1 Energy Efficiency and Renewable Energy

Chapter 16

2 Energy Efficiency

- Percentage of total energy input into an energy conversion device or system that does useful work

3 Commercial Energy Flow in US

- **41% energy wasted due to 2nd law thermo-dynamics**
- **43% energy is unnecessarily wasted**

4 **Advantages of reducing energy waste**

- **Prolongs fossil fuel supplies**
- **Reduces oil imports**
- **Very high net energy**
- **Low cost**
- **Reduces pollution & environmental degradation**
- **Buys time to phase in renewable energy**
- **Less need for military protection of Middle East oil resources**
- **Improves local economy by reducing flow of money out to pay for energy**
- **Creates local jobs**

5 Efficiencies

6 **Least Energy Efficient Devices**

- **Electricity from Nuclear Power Plant to heat a home (86% waste)**
- **Incandescent lighting (95% waste)**
- **Internal combustion engines (86% waste)**
- **Coal burning power plants (66% waste)**

7 **Heating with Solar Energy (not including batteries for storage of energy for later)**

8 Saving Energy: Use/Develop More Energy Efficient Devices

- **Energy efficient cost more up fronts but have lower lifetime operating costs**
- **Insulation**
- **Elimination of air leaks**
- **Air to air heat exchangers**
- **Cogeneration of electricity and heat**
- **Efficient electric motors**
- **High-efficiency lighting**
- **Increasing fuel economy**

9 Net energy efficiency

- Every step in the energy conversion process is counted towards net energy efficiency
- Keep the number of steps in an energy conversion process as few as possible
- Strive to have the highest possible energy efficiency for each step in an energy conversion

process

10 ☐ Cogeneration (CHP)

- Combined heat and power systems
- 2 useful forms of energy are produced from the same fuel source
- Efficiency climbs to 80%
- Emit 66% less CO2 per unit of energy produced than conventional coal burning plants

11 ☐ Update electric motors used in industry

- Most electric motors in industry run at one speed, full out, output is throttled to match the task
- Consumes more energy than it produces in products
- Replace with adjustable-speed drive motors

12 ☐ **Transportation Energy Use (thousands of Btus per passenger mile)**

13 ☐ Corporate Average Fuel Economy Standards (CAFE)

- Government mandated
- Automakers have powerful lobbies to prevent rise of CAFE standards
- If raised by 5% for 10 years, we wouldn't be importing oil from Persian gulf
- Automakers sold the US public on larger, less efficient vehicles

14 ☐ Real Price Gasoline (1993 $) in US

- Use 40% world's gas
- $ less than bottled H2O
- Raising CAFE standards would save energy

15 ☐ Hybrid Electric Cars

- Uses a small electric internal combustion engine that runs on gasoline, diesel fuel, or natural gas and a small battery charged by the engine for energy needed for acceleration or climbing hills
- Toyota Prius, Honda Insight, Honda Civic Hybrid

16 ☐ Hybrid Gas Electric Engine

17 ☐ Fuel Cell Cars

- Burns hydrogen fuel to produce the electricity
- The hydrogen fuel in the liquid reformer combines w oxygen to produce electricity to power the car and releases water vapor as a byproduct
- some use hydrogens from fossil fuels others can utilize sodium borohydride which produces borax as a byproduct
- Best way would be to split water to get hydrogen

18 ☐ Ways to Reduce Carbon Emission

19 ☐ Energy Saving Energy House Designs

- A cost effective commercial building technologies could reduce energy use by 75% in the US
- Cut CO2 emissions in half
- Save more than $130 billion per year in energy bills

20 Electric Bicycles and Scooters

- Cost $500 to $1K
- Can attain speeds of 20 mph
- Travel 30 miles without pedaling
- Produce small amount of pollution for electricity to recharge them
- Scooter-travels farther slightly faster

21 Fuel cell system

22 Fuel Cell Car

23 Improving the energy efficiency of houses

- Superinsulated house cost more (5%) but save more over 40 year period
- Strawbale homes (R 35, R 60 compared to R12, R 19 – resistance to heat flow)
- Use passive solar heat
- Use active solar cells for electricity
- Use wind for electricity (split water for H)
- Plant covered roof gardens
- High efficiency furnace

24 Insulation Rating

- R value insulation ratings are used to measure insulations ability to resist heat flow. The higher the R value, the more effective it is. House Insulation should be purchased based on its R value, not thickness or weight.
- R value performance testing is done in a 70 F environment with no air movement. When you need insulation the most you're not in these ideal temperatures or conditions. This can result in the rated house insulation R value being higher than the actual effective R value.
- The average recommended R value of insulating material for basement insulation in North America is R-12.

