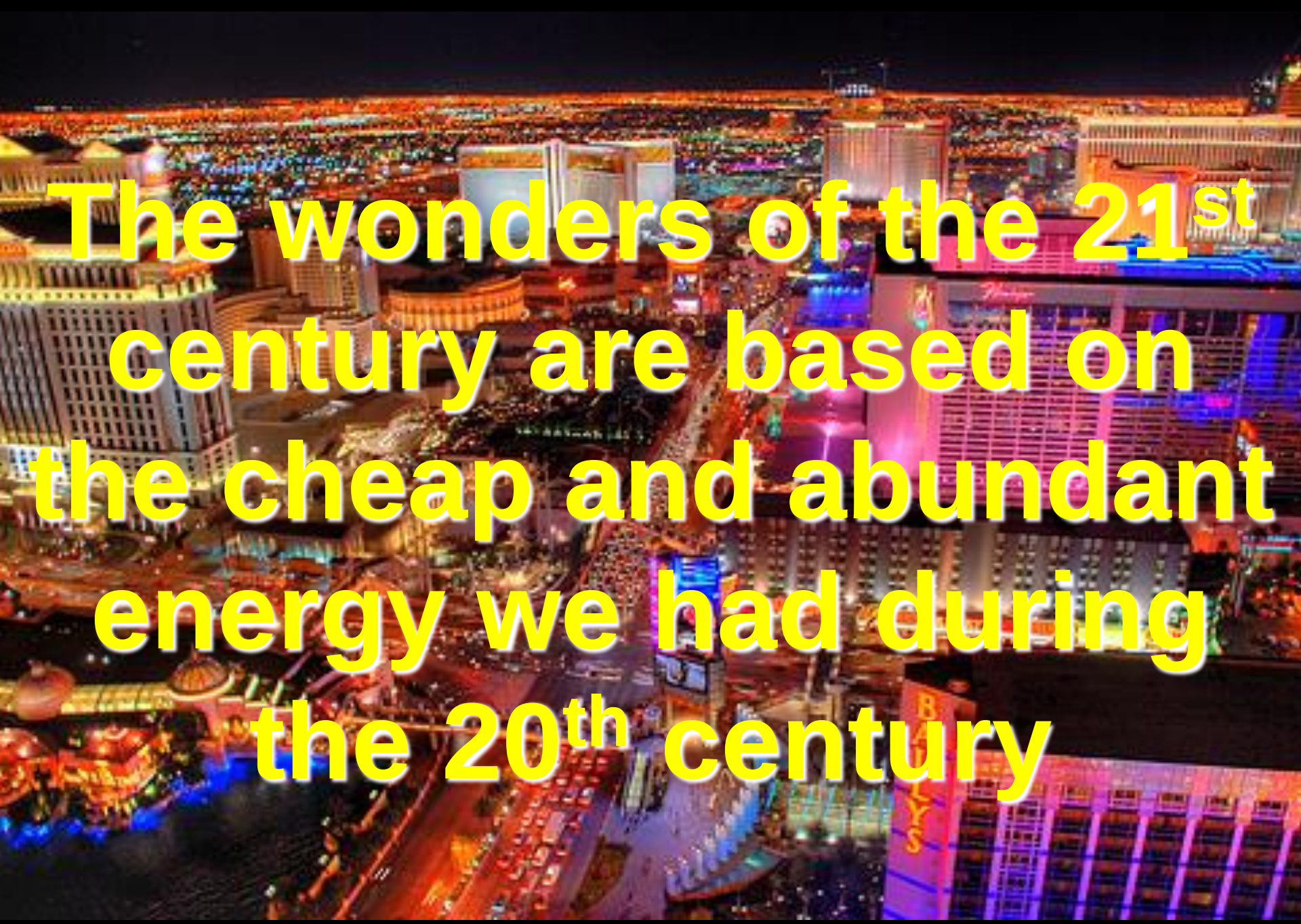
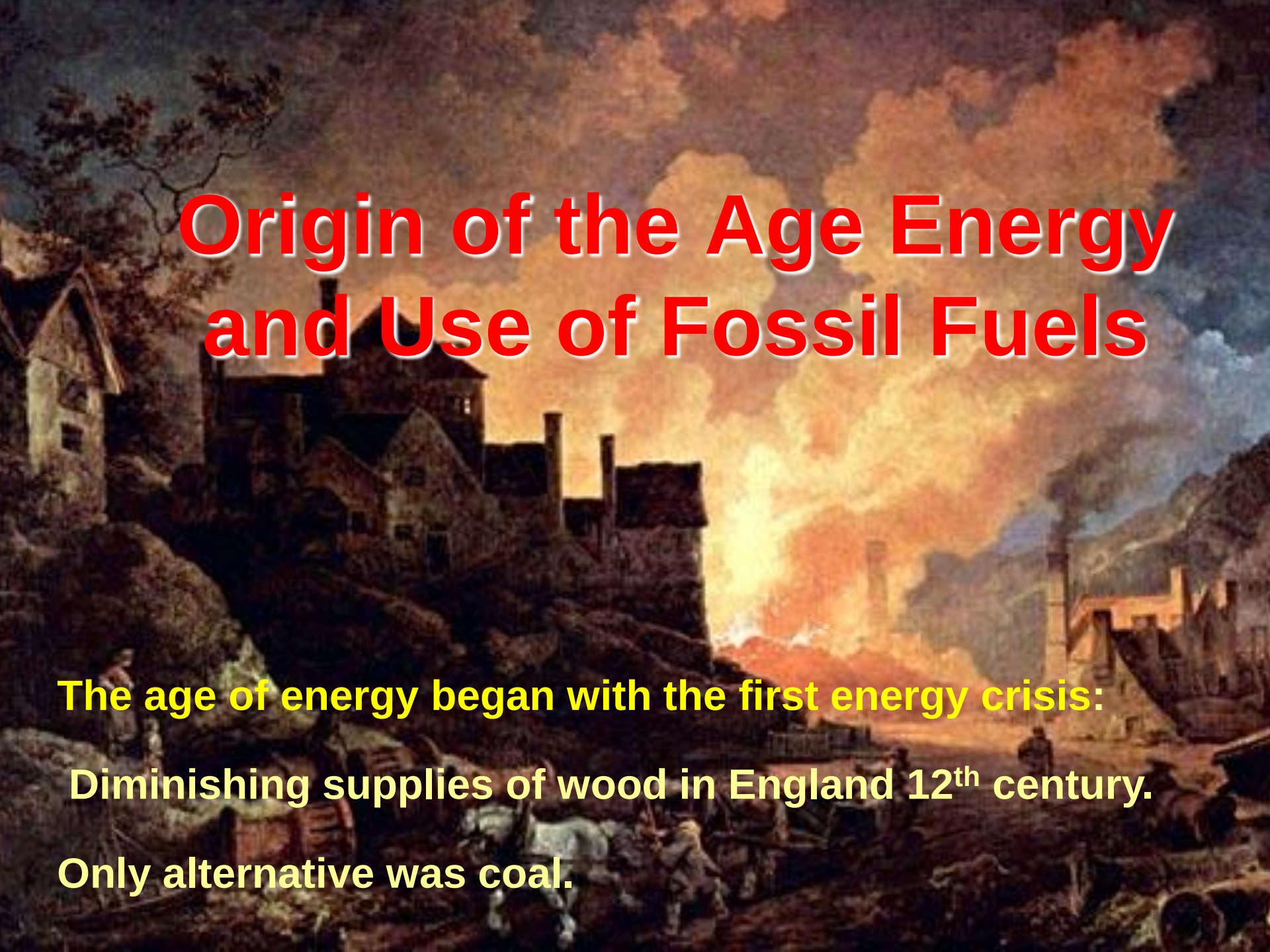

The wonders of the 21st century are based on the cheap and abundant energy we had during the 20th century



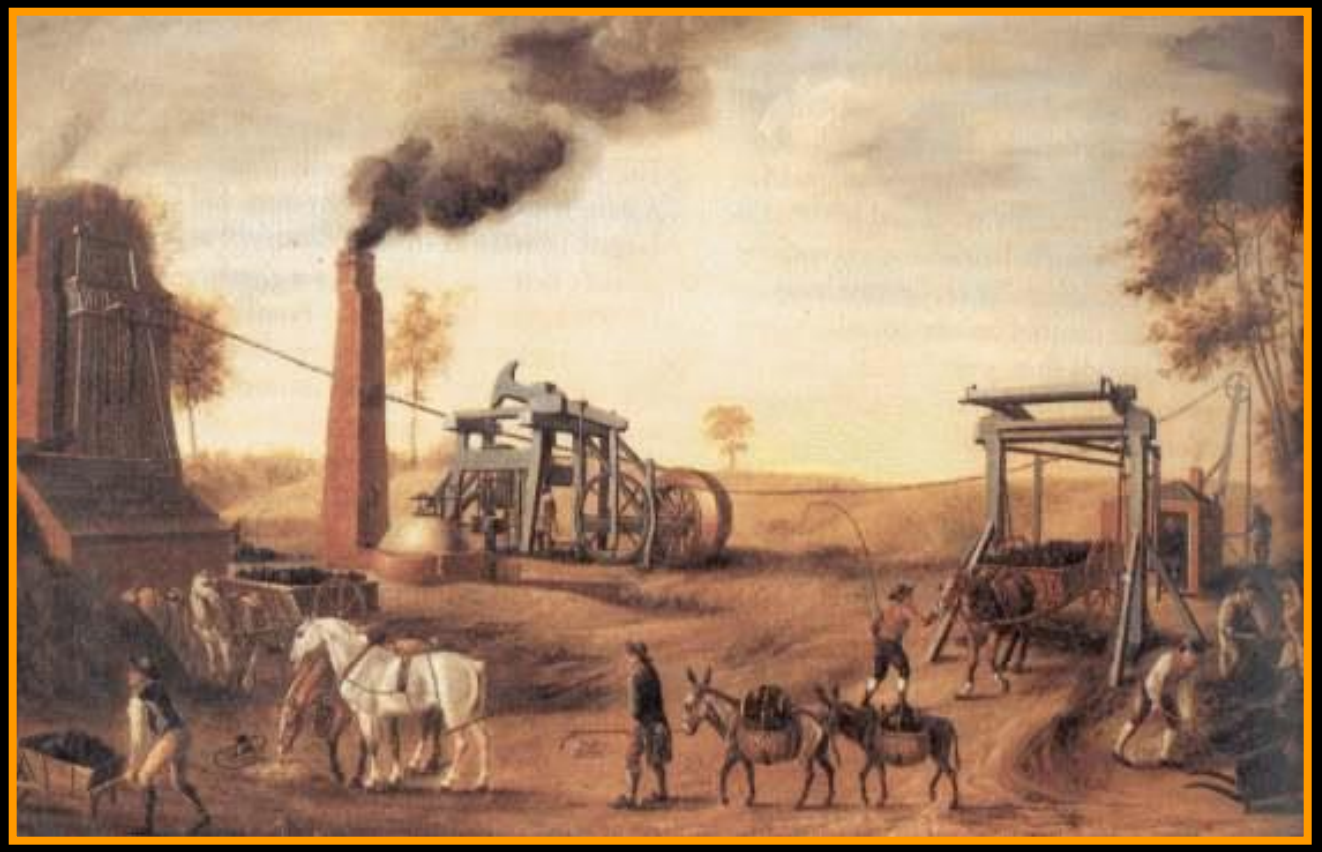
Origin of the Age Energy and Use of Fossil Fuels

