# *Active Solar: Photovoltaics and Solar Thermal*

ARC 3723 | EBS II
MS State University | CAAD

## Photovoltaics and Solar Thermal

### Introduction

Photovoltaic (PV)

- Produce the high-grade energy of electricity.
- Electricity considered high-grade because it can be used to do all kinds of work (generate light, move elevators, etc.)

Solar Thermal Panels

- Produce the low-grade energy of low-temperature heat.
- Low-temperature heat can do little more than heat water or a building.

*(Source: Heating, Cooling, Lighting by Lechner)*

## The Almost Ideal Energy Source

- Sustainable
- Nonpolluting
- Not dangerous to people or the planet
- High-grade energy useful for any purpose
- Silent
- Supplies power where it is needed (no need to transport energy)
- Most available at peak demand time (e.g., hot, sunny day)
- May have the benefit of creating the building envelope (i.e. displaces conventional building materials)
- High reliability
- No moving parts
- Little maintenance required
- Modular (can come in any size required)
- Low operating cost
- Low initial cost
- *Supplies energy all the time*

*(Source: Heating, Cooling, Lighting by Lechner)*

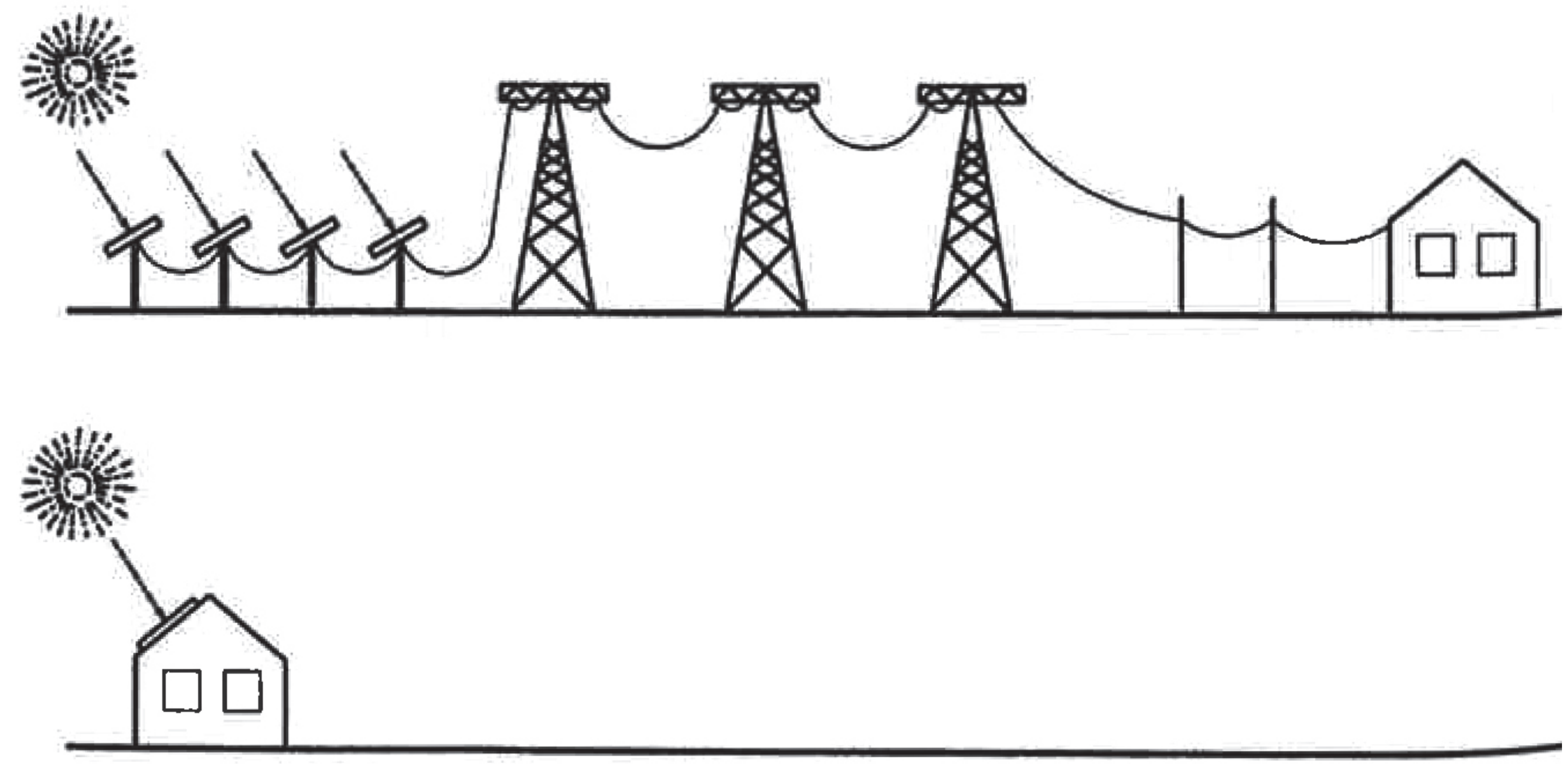


**Figure 17.1** On-site or district PV greatly reduces electrical-transmission losses, which can be as high as 25 percent with the existing power grid with its large central power plants including large remote PV farms.

## The Almost Ideal Energy Source

- *Supplies energy all the time?*

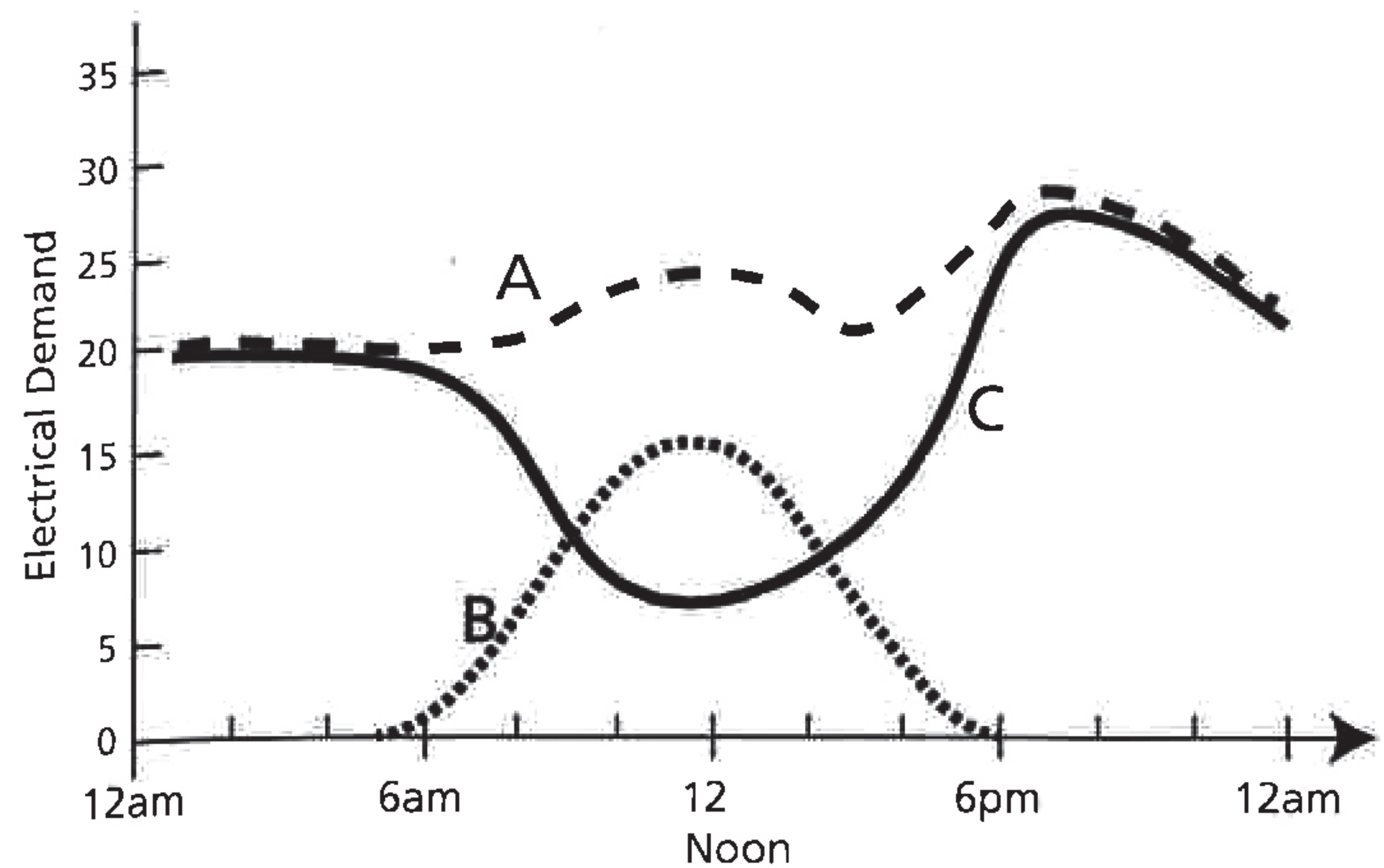
Remaining hurdle to widespread use of PV is intermittent nature of PV produced electricity.

"Duck Curve"

Solution to the problem of the time delay between peak production and peak demand is storage in the form of batteries.

- **Curve B** represents the electricity supplied to the grid on a sunny day when a lot of PV have been installed.
- Around the noon hours, much of the electrical demand **(Curve A)** can be met by PV
- **Curve C i**s the uneven demand on the power company's generators.
- Storing electricity by saving some peak solar production for the evening when the demand is highest.

*(Source: Heating, Cooling, Lighting by Lechner)*



## The PV Cell

(Also Solar Cell)

- Made from semiconductor materials that convert light directly into electricity.
- Most use silicon with small amounts of certain impurities added to create an excess of electrons in one layer and lack of electrons in another layer.
- Photons of light create free electrons in the top layer.
- A conducting strip enables electrons to flow through an external circuit to reach the bottom layer that lacks electrons.

