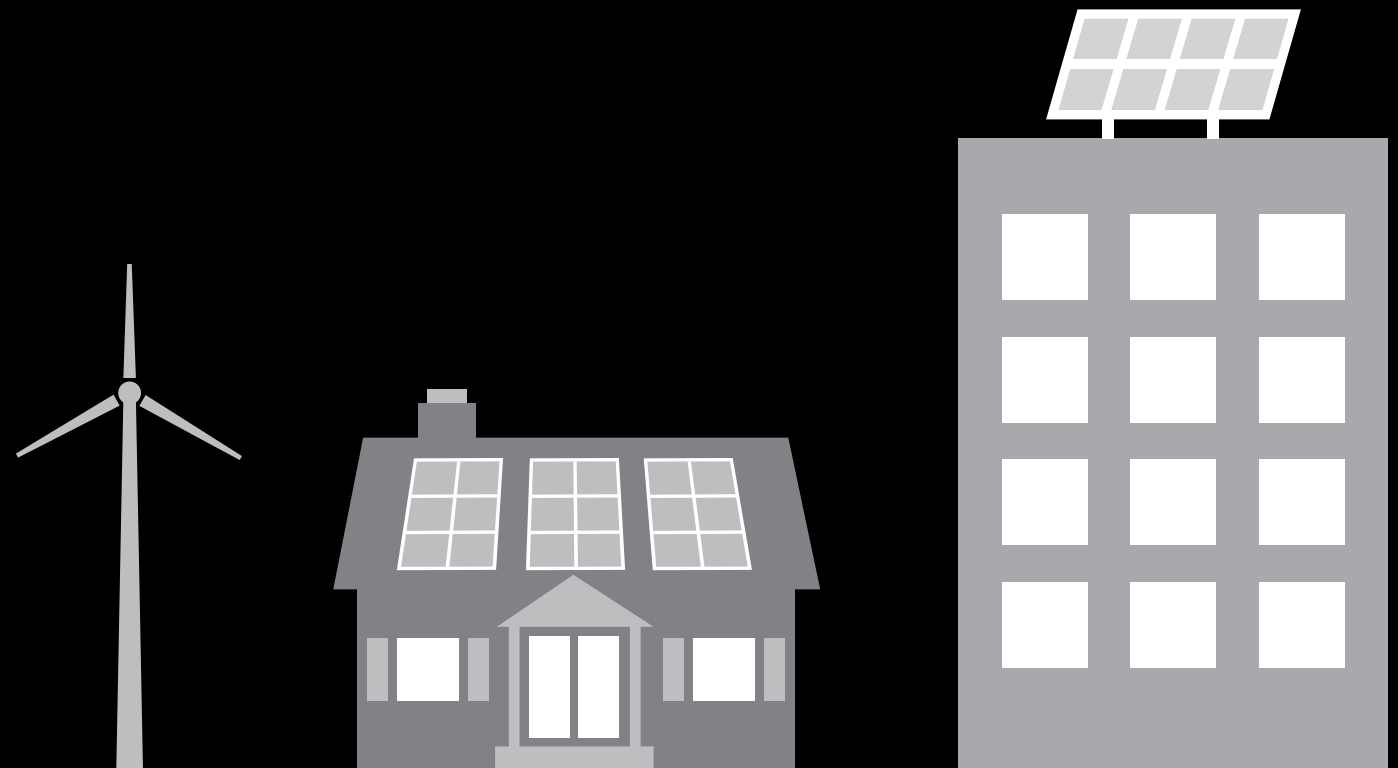




Architect's Primer on Renewable Energy



SPRING 2021

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I. Introduction

With the impacts of climate change increasing dramatically, and the cost of renewable energy technologies decreasing dramatically, now is the time to incorporate a renewable energy solution for every project you undertake. As an architect, clients and the design team look to you for leadership, setting the tone for design and the design process. You have the power to offer renewable energy for serious consideration.

The good news is that incorporating renewable energy into your projects is probably easier and more affordable than you think. You don't have to be an expert. You simply need enough information to begin the necessary conversations and investigations, and to find the right expertise for the design team.

The basic steps for most projects:

1. Set energy use intensity (EUI) targets
2. Use design strategies to optimize energy performance (e.g., massing and orientation, natural ventilation, solar and shading, daylight, envelope/ façade) and select energy efficient technologies and strategies (e.g., HVAC equipment and schedules, internal loads reduction strategies and schedules).
3. Use building performance simulation (aka energy modeling) to determine the anticipated energy needs of the building from both conventional and renewable sources.
4. Offset EUI from conventional sources with renewable energy—on-site and/or off-site.

5. Design “solar ready” if solar is not installed as part of the project already.

6. Discuss resilience and energy storage with your client.

A roof-mounted solar photovoltaic (solar PV) is the simplest, most economical form of renewable energy for most building types and climates. Small wind systems, micro-hydro systems, and heat and electricity from biomass are also options. Energy efficiency technologies that use some form of renewable energy (e.g., solar thermal systems and air-source, ground-source, and water-source heat pumps) are good options to pair with other renewable energy technologies. Battery and thermal storage can help you optimize the use of renewable electricity generation. And if you can't include renewable energy on a project, procuring off-site renewable electricity and designing “solar-ready” are musts.

Buildings as energy producers: This is the cutting edge of design for architects today. The electric grid is changing significantly. Nearly all electricity in the U.S. used to be generated by coal-fired power plants and large hydroelectric projects, and that electricity was distributed to customers far and wide with a lot of inefficient losses in the process. More and more electricity is now being generated by “distributed resources” such as rooftop solar PV, rather than centralized power plants. The electric grid is a massive network, and, historically, buildings have been passive consumers on that network, consuming 70% of the electricity generated in the

U.S. Increasingly, with distributed energy systems, leading the charge, buildings are becoming active participants in that network—as energy producers, not just passive consumers. Already in some jurisdictions, renewable energy is a requirement, not a choice, for new construction. Requirements for “solar-ready” new construction are becoming more common. With climate change becoming a more urgent issue, it stands to reason that these kinds of requirements will not remain outliers. If you want to remain competitive and distinguish yourself in a crowded field of architectural firms, your projects must include solar PV (or other on-site renewable electricity) as a critical part of their design or, at the very least, be solar ready.

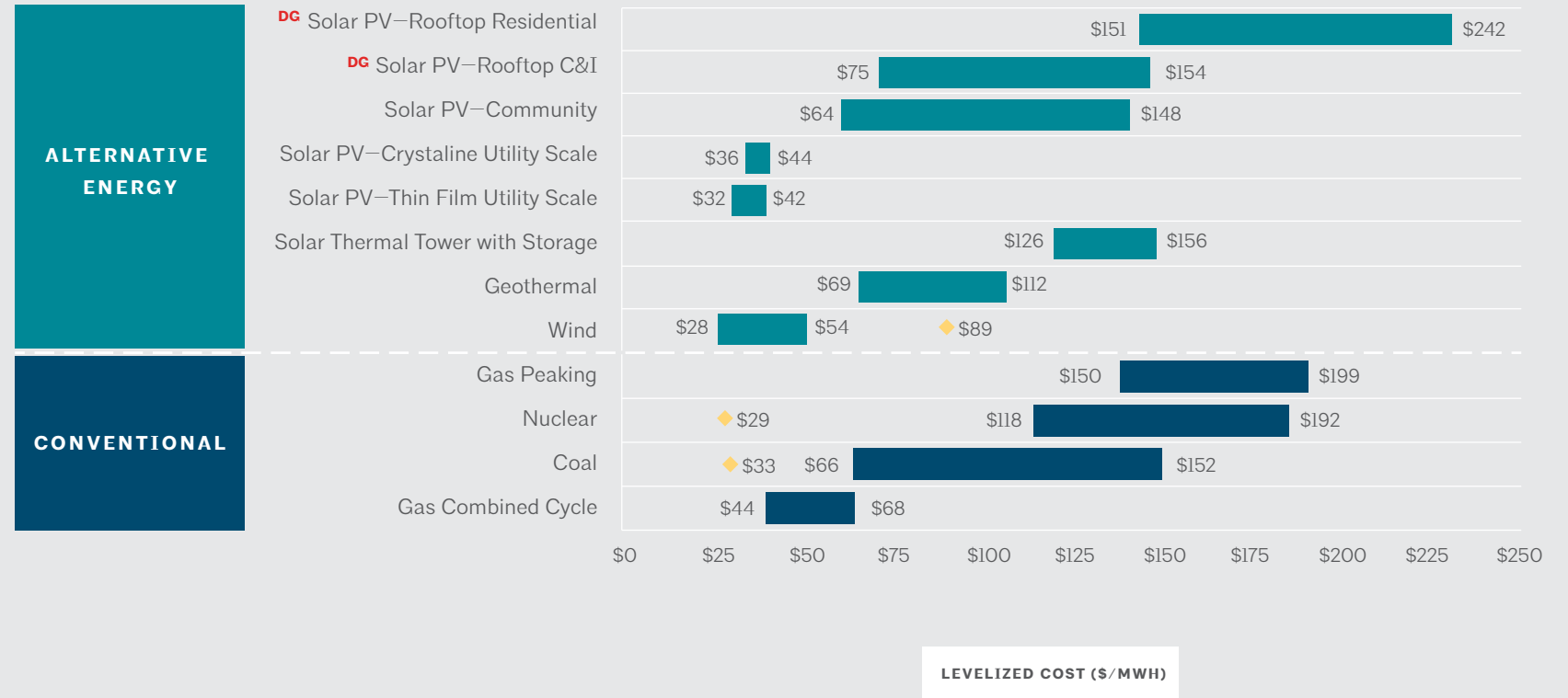
The financial case for renewable energy

Arguments in favor of renewable energy used to be about the environment and combating climate change, but for many projects, the costs just didn't pencil out. Recently, costs have come way down, while the environmental benefits remain.

The cost of renewable electricity is increasingly competitive with conventional electricity.

The cost of renewable electricity generation has decreased dramatically, even when financial incentives are not considered. Utilities, a notoriously conservative business sector, are building solar and wind generation because it is cheaper than fossil fuel and nuclear or hydro generation. As they add more renewable capacity, it helps lower the price of renewables for everyone else.

UNSUBSIDIZED LEVELIZED COST OF ENERGY COMPARISON

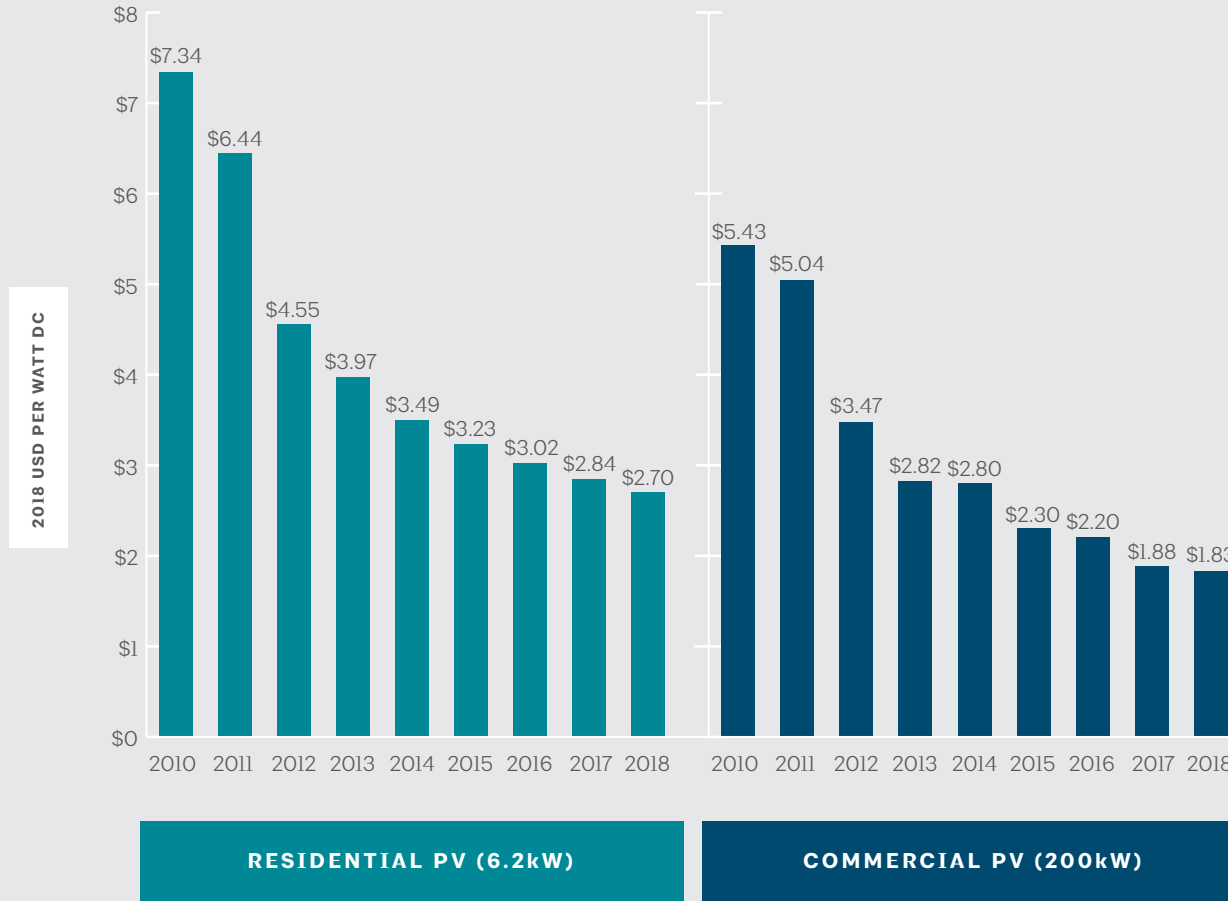


DG Distributed generation

Solar PV—the most likely choice for architects—is seeing significant cost reductions.