The age of energy began with the first energy crisis:

Diminishing supplies of wood in England 12th century.

Only alternative was coal.

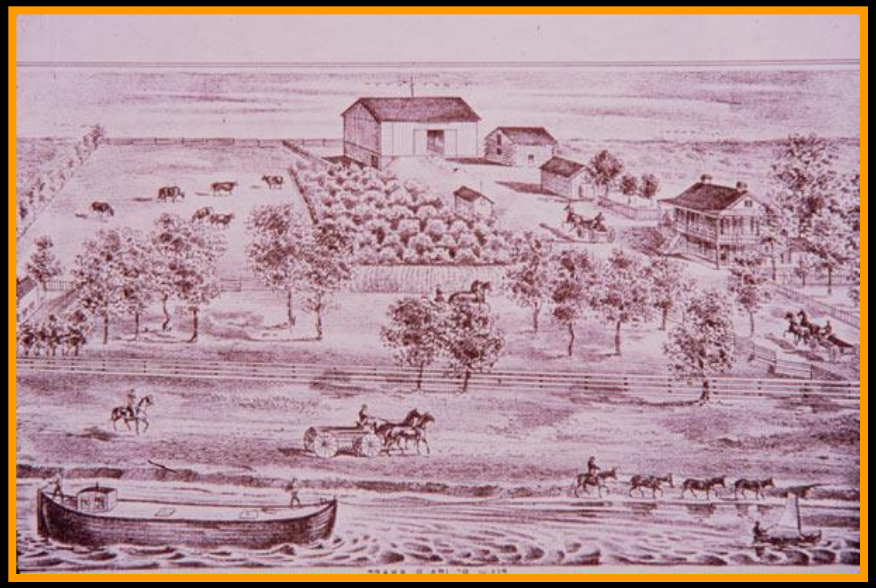
Coal Transformed England



Late 18th century coal mining operation, Midlands, England.

Powered early steam engines used in mining of coal.

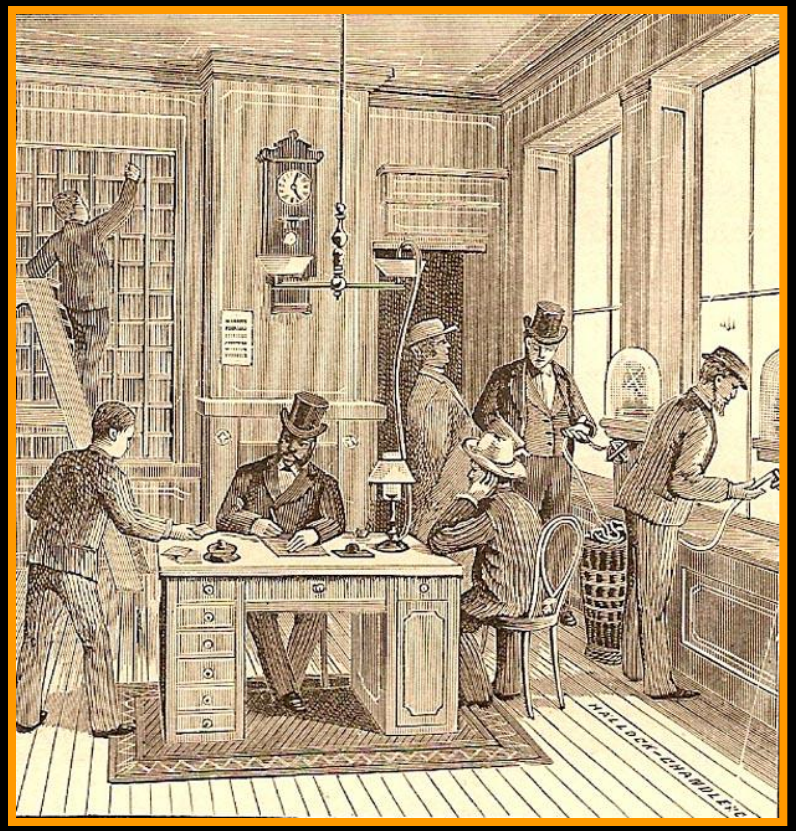
Demand for Coal Continued to Increase



Earliest mass transport was by ship and barges.

Railroads were used to transport coal to small ships and barges, coal was then loaded onto larger ships and sent directly to the end user.

During the 17th Century Artificial Lighting Using Coal Gas was Introduced



Limited to cities that could build the needed infrastructure for gas light.

Whale Oil Lamp

Whale oil lambs was the primary source of light

Decline in Sperm Whale Oil During the Mid-1800's Led to a Second Energy Crisis

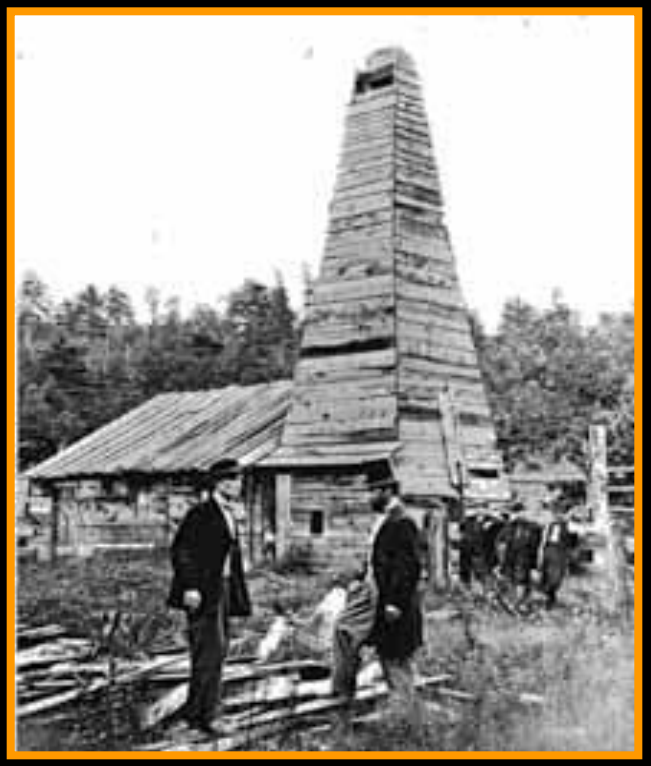
Sperm whalers

Whale oil

Whale oil became widespread as it did not require any infrastructure and could be used anywhere.

Decline of whale oil prompted a search for alternatives which led to the discovery that kerosene refined from oil could be used to replace whale oil for lighting.

Age of Oil



First oil well in Pennsylvania

Oil provided a cheap and convenient replacement for whale oil and became the chief source for lighting.

A new industry was born and the world change.

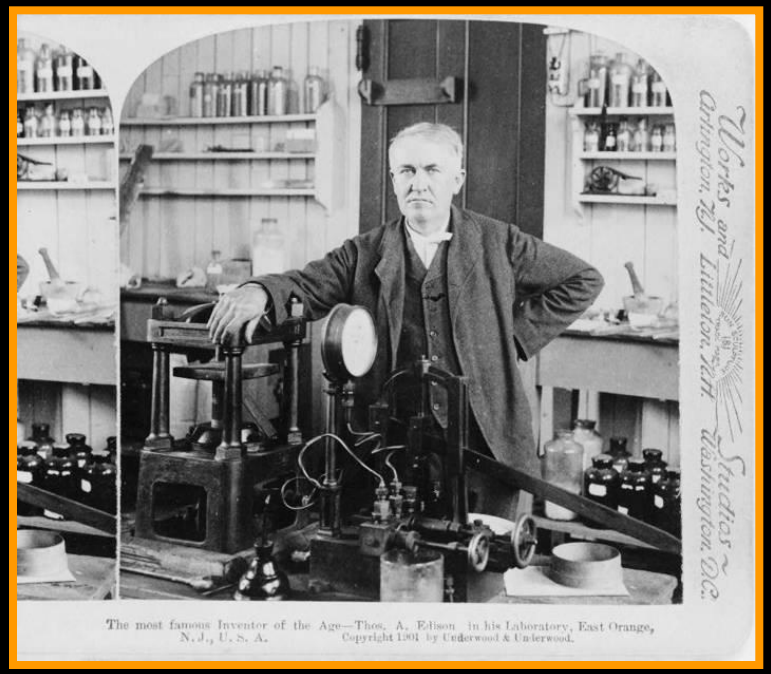
Is Oil Running Out!!! *Maybe*

"The amazing exhibition of oil" is only "a temporary and vanishing phenomenon – one which young men will live to see come to its natural end." – State Geologist of Pennsylvania, **1885**.

