BUS-183 - Sustainable Energy

Stanford Continuing Studies

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Many references from: *Sustainable Energy*: Choosing Among Options. J. Tester, E. Drake, M. Driscoll, M. Golay, W. Peters. 2005. The MIT Press. ISBN 0-262-20153-4

Question

When will we run out of oil?

Answer

Never!

There will always be a little oil someplace we can extract at a some price.

However, we will soon reach the end of cheap oil - IEA predicts by 2020.

Oil is NOT a sustainable energy source!

Source: http://www.economist.com/businessfinance/displaystory.cfm?story_id=15065719

Max Dunn Bio

- Studied Engineering Physics at UCB
- Degree in Computer Science at UCSC
- Started and ran 4 high-tech businesses
- Getting a Sustainable MBA at Presidio Graduate School

Why Study Sustainable Energy?

- Large amounts of energy go into creation of products
- Understanding sustainable energy is necessary for creating sustainable products

What Makes Energy Sustainable?

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What Makes Energy Sustainable?

- Balance: Impacts and progress
- Environment Impacts
  - Mercury
  - SO2, NOx
  - Coal Ash
- Other Inputs Needed
  - Water for cooling
  - Electricity, natural gas
- Sources
  - Flows not stocks
  - Period to replenish

Four Primary Sources of Energy

?

Four Primary Sources of Energy

- **Solar Radiation**
  - Wind
  - Waves
  - Hydropower
  - Fossil fuels
  - Biomass
- **Nuclear**
- **Tides** (Gravity of Moon and Sun)
- **Geothermal** (Earth creation, radioactive decay)

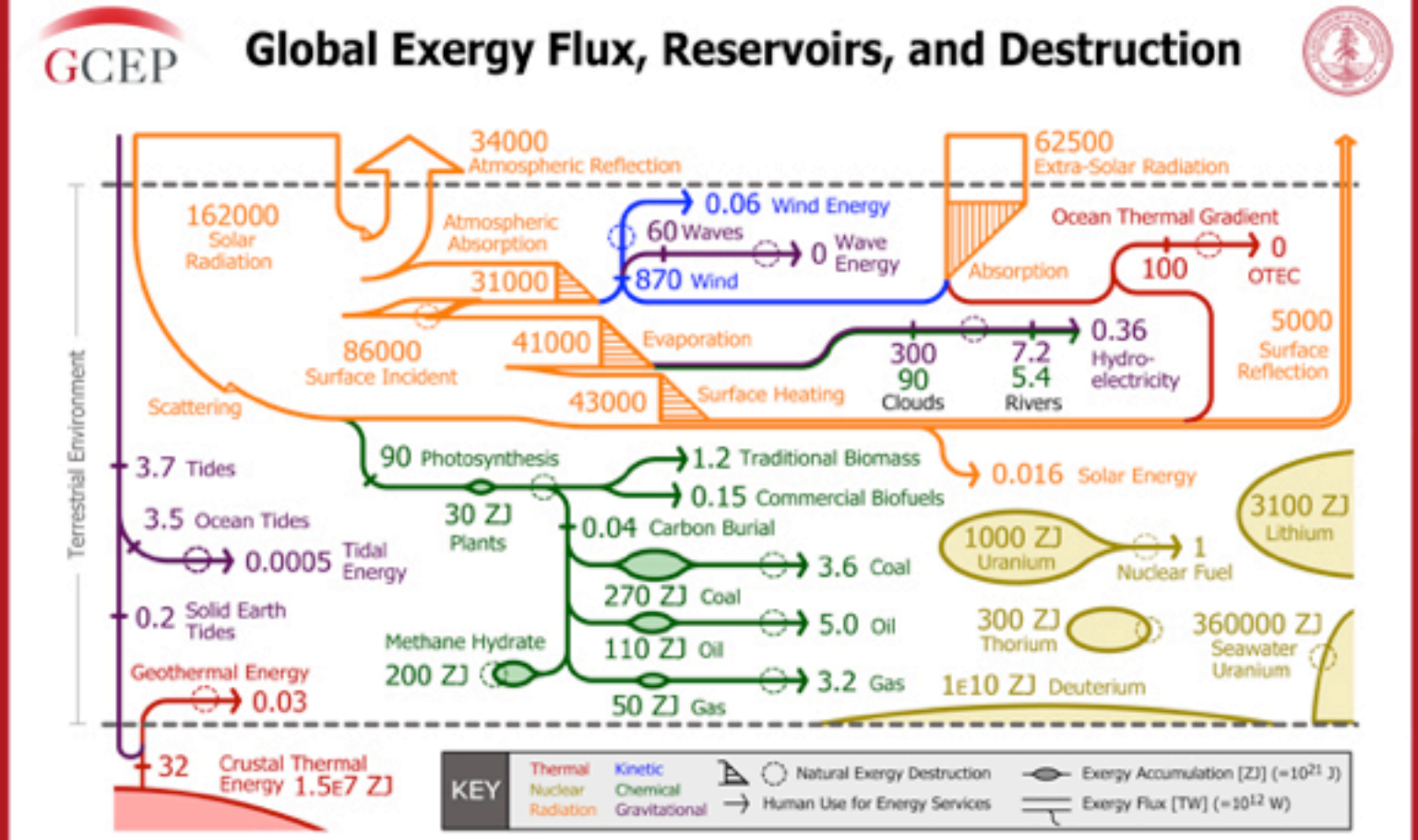
Energy Flows vs Stocks

- **Solar Radiation** - Flow or Stock?
- **Nuclear** - Flow or Stock?
- **Tides** - Flow or Stock?
- **Geothermal** - Flow or Stock?

