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Using photovoltaic installations in building design to meet energy goals

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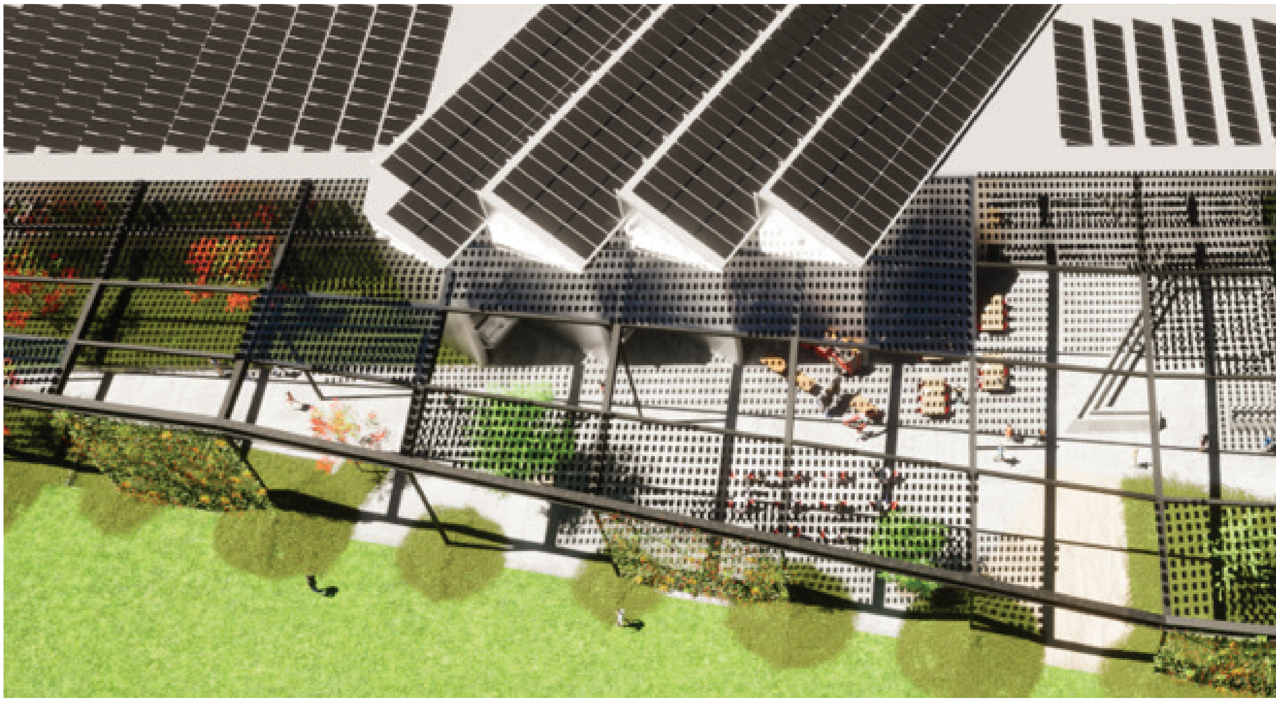

Understand the early design considerations for projects to take advantage of photovoltaic installations to achieve energy goals

LEARNING OBJECTIVES

Understand what EUI is and its relevance in high-performance and zero-energy building design.

Recognize how to compare the cost-effectiveness of further increasing energy conservation measures against increasing PV production as it relates to the project's budget and energy goals.

Identify the importance of early, holistic project team involvement in PV design.

Energy

Electrical and Power

ENERGY INSIGHTS

WHILE ROOFTOP-MOUNTED SOLAR TECHNOLOGY IS A VALUABLE SOLUTION FOR OFFSETTING ENERGY CONSUMPTION, CHALLENGES ARISE IN ENERGY-INTENSIVE OR MULTISTORY BUILDINGS, PROMPTING ENGINEERS TO EXPLORE INNOVATIVE SOLUTIONS.

THE AIA 2030 COMMITMENT AND MEP 2040 CHALLENGE REPRESENT COLLABORATIVE EFFORTS WITHIN THE ARCHITECTURE AND ENGINEERING COMMUNITY TO CREATE SUSTAINABLE BUILDING DESIGNS.

