RENEWABLE ENERGY
(cont’d)
<table>
<thead>
<tr>
<th>Fossil</th>
<th>Renewable</th>
<th>in Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
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<tr>
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<td>Biomass</td>
</tr>
<tr>
<td></td>
<td>Wind</td>
<td>Biogas</td>
</tr>
</tbody>
</table>
WATER POWER
WATER POWER

Known since antiquity

Used in **watermills**

Used water from springs, rivers, tides
Oldest Watermill Using a Crank and a Connecting Rod
Roman, 3rd Cent. CE
Roman water-powered grain mill. It used a gear to transmit the movement from the water wheel.
Undershot and Overshot Water Wheels for Milling
1st Cent. CE
Breast Shot Water Wheel for Milling
3rd Cent. CE
Water Mill in Belgium – 12th Cent. CE
VAPOR POWER
Denis Papin’s “Steam Digester”, London, 1679
Denis Papin’s First Piston Machine – Marburg, Germany, 1690
First Locomotive – Richard Trevithick, 1804
George Stephenson’s First Locomotive
1816
Steam Locomotive – France 1930
HYDROELECTRIC POWER
Global Public Support for Energy Sources - 2011

Global public support for energy sources

"Please indicate whether you strongly support, somewhat support, somewhat oppose, or strongly oppose each way of producing energy"

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Support Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar</td>
<td>97</td>
</tr>
<tr>
<td>Wind</td>
<td>93</td>
</tr>
<tr>
<td>Hydroelectric</td>
<td>91</td>
</tr>
<tr>
<td>Natural gas</td>
<td>80</td>
</tr>
<tr>
<td>Coal</td>
<td>48</td>
</tr>
<tr>
<td>Nuclear</td>
<td>38</td>
</tr>
</tbody>
</table>

Source: Ipsos, May 2011
Hydroelectric Power

Low-cost, non-polluting energy source

Raising water level by building a dam on a river

Water is forced to fall by gravity through turbines that turn generators

Generators create electricity
Hydroelectric Dams are the Most Widely used Form of Sustainable Energy
Hydroelectric Dam

Diagram showing the components of a hydroelectric dam, including the reservoir, intake, powerhouse, penstock, turbine, and long distance power lines.
Turbine and Generator

Diagram of a hydroelectric generator showing the turbine and generator components.
Water Dams

3000 BC – Jawa Dam, Jordan – 9 m high
2800 BC – Sadd-el-Kafara Dam, Egypt – destroyed
1700 BC – Great Dam of Marib, Yemen – 4 m high
15th-13th Cent. BC – Eflatun Pinar – Konya, (Hittites)
251 BC – Du Jiang Yan – Oldest dam in China
220 BC – Various dams in India

Roman dams - Lake Homs and Harbaka in Syria – water-proof mortar

Middle Ages - Amstel-dam, Rotte-dam
Xia Dynasty in China
c. 2070 – c.1600 BC

First dynasty in the traditional Chinese history

Yu – First emperor of this dynasty

Stopped the Yellow river flood by building canals for drainage and irrigation of fields

Vast agricultural progress

Early medicine
Roman Dam at Cornalvo, Spain
2000 years old
1770s French Bernard Forest de Bélidor wrote about hydraulic machines.

19th century – *Electrical generator developed*

1878 – *First hydroelectric power in England*

1881 – *First waterpower in USA*

1886 – 45 hydroelectric power stations in the US and Canada

1889 – 200 stations in US

1920 – *40% of the power in USA was hydroelectric*

1936 – Hoover Dam
Hydropower in Modern Times

1936 – **Hoover Dam** - 1,345 MW
1942 – **Three Gorges Dam** (China) – 22,500 MW
1984 – **Itaipu** (Brazil & Paraguay) – 14,000 MW

**US has over 2,000 hydroelectric power stations** ⇒ 6.4% of its total electrical production

<table>
<thead>
<tr>
<th>Country</th>
<th>Percentage of Total Electrical Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Norway</td>
<td>98%</td>
</tr>
<tr>
<td>Brazil</td>
<td>68%</td>
</tr>
<tr>
<td>Venezuela</td>
<td>67%</td>
</tr>
<tr>
<td>Canada</td>
<td>60%</td>
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</tbody>
</table>
### 2012 World (Civil) Electricity Generation by Fuels