Energy Flows vs Stocks

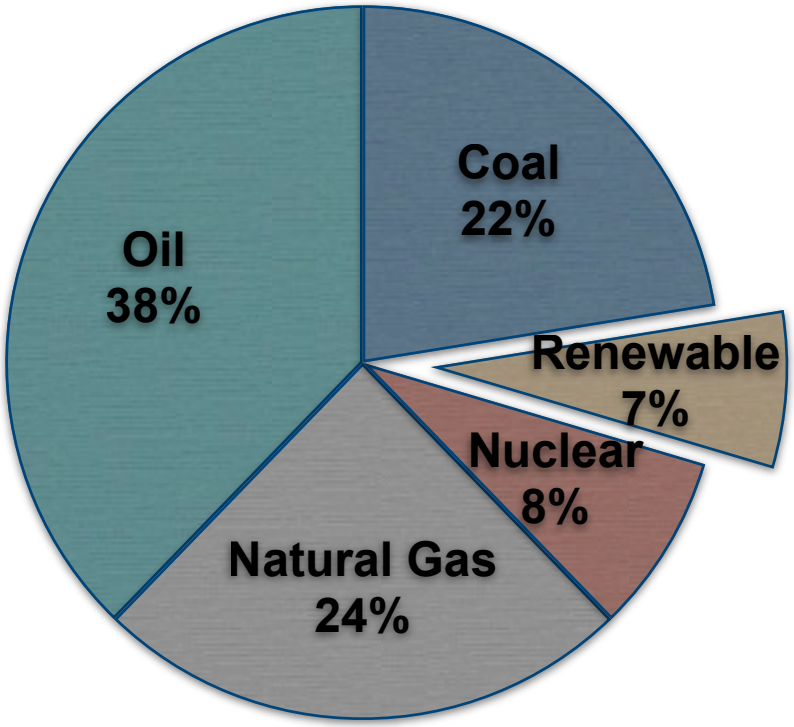
- **Solar Radiation** - Flow
- **Nuclear** - Stock
- **Tides** - Flow
- **Geothermal** - Stock

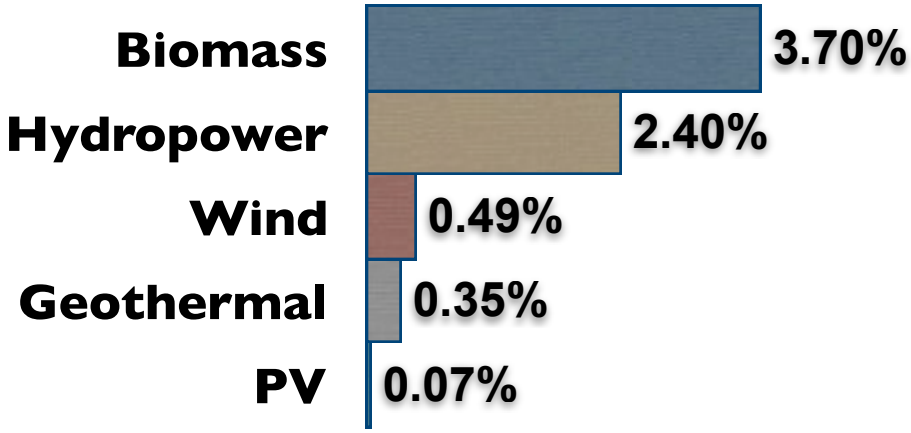
Size of Energy Flows and Stocks



Source: GCEP Exergy chart

Energy Resources Used - 2008





Source: 2008 EIA Renewable Energy Consumption http://www.eia.doe.gov/emeu/aer/pdf/pages/sec10.pdf

Useful Energy Conversion

	Light	Heat	Work	Electricity
Solar				
Geothermal				
Fuel				
Nuclear				
Wind, Water				
Electricity				

Useful Energy Conversion

	Light	Heat	Work	Electricity
Solar	Window	Solar Pool Heater	--	PV, Solar Thermal
Geothermal	--	Hot Springs	--	Geothermal Plant
Fuel	Candle	Fire, Gas Heater	Food, Car	Coal Power Plant
Nuclear	--	--	--	Nuclear Plant
Wind, Water	--	--	Waterwheel	Wind Turbine, Hydropower
Electricity	CFL	Heater, A/C	Electric Motor	Transformer

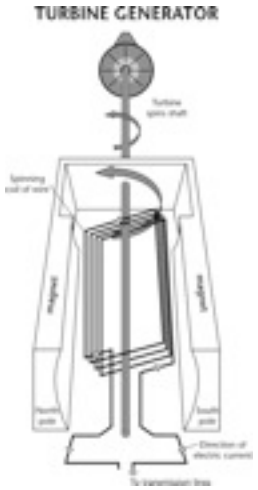
Energy Conversion Conclusion

Electricity is the most universal energy carrier

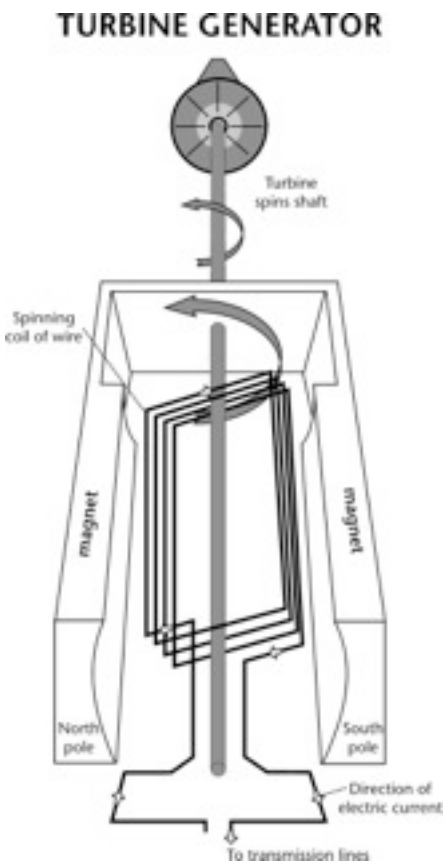
Electricity Production

Generator

- Goal of a power plant is to rotate a generator
- A generator is basically a big motor run in reverse