Western Pennsylvania, 1860's

- **The chances of finding another large field "are at least 100 to 1 against it."** (Standard Oil specialist, **1885**)

Electricity = New Source of Light



Thomas Edison

Edison's light bulbs

Electric light began to supplement kerosene lamps for light in cities.

Crisis for the oil industry.

Electrical Generation Facility

Early 20th century generation facility

The need for electrical generation greatly increased the demand for coal.

Coal became King.

Henry Ford to the Rescue

Henry ford on one of his early cars

Just as electricity began to reduce the demand for kerosene lighting, a new demand for oil appeared - gasoline

Effects of Abundant Cheap Energy

The net effect of abundant and cheap energy **increased the demand for the energy** by encouraging the use of products that utilized energy.

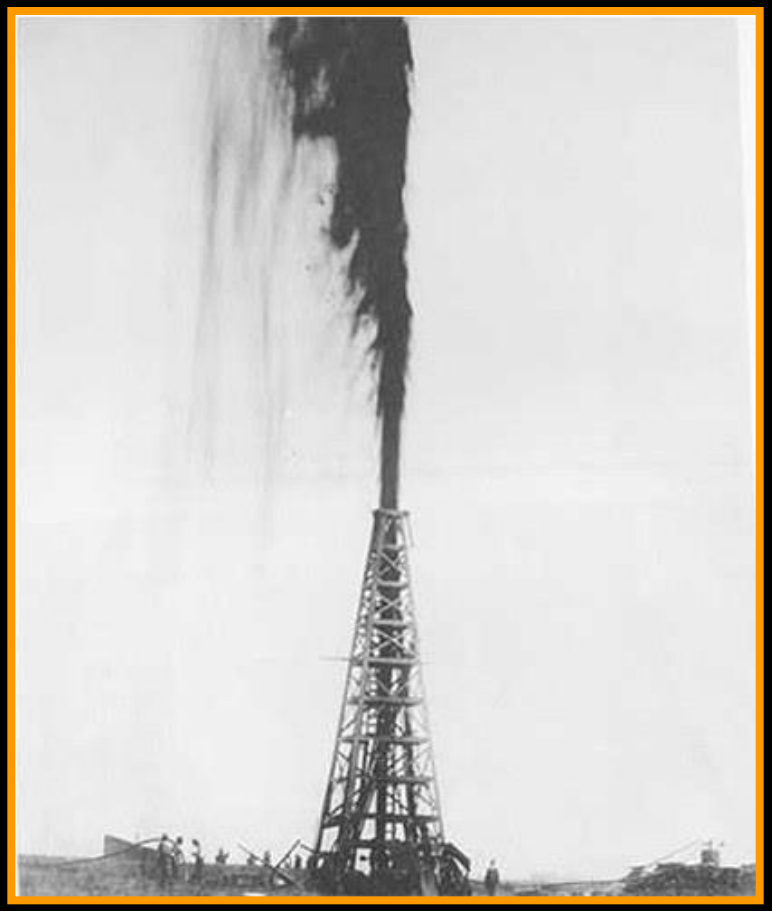
Increase the demand for energy by reducing the cost of energy.

The more products that use energy increase the demand for energy.

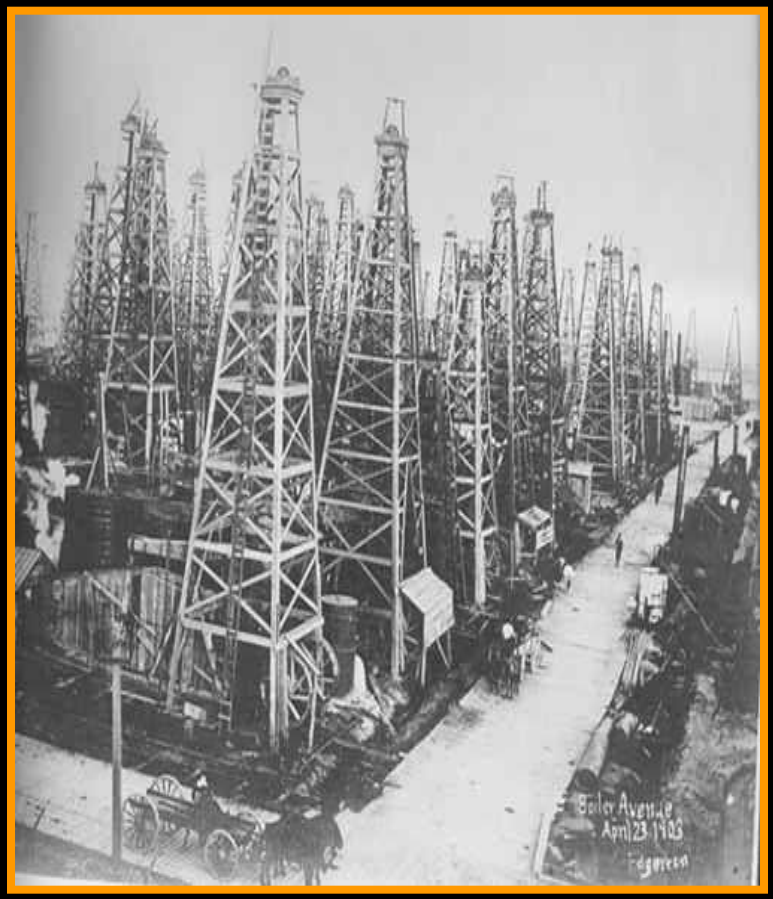
The net result - **more money for the producers of energy and more demand for products that use the energy.**

Produced the proverbial **"win-win situation"** for both the suppliers and users, everybody is happy.

Beginning of the 20th century



Jan 1901 Spindletop, Texas



Oil was everywhere

The world of energy was changed forever

Oil Becomes a Strategic Commodity

"To commit the Navy irrevocably to oil was indeed to take arms against a sea of troubles."

Winston Churchill, 1911.

All nations began to think about sources of oil

World War I Confirmed that Oil Was Needed for National Survival

Motorized vehicles became vital to carrying out war

Roaring 20's

Car production rapidly expanded.

The price of a car dropped.

Cars became affordable for the average American.

Demand for gasoline increased dramatically.

First Oil Cartel

During the 1920's major oil companies feared that their oil would run out.

They needed to control of oil production.

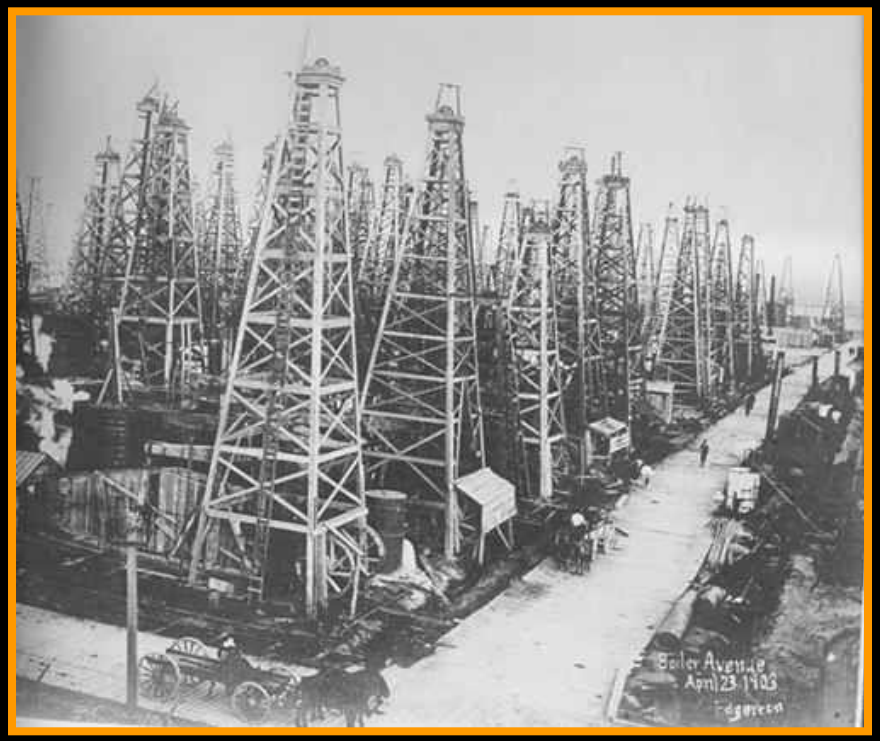
Major oil companies formed a global cartel abroad, (not in USA) to control the production and price of oil.

This led to the consolidation and sharing of Middle Eastern oil fields by the major oil companies.

Third Energy Crisis
Too Much Oil

Instead of running out of oil, new discoveries led to the production of "oceans of oil."

Prices dropped to less than 5 cents a barrel.