Solar PV has recently become cost-competitive with conventional electricity generation in many states, especially those with favorable policies. The “soft costs” of PV (e.g., design, permitting, financing, installation, and labor) remain relatively high compared to the hardware (PV modules, mounting system) and balance of systems (BOS) (inverter, wiring, switches, meters, batteries) costs. Nevertheless, total first costs have decreased significantly and will continue to do so as more building-scale installations occur, enabling expertise to grow and spread. Although design fees are part of soft costs, it’s important to note that reducing soft costs does not mean reducing fees. It means reducing the designer’s learning curve to increase profit.

2018 COSTS FOR RESIDENTIAL & COMMERCIAL PV



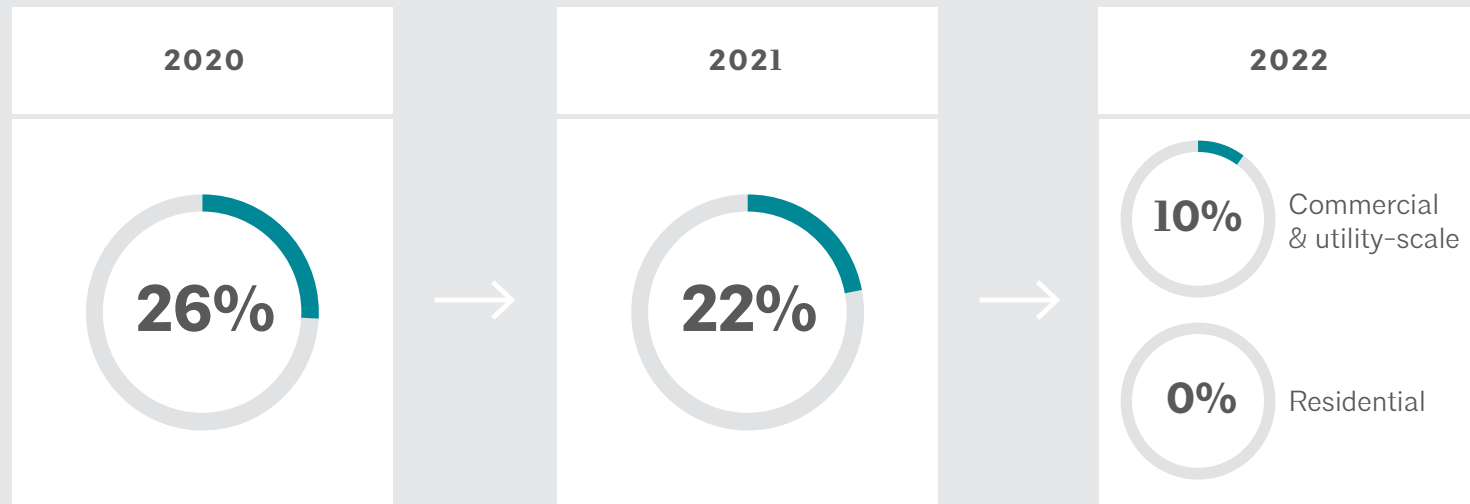
Now is a good time to invest in solar

Tax credits and financial incentives reduce the initial costs of solar PV systems. A federal investment tax credit (ITC) for solar is beginning to scale down, but it still reduces the cost of the system significantly. There are also many utility, state, and local incentives for energy efficiency and renewable energy projects. The best source of information about these incentives is the [Database of State Incentives for Renewables & Efficiency](#) (DSIRE). You should also check with your local utility and state energy office for information about incentives. The National Association of State Energy Offices (NASEO) has a helpful [membership directory](#) of state energy offices.

Fuel for solar, wind and micro-hydroelectric systems is free

Unlike fossil fuel systems, once these renewable energy systems are up and running their operational costs are very low. Renewable energy systems need differing levels of maintenance, but except for biomass systems, their fuel is free as long as the sun shines, the wind blows, and the water flows. Depending on the specifics of the project, biomass fuels can also be much less expensive than fossil fuels.

SOLAR ITC SCHEDULE



Benefits of renewable energy generation

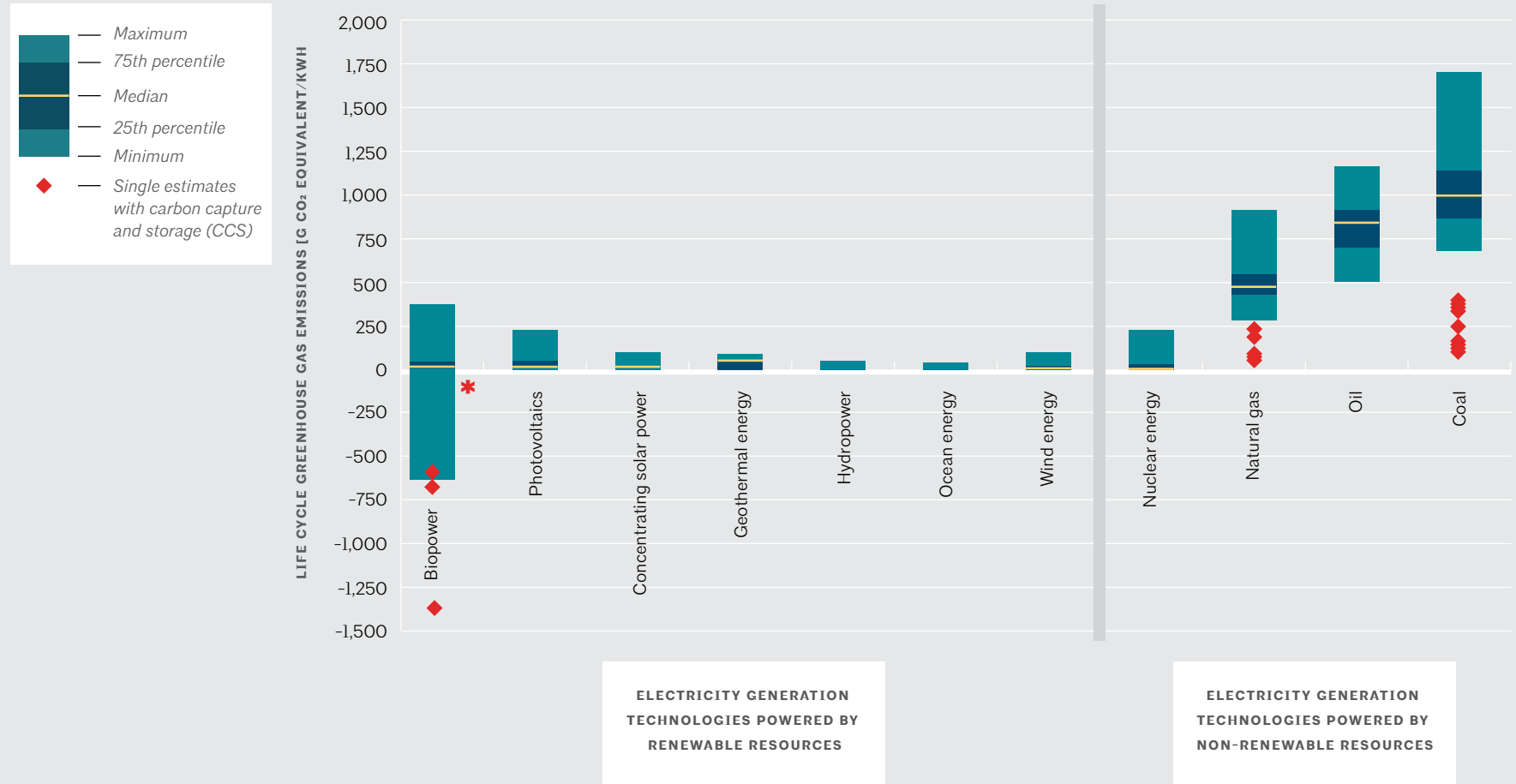
Transitioning to renewable electricity generation is essential for environmental quality and to reduce climate change.

The environmental benefits of renewable energy have only become more important in recent years. The AIA declared a climate emergency in July 2019 and adopted the [AIA Resolution for Urgent and Sustained Climate Action](#). To address the emergency, we must decrease the carbon intensity of electricity. Renewable electricity emits significantly less greenhouse gases than fossil-fuel generation.

Renewable energy is the future

Any important investment must consider the future. Both new and retrofitted buildings certainly qualify as important investments. Currently, the median lifespan of a commercial building is 70 to 75 years and should be longer. Because that lifespan has a lot of ripple effects for society at large, considering the future of a building is especially important. Diverse sources (e.g., [Bloomberg](#), [Deloitte](#), and [Forbes](#)) predict that renewable electricity will be the energy of the future.

RENEWABLE ENERGY TECHNOLOGIES HAVE LESS GREENHOUSE GAS EMISSIONS



* Avoided emissions, no removal of greenhouse gases from atmosphere

2. Before you begin

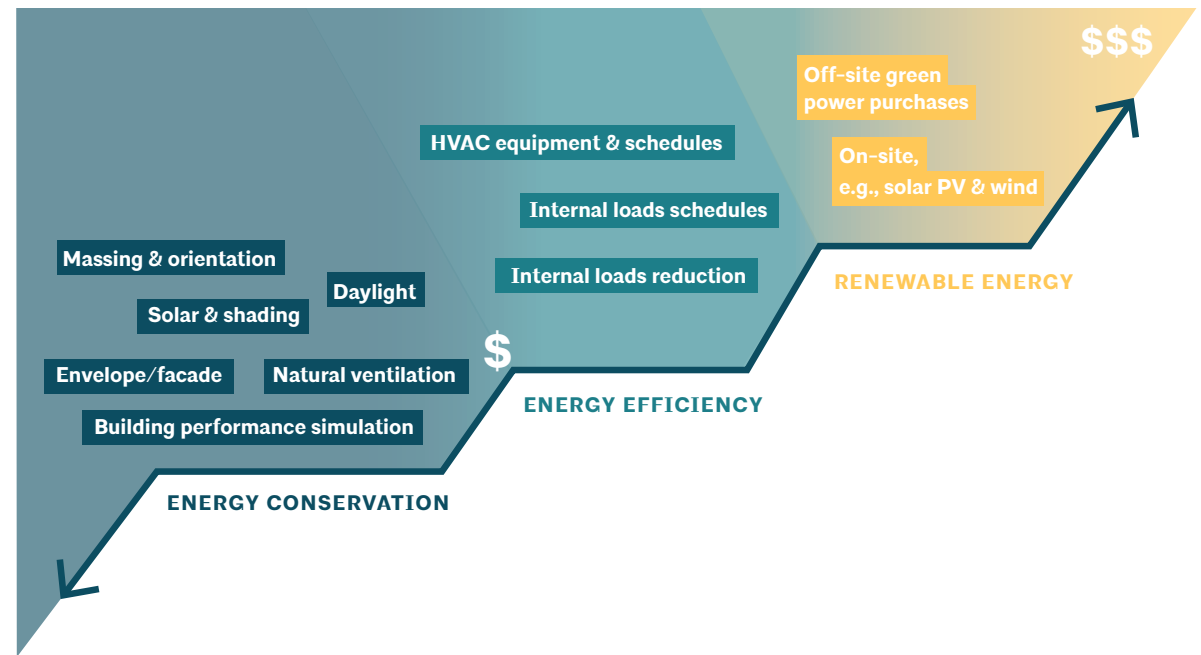
There are a few things to consider before you dive right into incorporating renewable energy into your next project. If you aren't familiar with the integrated design process, you should be. Designing a building that effectively and economically incorporates renewable energy requires multiple points of view on the design team early on and through multiple iterations of the project. [LEED 4.0](#) offers information about (and one point for) using an integrative process. You will also want to optimize energy performance by designing for energy conservation and efficiency first, and making rigorous use of building performance simulation (energy modeling).

Design for energy conservation and efficiency first

Including renewable energy in a project does not replace the need for good energy design practices. Designing for energy conservation and efficiency is essential to reducing the first costs of any renewable energy system; the less energy the building uses, the smaller the renewable energy system needs to be. Energy conservation and efficiency also add other benefits, including reducing building first costs through load reduction and operational utility costs. The [Architecture 2030 Palette](#) offers specific design strategies (scroll down for site- and building-specific strategies). The [AIAU AIA + 2030](#) series also explores many of these strategies.

