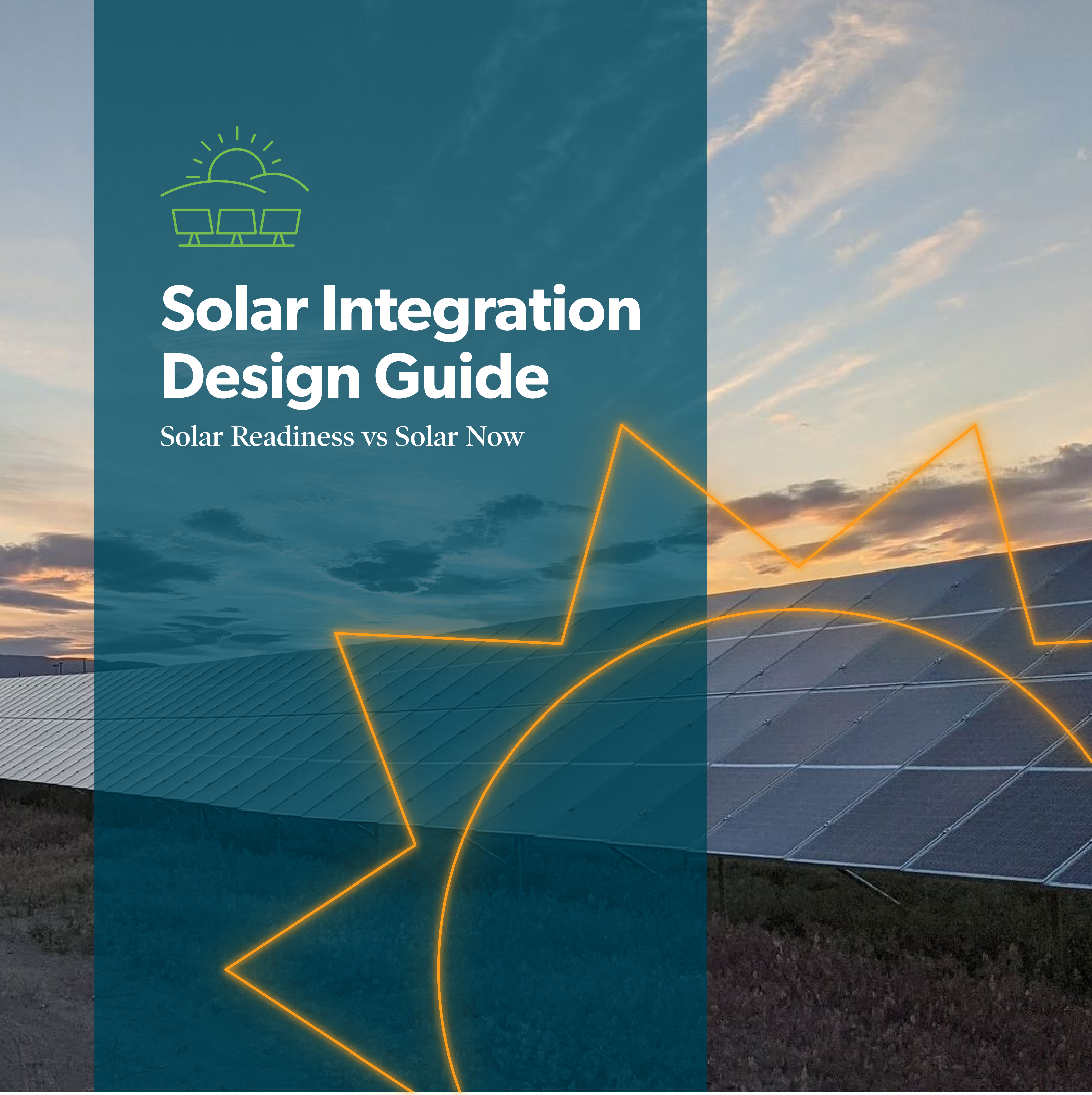

Solar Integration Design Guide

Solar Readiness vs Solar Now

Authors:

Nathan Bronec, Energy Services
Tim Johnson, Energy Services
Ashleigh Powell, Director of Sustainability
Tyler Victorino, Energy Services

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The urban built environment is responsible for 75% of annual global GHG emissions: Buildings alone account for 39%. Eliminating these emissions is the key to addressing climate change and meeting Paris Climate Agreement targets.

