Solar cells (also called photovoltaics) absorb sunlight and convert it directly to electricity. When sunlight hits the cell, electrons are released. The electrons then flow onto wires, forming direct current (DC), which is the same kind of current that flows from a regular battery. At present, solar cells turn between 12 and 20 percent of the sunlight that hits them into electricity, but recently terrestrial solar cell efficiency has been documented as high as 32.3%. New cells have been tested at much higher efficiencies and they should be available in the near future.

Solar modules can be free-standing units, but there are also building-integrated solar products, such as solar roof shingles and opaque glass photovoltaic facades. When these products replace conventional building materials, it will reduce the cost of incorporating solar electricity into a building.

The DC power from solar cells can be used directly to operate many household items. Alternatively, using a device called an inverter, the DC current can be converted to alternating current (AC) for standard household appliances as well as for fuel sensing, actuating, and display equipment.

The Two Types of Systems

There are two types of photovoltaic systems: (1) stand-alone systems and (2) systems that are connected to the electric power lines of the utility grid. Stand-alone systems are best in settings far from electric power lines or in locations where it would be costly or inconvenient to connect them to the utility grid.

Homeowners with stand-alone systems are completely independent of the utility grid, relying on their own power systems to meet all their electricity needs. They connect their solar cells to batteries that store electricity for use when the sun is not shining.

Active Trackers

Active trackers use photocells, electronics, and linear actuators to track the sun very accurately. A small controller bolted to the array is programmed to keep equal illumination on the photovoltaics at the base of an obelisk. Power comes from tapping off the PV array and averages a miniscule 0.5 watts per hour. Dual-axis, azimuth tracking can be used and is easily programmable. Active trackers average 10% to 15% more collection per day than a passive tracker in the same location. Due to the high costs for controllers and linear actuators, active trackers are more economical for larger PV arrays.

Lenses and mirrors are also being used on larger arrays to focus sunlight onto heat exchangers. curved parabolic reflecting mirrors can be used that always have the same focus no matter what angle the light comes from. Lenses or mirrors could also be on a two-axis tracking system to follow the sun as it travels across the sky. This can be digitally monitored by light sensors which relay wavelength and exposure information to a tracking system so that the PV system actually "finds" the greatest amount of PV energy.
Integrated Photovoltaic Systems

The Flachglas production facilities in Germany utilize a fully integrated photovoltaic facade as an architectural element. The south and west facades of the stairwell tower have been clad with a rear ventilated curtainwall system which uses polycrystalline photovoltaic modules. A range of module sizes was used to ensure that the installation was fully architecturally integrated. The 12.5kWp system is grid connected via five identical inverters, three of which operate in “master-slave mode” so the building will either draw or dump energy as sensors detect a surplus or shortage of amperage.

Researchers at NREL laboratories utilize much of the technology they produce in creating “test pieces” for fully integrated residential use. Shown to the right are a few of the components they have linked to create an electronic system for sustainable building: PV shingles or arrays feed electricity to the system where it is stored, monitored, or channelled for use. A fully automated system has environment sensing ability (mostly light, heat, moisture, and chemical composition), would monitor itself, and in the future will be able to allow almost maintenance-free operation of building systems.

The Serf Building at the NREL Laboratories in Golden, Colorado has been developing fully integrated photovoltaic building systems for the last decade. Much of their research has resulted in products providing greater electronic, thermal, and environmental performance in residential and commercial applications. The Serf Building stands as the testing ground for new building products, from fully automated and digital monitoring systems w/ environment sensing controls to PV shingles (see examples below).
Integrated Photovoltaic Systems

Architect(s): Earthship Biotechture
Location: Taos, New Mexico

Technology for Waste Management

The Earthship in Taos, New Mexico also utilizes PV technology and a system of sensors to monitor and accelerate the anaerobic process of waste for food production, landscaping, and to maintain a greywater and treatment system within the building. An optional line out goes to rubber lined exterior plant cells (size and quantity varies) that are constructed very similar to an interior greywater treatment planter. This allows containment of remaining effluent and directs its use toward exterior landscaping since the water stays measurably below monitored nitrate levels. Currently Earthship designers are attempting to integrate more evolved sensing and actuating equipment for more efficient food production and system maintenance.

A Solar Pumping System

In this system, all energy produced by the Earthship PV module goes directly to submersible pumps. Water is delivered to a raised storage tank to gravity feed the plumbing system. This kind of system (without battery storage) is called PV-direct, and is the most efficient way to utilize PV energy. Eliminating the electro-chemical conversion of the battery saves about 20%-25% of the energy lost in DC/AC conversion.

The Earthship also uses a PV-direct controller, or Linear Current Booster (LCB), unique to systems without batteries. This solid-state device will down-convert excess voltage into amperage that will keep the pump running under low light conditions when it would otherwise stall, soon to be monitored digitally. An LCB can boost pump output by 40% or more, thus saving energy efficiency.

MISCELLANEOUS FACTS
Earthship Designs have been used across the globe.
Interior Designer: N/A
Year of Completion: Not yet complete
Size: + 2,000 sf
Type of Project: residential
Contractor: Earthship Biotechture
Construction Cost: ??
Web Link: www.earthship.org