Low EUI targets are crucial to buildings that incorporate renewable energy systems. Achieving these low EUIs, or getting all the way to net zero energy

CONSERVATION, EFFICIENCY, & RENEWABLE ENERGY



(buildings that produce as much energy as they use over the course of a year), can be challenging on many levels. Some architects perceive high-performance low-energy design and aesthetic design decisions as an “either/or.” In other words, they might perceive achieving a low EUI as an unwanted challenge to their creativity as a designer. However, it can just as easily be said that if the architect isn't designing a building

that is high-performance, low-energy, and beautiful, how creative are they actually being? Designing beautiful buildings with low EUIs that incorporate renewable energy is the creative challenge for the architectural profession in the 21st century. AIA's [Framework for Design Excellence](#) (formerly COTE Top Ten) clearly supports this idea, in particular with its [Designing for Energy](#) component.

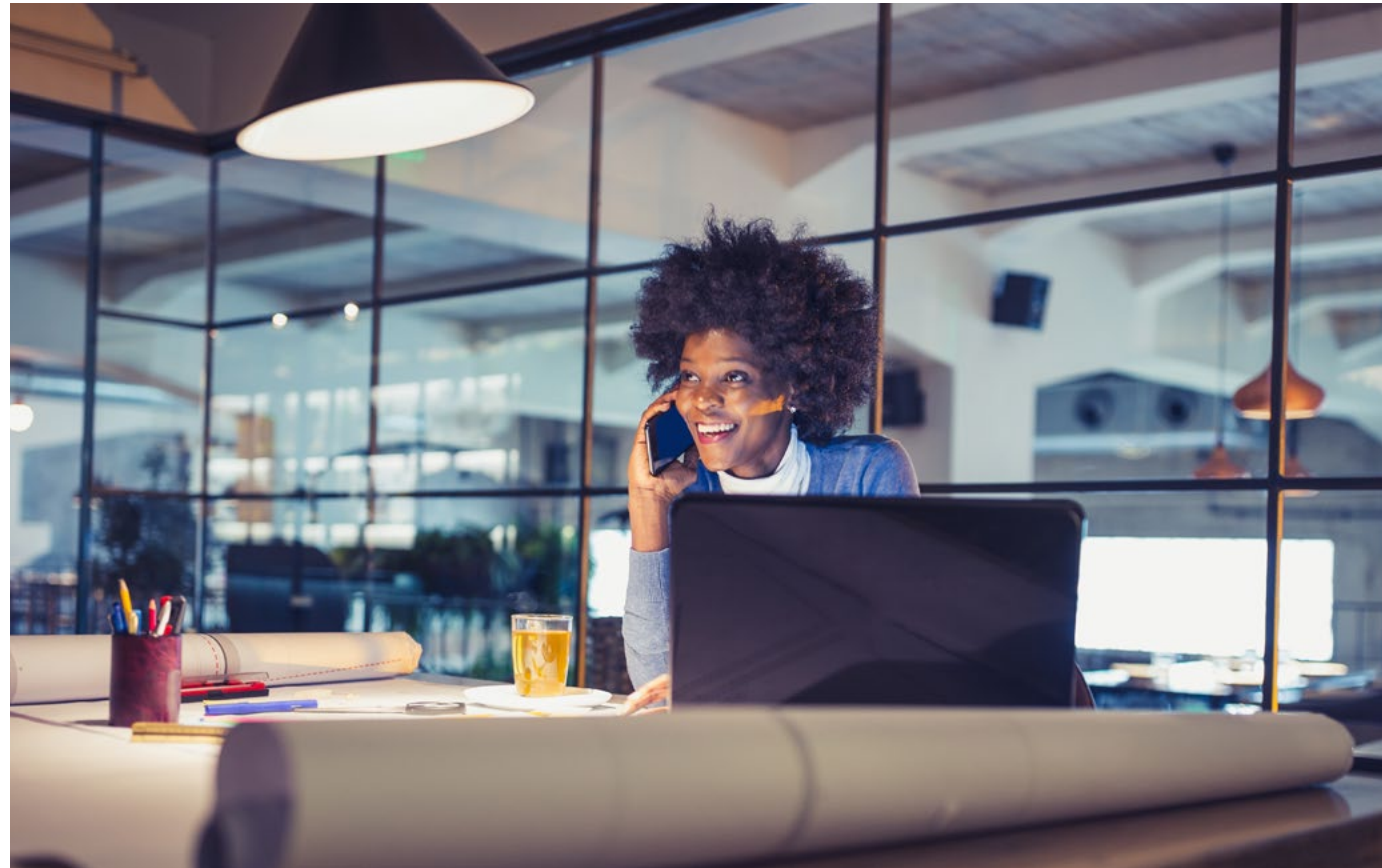
Building performance simulation/energy modeling is a must

To design a building best suited for a renewable energy system, and to reach critical EUI targets, building performance simulation is essential. AIA's [Architect's Guide to Building Performance](#) can help you integrate building performance simulation into the design process and make better design decisions.



Have the renewable energy talk

Clients and design team members already look to architects for discussions about budget, square footage, program, materials, and more. Clients will also look to architects to lead discussions about strong EUI goals and renewable energy. The architect must provide the leadership to establish an energy budget that includes renewable energy and communicate that budget to the client and the design team. Similarly, the architect must be the one to lead discussions about, and make the case for, zero energy design. To do that, architects need to know more.



3. Renewable energy technologies

Having an open, curious, and creative mind is the best approach to selecting the right renewable energy system or systems for any project. Solar PV is usually the obvious choice for most projects. Nevertheless, there are other technologies that can work well for some projects, depending on location and available resources. For this reason, information about small-wind, micro-hydroelectric, biomass, and solar thermal systems is included in this brief.

The AIA+2030 online series includes a course entitled [The Role of Renewable Energy](#).

Solar Photovoltaic Technology

In recent years, PV prices have steadily decreased, making it cost-competitive with electricity generated from fossil fuel in many markets. If you haven't looked at incorporating PV into your projects lately, look again.



Rigid solar PV panels being installed on a roof.

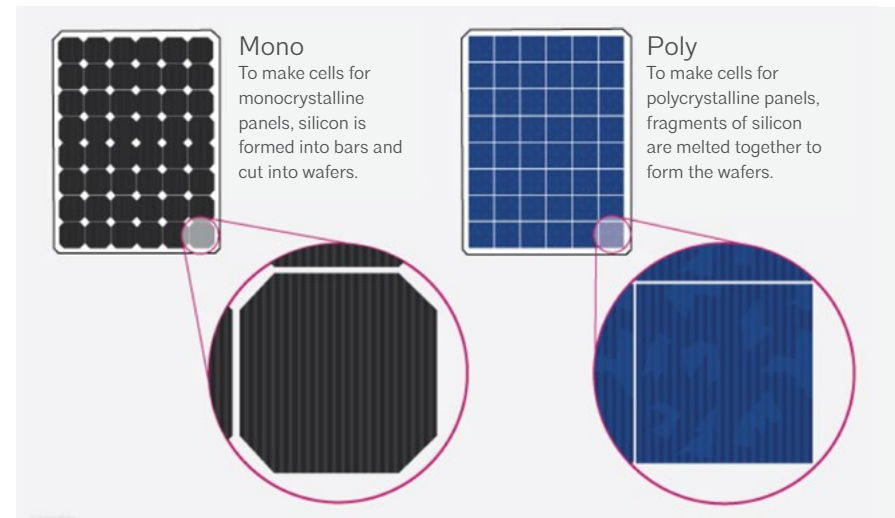


Illustration of mono- and polycrystalline solar PV cells.

There are two basic types of PV:

1. Rigid panels (either monocrystalline or polycrystalline)

- » 90% of the PV market
- » More efficient electricity production— monocrystalline 22–24%; polycrystalline 16–18%
- » Most common on rooftops
- » Additional options:
 - awnings, carports, shade structures, courtyard and walkway coverings
 - replacing façade to envelope materials

2. Flexible thin films

- » Less efficient electricity production (6–10%)
- » Require more square footage compared to rigid panels because they do not provide as much electricity output per square foot
- » Commonly used on glazing or in roofing materials
- » “Peel and stick” PV also an option
- » Typically, less available and less widely used; ensure there is local expertise for design, installation and maintenance

There are multiple options for integrating solar PV into building design or mounting solar PV on a structure or site.

Building Integrated PV (BIPV)

- » PV (rigid or thin film) is integrated into the building envelope.
- » BIPV replaces a building component or material (e.g., roofing, curtain wall, glazing, exterior cladding).

Design considerations

Design decisions—orientation and tilt of the PV system and available area without shade—have a much greater influence on the performance of solar PV than does building location. Like any building system, designing and installing a solar PV solution that integrates successfully with overall building design requires specific expertise, and that expertise needs to be on the design team from the very beginning. If you don't have expertise in-house, a solar consultant or installer can help.

Orientation

- » Building design must feature an open roof area or façade with long east-west axis for maximum southern exposure.
- » South-facing PV generates the most electricity.
- » Southeast, southwest, and west orientations can work too—don't stress over perfect orientation.
- » Solar PV system designers and installers use software to predict annual performance of different PV system solutions.

Tilt

- » PV systems should be tilted toward the sun at an angle equal to the latitude of the location.
- » A 15- to 40-degree pitch can work; don't stress over perfect tilt.
- » Tilt has less of an impact than orientation.
- » Rack-mounted PV on flat roofs require a suitable tilt, but design must ensure one panel doesn't shade another to an extent that it compromises the optimal operation of the system.



Skylighted entryway featuring solar PV laminated to glazing provides electricity as well as shade and daylight.

Solar resources

Contrary to a common myth, solar PV makes as much sense in the sunny Southwest as it does in the Northeast. Policies and incentives have a much greater impact than solar resource. That said, it is important to understand that solar PV is an intermittent source of electricity, usually generating the most electricity 10 am–2 pm, with more generation in summer than winter. But that doesn't mean it doesn't generate anything during the winter, because the sun still provides light; plus, cooler temperatures often make PV operate more efficiently. The National Renewable Energy Laboratory (NREL) online [PVWatts Calculator](#) is a great place to start exploring available solar resources at a specific site.

Roof-mounted PV options:



A flush-mounted rooftop solar PV system.



A tilted-rack mounted rooftop solar PV system.



A rooftop solar PV system with ballasted footing mounts.



Solar PV flush-mounted to a carport/shading structure.

Shade

- » PV panels must be located so that they are not shaded.
- » Even a partially shaded PV panel or portion of a PV panel provides reduced electricity production.
- » As a rule of thumb, no panel should be shaded more than 10% during peak hours of operation.
- » Other buildings and structures, building equipment, trees and landscaping, and other PV panels can cause shade.
- » Consider both present and future shade potential.
- » Keep landscaping and trees trimmed to prevent shading.
- » Research possibilities for neighboring new construction; not all jurisdictions have solar access and easement laws to protect each building's right to the sun.

Site layout

- » Careful site planning ensures the greatest amount of area possible for the PV.
- » The area (or areas) with the greatest solar resource and the least shading are best for solar PV placement.
- » Whatever surrounds it must not cast a shadow over the PV.