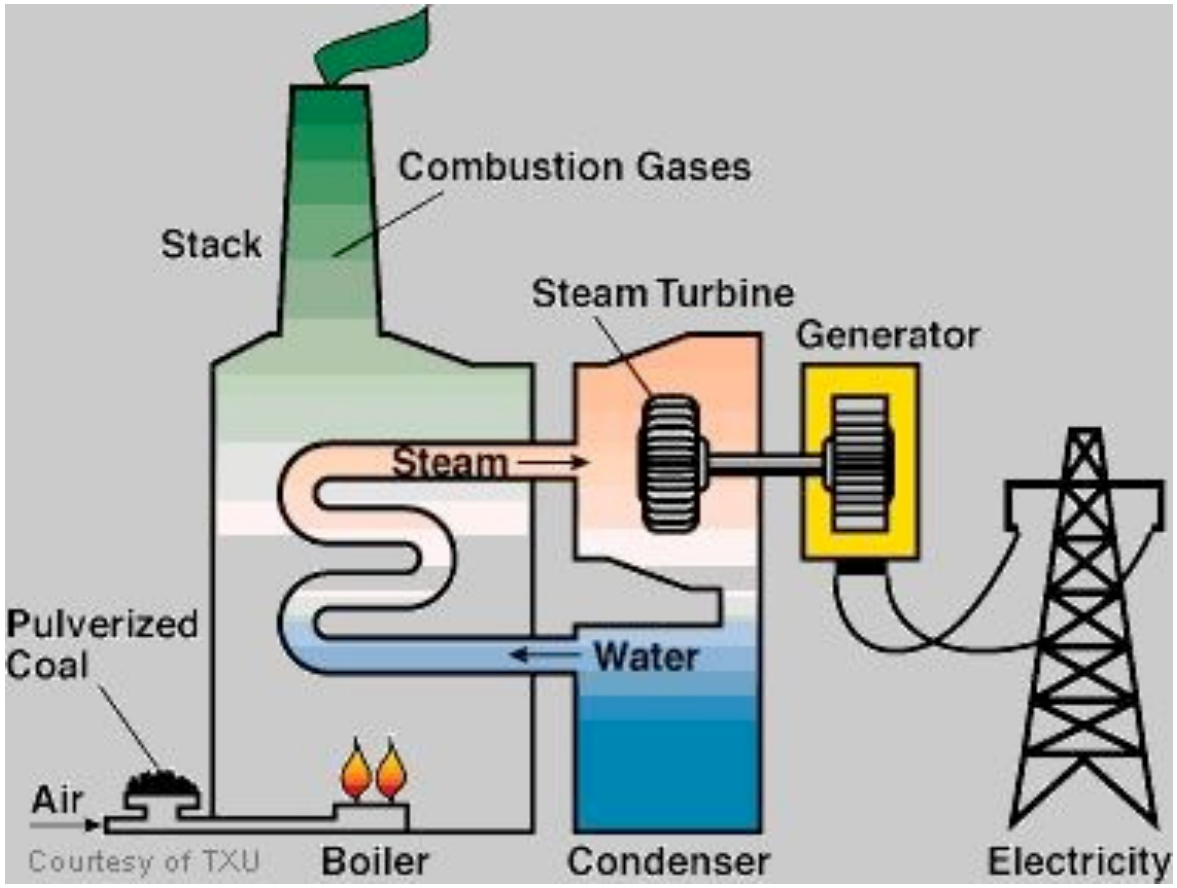


Turbine connected to the generator



Now, how do you make the turbine turn?

