Agenda Cleantech and Politics

- Background
- Political Issues
- Economic Factors
- Uses and Sources of Energy
- Alternatives
- Can Technology Save Us?
- Investors - Commercializing Technology

The preliminary information presented includes original material as well as information collected or compiled from numerous sources by R. Helfrich. Some forecasts are the opinion of Richard Helfrich without external sources.

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What is Cleantech

- Enhances the global quality of life
- Provides solutions to pressing local, regional, national and global problems
- Improves the effectiveness of technology
- Improves the availability of basic necessities to the general populace
  - Clean Water
  - Clean Air
  - Abundant and Low-Cost Energy free from pollution with lesser CO2
  - Energy use at high efficiency with less waste

Cleantech - Linkages

- Technology exists to clean waste **water** and desalinate sea water to potable water
  - Energy required for water cleaning is high
  - **New inventions needed to improve efficiency**
- Clean **air** requires less vapor effluent
  - Reducing effluent uses energy & capital equipment
  - **New inventions needed to improve efficiency**
- Electricity **transport** results in large losses
  - **New inventions needed to improve efficiency**
- Energy **demand** varies 2 to 1 over time of day
  - **New inventions needed for efficient storage**

Cleantech

- Cleantech is more than being green
- **Plentiful and low-cost water and electricity can solve historical political disputes**
- Cleantech and its needs are
- Energy - economically viable solution
- Energy Storage - increased capacity - auto +
- Energy Efficiency - attractive cost per watt
- Water - need energy efficient purification

Politics - Benefit or Plague

- Why government?
  - Extensive Value Re **elections**
  - Source Of **new revenue** for Governments
  - Potential source of **jobs** and wealth vs. offshore
  - Solutions to pressing problems - **balance of trade**
- How governments may help
  - University R+D funding
  - Early R&D funding before open market investors are interested
- How Governments may hurt
  - Over **regulation and taxation** of new technology before self sustaining
  - Succumb to **special interests** (coal) for status quo

Taxes and Tax Credits

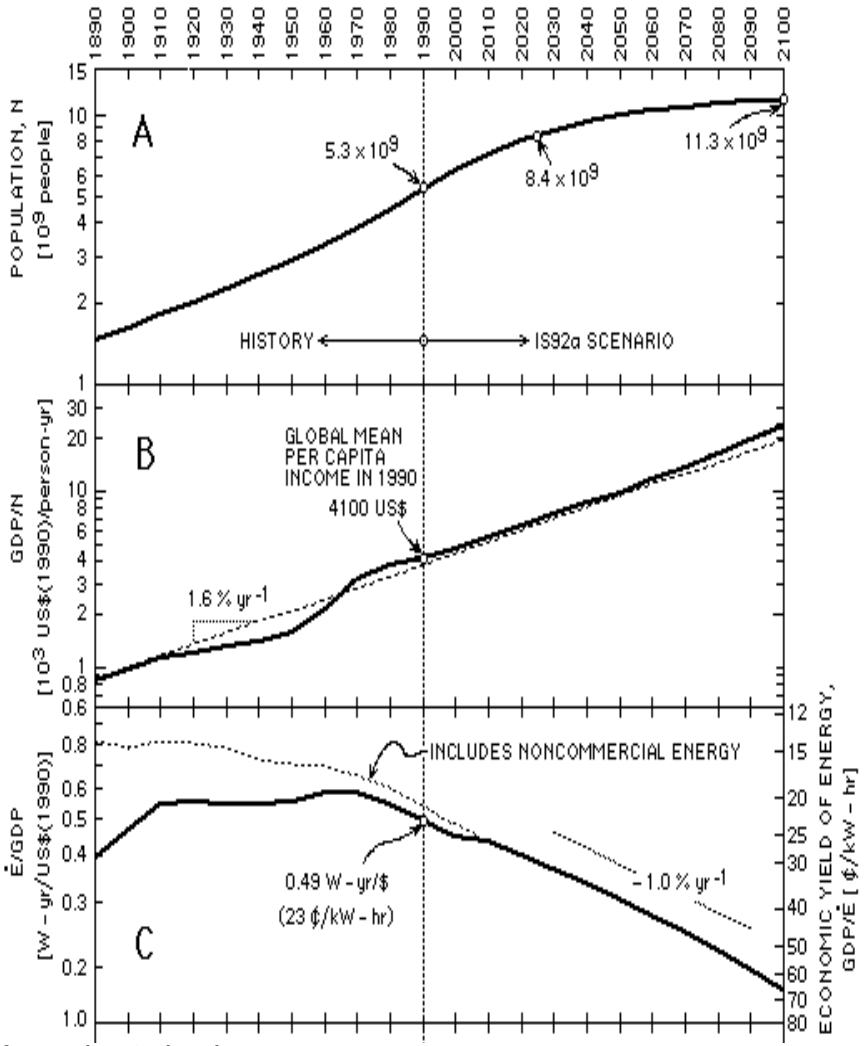
- Can taxes jump start some/all Cleantech sectors?
  - Makes traditional energy expensive for everyone
  - Provide tax incentives for alternatives
  - May (or may not) provide incremental R&D funding
  - Is it appropriate for government to make decisions on cleantech instead of market?
- Government will receive Revenue without calling that revenue a tax
  - Carbon Cap and Trade
  - Fully implemented in UK to harsh public criticism
    - “fee” charged on airline tickets in UK
    - Resulted in windfall for coal
  - **UK type approach likely in US within 24-mo.**

