof is in relatively good condition. The building has lightning protection, and has an 18” parapet.
Solar Electric Assessment
This is a great site for solar. There is abundant shade-free south-facing roof space, with nearly 10,000 ft\(^2\) of usable space to install a relatively large solar array.

The building is well-oriented, approximately 6° off cardinal south. There is open access to the roof, but the 18” parapet does not provide adequate height to provide a safe space for visitors. However, the energy production would coincide well with peak energy demand in the building.

The image below could support up to a 60 kW array. However, given the current cap on available financial incentives, a 25 kW array might be a more cost-effective start.

Figure 92 Blue shaded area is proposed location for 60 kW array (image courtesy of Google maps)

Mounting Options
The building’s roof appears adequate to support the weight of a ballasted array. The modules would be installed in south-facing rows at a 10° tilt with spacing between each row to eliminate or minimize shading from adjacent modules. Figure 93 shows a different perspective on the rooftop.
System Configuration and Building Integration

**Modules**
Given the available roof space, polycrystalline modules are recommended to maximize the price/performance balance. The designated area on the roof could support approximately 400 modules, depending on the size.

**Inverters**
Microinverters would simplify installation and minimize any production losses from temporary shading of rooftop equipment. Alternatively, bulk inverters may be less expensive to replace and maintain.

**Energy Systems and Distribution**
The Ameren service entrance and meter are on the east exterior wall and the distribution panels are immediately inside this location. The electrical service to the building is and the building distribution is

According to staff, the building can be de-energized to complete the interconnection. That work would be done on the weekend to minimize impact to operations.
Storage, Staging and Installation
A 25kW system would require approximately 200 square feet for storage of 6-8 standard pallets, including modules, inverters, racking and ballast. Typically the solar installer will accept delivery of the equipment off site and deliver to the site when the timing is optimal for installation. A crane will be required to lift the equipment to the roof.

The electrical conduit would run through roof into the maintenance bay, and connect into a 75 kVA 208V step-down transformer in the electrical room.

When the pallets are lifted to the roof (whether initially or after a delay), they will have to be placed directly on the structural columns or beams to ensure adequate long-term loading capacity. These locations should be physically confirmed and marked to ensure accurate placement. The goal would be to install within a few days, but that could be delayed by weeks or months under worst-case conditions. The heaviest pallet for a system of this size usually is less than 2,000 pounds.
Energy Production
The proposed 25 kW system would produce approximately 30,800 kWh annually, with higher production in the longer days of summer (see bar chart below). The total energy produced over the expected 30 year life of the system is approximately 860,000 kWh, factoring in a typical annual degradation factor of 0.5%. The estimated value of this energy is $150,000.

![Forecasted Energy Production](image)

*Figure 94 Estimated annual energy production for 25 kW system at 10° tilt and 184° azimuth*
Financial Analysis
The turnkey cash installation cost for the 25 kW rooftop system using polycrystalline modules is estimated at $170,000 in 2011 dollars. That is calculated based on American-made components (complying with ARRA requirements) and prevailing or union labor rates. This should include design services, installation labor, materials, and equipment, including modules, inverters, and balance-of-system components necessary to comply with the local building code and Ameren interconnection requirements.

The PV system will require annual cleaning and inspection by building management personnel. Annual monitoring and maintenance contracts are available and would cost in the range of $600-700 per year. This is not included in the financial performance evaluation. Insurance is estimated at $600 per year for casualty loss coverage, and this cost is included in the financial performance model.

Applicable Incentives
The financial model to calculate the total value of the incentives includes the utility rebate, which is received within 90 days of the completed installation. Potential income from the sale of SRECs can also be factored in to maximize the payback. The net cost after these incentives are applied is shown below.

<table>
<thead>
<tr>
<th>Amount</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$170,000</td>
<td>Initial Installed Cost</td>
</tr>
<tr>
<td>$ 50,000</td>
<td>Utility Rebate</td>
</tr>
<tr>
<td>$ 15,200</td>
<td>Sale of SRECs(^\text{17})</td>
</tr>
<tr>
<td>$ 104,800</td>
<td><strong>Net Cost After Incentives</strong></td>
</tr>
</tbody>
</table>

\(^{17}\) This value is an estimate of the sum of the first five annual payments from Ameren’s Standard Offer Contract. Cash flow projections in the financial model include additional SREC income for years 6-10.
Environmental Benefits
The electricity generated by a 25 kW system would result in reduced emissions from the coal-fired power plants that support the Ameren Missouri distribution region. This amounts to a reduction of 28 tons of carbon not polluting the atmosphere each year. This is equivalent to:

- The CO₂ absorbed by 28 acres of dense, hardwood forest (an area about 1.4 times the size of Shaw Park in Clayton), or
- 2,500 gallons of gasoline not burned in automobiles each year.