*(Source: Heating, Cooling, Lighting by Lechner)*

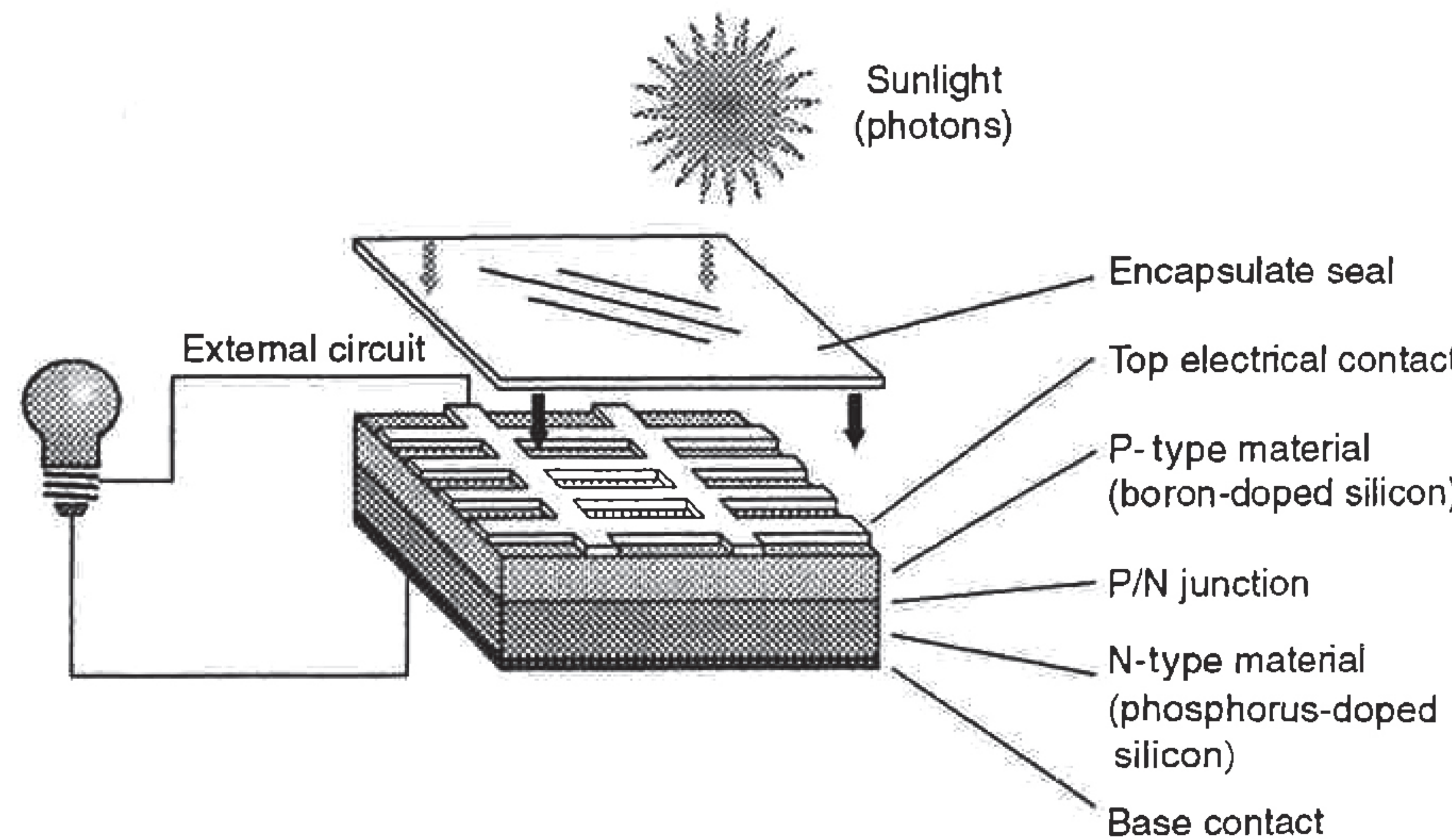


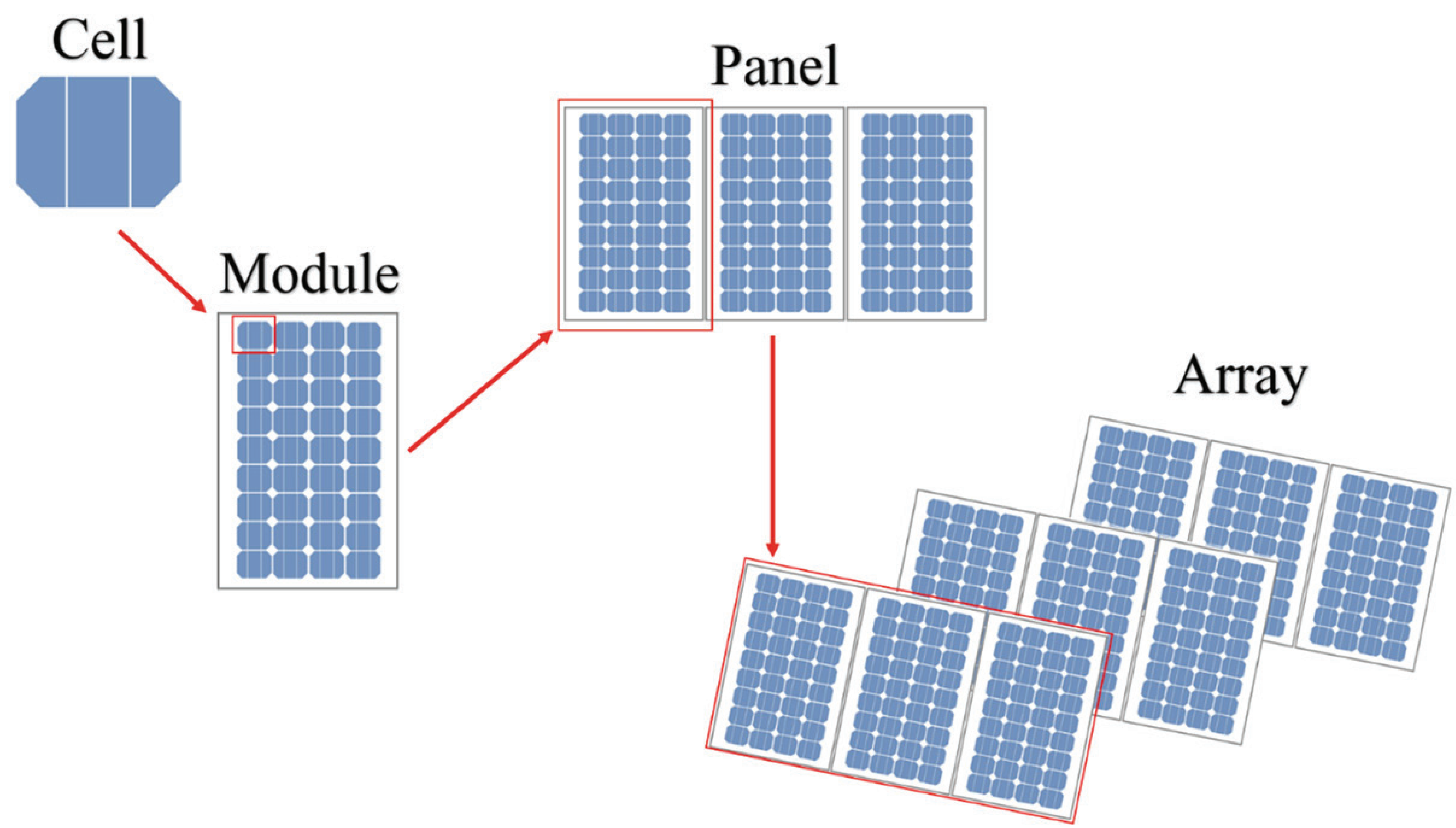

**Figure 17.2a** A section through a typical PV cell. Photons of light generate free electrons. The metal grid on the top and the metal plate on the bottom allow for the collection and return of the free electrons through an external electric circuit. (Drawing from Fact Sheet No. 11 from State Energy Conservation Office of Texas © Texas Comptroller of Public Accounts.)

**The PV Cell - Module - Panel - Array**

(Also Solar Cell)

- Cells encased to form modules
- Modules combined to form panels
- Panels combined to form an array