More People Living Better means Much More Energy Needed

Population Growth to
10 - 11 Billion People in 2050 **~1% per year**

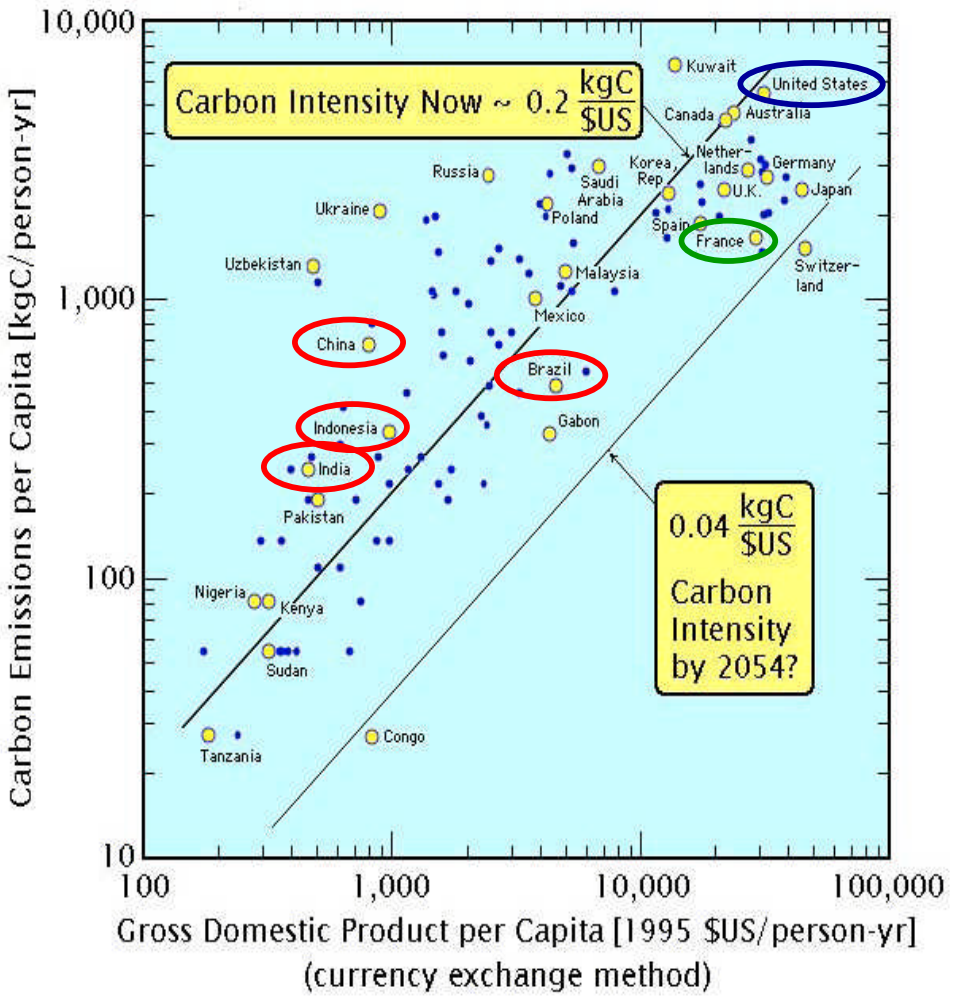
Per Capita **GDP Growth at 1.6%** yr^{-1}

Opportunity
Energy consumption per Unit of GDP **declines** at 1.0% yr^{-1}



Sources: US Energy Information Agency, Prof. Lewis, Caltech

Carbon Intensity vs. GDP



Sources: US Energy Information Agency, Prof. Lewis, Caltech

Concern

3 of 4 countries with the world's largest population in 2050 along with high GDP growth are carbon intense users in 2006 and likely to remain so

Alternative

France's nuclear provides advantage

Economics and Mass Markets

- **Little Value without huge user base**
- Early adopters try many new technologies
  - Photovoltaic installed with warranties at $8/watt OK
    - ~$4 Panel plus ~$4 Other minus tax credits
    - Time to Payback of 8-15 years depending on location
- BUT early adopters will not impact local, regional, national or global results
  - **Photovoltaic provides less than 1% of electricity**
- Mass markets adopt technology
  - **Cost Vs Payback**
- PV requires about 6,000 hours of operation to recover energy used to make and install PV

Who Pays for Cleantech?

- Government may subsidize some cleantech
- Universities devoting resources to cleantech
- Companies are developing cleantech
- Investors are putting capital into cleantech
- Governments are likely to tax alternatives to promote cleantech (Carbon Cap and Trade)

HOWEVER

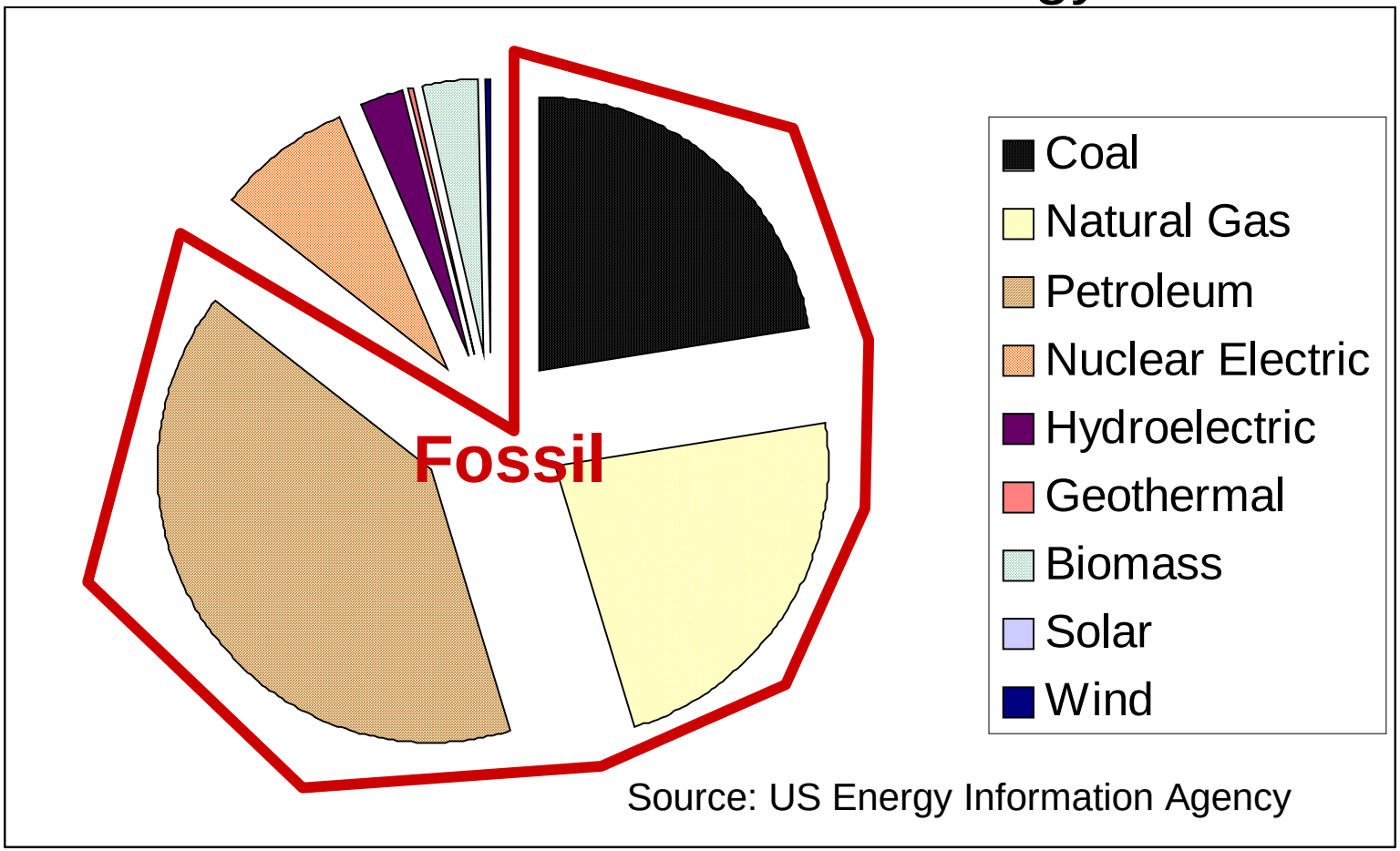
- Consumers in the short- to medium-term can expect
  - **Higher Prices** for all carbon based or derived fuels and their end products
  - -Gasoline - Electricity - Natural Gas - Airline Seats - Food - Plastics