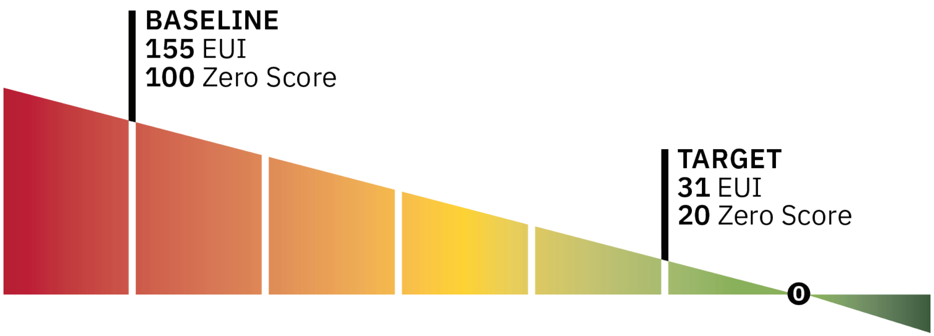

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Figure 1
A Zero Energy Design Approach requires steep cuts in Building Energy Use. Inevitably some amount of renewable energy generation is required to offset the remaining consumption to achieve net zero operations.

Courtesy: AIA Zero Tool

Mechanical, electrical and plumping (MEP) engineers manage many multifaceted challenges in the realm of building system design to create structures that are functional and efficient. Among these challenges, decarbonization has emerged as a paramount concern, demanding solutions that mitigate building's impacts on the environemnt.

Tackling decarbonization in the built environment requires that MEP engineers practice a holistic understanding of energy consumption benchmarks and trends, energy conservation technologies and sustainable design strategies.

The American Institute of Architects (AIA) 2030 Commitment is an initiative within the architecture and design community that challenges firms to prioritize sustainability by pledging to design carbon-neutral buildings by 2030. The MEP 2040 Challenge complements the AIA 2030 Commitment by focusing on the engineering aspects of building design. It set ambitious targets for achieving zero-operational carbon buildings by 2030 and zero-embodied carbon by 2040. These goals represent a concerted effort across the architecture and engineering disciplines to collaboratively advance sustainable building practices and drive the industry toward environmentally responsible, energy-efficient buildings that contribute to a more sustainable and resilient future.

These pledges both aim to minimize operational carbon in buildings by reducing energy use with a goal of being zero-energy. Generally, a zero-energy building is one that produces as much renewable energy on-site as it consumes over the course of a year. This design approach involves a comprehensive strategy that integrates energy-efficient technologies, passive design principles and on-site renewable energy sources.
By prioritizing energy conservation measures and generating clean energy on-site, zero-energy building design aims to create buildings that not only reduce their carbon footprint during operation, but also actively contribute renewable energy to the benefit of other uses in the community.

↑ Figure 2
Offsetting robust EUI metrics in commercial buildings will require looking beyond obvious solutions to achieve zero energy designs. One example is extending the building's roof area beyond its program by creating canopied courtyards or other shaded, publicly accessible features.

Courtesy: CannonDesign

Energy Use Intensity

Energy use intensity (EUI) is a crucial metric in the realm of zero-energy building design that represents the key indicator of a structure's energy efficiency — the amount of energy consumed per square foot annually. This provides a quantitative measure of a building's overall energy performance. The lower the EUI, the more efficient the building is considered. Architects and engineers use EUI as a benchmark to assess and compare the energy efficiency of different buildings, guiding the design process toward more sustainable outcomes.

To attain this zero-energy goal, designers strive to minimize EUI by incorporating energy-efficient technologies, optimizing building orientation and employing advanced enclosures. By prioritizing energy conservation measures, architects and engineers can push EUI below current benchmarks and toward zero-energy design outcomes.

Architects and engineers seek to minimize EUI through a number of methods:

Optimized building program: streamlining the building program by eliminating unnecessary spaces or functions reduces the overall energy demand.

Building size reduction: designing smaller, more compact structures inherently lowers energy requirements, minimizing the environmental footprint.