*(Source: Heating, Cooling, Lighting by Lechner)*

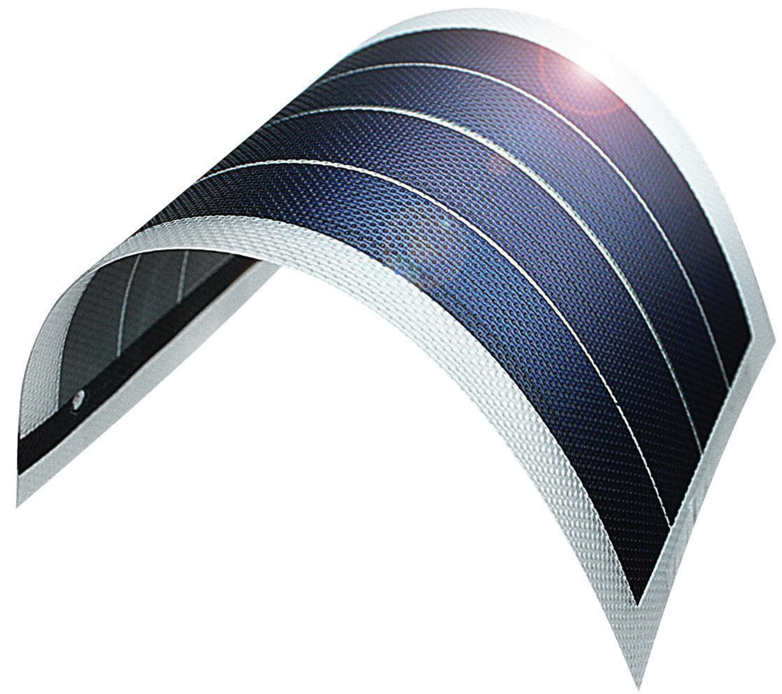


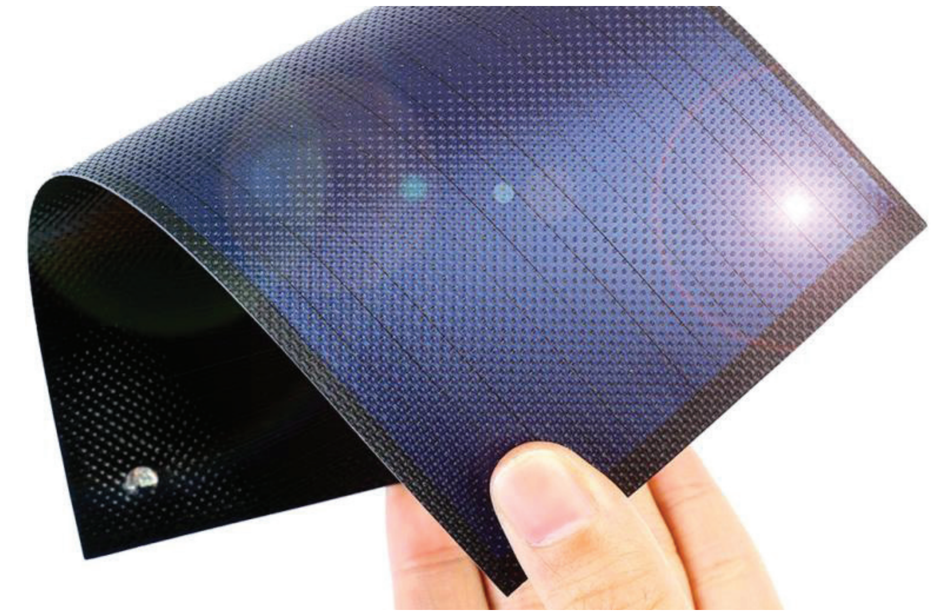
## Photovoltaics and Solar Thermal

### Thin Film PV (TFPV)

- Lower cost
- Flexible and can conform to non-flat forms
- But convert sunlight to electricity at a lower efficiency

*(Source: Heating, Cooling, Lighting by Lechner)*





## Photovoltaics and Solar Thermal

### Organic PV (OPV)

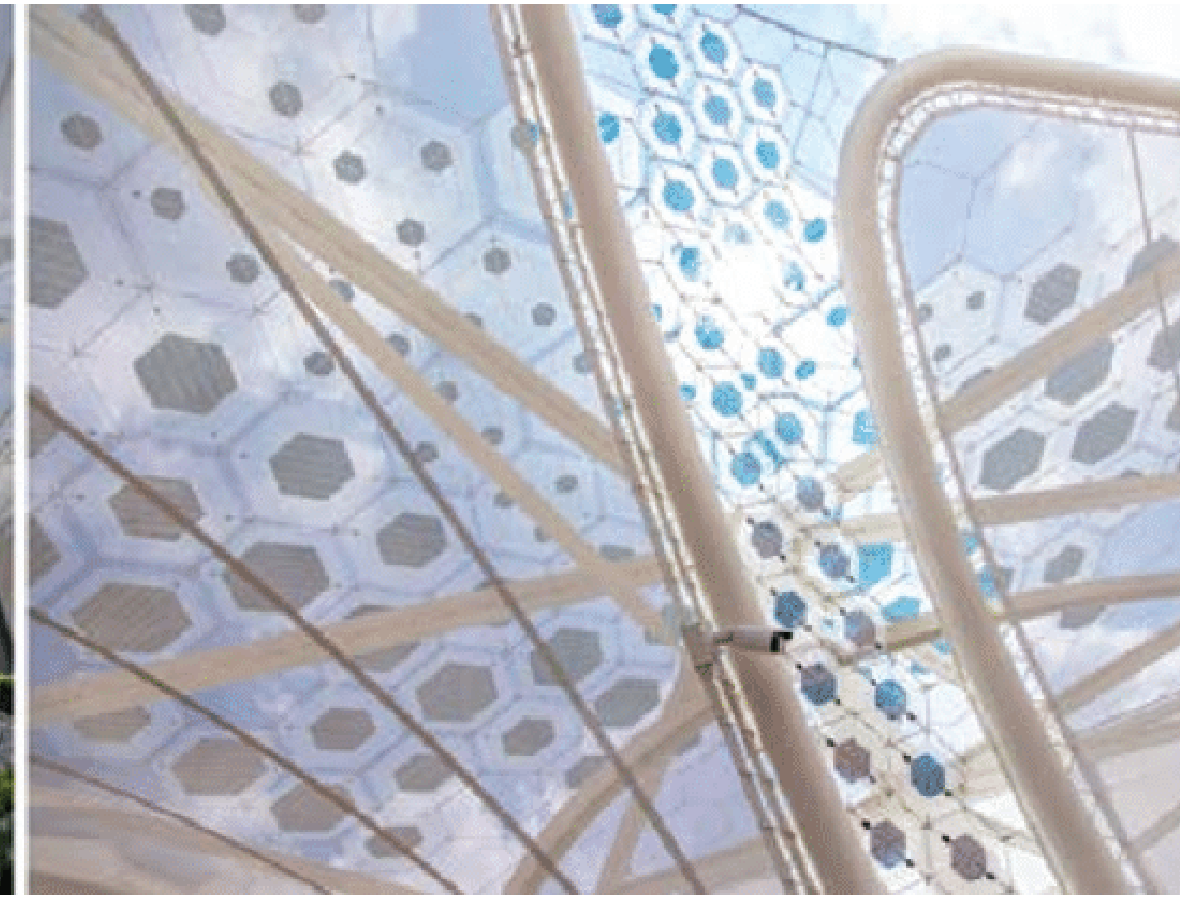
Instead of silicon, researchers are working on organic photovoltaic (OPV) technologies. Organic simply means carbon-containing molecules and OPVs can be thought of as plastic solar cells. They offer advantages over silicon-based solar panels.

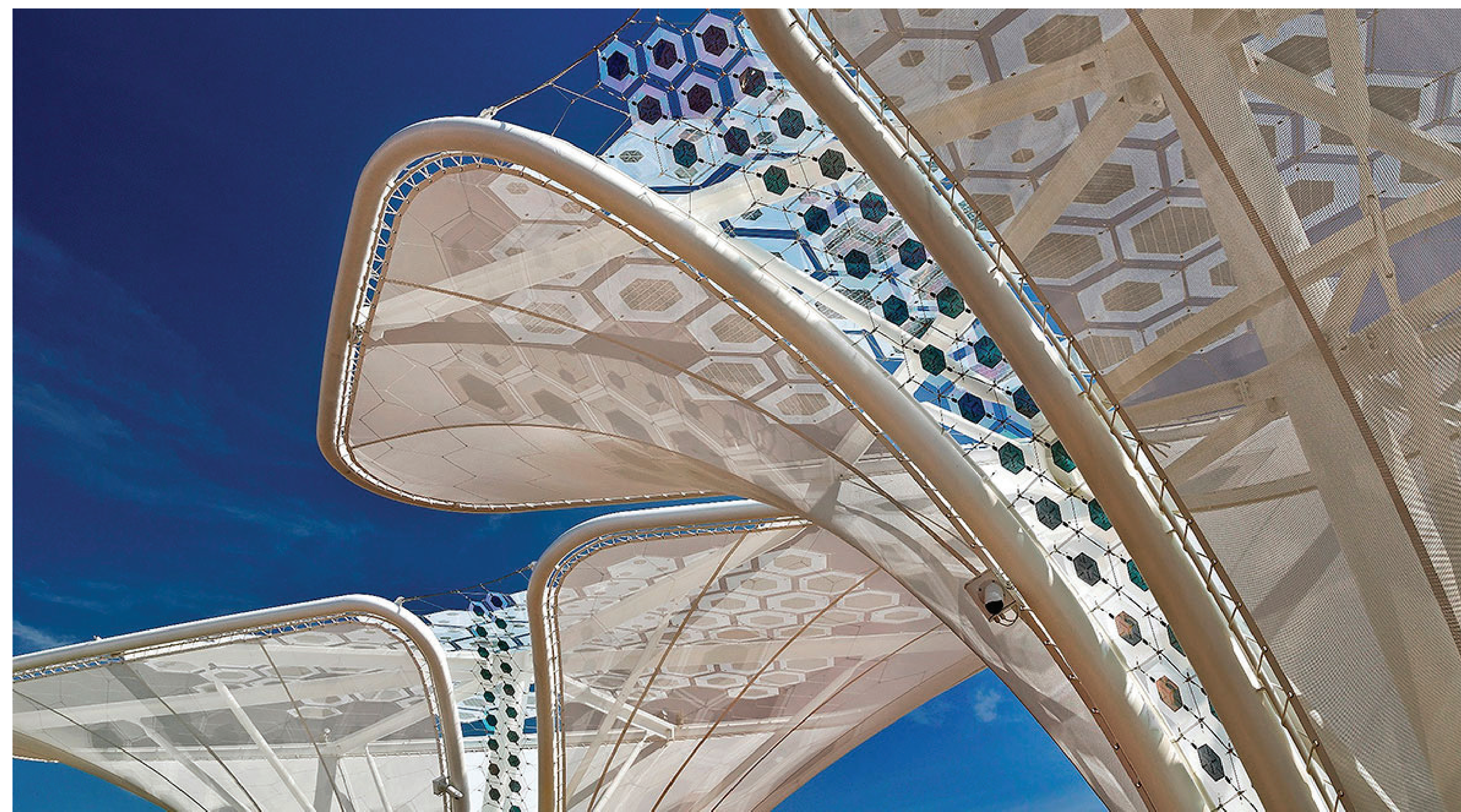
Their manufacture process (has the potential to be) cheaper, they are lightweight, offer flexibility in their architecture and in principle they can be more environmentally friendly.

