

Introduction



- Importance of energy issue
- Impact of photovoltaic power
- Electricity generation overview
- Why use solar cells?
- Historical perspective of solar cells
- Current state of photovoltaics
- Trends & predictions for photovoltaics

Importance of the energy issue



- Developed countries:
 - Energy independence and security
 - Energy use/generation leading cause of pollution and carbon dioxide emissions (global warming)
 - Energy choice strongly impacted by policy
 - Increasing problems with supply

“Two particular tasks face the world's rich nations: sorting out Africa, and dealing with climate change.”

Tony Blair, editorial, Economist Dec. 2004

“If President Bush is looking for a legacy, I have just the one for him - a national science project that would be our generation's moon shot: a crash science initiative for alternative energy and conservation to make America energy-independent in 10 years.”

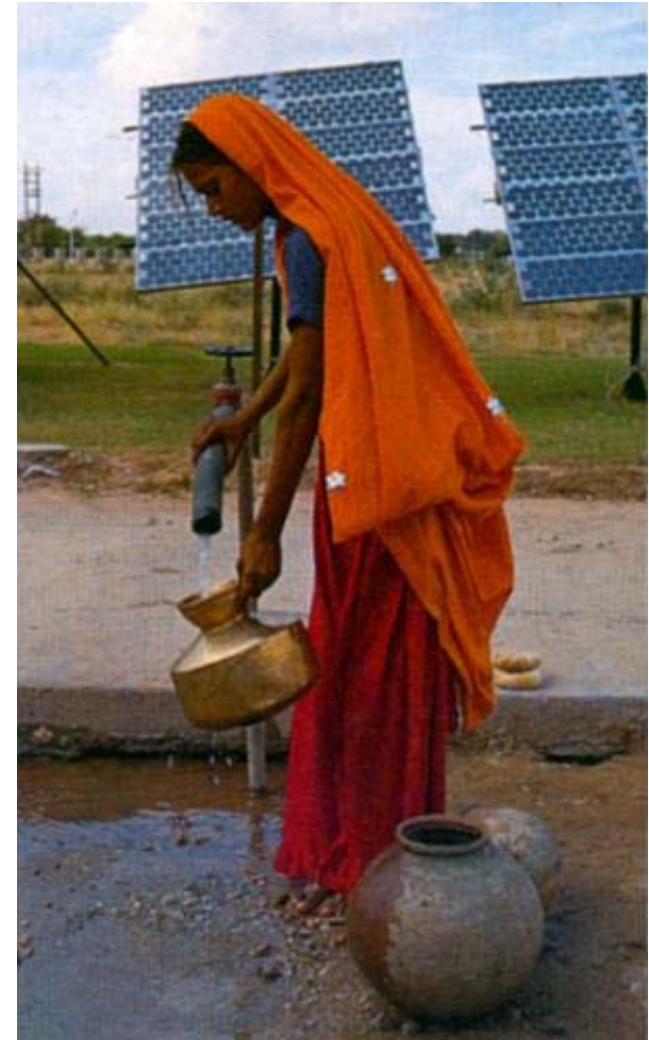
New York Times, T. Friedman, Dec. 2004

“Researching, developing, and commercializing carbon-free primary power technologies capable of 10-30 TW by the mid-21st century could require efforts, perhaps international, pursued with the urgency of the Manhattan Project or the Apollo Space Program.”

M. I. Hoffert, Nature, 1998

Importance of the energy problem

- Impact of energy less developed countries
 - Poverty abatement
 - Water (people, farming – both agriculture and livestock).
 - Health care
 - Education
 - Social Impacts: new movement towards cities
- 1.5 billion people without access to electricity



