Introduction to Buildings Integrated Photovoltaics (BIPV)

Byron Stafford and John Thornton

National Renewable Energy Laboratory
Golden, Colorado 80401

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Introduction

Purpose of Course

Provide a basic introduction to PV in buildings: its design, operation, and applications

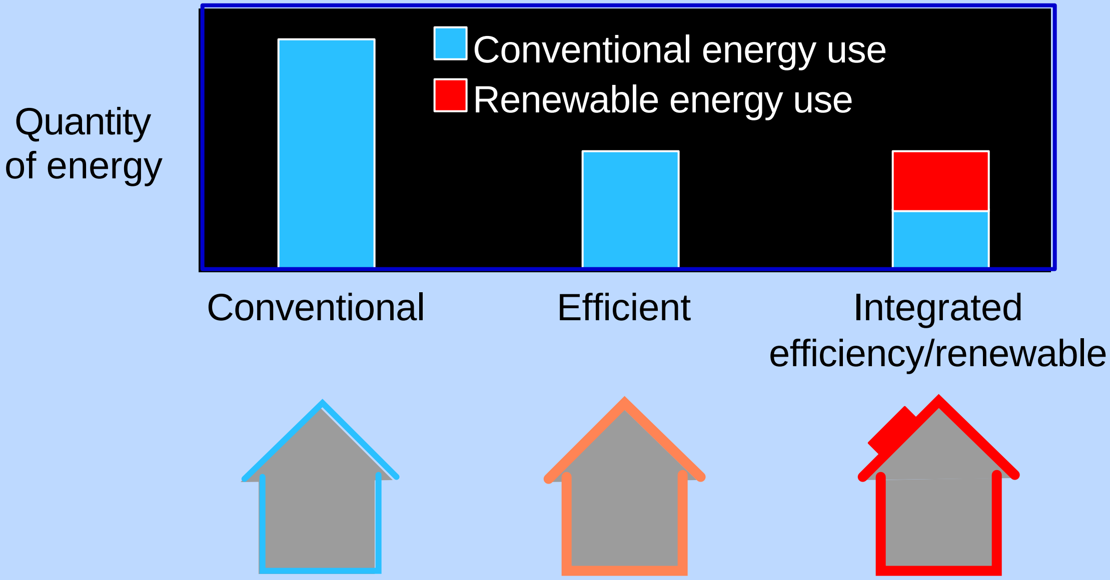
Three Concepts to Remember

- Importance of Energy Efficiency
- What is BIPV?
- What is a “zero energy building (ZEB)?”

"Every watt not used is a watt that doesn't have to be produced, processed, or stored."

Richard Perez, *Home Power* Magazine

Energy Efficiency Comes First!



Using efficiency PLUS renewables can mean big savings!

"One dollar spent on an energy efficient appliance will save three dollars on PV components."

Richard Perez, 1991

What is BIPV?

BIPV – where the PV arrays are ***integrated*** into the building fabric

What is a “Zero Energy Building (ZEB)?”

A “zero energy building” is one, that at the very least, will generate as much energy as it it consumes on an annual basis. Preferably a “ZEB” should be self-sustaining, or even a net exporter of energy

The Lord House • Coastal Maine

Examples of PV in Building Applications

Sherman Indian School (BIA) • San Bernardino, California

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Federal Energy Regulatory Commission • Washington, DC

Pinnacles National Monument, California

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Visitors Center, Zion National Park, Utah

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Townhouses • Bowie, Maryland

4 Times Square, Manhattan • New York City

Williams Building (GSA) • Boston, Massachusetts

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Natatorium, 1996 Olympics • Atlanta, Georgia

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Thoroeau Center, The Presidio (NPS) • San Francisco, California

The Berlin Bank • Berlin, Germany

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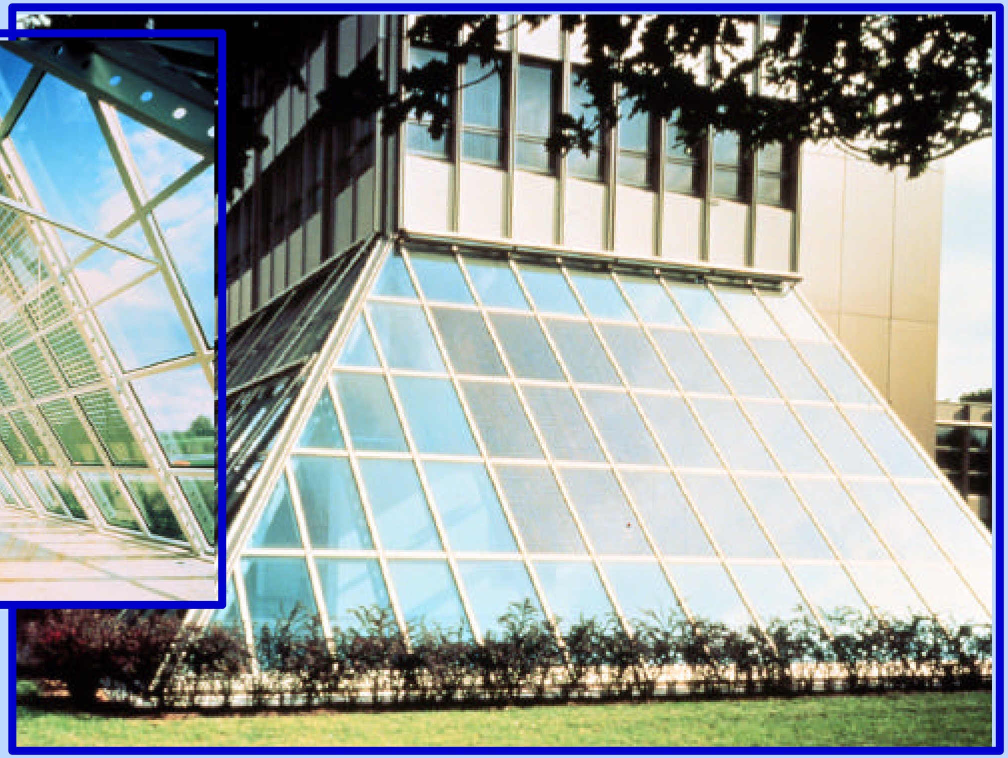