25 Some R values of insulation materials

- 1 inch of insulation is = to 30 inches of concrete
- House Insulation R value of Blown in Cellulose Insulation is 3.70 per inch
- House Insulation R value of Fiberglass Insulation is 3.14 per inch
- House Insulation R value of Expanded Polystyrene is 4.00 per inch
- Straw bales is 2.38 per inch (bales are about 23” thick) (Oak Ridge TN tests lower 0.94 per inch)

26 A superinsulated house

27 Easy ways to save energy

- Plug leaks around windows and doors
- Install energy saving windows low emissivity windows
- Wrap water heater
- Tankless instant water heaters
- Install energy saving lighting
- Use energy saving appliances

28 **Net Energy Efficiency**

29 ## Simple Ways to Save Energy

- TURN OFF DEVICES NOT IN USE!
- Use less.
- Use more efficiently.
- Buy devices that are more efficient. (Brown students found that replacing lightbulbs in exit signs w fluorescent bulbs would save school $40K/yr)

30 ## Cost of Electricity for 10,000 Hours

31 ## Why don't we switch to energy saving appliances and other devices?

32 ## Advantages of Direct and Indirect Solar Energy

Save money (wind)

Reduce air pollution (99% less than coal)

Greatly reduce CO_2 emissions

Reduce dependence on imported oil

Last as long as coal and nuclear plants (30–40 years)

Land use less than for coal; Low land use with new solar cell and window glass system

Backup and storage devices available (such as gas turbines, batteries, and flywheels)

Backup need reduced by distributing and storing solar-produced hydrogen gas

33 ## Disadvantages of Direct and Indirect Solar Energy

Making solar cells produces toxic chemicals

Solar systems last only 30–40 years

Take large amounts of land because of diffuse nature of sunlight

Can damage fragile desert ecosystems used to collect solar energy

Need backup systems at night and during cloudy and rainy weather

34 ## Using Solar Energy to Heat Houses and Water

- Passive heating system absorbs and stores heat from the sun directly within a structure
- The house's windows and other solar collecting structures, are oriented towards the sun
- Walls and flooring materials are chosen to hold heat, such as concrete, stone, water in metal or plastic, adobe, and brick
- Collect solar energy as heat and release the heat slowly throughout the day/night

35 **PASSIVE solar heat**

36 **ACTIVE Solar Heat**

37 Passive Solar Design

38 A Passive Solar Design

39 Passive Solar Design

40 Passive Solar Design

41 Active Solar Heating systems

- Collectors absorb solar energy
- Fan or pump distributes heat
- Some heat stored in insulated tanks that contain rocks, water, or heat-absorbing chemical

42 Solar Energy Unlikely to be Widespread in Existing Structures

- Buildings not oriented to the sun
- Access to sunlight blocked by other buildings or structures

43 Cooling Houses Naturally

- INSULATION
- Blocking the high summer sun w deciduous trees, window overhangs, and awnings
- Using windows and fans to take advantage of breezes or circulate the air
- Block radiative heat from attic w reflective insulation
- Using large earth tubes underground where the earth is cool year round and using a fan to pipe cool and partially dehumidified air into an energy-efficient house

44 Global Solar Energy Availability

45 Advantages of heating a house w passive or active solar energy

Energy is free

Net energy is moderate (active) to high (passive)

Quick installation

No CO_2 emissions

Very low air and water pollution

Very low land disturbance (built into roof or window)

Moderate cost (passive)

46 Disadvantages of heating a house w passive or active solar energy

Need access to sun 60% of time

Blockage of sun access by other structures

Need heat storage system

High cost (active)

Active system needs maintenance and repair

Active collectors unattractive

47 Solar Thermal Systems

- Collect and transform radiant energy from the sun into high temperature thermal energy which can then be converted to electricity
- Power tower: central receiver system has arrays of heliostats, mirrors, which are controlled by computer to orient to the sun

48 Solar Power Tower

49 Thermal Plants

- Thermal plant: distributed receiver system, sunlight collected and focused on oil-filled pipes
- Concentrated sunlight can generate temperatures high enough for industrial processes or for producing steam
- Gas turbines used on cloudy days and at night

50 Solar Thermal Plant

51 Parabolic Dish Collectors

- Track the sun along two axes
- Combined w a natural gas turbine backup should be able to produce electrical power costing about the same as coal powered plants

52 Nonimaging optical Solar Concentrator

- Intensifies incoming solar energy (by about 80Kx)

53 Nonimaging Optical Solar Concentrator

54 Solar Cookers

- Focus and concentrate sunlight and cook food

- Hold pots in transparent box

55 ☐ Advantages of Using Solar Cells to produce electricity

Moderate net energy

Moderate environmental impact

No CO_2 emissions

Fast construction (1–2 years)