Black Giant of east Texas

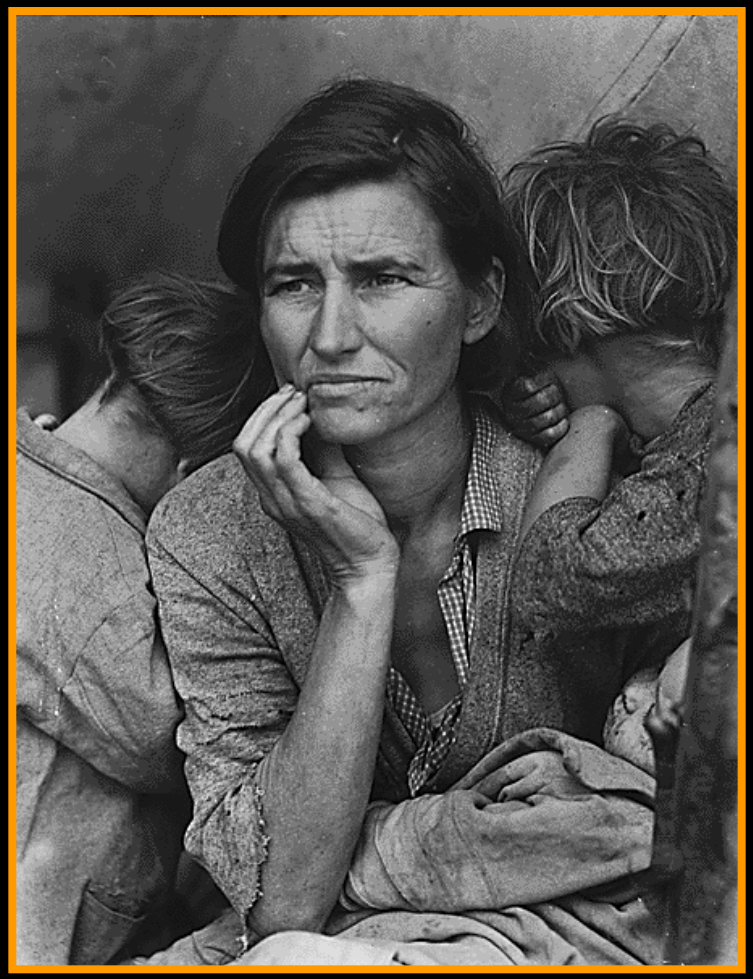
Great Depression 1930s

Unrestricted production of oil.

Decrease in demand because of the Great Depression.

Led to a near collapse of the oil industry.

Control and regulation of oil production became essential to the survival of the oil industry.



Control of Oil Production USA
Texas Railroad Commission

Established to reduce excess oil production.

Producers were allowed to produce only a certain amount of oil.

Production was less than full capacity.

Oil producers initially resisted regulation of production.

In emergencies, producers could increase their production.

TRC lead to a rise in crude oil prices and thus avoided a collapse of the oil industry.

Regulation of crude oil production extended the life of the oil fields and long term prosperity of the oil companies.

Rural Electrification, 1930's

Expansion of Electrical Grid and Hydroelectric Heneration

Tennessee Valley Authority (TVA)

Electrical grid

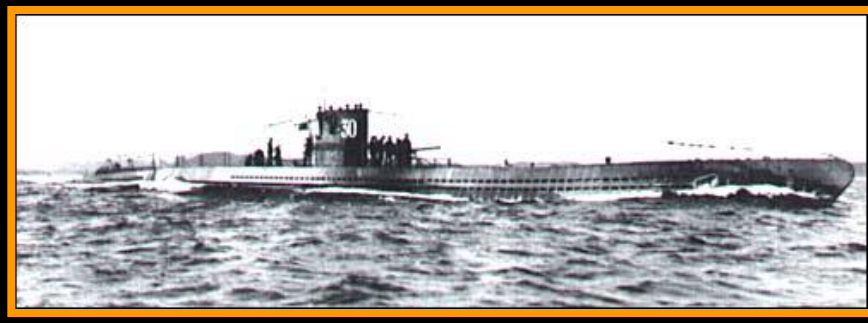
World War II
First War Decided by Oil

Quote from Erwin Rommel personal papers following battle of El Alamein in 1942

“The bravest men can do nothing without guns, the guns can do nothing without plenty of ammunition and neither guns nor ammunitions are of much use in mobile warfare unless there are vehicles with sufficient petrol to haul them around”

Allies Won WW II on an "Ocean of Oil" from the USA

Sinking oil tanker off East Coast



German U-boat

WW I showed that oil is vital to war.

Axis and Allies understood this concept quite clearly.

Strategies on both sides focused on oil as a weapon.

The side with the most oil wins!

The Big Inch - First intercontinental Pipeline Built during WW II

Final section laid in Pennsylvania

Big Inch pipeline

Post-WW II Oil Led to Life Style Changes

Suburbs

Freeway systems

Primary Source of Energy Shifts from Coal to Oil

During the late 1940's, Europe and Japan were rebuilt, and oil played a large role.

Most of this oil came from the Middle East.

There was a conscious effort to shift from American sources of oil to Middle Eastern sources in order to preserve U.S. oil resources.

Rise of Nuclear Energy
Electricity would be Free

Reactor and cooling tower

Reactor core

Three Mile Island & Chernobyl
Nuclear Dream Fades

Three Mile Island

Chernobyl

Seeming Limitless Energy Supply leads to Increasing demand

Products that Use Oil Derivatives

First Clouds on the Horizon of the Age of Energy (1970-1972 period)

U.S. oil production reaches all time high - 11.3 million barrels per day in 1970 oil. From that day on oil production in the United States has been declining.

Texas Railroad Commission allows production at 100% capacity – no excess capacity!

From that point on the U.S. began to depend on imported oil to meet their demands.

U.S. Failed to recognize the significance of increased foreign oil imports – dependence on foreign oil and movement of wealth from the U.S. to overseas.

Second Global Energy Crisis

1973 Israeli/Arab war

Oil used as a weapon by Arab producing states.

Created temporary oil shortages.

First warning shot of the things to come.

A lesson We Didn't Learn

Gas lines

Governmental intervention (Gasoline price caps and windfall taxes) insolated the American public from the real world, therefore there is no need to conserve.

Dependence on foreign oil increased.

Third Global Energy Crisis (Late 1970's - Early 1980's

Khomeini

Saddam Hussein

Shah of Iran

Collapse of the Shah of Iran and rise of Islamic fundamentalism.

Iraq-Iran War sowed the seeds for the first Gulf War in 1991.

A Lesson Learned in the West

Increased energy efficiency and productivity leading to reduction in demand for oil.

New supplies of crude oil from Alaska, North Sea and elsewhere reduced dependency on Middle Eastern oil.

Reduced demand and new resources lead to crisis in OPEC and developing world.


Price of Cheap Energy

Rise of Environmental Movement

From the late 60's onward, the public has become increasingly concerned about the environment.

Closer watch on energy development projects.

Rise of the environmental movement. NIMBY (Not in my back yard) and BANANA (Build absolutely nothing anywhere near anybody).

Slowed down, and in many cases stopped new energy projects.

Destruction of the Land

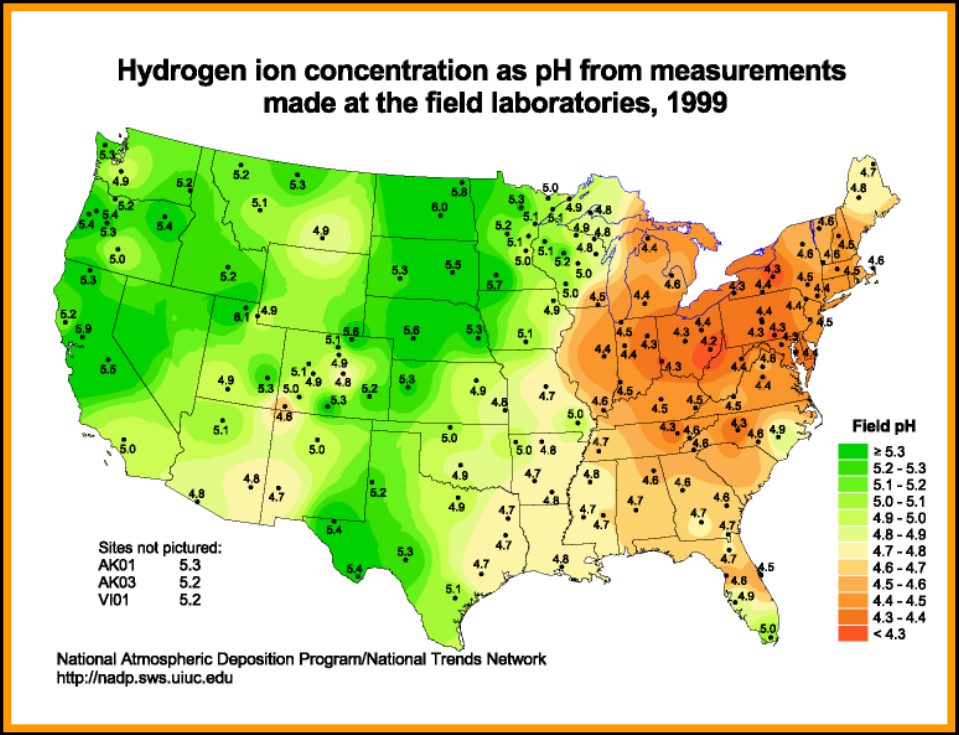
Mountaintop mining in West Virginia

Global Environment – Air Quality

Los Angeles

Global Environment

Acid Rain



Acid rain regions

Damaged forest in Northeast

Disruption of Cultures & Societies

Nigeria

Angola

Curse of oil

The World is Changing
The Party's Over

Ever increasing global population has led to an ever increasing demand for energy.

Depletion of energy reserves (not fully recognized or believed by many).

End of cheap energy.

Recognition of the environmental consequences of energy use.

What are we going to do?

Will we continue to live in a dream world or face reality?


Energy & Society
BALLYS

Understanding Energy in Societal Context

A difficult task requiring an understanding of:

1. **Acquisition, processing, distribution, and marketing of fossil fuels.**
2. **Economics of fuel usage.**
3. **Environmental impact of fossil fuel usage.**
4. **National and international politics of fossil fuels.**

Forms of Energy

Energy is defined as the "capacity to do work."