Commercial Office Building • Germany

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BP Triangular Module for BIPV Applications

PV Economics

One of the World's Best Kept Secrets — Photovoltaics!

- $3–3.5 billion in sales in 2001
- Average annual sales growth of 35% for last five years
- Annual growth nearly twice that of U.S. PC market
- World demand exceeds world supply

What's Driving the Current PV Market?

- International: Demand exceeds supply
  - $3–4 billion per year industry
  - 35% average annual sales growth
  - Manufacturing costs dropping
  - Sales price steady (or rising slightly)
- Domestic: Relatively high capital cost
  - Cannot compete with established central power
  - Cost-effective utility markets limited
  - PV often competes on capital cost basis

Economics of PV Located Near Established Utilities

- $5 to $8 per watt for larger systems, typically 30–45¢ per kilowatt-hour
- Usually does not compete well against established utilities
- Sometimes competes when major construction is needed

Economics of Grid-Independent PV

- $10 to $15 per watt for small systems, installed, depending on site, storage needs, duty cycle, etc.
- Installed cost of PV often competes with line extensions, remote diesel

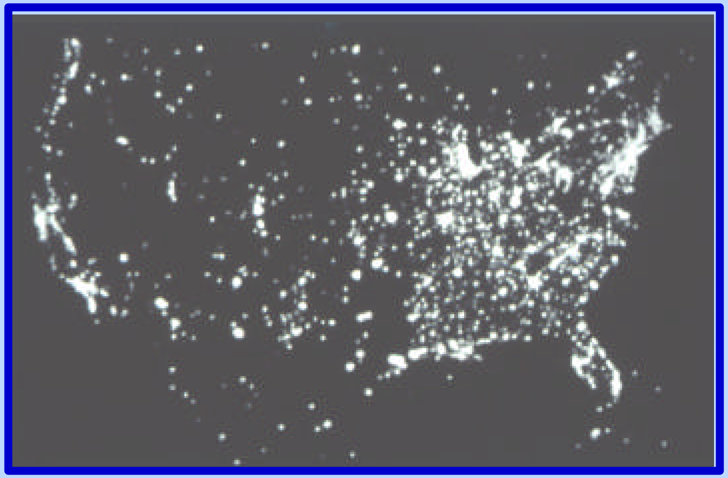
What is Value of Electricity if you don't have any?

The Power Reliability and Quality Problem

- Today's digital economy — “6-9s” reliability required
- Inadequate investment in maintenance/new capacity
- Utilities typical “2-9s” reliability allows nearly nine hours allowable outage/year
- “6-9s” reliability means 32 seconds allowable outage/year

Blackout! It Can Happen To You.

July 2, 1996



Before

After

Some Recent Impacts of Electrical Service Disruptions

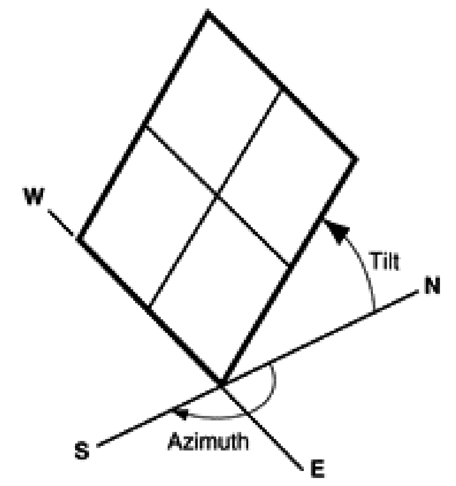
- Chicago Board of Trade, Summer 2000: 1 hour outage prevented $20 *trillion* in trades
- Honda, Ohio, 2000: $250,000 in payroll for workers sent home
  during blackouts
- New York, July 2000: 200,000 left in dark
- Summer 2000: Utilities pay up to $2,500 per MWh vs. usual $100 per MWh
- Chicago, Summer 1998: Rolling blackouts cause 800 deaths
- Silicon Valley, June 2000: Internet companies lost $75 million
  per day; some $6 million per hour
- California, January 2001: Spot prices reach $1.18 per kWh

Will This Be You? Which One?

Design Considerations

Determine the Solar Resource

- Location
- Tilt
- Orientation
- Type of PV Mounting
  - Fixed or tracking
- Check out: *http://rredc.nrel.gov/solar/old_data/nsrdb/redbook/sum2/*



PV array facing south at fixed tilt.