US Energy Independence Issues

- Energy imports create a large portion of negative balance of trade
  - Negative trade balance driving weaker dollar
- Weaker dollar helping grow industrial exports
  - Weaker dollar makes consumer goods imports more expensive (although not much change from China - **YET - But China will revalue**)
- US energy independence would drive down oil to under $20/barrel and maybe under $10
  - OPEC countries could become poor again
- **Energy can be used to desalinate Water**

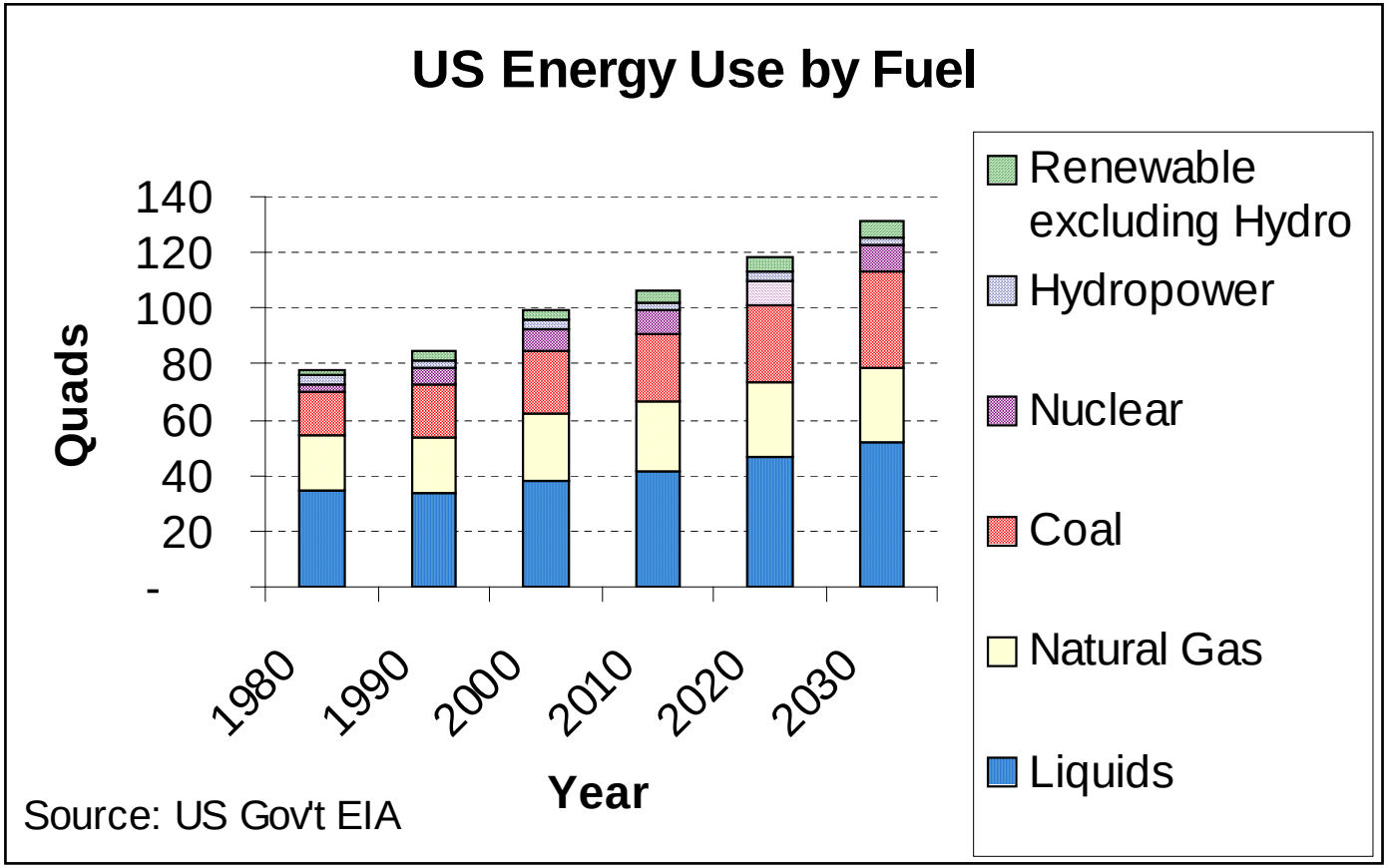
Sources of Energy

- Fossil Fuel about 85% of all Energy 1980-2020



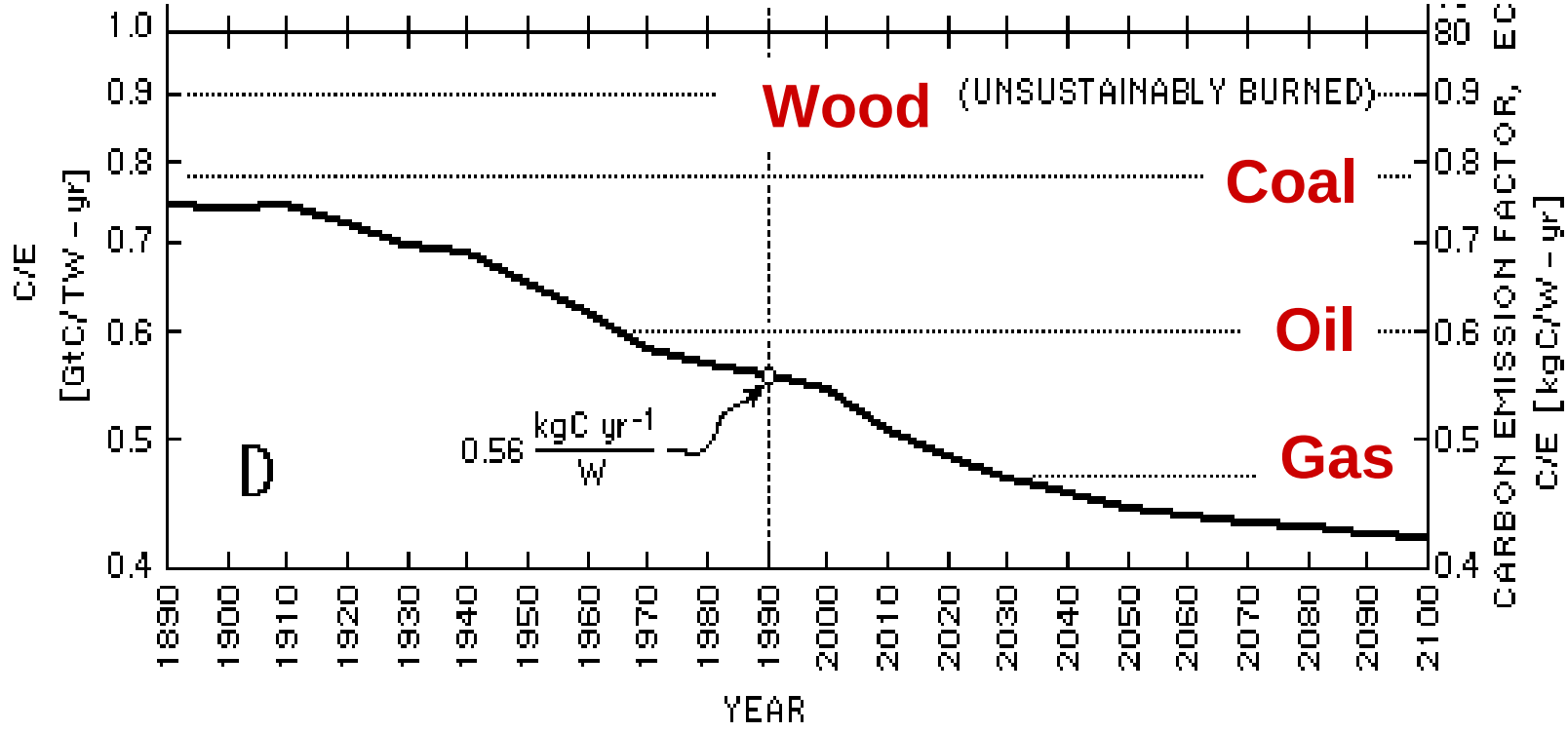
US Energy Use Trends

US uses so much energy that changing energy sources requires multiple decades and trillions of dollars



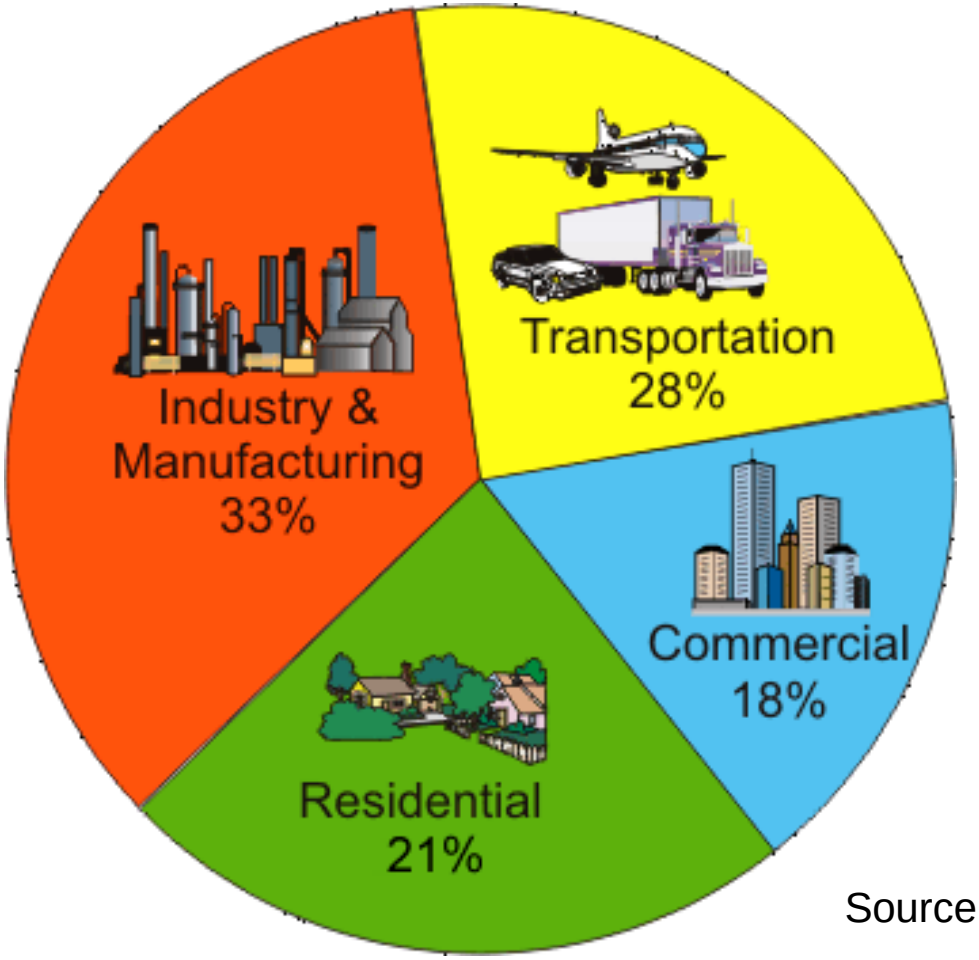
Carbon Intensity of Energy Mix

Easy transport or storage of energy creates value
- Electric and oil are better than others