The lifetime contribution of this system will effectively eliminate 790 tons of CO₂ from the atmosphere.

Implementation Schedule
Installing the solar-PV system would require approximately 10-11 weeks, depending primarily on equipment availability. The permitting task includes the following:

- Electrical permit issued by St Louis County;
- Approval from the Clayton Architectural Review Board;
- Interconnection and Net Metering Agreement from Ameren Missouri. By rulemaking, this is declared to be a 90-day or less interval. Typical approval period is 30-45 days.

Equipment lead times for the project as described above typically are 4-5 weeks, but this could vary significantly depending on project timing and conditions in the global markets. This should be reassessed at the time the project is planned.
Solar-Thermal Assessment
Hot water is supplied by centralized equipment in the Administration building. Solar thermal for the complex would be best located on the Police Headquarters roof.

Geothermal Assessment
The building is not a candidate for a geothermal HVAC system. The size of the building and nature of the shared heating and cooling on the campus makes this impractical to consider for ground source heating & cooling.
Energy Efficiency
During the site visit, a number of observations were made regarding the energy performance of the building.

- We recommend replacing the T12 fluorescent fixtures with more efficient T8 lamps with electronic ballasts. Financial incentives to do this will no longer be available after this year, so there is limited time to act.
- Install occupancy sensors to automatically turn off lights in unoccupied spaces.
- There are 15-20 vending machines in the building that could be retrofitted with energy misers to reduce the energy consumption.

A full audit will provide more detail analysis and recommendations, and a retro commissioning of the HVAC system will reduce energy consumption.
Justice Center
A site survey was conducted on September 14, 2010 by Steve O’Rourke and Marc Lopata. George Carroll provided an escort and background on the building. The sky was clear and the weather was mild. This section documents the specific findings and recommendations based on that visit and subsequent analysis.

Facility Description
The Buzz Westfall Justice Center is a 522,000 ft² facility located in downtown Clayton at the corner of Carondelet and South Central Avenue. The facility was built in 1998 and is used to house inmates of the St. Louis County correctional system.

The center employs a staff of approximately 350 full-time employees, providing supervision and support services to over 1,000 incarcerated individuals. Given the nature of the facility, it runs 365 days a year, 24 hours a day.

The building has eight floors plus one subfloor. The basement houses the kitchen, laundry, fingerprint operation and storage. The ground floor primarily consists of the lobby and visiting area, plus specialized use space. The second floor is exclusively office space. The third level includes office space,

Figure 96 View of the Justice Center from the north (Image courtesy of Bing Maps)
an infirmary, and courtrooms. Levels 4-7 are dedicated to inmate housing and recreation, and the eighth floor holds maximum security housing and a staff dining room. The top floor is dedicated to building maintenance, including HVAC equipment and other infrastructure. The building has a complex architecture, with angled roof lines at two levels. The primary roof above the ninth floor is a large, flat space that houses the facility's cooling towers behind a screen. The two wings each contain about of 7500 ft² of relatively unshaded space with few roof obstructions. The parapet around the building is approximately 12” in height, and has lightning protection. The roofing material is a white membrane that has good drainage.

Additional information about the building is documented in the Energy Efficiency section on page 157.

**Solar Electric Assessment**
The two primary sections of roof have great southern exposure with limited shade from the commercial office building directly to the south. There is no vacant land that could be developed that might result in shading of the areas of the site identified for system installation.

The building’s electric demand is very high, and the solar electric system would offset a small fraction of the overall electric consumption. The limited roof space would be better suited for solar thermal.

**Solar-Thermal Assessment**
The demand for hot water in this facility is high, with kitchen, laundry and regular use of hot water by inmates for showers. But more importantly, the demand is consistent with very little variability with seasons or days of the week.

This consistency makes the Justice Center an ideal candidate for solar thermal water heating. This will deliver a continuous supply of low-grade heat in the range of 120°F to 160°F, which is well suited for domestic end uses – sanitation, bathing, cooking, dishwashing, etc. Some uses may require water hotter than that range, such as dishwashing; in those cases, a boost heater should be used. ¹⁸

**Mounting Options**
The solar collectors would be the flat-plate configuration, 10’ tall and 4’ wide. They are mounted on racks at an angle of 45° to horizontal. One standard rack holds eight collectors, for a total of 320 ft² of collector area.

Because of their high wind resistance, the racks and collectors are required to be mechanically fastened to the roof structure. However, the mounting systems are fully compatible with roof warranties and when installed correctly, pose a negligible risk of roof leakage.

