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Solar Energy: the future is here

So much more than Photovoltaics

When most people think of solar energy, images of photovoltaic arrays on gently sloping, south-facing rooftops are conjured up. Individuals attuned to green building issues recognize that passive architectural design features, such as shading and orientation, play an important role in the solar heat gain of a structure. However, solar energy isn't limited to these basic passive design or active technology features.

An optimized solar system is far more detailed and sophisticated than technology on a rooftop or the orientation of a building. A truly integrated solar arrangement follows a whole-systems approach to building, which intricately links the natural and the built environments and allows a harmonious interplay of light and mass. This type of solar system incorporates the natural features of both the land form and the structure, addressing issues such as natural air conditioning, proper ventilation, on-site thermal sources and sinks, appropriate land use and site design, and sustainable, low-energy architecture.

Ignoring the daily, monthly, and seasonal movement of the sun, and the resulting wind, water, and weather patterns, can lead to vast inefficiencies and missed design opportunities. By appropriately addressing the natural cycle of the sun, designers can not only increase a building's performance, but they can also create a symphony of light and shadow within the building envelope.

Practical Applications

According to Doug Schroeder, Associate Director of the Sustainable Buildings Industry Council (SBIC), "there is no reason to put a solar system on a building that is not efficiently designed. Adapting solar technologies to existing buildings, which may have not been initially designed to optimize the use of energy, will not typically produce the results desired by the building designer and owner. Good solar design begins in the conception phase, and its not just about sexy technology. There is a gap between the design and technology communities that needs to be closed if we are going to create truly high-performance buildings." Doug says that through increased interaction between designers and technologists, misconceptions about solar technology, namely that they cost too much to be practical and that they are difficult to install and maintain, can be dispelled.

The U.S. Green Building Council affirms that systems that effectively integrate solar technology and design can reduce the energy requirements of a building by as much as 80%. The more energy efficient a building is in design, the greater the impact a solar system will have. Before implementing a solar system, buildings should be weatherized and insulated to very high standards. In water heating applications, it is best to insulate pipes and utilize low-flow water conserving fixtures to get the best results.

Site planning is pivotal to good solar design. By taking advantage of natural systems and resources, such as sun exposure for heating in the winter and wind patterns for ventilation and cooling in the summer, a building can moderate space heating and air conditioning demands. Depending on the heating and cooling system, this can dramatically improve indoor air quality (particularly if a building has a forced air system that blows air from ducts in the floor or ceiling).

Day-lighting from windows, skylights, atriums, and clerestories can also reduce energy demand by replacing the need for interior electrical lighting during sun-filled hours. Additionally, and of no less import, day-lighting connects inhabitants with the natural environment, lifting the spirit and improving productivity.

Conscientious decisions about energy efficient lighting, appliances, windows, and insulation can also make a significant difference in energy requirements.

Passive Solar Strategies

The goal of all passive solar designs is to capture heat within the building's elements when the sun is shining and then release that heat during hours of darkness or cloudy periods. In a passive solar system, the interior space acts as a solar collector, heat absorber and distribution system. It is important to conduct a heat load analysis of a structure in order to optimize passive design.

Some of the primary components of passive solar design are:

- Appropriate siting and building form: it is imperative to recognize that every location is distinctive, with unique land features, climates, and ecosystems. Designers must carefully consider the natural systems that are in place, including the water flows, topography, geology, and natural energy (solar and wind), and locate buildings to take advantage of beneficial site attributes.
- Orientation: properly designed systems are on an east-west axis with south facing glazing, allowing sun to enter the building between the hours of 9:00 A.M. and 3:00 P.M. during the heating season.
- Properly sized thermal mass: water and masonry materials (tile, stone, or brick floors and walls) will absorb heat from the sun during the day and slowly release it overnight. Thermal mass will store excess heat gain, prevent the interior space from overheating, and moderate heat delivery to the building. For optimum performance, masonry floors should be a medium-dark color. A rule of thumb to follow is for every square foot of south glass, a building should have 150 pounds of masonry or 4 gallons of water. It is important not to exceed 6 inches of thickness in thermal mass materials and not to cover these materials with coverings such as wall-to-wall carpet.

- Shading glass and other glazing with overhangs, porches, and landscaping (vines, trees, etc.): these features can help to cool a structure naturally and reduce unwanted solar gain that increases cooling demand. These elements can also improve the aesthetic appearance of a building, providing a vibrant organic overlay to a fixed façade.
- Glass positioning and material selection (such as window glazing with superior R-values and low-emissivity coatings): if designed properly, a direct gain system will capture and use 60 - 75% of the heat that strikes the windows.
- Ventilation: operable windows and other design features are essential to provide air flow throughout structure. Not only does this reduce space cooling demands, but it can also greatly contribute to improved indoor air quality. Different types of windows allow varying amounts of ventilation. For example, casement windows offer the greatest amount of airflow through a room. Awning windows offer the best rain protection and perform better than double hung windows, but need to be opened fully or else incoming air will be directed towards the ceiling. If a room is designed so that it can only have windows along one wall, it is better to have two widely spaced windows as opposed to one large window.
- Room placement within a building and interior design: rooms requiring the most light and heating should be along the south face of the building. Rooms that are used less often or necessitate cooler temperatures should be located on the north side of the structure.