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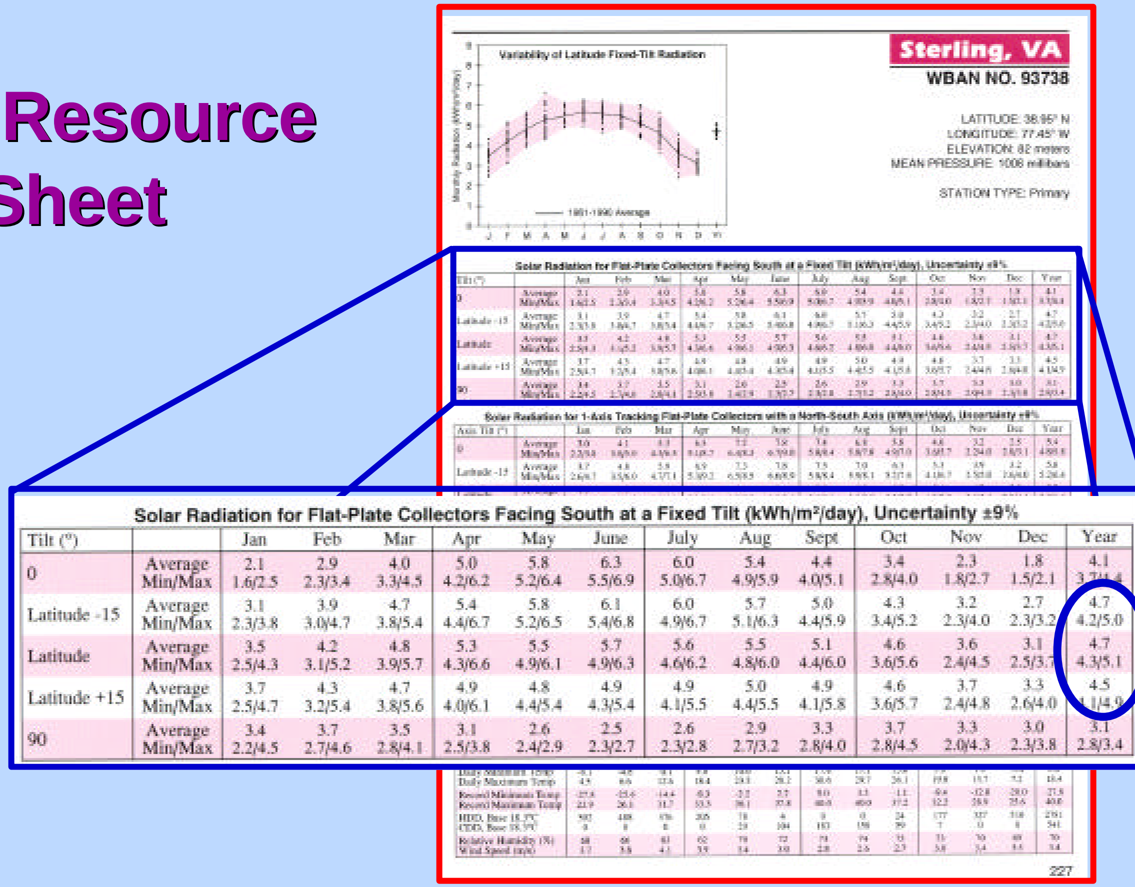
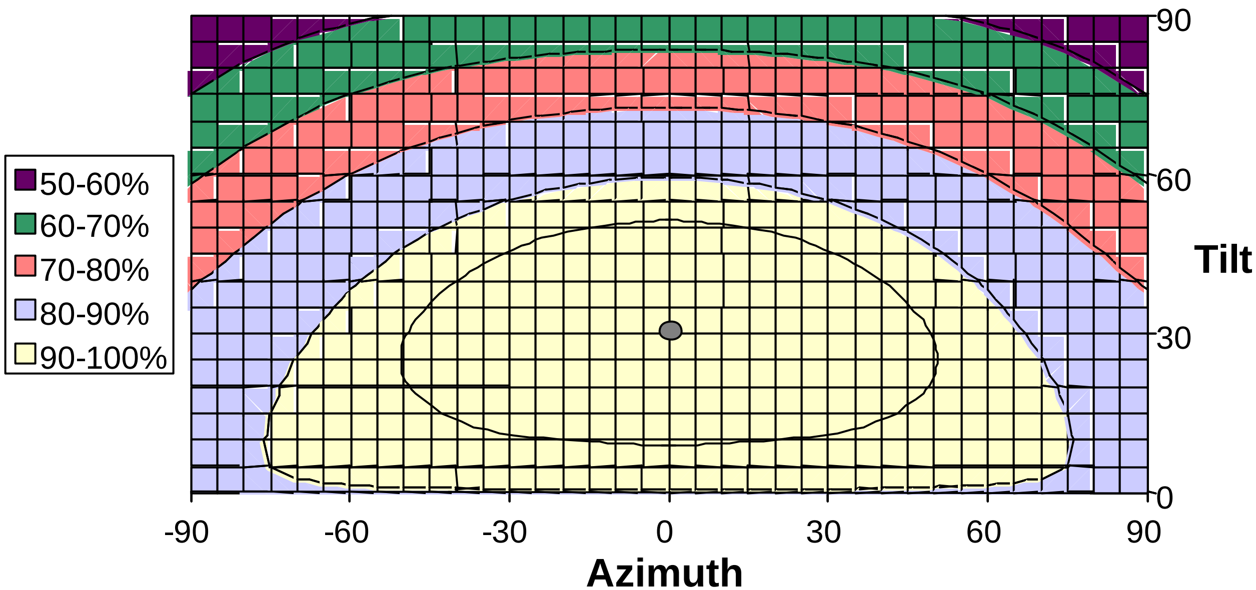
Solar Resource Data Sheet



Solar Radiation for Flat-Plate Collectors Facing South at a Fixed Tilt (kWh/m²/day), Uncertainty ±9%