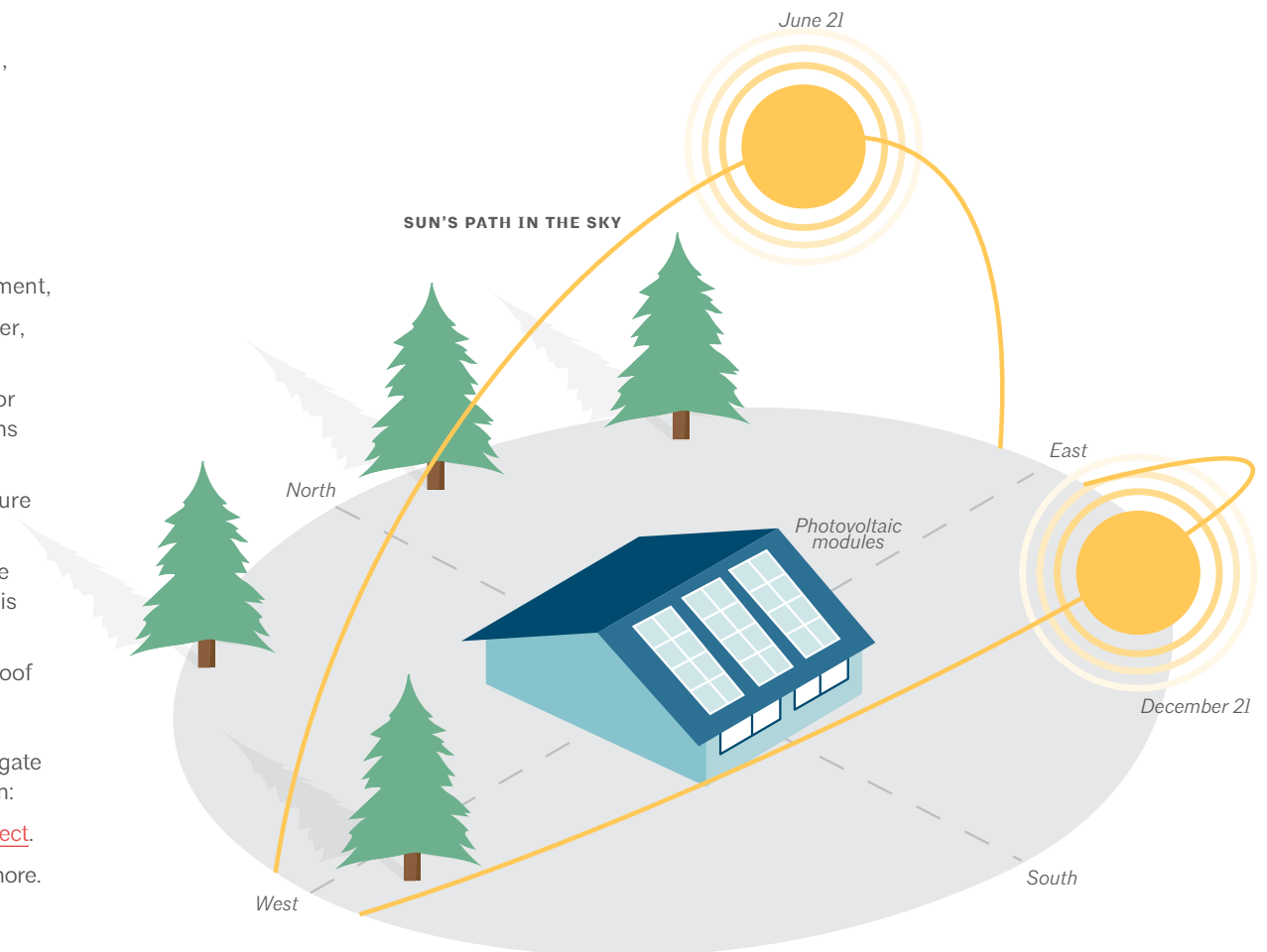
Roof considerations

- » Roofing type will likely determine how the PV system is mounted.
- » Most roofing types work: metal standing seam, Spanish and clay tile, EPDM, TPO, and PVC.
- » Slate and wood shingles are not good roofing materials for PV installation.
- » Area available for PV is maximized by:
 - minimizing roof penetrations,
 - minimizing area dedicated to rooftop equipment,
 - grouping penetration and equipment together, and locating them on the north side.
- » Walking aisles and perimeter provide access for façade and roof maintenance; roof penetrations can be grouped near aisles.
- » Safety equipment for solar installation and future access to the PV system are required.
- » A PV system can add 3 to 6 pounds per square foot; work with an engineer to ensure the roof is capable of carrying the load.
- » Wind loads should be analyzed to ensure the roof structure can support the PV system.

A number of resources are available to further investigate solar PV technology and the feasibility of a PV system:

- » AIAU offers a course on [Solar PV and the Architect](#).
- » energysage offers a [Solar IOI](#) series and much more.

INTEGRATING SOLAR PV INTO DESIGN





Solar-ready architecture featuring a long east-west axis with adequate south-facing roof for solar PV

Solar-Ready Design

[Consumer preferences](#), [state and local policies](#), and costs are all pushing us toward a renewable energy future. You want to be ready, and you want your clients to be ready. Even if you can't find a way to include solar PV on a building project today, any new or renovated building project should be optimized for solar PV in the future.

[NREL's "Solar Ready Buildings Planning Guide"](#) offers detailed information, and its [State, Local, & Tribal Governments program blog](#) offers the highlights. Solar-ready building features include:

- » Design building massing and orientation to optimize solar PV performance. Usually this means a long east-west axis to maximize south-facing roof area, but west- and/or east-facing PV may also make sense.
- » Be mindful of current and future shading.
- » Minimize and group roof obstructions.
- » Design extra roof load capacity, and specify roofing materials that will last the life of the solar PV system.

- » Pre-install conduit from roof to equipment room.
- » Set aside space in the equipment room for balance of systems (e.g., inverter, breaker, meter).
- » Ensure buildings systems can accommodate PV interconnect/disconnect infrastructure.
- » Set aside space and ensure infrastructure for future battery storage.

Other renewable energy technologies

Whereas solar PV is the most common renewable energy technology specified, it isn't the only option. Small wind and micro-hydroelectric are potential options for building sites with adequate resource and available space. Biomass for heating or electricity generation (or both) can be either a building-level or building-site technology.

Wind

Architects are most likely to consider small wind systems (up to 100kW). Larger wind systems are generally considered utility-scale. Small wind systems consist of blades, a rotor, generator or alternator, and usually a tail, all of which are mounted on a tower. The rotating axis of the turbine can be either horizontal or vertical.

Wind resources

Wind systems need adequate wind resource to produce enough electricity to make the investment cost-effective. The [WINDExchange](#) website has abundant information about wind resource. These maps are a good place to start, but more in-depth site-specific analysis is required. A local dealer or wind-turbine manufacturer can usually estimate the annual production of a specific turbine size at a specific height, given the microclimate of the site. It can assess the best system to match the



A typical horizontal-axis small wind turbine with blades, rotor, generator/alternator and tail atop a tower.



Small vertical-axis wind turbines

demand of the building to determine whether the wind system alone is sufficient, needs to be paired with another solution, or isn't a good option at all.

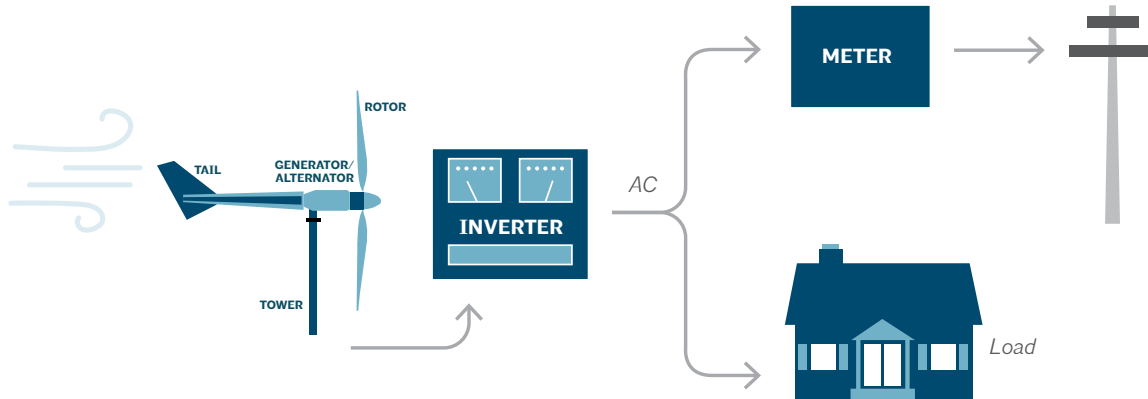
Design considerations

Generally speaking, wind is not a building-level technology. Turbines are usually installed on a tower on the building site rather than on a building because vibration from normal operation of the turbine travels down the tower and into the building. Towers enable turbines to both reach higher wind speeds and reach above the wind turbulence that can be present closer to the ground. Relatively small investments in increased tower height can result in very high rates of return in electricity generation. If a building-mounted system is desired, the building must be engineered to support the loads of the tower and turbine (e.g., weight and vibration), and provide adequate access to the wind resource and clearance for the equipment.

Small wind systems require adequate space for equipment and equipment clearance:

- » The U.S. Department of Energy (DOE) recommends building sites of at least 1 acre, but specific site conditions are the ultimate determinant.
- » Towers range from about 100 to 300 feet in height; they require:
 - clearance from surrounding buildings, structures, and trees;
 - enough clearance to accommodate the blades of the turbine (e.g., 15-foot turbine blades require a minimum clearance of 30 feet); local ordinances and/or insurance companies may require clearance that equals 1.25 to 1.5 times the height of the tower.

SMALL-WIND GRID-TIED SYSTEM



Whereas a manufacturer can provide analysis, it will likely refer you to a local dealer that can act as a consultant on the design team, install the system, and provide aftermarket maintenance. Ongoing maintenance by a qualified technician is critically important for a small wind system.

Some projects may want a small-wind system specifically because they are highly visible renewable energy systems. Schools, for example, may like the visibility of wind for educational purposes. A business or municipality may choose wind because it's good marketing and outreach to customers and the community—a farm supply company or municipal building in Iowa, for example, where farmers often lease their land to wind farm developers.

To further investigate small wind technology and the feasibility of a wind system, DOE has published an extensive [Small Wind Guidebook](#) (available online and as a PDF).

Hydroelectric

Hydroelectric power is most often a utility-scale technology associated with large dams. Those dams have significant environmental impact, so even though they produce low-carbon electricity that offers steady baseload power, in comparison to intermittent variable technologies like solar and wind, large-scale hydroelectric power is not ideal.

However, run-of-water micro-hydroelectric (“micro-hydro” for short) systems, if implemented correctly, cause less environmental impact. These small systems (thus “micro”) can be suitable for building sites that have access to naturally flowing water via a stream or river with suitable vertical drop. They use the natural downward flow of rivers and streams and micro turbine generators to generate electricity. Typically, water is taken from a river or stream at a high point (the diversion) and gravity-fed down a pipe (the penstock) to a lower point where it emerges through a turbine generator and re-enters the regular water flow. Installation of such a system can be

relatively cheap, has less environmental impact than larger hydroelectric power options, and still provides baseload (vs. variable) power.

Micro-hydro resources

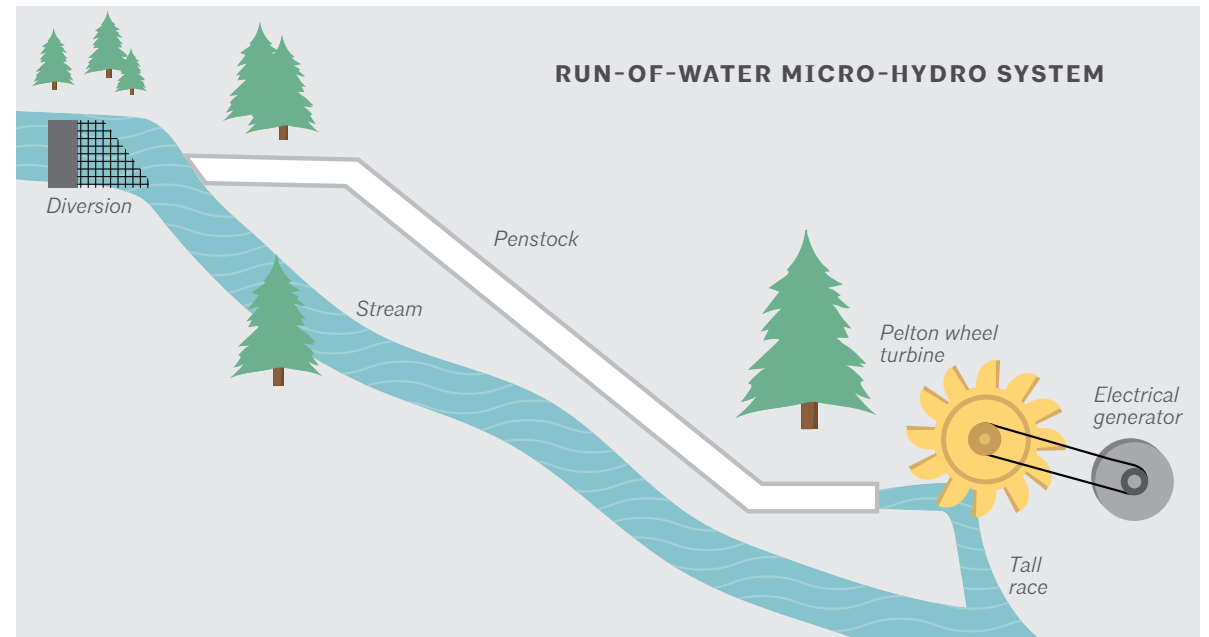
To determine the feasibility of a micro-hydro system, a site assessment is critical. This includes accurate measurements of head and flow.

- » Head: measure of total vertical drop of water—the difference in elevation of the source of water and the turbine; typically measured in feet
- » Flow: volumetric measure of moving water; should be measured throughout the year; typically measured in gallons per minute

Design considerations

Micro-hydro systems are not a building-level technology, but they can have significant site impacts. When designing the system there are important environmental and aesthetic considerations.

- » Design and locate intake diversion and screen (where the water leaves regular flow and enters the penstock) for easy maintenance access and minimal impact to wildlife.
- » Correctly size penstock, typically PVC or HDPE pipe, and install with minimal damage to the environment.
- » House turbine and generator, and install run of wire (carries electricity to building load) to maximize aesthetics and minimize environmental impacts.



Micro-hydro systems have specific permitting requirements that may involve more than local codes and ordinances. Depending on local utility policies, tying the system to the grid may be more complex than solar PV or small wind. Because the system typically impacts naturally flowing water, entities concerned with water resource rights and quality—including the U.S. Army Corps of Engineers and state/local natural resources and fish and game departments—may also have requirements. The importance of researching these permitting requirements before committing to such a system cannot be overstated.

The DOE has additional resources ([Microhydropower Systems](#) and [Planning a Microhydropower System](#)) as does Alternative Energy News ([Micro Hydro Power—Pros and Cons](#)). Appalachian State University provides a [Fact Sheet: Microhydro](#) that is intended for North Carolina but also contains helpful general information.