Project: OPV integrated solar trees of German Pavilion, Milan Expo 2015

https://vimeo.com/134821149

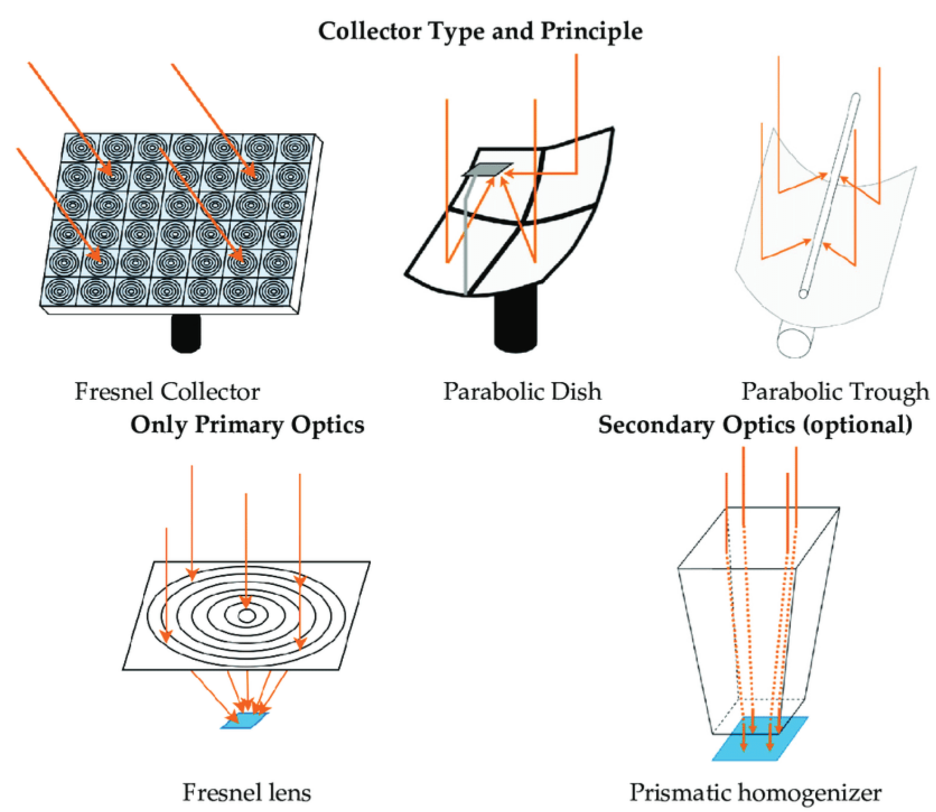
*(Source: https://ec.europa.eu/)*

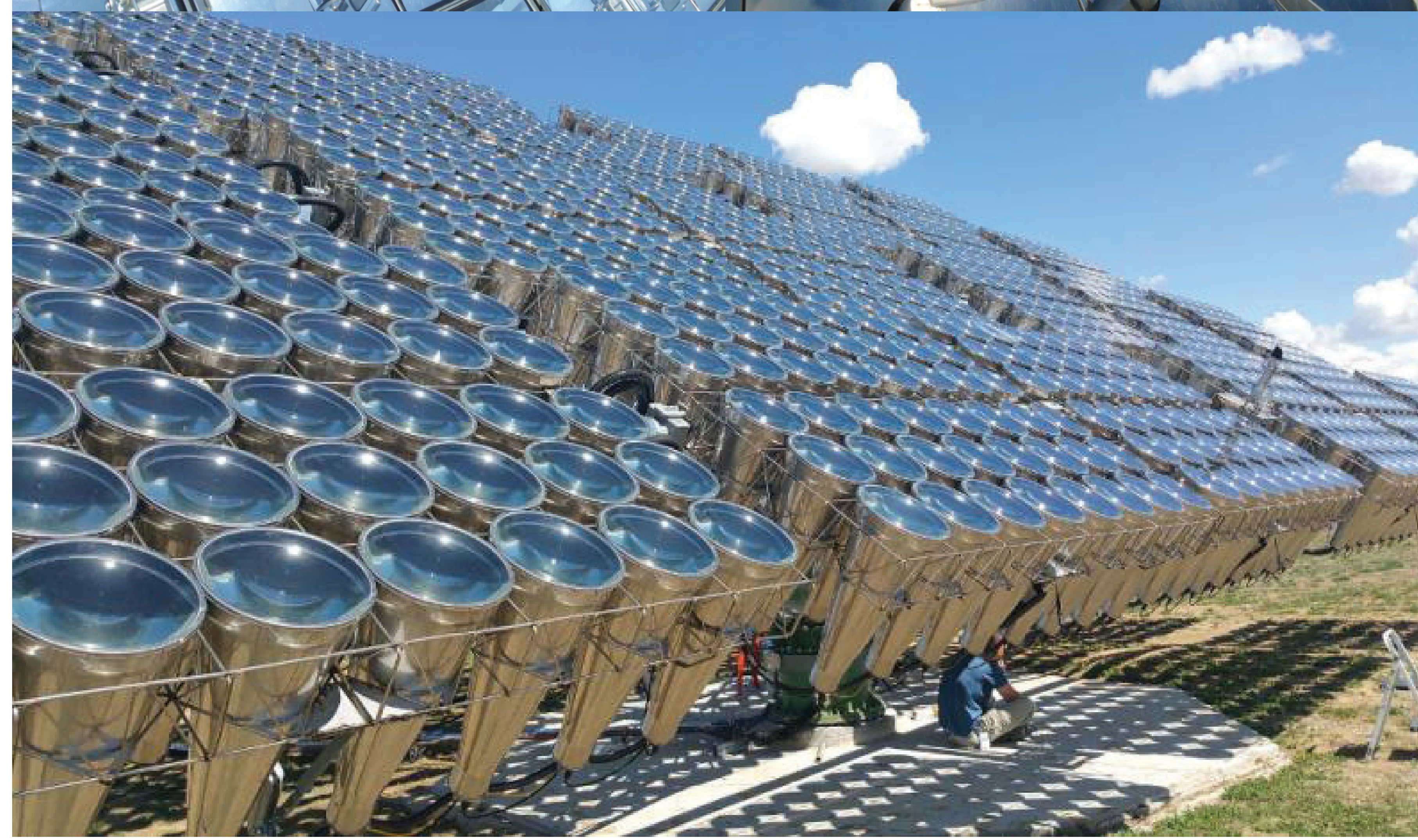




## Concentrator Photovoltaics (CPV)

Concentrator photovoltaics (CPV) (also known as concentration photovoltaics) is a photovoltaic technology that generates electricity from sunlight. Unlike conventional photovoltaic systems, it uses lenses or curved mirrors to focus sunlight onto small, highly efficient, multi-junction (MJ) solar cells.



**Photovoltaics and Solar Thermal**

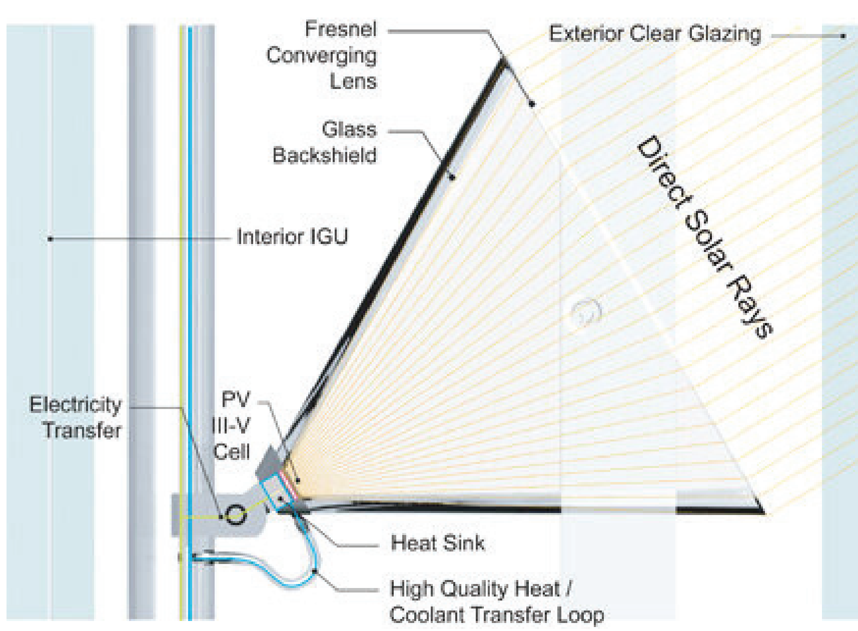
## Concentrator Photovoltaics (CPV)

CASE - Center for Architecture Science and Ecology

Next Generation High-Efficiency Solar Power Systems for Building Envelopes

The Integrated Concentrating Solar Facade (ICSF) is a building-integrated photovoltaic system that takes a dramatically different approach to providing interior space with electrical power, thermal energy, enhanced daylighting, and reduced solar gain. It surpasses existing building integrated photovoltaic (BIPV) or concentrating PV technologies in these benefits, and is applicable to both retrofits and new construction. The system integrates architecturally into facades and atria, harvesting solar energy, while still providing outside views and diffuse daylight for the building users.