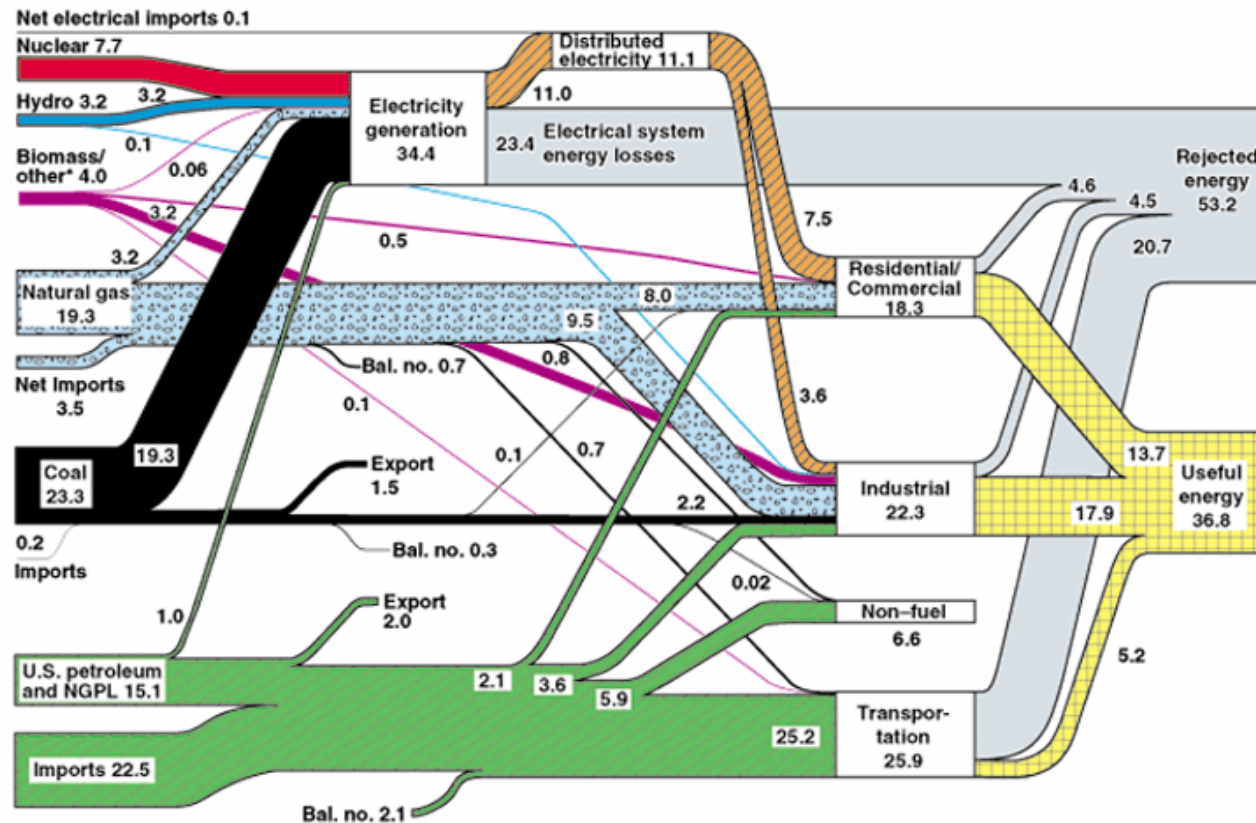
Importance of the energy problem

- While grid electricity accounts for the bulk of the power generated, modern lifestyle relies on “remote” sources of power for applications such as navigation and communications.
 - Satellites are nearly all PV powered – aircraft navigation, ship navigation, etc.



Energy Overview

- How much and what forms of energy are used?
 - Residential, industrial, transportation
 - Supplied by mix of sources, with fossil fuels dominant



Source: Production and end-use data from Energy Information Administration, Annual Energy Review 1999
 *Biomass/other includes wood and waste, geothermal, solar, and wind.

March 2001
 Lawrence Livermore
 National Laboratory

Energy Overview



- Methods of electricity generation
 - Most common energy conversion process is mechanical energy into electrical energy via a generator or turbine
 - Source of mechanical power: most commonly is thermal expansion/compression cycle via a generator; can also use a turbine or other types of engines
 - Nuclear, solar thermal, coal, gas
 - Other sources of mechanical power: Hydro, wind, wave or tidal.
 - Direct conversion process are “new” form of energy conversion, of which light into electricity via the photovoltaic effect is most common.
 - Other examples: Seebeck effect – heat directly into electricity.