- 2030 Challenge

Introduction

As members of the design community, one of the biggest challenges we face today is reducing the impact of the built environment on the natural environment, especially as it relates to energy use and greenhouse gas emissions and their impact on global warming. A fundamental rethinking of how we design and how we build is taking place as we experience the effects of climate change all around us.

With the push to achieve zero net energy (ZNE) and meet the AIA 2030 commitments, we can only get so far with a building designed to meet the highest sustainability standards. Even with the most energy-efficient systems and materials, a building will take more than it gives unless on-site energy production is tied into the building to achieve ZNE goals.

For this integration guide, we look specifically at solar integration (photovoltaic/PV) with buildings.

Key Terms to Know

Photovoltaic (PV) Panels: Panels composed of a series of solar cells made from silicon that convert sunlight into electricity using the photovoltaic effect.

PV Racking: The structure on which PV panels are mounted. Typically made from steel or aluminum, PV racking can feature fixed tilts or tracks that move with the position of the sun throughout the day.

PV Arrays: The interconnected system of PV panels and inverters that function as a single electricity-producing unit.

Net Metering: A metering and billing arrangement designed to compensate owners of distributed energy generation systems for any power that is exported to the utility grid.

Distributed Energy Resource: Any small-scale power source that is generated or stored locally and is connected to a distribution system.

Renewable Energy Certificates (REC): A tradable, legal mechanism that represents the environmental benefits associated with one megawatt-hour of electricity generated from a renewable energy resource.

Zero Net Energy (ZNE): ZNE buildings produce as much energy through renewable sources as they consume. They typically combine both energy-efficiency measures and renewable energy production.

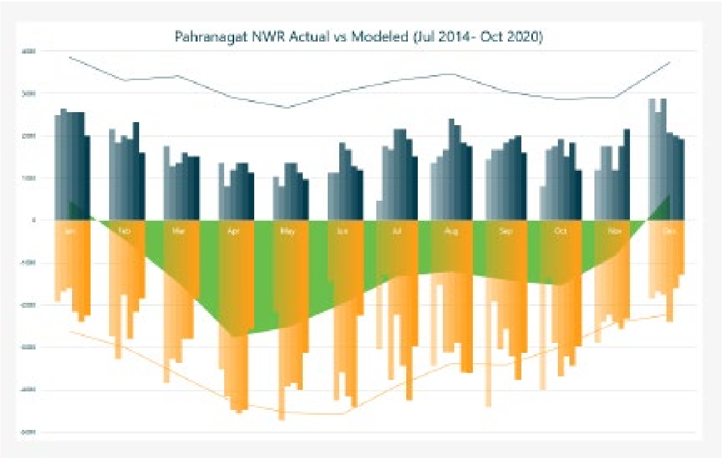
PROJECT SPOTLIGHT

Setting the Example for ZNE

The Pahranagat National Wildlife Refuge Visitor Center in Alamo, Nevada, is a great example of clean energy generation and use, achieving zero net energy and LEED Silver certification. Conservation measures include upgraded building insulation, daylight harvesting, and ground-source geothermal HVAC. On-site renewable energy is provided by roof-mounted solar photovoltaic panels.

For this project, extensive energy modeling was used in conjunction with early architectural modeling to inform the building orientation and massing, as well as the materials and systems used. The team focused on energy load reduction first and foremost to get the usage as low as possible and then incorporated on-site solar generation.

The result is a cost-effective, high-performing building that met — and exceeded — the client's ZNE goals.



Design decisions for the Pahranagat NWR visitor center were based on factors such as building orientation, weather patterns, construction materials, HVAC systems, and building-use predictions.

The Path to ZNE

Determining the Best Option for Your Project

Having the on-site renewable energy conversation with clients is, in many cases, getting easier. The topic is becoming more familiar, and the concerns and implications of not being a part of the solution have become much more immediate and tangible. Sometimes, clients even come to the table with the solar option already in mind as part of their specific ZNE goals.

The first hurdle is helping your client weigh the options to achieve ZNE and understand the return on investment (ROI).

Note: *For the following ROI comparison, we assume the building will be designed to meet the highest standards of energy efficiency through building orientation and envelope, as well as mechanical and electrical systems.*

Weighing the Options and Assessing Return on Investment

Option #1: The building you design/construct for your client is the gold standard in sustainable design. Additionally, your client chooses to purchase preferred RECs — such as through Green-e Certification — to offset energy use. You feel good; your client is investing in the local utility growing its renewable energy provisions. However, you could feel better. Each month, your client will be paying for both the building's energy use and 100% RECs.