Tilt (°)		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
0	Average Min/Max	2.1 1.6/2.5	2.9 2.3/3.4	4.0 3.3/4.5	5.0 4.2/6.2	5.8 5.2/6.4	6.3 5.5/6.9	6.0 5.0/6.7	5.4 4.9/5.9	4.4 4.0/5.1	3.4 2.8/4.0	2.3 1.8/2.7	1.8 1.5/2.1	4.1 3.7/4.4
Latitude -15	Average Min/Max	3.1 2.3/3.8	3.9 3.0/4.7	4.7 3.8/5.4	5.4 4.4/6.7	5.8 5.2/6.5	6.1 5.4/6.8	6.0 4.9/6.7	5.7 5.1/6.3	5.0 4.4/5.9	4.3 3.4/5.2	3.2 2.3/4.0	2.7 2.3/3.2	4.7 4.2/5.0
Latitude	Average Min/Max	3.5 2.5/4.3	4.2 3.1/5.2	4.8 3.9/5.7	5.3 4.3/6.6	5.5 4.9/6.1	5.7 4.9/6.3	5.6 4.6/6.2	5.5 4.8/6.0	5.1 4.4/6.0	4.6 3.6/5.6	3.6 2.4/4.5	3.1 2.5/3.7	4.7 4.3/5.1
Latitude +15	Average Min/Max	3.7 2.5/4.7	4.3 3.2/5.4	4.7 3.8/5.6	4.9 4.0/6.1	4.8 4.4/5.4	4.9 4.3/5.4	4.9 4.1/5.5	5.0 4.4/5.5	4.9 4.1/5.8	4.6 3.6/5.7	3.7 2.4/4.8	3.3 2.6/4.0	4.5 4.1/4.9
90	Average Min/Max	3.4 2.2/4.5	3.7 2.7/4.6	3.5 2.8/4.1	3.1 2.5/3.8	2.6 2.4/2.9	2.5 2.3/2.7	2.6 2.3/2.8	2.9 2.7/3.2	3.3 2.8/4.0	3.7 2.8/4.5	3.3 2.0/4.3	3.0 2.3/3.8	3.1 2.8/3.4

Percent of Solar Energy Collected Based on PV Module Orientation



Christensen and Barker, Effects of Tilt and Azimuth on Annual Incident Solar Radiation for United States Locations, ASES 2001

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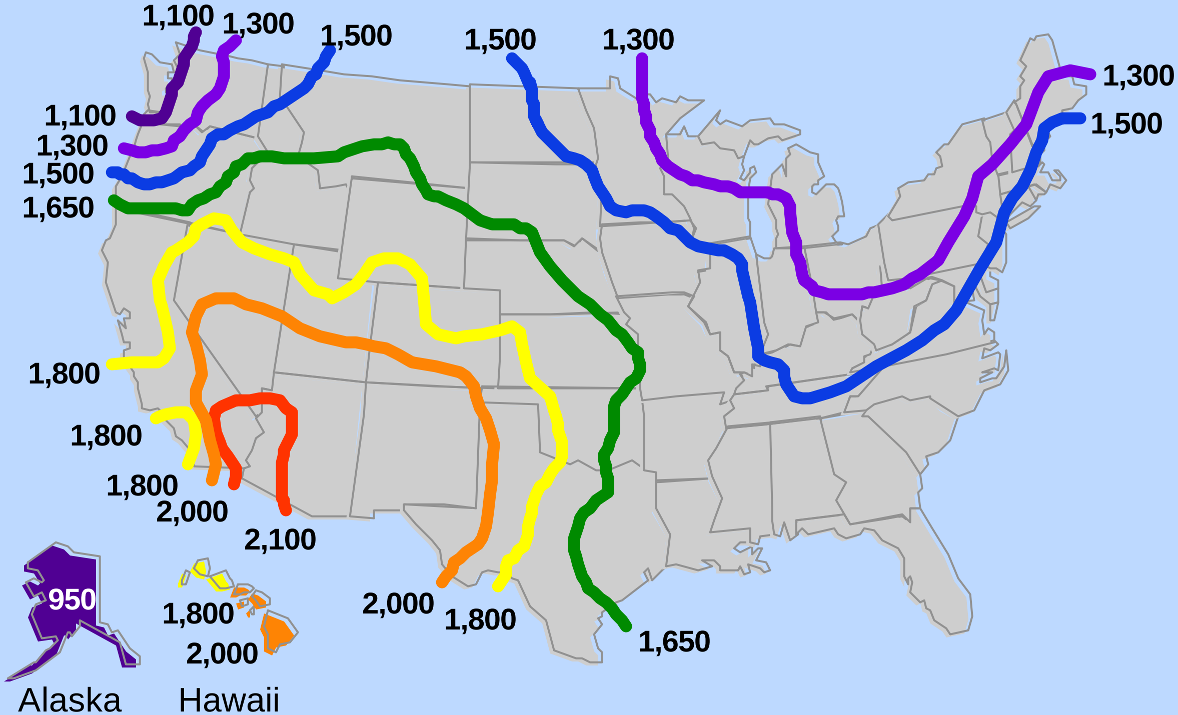
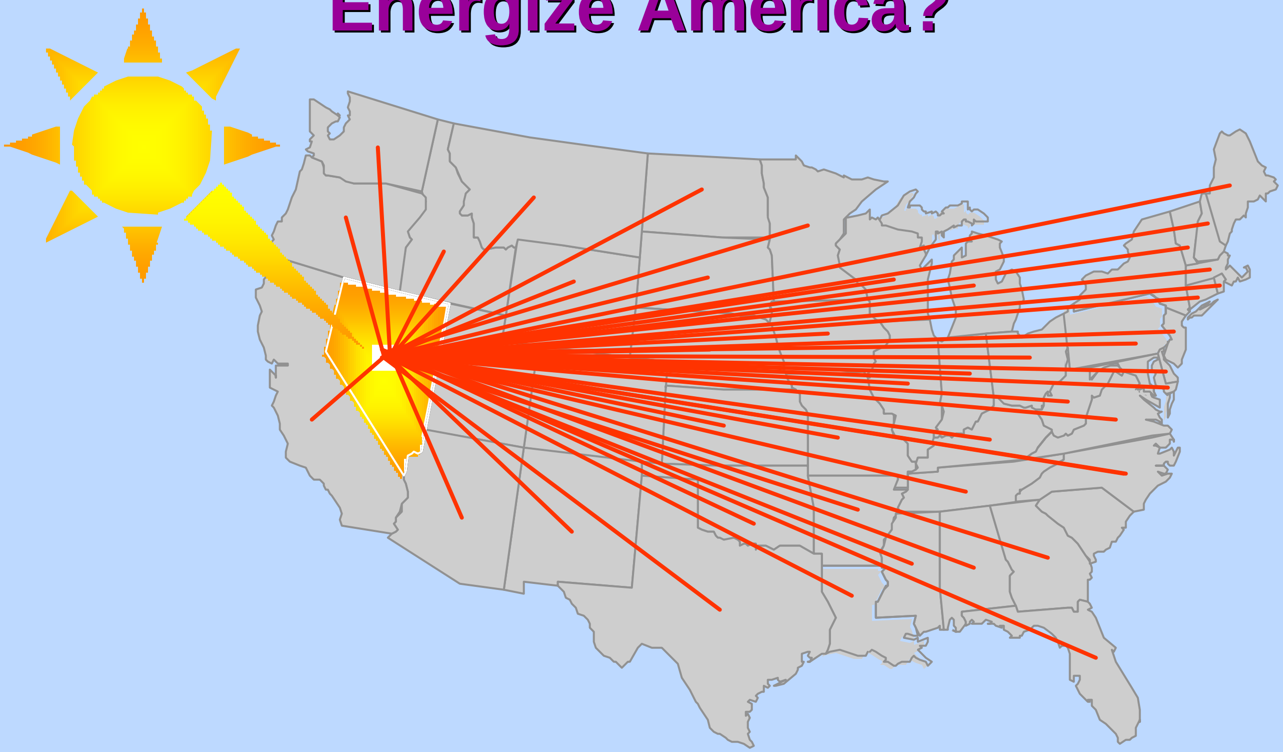
Photovoltaic System Production (kWh/year)[1]