<table>
<thead>
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<th>Fuel Type</th>
<th>Percentage</th>
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<tr>
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<td>Nuclear fission</td>
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<td>Oil</td>
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<tr>
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</tr>
</tbody>
</table>
Hoover Dam – 176 ft. high - 1936
Itaipu Dam – 1984
Parana River, Brazil & Paraguay
94.7 TWh in 2008

1 TWh = $10^{12}$ watt/hour
Three Gorges Dam – 2003 - 2009
Central China, Yangtze River
The Largest Hydroelectric Power
98.1 TWh in 2014
Three Gorges Dam Turbine
The Top Five Hydroelectric Power Producing Countries

China
Brazil
Canada
USA
Russia
## ENERGY RESOURCES

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</table>
WIND POWER
**WIND POWER**

**Definition:** Use of air flow through wind turbines to mechanically power generators to produce electricity.

*Wind farms* consist of many wind turbines connected to the electric grid.

**On shore and off shore farms.**

Inexpensive source of renewable energy very much adopted by many countries.

China and India made progress.

Denmark generates 40% of its electricity from wind.
Wind Power - History

Known and used since sailing.
Netherlands, USA, and Australia used wind mills.
1887 - James Blyth - Glasgow - to power home lightning
1888 - Charles Bush - Cleveland OH - 17m in diam.
19th Cent. - Introduction of electric power.
A Mycenaean Boat
Spanish galleon – 16th century
Royal Yachting Association
Charles Brush Windmill - 1888
Which Should Be Increased in Scotland?
California Wind Turbines at Altamont Wind Farm (6000 Turbines)
Wind Turbine in Texas
U.S. Landowners Typically Receive $3,000–$5,000 Annual Rental Income
Float-wind Turbine “Windfloat”, Operating at Rated Capacity (2 MW) - Portugal
Vertical Axis Wind Turbine – Bristol, UK

5 M HIGH AND 3 M ACROSS
Worldwide Electricity Generation from Wind (up to 2012)
Top Windpower Electricity Producing Countries (in TWh)

<table>
<thead>
<tr>
<th>Country</th>
<th>Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>141</td>
</tr>
<tr>
<td>China</td>
<td>118</td>
</tr>
<tr>
<td>Spain</td>
<td>49</td>
</tr>
<tr>
<td>Germany</td>
<td>46</td>
</tr>
<tr>
<td>India</td>
<td>30</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>19</td>
</tr>
<tr>
<td>France</td>
<td>15</td>
</tr>
<tr>
<td>Italy</td>
<td>13</td>
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Wind Resources and Transmission Lines in USA
<table>
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ENERGY DEVELOPMENT
NUCLEAR ENERGY
Greek and Indians introduced the philosophical concept of the atom

(a-tom = that cannot be divided)

19th cent. - The atom is the smallest constituent of the matter
Henri Antoine Becquerel (1852-1908) French Physicist
Spontaneous radioactivity is a famous example of serendipity. “Chance favors the prepared mind”
Becquerel in his Lab
1897 – Sir John Joseph Thomson (English physicist):
   Cathode rays are made by electrons. “The plum pudding“ model

**Electrons** = identical to particles given off by photoelectric and radioactive materials

**Electrons** carry the negative electric charge of the atom

**Electrons** carry the electric current in metal wires
Atomic Nucleus

1911 – Ernest Rutherford described the **nucleus**

1932 – **Protons** and **neutrons** were described

**Nucleus** = largest part of the atom
The Electrons

1913 - Niels Bohr – Electrons move on orbits around the nucleus. “Quantum leaps” btw. orbits
Nuclear Energy - History

1932 – Ernest Rutherford: immense amounts of energy released by protons hitting lithium atoms in an accelerator

1932 – James Chadwick discovered the neutron

1934 – Frédéric and Irène Joliot-Curie discovered induced radioactivity, which emits rays: alpha, beta, gamma
URANIUM (U)
Uranium Ore (Pitchblende)
Enrichment of Uranium U-235