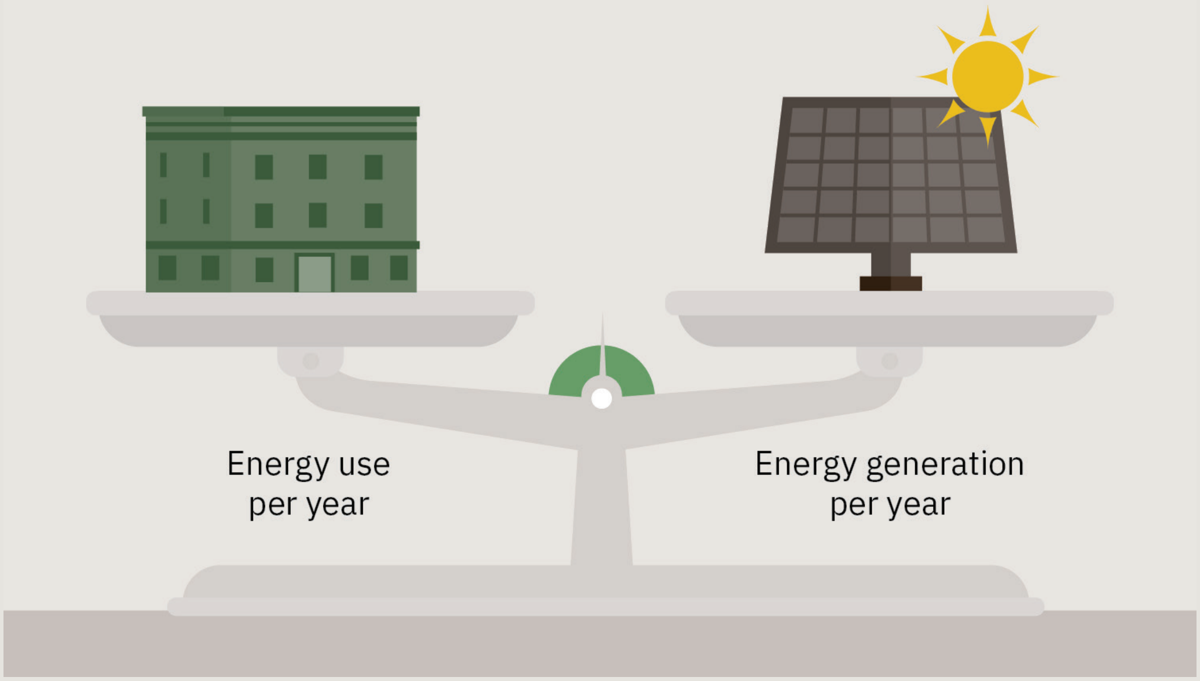
Orientation: proper building orientation can maximize natural daylight and passive solar heating, reducing the need for electric lighting and heating systems.

Enhanced enclosure: improving the building envelope through insulation, high-performance windows and airtight construction minimizes heat transfer, reducing the need for heating and cooling.

Energy-efficient systems: employing advanced heating, ventilation and air conditioning (HVAC) systems, such as geothermal or radiant heating, improves energy efficiency and reduces overall energy consumption.

Occupancy sensing: implementing occupancy sensors for lighting and HVAC systems ensures that energy is only consumed when spaces are occupied, preventing unnecessary usage.

Smart building controls: using advanced building automation systems allows for the precise control of various building systems, optimizing energy use based on real-time needs.



↑ **Figure 3**
Risks and opportunities supporting either deeper energy conservation or enhanced renewable energy potential need to be balanced and weighed against each other in order to find the greatest value and return on investment.

Courtesy: CannonDesign

Cost-effective zero energy approaches

A zero-energy design approach should focus on reducing total site energy first, then deploying energy conservation strategies to minimize energy use through efficient building envelopes, advanced insulation, smart technologies and optimized HVAC systems.

However, as designs move closer to achieving net zero energy status, the pursuit of further energy efficiency becomes increasingly challenging and often exhibits diminishing benefits in terms of cost effectiveness.

The initial steps toward net zero energy, such as improving insulation, upgrading windows and optimizing HVAC systems, typically yield substantial energy savings at a relatively reasonable cost. Fine-tuning a building's energy performance to meet the stringent criteria of net zero, however, may involve incorporating advanced technologies, such as highly efficient appliances, smart controls and cutting-edge energy recovery systems. The cost of these technologies, coupled with the complexities of integrating them seamlessly into the building design, can escalate rapidly. The additional investments required to achieve marginal gains become more significant, reducing the return on investment from the earlier, more cost-effective measures.