Sources of energy

Wave and tidal:
Limited generating capacity



Wind:
Site issues



Biomass:
Large land use



Hydro:
Large dam sites already developed

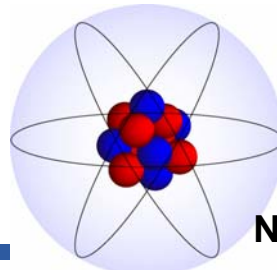


Photovoltaics



Geothermal:
Location of resource

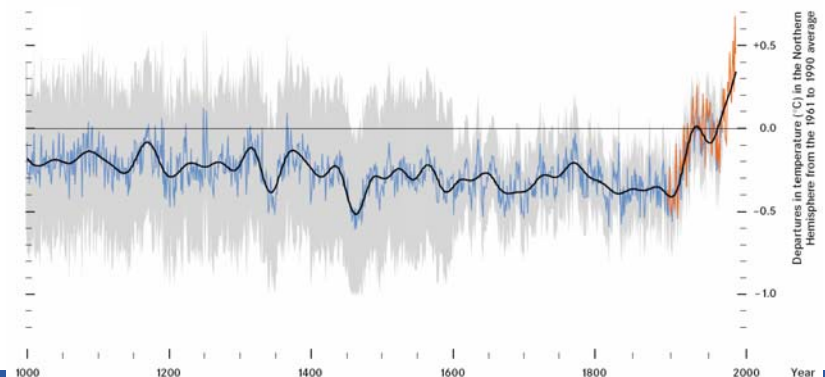
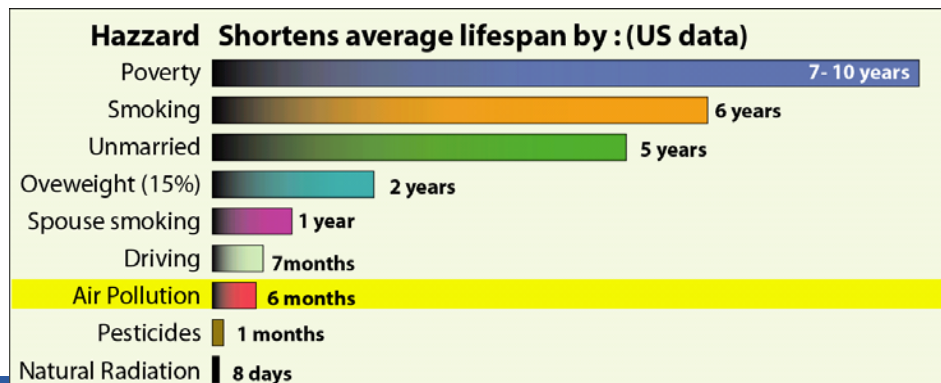
Solar thermal:
Useful for low-grade heat; electricity use limited to desert regions