Natural Uranium
0.72% U-235

Low-enriched Uranium
(reactor grade)
3-4% U-235

Highly enriched Uranium
(Weapons grade)
90% U-235
PLUTONIUM (Pu)

1940 – Produced and isolated by deuterium bombardment of uranium in the Berkeley Radiation Laboratory of the University of California, Berkeley

1945 – “Trinity” - first implosion at Alamogordo, NM

1945 – “Fat Man” atomic bomb dropped at Nagasaki
Nuclear Fission: 1938 - Otto Hahn directed neutrons onto uranium ⇒ radiobarium, radiokrypton, and 3 neutrons
Nuclear Fission
Otto Hahn’s Experimental Apparatus
Enrico Fermi – Used neutrons to increase the effectiveness of \textit{induced} radioactivity

Leo Szilard – \textbf{Self-sustaining nuclear chain reaction}

Chain Reaction
December 2, 1942, when Scientists Observed the First Man-made Nuclear Reactor, the “Chicago Pile-1” at University of Chicago
**Definition:** Energy released from nuclear reactions generating heat

**Nuclear reactions:** nuclear fission, decay, fusion

**Nuclear power plant** heat $\Rightarrow$ steam turbines $\Rightarrow$ electricity

Fission - electric power plants

Since 1970, fission-electricity prevented release of 64 Bil. Tonnes of CO$_2$
Hiroshima after Dropping the Uranium-based Atomic Bomb (1945)
Plutonium Implosion Atomic Bomb
Nagasaki, Japan, 1945
First Light Bulbs Lit with Electricity from a Nuclear Reactor (Chicago, 1951)
High-Energy Physics (3)

Fusion

The only man-made device to achieve nuclear fusion is the **hydrogen bomb** (called “Ivy Mike”) in 1952.
High-Energy Physics (4) 
Decay

The nucleus emits an alpha particle and transforms (decays) in an atom with a smaller mass.
Nuclear Energy – History of its Applications

1940s - Manhattan Project - Enriched uranium ⇒ First nuclear weapons - Hiroshima and Nagasaki
Dec. 20, 1951 - First electricity generated – Arco, ID
June 27, 1954 - First world nuclear power plant for electricity in USSR
1955 - UN Intl. Atomic Energy Agency (IAEA)
Aug. 27, 1956 - First commercial nuclear power station - Calder Hall, UK
US – 75 nuclear submarines; Russia – 61 nuclear submarines
Main applications: Electricity, Weapons, Satellites
USA and Russia Nuclear Weapons Stockpile
US Nuclear Power Ships (1964):
USS Bainbridge, USS Long Beach, USS Enterprise
Nuclear Energy (NP)  
Its Changing Status in the World

Installed nuclear capacity: 1960 – 1 GW
1970 – 100 GW
1980 – 300 GW

After 1970 – 2/3 of nuclear plants cancelled
1973 - Oil crisis - France and Japan ⇒ more NP
Mid-1970s - anti-nuclear protests. Opposition to NP
2001 - “Nuclear renaissance” b/o oil prices ↑ and greenhouse emissions ↑
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August 27, 1956. Calder Hall, UK
The World's First Commercial Nuclear Power Station Connected to the National Power Grid
Electricity (TWh) Supplied from Nuclear Reactors
1995-2015
Annual Electricity Generated (Bil. kWh)

USA (19%)*
France (80%)*
Japan
Russia
S. Korea

* % of total electricity
Applications of Nuclear Energy

**Consumer products:** Household appliances

**Food & Agriculture:** Approved to preserve food and to eradicate pest insects

**Industrial uses:** Auto and aircraft, mining, oil exploration, construction

**Medicine & Scientific Research:** Nuclear medicine imaging; radioactive tracers

**Space Exploration:** Essential

**Oil and Gas Exploration**

**Water desalination**
Smoke Detector uses NE
Radura Logo Shows that Food has been Treated with Ionizing Radiation
Nuclear Energy - Economics

Uranium resources reportedly available for “160,000 years”

Costs (2012): Natural gas $64/MWh
               Nuclear power $96/MWh
               Solar power $130/MWh

Risks and Concerns: Nuclear accidents
                     Terrorist attacks
                     Increasing cost of oil

Nuclear fission = 2.5% of global energy consumption

“New renewables” = 2.0% of global energy consumption
Nuclear Energy Accidents

1979 - Three Mile Island, NJ – Solid decay products were contained.
One cancer death / 2 Million people.