Biomass

Biomass is the use of organic material (i.e., from plants and animals) for energy production. Examples of biomass energy sources include wood, forestry and agricultural waste, specific crops, and landfill waste and gas. Biomass consists of three main types: biofuels for transportation; bioenergy for heat and electricity generation; and bioproducts for plant-based plastics and other materials. Bioenergy for heat and electricity are the technologies architects will most likely be concerned with. There are three ways to generate bioenergy:

1. Burning

- » Provide heat directly for space heating (e.g., woody biomass fueled boiler for hydronic heat).

- » Create steam to drive turbines to generate electricity, including in “co-generation” with fossil fuels.
- » Generate syngas through gasification (similar to combustion, but with limited oxygen input) to generate electricity and waste heat for combined heat and power.

2. Bacterial decay

- » Collect biomass material in oxygen-free “digesters” where it decomposes, producing methane. Burn the methane to provide heat or generate electricity.

3. Conversion to gas/liquid fuel

- » Fuels can act as substitutes for or complements to natural gas for heating and/or power generation.

Biomass can stimulate complex discussions about just how low carbon the technology actually is. There are also concerns about whether growing feedstock (plants) for biomass requires land to be cleared that otherwise wouldn't have been or uses land that is better-suited to grow food.

The environmental and climate impacts are not as clear-cut as they are for other renewable energy technologies. On the other hand, human society produces waste, and it may be better than not to burn, decay, or convert that waste. Consider waste byproducts from paper and lumber mills, crops, food, and municipalities, which are all potential sources of biomass. Methane from agricultural manure and human sewage are also abundant and will produce methane whether it gets used as a biofuel or not. In some areas of the U.S., historical forestry practices have resulted in conditions that contribute to wildland



A pellet-fueled boiler system in the Ketchikan, Alaska, airport. Current generation bioenergy equipment benefits from decades of R&D and is currently cleaner, more efficient, and smaller than its predecessors.



A community/very small bioenergy-fueled district system (4–6 block radius) in Burns, Oregon. The system provides hot water heat to the county circuit court, sheriff's office, and jail as well as an elementary school and a mental health center. The new one-boiler system replaced three oil boilers. Because modern equipment is more efficient, it uses less resource to achieve desired heat and/or power output and has less impact on air quality.

fires and limit forest diversity. Considering any of these sources of waste, using biomass resources to generate bioenergy for heat and electricity makes sense generally, and, depending on location and access to biomass resources, may make good sense for your project specifically.

Biomass resources

The National Renewable Energy Laboratory provides [multiple geospatial maps of biomass resources](#) that can be great places to begin when it comes to understanding the availability of and proximity to biomass resources for any project. However, like any project considering renewable energy, it is critical to consult an expert early on to get a better understanding of resource and feasibility issues.

Because of the extra sensitivity around the true sustainability of biomass resources, it's crucial to understand how the project influences and interacts with local supply of biomass. Questions to consider: Will using the biomass resource help make an area forest healthier or make good use of local biomass waste? Will it support the local economy (e.g., forest-related or agricultural businesses)? Can green waste be diverted from landfills to supply the resource? Are there waste streams for biodigester processes that can be used?

When the biomass resource is understood, it is critical to scale systems appropriately. You don't want to create more demand for biomass resource than there is adequate supply.

Design considerations

Generally speaking, bioenergy is a more effective commercial or industrial solution (with the exception of modern woody biomass boilers for residential



Biogas plant

applications). Schools, municipal buildings, year-round swimming pools, businesses that require process heat, electricity-intensive industries, district heating—these are all examples of projects for which bioenergy can make sense. With district systems there also may be opportunities for co-generation and combined heat and power. Because bioenergy systems are diverse, it's important to research design considerations for a specific system. That said, some very general design considerations include:

- » All systems require space (e.g., a combustor and boiler for woody biomass systems).
- » Electricity generation systems also require space for a turbine, generator, and cooling tower.
- » Storage or collection for biomass fuel.
- » Means of delivering the fuel (e.g., a conveyor to the combustor in the case of woody biomass or a

manure management system for a digester).

- » Most components are integrated into one unit for smaller space heating systems using woody biomass; larger systems are usually configured specifically.
- » Space heating systems may also require conventional backup.

[The Whole Building Design Guide](#) by the National Institute of Building Sciences (NIBS) provides more in-depth information about bioenergy systems for [space heating](#) and [electricity generation](#) as well as producing [biogas](#). The [Biomass Energy Resource Center](#) (BERC) has general information about biomass and works to support community-scale biomass energy. The [Biomass Thermal Energy Council](#) (BETC), in particular its [Resource Center](#), has information about biomass for heat and combined heat and power.

Energy efficiency technologies that use renewable resources

In addition to true renewable energy technologies that generate electricity or provide heat, there are important energy efficiency technologies that use renewable resources or complement renewable energy systems, or both.

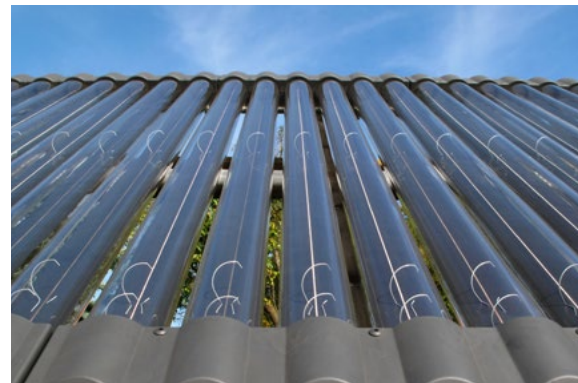
Solar thermal

Unlike solar PV, which converts sunlight to electricity, solar thermal systems capture the sun's heat in a collector containing a fluid such as air, water, or propylene glycol. Solar thermal systems can be used for pool heating, water heating, space heating, or preheating for high-temperature water or steam. Because most of these projects require additional or backup heating systems to operate, they are not strictly considered renewable energy systems, but rather energy efficiency measures that use renewable energy. In recent years, it's often cheaper to use solar PV to power heat pump systems rather than investing in solar thermal for space and water heating on a smaller scale (e.g., residential, small commercial). Solar pool heating and domestic water heating in no-freeze climates are the exceptions; these systems can often pay back relatively quickly. Solar thermal systems are definitely worth considering for any project that has high-volume and/or high-temperature hot-water demand. The cost of such demand may very well make the system cost-effective and worth any extra effort for maintenance. Examples include dormitories, camps, recreational centers, hotels, laundries, and industrial processes.

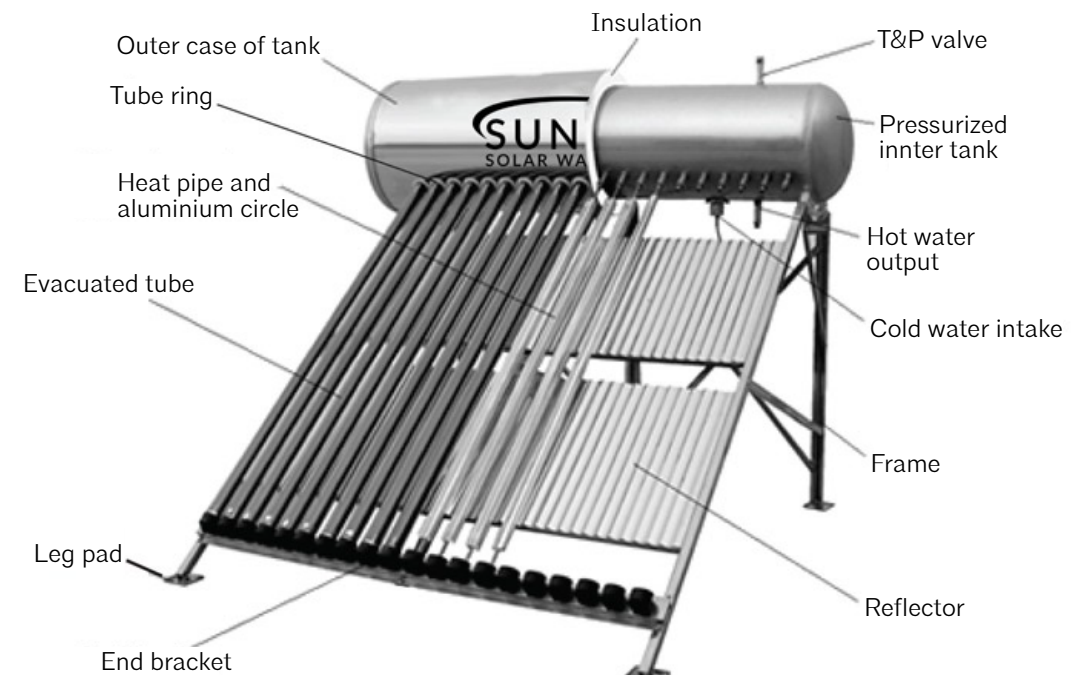
Solar thermal systems can be active or passive systems that use flat-plate, evacuated tube, or unglazed collectors. Active systems, which are more common in freeze climates, use circulators and other mechanical parts to function. Passive systems, which are more common in non-freeze climates and for pool heating, require no circulators.

Passive Solar Thermal Systems

- » Passive systems have integrated storage or no storage.
- » Hot water rises naturally from the collector to the storage tank.
- » Roof must be able to support the weight of the system.
- » In no-freeze climates, they may be as cost-effective as solar PV.
- » Systems operate with less risk and maintenance.
- » Systems don't require backup.



PASSIVE SOLAR-THERMAL SYSTEM WITH AN EVACUATED TUBE COLLECTOR AND INTEGRATED STORAGE

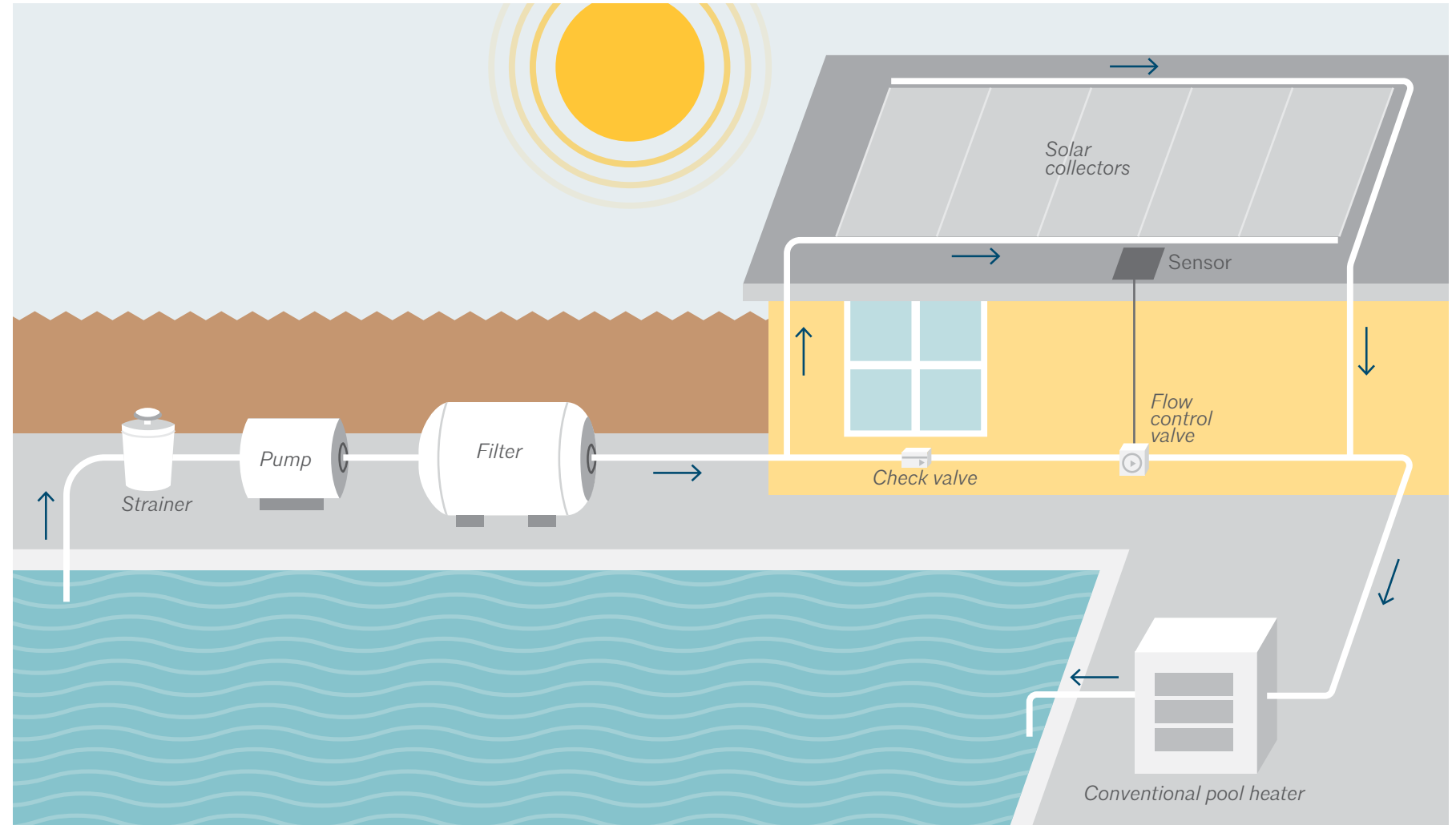


Solar Pool Heating Systems

- » Passive systems with unglazed collectors (typically).
- » Pool is the storage system.
- » Water is heated directly in the loops of the collector and circulated to the pool via the pump.
- » Using nighttime cooling, can be “reversed” to lower pool-water temperature.
- » Freeze or no-freeze climates—solar pool heating works as long as the system is drained before a freeze.
- » Little to no maintenance required.