Active Technology

Once passive solar design strategies have been addressed, then technology can be considered. Photovoltaic systems, or PVs, convert sunlight into electricity by utilizing electrons that are freed when the sunlight hits the silicon that is embedded within semiconductors in the cells. PVs are revered because of their ability to produce energy without emitting noise or air pollution.

In buildings, PV systems transform direct current (DC) electricity through a converter into alternating current (AC) electricity, which can be harnessed and used to power lights, appliances, computers, and televisions. The PV panels, or solar cell collectors, are the essential ingredients of these systems. Other components, consisting of mounting racks, battery banks, meters, inverters, disconnects, conditioning equipment, and wiring, are referred to as the 'balance of system', or BOS.

Many types of PV systems can be integrated into the utility grid, so that a building can have access to both systems. With grid-connected systems, solar generated power can be routed back to the utility company to offset a building's electrical consumption. Energy that is 'sold back' gets deducted from monthly energy bills or creates a credit for the building to use in colder months or at times when energy demand is at its peak. This process is called 'net metering'.

As with passive design, orientation is an essential feature of PV systems. In the U.S., the sun is predominantly in the southern part of the sky; so placing PVs on southern facing rooftops, typically within 30 degrees of due south, with a 45-degree slope will generally provide optimal performance (the 45-degree slope will help mitigate shorter winter days by facing the panels more directly at the lower sun.) West and east facing roofs are also acceptable but will produce less power in most scenarios. It is also important that trees, other architectural features, or buildings do not obstruct the PVs. The sun's daily and seasonal movement should be considered as well when designing and placing systems. Other issues, such as local weather patterns, climate, and altitude will affect system requirements.

Although there have been relatively few innovations in solar panel technology over the past few years, major developments have occurred in the process by which energy gets harnessed from photovoltaics and stored in batteries. Reasonably priced computer controlled solar systems, such as the ones provided by Outback Power (based in Arlington, WA, www.outbackpower.com), are now available that capture and utilize energy more efficiently than predecessor systems. In these systems, the components, such as the change controllers and inverters, 'talk' via an electronic bus, allowing the system to optimize energy storage, resulting in up to 20% more power from solar panels in certain weather conditions.

Solar system aesthetics are improving too—there are even 'invisible' solar systems today that are concealed from curbside view (for more information, contact Dawn Solar Systems in Brentwood, NH or Zomeworks Corp in Albuquerque, NM).

Space heating systems range in price, from inexpensive wall heaters that run as low as $800 to large central systems which can cost over $4000. Space cooling systems are generally expensive to implement, with installed costs ranging from $4,000-$8,000 per ton. By implementing efficiency measures to reduce energy demand, smaller, less expensive systems are required.

Solar energy is also an affordable, highly effective way to heat water. According to the SBIC, water-heating within buildings accounts for approximately 17% of energy use in the U.S. and is the second largest household energy expense after space conditioning. There are a range of solar water heating systems that can appropriately address specific design, weather, and installation issues. Generally, solar water heaters are sized to provide 70% of the annual hot water heating load required by a building. Solar hot water heater designs are climate specific, particularly relative to freeze protection.

Solar domestic water heaters are reasonably priced, typically ranging from $1000-$4000, depending on hot water requirements and local climate conditions. Although solar hot water heaters require a larger initial investment than required for electric or gas heaters, they can show pay backs within a few years and ultimately have approximately a 20% lower life-cycle cost.

Time for Change

In order to understand the full importance of solar systems, it is valuable to consider a larger energy market perspective. Since its inception, the solar industry has been considered the ugly stepchild of the oil economy, which is ironic since there is no question that maintaining an entire financial system that is dependent on a single non-renewable resource is dangerous at best. Our fossil fuel dependency is particularly poignant now since the yield of U.S. oil and gas fields peaked in the 1970's and is in decline. Most global reserves that we have been depending on, including those in the middle-east, are peaking now (with natural gas yields in close tow). And, Mexican and Canadian fields have reached a plateau. Because our current energy policy perpetuates dependency on foreign sources and suspected climate change of potentially catastrophic proportions, it is time to rethink our oil-based economy.