Source: https://www.case.rpi.edu/research/icsolar




## Photovoltaics and Solar Thermal

**Concentrator Photovoltaics (CPV)**

CASE - Center for Architecture Science and Ecology

Next Generation High-Efficiency Solar Power Systems for Building Envelopes

Source: https://www.case.rpi.edu/research/icsolar

## Grid Connected System

- Used where power grid exist
- Excess PV power is sold to the utility, and at night, power is drawn from the grid in a process called **Net-Metering**
- In effect, grid acts as a giant storage battery
- Advantage to both owners and power companies
- Power conditioner required to change direct current (DC) from the PV array to alternating current (AC) at the correct voltage and in phase with the grid

*(Source: Heating, Cooling, Lighting by Lechner)*

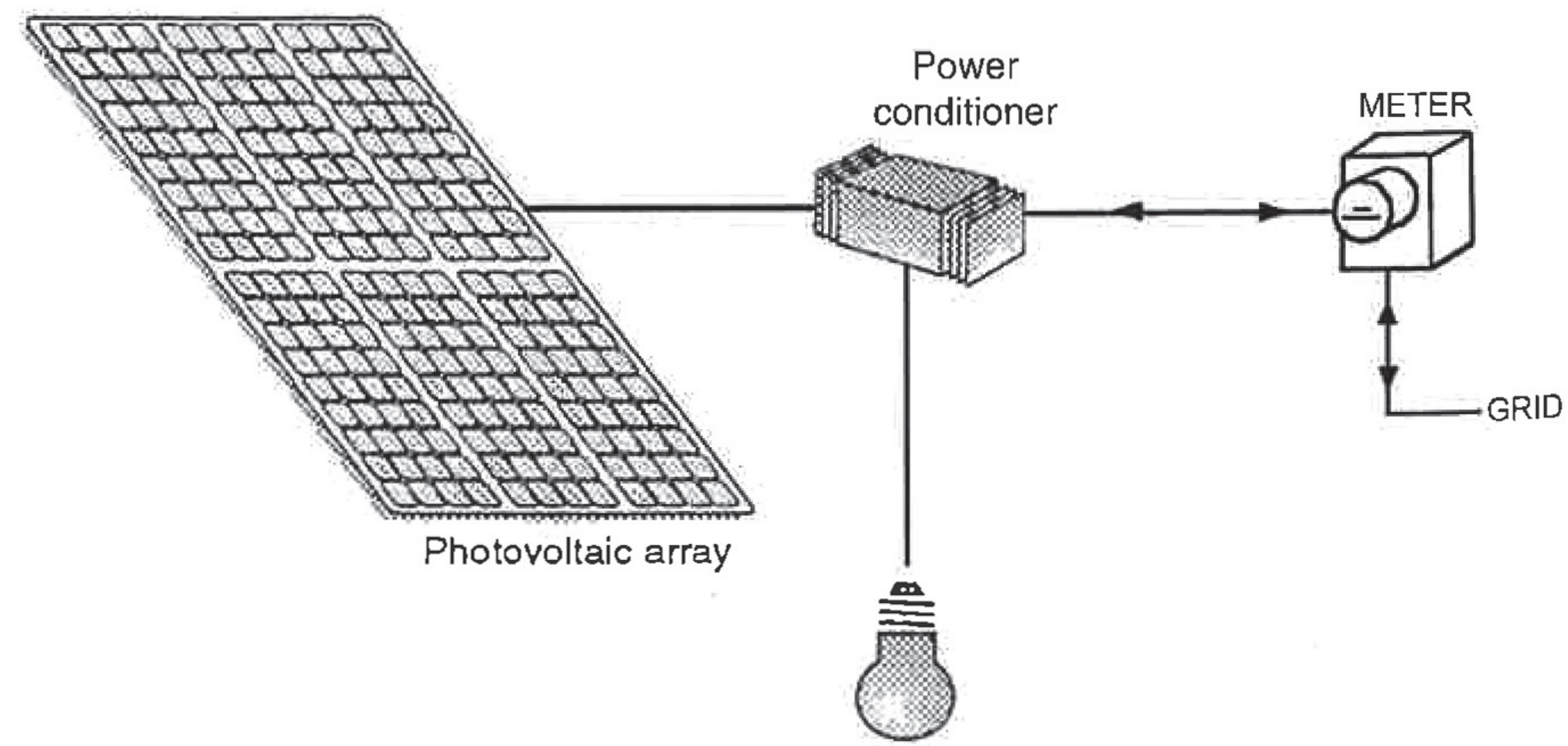



**Figure 17.3a** A typical grid-connected PV system. On a sunny day, the excess power will flow into the grid and the meter will run backwards. The power conditioner contains an inverter to change DC into AC.

## Stand-Alone System

- Excess electricity produced during the day is stored in batteries.
- Use as many low-voltage direct current (DC) appliances as possible to avoid cost and energy loss due to inverters.
- Smaller, less expensive inverters could be used for select AC appliances.

*(Source: Heating, Cooling, Lighting by Lechner)*

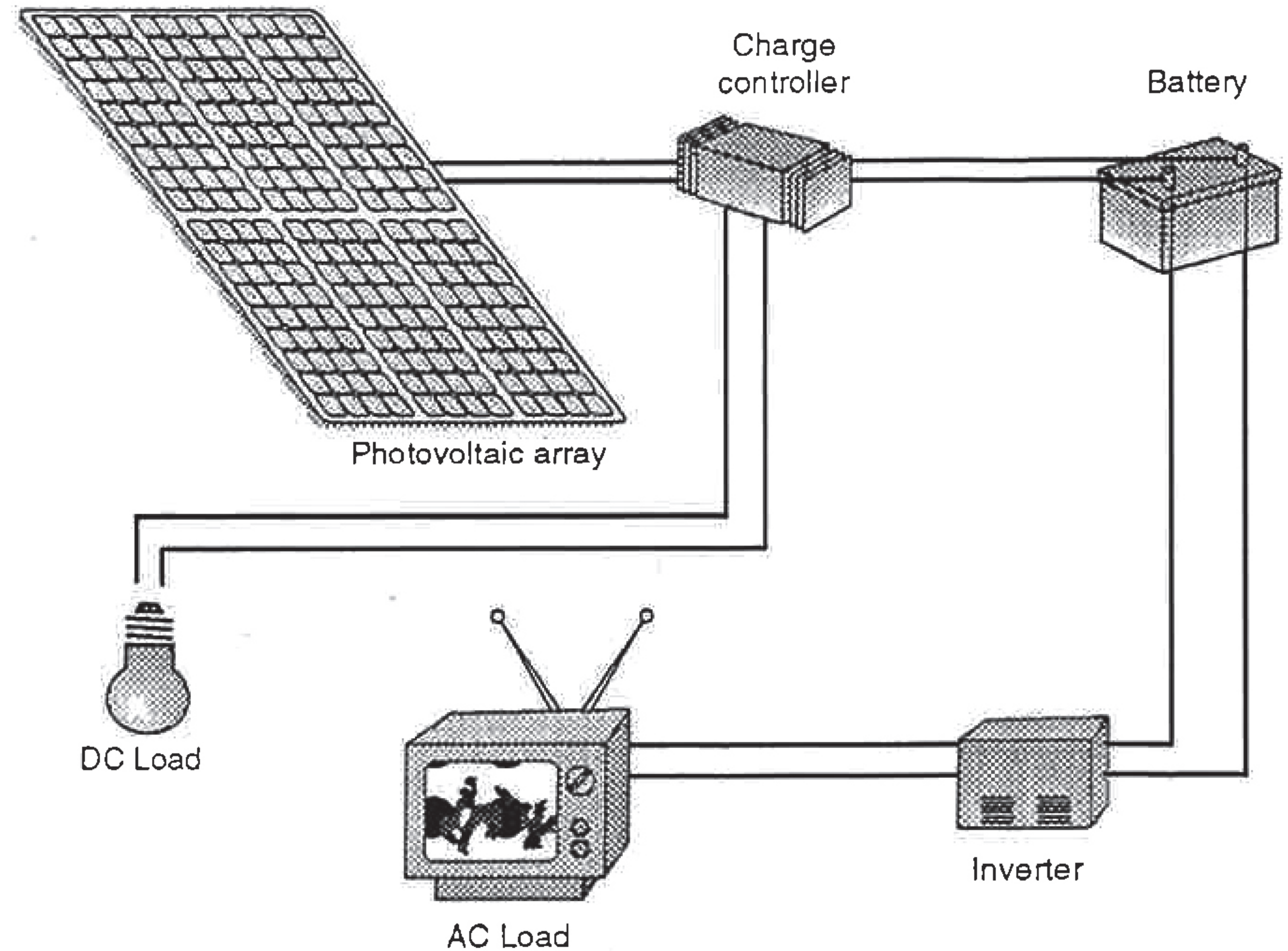



**Figure 17.3b** A stand-alone system needs batteries to store the electricity for nighttime use and an inverter to change DC to AC.

**Hybrid System**

- Solar and wind
- Wind power often ideal complement to PV because not only can the wind blow at night but it is usually extra windy during bad weather.