Coal-Fired - Steam Turbine

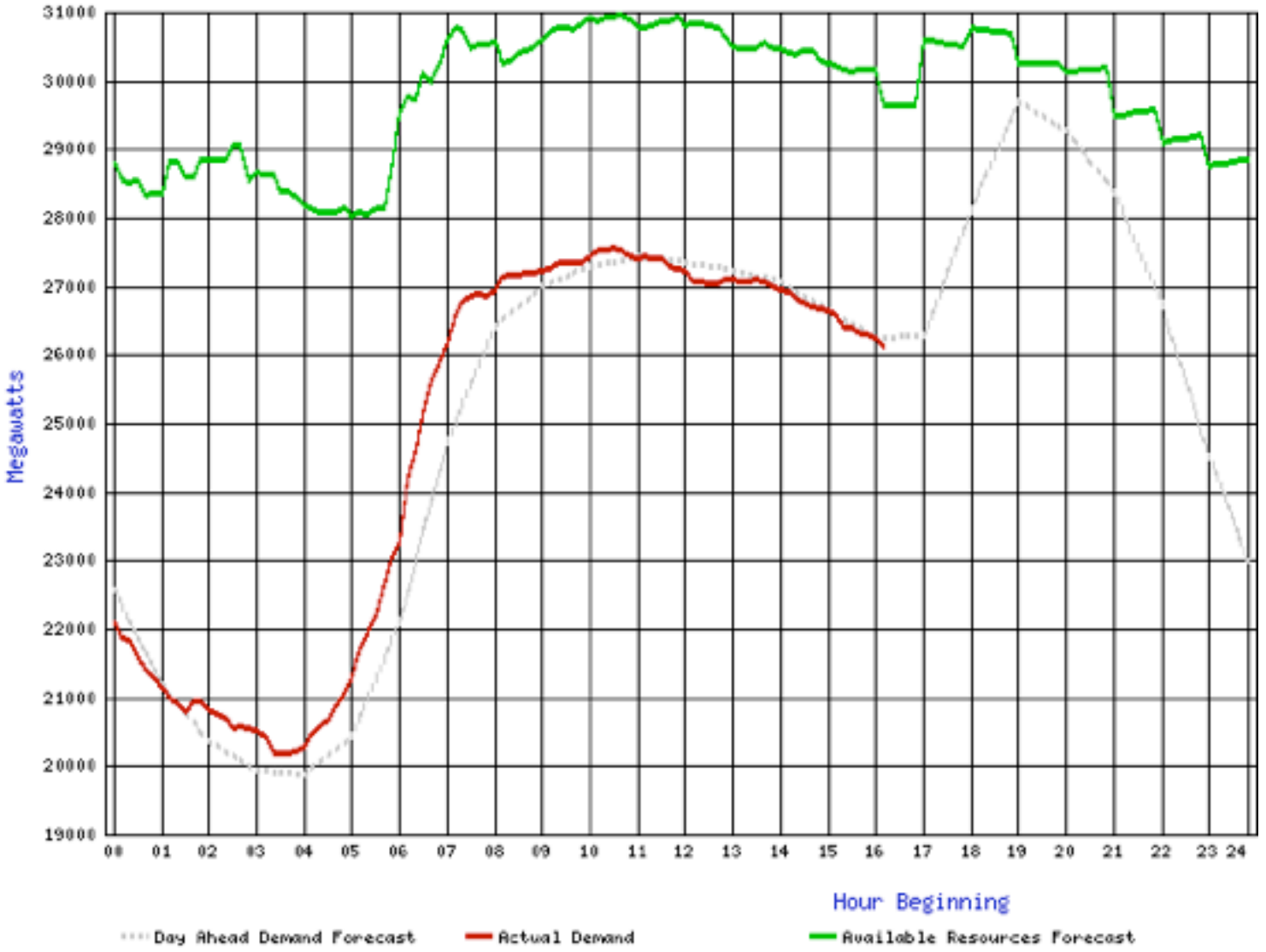


Energy Storage

No grid storage of electricity!

- Current
  - Pumped hydro
- Future
  - Compressed Air Energy Storage (CAES)
  - Hot salt
  - Batteries

CA Electricity Usage



From: http://caiso.com/outlook/SystemStatus.html for Feb 3, 2010

Kilowatt Hour (kWh)

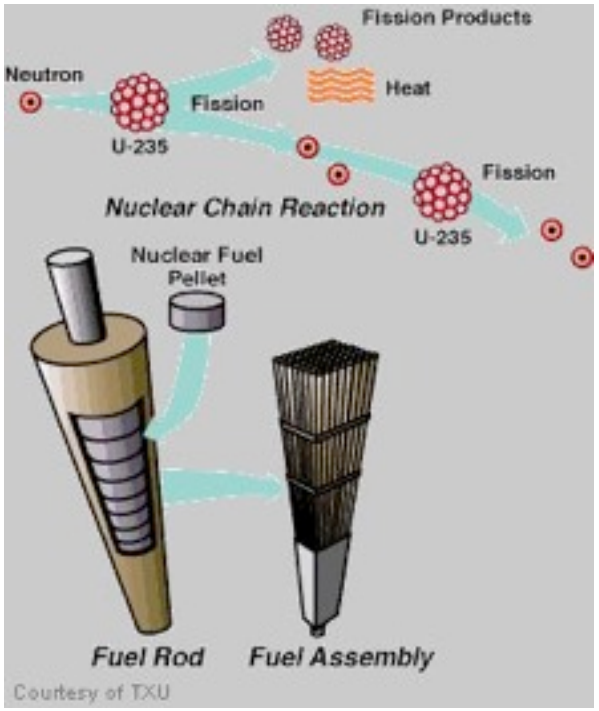
- Kilo = thousand
- Using a 1000 watt hairdryer for one hour uses one kWh of electricity
- Coal-fired electricity costs about $0.04 to $0.05 per kWh to produce
- We pay about $0.11 per kWh

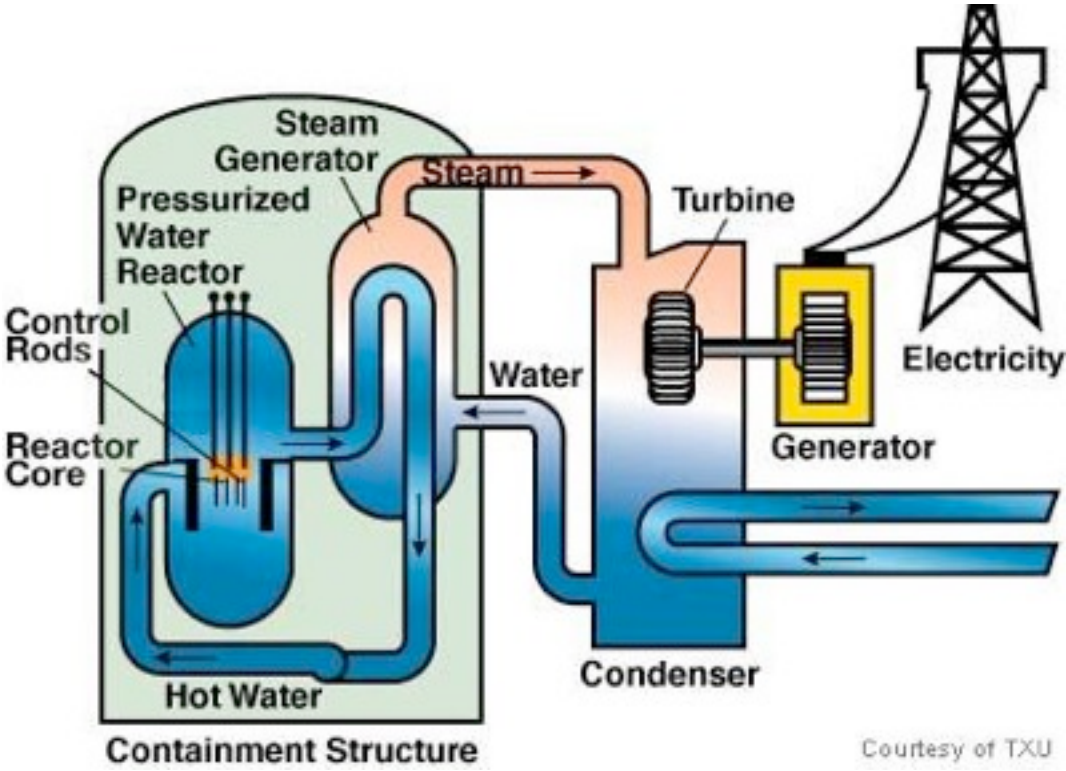
Types of Electricity

- **Base load**: On all the time, nuclear, coal
- **Spinning reserve**: Online in 10 minutes
- **Voltage regulation**: 4 second response
- **Peakers**: Expensive, used 10 to 20 hours a year in CA