**Potential Energy Production**
The optimal application is to size the system to produce approximately 1/3 of the hot water demand for the facility. This will ensure the system is never producing too much energy or possibly going into a

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¹⁸ A boost heater should be used for dishwashing whether or not solar thermal is employed at this facility. Dishwashing requires much hotter water than all other domestic uses, and keeping the entire DHW system hot enough for dish washing ends up wasting a lot of energy that isn’t needed for other building processes.
“stagnation” condition where the system is potentially overheating. When the sun is shining and the solar thermal system is transferring that energy to the DHW system, the existing DHW system will use significantly less natural gas. When the sun is not shining, the DHW system is already sized for peak demand, so there is no adverse impact to the solar thermal system.

Again, the system will need to be appropriately sized, but the estimates below are scalable.

- Standard rack is 8 collectors / 320 ft²
- Heats 600 gallons per day
- Annual system output of 33,000 kWh
- Assumes 80% efficiency of existing gas water heater
- Installed cost, including heat exchangers is $50,000.

**Building Interconnection**

The piping would transition from the roof to the mechanical floor through a roof penetration and “doghouse” fixture. A dedicated heat exchanger would be installed adjacent to the DHW boilers, and additional tap piping connected to the existing boiler and the heat exchanger.

**Environmental Benefits**

The energy generated by each 8-collector rack would offset 56,000 lbs. of CO₂ emissions annually, or 790 tons over the lifetime of the system. This is equivalent to:

- The CO₂ absorbed by 28 acres of dense, hardwood forest (an area 1.4 times the size of Shaw Park in Clayton), or
- 2,500 gallons of gasoline not burned in automobiles each year.

**Financial Analysis**

The financial performance of the solar thermal system is significantly improved by the federal tax benefits and incentives. Specifically, were the system owned by a for-profit entity, a 30% credit or grant could be secured to offset the cost of the complete system installation. For a 16 collector system, financed internally with a 4% cost of capital, the performance would look as shown in Figure 97.
The financial performance is as follows:

- **Internal Rate of Return (IRR)** of 76%
- **Payback period** of 1 year
- **Net Present Value** of $51,919.

Purchasing the solar thermal system without the federal incentives yields a cash-flow curve similar to as shown in Figure 98.
Geothermal Assessment
Given the age and demand for heating and cooling, this building is not a good candidate for a geothermal HVAC system.

Energy Efficiency
During the site visit, a number of observations were made regarding the energy performance of the building.

- The lobby is lit 24x7 by incandescent can lights. There were no automatic lighting controls for support areas. Emergency lights are on 24/7 and generate 50-80 foot candles (FC) of light. There were over 120 FC near windows. Recommend installing LED lamps in all 24x7 areas, including lobby, stairwells, exit lights, and secure areas, and de-lamp in areas that have higher illumination levels than IESNA standards.

- All of the air handling units (AHUs) are supplied with 100% outside air. The outside air comes from the roof where there is an Energy Recovery Unit (ERU) with an enthalpy wheel system to pre-condition the makeup air. However, due to the maintenance requirements, the ERU was decommissioned several years ago and is not being used. Recommend re-activating or replacing the rooftop ERU. The building presumably was designed to function optimally with the ERU operational, and not using it is probably impairing the performance of the building. Technology has improved significantly since the building was constructed, and modern ERUs perform better and require less maintenance. Even if the building functions acceptably without the ERU, given it is using 100% outside air, the ERU would provide a significant energy benefit. In fact, contemporary energy codes require ERUs for buildings like this.

- The building system is a 4-pipe HVAC system with chillers and hot-water boilers. The loop temperature is set twice a year. Recommend resetting the chiller CHW and boiler HW loop temperature based on outside air temperature, and not just seasonal adjustment. The daily temperature fluctuations make it inefficient to change the set point only twice a year. The controls will allow set-point change on a daily basis.

- Space heating is accomplished using a dedicated two-pipe hot-water system with 3 x 250HP dual-fuel steam boilers. One is required at all times, every day of the year, and they are configured in lead/lag mode. Even during the hottest summer months, one of these 250HP boilers runs continuously for space conditioning and dehumidification – specifically VAV reheat for the interior spaces (not adjoining exterior walls). Controls and ventilation should be
optimized so that the summer reheat isn’t required as much. Re-activation of the ERU will help solve this problem. Also refer to the recommendation for DHW, below.

- Domestic Hot Water (DHW) is provided by three combined-fuel boilers, which can run on either natural gas or diesel fuel. There is a recirculating pump that drives the building recirculation loop. There is no timer or control on that pump; it is recommended to install a VFD on the recirculation pump to reduce pumping energy. The recommended solar water heating system will service the DHW system as well as the HW space heating loop – particularly during summer months when solar energy is abundant but HW loop heating is still required.

- The CHW, HW, and DHW loop pumps run continuously. Recommend installing Variable Frequency Drives (VFDs) on all motors larger than 5HP that are running 24x7. This includes the chiller and hot-water loops, the DHW loop, and the cooling towers.

