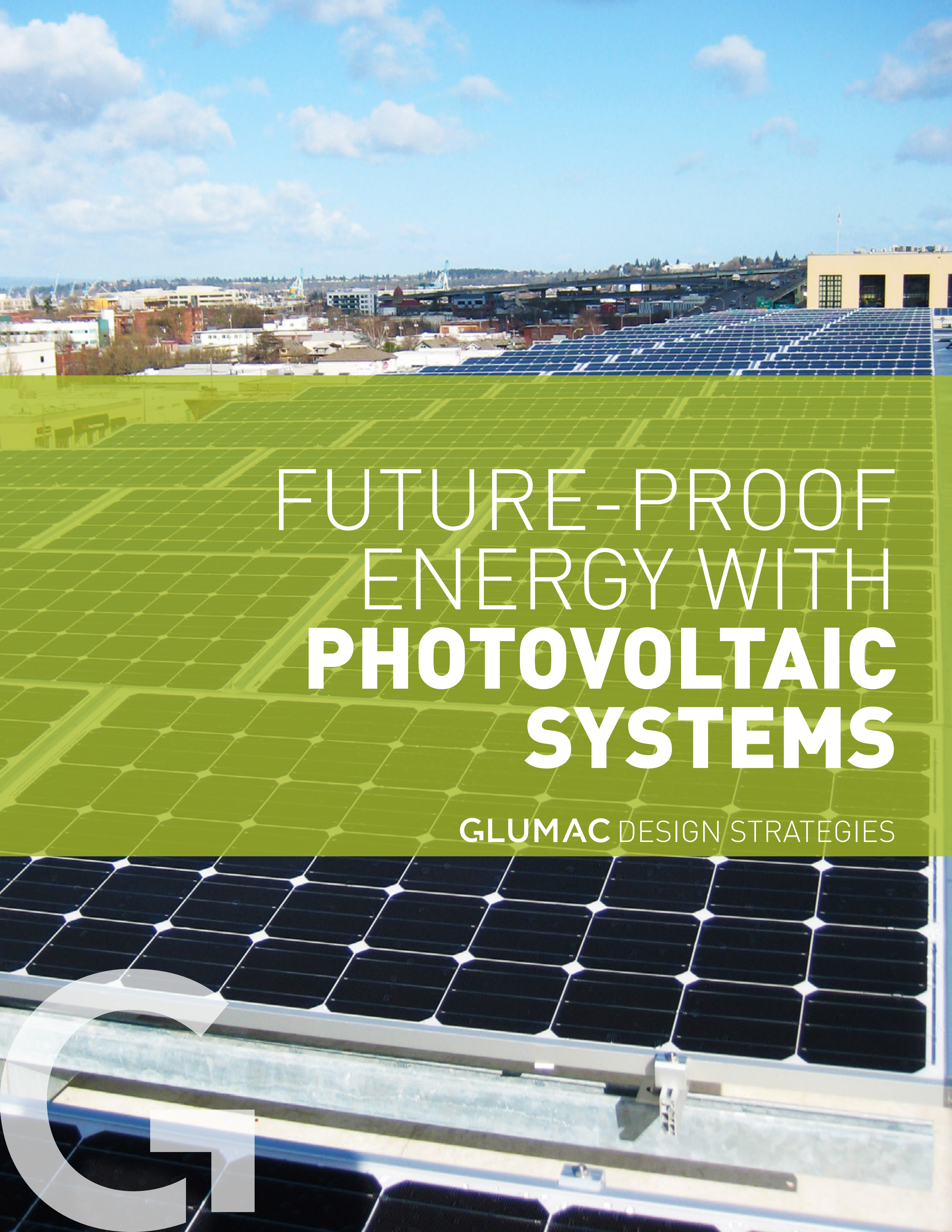


FUTURE-PROOF ENERGY WITH **PHOTOVOLTAIC SYSTEMS**

GLUMAC DESIGN STRATEGIES

SOLAR
PANELS FOR ON-SITE ENERGY

PHOTOVOLTAIC SYSTEMS

The direct conversion of sunlight into electricity with solar cells connected in a series and in parallel, and are a major tool in achieving net-zero energy.