[1]For a 1 kWac rooftop PV system, due south, modeled with PVGRID™

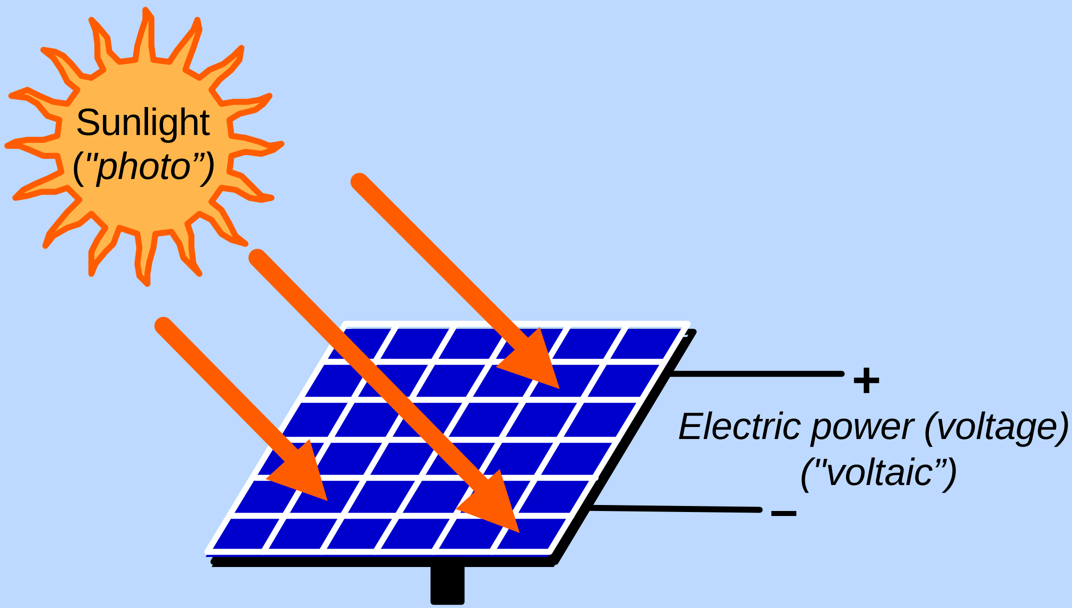
How Much Sunshine Does It Take to Energize America?