The building systems use a very large amount of energy, and have not been commissioned as part of original construction or as part of any ongoing maintenance program. A retro-commissioning of the lighting and HVAC systems will reduce energy consumption. A full audit will also provide more detail analysis and recommendations.
West County Enterprise Center
A site survey was conducted on December 7, 2010 by Steve O’Rourke and Marc Lopata. Mark Fincher provided an escort and background on the building. Mary Jane Parisi, administrator for the site, provided additional information about the building operations. The weather was clear and cold. This section documents the specific findings and recommendations based on that visit and subsequent analysis.

Facility Description
The West County Enterprise Center is located at 743 Spirit 40 Park Drive in Chesterfield. The two-story 46,000+ ft² facility was built in 1996, and is a small business incubator that provides subsidized rent on office and warehouse space for startup businesses. There are approximately 80-85 full-time employees that work in the facility, which typically operates during normal business hours of 8:00 a.m. to 5:00 p.m. Monday through Friday.

The office space consists of two stories with a blue hipped standing seam metal roof shown above. The warehouse space has a flat, low pitch roof running downstream to west. The gravel on membrane roof
is in average condition, and was assumed to be the original roof. Roof penetrations include vents and 10 rooftop HVAC units.

The lighting in the office is primarily T8 fluorescent fixtures with electronic ballast. In addition, the lobby has a number of 95W incandescent fixtures, and the exit signs have incandescent lighting. Lighting levels are slightly higher than necessary, with readings ranging from 40-50 foot candles in the hallways to 65-70 FC in conference room and offices. The parking garage is lit with 400W metal halide fixtures.

In addition to typical office equipment such as computers, printers and copiers, the facility serves power to a variety of other specialized equipment, including an electric kiln and incubator. A break room galley has vending machines, two refrigerators, two microwaves, and an ice machine.

The heating and cooling equipment is in average condition, with a variable air volume air handler with electric reheat. Ventilation was normal, with CO$_2$ levels inside the building very close to outside (550 ppm vs. 450 outside).

The building has a building management system that is monitored by an outside vendor. There are no reports provided, and the setback schedule does not appear to match the building’s operational schedule. There is no override feature on the building management system; tenants are required to contact the HVAC contractor using an emergency number to request support.

The building has an electric water heating system, with distribution pipes appearing to be largely insulated. The recirculation system did not appear to be working well, as it took over a minute for not water to reach the kitchen sink in 2nd floor break room galley.
Solar Electric Assessment
This site is a good candidate for solar. The building is situated approximately 11° off a “cardinal square” orientation, slightly southeast, so modules could be installed in line with the building and have an insignificant impact on energy production.

The building has a relatively good visibility, with a variety of tenants and visitors during business hours. This would provide educational opportunities for building occupants. Solar could be installed on the standing seam metal roof to provide a street-level view of the modules, and a supplementary array could be installed on the flat roof to create a larger array.

The image below shows a potential location for a 25 kW array to avoid shade from rooftop equipment.

Figure 99 Proposed locations for 25 kW array
Mounting Options

The flat roof on the warehouse appears adequate to support the weight of a ballasted array. The modules would be installed in south-facing rows at a 10° tilt with spacing between each row to eliminate or minimize shading from adjacent modules. Additionally, modules could be installed on the standing seam metal roof using specialized racking systems as shown in Figure 100.

Figure 101 shows a closer view of the standing seam metal roof, and Figure 102 shows the proposed area on the flat roof above the warehouse.
System Configuration and Building Integration

Modules
In order to create the triangular patterns on the standing seam metal roof, polycrystalline panels must be used. Monocrystalline are only manufactured in rectangle shapes, and thin film laminates come in a limited number of lengths.

Given the available roof space above the warehouse, polycrystalline modules are recommended to maximize the price/performance balance. The actual area on both the pitched and flat roofs can be determined once a detail design is completed and actual modules are selected.

Inverters
Microinverters would simplify installation and minimize any production losses from temporary shading of rooftop equipment. Alternatively, bulk inverters may be less expensive to replace and maintain.

Energy Systems and Distribution
The Ameren service entrance and meter are on the east exterior wall and the distribution panels are immediately inside this location. The electrical service to the building is and the building distribution is
According to staff, the building can be de-energized to complete the interconnection. That work would be done on the weekend to minimize impact to operations.

Storage, Staging and Installation
A 25kW system would require approximately 200 square feet for storage of 6-8 standard pallets, including modules, inverters, racking and ballast. Typically the solar installer will accept delivery of the equipment off site and deliver to the site when the timing is optimal for installation.

The electrical conduit would run through roof into the maintenance bay, and connect into a 75 kVA 208V step-down transformer in the electrical room.