In some scenarios, it becomes more cost-effective to allocate resources toward renewable energy sources rather than making additional investments in energy efficiency.

Investing in renewable energy technologies, such as solar panels or wind turbines, can offer a more economically viable path toward achieving net-zero energy. These technologies generate clean energy on-site, providing a direct and measurable contribution to the overall energy needs of the building.

By strategically balancing investments between energy efficiency and renewable energy, designers can navigate the economic challenges associated with achieving net-zero energy, ensuring a holistic and cost-effective approach to sustainable building design.

Energy conservation and passive energy design strategies emphasize the efficient management of thermal mass in reducing heat loss through a building's envelope. This involves a thorough understanding of the proportional relationship between enclosure and roof area to the overall volume of the structure. By strategically minimizing the surface area exposed to external elements, architects and designers aim to decrease the potential for heat transfer. This approach aligns with the principles of minimizing energy consumption and optimizing the thermal performance of the building envelope.

Conversely, maximizing roof area emerges as a key strategy to harness the full potential of a site's available solar resource. An expansive roof surface area presents an opportunity to host a more substantial solar array that can offset more of the building's energy needs. These dueling priorities underscore the balance architects must strike, considering

Rooftop-mounted solar technology

both passive design strategies for thermal efficiency and proactive measures for renewable energy integration, in the pursuit of comprehensive and sustainable building practices.

Architects and engineers must increasingly integrate energy design computational tools and algorithms to explore the vast array of design possibilities, so that they can take advantage of both energy conservation measures and renewable energy resources. Integrating energy modeling with the design process allows the design team to dynamically assess the impact of factors, such as orientation, shape, materials and system specifications, on the building's energy consumption.

It is important to engage this process early in the design workflow, as early decisions on orientation and massing have an outsized impact on renewable energy generation potential.

Traditionally, rooftop-mounted photovoltaic (PV) systems have predominantly fallen within the domain of integrators or contractors in the construction industry. However, as solar technology advances and becomes more mainstream, there is a growing trend toward collaboration among architects, engineers and integrators from the early stages of building design. This collaborative approach ensures that rooftop PV systems are integrated into the overall architectural vision, optimizing both aesthetic and energy performance for sustainable and visually cohesive building designs.

Integrators can deploy small PV systems on roofs that have already been designed by working around obstacles such as mechanical equipment and allowing for maximum energy yield within the design constraints. Depending on building type, 1%-15% of annual energy consumption may be achievable as a bolt-on system. This has been the traditional process of integrating renewable energy generation to satisfy modest sustainability standards and emerging code requirements.

However, achieving impactful energy production targets of 30%, 50% and 100% to meet zero-energy building requires a much more robust analysis that could impact the overall building mass, form and orientation.

While rooftop solar presents a valuable solution for offsetting energy consumption in buildings, it faces limitations when dealing with structures that are either energy-intensive or exceed a single-story height. The primary constraint lies in the limited roof area available for hosting a PV array of sufficient size to fully compensate for the energy demands of such buildings. Energy-intensive structures, like health care or science and technology spaces, often require a substantial amount of power, surpassing the capacity that a standard rooftop can host. In multistory buildings, the challenge is further exacerbated, as the available rooftop space becomes proportionally insufficient to generate the required energy to meet the building's needs.

Moreover, architectural features, equipment and obstructions on the rooftop can further restrict the available space for installing a solar array. As a result, even with advancements in solar technology and increasing efficiency of PV systems, there are practical limitations to the extent to which rooftop solar alone can offset the energy consumption characteristics of these buildings.

To enhance the solar energy generation potential of rooftop PV arrays, architects and designers will need to explore innovative solutions such as extending the roof line through additional covered areas or integrating parking canopies. By strategically extending the roof structure to cover outdoor spaces, such as walkways, patios or building perimeters, designers can effectively create additional surfaces for solar panel installation. This approach not only maximizes the use of available rooftop space but also contributes to the creation of functional and shaded areas, enhancing the overall usability and comfort of the built environment.