Option #2: On-site renewable energy is the more direct path to ZNE, but not every client is ready for the upfront commitment (time and money) or prepared to navigate the local utility integration. (Note: Some cities now require solar readiness as part of the building code.) Preparing a building for solar helps your client move a step closer to not only what will be the future of our built environment, but also to a self-sustaining energy system.

Option #3: The option with the greatest payback potential for your client is incorporating solar right from the start. This reduces monthly energy costs and the percentage of RECs needed. With the reduced monthly energy costs, a solar PV system can be paid off in 10-12 years. Additionally, with onsite renewable energy, your client will be eligible for tax incentives. The big bonus? This is the one system you can add to your client's building that is a guaranteed investment and saves money in the long term, especially as energy costs escalate.

RECs vs Solar Readiness vs Solar Now: ROI Comparison

OPTION 1

Purchase of Renewable Energy Certificates (RECs)

Construction Cost

$41,000,000

O&M Costs

- RECs purchase for 100% usage: $2,296.25/month*
- Utility expenses: $19,568.99/month
- 100% RECs purchase + utility expenses = $262,383 annually

Total: $6.6M over 25 years

Estimated Energy Use Offset

0%

PV Return on Investment

N/A

OPTION 2

Design/Build for Solar Readiness

Construction Cost

$41,030,000
(0.1% increase)

O&M Costs

- RECs purchase for 100% usage: $2,296.25/month*
- Utility expenses: $19,568.99/month
- 100% RECs purchase + utility expenses = $262,383 annually with 8% energy use offset beginning year of PV installation

Total: $6.2M over 25 years
(if PV is installed year 3)

Estimated Energy Use Offset

8% (beginning year 3)

PV Return on Investment

2.63% annualized ROI**

OPTION 3

On-site Solar Generation

Construction Cost

$41,209,000
(0.6% increase)

O&M Costs

- PV O&M: $2,000/year
- Utility expenses: $18,219.75/month (w/ PV)
- 92% RECs purchase with 8% energy use offset + utility expenses = $242,637 annually

Total: $6.1M over 25 years

Estimated Energy Use Offset

8% (beginning year 1)

PV Return on Investment

3.55% annualized ROI**

**Costs are estimated with RECs purchased through Northwestern Energy.*

***This estimate does not include incentives/rebates or energy cost escalations. These would result in greater cost savings and quicker ROI.*

PROJECT SPOTLIGHT

Stewards of History and the Environment

The project used for this ROI comparison is the Montana Heritage Center in Helena, Montana. The 133,000 sq. ft. cultural destination will comprise a lobby, exhibit space, archives, café, theater, and offices. Approximately 66,000 sq. ft. will be new space, while 67,000 sq. ft. will be renovated space with updates to the exterior and interior of the original building. With a strong commitment to sustainability, the client is pursuing USGBC LEED and IWBI WELL certifications.

The PV system chosen for this building will take advantage of the flat roof expanse of the original building and what will be a slightly inclined roof of the new addition. The roof-mounted, fixed-tilt system will attach directly to the roof deck. The team chose this option due to the need for a lighter-weight system that could tilt to a 35-to-40-degree angle and take advantage of peak solar production in Montana.

Although this project will have a 100kW array, a 50kW array is suitable for most commercial buildings and would produce power for about 6-7 cents per kilowatt hour, about half what it would cost to purchase from a utility (U.S. average). Thus, we can estimate a savings of 50% with on-site energy production. When it comes to large grocery stores, the savings can be even greater as they typically require a larger PV system and tend to be in more expensive markets for energy pricing.

Pro tip: With a roof-mounted system on new construction, it's important to ensure close coordination between the PV and roofing contractors. We recommend the roofing contractor not only be responsible for the building envelope and roof, but also for the PV racking system attachments and flashing boots. With one contractor responsible for the seal, there's a reduced chance of leaks, and if there are failures, it clearly falls under the roofing contactor's warranty.

*The **Montana Heritage Center** will produce an estimated 100kWs of clean, renewable energy, powering 8% of its operations (enough to power 18 average single-family homes per year). This will result in approximately $16,000 in energy savings per year and an emissions reduction of 108 metric tons per year, equivalent to 23 gas vehicles (assuming 22 MPG/11,000 miles per year per EPA). Additionally, the building has been designed to incorporate future battery energy storage and take the next step toward a microgrid system.*

For this project, the PV panels will be clearly visible, representing the client's commitment to sustainability and being stewards of the environment.