When the pallets are lifted to the roof (whether initially or after a delay), they will have to be placed directly on the structural columns or beams to ensure adequate long-term loading capacity. These locations should be physically confirmed and marked to ensure accurate placement. The goal would be to install within a few days, but that could be delayed by weeks or months under worst-case conditions. The heaviest pallet for a system of this size usually is less than 2,000 pounds.
Energy Production
The proposed 25 kW system would produce approximately 31,000 kWh annually, with higher production in the longer days of summer (see bar chart below). The total energy produced over the expected 30 year life of the system is approximately 866,000 kWh, factoring in a typical annual degradation factor of 0.5%. The estimated value of this energy is over $150,000.

![Forecasted Energy Production](image)

*Figure 103 Estimated annual energy production for 25 kW system at 10° tilt and 179° azimuth*
Financial Analysis
The turnkey cash installation cost for the 25 kW rooftop system using polycrystalline modules is estimated at $160,000 in 2011 dollars. That is calculated based on American-made components (complying with ARRA requirements) and prevailing or union labor rates. This should include design services, installation labor, materials, and equipment, including modules, inverters, and balance-of-system components necessary to comply with the local building code and Ameren interconnection requirements.

The PV system will require annual cleaning and inspection by building management personnel. Annual monitoring and maintenance contracts are available and would cost in the range of $600-700 per year. This is not included in the financial performance evaluation. Insurance is estimated at $600 per year for casualty loss coverage, and this cost is included in the financial performance model.

Applicable Incentives
The financial model to calculate the total value of the incentives includes the utility rebate, which is received within 90 days of the completed installation. Potential income from the sale of SRECs can also be factored in to maximize the payback. The net cost after these incentives are applied is shown below.

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Installed Cost</td>
<td>$160,000</td>
</tr>
<tr>
<td>Utility Rebate</td>
<td>$50,000</td>
</tr>
<tr>
<td>Sale of SRECs(^{19})</td>
<td>$15,200</td>
</tr>
<tr>
<td>Net Cost After Incentives</td>
<td>$94,800</td>
</tr>
</tbody>
</table>

\(^{19}\) This value is an estimate of the sum of the first five annual payments from Ameren’s Standard Offer Contract. Cash flow projections in the financial model include additional SREC income for years 6-10.
Environmental Benefits
The electricity generated by a 25 kW system would result in reduced emissions from the coal-fired power plants that support the Ameren Missouri distribution region. This amounts to a reduction of 28 tons of carbon not polluting the atmosphere each year. This is equivalent to:

- The CO₂ absorbed by 28 acres of dense, hardwood forest (an area about 1.4 times the size of Shaw Park in Clayton), or
- 2,500 gallons of gasoline not burned in automobiles each year.

The lifetime contribution of this system will effectively eliminate 790 tons of CO₂ from the atmosphere.

Implementation Schedule
Installing the solar-PV system would require approximately 10-11 weeks, depending primarily on equipment availability. The permitting task includes the following:

- Electrical permit issued by St Louis County;
- Approval from the Clayton Architectural Review Board;
- Interconnection and Net Metering Agreement from Ameren Missouri. By rulemaking, this is declared to be a 90-day or less interval. Typical approval period is 30-45 days.

![Figure 104 Typical Implementation Schedule](image)

Equipment lead times for the project as described above typically are 4-5 weeks, but this could vary significantly depending on project timing and conditions in the global markets. This should be reassessed at the time the project is planned.
Solar-Thermal Assessment
The demand for hot water in this facility does not warrant the use of solar thermal. Hot water is primarily limited to hand washing and light kitchen use, and the operational hours are typically limited to 50-60 hours per week.

Geothermal Assessment
This site is not a particularly good candidate for geothermal. While there may be suitable ground on which to drill vertical loops, the limited occupancy of this building would only provide marginal energy savings, as the building does not require heating and cooling overnight or on weekends.
Energy Efficiency
During the site visit, a number of observations were made regarding the energy performance of the building.

- Replace metal halide fixtures in parking garage with fluorescent T5 or T8 fixtures
- Install occupancy sensors to reduce lighting in unoccupied spaces, especially in break room/café area
- Replace incandescent exit signs with more efficient LED signs
- Install bi-level switching for all rooms except small offices, and reduce lighting in hallways and conference rooms
- Install weather seals on warehouse door
- Drop ceilings on warehouse space used for office could reduce heating and cooling requirements
- Recommend adding VFD on blower fans on 2 large RTU’s serving office building, and throttle blower motor based on airflow/pressure at VAV.
- Use EMS to program setback on weekends with 2-hour overrides on thermostats.
- Install timer on hot water recirculation pump to reduce energy usage during nights and weekends.
- Analyze the flow of the hot water recirculation system to determine why kitchen sink in 2nd story break room is not getting immediate hot water. A tankless water heater in the galley might be an alternative an expensive plumbing retrofit.
- Install energy misers on vending machine equipment
- Install outlet load controllers for outlets in tenant spaces to more effectively manage plug load.
- Install surge protection (tracer sensor?) to minimize possibility of damage to electronic equipment, including energy management system.