Nuclear: Cost, waste

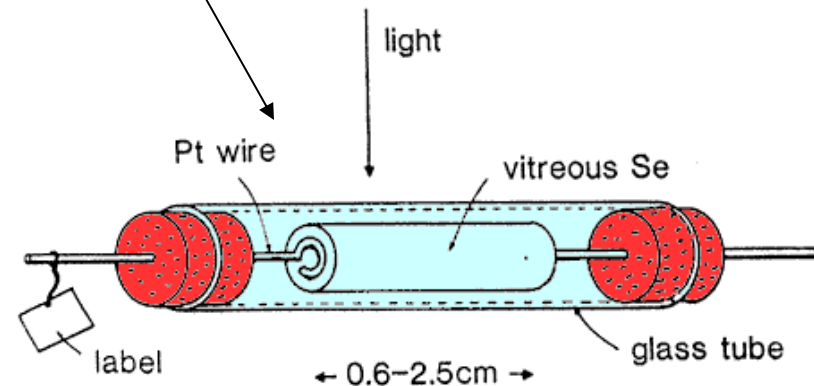
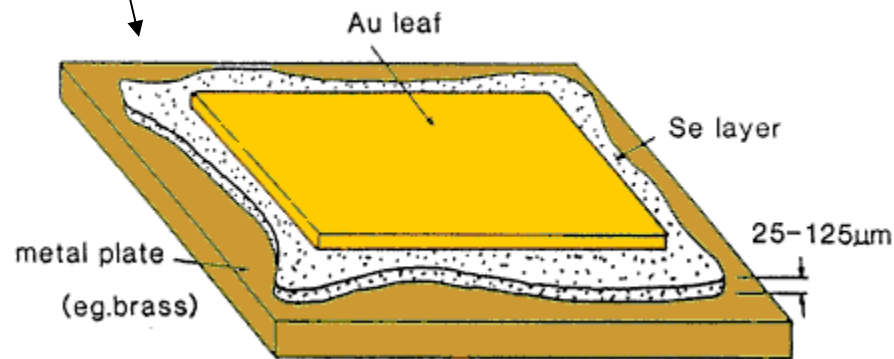
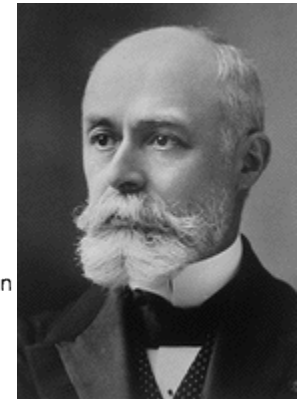
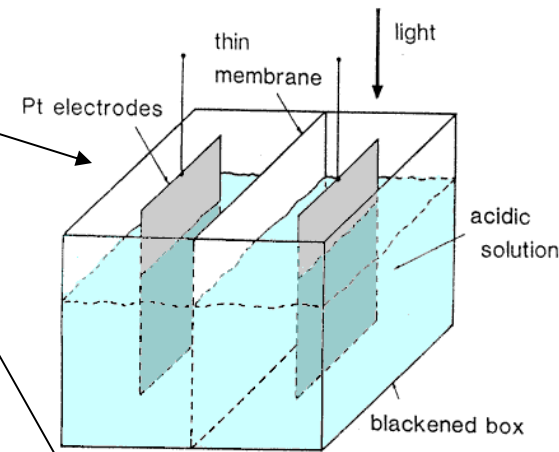
Why use photovoltaics?

- Technical characteristics of solar:
 - Reliable, modular, suited to remote operation; distributed generation
- Economic reasons:
 - Solar is the lowest cost energy source in many remote or transportable applications
- Externalities associated with existing bulk power generation
 - Global warming or other environmental effects
 - Personal choice
 - Political issues associated with energy production.



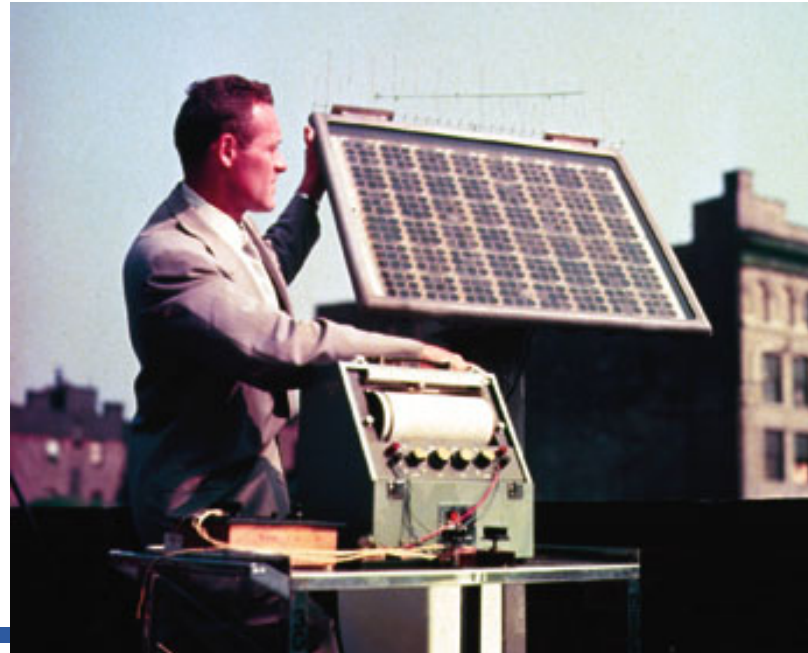
Overview of PV

- Photovoltaic effect first discovered by Bequerel in 1848
- Photoconductance measurements—1877 Day and Adams
- Photovoltaic device (Selenium) 1883
- Selenium in 1930's for use as a rectifier
- Silicon found to produce good rectifiers