- Thermal energy (heat)
- Kinetic energy (motion)
- Radiant energy (light)
- Chemical energy
- Electrical energy

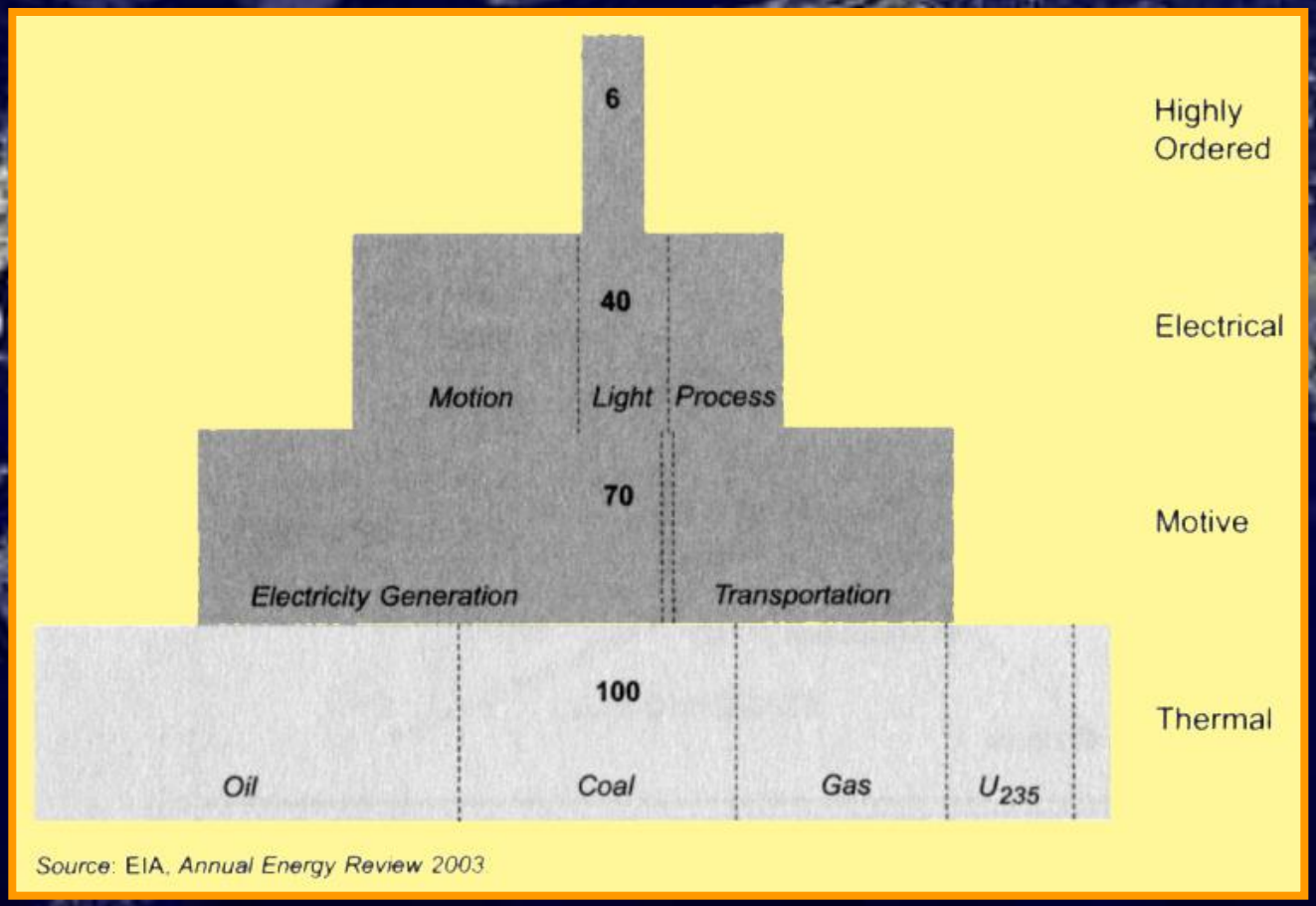
Energy System

Primary energy (thermal).

Secondary energy (energy not readily found in nature such as electricity, refined petroleum products, and nuclear)

Tertiary energy (end uses of energy)

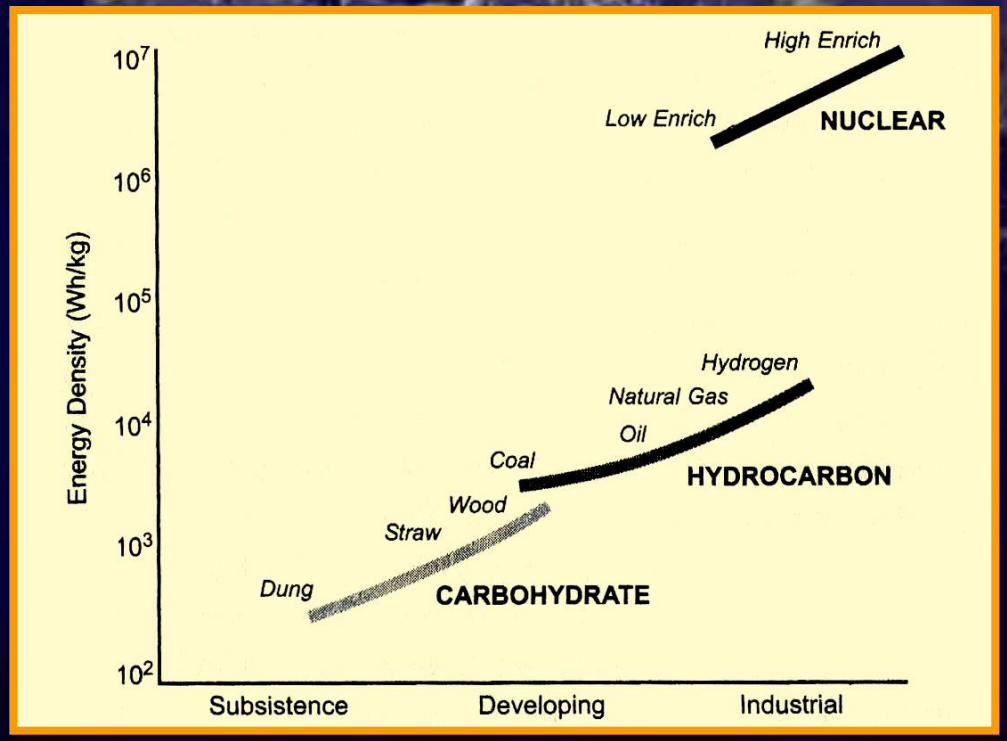
Energy Pyramid



Each level of the Energy Pyramid, the energy attains a greater order and increases in energy density.

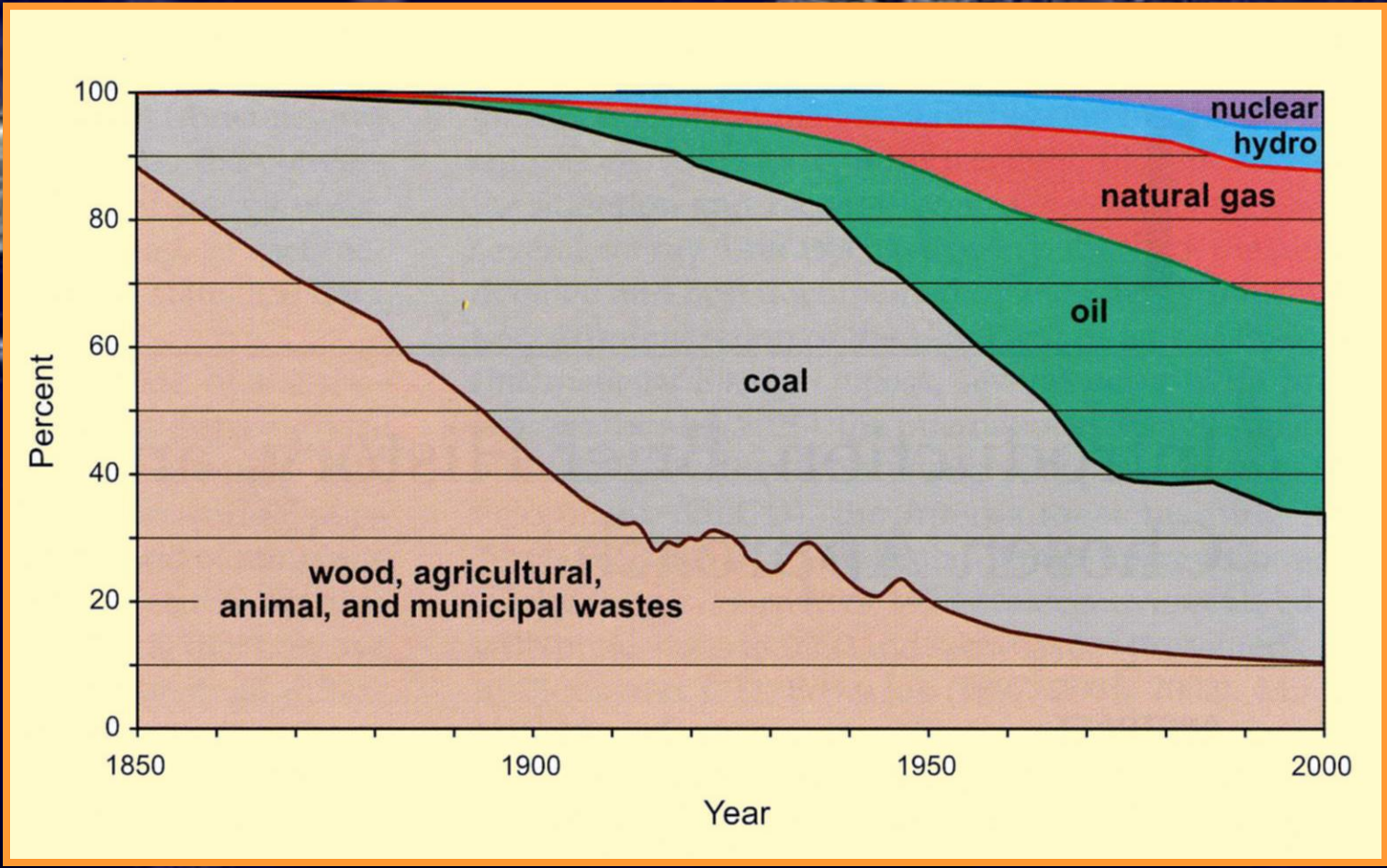
Power Density

- Power density = energy produced by a given volume of fuel



Energy density of primary fuels

History of Global Energy Usage



Type of fuel usage from 1850 to 2000.