1986 – Chernobyl, Ukraine – Solid decay products released 2%-3% increase in cancer deaths.

2011- Fukushima, Daiichi, Japan nuclear accident.
No reported disease or deaths related directly to the accident.
Anti-Nuclear Protest in Bonn, Germany, following the Three Mile Island Accident October 14, 1979.
Anti-nuclear Protest in Harrisburg, PA, following the Three Mile Island Accident, 1979
World Uranium Production and Demand

![Graph showing world uranium production and demand from 1950 to 2010. The graph displays two lines: one for production (mines) and one for demand. Production starts low and increases significantly around 1970, while demand shows a steady increase from the 1950s onwards.](image)
The Nuclear Fuel Cycle
Ionizing Radiation Hazard Symbol
Nuclear Energy Debate

1970-1980 - Debate about Use of NE for electricity

In favor: It is a sustainable cheap energy
- Reduces CO$_2$ emissions and air pollution
- Energy security - Oil resources will run out
- Promising for space propulsion

Against: Threats related to mining uranium ⇒ diseases
- Threats about processing, transport, storage – radioactive waste
- Accidents, sabotage
- Terrorism
- Risk of nuclear weapons proliferation
Nuclear vs. Renewable Energy

1. Solar, wind, and hydropower are the safest and cleanest
2. Energy from carbon dioxide sources is on the way out b/o air pollution, greenhouse gas levels, and global warming
3. Nuclear power develops slowly because of public reservations and opposition
4. Nuclear power is economical
5. Nuclear power introduced in several European countries in 20-50% of applications
6. Could account for 80+% of the world energy in 40 years at a cost of 1% of global GDP annually.
GEOTHERMAL ENERGY
The earth’s interior

- crust
- mantle
- outer core
- iron core
- magma
- magma and rock
**Definition:** Energy generated and stored in the Earth

Earth’s internal heat = thermal energy from

- Earth’s formation
- Radioactive decay

Temperature at core-mantle = 7,200°F

**Hot springs ⇒ Heating since ancient times**

2013 – Worldwide electrical energy = 11,700 MW

Cost-effective, reliable, sustainable, clean
Geothermal Energy - History

300 BC - Oldest source - Quin Dynasty - China

50 CE - Romans built a bath at Bath, England (*Aquae Sulis* = “Waters of Sul” a Celtic god)

14th Cent. - Chaudes-Aigues, South France, still working

1827 - Larderello, Italy - extracting boric acid

1892 - Boise, ID – District heating system

1904 - First geothermal generator at Larderello – 4 light bulbs

1943 - Iceland – Heating homes

1960 - **First geothermal electric power plant** - The Geysers, CA

1973 - Geothermal technology popular in Sweden
The Oldest Known Pool Fed by a Hot Spring, Built in the 3rd Century BC
China
Nesjavellir Geothermal Power Station
Iceland
## Installed Geothermal Electric Capacity 2010

<table>
<thead>
<tr>
<th>Country</th>
<th>Capacity MW</th>
<th>% of national Electricity Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>3,086</td>
<td>0.3</td>
</tr>
<tr>
<td>Philippines</td>
<td>1,904</td>
<td>27.0</td>
</tr>
<tr>
<td>Indonesia</td>
<td>1,197</td>
<td>3.7</td>
</tr>
<tr>
<td>Mexico</td>
<td>958</td>
<td>3.0</td>
</tr>
<tr>
<td>Italy</td>
<td>843</td>
<td>1.5</td>
</tr>
<tr>
<td>New Zealand</td>
<td>628</td>
<td>10.0</td>
</tr>
<tr>
<td>Iceland</td>
<td>575</td>
<td>30.0</td>
</tr>
<tr>
<td>Japan</td>
<td>536</td>
<td>0.1</td>
</tr>
</tbody>
</table>
Global Geothermal Electric Capacity
Installed vs. Realized Capacity