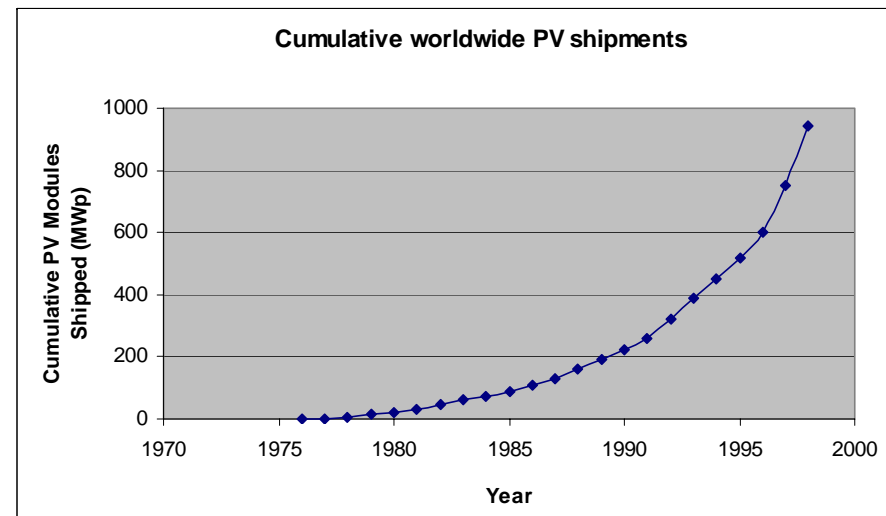
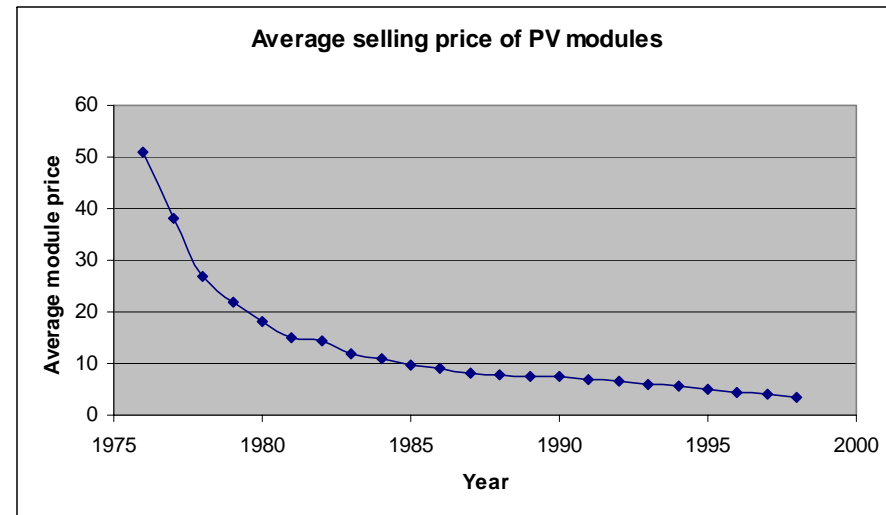
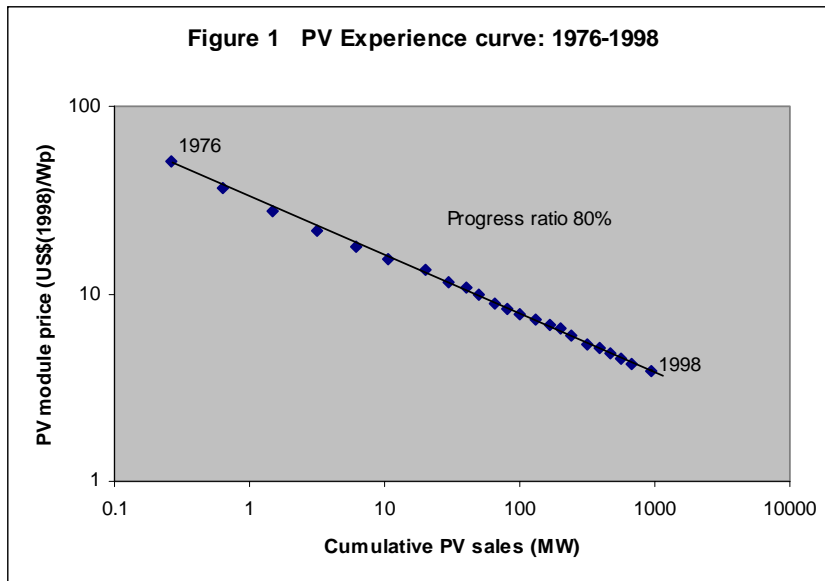
Overview of PV