*M. I. Hoffert et. al., Nature, **1998**, 395, 881*

Uses of Energy

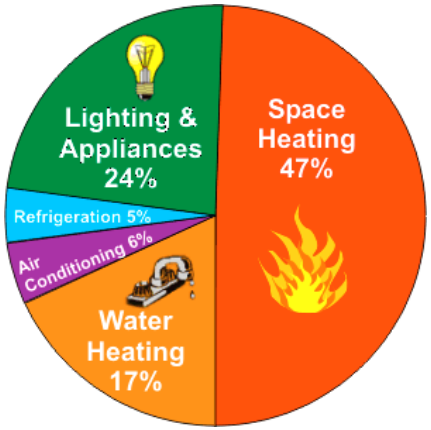


Lighting is a large use in all sectors

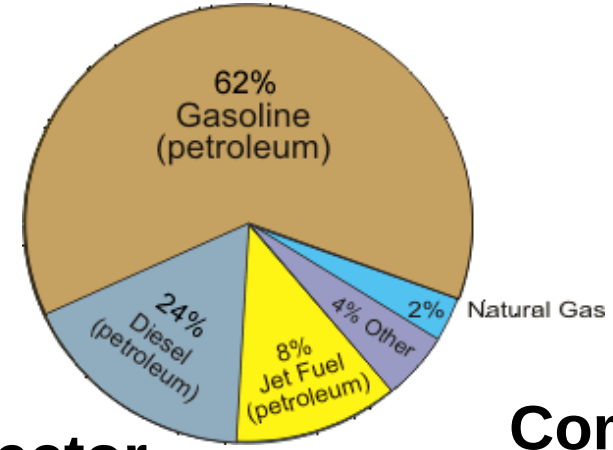
Source: US Energy Information Agency

Use Within Sectors

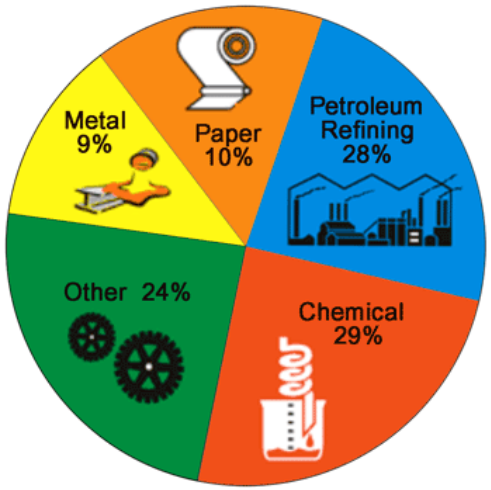
Residential Use



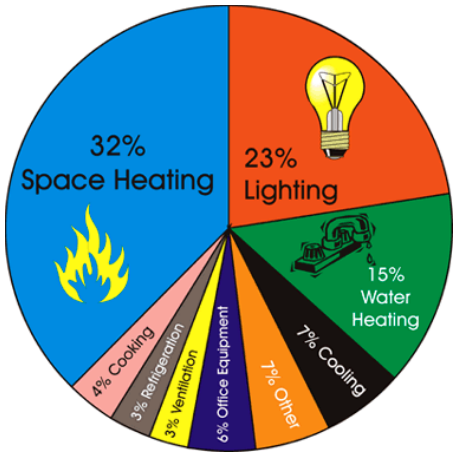
Transportation Fuels



