Part III

Overview of Renewable Energy choices

- Solar PV
- Solar Thermal
- Wind
- Geothermal (GSHP)
- Other Renewable Energy Options
Solar PV Cell Technologies

**Crystalline Silicon**
- Single Crystal: 25%
- Multi-Crystalline: 19%
- Ribbon: 16%
- Film: 16%

**Thin Film Materials**
- Amorphous Silicon (a-Si): 13%
- Cadmium Telluride (CdTe): 17%
- Copper Indium Gal. Diselenide (CIGS): 19%

**Concentrators**: 40%
### Solar PV Module Technologies

#### Crystalline Silicon

<table>
<thead>
<tr>
<th>Module Type</th>
<th>Mod. Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Crystal</td>
<td>14-15%</td>
</tr>
<tr>
<td>Multi-Crystalline</td>
<td>12-14%</td>
</tr>
<tr>
<td>Ribbon</td>
<td>12-13%</td>
</tr>
<tr>
<td>Film</td>
<td>8-10%</td>
</tr>
</tbody>
</table>

#### Thin Film Materials

<table>
<thead>
<tr>
<th>Material Type</th>
<th>Mod. Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amorphous Silicon (a-Si)</td>
<td>5-7%</td>
</tr>
<tr>
<td>Cadmium Telluride (CdTe)</td>
<td>7-9%</td>
</tr>
<tr>
<td>Copper Indium Gallium Diselenide (CIGS)</td>
<td>10-14%</td>
</tr>
</tbody>
</table>

#### Concentrators

20% +/-
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Design Guidelines for Integrating Renewable Energy in Commercial Buildings

Solar PV Cell Market Share

- Monocrystalline: 30%
- Multicrystalline: 60%
- Amorphous silicon: 6%
- CIS / CdTe: 4%
PV Roofing Products

South facing roof with 96 *Unisolar* photovoltaic shingles covering an area of approximately 280 square feet and surrounded by conventional asphalt shingles. The "name plate" rating of this array is 1632 Watts.
Global Solar has developed a proprietary process for manufacturing **thin-film Copper Indium Gallium diSelenide (CIGS) photovoltaic (PV)** modules. Unlike traditional solar panels that are rigid, heavy and fragile, Global Solar's thin-film solar modules are lightweight, flexible and durable.
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PV Glass Products

- Custom PV Laminated Glass
- Film Laminates
- Holographic PV
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Specialty PV Products

Color options

Custom Patterns

Die Ergebnisse des Forschungsprozesses BIMODE und einer Studie des Atominstituts Wien (Bild 111 und 112) zeigen Leiterbahnen als Dekor.

Das Forschungsprojekt PVACCEPT entwickelte Dekors aus semitransparenten Zellen in Dünnenschichttechnologie, ähnlich einer Radiertechnik (Bild 113 und 114).

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Solar PV Applications

- Freestanding
- Roof Mounted
- Building Integrated
- Tracking Systems
Solar PV Applications

- Freestanding
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Solar PV Applications

- Freestanding
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Solar PV Applications

- Freestanding
- Roof Mounted
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Loyola Marymount University
The largest solar electric rooftop system at any university in the world and the largest system in Southern California.

- In an innovative partnership between Los Angeles’ Loyola Marymount University, the Los Angeles Department of Water and Power (LADWP), the Southern California Gas Company, and solar electric company PowerLight
- Totaling 723-kilowatts peak power
- At Loyola Marymount's campus in Westchester on three of the university's largest buildings: Gersten Pavilion, University Hall, and the Von der Ahe Library.
- Estimated at more than $4.3 million, the project expense will be offset by rebates – $3.7 million from the LADWP, and $325,000 from the Gas Company
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Solar PV Applications

- Freestanding
- Roof Mounted
- Building Integrated
- Tracking Systems

Naval Base Coronado, Navy Region Southwest
Location: Naval Base Coronado, California
Date Completed: September 2002
System Size: 750 kWac
System Peak Capacity: 924 kW
Total Projected System Electrical Output: 1,244,000 kWh/yr
Number of solar panels: 3,078
PV surface area: 81,470 sq. ft.

In addition, the 750kW system photovoltaic system generates the electrical energy equivalent to 2,488 barrels of crude oil annually.
PV Roofing Modules with Insulation

Interlocking Solar Roof Tiles Protect & Insulate Your Roof

The PowerGuard Solar Roof System is a simple, high-density system for rooftop installation. The system’s non-penetrating modular design delivers reliable, clean electricity while insulating and protecting your roof. PowerGuard’s flat, lightweight solar tiles operate within your existing roofline and electrical system and install rapidly and securely without mechanical fastening.
Solar PV Applications

- Freestanding
- Roof Mounted
- Building Integrated
- Tracking Systems
Solar PV Applications

• Freestanding

• Roof Mounted

• Building Integrated

• Tracking Systems

- St Leonard’s College Sustainable Living Centre Cornish Campus, Bangholme Supply and installation of:
  - 1.28 kW PV System with communications.
  - Wind Generator (Whisper 200) with communications.
  - Hydronic Heating System with evacuated tubes.