- Photovoltaic effect could not be explained by classical physics, as explanation relied on quantum mechanics
- Combination of increased physical understanding and development of silicon devices as rectifiers allowed demonstration of first Si solar cell
- Silicon junction formation allowed formation of first practical devices, at Bell Labs



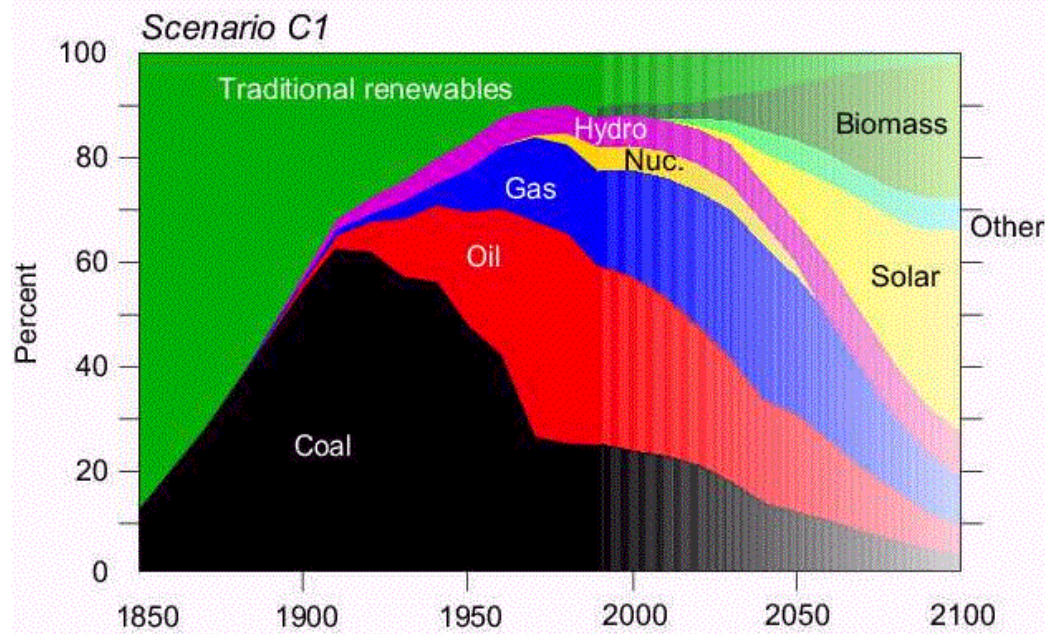
Current State of PV

- Photovoltaics has been growing at ~30% per year for about a decade.