Industry Sector

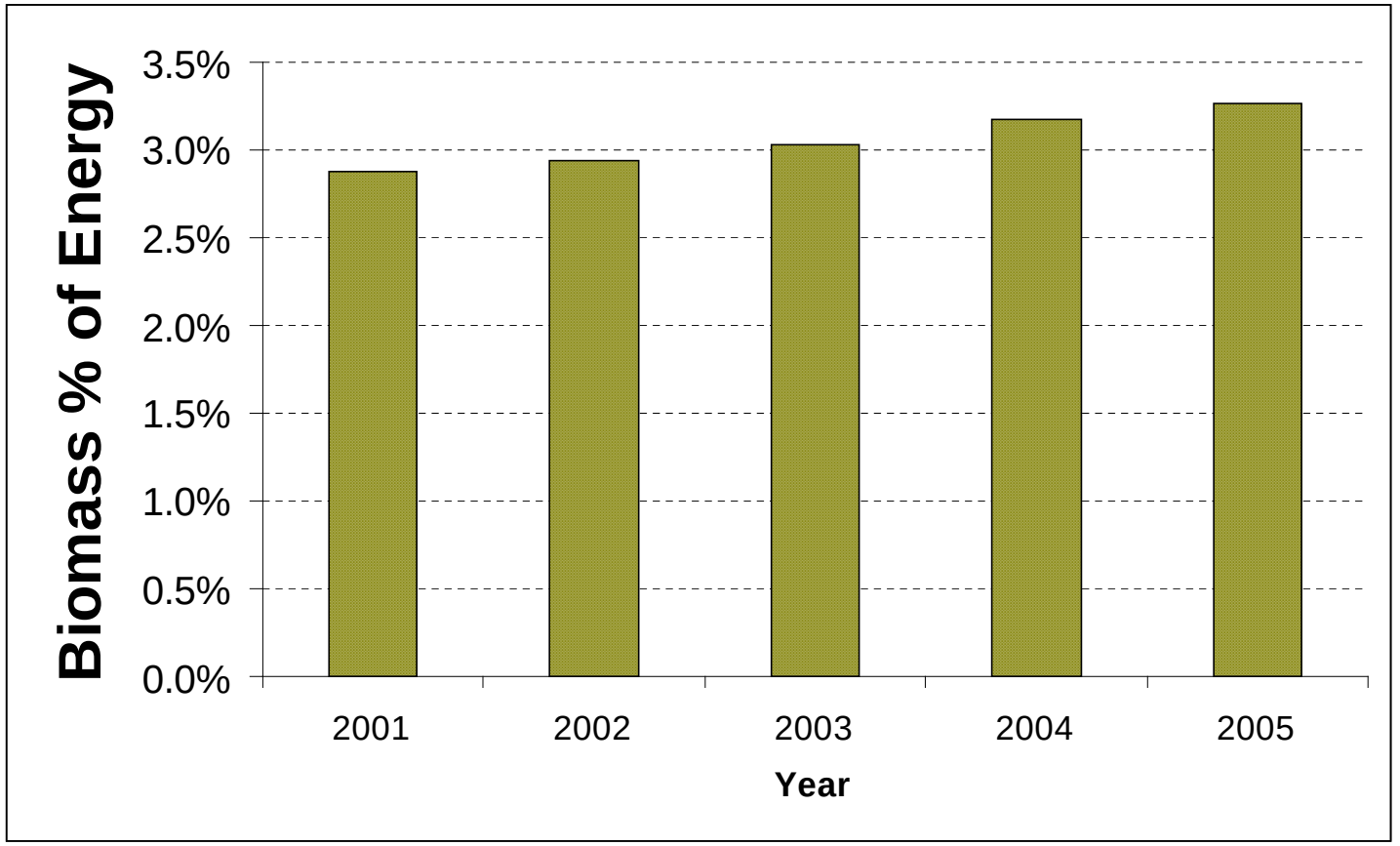


Commercial Use



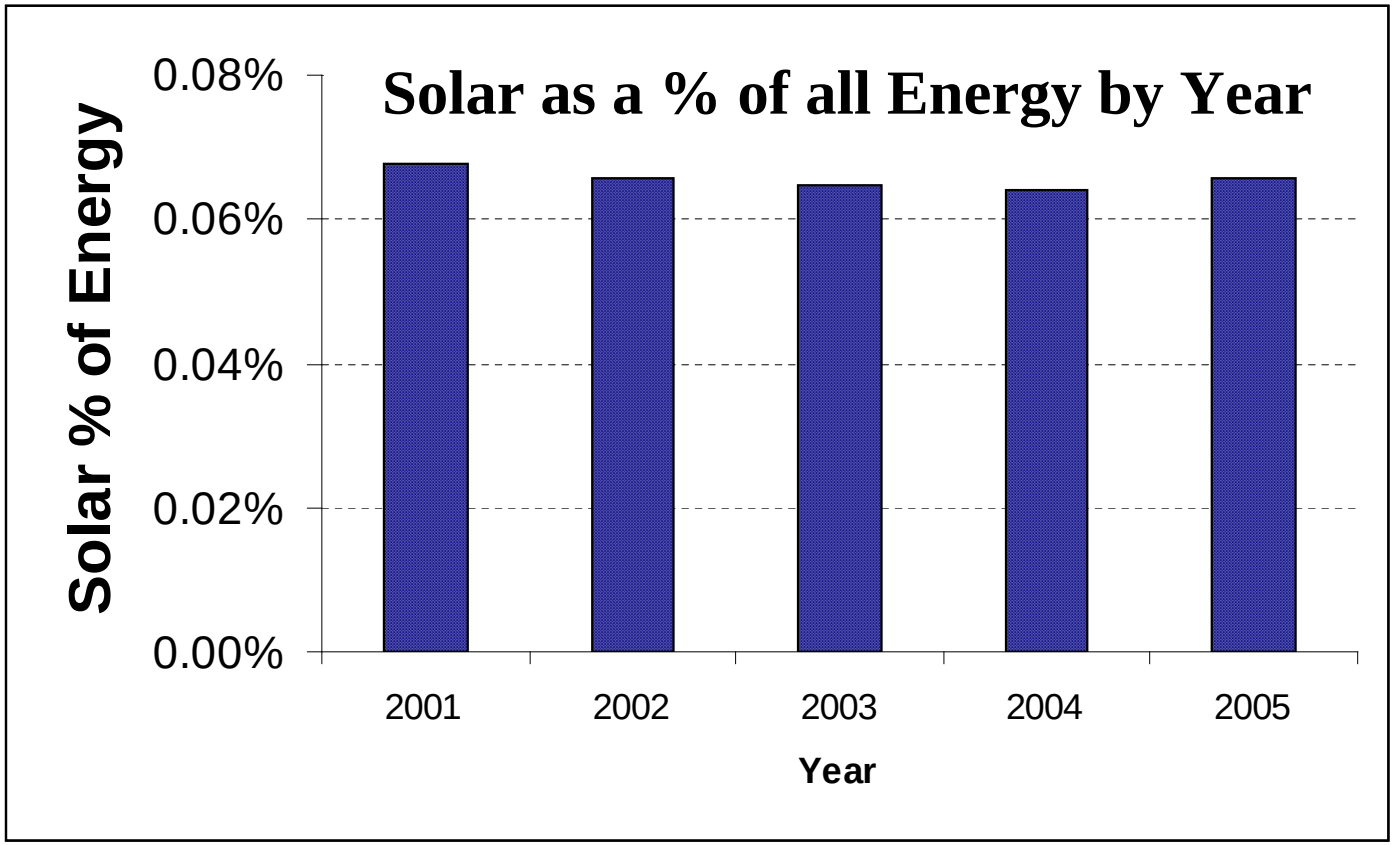
Source: US Energy Information Agency

Biomass Growing but Slowly



Source: US Energy Information Agency

Solar Growing but Miniscule



Installed Capital Cost and Field Lifetime Issues

Source: US Energy Information Agency

Alternatives to Fossil Addiction ?