SOLAR POOL-HEATING SYSTEM

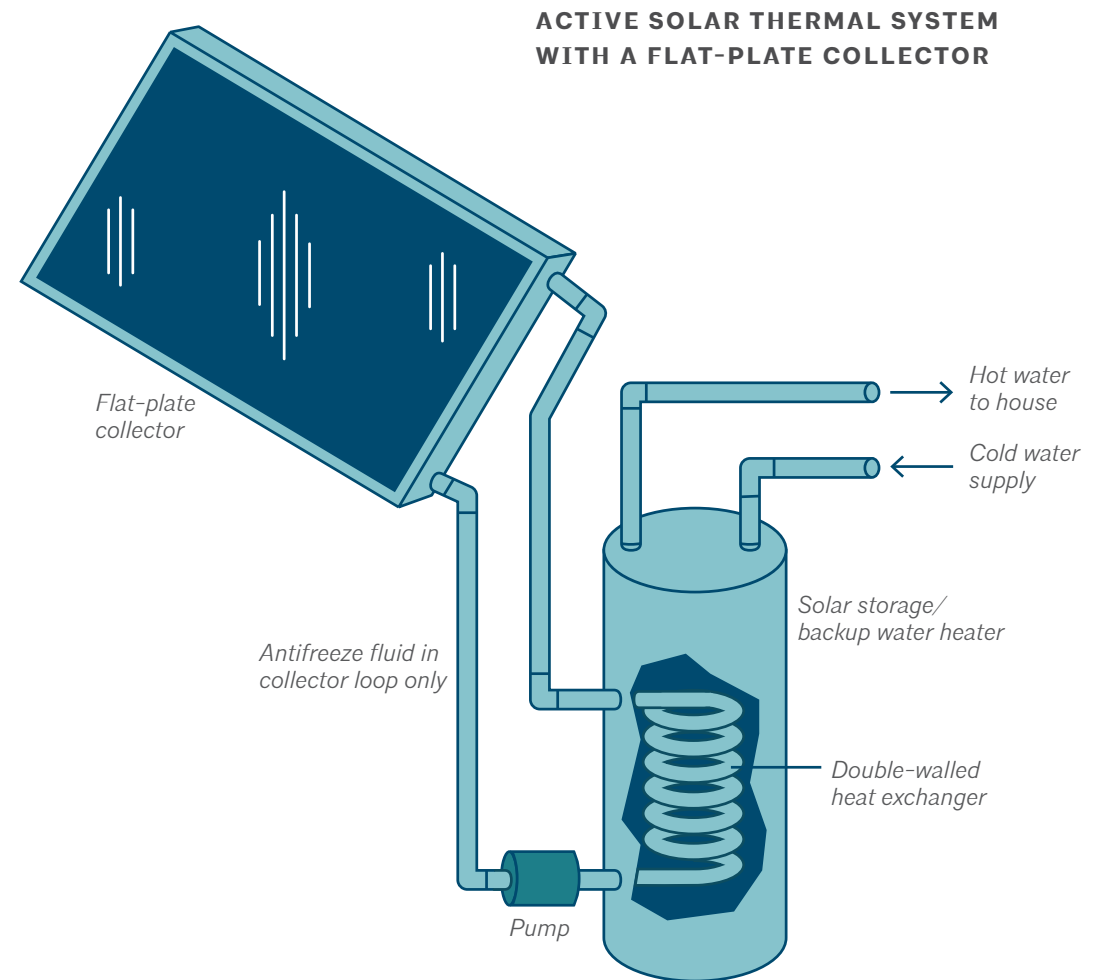




This recreation center features an active solar thermal system using evacuated tube collectors (foreground) that provides heat for a large public swimming pool. The solar PV on the roof provides electricity.

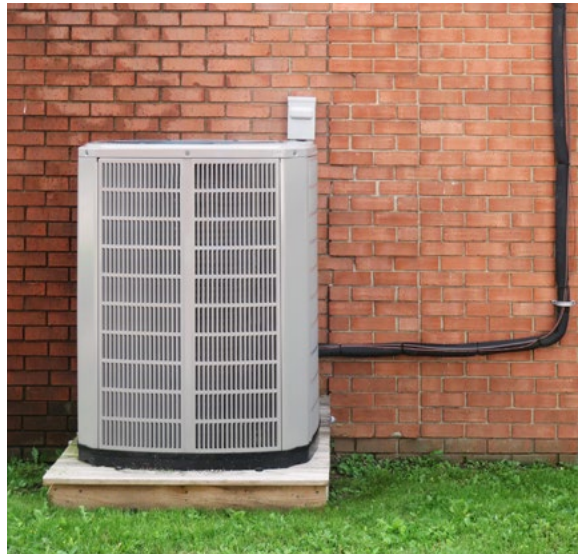
Active Solar Thermal Systems

- » Collectors have freeze-proof fluid in the loops of the collector.
- » Circulator moves fluid to a heat exchanger in a storage tank in a conditioned space.
- » Tank includes backup heating.
- » In climates with any risk of freeze, active systems are required.
- » Active systems are more complex than passive (more potential points of failure) and require at least annual maintenance.

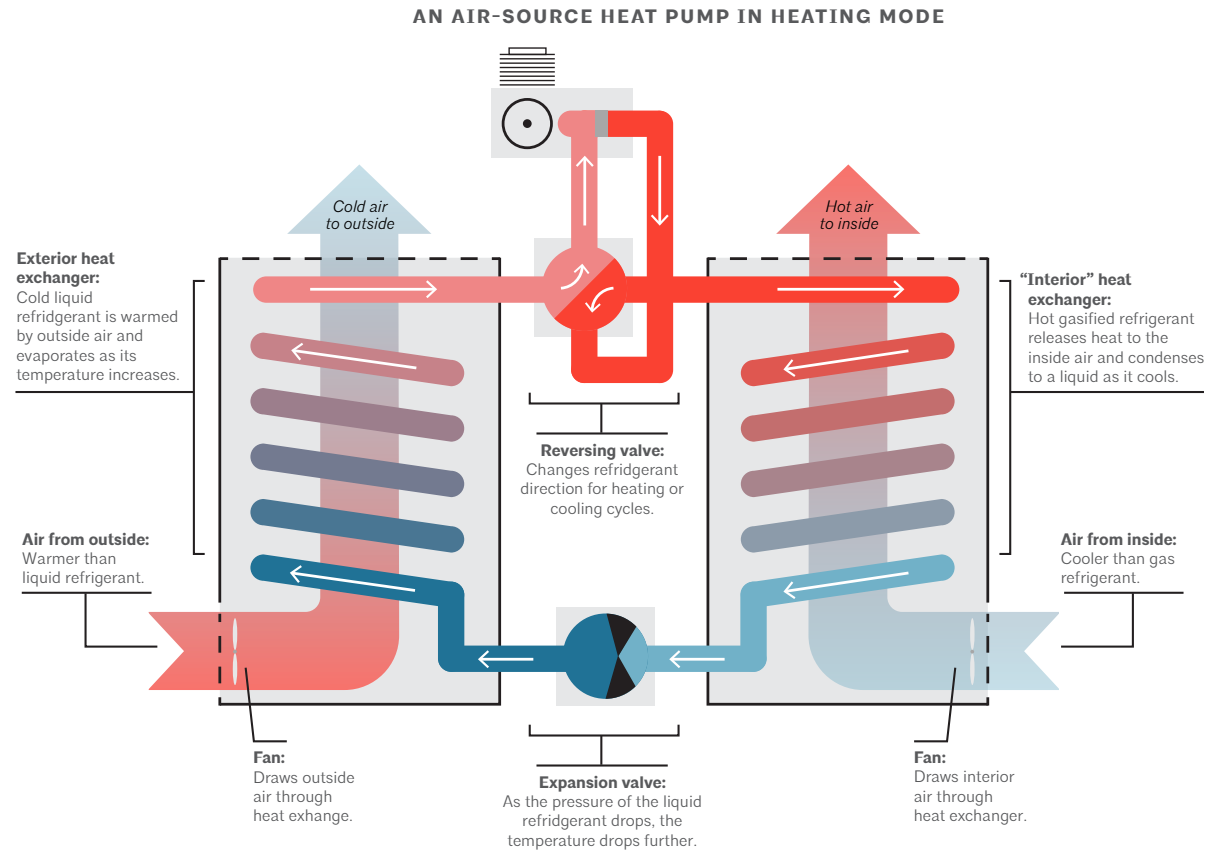


Heat pumps

Heat pumps provide space heating and cooling and hot-water heating. They work by moving heat from the air, ground, or water and don't actually generate hot or cold air. As a result, they are much more energy efficient than conventional HVAC and water heating systems. These systems, with air-source being the most common, are becoming the "go-to" space heating/cooling and water heating technology for all-electric buildings that use solar PV or other renewable electricity. The DOE offers basic information about [heat pump systems](#).

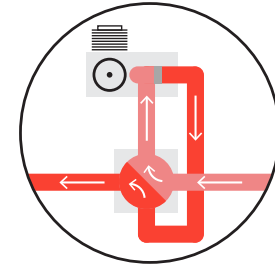


HOW A HEAT PUMP WORKS



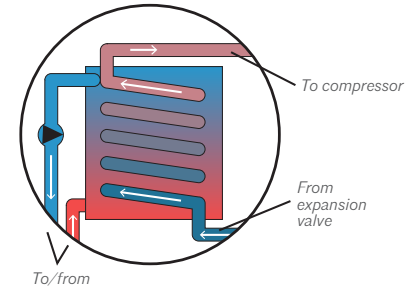
HEAT PUMP COOLING MODE

The reversing valve allows the whole system to run in reverse, extracting heat from the home's interior and releasing it to the outside.



GROUND-SOURCE HEAT PUMPS

Use a heat-transfer fluid and liquid-to-liquid heat exchanger to extract heat energy from the earth or a water source.



SPLIT SYSTEMS

The "interior" heat exchanger can be located outside, using ducting to move hot air to the inside space, or it can be located inside in a separate "split" unit that uses refrigerant to move heat between the two heat exchangers.

HEATING WATER WITH HEAT PUMPS

Like the liquid-to-liquid heat exchanger on the exterior side of a ground-source heat pump system, an interior heat exchanger can heat water for domestic use.

4. Storage

Storage related to buildings with renewable energy systems can be thermal or electric. Batteries provide electricity storage. Thermal storage uses electricity to nearly freeze a water and ethylene or propylene glycol mix in a storage container; then fans and heat exchangers are used to deliver cooled air to conditioned space. Similarly, electricity can be used to heat a fluid to deliver heat to a conditioned space.

Thermal storage strategies are already proven and cost-effective when used to take advantage of lower electricity rates. They can be even more effective when coupled with renewable energy systems because it allows for more flexibility. The value of the electricity generated on-site becomes an additional factor in optimizing the rates paid for electricity.

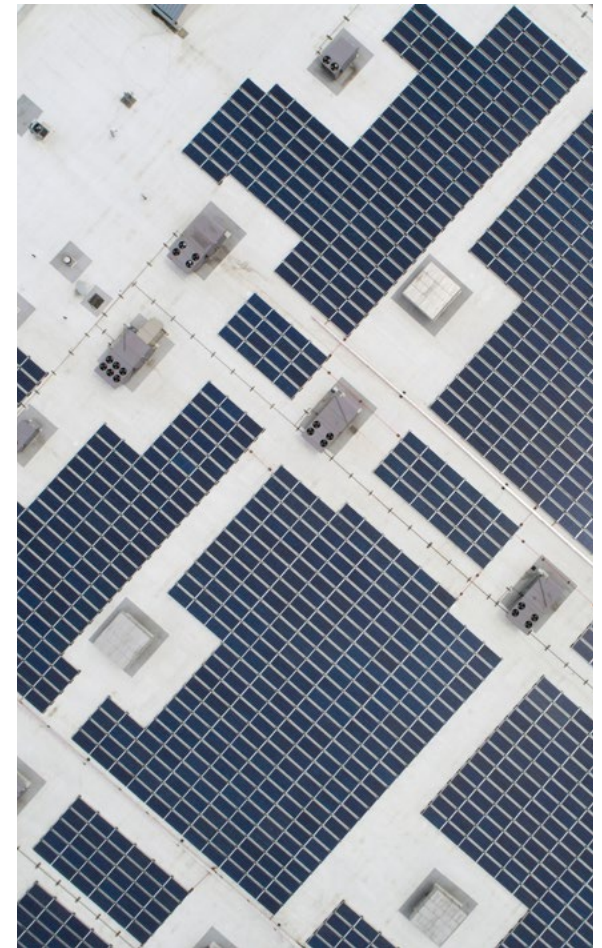
The cost-effectiveness of battery storage is less certain at this time. However, battery costs are coming down and the technology is improving, so it is likely batteries will become increasingly cost-effective into the future. Lithium ion batteries are the most likely choice for building-level battery storage. As the technology used in hybrid-electric and all-electric vehicles, it has a track record and a known lifespan of 10 years or more.