Costs reduced with natural gas turbine backup

56 ☐ Disadvantages of Using Solar Cells to produce electricity

Low efficiency

High costs

Needs backup or storage system

Need access to sun most of the time

High land use

May disturb desert areas

57 ☐ **Single Solar Cell (photovoltaic cell)**

58 ☐ Photovoltaic Cells (solar cells)

- Transparent wafer which contains a semiconductor material has thickness ranging from 5 to 10 micrometers
- Silicon is usually the semiconductor used and it is an alloy w boron or other nonmetals (P) to allow for electron transfer when the light energy strikes the surface
- About 15% efficient (only part of EM spectrum used)

59 ☐ Electricity generated by solar cells

- Direct current (DC) can be stored in batteries and used directly or
- Can be converted to alternating-current (AC) electricity by an inverter
- Electricity produced from solar cells is used in several undeveloped countries or poor countries (India is main purchaser of solar cells)

60 ☐ **Roof Options**

61 ☐ Advantages of using solar Cells to produce electricity

- Fairly high net energy

- Work on cloudy cays
- Quick installation
- Easily expanded or moved
- No CO2 emissions
- Low environmental impact
- Last 20-40 years
- Low land use if on roof or built in walls
- Reduces dependence on fossil fuels

62 Disadvantages of using solar Cells to produce electricity

- Need access to sun
- Low efficiency
- Need electricity storage system or backup
- High land use (solar cell power plants) could disrupt desert areas
- High costs (may be competitive in 5-15 years)
- DC current must be converted to AC

63 Approximate land use of systems for producing electricity in US

64 Using heated or moving water to produce electricity

- Hydropower plants over rivers
- Hydropower plants using tides or waves
- Using thermocline to generate electricity (OTEC) ocean thermal energy conversion
- Saline solar ponds
- Freshwater solar ponds

65 Hydropower plants across rivers

- Water flowing through pipes spin turbines and produce electricity
- Large scale dams major rivers and creates reservoirs
- Small scale dams have no reservoirs, stream flow spins turbine
- Pumped storage uses conventionally produced electricity to pump water to higher geographically level so that it falls and turns turbines

66 Hydropower Generated Electricity

- Supplies 6% of commercial energy
- 20% of world energy (10% of US)

67 Advantages of Hydropower

Moderate to high net energy

High efficiency (80%)

Low-cost electricity

Long life span

No CO_2 emissions during operation

May provide flood control below dam

Provides water for year-round irrigation

68 ☐ Disadvantages of Large Dams

High construction costs

High environmental impact

High CO_2 emissions from biomass decay in Shallow tropical reservoirs

Floods natural areas

Converts land habitat to lake habitat

Danger of collapse

Uproots people

Decreases fish harvest below dam

Decreases flow of natural fertilizer (silt) to land below dam

69 ☐ Tidal hydropower plants

- 2 large plants: Bay of Fundy and La Rance in France
- Few suitable sites (need large difference in tides and a constriction point)
- Few locations have adequate geography to tap wave power

70 ☐ **Tidal Power Plant**

71 ☐ **Wave Power Plant**

72 ☐ Generating Electricity from thermoclines

- Ocean thermal energy conversion (OTEC)
- Plants would be anchored at bottom of tropical seas (unlikely $$$ cost)
- Saline solar ponds accumulate heat in day could be used to generate steam to spin turbines (Dead Sea- closed $$ operating costs)
- Freshwater solar ponds line concrete basins with black plastic to accumulate heat

73 ☐ **Ocean Thermal Electric Plant**

74 ☐ **Ocean Thermal Electric Plant**

75 ☐ **Saline Water Solar Pond**

76 ☐ **Freshwater Solar Pond**

77 ☐ Wind power

- About 7 million homes' electricity generated from wind
- Most in Europe (Germany, Spain, Denmark)
- Becoming less expensive to generate power this method – comparable to coal
- Potential great in North Sea, China and India (Am west)
- In US, farmers can lease land to govt and draw royalties from wind farming

78 ☐ **Wind Turbine**

79 ☐ **Wind Farm**

80 ☐ Potential for wind power in US

81 ☐ Advantages of wind power

Moderate to high net energy

High efficiency

Moderate capital cost

Low electricity cost (and falling)

Very low environmental impact; land can be used for grazing

No CO_2 emissions

Quick construction; Easily expanded

82 ☐ Disadvantages of wind power

Steady winds needed

Backup systems when needed winds are low

High land use for wind farm

Visual pollution

Noise when located near populated areas

May interfere in flights of migratory birds and kill birds of prey

83 ☐ Biomass Burning

- Biomass is plant or animal wastes used as energy sources
- Can be burned directly or converted to gas or liquid biofuels
- Used for heating, cooking, and industry

- Indirect use for turbines, electricity
- Biomass burning accounts for 11% of world energy and 30% in developing countries
- Biomass is in short supply