More Educational Facilities Projects listed under Interesting Jobs by Product Supply Division

St Leonard’s College Sustainable Living Centre at Bangholme with the PV panels located at the top of the solar chimneys. The wind generator is shown above.
Solar PV Applications

- Freestanding
- Roof Mounted
- Building Integrated
- Tracking Systems
Solar PV Applications

- Freestanding
- Roof Mounted
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Solar PV Applications

- Freestanding
- Roof Mounted
- Building Integrated
- Tracking Systems

British Pavilion
Architect: Grimshaw Architects
Solar PV Applications

- Freestanding
- Roof Mounted
- Building Integrated
- Tracking Systems
Solar PV Balance of Systems

- Inverter
- Charge Controller
- Batteries
- Mounting Systems
- Monitoring, etc.
Solar PV Balance of Systems

- Inverter
- Charge Controller
- Batteries
- Mounting Systems
- Monitoring, etc.
Advanced Solar PV Technologies

- Advanced Concentrator Systems
- Advanced Glazing
- PV Paint (Nano PV)
- Bio-mimetic: PV Cells that mimic photosynthesis

Concept for focusing concentrator using fresnel lens collector – performs similar to a tracking system.

Dual axis concentrating system uses individually controlled mirrors.
Emerging Solar PV Technology by Energy Innovations

- Tracking Concentrator
- Sunflower™ 250
- SunPod™

High-Concentration Dual-Axis Tracking Solar System.
Emerging Solar PV Technology by Energy Innovations

- Tracking Concentrator
- Sunflower™ 250
- SunPod™

The Stirling-engine Sunflower™ concept is somewhat radical, because it is not based on photovoltaic (PV) cells and has moving parts. The Mfgr. believes that they can make this design much more cost-effectively than a PV-based system because it is simpler, more suitable for mass production, and uses significantly less energy in the actual production processes of the product.
Emerging Solar PV Technology by Energy Innovations

- Tracking Concentrator
- Sunflower™ 250
- SunPod™

The SunPod is designed around a plastic Fresnel lens that focuses incoming light along a thin line of highly efficient PV cells. Of course, concentrated light means a lot of heat, and one of our challenges was to dissipate that heat without getting in the way of tracking the sun. Each tube, measuring one foot in diameter and six feet in length, rotates on its axis to track the daily movement of the sun. Nine tubes are mounted together in a rack, which is angled based on the building’s latitude to provide optimal exposure throughout the year.
Solar Thermal Technologies

Solar Thermal Water (or glycol) Systems
- Flat Plate Direct Collectors
- Flat Plate Indirect Collectors
- Evacuated Tube Collectors

Air Systems
- Solar Thermal Air Collectors
- Transpired Air Collectors

- High Temperature Concentrators
Solar Thermal Collector Technology

- Flat Plate Collectors
- Evacuated Tube Collectors

Liquid flat-plate collectors heat liquid as it flows through tubes in or adjacent to the absorber plate.

Flat Plate Collectors on a Walmart Store in Texas

Photo Credit: Chromagen
Solar Thermal Collector Technology

- Flat Plate Collectors
- Evacuated Tube Collectors
- Solar Thermal Air Systems

Evacuated-tube collectors can achieve fairly high temperatures (170°F to 350°F), making them more appropriate for cooling and commercial and industrial applications. Evacuated-tube collectors are more expensive than flat-plate collectors, with unit area costs about twice that of flat-plate collectors.
Solar Thermal Collector Technology

- Flat Plate Collectors
- Evacuated Tube Collectors
- Solar Thermal Air Systems
  - Air Flat Plate Collectors
  - Transpired Air Collectors

**Air flat-plate collectors** The absorber plates in air collectors can be metal sheets, layers of screen, or non-metallic materials. The air flows past the absorber by using natural convection or a fan. Because air conducts heat much less readily than liquid does, less heat is transferred from an air collector’s absorber than from a liquid collector’s absorber, and air collectors are typically less efficient than liquid collectors.
Solar Thermal Collector Technology

- Flat Plate Collectors
- Evacuated Tube Collectors
- Solar Thermal Air Systems
  - Air Flat Plate Collectors
  - Transpired Air Collectors
Solar Air Heating Transpired Panel Technology & Applications

- Unglazed collector for air preheating
- Cold air is heated as it passes through small holes in the metal absorber plate
- A fan circulates this heated air into the building or other destination
Solar Thermal Applications

- Domestic Hot Water
- Pool Heating
- Space Heating
- Industrial Process Heating
- Space Cooling

This pool, located in a condominium complex in Oregon, is heated by solar thermal collectors.