*(Source: Heating, Cooling, Lighting by Lechner)*

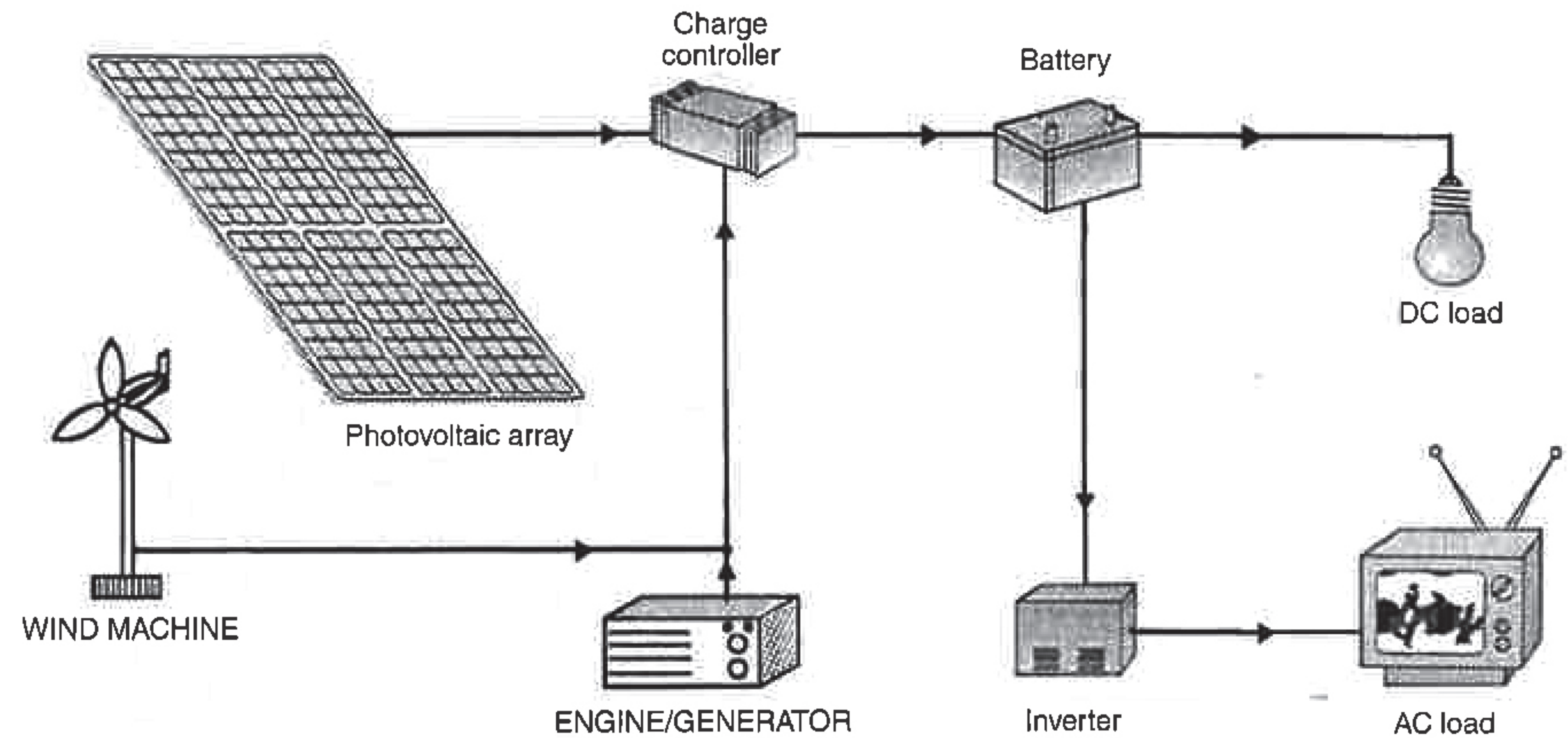



**Figure 17.3c** Hybrid systems give the most reliable power at the least cost for stand-alone installations. Hybrid systems use wind or an engine-generator for backup power.

## Photovoltaics and Solar Thermal

### Site-Integrated Photovoltaics

- PV Installations located at building site
- Array separate from the building for optimum solar exposure

*(Source: Heating, Cooling, Lighting by Lechner)*

## Photovoltaics and Solar Thermal

### Building Applied PV (BAPV)

- Existing buildings and some new construction
- Typically applied to the roof
- Supported by a frame that allows water and cooling air to pass underneath the panels / ventilates the back of the PV panel

*(Source: Heating, Cooling, Lighting by Lechner)*

**Building Integrated PV (BIPV)**

- Walls, roofs, and glazing

**Sawtooth clerestory**

*(Source: Heating, Cooling, Lighting by Lechner)*

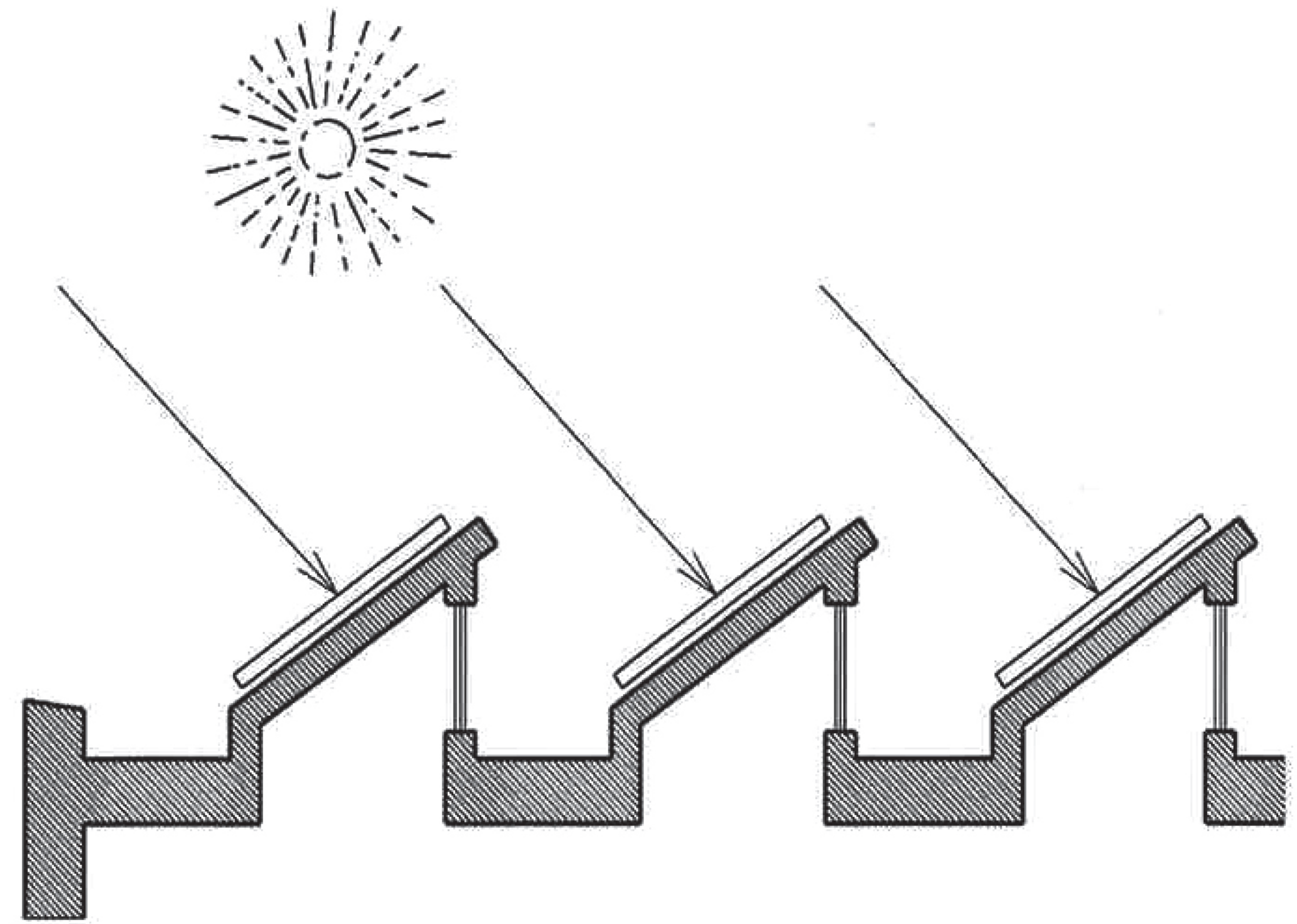


**Figure 17.4j** North-facing sawtooth clerestories can provide both daylighting and the proper tilt for BIPV.

**Building Integrated PV (BIPV)**

- Walls, roofs, and glazing

**Roof with plenum**

*(Source: Heating, Cooling, Lighting by Lechner)*

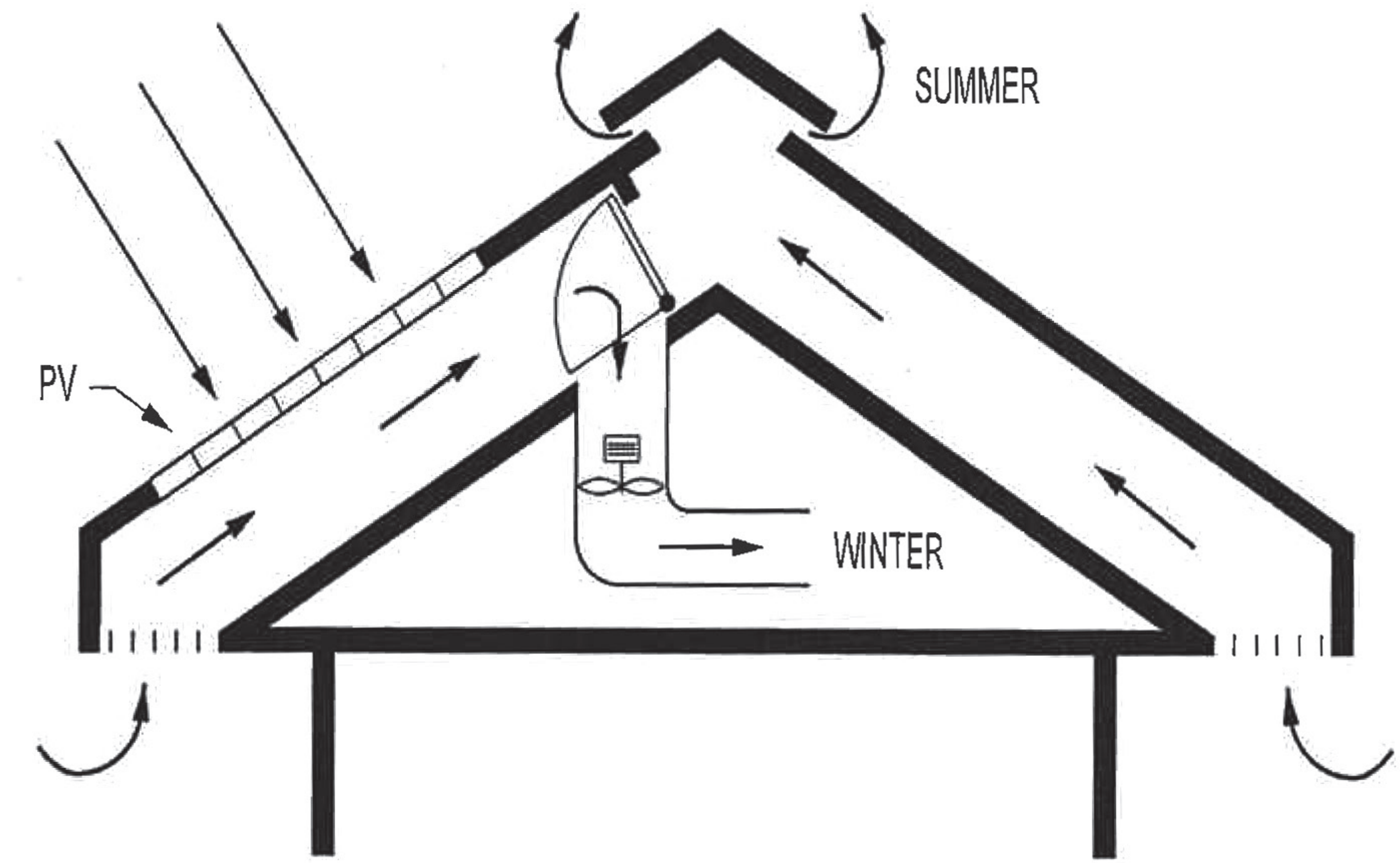



**Figure 17.4m** With building integrated PV systems, ventilate the underside of the PV in summer to keep the cells from overheating. In winter, this warm air can be used to heat the building.