Type	50-to-200 Years	10-to-20 –Years
Solar (D) **photovoltaic**	Major if installed price is ~ $1/watt w 25-year warranty	Rapid growth but small portion of energy
Efficiency (D) **Improvements**	Save 40%- Lighting, motors, pumps, CHP, etc.	Most cost-effective mid-term investments
Solar thermal (C)	Substantial GW from sunny locales in large systems	Portion of electric power efficient in MW sizes
Wind (turbines) (C)	Cost Effective – limited by regional wind - transmission	Strong growth but small % of energy
Nuclear (C)	Central power source at low-cost	~50% of Electricity if US does Manhattan project
Fusion (C)	All energy at lowest cost?	Not likely
Ethanol and Bio-diesel (T)	Peak in 2008 at minor role w/o further breakthroughs	Limited by water & need for food w 11B people
Bio-Oil (T)	Could be main transport fuel unless electric autos	technological inventions ?

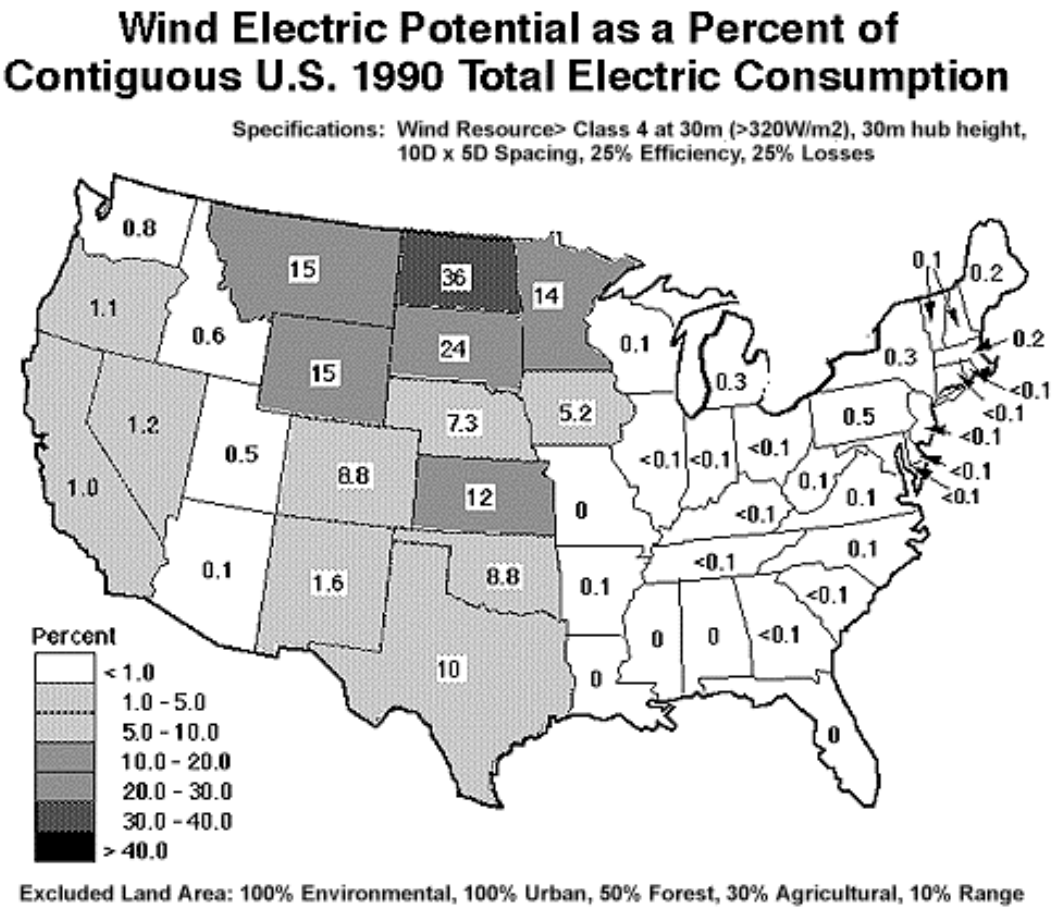
(D) Distributed Power requires no transmission (C) = Central Power (T) = Transportation

Wind Potential of US

Nice but very limited in US

Cost advantages

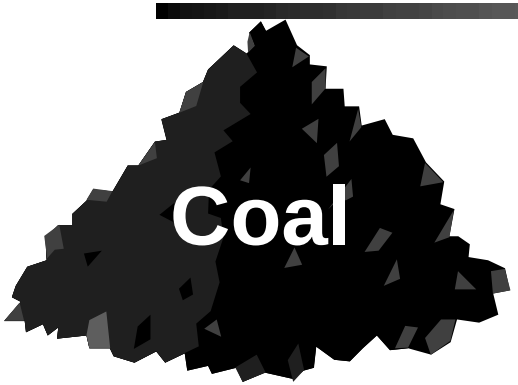
- Limited locations
- Random times
- Requires mass energy storage
- Sources far from largest consumers
- Indirectly from solar heating



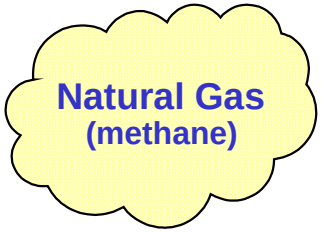
Biomass Factors and Bio-Nano

- **World Land with Crop Production Potential, 1990: 2.45×10^{13} m²**
  - Cultivated Land, 1990: 0.897×10^{13} m²
  - Additional Land needed to support population growth to 9 billion people in 2050: 0.416×10^{13} m²
- **Remaining land available for biomass energy: 1.28×10^{13} m²**
  - At 8.5-15 oven dry tonnes/hectare/year and 20 GJ higher heating value per dry tonne, energy potential is 7-12 TW
- Perhaps 5-7 TW by 2050 through biomass
- Likely to be **water resource limited**
- Challenge for chemists: efficient conversion of cellulose to hydrocarbon fuel via Bio and Nano
- Alternative? - **Water based GMO oil biomass like LBNL**