Solar electric – or photovoltaic (PV) – technology shows incredible promise in powering the world's buildings. The physics of PV have not changed: the energy of absorbed light transfers to electrons in the atoms of the PV cell's semiconductor material, converting sunlight directly into electricity. However, dramatic improvements in material chemistry allow those cells to produce energy from a much broader spectrum of light while making PV system junctions and other components more efficient. Today, the U.S. leads the world in R&D spending for solar technologies, with substantial investments in thin-film PV. The number of grid-connected PV installations as of Q1 2011 had grown 66 percent over Q1 2010. The cost of producing PV, too, continues to decline as manufacturing capabilities scale up, while installation costs drop with in more experienced, trained installers enter the work force. In fact, the average cost of these systems decreased by more than 30 percent from 1998 to 2008 thanks to numerous national, state and local incentives.

Solar potential spans the continent and may be applied virtually anywhere. Glumac continues to specify and design building-integrated PV systems for a growing number of projects. While first cost (currently around $2.50/W installed for 2011) remains higher on average compared to conventional energy sources, tax credits and utility rebates can make these installations cost-effective.

BUILDING INTEGRATED PHOTOVOLTAICS

While stand-alone PV systems represent a valid option, integrating photovoltaics into architecture can further optimize performance with several added advantages. Examples include:

- Shading canopies provide a triple benefit of generating electricity, reducing cooling loads, and minimizing glare.
- Using photovoltaic panels for rooftop equipment screening provides a dual benefit of creating electricity and reducing the solar load on the roof, as well as screening equipment with a material that provides a visible symbol of sustainability.
- Parking garage canopies utilize a rooftop PV array to shade cars, reduce cooling load and create energy. Additionally, the panels can assist in rainwater capture for toilet flushing or irrigation; otherwise, the top deck of a parking garage, typically contaminated with oil and gas, presents a problem for water quality.

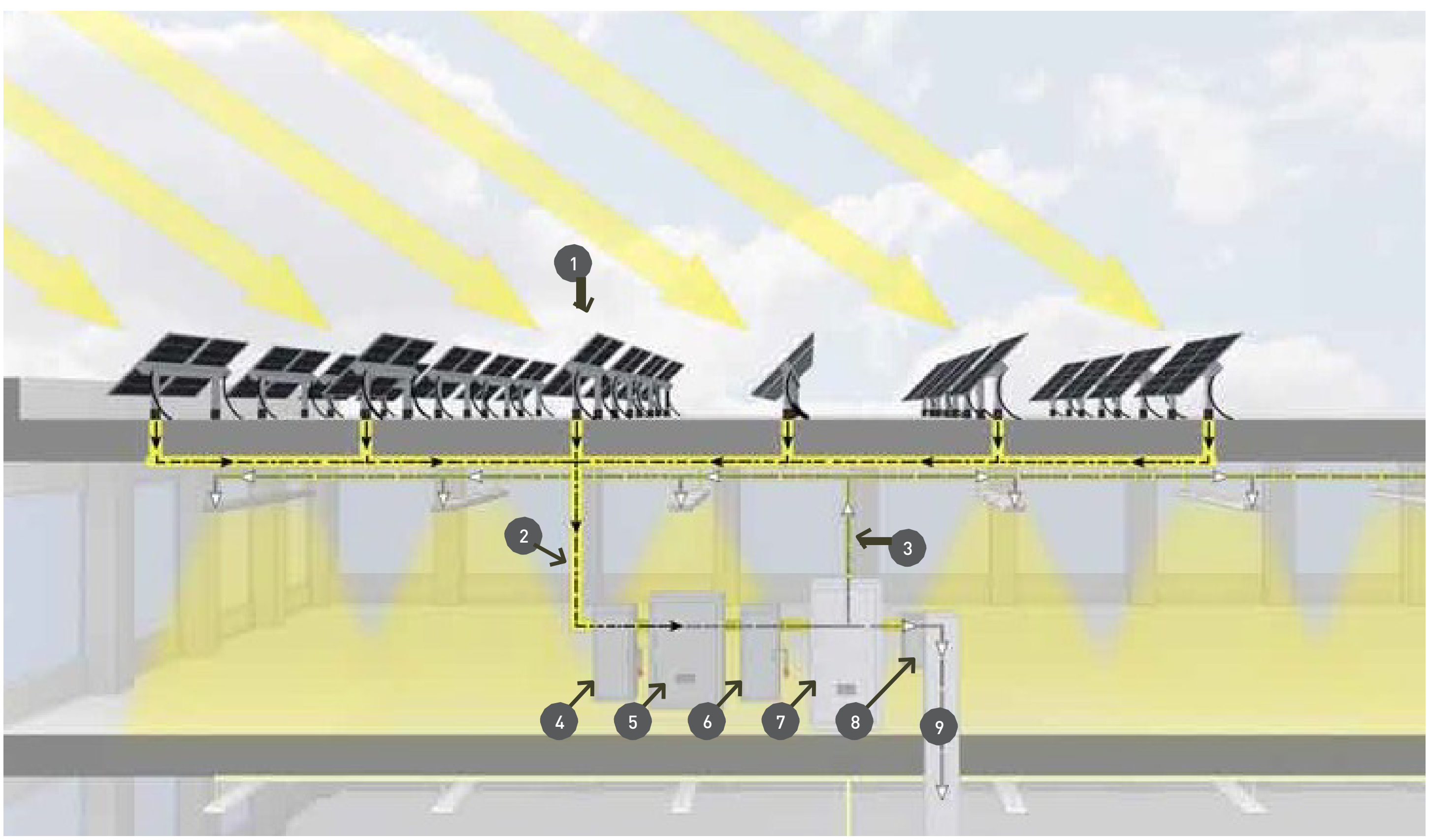
SOLAR CELLS, MODULES, ARRAYS AND THE BALANCE OF SYSTEM