There are several reasons to consider storage. If the grid goes down, a renewable energy system plus battery storage supports resiliency through continuity of operations. Many buildings have backup generators that require fuel and regular maintenance precisely for this purpose. For renewable energy systems plus

batteries, especially if they're financed together, you pay once but get a much more flexible (you can use it every day, not just for emergencies) and cost-effective solution that doesn't require additional fuel purchases and maintenance. For solar PV plus batteries, it is also possible, as long as the project meets certain requirements, to include the battery costs in the overall system costs to reap the benefits of financial incentives.

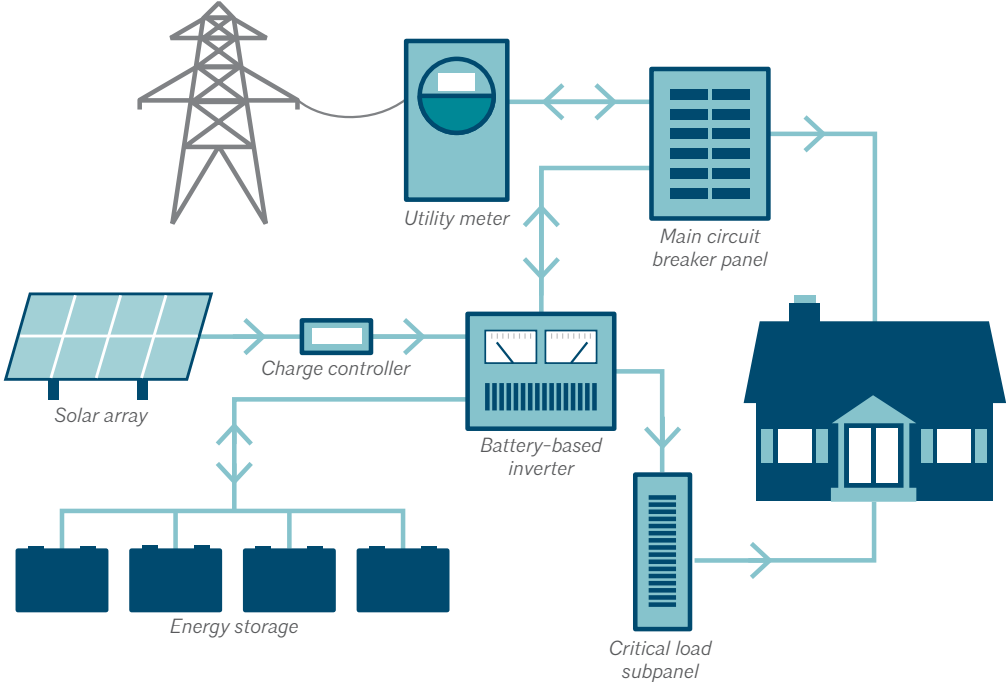
Renewable energy systems with either battery or thermal storage allow building owners to take advantage of time-of-use rates that don't usually coincide with times of peak generation from renewable energy systems. They can also help avoid demand charges. Renewable energy plus storage systems can also support low-carbon grid operations by reducing or eliminating typical afternoon peak electricity demand for electricity generated using fossil fuels.

Deciding on whether to choose storage at all, or which type of storage is right, depends on the value of continuity of operations, rate incentives, or carbon (or all three) compared to the cost of the storage solution. Just like EUI targets and renewable energy system options, storage is an essential discussion point for any project, and it has to be considered early in design. Given future projections about the increasing use and decreasing costs of batteries, even if battery storage doesn't make sense for the present, the design should absolutely plan for battery storage in the future.

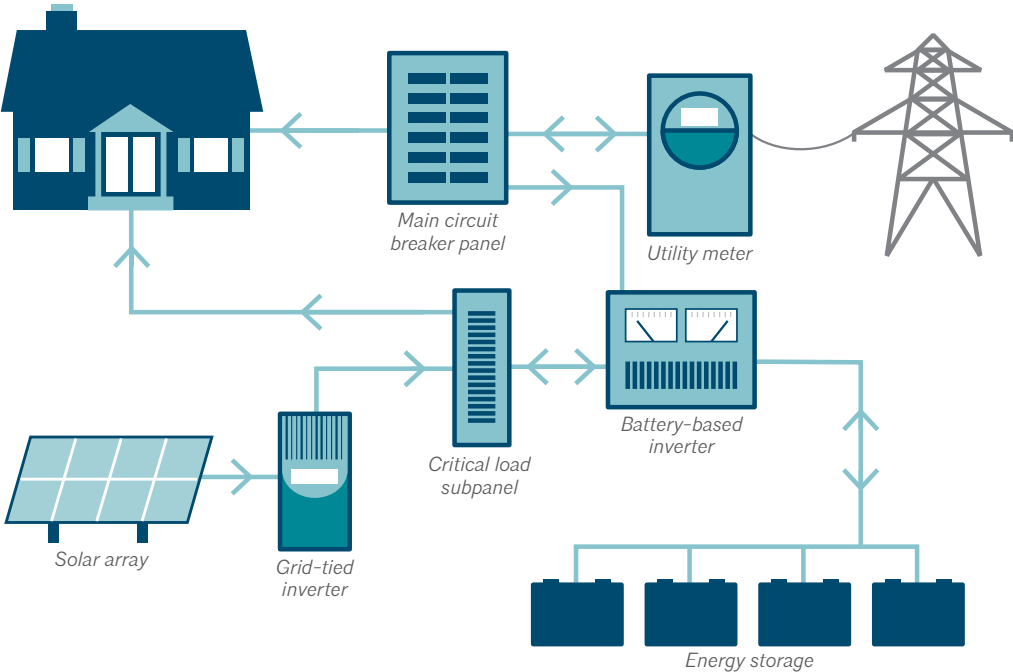


SOLAR + STORAGE SYSTEM OPTIONS

DC-coupled solar + storage systems allow batteries to charge directly from the solar PV. They tend to be the most cost-effective for new installations and operate with better battery-charging efficiencies.



AC-coupled solar + storage systems are usually recommended for existing solar PV installations.



5. Paying for renewable energy: on-site and off-site

For the architect, client, and design team, a key decision point fundamentally influences the way in which renewable energy systems are paid for. Will the system or systems be on-site, located on the building or building site, or off-site? Or will the project use a combination of on-site and off-site? With on-site systems, the building owner has the option to own the renewable energy system and reap the benefits of tax credits, depreciation, and available incentives. With ownership, of course, also comes the responsibility of operations and maintenance. With an off-site system, the owner is not likely to own the system, and therefore does not reap the aforementioned financial benefits. The different options for handling renewable energy credits (RECs) associated with either on-site or off-site generation may also be an influencing factor (see sidebar).

Renewable energy certificates (RECs)

There are a lot of different generation assets (e.g., fossil fuel, renewables, hydro, nuclear) on the grid. It is impossible to say whether the electricity you consume is coming from renewable sources. The REC system (aka renewable energy certificates or credits, or green tags) is basically an accounting and verification system that enables tracking and trading of the clean energy attributes of renewable electricity.

- » Electricity generated from renewable energy is assigned a value in RECs (1 MWh = 1 REC).
- » Each REC has a unique serial number to prevent double counting.
- » RECs can be:
 - associated with local or distant generation, and with generation from new or existing renewable energy projects,
 - traded and purchased,
 - “bundled”—traded/sold with the renewable electricity, or
 - “unbundled”—traded/sold separately from the electricity.

You are consuming renewable electricity if you:

- » own or lease an on-site renewable electricity system or enter into a power purchase agreement (PPA) and do retain ownership of the associated RECs,
- » purchase green power with bundled RECs, or
- » purchase bundled RECs from a local electricity provider.

You are not consuming renewable electricity if you:

- » own or lease an on-site renewable electricity system or enter into a PPA and do not retain ownership of the associated RECs,

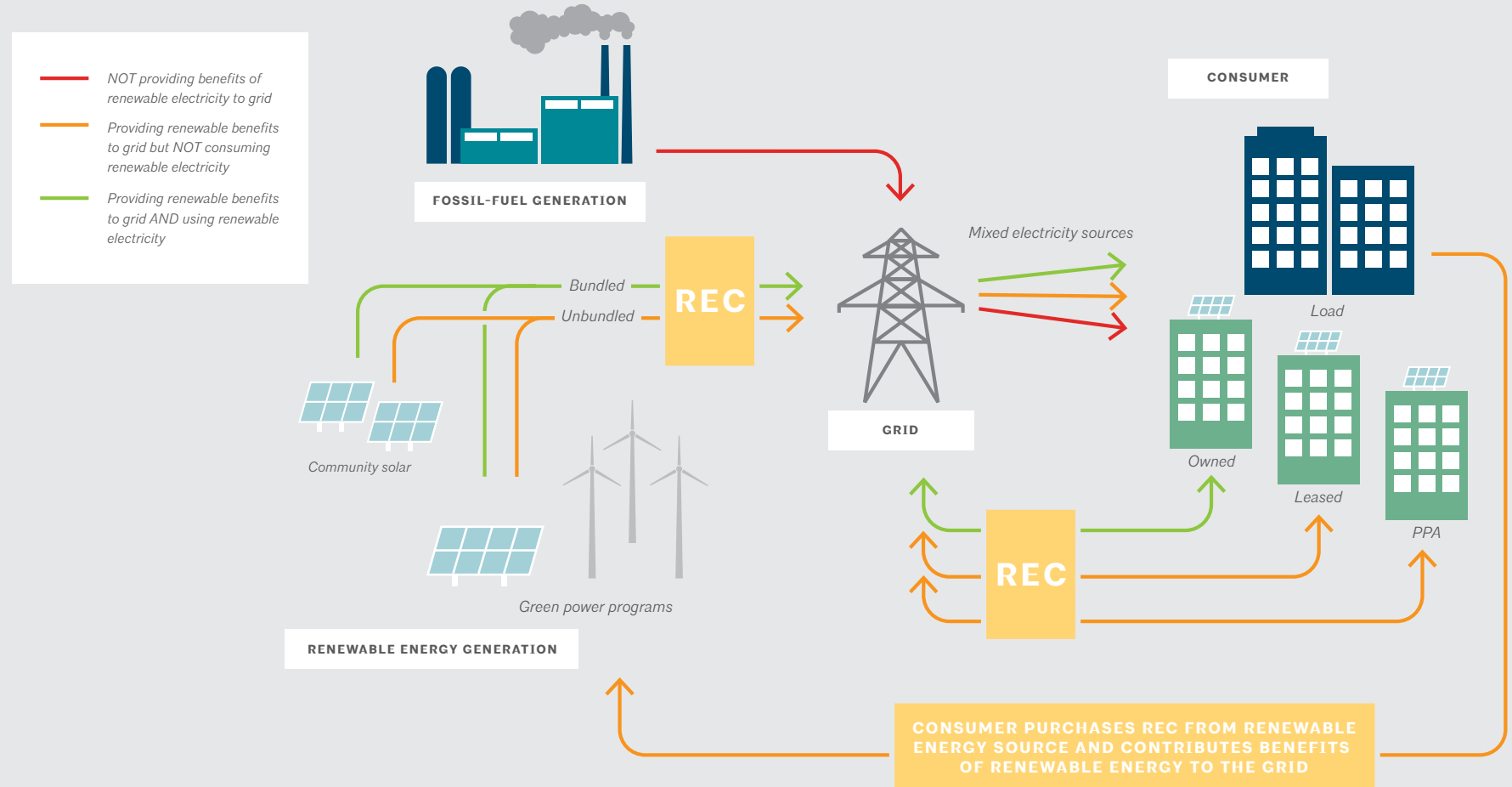
- » purchase green power with unbundled RECs, or
- » purchase unbundled RECs.

However you should choose to acquire RECs, you should ensure that they are third-party-certified and -verified (e.g., [Green-e](#)).

If the RECs associated with your electricity decisions are not bundled, you can still contribute renewable energy benefits to the grid, even if you aren't technically using renewable electricity. Examples include:

- » A building owner with an on-site solar PV system that is leased or procured via a PPA without retaining ownership of the RECs contributes the benefits of the system but isn't consuming renewable electricity because the lessor or PPA provider owns the RECs.
- » A building owner who owns an on-site solar PV system but sells the RECs associated with the electricity generation is not consuming renewable electricity but is still contributing benefits to the grid.
- » A building owner who has no on-site renewable generation but purchases bundled RECs is consuming renewable electricity while also supporting new or existing renewable electricity generation projects.