We also recommend structuring lease agreements to require energy efficiency review prior to tenant build-out, and write energy recovery guidelines into leases. The County might also consider contracting with Ameren to subscribe to the Abacus service to monitor electric usage.
Appendix A – Resources

The following resources may be of value in for additional research.

1. Database for State Incentives for Renewables and Efficiency, www.dsireusa.org
Appendix B - Case Study

COMMERCIAL GRID-DIRECT PHOTOVOLTAIC SYSTEM:
Denver Museum of Nature & Science

Overview

DESIGNER: Jason Sharpe, COO, & Stephen Irvin, CFO, Namaste Solar, namastesolar.com

PROJECT MANAGER: Ray Tuomey, co-founder, & Sam Mason, lead Installer, Namaste Solar

DATE: COMMISSIONED: June 11, 2008

INSTALLATION TIMEFRAME: 30 days

LOCATION: Denver, CO, 39.5°N

SOLAR RESOURCE: 5.5 kWh/m²/day

RECORD LOW/AVERAGE HIGH

TEMPERATURE: 31°F / 69°F

ARRAY CAPACITY: 99.38 kW

AVERAGE ANNUAL AC PRODUCTION:
135 MWh

Equipment Specifications

MODULES: 465 SunPower SPR-2 IS-WhT, 215 W STC, +5%/−5%, 5.4 Imp, 39.8 Vmp, 5.8 Isc, 49.3 Voc

INVERTERS: 3-phase, 277/480 Vac system, 3 SMA Sunny Towers, 36 kW each, 6 SBE000US per tower, 660 Vdc max input, 250-480 Vdc MPPT range

ARRAY: Eleven 27 module subarrays with nine modules per string (1,935 W, 5.4 Imp, 388.2 Vmp, 5.8 Isc, 434.7 Voc) and three circuits per inverter (5,605 W, 16.2 Imp, 385.2 Vmp, 17.4 Isc, 434.7 Voc); and seven 24 module subarrays with eight modules per string (1,720 W, 5.4 Imp, 318.4 Vmp, 5.8 Isc, 386.4 Voc) and three circuits per inverter (5,180 W, 16.2 Imp, 318.4 Vmp, 17.4 Isc, 386.4 Voc)

ARRAY INSTALLATION: Flat roof mounted, SunPower T-10 racking, 180° azimuth, 13° tilt

ARRAY COMBINER: Inverter integrated, 15 A fuses

SYSTEM MONITORING: Fat Spaniel Technologies, inverter direct with weather station; museum designed and installed mobile, wireless flash display for educational purposes

When it was commissioned, the PV array at the Denver Museum of Nature & Science was the largest building-sited PV system in Colorado. The system achieved even greater prominence when President Obama and Vice President Biden toured the site before signing the American Recovery and Reinvestment Act on February 17, 2009.

The project size was dictated by Xcel Energy’s rebate rules. This, along with the pricing structure for the PPA, favored a system as large as possible without exceeding 100 kW STC. Using SMA Sunny Towers allowed for significant design flexibility and a final array capacity of 99.38 kW.

The inverter and interconnection locations presented major implementation issues. The rooftop penthouse is large enough to house multiple inverters but not structurally strong enough for a single central inverter. Using Sunny Towers spreads out the inverter point loading. The mechanical subpanel in the penthouse is a 3-wire, 277/480 Vac panel without a neutral conductor. An isolation transformer is used to generate a neutral reference, and the Sunny Towers are configured for 277 Vac operation. This allows the system to interconnect on the rooftop, minimizing both the ac and dc wire runs and reducing the voltage drop and installation expenses.

“The Denver Museum of Nature & Science is the perfect place to showcase solar technologies. By using the PV array as a teaching tool, not just a power source, the Museum sets an example for other community organizations and visitors to follow, encouraging them to do their part for the environment.”

—Ray Tuomey, Namaste Solar

Figure 106 Case Study from Jun/Jul 2009 issue of Solar Pro magazine
REC SOLAR

Otto Peterson Elementary School

Overview

DESIGNER: Adam Ward, design engineer, REC Solar, recsolar.com
PROJECT MANAGER: Bryan Shull, operations manager, REC Solar
DATE COMMISSIONED: Sept. 2010
INSTALLATION TIME FRAME: 20 days
LOCATION: Scappoose, OR, 45.9°N
SOLAR RESOURCE: 4 kWh/m²/day
HIGH/LOW DESIGN TEMPERATURES: per solarpro.org/permitting/map:
86°F/19.4°F
ARRAY CAPACITY: 33 kW
ANNUAL AC PRODUCTION: 33 MWh