Sustainable Energy Production

Nuclear Power - Steam Turbine



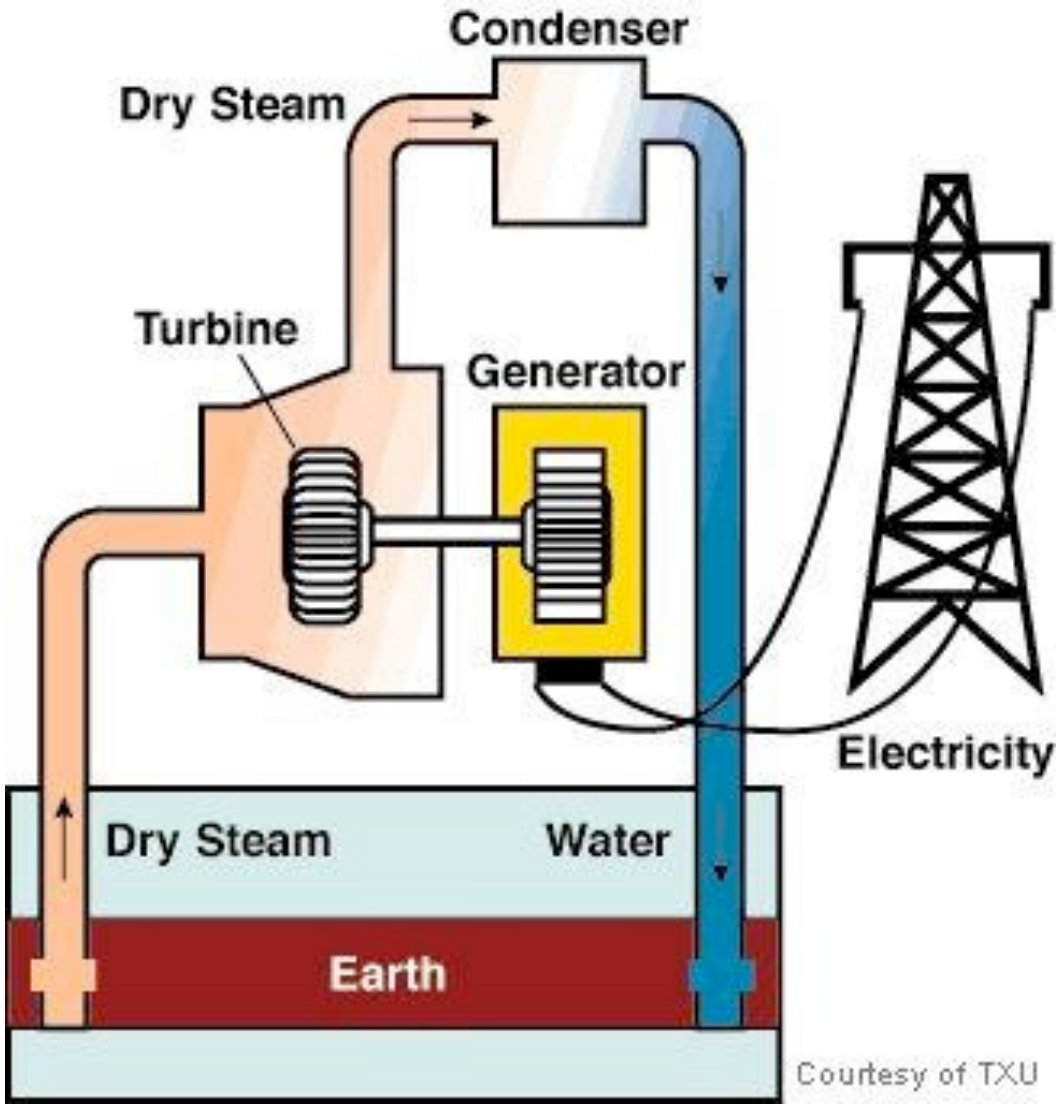


Nuclear Power

- **Cost**: $0.05-$0.07 kWh
- **Potential**
  - Enough uranium for about a century
  - Longer with breeding reactors and new discoveries
- **Advantages**
  - No CO2 emitted during use
  - Thorium could be substituted for uranium
- **Challenges**
  - Waste disposal
  - Produces nuclear weapons material
  - High capital costs
  - Political and permit uncertainty