HOW RENEWABLE ENERGY CERTIFICATES WORK



On-site options

Ownership

Renewable energy systems can be purchased outright with capital on-hand, or they can be financed. Renewable energy system providers/installers, especially for solar PV and wind, often offer information about financing, if not access to actual loans.

Options for residential systems:

- » Finance the system only via a loan.
- » Finance the system and additional construction or renovation via a loan.

- » Fannie Mae offers the [HomeStyle® Energy mortgage](#).
- » FHA [Energy Efficient Mortgages](#) are offered through a variety of lenders.

Options for non-residential systems (including multifamily):

- » Financing options are much more diverse.
- » The DOE's [Better Buildings Financing Navigator](#) is an excellent source of information.

A significant plus of ownership is the ability to reap the benefits of tax credits for the cost of the system as well as depreciation. Tax credits exist at the federal level and in some states as well. Additionally, states, counties,

cities, and utilities offer financial incentives and loan programs for renewable energy systems. The best sources for information about financial incentives are:

- » [Database of State Incentives for Renewables & Efficiency®](#) (DSIRE)
- » State energy offices; contact information can be found in the [membership directory](#) of the National Association of State Energy Officials (NASEO)
- » Local utilities
- » Local dealers and installers of renewable energy systems
- » Federal and state agencies (e.g., Department of Agriculture, National Forest Service, Department of the Interior, state natural resources agencies, university/county extension services) may have specific programs, for example, for agriculture, related to biomass

Leasing

Solar PV systems are relatively easy to lease. At least one company offers small wind leases, provided your site consists of at least 3 acres of land. Micro-hydro and bioenergy systems are typically not leased.

Solar PV leasing:

- » Upfront costs are reduced or eliminated.
- » Lessee provides benefits of renewable electricity to the grid.
- » Lessor maintains the system.
- » Lessor receives all tax benefits, incentives, and RECs.
- » Lease periods are typically 7–10 years or more.
- » Leases often have buyout options after about 7 years.

- » Lessee typically pays a flat monthly payment for the equipment.
- » Payments may escalate over time; ensure terms of the lease are fully understood.
- » Monthly payment is based on estimated electricity production throughout the year; if production is higher than estimated, lessee will likely receive a “true up” bill for the value of the extra generation.
- » Lease has to be transferred to the new owner, if a building is sold.
- » Leasing is generally recommended for owners who:
 - cannot afford upfront costs,
 - cannot reap tax benefits,
 - do not expect to sell the building for the life of the lease, or
 - are comfortable not retaining the RECs associated with generation.

On-site power purchase agreement (PPA)

- » PPA provider/installer installs, owns, and maintains the system.
- » PPA provider/installer reaps any tax and incentive benefits; usually keeps the associated RECs.
- » Consumer usually enters into PPA for about 20 years; if this commitment poses a challenge, leasing may be a better option.
- » Similar benefits to leased systems, with one significant exception: PPAs are not viewed as a debt, whereas leases are.
- » Consumer either pays a set kWh rate for the energy actually produced by the system each month or a flat monthly fee.



- » Flat-fee customers usually have a true-up period every 1 to 3 years.
- » Buyout options after about 7 years are common.
- » \$\$\$

Off-site options

There are many options for procuring off-site renewable electricity. Here are some examples:

- » **Green pricing.** Within noncompetitive electricity markets (the utility owns generation, transmission, and distribution), the local utility will likely have a voluntary green pricing program. The customer enters a short-term agreement (e.g., monthly) to pay a premium/fee beyond the usual utility rate to “buy” some or all of their electricity from a renewable power source. RECs may be bundled or unbundled. These programs are typically offered to residential and small-commercial customers.
- » **Competitive electricity markets.** Within competitive electricity markets (utility owns transmission and distribution but not all the generation), the consumer can choose from electricity providers. Typically, these markets have more renewable electricity purchasing options. RECs may be bundled or unbundled.
- » **Community solar.** A solar PV project that generates renewable electricity that is shared by more than one property with subscribers usually located in the same community or utility service area. The project can be owned by the community that shares the electricity, the utility, or a third party that provides the renewable electricity to the community. The project uses the local utility for

transmission and distribution. Subscribers purchase a percentage of their annual electricity usage from the project. Existing utility billing remains in place; subscribers typically receive a credit on their bill for the amount of electricity generated by the community project. The Solar Energy Industries Association (SEIA) has a “[Residential Consumer Guide to Community Solar](#).”

- » **Community choice aggregations (CCAs).** Local governments aggregate customer demand within a specified jurisdiction and procure power while continuing to use the local utility’s transmission and distribution services. CCAs allow the community greater choice in electricity generation.
- » **Utility green tariffs.** Similar to green pricing, but agreements are longer term (e.g., 10–20 years). The customer may have some say in the type of renewable generation, and electricity costs may be competitive (e.g., no fee above the utility’s usual rate and the possibility of locking in a fixed rate for term of the agreement). These programs are typically offered to a class of large commercial customers.
- » **Utility bilateral agreements.** One-to-one contract between a large commercial customer and a utility to procure renewable electricity of a specific type for an agreed-upon time period and rate.
- » **Power purchase agreements (PPAs).** Like the on-site PPA option, but generation is off-site. There are two types of off-site PPAs: physical and financial (also called virtual or synthetic PPAs). EPA’s Green Power Partnership offers information about [physical](#) and [financial](#) PPAs.
- » **REC purchases.** Consumers can purchase unbundled RECs from various organizations to

offset the electricity they use that is generated from fossil fuel sources. It is important that these RECs are third-party-certified and -verified. It should be noted that whereas RECs can be used to offset electricity consumption, there is some discussion about using them to offset on-site gas usage. For example, the EPA and eGreen do not recommend it, but the ZERO Code does allow it.

- » **Renewable energy investment funds (REIFs).** These accounts are set up to receive funds from building owners or developers when sufficient on-site renewable generation is not possible. The fund is typically managed by a local government with a role for the local utility likely as well. The fund is used to develop new renewable generation or

to purchase a virtual PPA. [ZERO Code](#) has more information about REIFs.

The details of how a consumer purchases renewable electricity can vary from state to state, utility territory to utility territory, and by customer type. Architecture 2030 published the “[ZERO Code Off-Site Procurement of Renewable Energy](#),” and the EPA’s [Green Power Partnership](#) website contains a wealth of information to assist with navigating these differences.



6. Stretch your thinking

Now that you've begun to learn more about renewable energy options for your projects, here is some information about the way renewable energy is starting to change the electric grid.

As more and more intermittent and variable renewable energy technologies are used to generate electricity, patterns of peak electricity generation are changing, but patterns of peak demand (mostly from buildings) are not. This creates a mismatch between the times when the utility is most able to generate electricity from renewable sources and the times buildings are demanding the most electricity. Generation from solar PV during very late summer afternoons is a good example. Electricity demand to power residential air conditioning ramps up and overlaps with existing demand from commercial buildings. Because this coincides with the sun getting lower in the sky, generation from solar PV is waning. Generation from wind can present a different problem. Electricity providers may have too much electricity at night when building demand is low. Meeting historical demand patterns in a high-renewable-generation scenario means the utility will likely bring more fossil fuel generation, especially natural-gas-fired peaking plants, online. However, if buildings can change their demand patterns to better match the times of peak generation from renewables, those fossil-fuel-generation assets may not be necessary.

The concept of building design and operation that actively takes grid conditions into account goes by a few names: grid-interactive efficient buildings,

grid-integrated energy-efficient buildings, grid-optimal buildings, grid-friendly buildings, and grid citizenship, to name a few. Regardless of the name, there are consistent themes:

- » Design for passive, energy conservation and energy efficiency first.
- » Include appropriate renewable electricity generation (e.g., on a solar-PV-saturated grid, west-facing PV in addition to south-facing PV could give the grid a little help during peak demand).
- » Include storage (thermal or battery).
- » Design and plan for grid-responsive operations (e.g., load shifting and demand response).

For further exploration of this topic:

- » U.S. Department of Energy [Grid-Interactive Efficient Buildings](#), including its informative "Buildings and the Grid" blog series
- » Rocky Mountain Institute [Grid-integrated Energy Efficient Buildings](#)
- » Building Green [Changing Building Design for a Changing Electrical Grid](#) (may require subscription to view the full article)



7. Credits & resources

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Page 5: [Lazard's Levelized Cost of Energy Analysis - Version 13.0](#)

Page 6: Original graphic from the National Renewable Energy Laboratory's [U.S. Solar Photovoltaic System Cost Benchmark: Q1 2018](#)

Page 7: Original graphic from the [Solar Energy Industries Association](#)

Page 8: Original graphic from the [union of concerned scientists](#)

Page 11: (Left) Photo by Dennis Schroeder, NREL 20030; (right) EnergySage, a website to comparison-shop solar energy and battery systems, as well as community solar.

Page 12: (Roof-mounted PV options from top to bottom, left to right)

Dennis Schroeder, NREL 45144, Dennis Schroeder, NREL 45230, Dennis Schroeder, NREL 45189, Dennis Schroeder, NREL 45167; (right) Lawrence Berkeley National Lab, NREL 01052

Page 13: Original graphics from Architectural Integration of Solar PV into Building Design

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Page 15: (Left) original graphic from DOE's [Small-wind Guidebook](#); (right) original graphic from [Aurora Power](#)

Page 16: Courtesy of Wisewood Energy, a biomass project development firm based in Portland Oregon

Page 17: (Left) courtesy of Wisewood Energy, a biomass project development firm based in Portland Oregon

Page 18: (Right) courtesy of Sunbank solar thesunbank.com

Page 19: (Right) original graphic from DOE [Energy Savers](#)

Page 20: (Left) Dennis Schroeder, NREL 45137

Page 23: Original graphic from [2015 Solar + Storage 101 publication by the Clean Energy Group](#)

Resources

If you'd like to dive deeper into the topics covered in this brief, here are some additional resources for you to explore. Please note that these resources are provided for general information and may contain reference to outdated information (e.g., energy codes, financial incentives and certifications such as Energy Star and LEED).

Energy conservation and efficiency

- » [AIAU+2030 Online Series](#)
- » Architecture 2030 [ZERO Code](#) and [2030 Palette](#)
- » [ASHRAE Advanced Energy Design Guides](#)
- » [Better Buildings Toolkits](#)

Energy modeling

- » AIA [Architect's Guide to Building Performance: Integrating simulation into the design process](#)

Solar PV

- » AIAU course: [Solar PV and the Architect](#)
- » Solar Energy Industries Association [Residential Consumer Guide to Solar Power](#)
- » [Better Buildings Toolkits](#)
- » energysage: [Solar IOI: how does solar energy work?](#)
- » SunPower has a [lengthy information-packed blog](#) to search, keeping in mind the blog also features plenty of promotion of their own products

Wind

- » DOE: [Small Wind Guidebook](#)

Micro-hydroelectric

- » DOE: [Microhydropower Systems](#) and [Planning a Microhydropower System](#)
- » Alternative Energy News: [Micro Hydro Power—Pros and Cons](#)
- » Appalachian State University: [Fact Sheet: Microhydro](#) (intended for North Carolina but contains general information)

Bioenergy

- » National Institute of Building Sciences Whole Building Design Guide: [space heating](#) and [electricity generation](#)
- » [Biomass Energy Resource Center](#)
- » [Biomass Thermal Energy Council](#) — [Resource Center: Strategic Communications](#)

Solar thermal

- » Environmental Protection Agency: [Solar Heating and Cooling Technologies](#)
- » National Renewable Energy Laboratory: [Solar Energy Basics](#) (includes information about other solar technologies too) and [Climate Neutral Research Campuses](#)

Heat pumps

- » DOE Energy Savers: [Heat Pump Systems](#)

Storage

- » Clean Energy Group: [Solar+Storage IOI](#) (battery storage)
- » CALMAC: [How Thermal Energy Storage Works](#)
- » Green Building Alliance: [Thermal Storage](#)

- » BuildingGreen: [Buildings on Ice: Making the Case for Thermal Energy Storage](#) (may require subscription to view the full article)

Financing

- » Fannie Mae [HomeStyle® Energy mortgage](#) (residential)
- » FHA [Energy Efficient Mortgages](#) (residential)
- » DOE [Better Buildings Financing Navigator](#) (non-residential, including multifamily)
- » [Database of State Incentives for Renewables & Efficiency®](#) (DSIRE)
- » National Association of State Energy Officials (NASEO): State and territory energy offices [membership directory](#)
- » [Your](#) local utility
- » Local dealers and installers of renewable energy systems
- » energysage: [Solar Financing](#)

Green power

- » [ZERO Code Off-site Procurement of Renewable Energy](#)
- » EPA [Green Power Partnership website](#)
- » energysage: [Green Power](#), [RECs](#)

Community solar

- » [Residential Guide to Community Solar](#)
- » National Renewable Energy Laboratory list of [community solar projects](#)
- » energysage: [Community Solar](#)

Changing electric grid

- » DOE [Grid-Interactive Efficient Buildings](#), including its informative “Buildings and the Grid IOI” blog series
- » Rocky Mountain Institute [Grid-Integrated Energy-Efficient Buildings](#)
- » BuildingGreen [Changing Building Design for a Changing Electrical Grid](#) (may require subscription to view the full article)