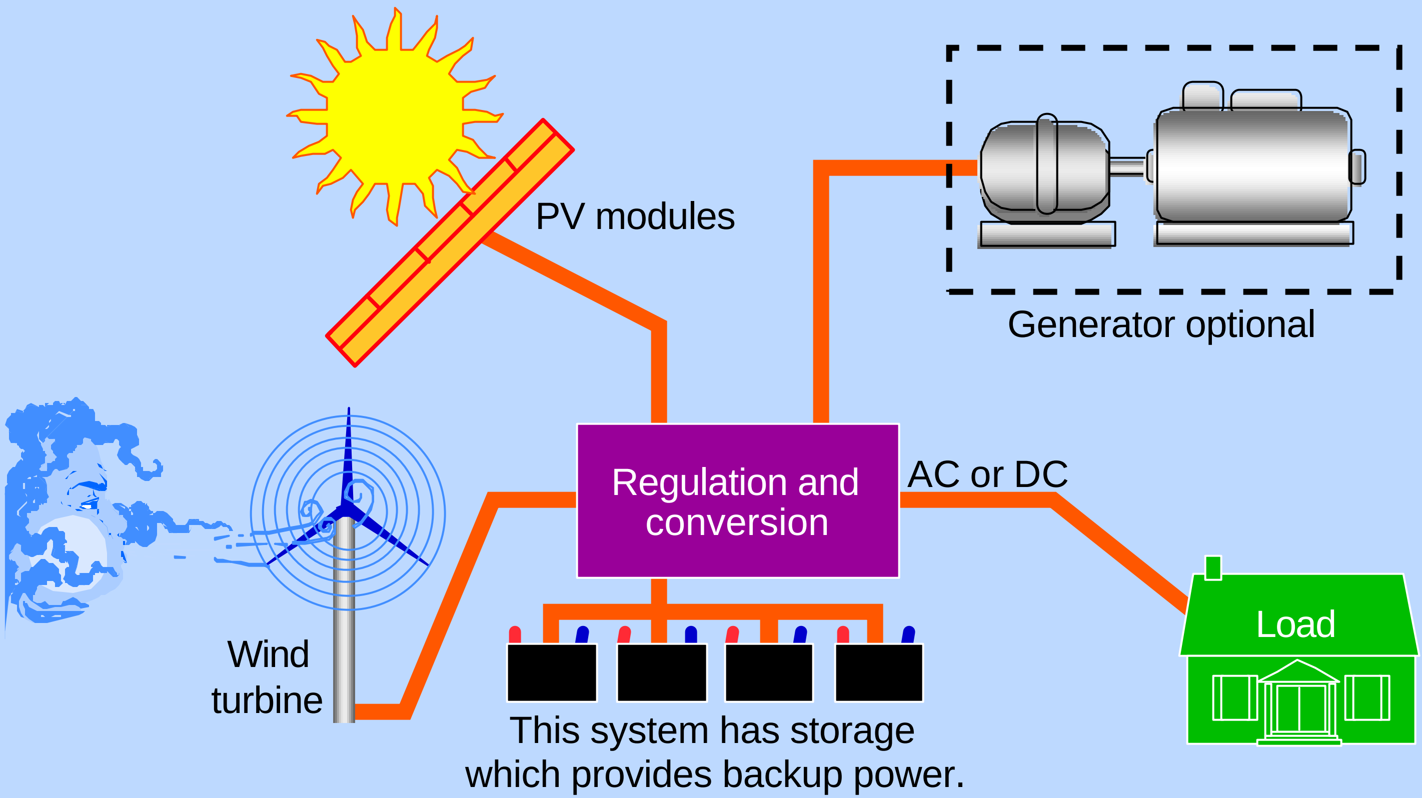
Load Analysis

- How much electricity is needed and when
- Reduce electrical need through conservation and energy efficiency
- Shift or reduce peak loads if necessary
- Shift to other energy or fuel sources if necessary

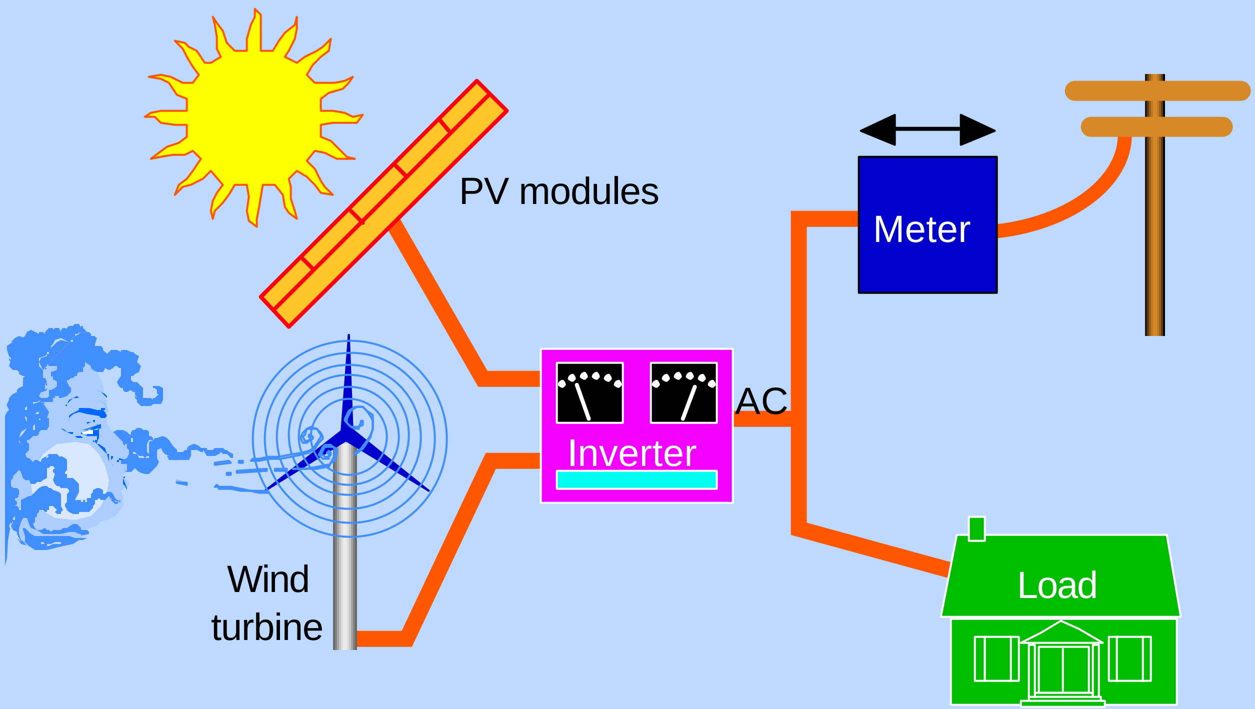
Basic Operating Principle of a Photovoltaic Cell