![Graph showing Global Geothermal Electric Capacity](image-url)
Looking to tap the desert’s energy
2 firms plan Imperial Valley geothermal plant

By Ivan Purch
GEOTHERMAL HEAT PUMP
A geosolar system. “Ground Source Heat pump” (GSHP)

Using the heat from solar energy which is absorbed into the Earth’s surface

Upper 20 ft. of Earth’s crust has constant temp. 50-60°F

Caves are warm in winter and cool in summer. A pump system may cool the house in summer and warm it in winter

Cost vs. energy savings

Annual growth of 10%
Ground Source Heat Pump - History

1853 - Lord Kelvin developed the Heat pump
1940 - R. Webber built the first GSHP
1948 – First commercial project installed - Portland, OR
1970 – GSHP popular in Sweden
2004 >1 million units worldwide

Great potential
Heat and Cold Pump

Heat storage

Summer cooling

Heat storage

Winter heating
High cost – Low operational cost

What’s the cost of electricity and fuels?

Government incentives may reduce cost

2011-1012 State of Maryland incentives \(\Rightarrow\) cost of $26,700 for a home unit; $1.90/ Watt used

Cost varies widely

May be economical and reliable
BIOMASS ENERGY

**Definition:** organic matter derived from living organisms

**Sources:**

1st-generation biofuels = Sugarcane and corn stocks
  ↦ bioethanol ↦ electricity

2nd-generation biofuels = Burning wood (oldest biomass) and municipal waste = lignocellulose mass

Huge mass available for energy

Major disadvantage – air pollution
Biomass Energy - Economics

World resource: Annual production = 100 Bil. Tonnes of carbon = 1.4 times the Terawatt hours required

Problems: Air pollution
Cost of transportation
Environmental concerns
Biomass-Producing Electricity in Billion kW/h
Biomass – An Ingenious Machine for Stump Removal
BIOGAS ENERGY
**BIOGAS ENERGY**

**Definition:** Mixture of gases produced by the breakdown of organic matter in absence of oxygen (anaerobic)

**Anaerobic digestion** – fermentation of biodegradable materials

**Raw materials:** Agricultural waste, manure, municipal, sewage, plant, green, and food waste

Biogas is: Methane 40-75%
Carbon dioxide 23-50%
Nitrogen 0-10%
Biogas – Uses and Production

**Uses:** Fuel, Heat, Energy. Compressed into liquid may replace 17% of vehicle fuel (UK)

**Production:** “Anaerobic digester” – Microorganisms digest the waste → biogas. The digestate is agricultural fertilizer

**Renewable resource** ⇒ **Continuous production-and-use cycle**

**Manure** ⇒ **high levels of methane**

Millions of cattle in US ⇒ 100 Bil. kWh electricity for millions of homes

One cow ⇒ manure/d ⇒ electricity for one 100W light bulb (!)

Explosive. The odor is due to added substance
Basic Design of a Biogas Plant

1. Organic matter and water go in

2. The material ferments, releasing biogas

3. Gas rises to the top

4. Pipe carries gas to the top

5. Waste material is removed for use as fertilizer

6. Gas burned to make light and heat
Biogas Bus and Biogas Train in Sweden
END OF LECTURE #8
End of this Course
What Did We Accomplish?

We have reviewed the Natural **Resources and the interactions of the Humans with them**:

Air, Water, Food, Metals, Minerals, and Energies

1. **Their Place on Earth**
2. **Their History**
3. **Their Economy**
4. **Their Social Molding of Humankind**
5. **Their Political Impact on the Society**
We Also Learned About our Patterns of Action

1. We find a resource
2. We exploit the resource to the maximum ⇒ Toxic effects? Environmental hazards? Diseases?
3. We cannot replenish the resource
4. We search for other resources
5. We have been late in using available, renewable, non-toxic resources
6. What do we do for future generations?
Some Thoughts

Nature has many resources
It is for us to observe and discover
Man is a good observer
Progress has been slow
Progress has been marred by greed, disregard, and incompetence
We must educate our children and our youth
They are the future on our planet
THANK YOU