



1 Overview

- Ch. 16: Renewable Energy
 - Putting Solar Energy to Work
 - Indirect Solar Energy
 - Hydropower
 - Wind power
 - Biomass energy
 - Renewable Energy for Transportation
 - Additional Renewable-Energy Options
 - Geothermal energy
 - Tidal power & wave power
 - Policies for a Sustainable-Energy Future



2 Solar Energy

- 1 • Radiant energy from Sun
 - Solar constant: 1,366 watts/m²
 - 50% to Earth's surface: ~ 700 watts/m²
 - Ultimately converted to heat
 - Enormous amount of energy
 - Diffuse & intermittent in many places
- 2 • Hurdles to overcome
 - Collection
 - Conversion
 - Storage
- Photosynthesis
 - Collects solar energy with leaves
 - Converts to chemical energy with in chloroplasts
 - Stores as sugars & starch



3 Solar Heating: Water

- 1 • Flat-plate solar collectors
 - Water circulates in tubes heated by sun
- 2 • Solar water heaters
 - Active system
 - Heated water moved by pumps
 - Passive system
 - Natural convection currents
 - Collector is lower than the tank



4 Solar Heating: Air

- 1 • Air circulates through collector box
 - Flat-plate collectors
 - Homemade devices
 - Passive: convection circulates heated air
- Energy Star program
 - Energy conservation
 - Extended to public & corporate buildings
 - Use 40% less energy
 - Tax deductions
- 2 • Solar space heating
 - Building designed as collector
 - Well-insulated building is the best storage
 - Landscaping can contribute to efficiency
 - Earth-sheltered housing
 - Earth berms against walls
 - Cover with earth, southfacing windows
 - Dehumidifiers for moisture problems



5 Solar Production of Electricity

- 1 • Photovoltaic (PV) cells
 - 4 in.² for 1 watt power
 - How they work
 - Light dislodges electrons creating electrical current
 - 15 – 30% efficient
 - Uses
 - Calculators, satellites
 - Net metering
 - Connected to power grid
- 2 • Cost
 - \$0.25/kilowatt hour
 - Grid: \$0.12/kWh in CA
 - Fastest growing technology industry
 - Inverters
 - Interface between PV cells & grid or battery
 - Direct current (DC) → alternating current (AC)

6 Solar Production of Electricity

- 1 • Photovoltaic (PV) cells
 - Utilities
 - Large-scale installations
 - Commercial & residential rooftops
 - New PV technologies
 - Thin-film PV cells with amorphous Si or CdTe
 - Thinly sliced Si crystals
 - Glass coated with dyes that transmit energy to solar cells on the edge
- 2 • Concentrated solar power (CSP)
 - Heat → conventional turbogenerators
 - Solar-trough collector system
 - SCE: 9 in Mojave Desert
 - Power tower
 - Molten-salt liquid heat
 - Dish-engine system
 - Molten sodium to engine
 - 30% efficiency!

7 Future of Solar Energy

- 1 • Solar industry
 - \$20 billion industry
 - Growing 40% per year
 - Disadvantages
 - Available technology still more \$ than conventional energy
 - Excluding environmental costs of conventional
 - Only works in daytime
 - Some places not sunny enough in winter
- 2 • Matching demand
 - 70% of electrical demand during daylight
 - Reduces need for coal & nuclear power
 - Shorter start-up time, easier to add capacity
 - Not vulnerable to terrorist attacks
 - Developing countries
 - Solar can be used without a power grid

8 Indirect Solar: Hydropower

- 1 • Sun's energy drives the hydrologic cycle
 - Advantages of dams
 - Better than fossil fuels
 - Flood control & water for irrigation

- Recreation
- Pumped-storage power plants
 - Up at night (demand ↓), down in day (demand ↑)

- 2 • Disadvantages of dams
 - Drowns valuable land
 - E.g., canyons, farmlands
 - Displace rural populations
 - Impedes fish migration
 - Downstream: dry or flooded

9 **Indirect Solar: Hydropower**

- 1 • More dams?
 - Most developed countries at capacity
 - Controversy in developing countries
- 2 • Dam report
 - Mixed blessing
 - Should be built only if no other options exist
 - New dams will be built in developing countries
 - Especially China, India, & Brazil

10 **Indirect Solar: Wind Power**





- 1 • Increasing capacity
 - Decreasing cost
 - 1.5% of global demand
 - Could ↑ to 12% by 2020
- Design
 - Wind turbines
 - Wind-driven propeller blades
 - Wind farms
 - Land beneath can still be used for farming
 - 20% in U.S. by 2030?
- 2 • Drawbacks
 - Intermittent source
 - Backup or storage
 - Aesthetic concerns
 - Hazard for birds
 - Migratory routes & critical habitats should be avoided

11 **Indirect Solar: Biomass Energy**

- 1 • Firewood
 - 7% of total energy
 - Pellet stove
 - Fuelwood crisis?
 - Consumptive vs. productive use
 - Not a significant cause of deforestation
- Burning wastes
 - E.g., from sawmills, sugar cane, etc.
- 2 • Producing methane
 - Anaerobic digestion of sewage sludge or manure
 - Biogas + residue (fertilizer)
 - Cooking, heating, lighting
 - India & China

12 **Transportation: Biofuels**

- 1 • Ethanol
 - Farm products
 - 5% of gasoline used
 - Starch based (1st-gen.)
 - Concerns