Note that wood, agricultural, animal waste still provide a significant source of energy in many 3rd world countries.

Understanding Energy Units

Confusion/uncertainty about types and usage of energy units :

- **Volume**
- **Mass (weight)**
- **Source based energy units**
- **Interchangeable use of weights and volumes**

How Much Oil in a Barrel?

Depends:

1 barrel of oil = 42 gal (19th century whiskey barrel

1 barrel of oil metric = 34.9 Imperial gal

1 drum = 55 gal (used to transport fuel)

1 barrel of beer (American) = 31 gal liters

1 barrel of beer UK = 36 gal

Whiskey barrel

Drum

Unit conversion factors

Long ton = 2240 lb = 1016 kg

Short ton = 2000 lb = 907.18 kg

Metric ton (tonne) = 1000 kg = 0.907 short ton

1 barrel of crude oil = 42 gal = 159.0 l

1 barrel of crude oil = ~0.136 tonnes

1 tonne of crude oil = ~7.5 bbl - Crude oil measure tonnes on oil tankers

Energy Units

Differences in how energy units are defined and used can and often lead to confusion and misunderstandings.

Basic energy units – definition is not related to particular fuel.

Sources based energy units – definition is related to idealized (average) properties of a specific fuel.

Basic Energy Units

Calorie = Amount of energy to raise I gram of water 1º C, from 14.5º C to 15.5º

Btu (British Thermal units) = the energy required to raise 1 pound of water 1ºF 1Btu = 251.9950 cal.

Joule (metric) = unit of energy equal to the work done when the point of application of a force of 1 newton is displaced 1 meter in the direction of the force.

Sources Based Units

In discussing the production and use of energy, it is convenient to speak in terms of bulk amount of fuel (a barrel of oil or ton of coal).

Different physical characteristics and actual heat content of each type of crude oil or coal produces a range of energy content per unit mass.

Source based units of energy content is based on weighted averages of fuels consumed in the U.S. in 1995.

Range of Energy Content Per Unit Mass

Coal	Carbon %	Energy (Btu/lb)
Lignite	30	5,000 -7,000
Sub bituminous	40	8,000-10,000
Bituminous	50-70	11,000-15,000
Anthracite	90	>14,000

Source Based Units

MBtu = million of Btu

Mtoe = Megatonne of oil equivalent

Gtoe = gigatonne of oil equivalent

1 barrel of oil equivalent = 5.80 MBtu

1 tonne of coal equivalent = 27.8 MBtu

Natural gas = ranges from 900 Btu/ft^3 to 1100 Btu/ft^3
rounded off to 1000 Btu/ft^3

Therm energy equivalent 1 therm = 100,000 Btu

Source Based Energy Content (Energy Density)

Fuel	Btu
1 barrel of oil	5,800,000
1 gallon of gasoline	124,000
1 gallon of ethanol	76,000
1 gallon of diesel	139,000
1 gallon of heating oil	139,000
1 cubic foot of natural gas	1,031
1 gallon propane	91,000
1 pound of coal	10,000
1 short ton of coal	20,754,000
1 pound of wood	3,500
1 kilowatt of electricity	3,412

Let's Put These Quantities in Perspective

1 tank of gasoline (20 gal) equals 2,480,000 Btu.

248 lbs of coal to equal the Btu in one tank of gasoline.

1 billion Btu equals all the electricity that 300 households consume in one month.

1 trillion Btu is equal to 500 100-ton railroad cars of coal intended for electric power plants.

1 quadrillion Btu is equal to 172 million barrels of crude oil.

Large Scale Units

1 quad (quadrillion) = 10^9 MBtu

1 exajoule (EJ) = 10^{18} J

10^9 tonnes coal equiv	27.76 quad
10^9 barrels of oil equiv	5.80 quad

In 2003, the United States used 98 quadrillion Btu of Energy:

39 quadrillion Btu of petroleum

23 quadrillion Btu of natural gas

23 quadrillion Btu of coal

8 quadrillion Btu of nuclear energy

6 quadrillion Btu of renewable energy

Vast Amounts of Energy Require an Enormous Energy Extraction Industry

Global Geographic Divisions of Energy Usage

OECD (Organization for Economic Cooperation and Development)

Australia, Austria, Belgium, Check Republic, Denmark, Finland, France, Germany, Greece, Hungry, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Poland, Portugal,, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States

Non-OECD- other western European nations

FSU – Former USSR

Middle East –Bahrain, Iran, Iraq, Israel, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, UAE, Yemen (Turkey in OECD)

China

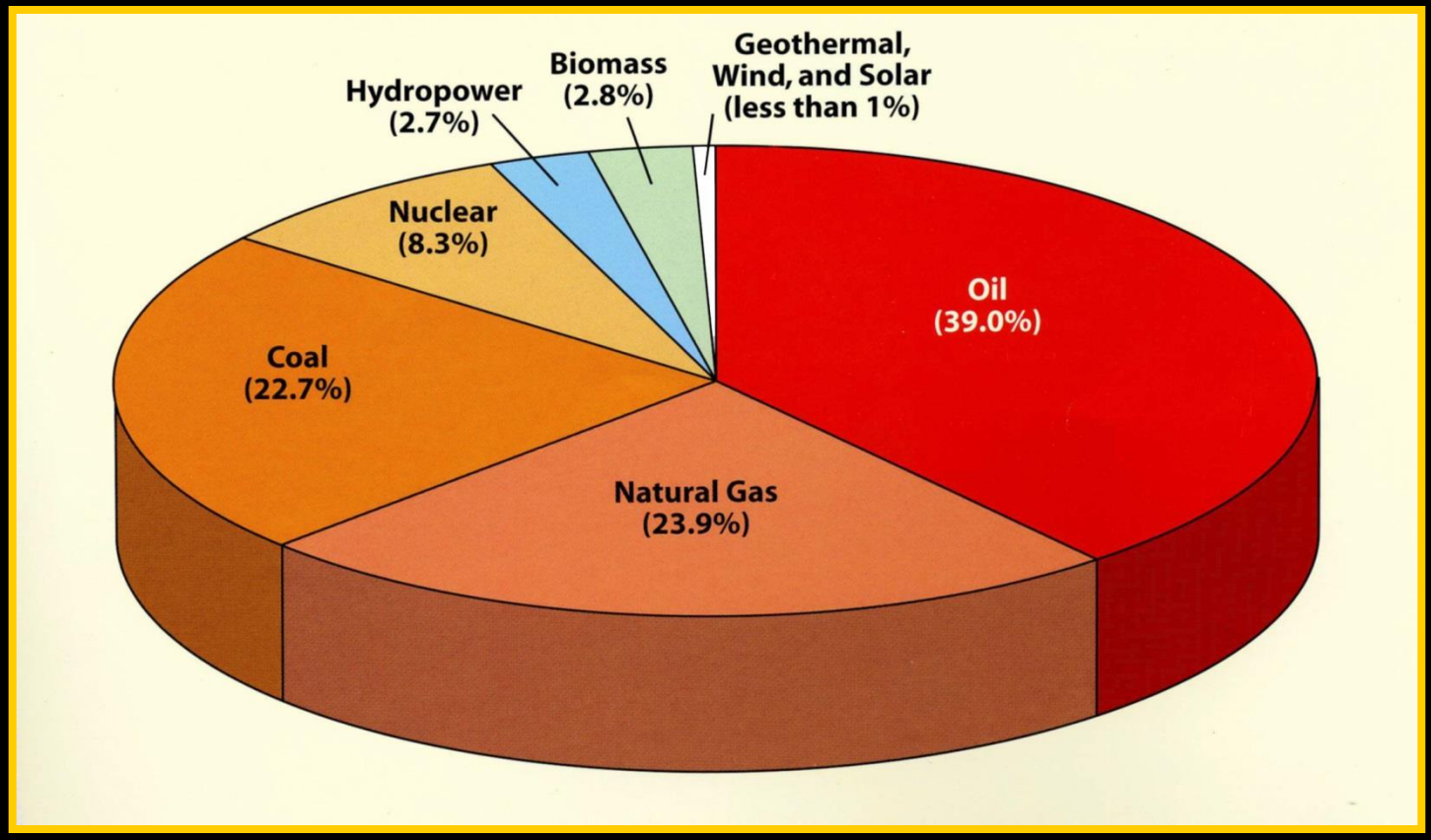
Asia – All Asian nations except, Japan, Korea and China