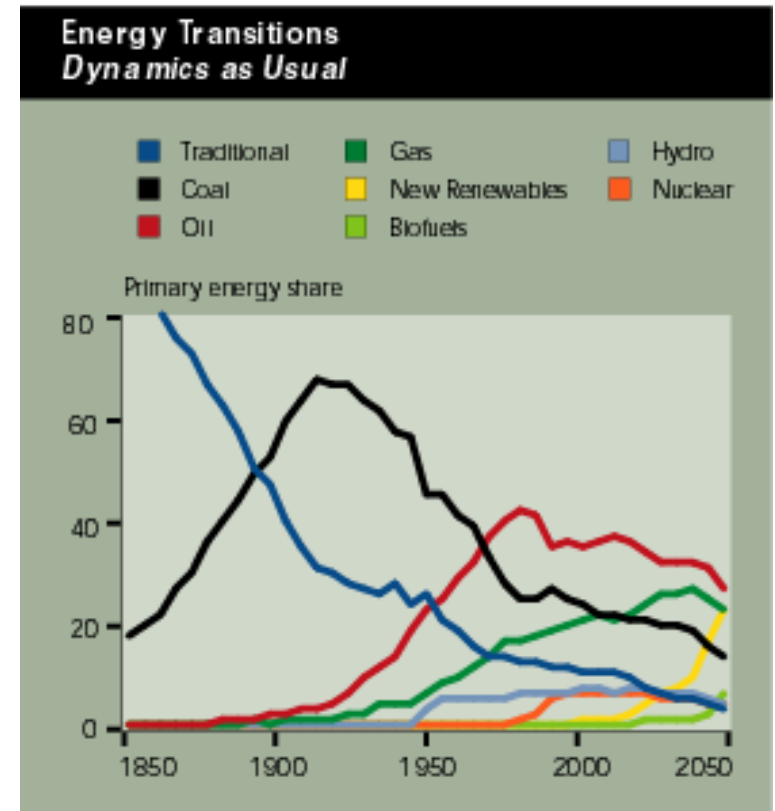


Energy Future

- What are future sources of energy?
 - Scenarios take into account population growth, economic growth, energy intensity, etc, and impact of goal of CO₂ reductions, etc.
 - Scenarios agree on decreasing share of coal, oil gradually reducing, hydro stable and increasing renewables.



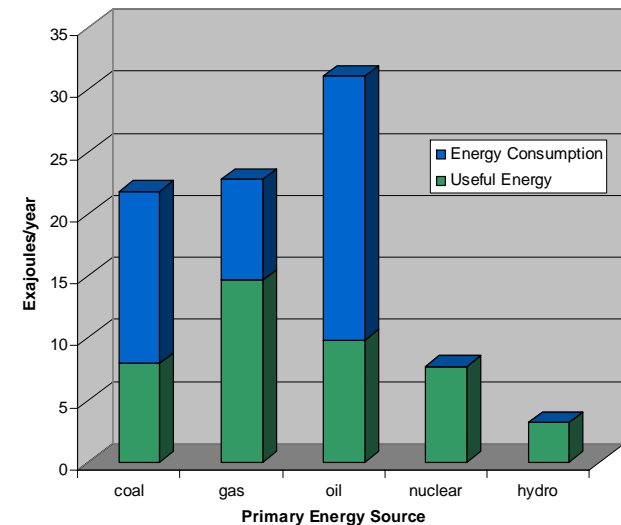
Source: World Energy Council



Source: Shell: Energy Needs, Choices and Possibilities: Scenarios to 2050.

How much energy do we need?

- US 2000 data
 - Use for primary energy consumption 90 Exajoules or 90×10^{18} J (energy equivalent to average production 3 TW).
 - Average electricity production is 250 GW.
- World energy data
 - Primary energy use: 430 Exajoules or average production of 13.7 TW.
 - Average electricity production 1.63 TW.
- Future scenarios
 - Generally assumes ~ doubling by 2050 (average growth rate of 1.5%)
 - By 2050, need world wide additional 13.7 TW **primary** energy or ~ 2 TW electricity (assuming mix of energies stays similar)



Photovoltaics



- Photovoltaics has *technical* characteristics to meet growing energy markets
 - Distributed source
 - Reliable
 - Minimal environmental impact
- Enough energy to meet demand: Assuming 30% growth rates:
 - Takes 30 years to meet ***new US electricity demand*** for the next 50 years.
 - Takes 37 years to meet ***new world electricity demand*** for the next 50 years.
 - Need 48 years to meet ***entire primary energy demand*** for world over next 50 years.

Course Outline



- Solar radiation – calculate properties of sunlight
- Solar Cell Operation and Technologies
 - Semiconductor Basics
 - Solar cell Operation
 - Solar Cell Technologies
- PV system basics
 - Analyze power flows and system performance
 - System design and troubleshooting
- System Components
 - Solar Cell
 - Battery
 - Power Conditioning
- Economics and System Analysis