Equipment Specifications

MODULES, ROOF: 134 REC220AE-US, 220 W STC, +13%/−3%, 7.8 Imp, 26.4 Vmp, 6.4 Iso, 36.4 Voc
MODULES, AWNINGS: 16 Sanyo HIP-195DA3, 195 W STC, +10%/−0%, 3.5 Imp, 55.8 Vmp, 3.73 Iso, 68.7 Voc
INVERTERS: 3-phase, 277/480 Vac service, three SB 7000-US, 7KW, 600 VDC max, input, 250–480 Vdc MPPT range; two SMA SB 5000-US, 5 kW
ARRAY, ROOF: Twelve REC 220 W modules per source circuit on three SB 7000-US inverters (2,640 W, 7.8 Imp, 540.6 Vmp, 6.4 Iso, 450.6 Voc); three circuits per Inverter (7,920 W, 23.4 Imp, 540.6 Vmp, 32.2 Iso, 436.8 Voc); 13 modules per source circuit on one SB 5000-US inverter, two circuits total
ARRAY, AWNINGS: Six Sanyo 192 W modules per source circuit (1,112 W, 5.6 Imp, 334.5 Vmp, 4.73 Iso, 412.2 Voc); three circuits on SB 5000-US inverter (3,310 W, 15.5 Imp, 334.5 Vmp, 11.2 Iso, 412.2 Voc)

ARRAY INSTALLATION, ROOF: Proprietary seam clamp and SnapNack tilt mount kit, 156° azimuth, 10° tilt
ARRAY INSTALLATION, AWNINGS: Custom fabricated curtain wall brackets and racking, 140° azimuth, 15° tilt
SYSTEM MONITORING: SMA Webbox

The PV installation at Otto Peterson Elementary School in Scappoose, Oregon—a new construction project—required close collaboration with the general contractor, P&G Construction, and the architect, DLR Group. Product delivery and installation timing were critical, while in-field design changes and construction flexibility were important for the installation team.

To minimize the amount of racking materials used and maximize energy production, a low-profile tilt racking system was specified for the standing-seam metal roof. The proprietary seam clamp system was used to eliminate roof penetrations while allowing a tilt angle for the modules. This approach limits wind loading and allows for a more power-cense rooftop installation. The tilted rows also allow for better access to the modules for array maintenance.

Maximizing the production of the awning arrays posed some architectural challenges. For example, REC Solar’s performance standards required a lower row of proposed awnings to be eliminated due to excessive shading from the building. In addition, the awning arrays needed several adjustments to ensure that they were appropriate for the string and inverter sizing and that they fit the window openings, both aesthetically and structurally. Due to the long distances between each of the three awning sections, splitting strings was not a viable option.

“Solar systems on schools are always dual-value projects: they provide a tangible example of solar with on-site educational opportunities for students, while helping the schools reduce their overall operating expenses.”

— Andy Noel, regional manager, REC Solar

Figure 107 Case Study from Feb/Mar 2011 issue of Solar Pro magazine
COMMERCIAL SOLAR WATER HEATING SYSTEM:
Alta Torre Senior Housing

Overview

DESIGNERS: Justin Wel, president, SunWater Solar, sunwatersolar.com; structural engineering, Dave Helmich, DPM Engineering, dpmengineer.com; underground piping design, Jim Andrews, Thermal Pipe Systems, thermalpipesystems.com
LEAD INSTALLER: Jerry Saechao, foreman, SunWater Solar
DATE COMMISSIONED: May 2010
INSTALLATION TIME FRAME: 30 Days
LOCATION: Palo Alto, CA, 37.4°N
SOLAR RESOURCE: 8.4 kWh/m²/day
ANNUAL HEATING DEGREE-DAYS: 2,649, base 65°F
RECORD LOW TEMPERATURE: 15°F
COLLECTOR ARRAY AREA: 960 sq. ft.
AVERAGE ANNUAL PRODUCTION: 85.6 MWh

Equipment Specifications

COLLECTORS: 24 HelioDyne 410-002, 40 sq. ft. each
HEAT EXCHANGER: Young HEX 64 Y 2PB External
PUMPS: Two Grundfos UPS-60-80/2 VersaFlo, 7/8 hp
STORAGE: Two 534-gallon Hanson GS-42-534-Y tanks, 1,068 gallons total
CONTROLS: Stocx TR 0301 U
FREEZE CONTROL: Closed-loop glycol
COLLECTOR INSTALLATION: Custom pipe racking on low-slope roof, modified bitumen, 180° azimuth, 34° tilt

The solar thermal system at Alta Torre Senior Housing was added after the building had been designed. Unfortunately, this is an all-too-typical scenario for solar thermal installations, and it inevitably leads to “hide the big tank” meetings. In this case, the tanks could not be installed near the collectors due to space constraints. The decision was made to locate them 100 feet from the collectors in a concrete-block outbuilding that would also house a backup generator.