84

85 Advantages of burning biomass

Large potential supply

Moderate costs

No net CO_2 increase if harvested and burned sustainably

Plantation can be located on semiarid land not needed for crops

Plantation can help restore degraded lands

86 Disadvantages of burning biomass

Nonrenewable if harvested unsustainably

Moderate to high environmental impact

CO_2 emissions if harvested and burned unsustainably

Low photosynthetic efficiency

Soil erosion, water pollution, and loss of wildlife habitat

Plantations could compete with cropland

Often burned in inefficient and polluting open-fires and stoves

87 Generating Hydrogen

- Water can be split by water or heat to form gaseous hydrogen and oxygen
- Hydrogen can be produced by reforming using high temperatures and chemical processes to pick hydrogens off hydrocarbons
- May be generated by gasification of coal or biomass
- Some algae and bacteria can be used to produce H

88 Problems generating Hydrogen

- Takes energy and money
- Costs more to generate than product produces

89 Using renewable energy to generate hydrogen

- Use solar energy to decompose

- biolysis

90 Hydrogen Gas as an Energy Source

91 Hydrogen storage

- Can be stored in compressed gas storage tanks
- Storage tank production is costly and they are large and heavy
- Liquid hydrogen (costs to keep cold –250C)
- Solid metal hydrides cooled store H, heated release H2
- Absorb on activated charcoal or graphite and then heat to release
- Store in glass microspheres (molecular level)

92 Hydrogen Fuel Cells

- Burn hydrogen and oxygen gas to form water vapor
- High efficiency (65%)
- No moving parts-quiet, low wear and tear
- Low CO2 (if source is hydrocarbon)
- Better than electrical grid

93 Advantages of using hydrogen as fuel

Can be produced from water

Low environmental impact

No CO_2 emissions

Good substitute for oil

Competitive price if environmental and social costs are included in cost comparisons

Easier to store than electricity

Safer than gasoline and natural gas

High efficiency (65–95%) in fuel cells

94 Disadvantages of using hydrogen as fuel

Not found in nature

Energy is needed to produce fuel

Negative net energy

High costs (but expected to come down)

Short driving range for current fuel cell cars

95 Geothermal heat: tapping Earth's energy

- Geothermal energy heat underground reservoirs of dry steam (no water droplets)
- Wet steam
- Hot water
- Reservoirs close to Earth's surface can be tapped by drilling
- Hot rocks zones; warm rock zones; magma

96 ☐ Tapping Geothermal Energy

97 ☐ Known Reserves of Geothermal Energy

98 ☐ Advantages of Geothermal Power

Very high efficiency

Moderate net energy at accessible sites

Lower CO_2 emissions than fossil fuels

Low cost at favorable sites

Low land use

Low land disturbance

Moderate environmental impact

99 ☐ Disadvantages of Geothermal Power

Scarcity of suitable sites

Depleted if used too rapidly

CO_2 emissions

Moderate to high local air pollution

Noise and odor (H_2S)

100 ☐ Paradigm shift from macropower to decentralized micropower

- Natural gas burning microturbines for commercial buildings and residences
- Wind turbines
- Stirling engines
- Fuel cells
- Household solar panels and solar roofs

101 ☐ Centralized Power system

102 ☐ Decentralized power system

103 ▭ Advantages of micropower systems

Small modular units; Fast factory production; Fast installation (hours to days)
Can add or remove modules as needed
High energy efficiency (60–80%)
Low or no CO_2 emissions; Low air pollution emissions
Reliable; Easy to repair; Much less vulnerable to power outages
Useful anywhere-Especially useful in rural areas in developing countries with no power
Can use locally available renewable energy resources
Easily financed (costs included in mortgage and commercial loan)

104 ▭ Solutions for improving energy efficiency

- Increase fuel-efficiency standards for vehicles, building, and appliances
- Mandate government purchases of efficient vehicles and other devices
- Provide large tax credits for buying efficient cars, houses, and appliances
- Offer large tax credits for investments in efficiency
- Reward utilities for reducing demand
- Encourage independent power producers
- Greatly increase efficiency research and development

105 ▭ More Renewable Energy

- Increase renewable energy to 20% by 2020 and 50% by 2050
- Provide large subsidies and tax credits for renewable energy
- Use full cost accounting and least cost analysis for comparing all energy alternatives
- Encourage government purchase of renewable energy devices
- Greatly increase renewable energy research and development

106 ▭ Reduce pollution and health risk

- Cut coal use 50% by 2020
- Phase out coal subsidies
- Levy taxes on coal and oil use
- Phase out nuclear power or put it on hold until 2020
- Phase out nuclear power subsidies

107 ▭ The question is….

- Currently the question is not between renewable energy sources and nonrenewable energy sources!

108 ▭