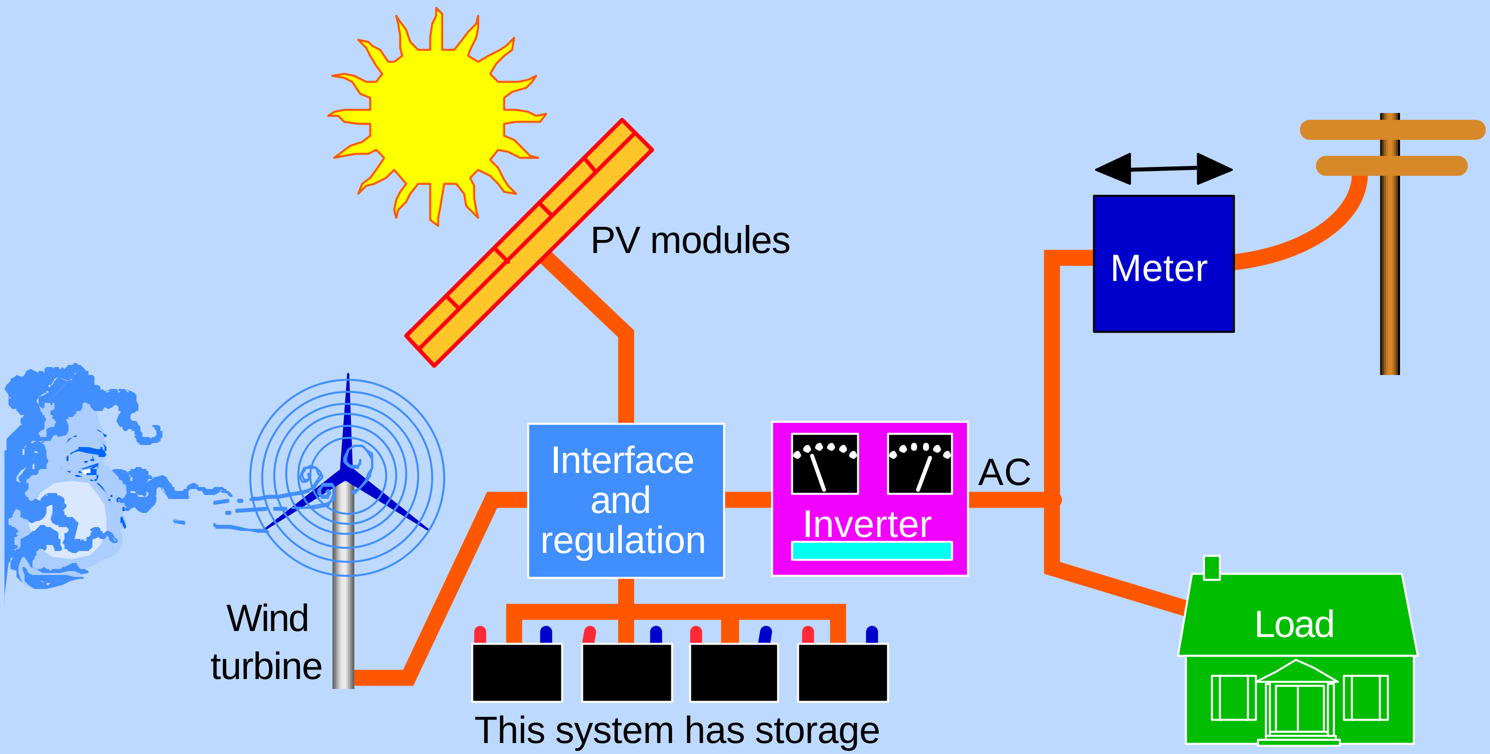
Off-Grid Renewable Energy Systems



On-Grid AC System without Storage



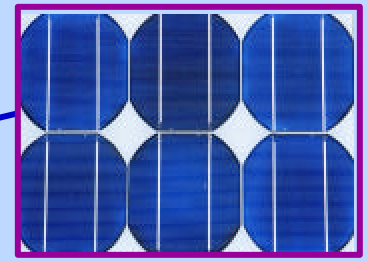
On-Grid AC System with Storage

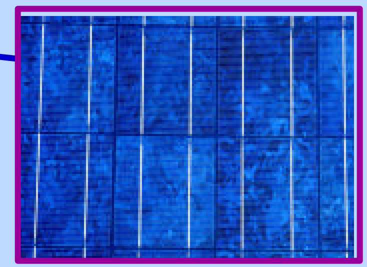


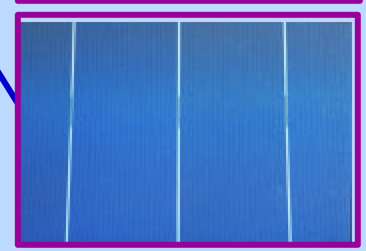
This system has storage which provides backup power.