Latin America – except for Mexico

Africa – All African nations


U.S. Energy Usage
BALLYS

U.S. Energy Usage

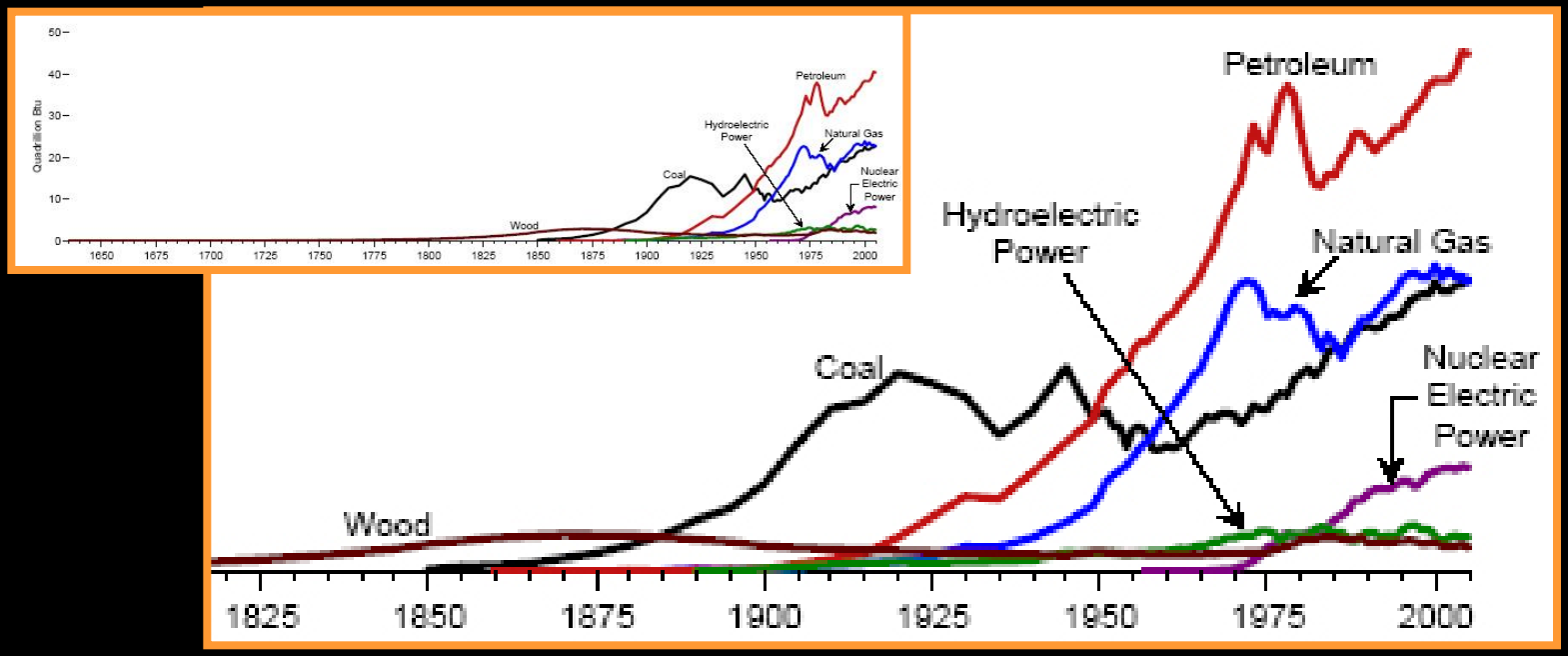


Division of Energy Usage

Motive (transportation) - oil and gas, <1% electricity

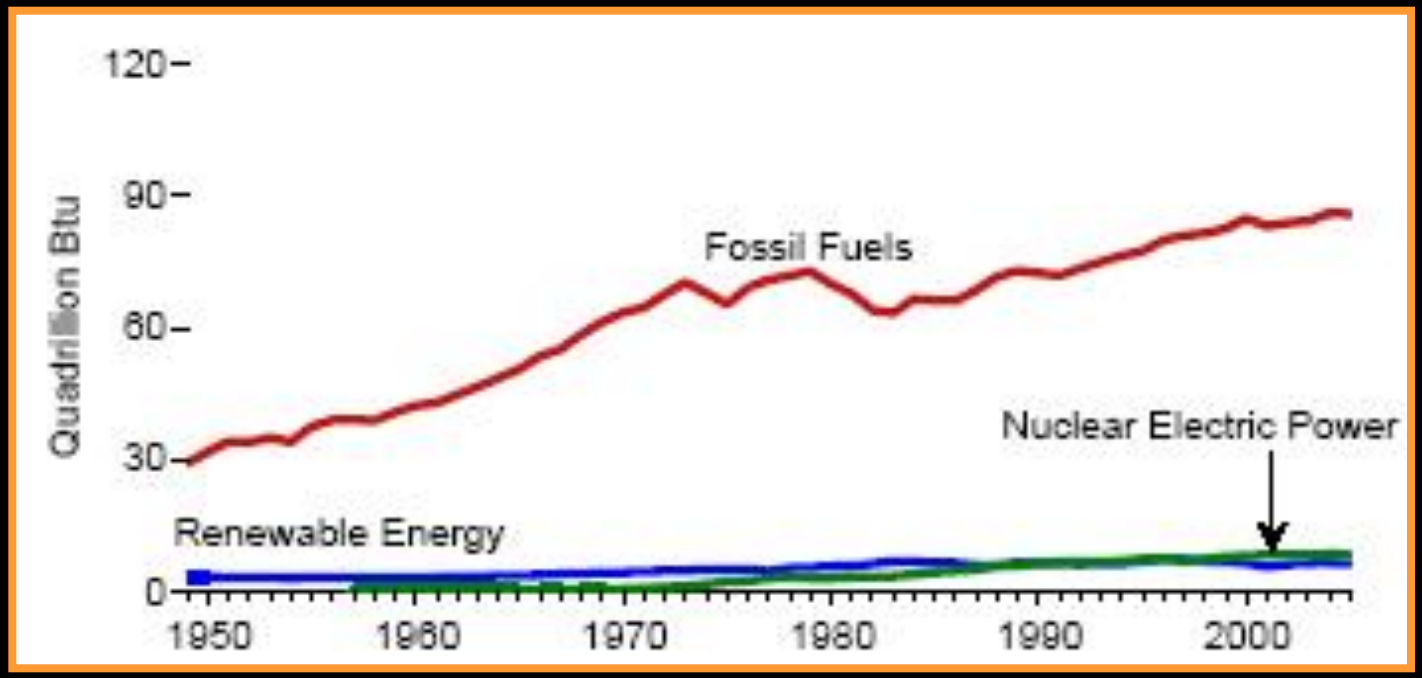
Electrical generation - (coal, gas, hydroelectricity, nuclear, ~1% renewable resources)

U.S. energy consumption by source 1635-2005



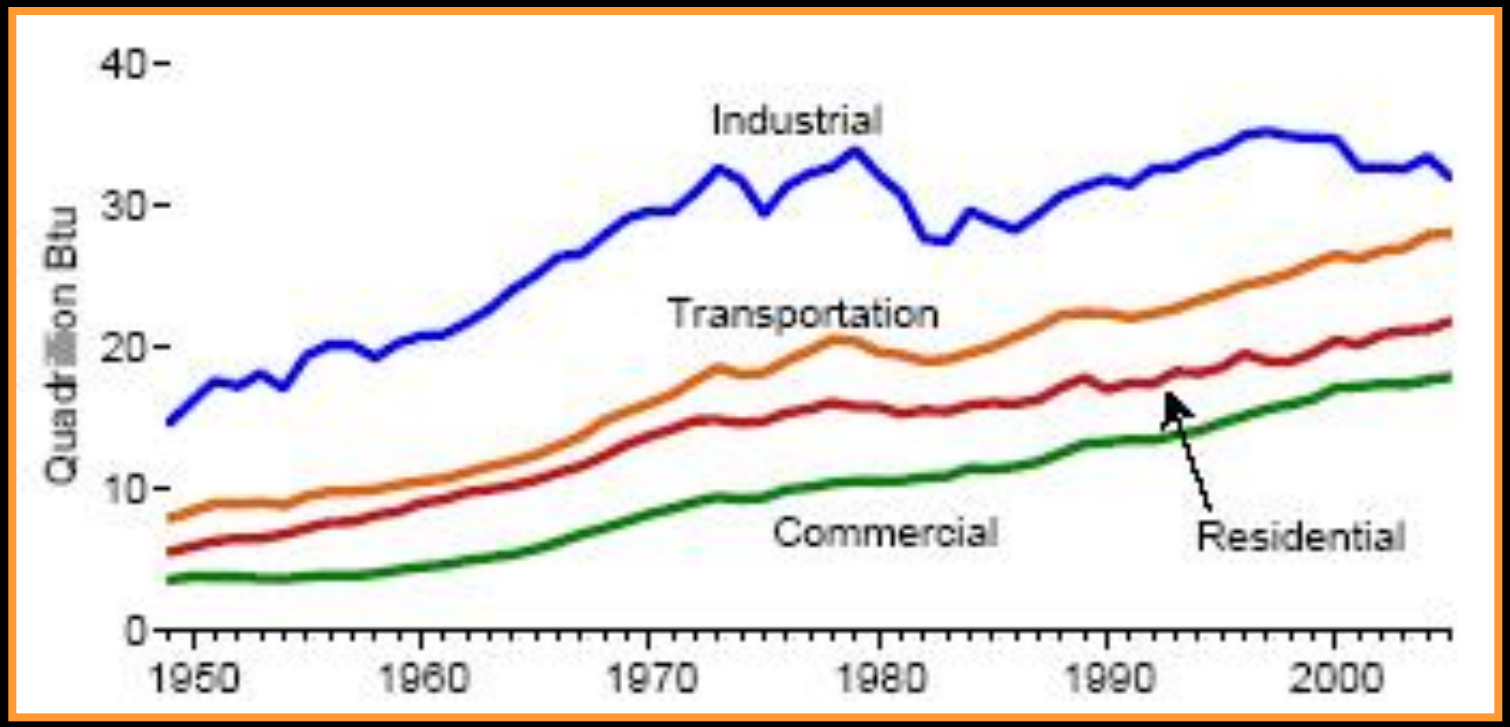
Sources of energy
Wood - brown
Coal – black
Petroleum - red
Natural gas blue
Hydroelectric – green
Nuclear- purple