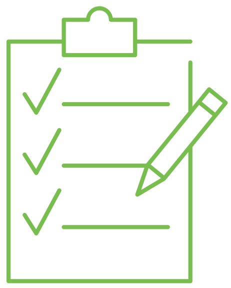
Design Considerations Checklist

To integrate solar, you need a whole-building approach and an expert team that can drive coordination with contractors and manufacturers, assess site conditions, and review city and state regulations, as well as utility requirements and available rebates. Following is a checklist of design considerations that will help you prepare for and realize a successful on-site solar project.

Energy Efficiency

In all areas, from the electrical and mechanical systems to windows and shading devices, your building must first be designed and built to meet the highest energy efficiency standards. Consider all the places energy use can be reduced and energy efficiency increased.

An energy model can help the design team apply the most effective energy efficiency measures for each building. Proper use of energy modeling often results in 20-30% energy savings over a minimally code-compliant building with cost-effective measures. Designing to achieve third-party certifications, such as USGBC's LEED, also can help ensure all influencing factors are taken into account.



State and Local Utility Agreements

Net metering is a billing mechanism that credits solar energy system owners for electricity they add to the grid. When an owner's solar system produces more electricity than what is needed for their own operations, that electricity can be used by the power grid and the owner receives credits. When the owner's solar panels don't produce enough power (at night or in winter, for example), and they need to pull electricity from the grid, net metering credits can offset their utility bills.

Because net metering is a fairly new mechanism, the agreements can be one of the more complicated endeavors of integrating solar. Programs vary between states with limits on how much power can be produced and pushed back onto the grid. The benefits of net metering, however, are clear. Utility companies can benefit not only from load reduction, but also from a more even demand load during peak times. PV system owners can create their own on-site electricity and save money in the process, while reducing strain on distribution systems. Additionally, net metering can help create additional demand for solar energy.

Learn more about state net-metering policies.

Tax Credits and Incentives

While the cost of solar has declined over the last decade, there's still a significant up-front cost for this investment and resulting long-term payback. To encourage greater adoption of solar, the federal government, state and local governments, and some utilities offer incentives to help make solar more affordable. These incentives typically take the form of rebates or tax benefits and can be performance-based.

For more information on incentives, visit:

- The Database of State Incentives for Renewables and Efficiency
- Residential and Commercial Federal Investment Tax Credits

Interconnection Requirements

Utility companies in different regions have varied requirements for interconnection. Thus, it's important to carefully coordinate with the utility prior to initiating the design to address constraints related to the PV array's kilowatt rating and the physical size of the system. Additionally, the details related to interconnection can have an impact on the return on investment of the array, depending on the net metering compensation.

The equipment necessary for an interconnection includes a meter (or in some cases two), a lockable disconnection switch, and a rapid shut-down device. The meter is provided by the utility while the solar system owner is responsible for the disconnection and rapid shut-down mechanisms, which are installed by a contractor. The disconnection and rapid shut-down mechanisms allow for routine maintenance and assist in the case of a power outage or emergency.

Net metering is used when the PV system owner plans to export power to the grid without a Power Purchase Agreement (PPA). In this scenario, the owner signs a net-metering agreement, and the utility monitors the electricity produced and the electricity used. When production is high, excess electricity is exported onto the grid and the owner receives credits. When production is low, the system pulls electricity off the grid in exchange for the credits.

If the owner has a PV system larger than the net metering limits, the system must be set up so it does not export power to the grid. In this scenario, the owner applies for a small interconnection agreement, which allows the utility to have oversight of the system design. A protective relay on the incoming service replaces the net metering. If solar production approaches the building's total electricity usage, the protective relay shuts down or throttles back the arrays to prevent the system from exporting power. Key to this scenario is designing a system to match the base load of the building as closely as possible (unless battery storage is included in the design).

Building Code Requirements

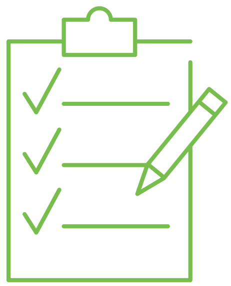
Compliance with building, fire, and electrical codes must all be addressed. These are adopted at the state level in some cases and at the municipal or local level in others (Source: SunShot and CleanEnergy States Alliance). Because of this, part of the work is determining which codes apply to the location of your project. Specific international and national codes to reference are the International Fire Code and the National Electric Code.

PV Racking Installation

This is where you will need close coordination between your roofing and structural leads and the PV racking installation contractor. There are different types of racking systems to choose from depending on your roof and roof membrane type with considerations that include: 1) how the system may affect the roof warranty, 2) the time frame needed to install the system, 3) whether the roof will need to be replaced before the PV system's end of life, 4) the distributed loads and reaction forces (uplift in strong wind, for example) of the mounting systems, and 5) the amount of tilt needed.