References: Sustainable Energy. pp 706 and pp 388

Geothermal - Steam Turbine

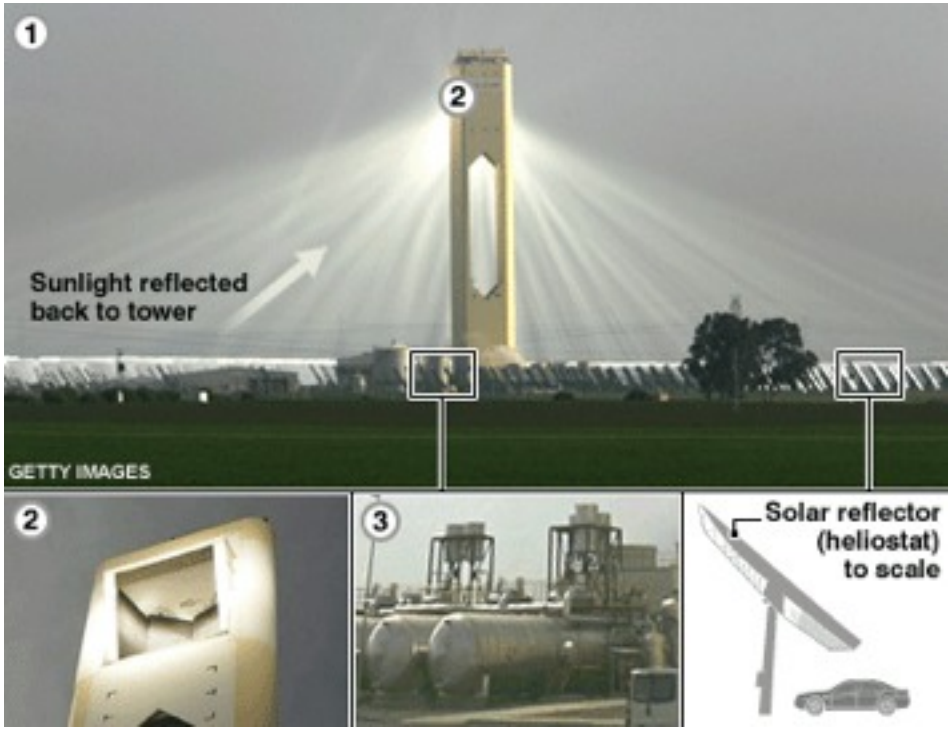


Geothermal Power

- **Cost**:
  - High-grade already competitive: $0.04 - $0.08 kWh
  - Low-grade: $0.10 to $0.47
- **Potential**
  - Currently: 7% of CA electricity, 25% of Hawaii
  - 0.1% of accessible resource would supply all of US
- **Advantages**
  - Long life: 20 to 40 years
- **Challenges**
  - Drilling is expensive (exponential with depth)
  - May need lots of water

References: Sustainable Energy. pp 467, 495

Solar Thermal - Steam Turbine



Solar power heats a fluid,
which is used to generate steam

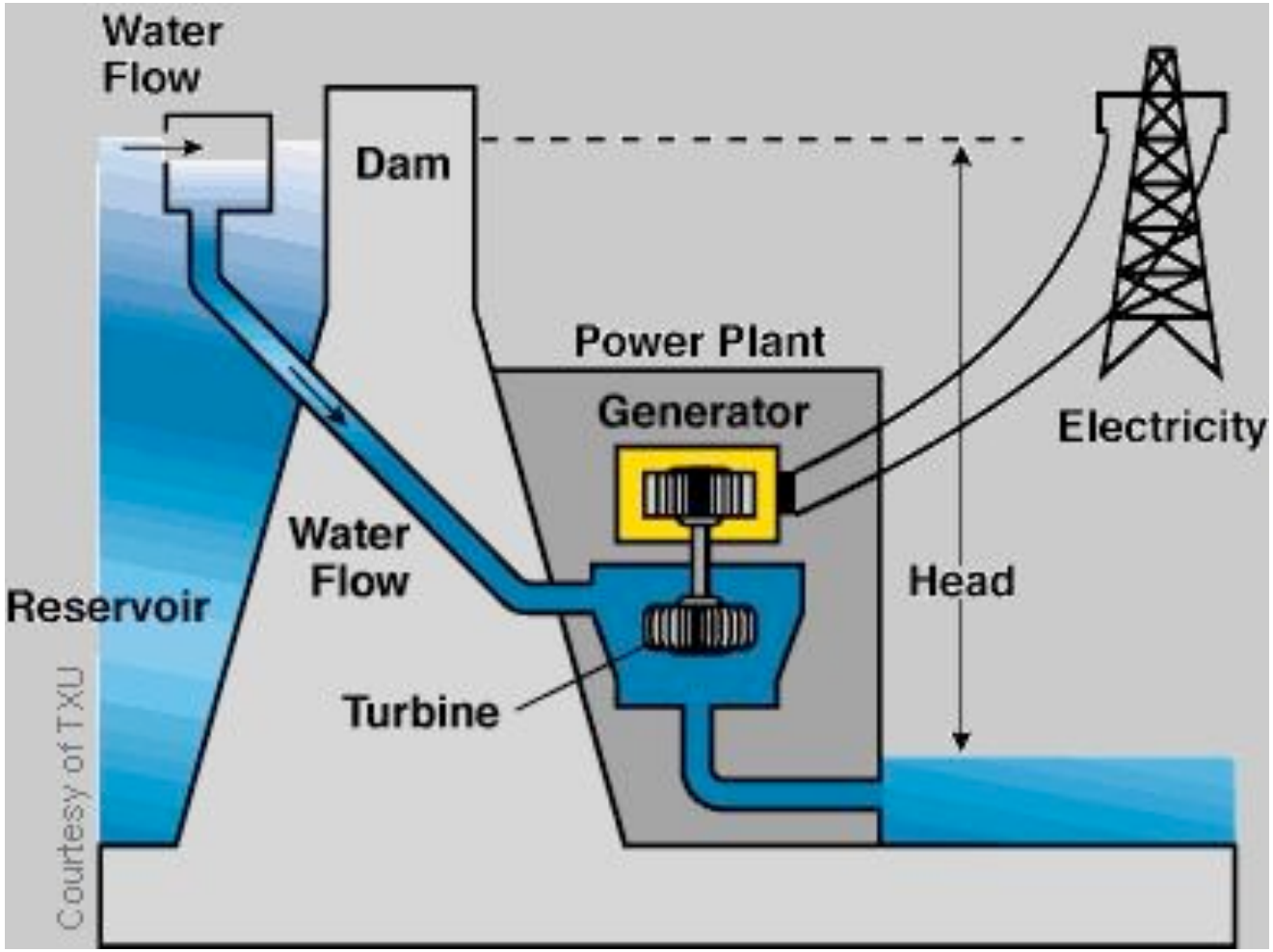
http://www.seao2.com/solarsphere/images/csp_images/solar%202.JPG

Solar Thermal Power

- **Cost**: $0.08 kWh
- **Potential**
  - 100 mile x 100 mile square could power US
- **Advantages**
  - Can store heat energy in molten salt
  - Can use natural gas as backup
- **Challenges**
  - Transmission of electricity
  - Might need cooling water