### Building Integrated PV (BIPV)

- Walls, roofs, and glazing

### Double-Wall Design

*(Source: Heating, Cooling, Lighting by Lechner)*

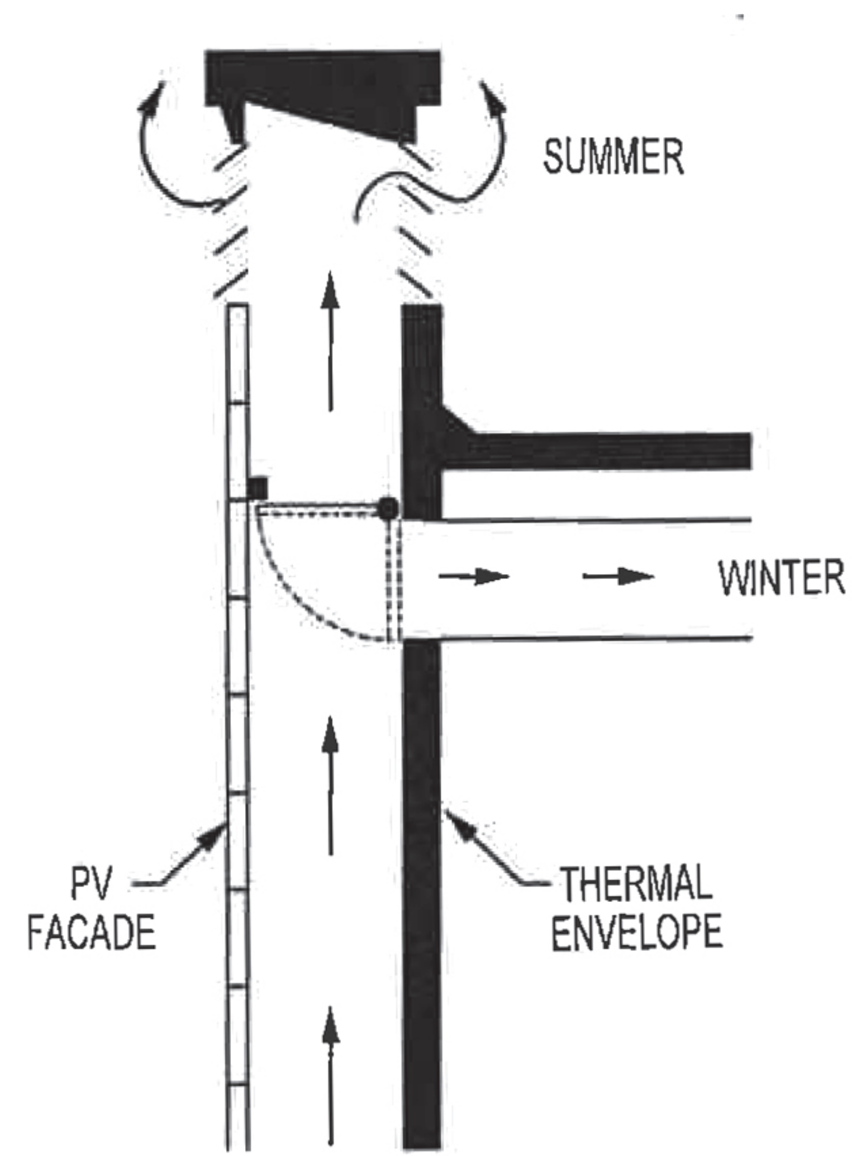



**Figure 17.4n** In this building integrated facade, the double-wall design enables the air behind the PV to be vented in the summer to cool both the PV and the building. In winter, the hot air can be used to heat the north side of the building.

## Photovoltaics and Solar Thermal

### Building Integrated PV (BIPV)

- Walls, roofs, and glazing

### Glazing

- Transparent
- Translucent
- Opaque

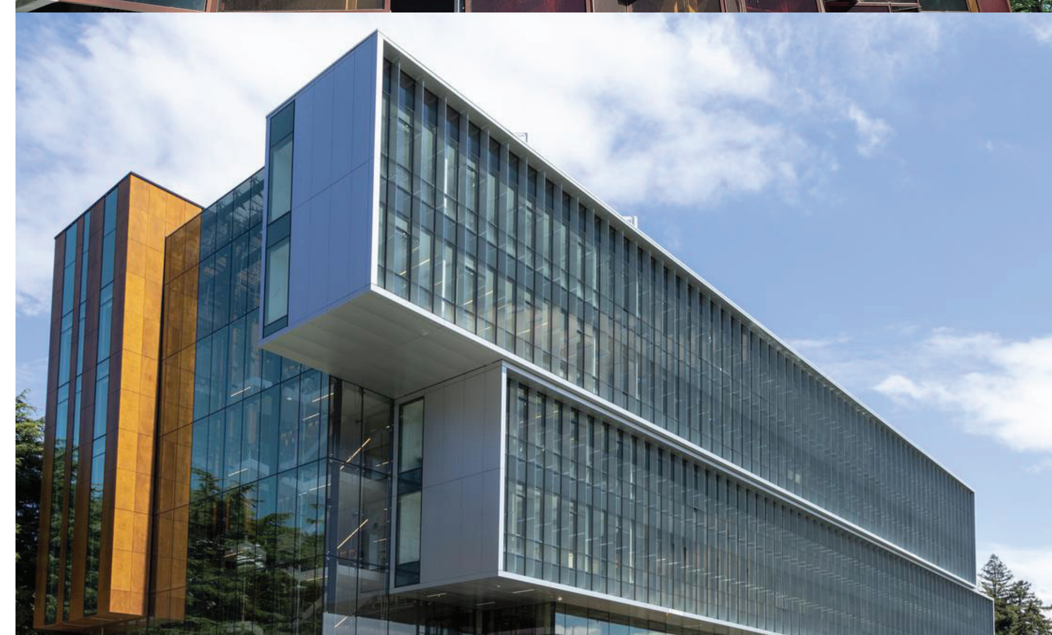
Since PV only uses part of the solar spectrum, the rest of the light can be allowed to pass through and views maintained.

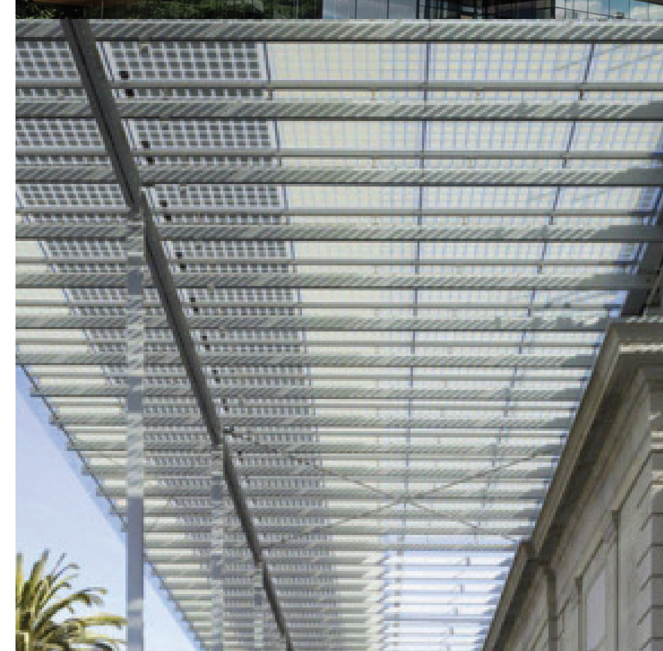
Car park in Vallastaden, Lindköping - Soltech

The Life Science Building,  University of Washington - Perkins + Will

The California Academy of Sciences - Renzo Piano

*(Source: Heating, Cooling, Lighting by Lechner)*





## Photovoltaics and Solar Thermal

### Solar Thermal

Most solar thermal systems use water rather than air as a heat-transfer-and-storage medium. Such water-based systems can also be easily used for space heating.

Each system has

- Collector
- Heat-transfer fluid
- Storage Device

### Flat-Plate Collector

- Collector used for producing domestic hot water
- Consists of metal plate coated with a black selective surface to reduce heat loss by re-radiation
- Glass cover creates greenhouse effect to maximize energy collected
- Insulation used to reduce heat loss
- Water is pumped through well insulated pipes to storage tanks.

*(Source: Heating, Cooling, Lighting by Lechner)*

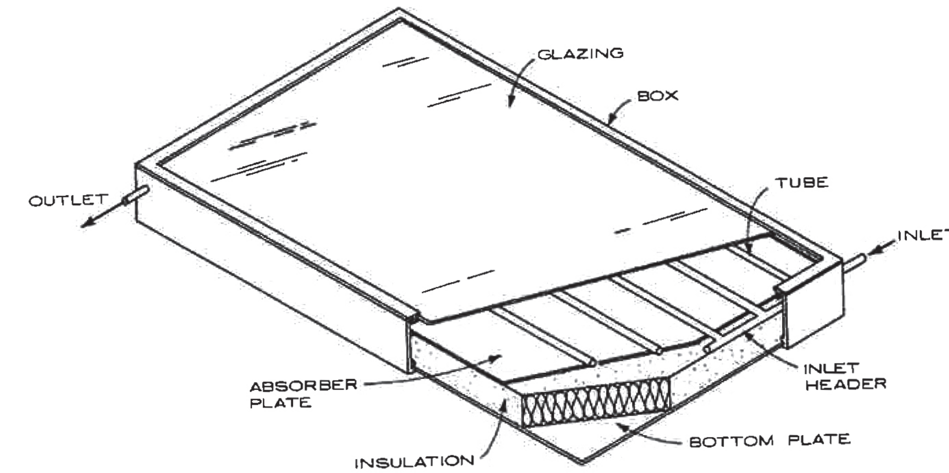



**Figure 17.11a** A typical flat-plate collector designed to heat a liquid. To keep sizes manageable, the collectors vary from 3 to 4 ft wide and 6 to 10 ft long. (From *Architectural Graphic Standards*, Ramsey/Sleeper, 8th ed., John R. Hoke, editor © John Wiley & Sons, Inc., 1988.)

