The Solar Resource

ECEN 2060
The Solar Resource

• Sun radiates $3.8 \times 10^{20}$ MW of power

• Solar irradiation or “insolation” is the solar power received per unit area
  - AM0, outside Earth’s atmosphere: 1.377 kW/m²
  - AM1.5 (air-mass ratio $m=1.5$), is the reference solar spectral irradiance standard in evaluations of PV systems
    - 2% ultraviolet, 54% visible, 44% infrared

• Clear-sky insolation at the Earth’s surface: 1 kW/m² (“1-sun of insolation”)
Average Insolation Data

“Hours of full sun” \[\text{kWh} \div \text{m}^2 \text{ day}\]

- Examples of the yearly averages of “hours of full sun” for south-facing collectors at tilt angles equal to the latitude
  - Boulder, CO: 5.5
  - San Diego, CA: 5.7
  - Phoenix, AZ: 6.5
  - Seattle, WA: 3.7
  - Boston, MA: 4.6
- Textbook includes various insolation tables
- Comprehensive insolation data and performance calculators available at NREL PVWATTS site (linked on the ECEN2060 Reference Library):
  http://rredc.nrel.gov/solar/codes_algs/PVWATTS/
US solar PV resource map assuming flat, south-facing surfaces at tilt equal to latitude
Variations in Insolation

Cells that are not in direct sun can still experience substantial irradiance from clouds, reflections, diffusion.

Direct (beam) irradiance as measured by a Kipp & Zonen pyrheliometer mounted on a Sci-Tec tracker with a 5 degree field of view.
Detailed Insolation Data

Global (beam + diffuse) solar irradiance on a south-facing surface tilted 40 degrees (latitude) from horizontal. This is the solar resource for collectors with fixed-tilt, optimized for year-round performance.
Approaches to Solar Power Utilization

http://www.nrel.gov/solar/

- Passive solar heating, water heating, daylighting, etc.
- Concentrating solar power (CSP) plants (see textbook Section 4.3)
- Photovoltaics
  - Large grid-connected utility-scale systems
  - Grid-connected roof-top residential or commercial buildings
  - Stand-alone (off-grid) systems
Current PV statistics

• Current statistics
  ▪ Annual production of PV modules in 2005
    • about 150 megawatts (MW) in the U.S. and
    • about 1.7 gigawatts (GW) worldwide
  ▪ PV industry has grown at a rate greater than 40% per year from 2000 through 2005
  ▪ Capital cost of PV modules is around $4/Wp (peak output power)
  ▪ Capital cost of complete grid-connected systems is around $8/Wp (PV arrays, converters, installation); cost of energy produced: 20-30¢/kWh.
  ▪ Each installed Watt of PV generates approximately 1.5 kWh of energy per year in Colorado

• Rooftop potentials
  ▪ Rough estimate*: 600-1000 GWp, 900-1500 TWh annually

• Intermittency becomes a major limiting factor if % PV in the total energy supply increases

*P. Denholm, R. M. Margolis (NREL) and K. Zweibel (PrimeStar Solar, Inc), “Potential Carbon Emissions Reductions from Solar Photovoltaics by 2030” (linked to ECEN2060 Reference Library)