References: Sustainable Energy. pp 563

Hydro Power

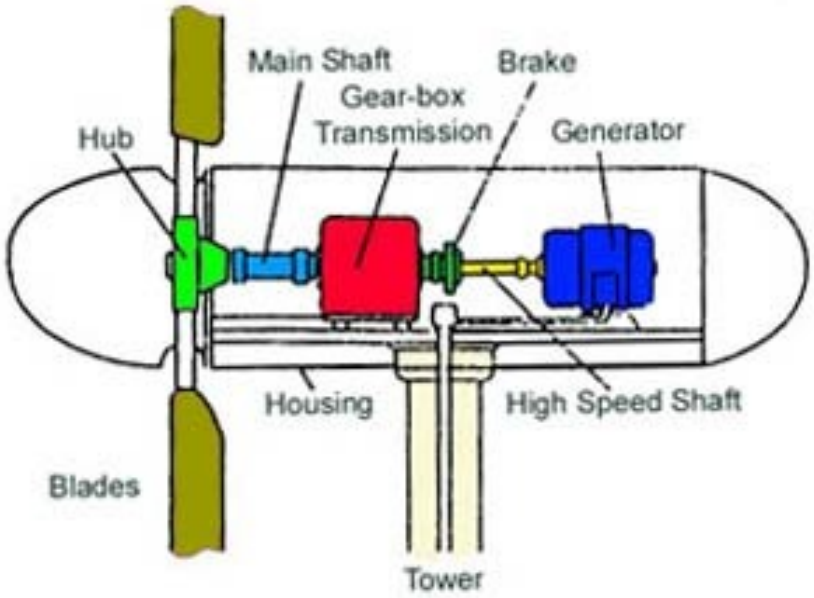

Water
Flow
Dam
Power Plant
Generator
Electricity
Water
Flow
Reservoir
Head
Turbine
Courtesy of TXU

Hydro Power

- **Cost**: $0.03 kWh
- **Potential**
  - Currently 20% of world's electricity
  - Potential for 3 times as much
- **Advantages**
  - Clean
  - Durable
  - Large scale
  - Provides storage (some pumped)
- **Challenges**
  - Environmental issues will limit growth

References: Sustainable Energy. pp 520, 537

Wind Turbine

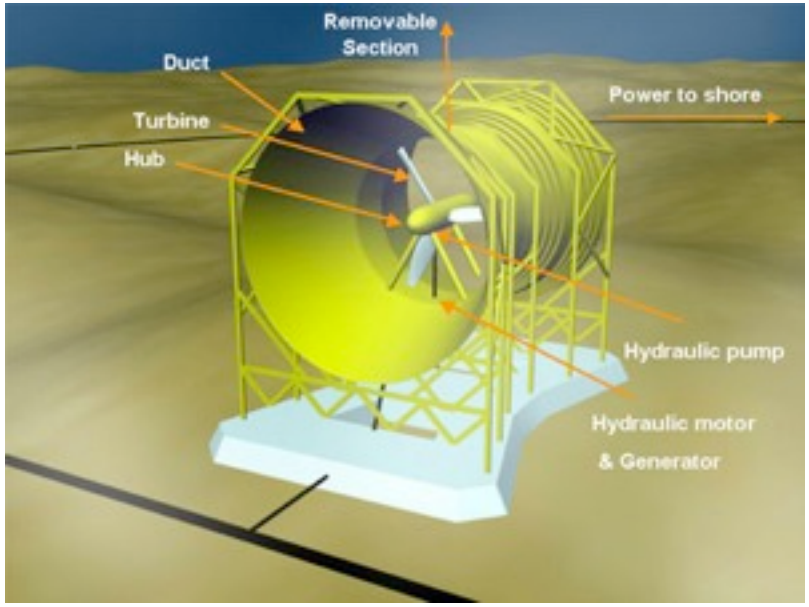


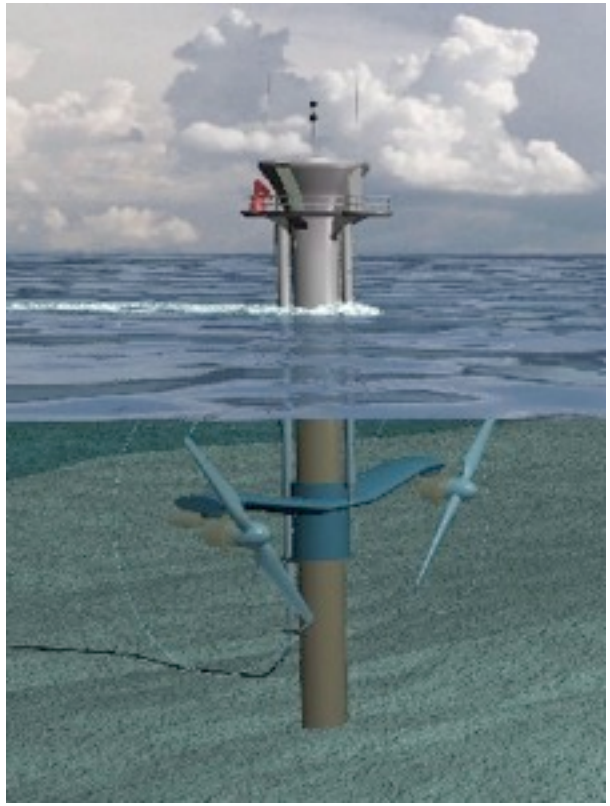
Wind Power

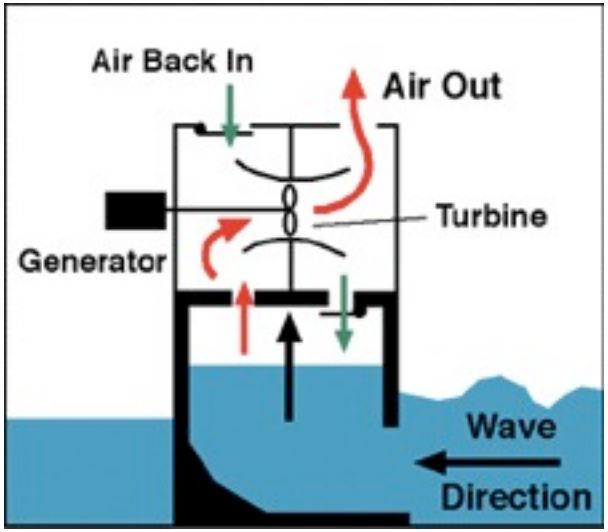
- **Cost**: $0.065 kWh
- **Potential**
  - North and South Dakota could supply half of US needs
- **Advantages**
  - Clean
  - Fast to install
  - Cheap
- **Challenges**
  - Transmission of electricity
  - Intermittent: above 20% could destabilize grid
  - Noise, aesthetics