One of the downsides to locating the tanks away from the solar collectors is the expansion of the underground piping, which needs to be taken seriously. In thermal systems, temperatures can reach 250°F and then cool to less than 100°F with the start of the pump. We specified a preinsulated product called Copper-Core, a gasketed piping system that features integral bronze couplings with built-in expansion control. Copper-Core’s couplings are not fixed joint, and the sections are not soldered. A concrete thrust block was installed at each corner in the trench to prevent excessive pipe movement.

“At the very end of the project, after we had placed our tanks and installed all of the related equipment, it was discovered that the generator was too close to the neighboring building to meet the local fire code. The architect determined that if a roof was not put on the mechanical building, the generator could stay where it was. To deal with this new plan, we gladly jacketed all of the above-ground piping and had custom metal coverings made for items such as pumps and controls.”
—Justin Wel, president, SunWater Solar

Figure 108 Case Study from Oct/Nov 2010 issue of Solar Pro magazine
Figure 109 Case Study from Aug/Sep 2010 issue of Solar Pro magazine
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<tr>
<th>SELECTION CRITERIA</th>
<th>Description</th>
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<tr>
<td>Public visibility</td>
<td>Will the installation be visible to the site users/occupants?</td>
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<td>Employees working on site</td>
<td>More employees represent more internal educational opportunities</td>
<td>22</td>
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<tr>
<td>Non-employees visiting the site</td>
<td>More visitors represent more community educational opportunities</td>
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<tr>
<td>Effective energy rate</td>
<td>Average energy including demand charges</td>
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</tr>
<tr>
<td>Electrical connection feasibility</td>
<td>Building voltage and capacity, Condition of distribution hardware</td>
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<tr>
<td>Production factors</td>
<td>Optimal orientation, plus unshaded sun resource without sun removal</td>
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</tr>
<tr>
<td>Mounting &amp; racking</td>
<td>Roof age condition, capacity, parking, grading</td>
<td>0.07</td>
</tr>
<tr>
<td>Security</td>
<td>Restricted access required, either flight above ground, fence, or moat</td>
<td>0.07</td>
</tr>
<tr>
<td>Installation costs</td>
<td>Expectations for benchmark performance, given relative installation cost</td>
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<tr>
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</tr>
<tr>
<td>Effective energy rate</td>
<td>Average energy including demand charges</td>
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<tr>
<td>Electrical connection feasibility</td>
<td>Building voltage and capacity, Condition of distribution hardware</td>
<td>0.06</td>
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<tr>
<td>Production factors</td>
<td>Optimal orientation, plus unshaded sun resource without sun removal</td>
<td>0.08</td>
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<tr>
<td>Mounting &amp; racking</td>
<td>Roof age condition, capacity, parking, grading</td>
<td>0.07</td>
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<tr>
<td>Security</td>
<td>Restricted access required, either flight above ground, fence, or moat</td>
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<td>Installation costs</td>
<td>Expectations for benchmark performance, given relative installation cost</td>
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<th>SOLAR THERMAL (ST)</th>
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<td>Accessibility to drill wells</td>
<td>About 50% of conditioned floor space required for well field</td>
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<tr>
<td>HVAC equipment</td>
<td>Age, schedule for life-cycle replacement, deficiencies, refrigerant concerns</td>
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<tr>
<td>Central plant configuration</td>
<td>System integration design questions</td>
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<tr>
<td>Consistency of operations</td>
<td>Consistency of the building load throughout the day and week; heated and cooled</td>
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<td>Installation costs</td>
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<th>ELECTRIC VEHICLE CHARGING STATIONS</th>
<th>Description</th>
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<td>Potential for fleet</td>
<td>Demand consistency for EV charging</td>
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<tr>
<td>Potential for visitor</td>
<td>Suitability of EVs for vehicle uses</td>
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<tr>
<td>Installation costs</td>
<td>Expectations for benchmark performance, given relative installation cost</td>
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</tr>
</tbody>
</table>

NOTES:
(a) Investment exceeds financial hurdle.
(b) Scored "X" if strategy not feasible, rejected, or otherwise impractical. Scored "H" if favored by owner.
(c) "1" if positive NPV.
(d) "0" if unknown or not applicable.
(e) LED certification would include high-performance building envelope, water-efficient plumbing fixtures, lighting optimization, and other energy, water, and resource of efficiency measures.
(f) "1" if negative.

Appendix C - Site Ranking

Appendix

Appendix D - Cost and Benefit Analysis

Appendix E - Building Operations and Maintenance Cost

Appendix F - Energy Codes and Standards

Appendix G - Case Studies

Appendix H - Literature Review

Appendix I - Glossary

Appendix J - Acknowledgments

Appendix K - References

MicrogridEnergy.com