Consumption of Energy by Source



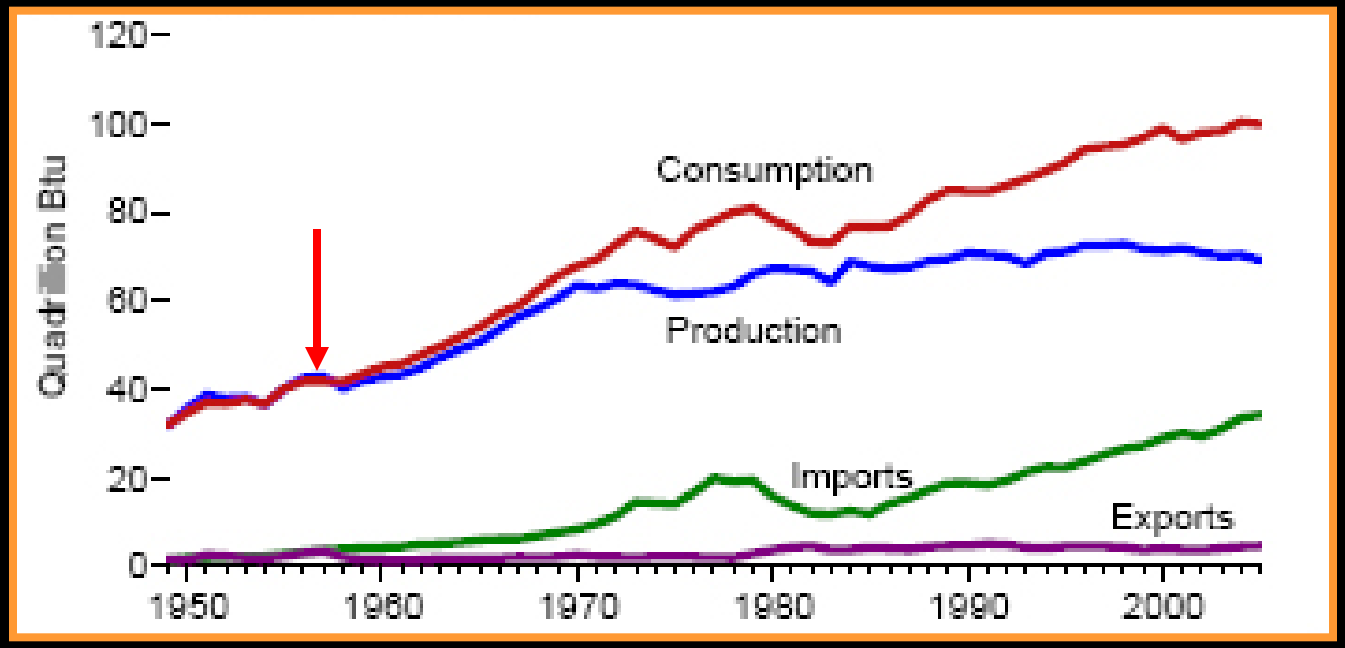
Most energy comes from fossil fuels

What Do We Use Energy for in Our Society?



Consumption by sector – end user

Overview Requirements and Sources of Energy in the U.S.



Until the late 1950's, the US was self-sufficient in energy.

Since that time, the US has had to import energy to bridge the gap between domestic production and consumption.

Fossil Fuels

Physical and economics characteristics of fossil fuels constrain their uses as an energy source.

Type and proportion of fossil fuels used to generate energy have changed dramatically during the 20th century.

Type and proportion of fossil fuels used in the 21th century will change dramatically!

Advantage of Oil as a Source of Energy

Unique combination of desirable and useful characteristics:

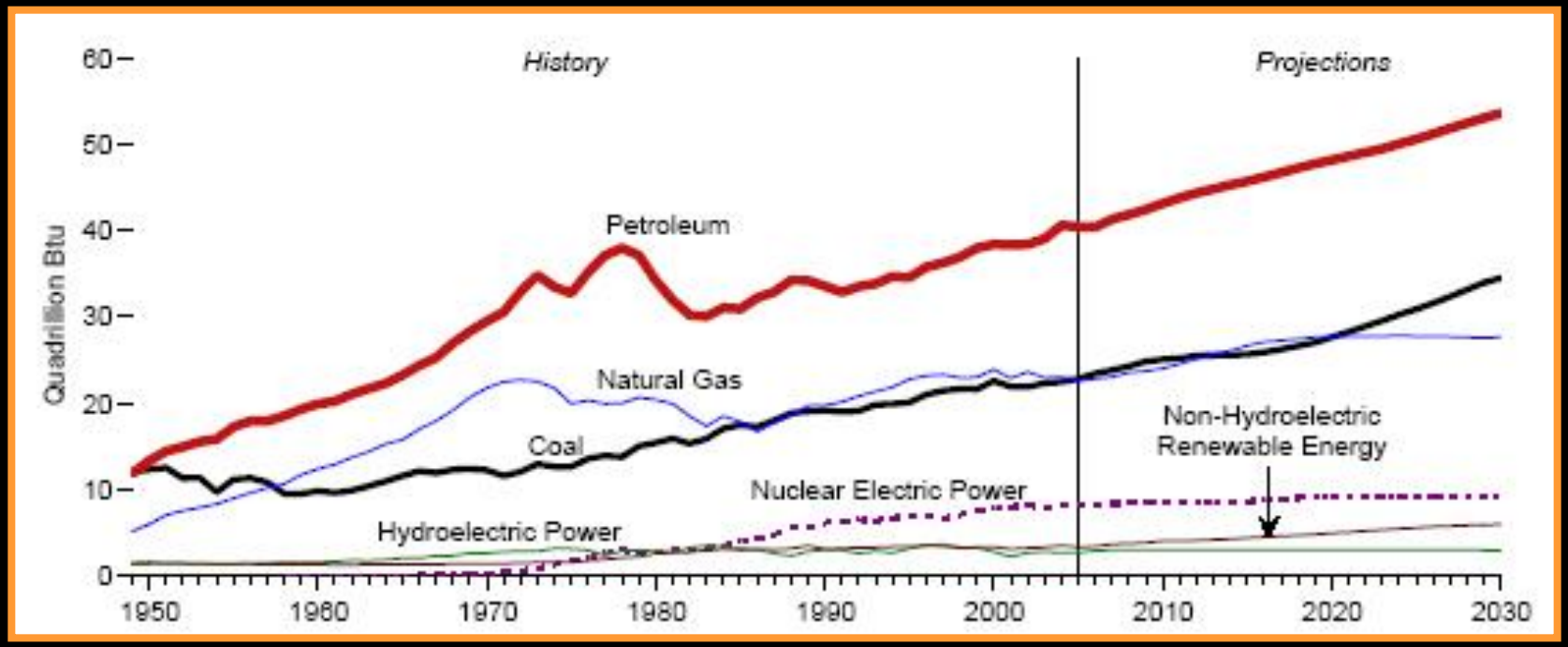
- High energy density.
- Currently available in abundance.
- High net energy recovery (EROEI) – energy return on energy invested).
- Ease of transportation and storage.
- Relatively safe.
- Great versatility in end use.

What Does the Future Hold for Energy?

Night view 1970

Night view 2005

Projected Energy Consumption 1949-2030



Energy Usage Per Capita

	Barrels of oil/year (1992)
United States	23.8
Japan	15.9
China	0.8
India	0.5

	Barrels of oil/year (2006)
United States	25
China	3
India	3

14,500,000 Btu per capita each year in US (2005).

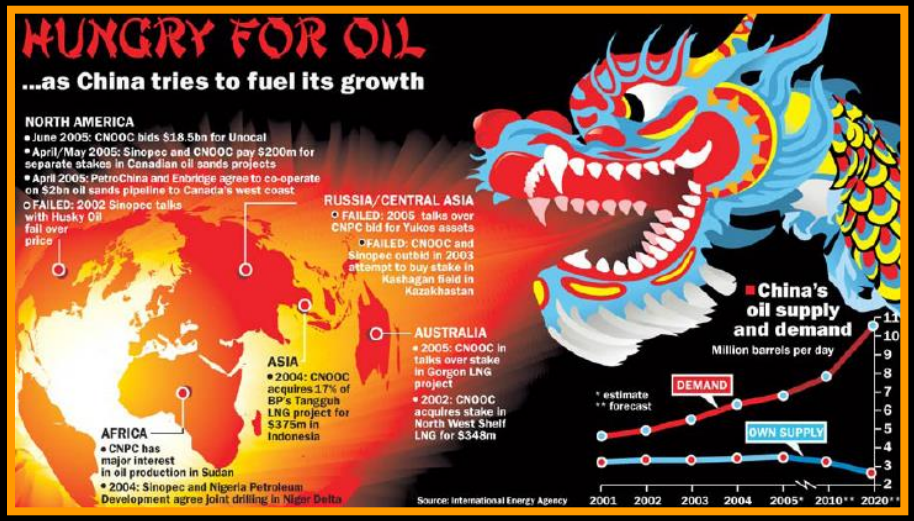
1,740,000 Btu per capita each year in China & India.

What Does the Future Hold for Energy?

Our energy needs will continue to grow.

The energy needs of other countries will grow at an even a faster rate.

Supplies of oil and gas will begin to gradually decrease during the 21st century.



Developing Nations & the “Good Life”

National Geographic story on energy usage in China

Alternative Energy Sources

Alternative energy sources must be compared with all the various attributes of oil, when their substitution for oil is being considered.

EROEI (Energy returned on energy invested) = Fossil fuels have exceptionally high EROEI.

Changes Will Have to be Made!

What types of changes will have to be made?

Will changes be based on the discovery of new sources or technological breakthroughs?

Can these changes be made soon enough to avoid a severe energy crisis?

Are we willing to make these changes?

What sacrifices are we willing to make?