For all support systems on membrane or asphalt-shingle roofs, designers should check with the roof manufacturer for information on how the PV racking system may impact the roof warranty.

The National Renewable Energy Laboratory's PV Watts program is a good resource for preliminary design and sizing of PV arrays.



Panel Orientation and Tilt

The tilt of the PV racking plays a large role in annual energy production for fixed racking systems. By adjusting the tilt, you can boost production during the time of year with the highest load or need. For example, if you have an off-grid site, it may be best to maximize winter production when there's less solar availability to limit generator run time. Conversely, if your building has a large load from air conditioning, it may be more beneficial to target summer production to offset the increased load.

To achieve optimal functionality, the angle of the panels can be adjusted to be steeper or shallower than the site latitude. An angle that is shallower than the site's latitude will produce more power during summer months, whereas an angle that is steeper than the latitude would favor production during winter months. For the best year-round performance, it is recommended that you target an angle that matches the site's approximate latitude. Generally, maximum annual power output is achieved with the panel orientated due south.

Pro tip: The tilt needed will impact the PV racking system chosen because most manufacturers only allow for a standard tilt of up to 35 degrees. For sites in the northern United States, you may need a premium or custom rack to match the site latitude. Additionally, for many sites, the optimum solution may not match the exact latitude due to physical area constraints.

How Tilt Affects Annual Production Based on Site Location

Latitude	System Energy Yield (kWh)								
	0° tilt	5° tilt	10° tilt	15° tilt	20° tilt	30° tilt	35° tilt	40° tilt	60° tilt
20	1352	1377	1394	1402	1402	1377	1353	1320	1118
30	1445	1498	1540	1571	1592	1603	1593	1574	1407
35	1698	1778	1844	1897	1937	1975	1976	1963	1797
40	1452	1524	1584	1633	1672	1715	1720	1715	1587
45	1278	1355	1422	1478	1542	1585	1600	1604	1523
60	786	838	886	928	963	1016	1032	1042	1021

Notes:

1. Green boxes indicate the tilt angles with the highest production for the latitude.
2. This table serves as a comparison of what the tilt can do in general to production capabilities at a set location. There are additional impacts, such as a site's weather, that would also affect the numbers.
3. These numbers should not be used to estimate the amount of kilowatt hours your site will produce based on kilowatts installed. Rather, this should be done via PV watts.
4. For northern locations, peak production tends to be less than the site's latitude due to shorter daylight times.

PROJECT SPOTLIGHT

A Demonstration of Values

For many companies, making an investment in solar is a demonstration of their values, and they're willing to experiment with how solar is integrated into their buildings. For example, a large tenant located in a dense urban high-rise without the land or rooftop area for solar chose to incorporate solar panels into exterior shading devices on their south-facing terraces. With the plan already set to have shaded outdoor amenity spaces, why not go a step further to incorporate PV into what would otherwise be a solid shading material?

For this complex design, the PV arrays became an added architectural feature, helping to keep the outdoor terraces cool. There are various benefits of this unique system beyond energy production and offset, including making an investment in the local utility's ability to expand solar opportunities.

The solar panels being incorporated into the terraces of this downtown high-rise offer shading, rain gardens, and green space for tenants. Preliminary estimates indicated the terrace spaces maximized with PV could support a 154kW array that would produce approximately 235,000 kWh of electricity and offset up to 58% of the estimated lighting load at peak output. However, as the design progressed, the terrace shading was adjusted for other factors, including base building design considerations and maintenance.

Discovering the Potential of Solar

Imagine all the existing building rooftops that could support a PV array and you can imagine the potential for integrating on-site solar — for both existing and new buildings. Solar has become much more cost effective, and there are many incentives tied to the investment for the system owners. While we've just scratched the surface of the topic with the design considerations in this guide, there are experts who focus on this solution entirely. With increased applications in different environments and for different building types, this field of knowledge and the related innovations will continue to grow at a fast pace.

Every building offers unique challenges and opportunities as we work to realize a built environment that's closer to a net zero outcome.

> *[Green buildings] provide some of the most effective means to achieving global goals, such as addressing climate change, creating sustainable and thriving communities, and driving economic growth."*
>
> \- **World Green Building Council**

Have questions or need a deeper dive?

Reach out to our Energy Services team and tell us about your project.

energyservices@cushingterrell.com

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