Photovoltaic Modules

- Flat plate types
  - Crystalline silicon
    - Single-crystal
    - Polycrystalline
  - Amorphous silicon
  - Cadmium-tellurium
  - Copper-indium-diselenide







Balance of System:

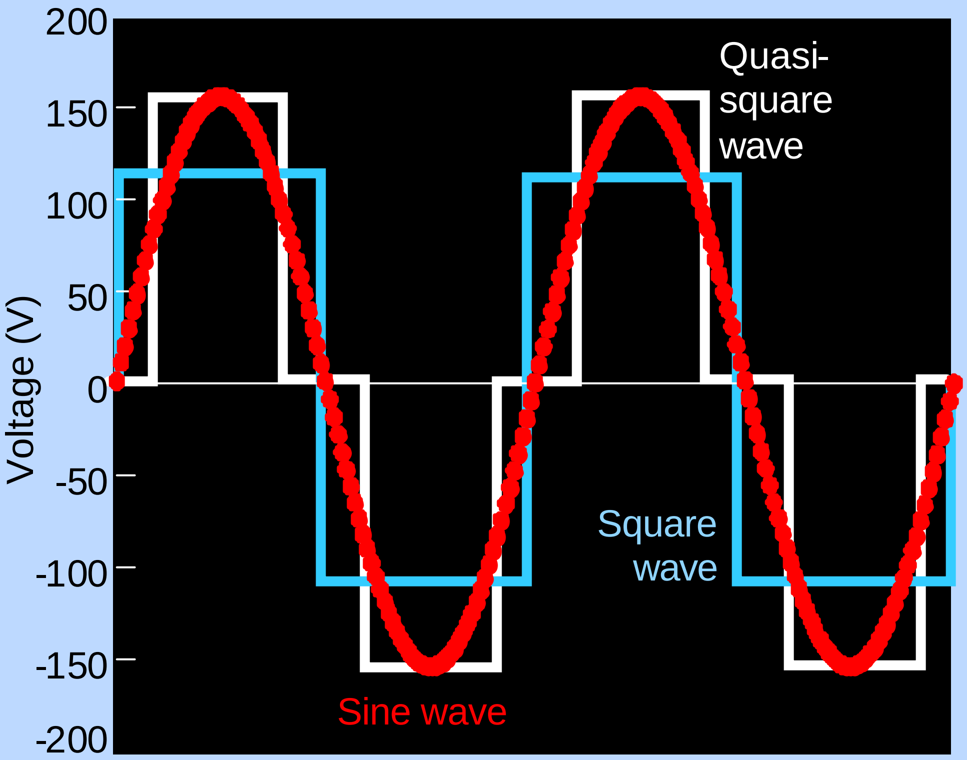
the Remaining Equipment for a Safe, Reliable System

- Charge controllers
- Meters
- Circuit breakers, fuses
- Wiring
- Inverters
- Batteries
- Battery rooms

Inverters:
to Change DC to AC Electricity

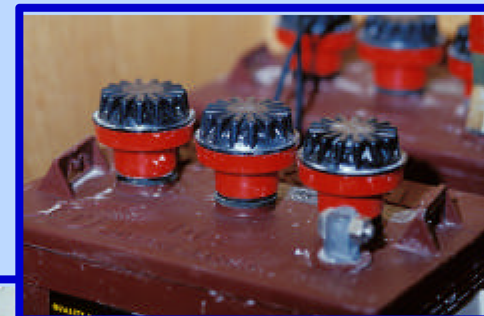
- Utility interconnected
- Stand alone
- UPS
- Power quality
  – Square wave
  – Modified square wave (modified sine wave)
  – Sine wave

Inverter Outputs



Batteries:
to Store DC Electricity

- Lead-acid
  - Flooded
  - Sealed, VRLA, valve-regulated, no maintenance, AGM, absorbed glass mat, gel



PV Warranties, Lifetimes and Maintenance

- Warranties
  - PV modules: 20–25 years typical
  - Inverter and controls: 10 years typical
- Lifetimes
  - Batteries: 3 to 5 years typical, depends on the
    type of battery
- Maintenance agreements available

Other Installation Considerations and Costs

- Building permits and inspections
- Zoning regulations
- Interconnection agreement
- Property taxes
- Sales taxes
- Utility charges (interconnection, insurance, etc.)

Maintain System and Monitor the Performance

- Perform vendor recommended maintenance on the system
- Have a visible indicator (meter, display, light) that shows if the system is working
- Monitor system performance to verify how well the system is working

Maintenance Issues

- PV systems are low maintenance — but are not “no maintenance”
- Make maintenance part of someone’s job description
- Follow vendor’s recommended maintenance schedules to maintain warranties

Frequently Encountered Problems

- ✓ Fatal Error #1 Ignore or don't coordinate with electric utility or local building inspectors
- ✓ Fatal Error #2 Overestimate solar resource
- ✓ Fatal Error #3 Underestimate loads or energy needs
- ✓ Fatal Error #4 Undersize the PV or batteries to trim costs
- ✓ Fatal Error #5 Nobody is responsible for well-being of project and equipment

For More Information

- Byron Stafford, NREL, 303-384-6426, byron_stafford@nrel.gov
- John Thornton, NREL, 303-384-6469, mr_pv@nrel.gov