Photovoltaics
energy from the Sun
Global warming and greenhouse effect

Alps 2007
Energetical resources:
fossil and nuclear fuels compared to the energy from the Sun

energy coming from the sun per year

total reserves:
uranium
oil
gas
coal

world consumption/year
Fossil fuel – 87% over last 25 years, nuclear declining
Share of energy sources in gross German power production in 2016.

- **Renewables**: 188.3 TWh (29.0%)
  - Wind onshore: 65.0 TWh (10.0%)
  - Wind offshore: 12.4 TWh (1.9%)
  - Hydro power: 21.0 TWh (3.2%)
  - Biomass: 45.6 TWh (7.0%)
  - Solar: 38.2 TWh (5.9%)
  - Waste: 6.0 TWh (0.9%)
- **Lignite**: 150.0 TWh (23.1%)
- **Nuclear**: 84.6 TWh (13.1%)
- **Hard coal**: 111.5 TWh (17.2%)
- **Natural gas**: 80.5 TWh (12.4%)
- **Mineral oil**: 5.9 TWh (0.9%)
- **Others**: 27.5 TWh (4.3%)
Greenhouse gases emissions

Greenhouse gases (grams per kilowatt-hour of CO₂ equivalent)

- Coal: 900
- Oil: 850
- Gas combined-cycle: 400
- Biomass: 40
- Multi-crystalline silicon: 37
- Cadmium telluride (thin film): 18
- Wind: 11

EPIA
History

• Becquerel 1834 electrolyte
• Adams & Day 1877 Se
• Chapin, Fuller, Pearson 1954 Si 6%
• CdS pn junction 6% 1954
• Vanguard 1, 1958

The First Practical Solar Cell-1954

Vanguard, 1st terrestrial satellite, 1958
Large and small applications
Topics

1. Characteristics of sunlight

2. Basic concepts in semiconductor science necessary to describe photovoltaic device
   a. energy bands in semiconductors
   b. free carriers: holes and electrons, doping
   c. electron and hole current: mobility, drift current, diffusion current
   d. optical generation: absorption of light, direct and indirect bandgap
   e. recombination of carriers: lifetime and diffusion length
   f. pn junction and heterojunction

3. Solar cell – principles of operation

4. Conversion efficiency: efficiency limits and photovoltaic losses

5. How to enhance performance and reduce losses

6. Simulation of the solar cell performance

7. Monocrystalline solar cells: silicon, GaAs

8. Thin film solar cells: amorphous silicon, heterojunction cells (CIGS, CdTe, kesterites)

9. Other concepts: Graetzel cell, organic, perovskites, etc
9. 3rd generation photovoltaics, new ideas
10. Light management: concentration, light confinement, photon harvesting
11. Modules and systems: design, problems & solutions

**Literature**

J. Nelson „The physics of solar cells”
S.R. Wenham „Applied photovoltaics”
R.H. Bube „Photovoltaic materials”
A. Rockett „The materials science of semiconductors”
P. Wurfel „Physics of solar cells”
PV CDROM
+ other material provided by the lecturer

[www.if.pw.edu.pl/~igalson](http://www.if.pw.edu.pl/~igalson)

Mechatronics Building (South Campus), room 325