Let's apply basic economics—as energy demand increases and oil supply decreases, prices will rise and energy hungry countries, the U.S. included, will be competing for a valuable and diminishing resource.

Furthermore, with the burning of more fossil fuels (including coal), we will continue to increase greenhouse gas emissions, exacerbating global warming and climate change issues. Not to mention, current energy prices do not accurately reflect the true cost that fossil fuel extraction has on the environment or the economy. If this cost was properly represented (including costs for defense, ecosystem remediation, and health and safety), gas prices would be an order of magnitude higher than what they are today. Unless, of course, we start thinking seriously about implementing alternative, renewable energy strategies.

The challenge of climate change and fossil fuel dependency offers a historic opportunity to develop a new approach to energy use, and there is no better place to start than the building industry. According to the U.S. Green Building Council, U.S. buildings account for:

- 36% of total energy use
- 65% of electricity consumption
- 30% of greenhouse gas emissions
- 30% of raw materials use
- 30% of waste output (136 million tons annually)
- 12% of potable water consumption

Back to Nature

Solar energy has come a long way since its market entry in the 1970's. Technology and design have evolved to a point where solar systems have become a viable and financially feasible option for many different types of applications, namely space and water heating. The physics and economics of solar systems are favorable, and the aesthetics are improving. What was once a clunky, burdensome technological solution is now elegant and streamlined.

Moreover, the political climate is warming to solar power. Some states have policies and programs in place that encourage the use of renewable energy. These programs include financial incentives that can mitigate the cost outlay of a solar system, such as elimination of sales tax on the purchase of the system, rebates and buydowns for the system, and property tax exemptions.

The proliferation of state and federal incentive programs has been precipitated, in part, by consumer demand. This is exemplified by the fact that more renewable energy requirements were passed by voters in the 2004 elections than ever before. Reflecting voter support, many states are passing laws requiring that a specific percentage of energy consumed within the state come from renewable energy sources.

For example, Colorado voters recently passed Amendment 37, which requires large Colorado utilities to generate or purchase a percentage of their electricity from renewable sources. Additionally, standard rebates will be offered for solar electric generation equipment, with utilities paying customers a minimum rebate of $2.00/watt of installed solar electric capacity, up to 100 kW. A net metering system will be also implemented where excess generation may be carried forward as a credit to the following month's consumption.

More people are also becoming attuned to the fact that solar power actually encompasses other renewable energy sources that are derived from weather patterns. For example, wind, which is driven by solar flux, has become a viable energy option and is growing at 30% per year. In fact, in the mid-west, the cost of a wind-generated kilowatt-hour of energy has become cheaper than the same amount of energy produced from natural gas. Rain patterns are also determined by the sun and are an important feature of solar design. If buildings become more efficient in harvesting storm water for non-potable applications, they can significantly reduce their demand on municipal water systems and the energy required in the treatment process.

Despite the obvious environmental, social, and financial benefits of solar systems, the U.S. is lagging behind many other countries, such as Germany, Japan, and Israel, in its use of solar energy. According to Colorado-based solar system designer and installer, Mike Sullivan, it is up to American citizens to speed up the pace of solar adoption in this country. Mike says "if people feel strongly about renewable energy and leaving the world a better place for future generations, then they can do two things. First, they can implement solar systems in their homes and offices. Second, they can become political, helping to raise our collective voice to get support from elected officials, businesses, and utilities for increased renewable energy."

Indeed, it is time for us all to promote greater stewardship through responsible action. Using and promoting solar energy is part of this process, particularly since there is widespread, affordable technology available for home and building owners. Supporting local, regional and national solar energy organizations and communicating with elected officials, regulators and utility companies to is also important to help increase awareness and advocacy of energy issues.

Through our actions, we must begin to develop a new language that incorporates the natural and built environment, celebrating people and place, delighting in light and landscape, and fusing innovation and ecology. As the visionary architect Frank Lloyd Wright stated that buildings should be "*of* the hill, not *on* the hill". Every building we construct is a monument, a testament, to our ability to be proper stewards of this planet. Therefore, our buildings should respond to the land form, reflecting and complimenting the natural environment, and incorporating the most powerful, valuable resource that we have, the sun.

Ron Jones and Sara Gutterman are Co- Founders of Green Builder, a leading development and consulting firm in the green building space. Green Builder® is entirely dedicated to sustainable development, bringing environmental, economic, and spiritual health to people and projects. For more information, visit www.thegreenbuilder.com or contact Sara at sara@thegreenbuilder.com.

Resources:

Web:
American Energy Society—www.ases.org
Solar Energy Industries Association—www.seia.org
Solar Energy International—www.solarenergy.org
U.S. Department of Energy—www.eere.energy.gov
Database of State Incentives for Renewable Energy—www.dsireusa.org

Publications
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