Individual solar cells, the building blocks of a PV system, vary according to crystallinity, bandgap, absorption and manufacturing complexity. Because a basic solar cell produces a relatively small amount of power (typically 1 or 2 watts), manufacturers connect cells together to form PV modules or panels that may extend up to 4 feet by 10 feet (1.2m by 3m) in size. In turn, installers combine and connect panels to form PV arrays of different dimensions and power output to meet varied, and growing, electrical requirements. As part of an array, panels may be fixed in

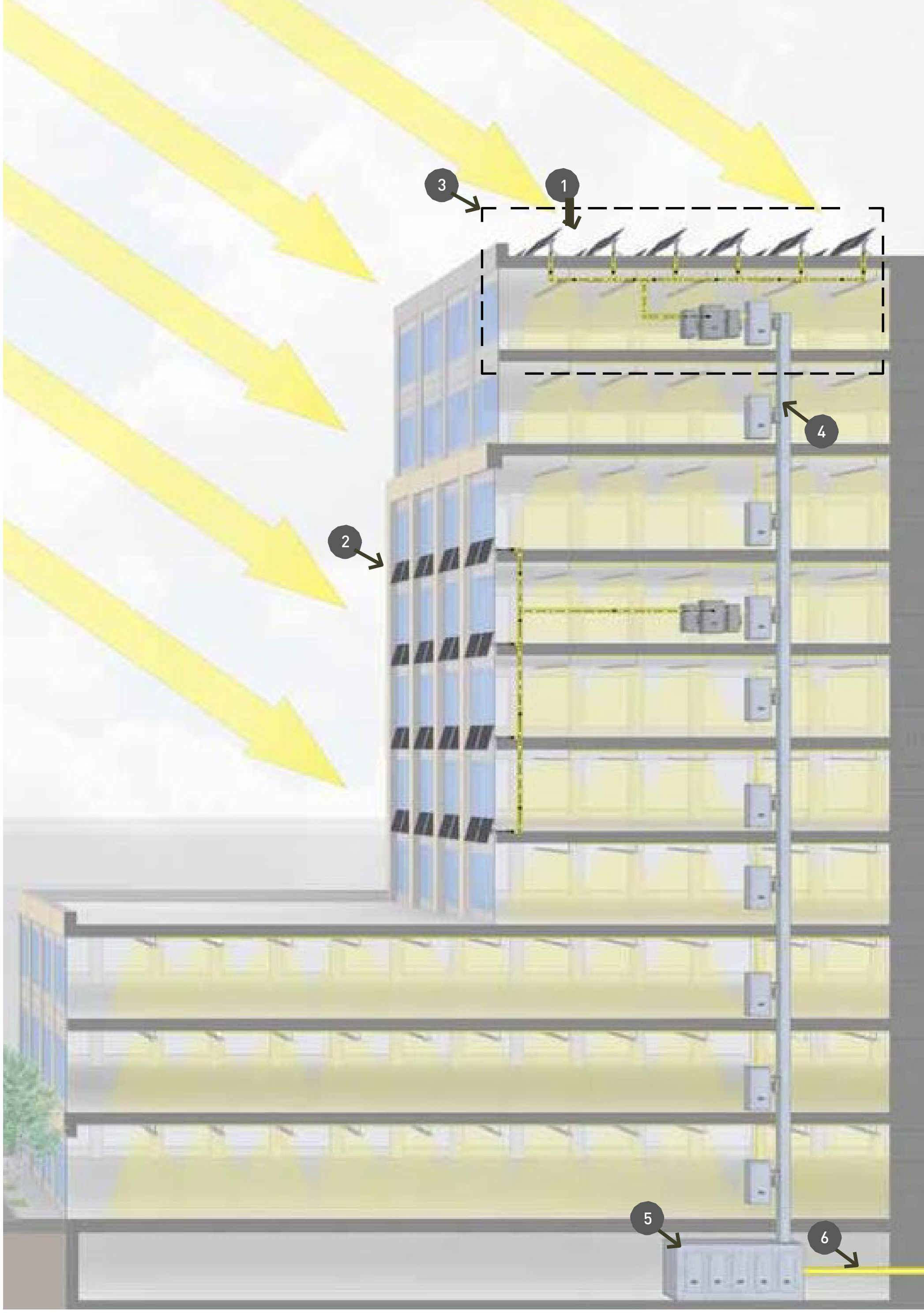
THE BREWERY BLOCKS ROOFTOP PHOTOVOLTAIC SYSTEM