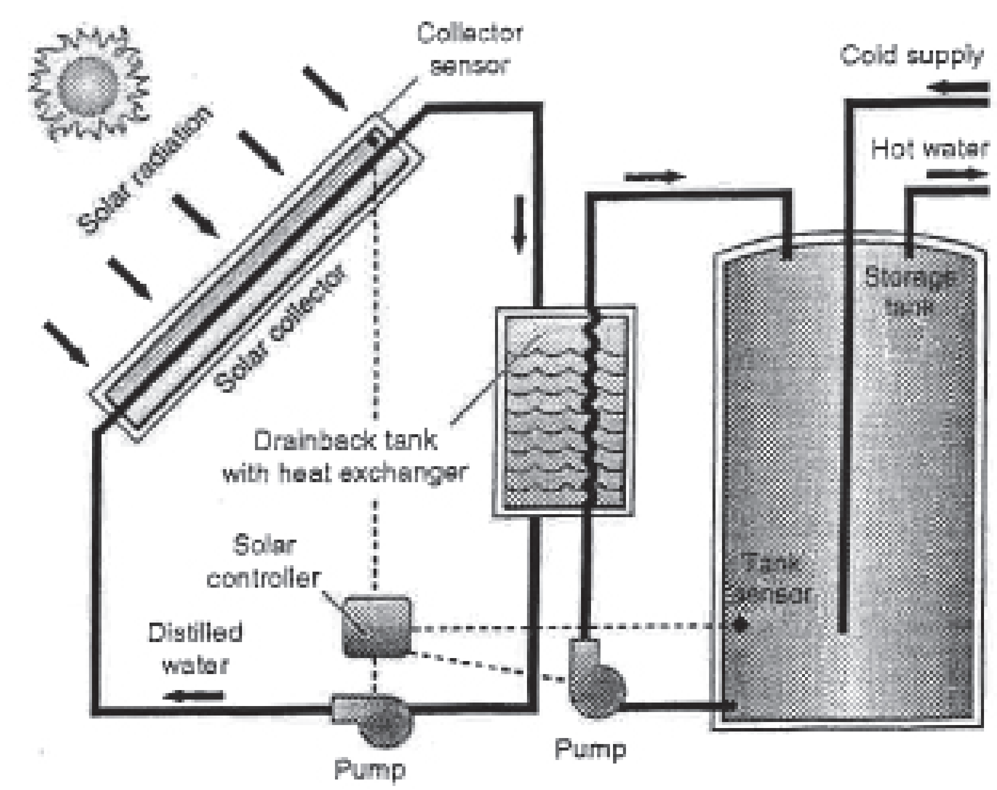



**Figure 17.11b** The drain-back solar hot-water system is shown. To prevent contamination of the domestic hot water, a heat exchanger is used. A space-heating system can also utilize the hot water in the tank. (From the Texas State Energy Conservation Office, Fact Sheet #10.)

## Photovoltaics and Solar Thermal

### Solar Thermal

### Vacuum-Tube Solar Collector

- High efficiency
- Convective and conductive losses are eliminated by the vacuum.
- Most radiant losses eliminated by a selective coating.
- Resistance to freezing
- Heat pipe used when only one end has connection
- If both ends have connection, water flows through the vacuum tube.

*(Source: Heating, Cooling, Lighting by Lechner)*

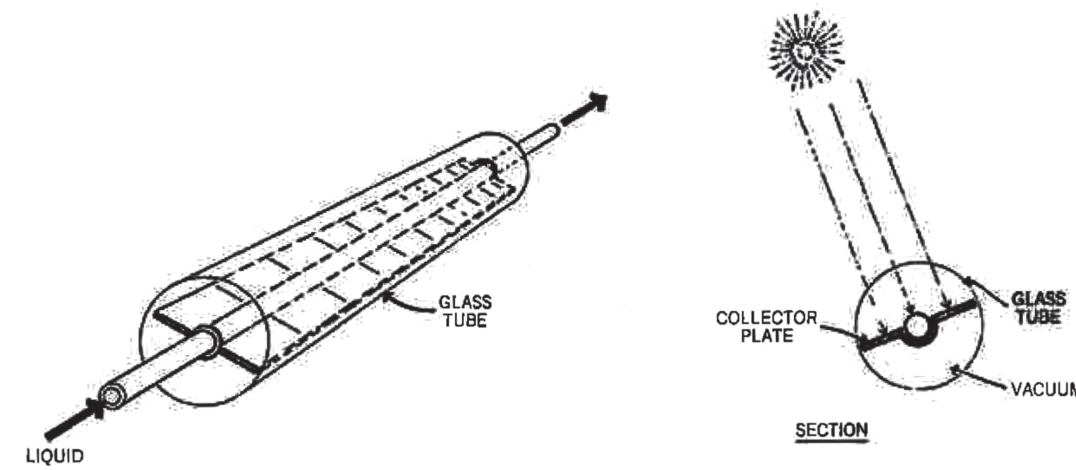



**Figure 17.11c** A vacuum-tube collector achieves high temperatures by reducing heat loss. All convective and most conductive losses are eliminated by the vacuum, and most radiant losses are eliminated by a selective coating. They come in two types. When only one end has a connection, a heat pipe is used. When there is a pipe at both ends as in the case shown in this figure, water flows through the vacuum tube.



## Solar Thermal

### Transpired Solar Collectors

- Preheating ventilation air
- Buildings need a carefully designed ventilation system, and in winter, preheating this fresh outdoor air will save a great amount of energy.

*(Source: Heating, Cooling, Lighting by Lechner)*

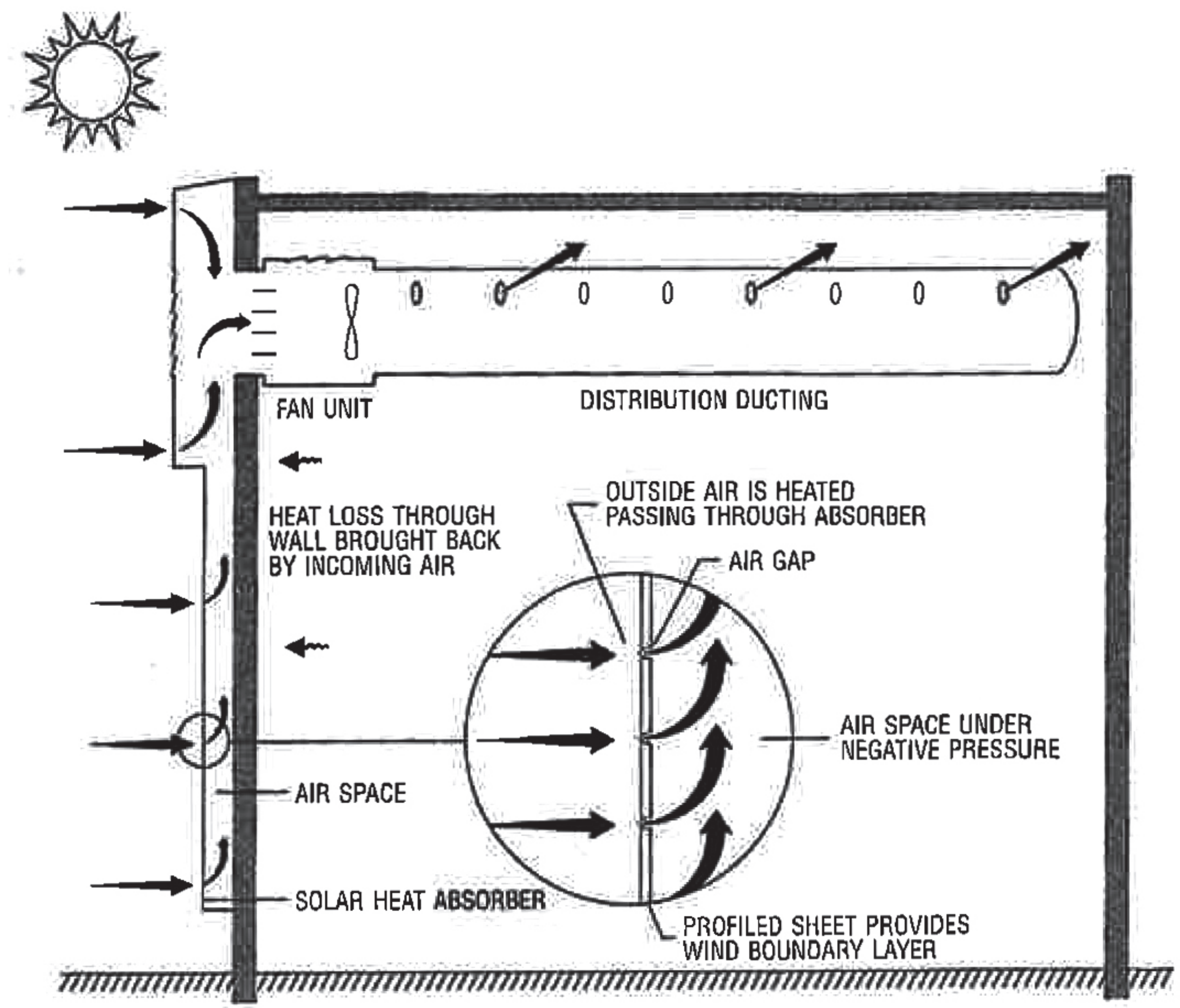



**Figure 17.14a** A solar thermal transpired ventilation preheater system is shown. By perforating the dark-colored metal cladding, warm ventilation air heating is achieved at high efficiency. (Courtesy of Conserval Systems Inc., makers of the Solarwall system.)