References: Sustainable Energy. pp 617, 633

Tidal Power


Removable
Section
Duct
Power to shore
Turbine
Hub
Hydraulic pump
Hydraulic motor
& Generator




Air Back In
Air Out
Turbine
Generator
Wave
Direction

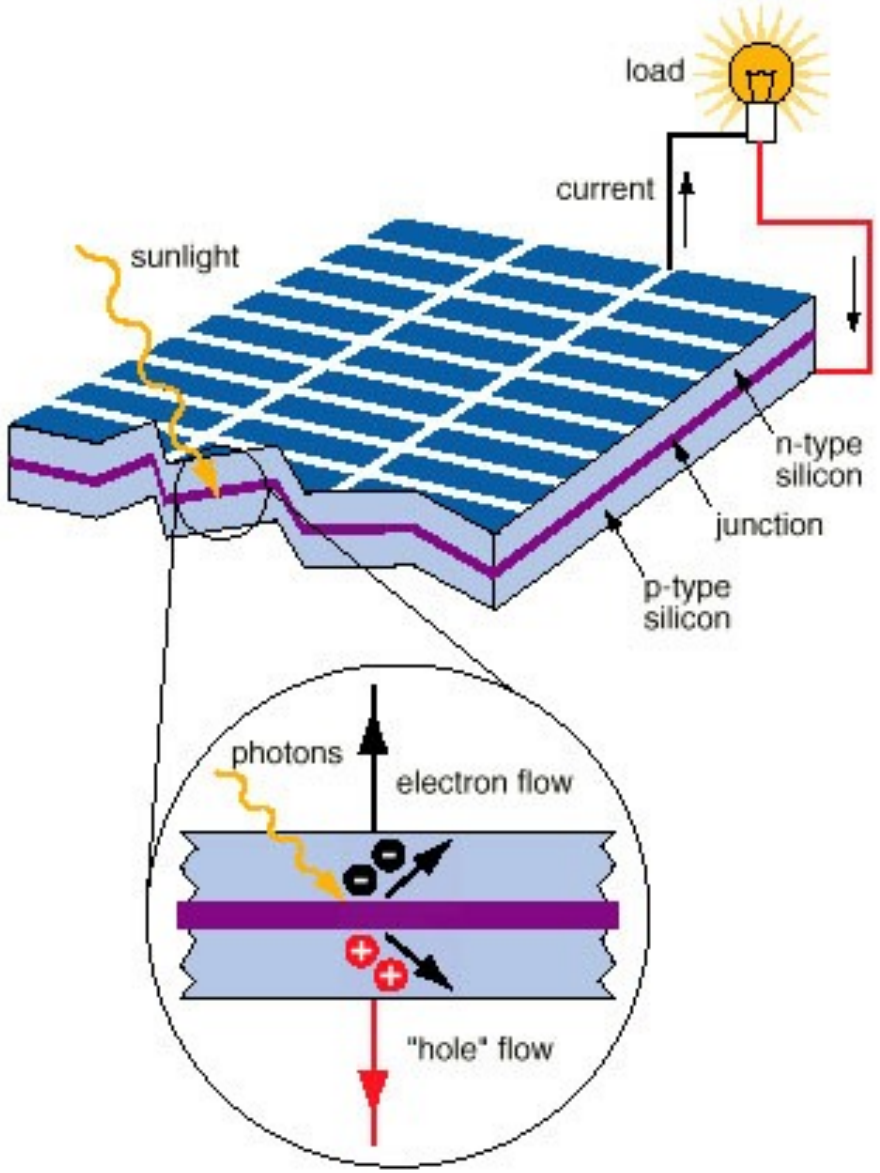
Ocean Power - Tides, Currents, Waves

- **Cost**: Tides $0.04 kWh, others expensive
- **Potential**
  - Tides: Could supply 0.1% of world's energy needs
  - Currents: 0.3%
  - Waves: 3%
- **Advantages**
  - Fairly predictable
- **Challenges**
  - Limited locations
  - Barnacles and corrosion
  - Silting and environmental concerns

Reference: Sustainable Energy. pp 593

Solar Cells - Photovoltaic

The Singleton photovoltaic solar array



http://www.rise.org.au/info/Tech/pv/index.html

Photovoltaic (PV) Power

- **Cost**: $0.15 kWh
- **Potential**
  - 100 mile x 100 mile square could power US
- **Advantages**
  - No moving parts: lasts longer, little maintenance
  - More predictable than wind
  - House or municipal level eliminates transmission needs
- **Challenges**
  - No storage
  - Higher cost

References: Asera Project, municipal size

Biomass Power

- **Cost**: High, unless using residual biomass
- **Potential**
  - Currently 3%
  - Could displace 25% of US oil use
- **Advantages**
  - Widely available
  - Much is residue
- **Challenges**
  - Plants only 1-2% efficient
  - Needs drying
  - May stress water and compete for food resources
  - Transportation costs high (25 mile maximum)

References: Sustainable Energy. pp 429

Conclusion

- World will soon run out of cheap fossil fuels
- We get more than enough energy from the sun
- Sustainable energy is practical
- Creating sustainable products requires using sustainable energy

Thank You!

Other Topics

- Climate Change
- Climate Gate
- Clean coal
- EVs
- Transportation
- Peak oil
- Hydrogen