1. PV rooftop array
2. DC source circuit wiring
3. branch circuit wiring
4. DC disconnect
5. inverter
6. AC disconnect
7. distribution panel
8. bus plug-in circuit breaker
9. electrical riser busway

Portland PV: Even the Pacific Northwest offers viable solar potential to offset fossil-fuel based power. Glumac's photovoltaic scheme for the Pearl District's Brewery Blocks development combines rooftop and building-integrated photovoltaic systems, connected through a system of collectors and inverters to the electrical distribution system of one building – producing more than 20,500 kW annually.



THE BREWERY BLOCKS INTEGRATED PHOTOVOLTAIC SYSTEM



1. rooftop PV array
2. building integrated PV array
3. area shown in detail illustration
4. electrical riser busway
5. main switchboard
6. electrical service from utility grid

place, generally facing south, or mounted on a tracking device to follow the sun.

Glumac designers give careful consideration to connecting enough PV panels to achieve a terminal voltage of 380 to 400 volts. Next, they combine strings of 15 or 16 panels each to add capacity (in a typical scenario). While south-facing roofs and surfaces offer the most ideal orientation for energy production, it is also critical to mount and position PV panels so an entire array receives equal amounts of sunlight. Balance of system (BOS) components consist of mounting or tracking structures for the PV arrays and power conditioners, which serve an essential function in processing the electricity produced by the PV system to meet energy load demands. For DC applications, regulators provide power conditioning; for AC loads, the equipment must include an inverter to convert DC electricity into AC power. Batteries and a battery backup system store solar energy for use when the sun is not shining. Finally, charge controllers protect batteries from overcharging and excessive discharge. Inverters also serve a critical purpose in power generation, commonly applied in three ways: to support discrete loads, for battery backup, or as part of a grid-connected system – contributing energy to a utility's electrical grid during the day, then pulling load from the grid in the evening.

PROCESS/TOOLS

In planning and sizing PV systems, Glumac utilizes Department of Energy (DOE) software to calculate projected

Application of **photovoltaic technology** to projects for supplemental energy continues to grow – and is helping projects achieve greater levels of **sustainability** and **energy efficiency** across the globe.

kilowatt hours per year for a given location and orientation. Designers also offer several best practices and rules of thumb when applying photovoltaic technology:

- Influence the architecture to suit PV systems – making it easier to incorporate later
- Maximize square footage if possible: regardless of location or orientation, the more space allocated to PV, the more energy produced
- Ensure consistent maintenance practices – clean panels will optimize output
- Understand that a 100 kW PV array, for example, does not always produce 100 kW of electricity. Capacity represents the biggest misnomer about PV systems, with energy production lower in early mornings and late afternoons; even an overcast mid-day only generates approximately 80 percent out of each panel. As a result, designers recommend sizing the system's inverter so that more strings may be added later as needed.

FURTHER DESIGN FACTORS

The decision to pursue PV relies on a motivated client willing to pay a (rapidly falling) higher first-cost and dedicate an adequate percentage of available area to the system. LEED and government incentives continue to drive its adoption as well. Ultimately, design for photovoltaics comes down to timing, peak demand, and building load targets. Energy use and storage choices, in particular, call for determining whether a PV application utilize batteries or operate as a stand-alone system.

The introduction of third-generation PV cells and new federal solar initiatives make this an exciting arena as well. In addition to research on more reliable inverters and long-duration energy storage, the DOE's SunShot program aims to cut the installation of large-scale solar power to $1 per watt without government subsidies by 2020. G