- ↑ food prices
- Energy required to produce crop
- Habitats cleared for new land
- 2nd-generation biofuel
 - Crop & logging residues
 - Cellulose based
- 2 • Ethanol & air quality
 - Reformulated gasoline
 - Burns cleaner
 - Additive: ethanol or MTBE (carcinogen)
 - Clean Air Act
 - Biodiesel
 - 20% soybean oil
 - E.g., recycled oil from frying foods
 - Any oil can be used
 - E.g., turkey wastes
- 13  **Transportation: Hydrogen**
 - Little H₂ gas on Earth, most in water
 - Splitting water
 - Mimic photosynthesis
 - Catalyst from cobalt & phosphorus (from MIT)
 - Electrolysis
 - Electric current through water
 - H₂ collected, compressed & stored in cylinders
 - Using solar energy to create electric current
 - Move H₂ through underground pipelines
 - Goal: hydrogen economy
 - No longer tied to fossil fuel economy
- 14  **Transportation: Hydrogen**
 - Difficult to store enough H₂ to drive long distances
 - Model U (concept car)
 - Internal combustion engine with a hybrid electric drive
 - 4 tanks
 - Need hydrogen-fueling infrastructure
- 15  **Hydrogen Fuel Cells**
 - 1 • H₂ chemically recombined with O₂
 - Produce an electric potential to drive electric motor
 - Very efficient
 - 45% - 60%
 - Cars also need:
 - H₂ storage device
 - Cooling system
 - Device to force O₂ into fuel cells
 - 2 • Obstacles
 - High cost
 - Lack of infrastructure
 - Hydrogen refueling
 - FreedomCAR & Fuel Partnership initiative
 - Originally for fuel-cell powered vehicles
 - Partial shift towards plug-in hybrid electric vehicles
- 16  **Geothermal Energy**
 - 1 • Natural heated water or steam
 - Heat buildings
 - Drive turbogenerators

- Drill holes several miles deep
 - 400 + granite
 - Inject pressurized water in one hole
 - Steam from another hole to power plant
- 2 • Heat pumps
 - Heat exchange pipes underground
 - Constant temperature
 - Loops with antifreeze
 - Pump & air handler

17 **Oceans**

- 1 • Tidal power
 - Tidal barrage (dam across a bay + turbines)
- Wave power
 - Waves move buoys
 - Pump water through turbines
- 2 • Ocean thermal-energy conversion (OTEC)
 - Use thermal gradient
 - Pressurize ammonia to drive turbogenerators
 - Not economically viable
 - Unless coupled with other operations (e.g., nutrient-rich water for aquaculture)

18 **Policies for Sustainable Energy**

- Fossil fuels are not sustainable
- Global targets
 - Stable atmospheric levels of greenhouse gases (especially CO₂)
 - A sustainable-energy development-and-consumption pattern based on renewable energy
 - Development of sustainable energy (supply-side)
 - Energy conservation & efficiency (demand-side)

19 **National Energy Policy**

- 1 • Fossil fuel problems
 - Oil-transportation
 - Import ⅓ of our oil
 - Natural gas cost
 - Energy security
 - Whims of OPEC
 - Terrorist vulnerabilities
- Renewable portfolio standard (RPS)
 - CA: 33% by 2020
 - No federal RPS for U.S.
- 2 • U.S. laws
 - 2005 Energy Policy Act
 - 2007 Energy Independence & Security Act
 - 2009 American Recovery & Reinvestment Act
 - Double renewable energy by 2012

20 **National Energy Policy: Supply-Side**

- Establish a renewable fuel standard (RFS) for ethanol & biodiesel
 - To 15 billion gallons by 2015
 - To 36 billion gallons by 2022 from non-corn sources
- Funding for research & development on renewable energy
- Tax credits for renewable electricity
 - Extend production tax credit
 - Provide investment tax credit
- Enable geothermal to compete with fossil fuels

21 **National Energy Policy: Demand-Side**

- Raise Corporate Average Fuel Economy standard
 - Cars: 39 mpg, light trucks: 30 mpg by 2016

- Extend Energy Star building efficiency
 - Schools, retail, private homes, health care facilities
- Energy efficiency tax credits
 - Homes & commercial buildings
- Require 30% increase in lightbulb efficiency
 - Met by compact florescent lightbulbs (CFLs)

22  **National Energy Policy: Demand-Side**

- EPA to inventory waste-energy potential
 - Encourage waste-energy recovery
- Develop efficiency standards for appliances
 - Tax credit for manufacturers of energy-saving appliances
- Funding for vehicle development
 - FreedomCAR (fuel-cell vehicles)
 - Plug-in hybrid electric vehicles (PHEVs)
- Income tax credit for purchase of new hybrid vehicles, PHEVs, or fuel-cell-powered vehicles

23  **Alternative Energy**

National Geographic
[YouTube video](#)

24  **Reminders**

- *From Today*
 - Study Ch. 16; Read Ch. 17 for next lecture
 - Read! Study figures! Learn terms!
 - Review textbook questions for this chapter
 - Review with online activities
 - 11/7: Complete the exercises assigned in MasteringEnvironmentalScience
 - Monday, November 7th: EXAM 4 (Ch 13 – 16)
 - Scantron, RCCD ID, pencil, eraser