Parking lots offer expansive, open areas that can be optimized for solar energy generation without compromising valuable roof space. Solar parking canopies not only provide shade for vehicles, but also generate clean energy simultaneously, turning traditionally underused spaces into dual-purpose, sustainable assets. By creatively extending the reach of PV arrays through architectural innovations, designers can overcome the challenges posed by limited rooftop space and harness solar energy more efficiently.

To illustrate the importance of minimizing EUI and early project team engagement with PV design, consider a two-story university building in the Midwest. The gross floor area of this building is just over 85,000 square feet. To reach the AIA 2030 Commitment's current metrics, this building would need to be designed to meet an 80% energy consumption reduction from a baseline building. Using Architecture 2030s Zero Tool, it was found that this would equate to an EUI of 31 or less for a university building in this location.

← **Figure 4**
More compact building massing (low rise buildings) presents better thermal performance through reduced heat loss exposure, enhanced photovoltaic yields through increased roof areas, and lower embodied carbon through simpler structures.

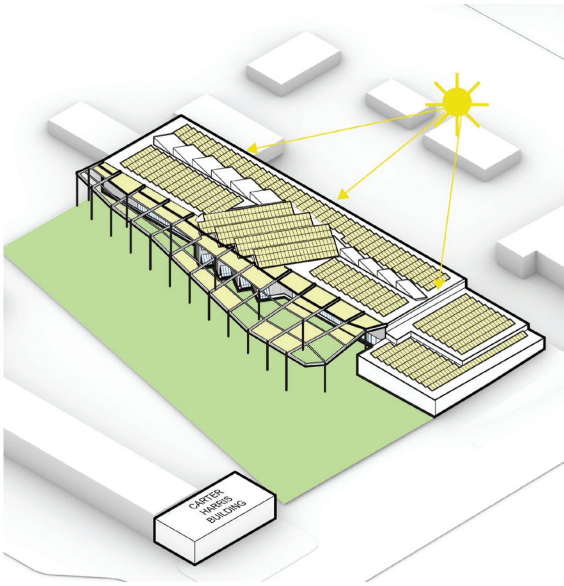
Courtesy: CannonDesign

Modeling for PV use

Targeting a low EUI is essential to making zero energy an achievable project goal. Each project will have unique goals, requirements and constraints; and consequently, the target EUI for each project will be unique. In many situations, once a sufficiently low EUI target has been established, it may be more cost-effective to focus efforts on increasing PV generation as opposed to minimizing energy consumption.

In this example, targeting a 31 EUI would equate to an annual consumption of just over 773,000 kilowatt-hours per year. The area of the conventional low-slope roof available to accommodate PV modules is just under 33,000 square feet. Using the National Renewable Energy Laboratory's PVWatts calculator, it was estimated that the roof area could support a 460-kilowatt PV array that can generate up to 632,000 kilowatt-hours per year.

With an 80% reduction in EUI from a typical building and by using available roof space, a design team could offset up to 82% of the energy consumed by the building. This was modeled using two-story building dimensions. A three-story building occupying the same footprint would have a very similar roof area available for a PV array. This would result in increased energy consumption, but similar energy production compared to the two-story building considered. As gross floor area is expanded vertically, the percentage of energy consumption offset is reduced.



↑ **Figure 5**
Low rise buildings present better ratios of roof area to program area; allowing for increased photovoltaic generation to offset intensive EUI values of commercial buildings.

Courtesy: CannonDesign

If it is a project's goal to achieve zero energy, then the project stakeholders will need to explore means of further reducing EUI or increasing surface area available for PV in these situations. These approaches will need coordination among the entire design team to implement. The earlier in the design phase that these are explored, the more effective they will be.

To meet the decarbonization challenge, architects and engineers will need to employ advanced design methodologies to achieve meaningful progress toward zero-energy buildings as a part of a standard of care. The zero-energy design process will include making hard decisions at project conception to prioritize different facets of sustainable design strategies, including energy conservation and renewable energy generation. Accomplishing impactful renewable energy generation requires architects and engineers to look beyond obvious solutions to develop integrated deployments of PV arrays.

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