The Sun Trapper solar water-heating system at the Santa Rosa Hospital Northwest in San Antonio, Texas, is able to produce 15,000 gallons of hot water a day, which is about 40% of their hot water consumption.
Solar Thermal Applications

- Domestic Hot Water
- Pool Heating
- **Space Heating**
- Industrial Process Heating
- Space Cooling

A transpired-air collector absorbs solar energy, providing heated ventilation air to the BigHorn Home Improvement Center in Silverthorn, Colorado. (Credit: Jim Yost)
Solar Thermal Applications

- Domestic Hot Water
- Pool Heating
- Space Heating
- Industrial Process Heating
- Space Cooling
Solar Thermal Applications

- Domestic Hot Water
- Pool Heating
- Space Heating
- Industrial Process Heating

- **Space Cooling**
  - **Solar absorption systems** use the thermal energy from a solar collector to yield a cooling effect, through a conventional type of refrigeration cycle.
  - **Double-effect absorption systems** are about twice as efficient as single-effect systems, but require higher input temperatures
  - **Solar desiccant systems** use thermal energy from the solar collector to regenerate dessicants
The Stirling-engine Sunflower™ concept is somewhat radical, because it is not based on photovoltaic (PV) cells and has moving parts. More cost effective - it is simpler and more suitable for mass production.

This solar thermal power plant located in the Mojave Desert, is one of nine such plants built in the 1980s. Oil in the receiver tubes collects the concentrated solar energy as heat and is pumped to an end use.

Left: This solar dish, a concentrator, is the primary solar component of the system, collecting the energy coming directly from the sun and concentrating it on a small area. A thermal receiver absorbs the concentrated beam of solar energy, converts it to heat, and transfers the heat to the engine/generator.

Right: In this design, mirrors can operate independently.
Wind Power

• Small Scale Wind Generators
• Large Scale Wind Generators
• Innovative Rotor Styles
• Tower Height
• Building Integrated Applications
Wind Power

- Small Scale Wind Generators
- Large Scale Wind Generators
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The McKinney Wal-Mart store has a 50-kilowatt wind turbine designed for areas with low-average wind speeds, down to just under 5 miles per hour. Mounted 120 feet in the air, the turbine has a rotor with a 46-foot diameter. Credit: Wal-Mart Stores
Wind Power

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- Large Scale Wind Generators
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Wind Power

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Wind Power

- Small Scale Wind Generators
- Large Scale Wind Generators
- Innovative Rotor Styles
  - Vertical Axis (VAWT)
  - Tethered Gas Filled

Show Video of QR5

A Giromill-type wind turbine
A Darrieus wind turbine once used to generate electricity on the Magdalen Islands
Aerotecture by Bill Becker
Wind Power

• Small Scale Wind Generators
• Large Scale Wind Generators
• Innovative Rotor Styles
  – Vertical Axis (VAWT)
  – Tethered Designs
• Building Integrated Applications

This is an artist's (Ben Shepard's) rendition from Professor Roberts' preliminary working drawings of the next planned Flying Electric Generator rated at 240kW with rotor diameters of 35 feet. 

www.skywindpower.com/
Wind Power

- Small Scale Wind Generators
- Large Scale Wind Generators
- Innovative Rotor Styles
  - Vertical Axis (VAWT)
  - Tethered Designs
- Building Integrated Applications

From Magenn power Inc comes an interesting new design for a wind turbine. Called the 'M.A.R.S' - Magenn Power Air Rotor System. The turbine is a lighter than air blimp, which rotates around a horizontal axis. A unique design orients the blimp into the wind and it is anchored to the ground by a 1000 foot cable.
Wind Power

- Small Scale Wind Generators
- Large Scale Wind Generators
- Innovative Rotor Styles
- Building Integrated Applications

Figure 8: New York Sports and Convention Center, KPF Associates
Overview of Other RE technology choices

- Geothermal (primarily GSHP)
- Biomass and Biofuels
- Solar Hydrogen Fuel Cell
- Combined Heat and Power (CGP)
- Wave Power
- Purchase Green Power
Ground-Source Heat Pumps

- Space/water heating and cooling
- Electricity operates on vapor compression cycle
- Heat drawn from ground in winter and rejected to ground in summer
Biomass and Biofuels Technology & Applications

- Controlled combustion of wood, agricultural residues, municipal waste, etc.,
- Combustion of Ethanol, Biodiesel, etc.

Photo Credit: Wiseloger, Art DOE/NREL
Photo Credit: Oujé-Bougoumou Cree Nation

Source: RETScreen.net
Hydrogen Fuel Cell

- Electric Power Generation and Water Heating as waste byproduct
- Suitable for Off-grid or Grid Tied Applications
- Flexible scale from UPS size to 500 kW systems
- Significant new developments in Hydrogen production and storage
Combined Heat and Power (CHP)

Simultaneous production of two or more types of usable energy from a single energy source (also called “Cogeneration”)

Source: RETScreen.net
Combined Heat and Power Applications (CHP)

- Single buildings
- Commercial and industrial
- Multiple buildings
- District energy systems (e.g. communities)
- Industrial processes
Combined Heat and Power Equipment & Technologies

- **Cooling equipment**
  - Compressors
  - Absorption chillers
  - Free cooling

- **Power generation**
  - Gas turbine
  - Gas turbine combined cycle
  - Steam turbine
  - Reciprocating engine
  - Fuel cell

- **Heating equipment**
  - Boilers
  - Waste heat recovery
Wave Power Concepts

- Powerbuoy Wave Generator
- Ocean Swell Powered Renewable EnergY (OSPREY)
- Shoreline Oscillating Water Column
The Green Power Option

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