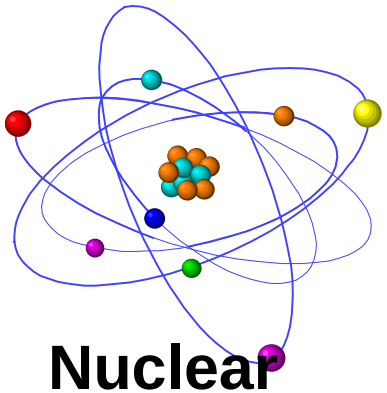
Electricity Generation Options



- Focuses on Sequestration of CO2 - will it work in vapor form
- Expand % of power from coal



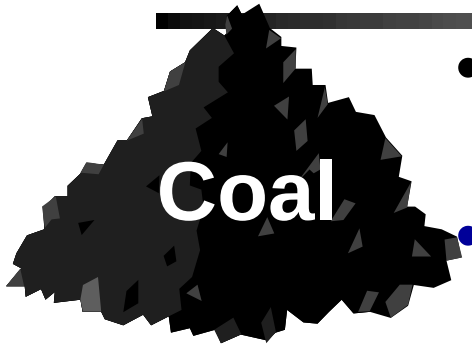
- Reduce use in electricity generation
- Shift supply to automotive fuel



Nuclear

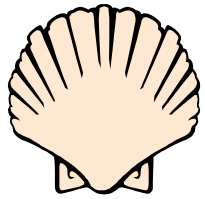
- Build safe plants where practical
- Improve long-term waste storage
- Improve reprocessing to reduce waste

CO2 Sequestration Issues



- Coal is plentiful in major consuming nations = US, China and India
- **Coal is convertible to natural gas**

- Sequestration of pressurized CO2 in old mines and caverns may work short to medium term
- Nature sequesters CO2 in shells in oceans
  - Safe and long-term
  - Positive energy reaction aided by biology



- A suitable **catalyst could allow safe large-scale sequestration of CO2 in carbonates at coal power plants**

Cost to Replace Coal with PV

- **EIA Forecasts Coal Use in 2020 at** 27.29 Quads
  - Equal to 93.2 Trillion KW-Hr.
- Each watt of installed PV solar = ~ 2,000 W-Hr over 12-mo
- 46.6 Trillion Watts of PV required to produce 27 Quad
- Assume
  - Linear PV Installations from 2011 to 2020 at 4.66 TW/yr.
  - 2011 Installed Price of Photovoltaic Solar = $5 per W
  - 2020 Optimistic Forecast for Installed PV = $1.00 per W
- Investment required $162 Trillion in constant 2007 dollars
- US must spend 1.2 times GDP every year for 10 years
- **$1/watt PV means >100 years replacing coal**
- **Need is PV panels/tiles mfg at $0.16/watt**

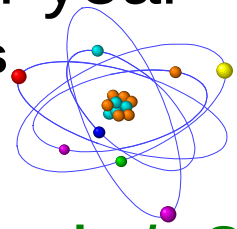
Energy Alternatives for Motion

- Shift to High Efficiency Automobiles
  - Lighter weight
  - Hybrid electric - internal combustion with plug-in option - **Motors at Wheels = 50% improvement**
- Shift busses, trucks and many autos to natural gas - burns cleaner and US supplies possible
- **Hydrogen not practical for next 40+ years**
  - National Academies very negative

Energy Independence Option

Using Existing Technology - no inventions

- 150 each 3-GW nuclear plants - 15 per year
  - **Domestic supply of fuel for thousands of years**
  - Safer boiling water reactors - not pressurized
  - On-site storage of spent fuel
  - Construction for plants ~ $180B/yr. - **Easily Financed w/o Gov.**



- CAFÉ standard raised to 50 mpg forcing plug-in hybrids with 50+ mile battery range
  - Li-Ion batteries practical and improving fast - **Fits Consumer $**
- Mandate new autos to use only natural gas starting in 2011 - Also reduces pollution
  - Domestic gas available when power plants close
- BONUS - **Boost to US Economy** - Jobs, $ Elect.

What can be done in < 20 Years

Energy

- US Could become energy independent and Reduce CO2 Emissions by > 50%
  - Solar - Wind - Mass Storage for 2% to 5% of Electricity with large and focused investments
  - Hydro and Geothermal similar to 2007
  - Build 450 Gigawatts new nuclear - 80% Electricity
  - Mandate autos “Plug-In Hybrids with 50+-mile Battery Range” natural gas for hybrid fuel
- Biofuels - Ethanol - minor solution not capital effective
- Biofuels - Possible GMO organisms like LBNL

Cleantech Applications

- Energy Generation
- Transportation of People/Goods
- Energy Storage on Mass Scale (TW-Hours)
- Central Power
- Energy Efficiency
- Distributed Power
- Potable Water from Seawater/Wastewater
- Greenhouse Gas Reduction
- Waste Water Treatment
- Gas Treatment - Effluent

Underlying Technologies

- Major base technologies
  - Semiconductor
  - Materials
  - Catalysis
- Enabling technologies that show promise to reduce costs
  - Nano
  - MEMS
  - Crossover

Sources of Innovation

- **USA**
  - Universities - doing more research targeted to real needs - applied research vs.. basic research
  - Corporate R&D - no longer the research leader
    - Great labs of old no longer exist for pure “R” - Bell Labs
  - National Labs - shifting towards real world technological needs
- **Europe** - Somewhat similar to US
- **Japan** - More corporate and less university than US
- **Asia** - Each government tends to set course

Emerging Tech Investments

- Level of Capital Required - higher than most
- Time to Revenue from Seed - longer than many
- Time-to-Attractive-Exit from Seed - **long**
- Risk of Failure - higher than others - **more unknowns**
- IRR - unknown - but likely much less than Google
- Intellectual Property (IP) - **major issue** - many patents
  - Changes in IP rules and Supreme Court rulings
  - International nature of market
- Seed - too many competing startups in every application sector
- **Payback - vast majority will fail, some will become walking wounded, and few become home-runs**

Value Creation Through Combined Technologies

- Fully Integrated Low-Cost Systems
- Creates Barriers to Competition
- Large Market Opportunities
  - Near Term
    - Revolutionize existing markets
  - Long Term
    - Create whole new markets

CleanTech Energy

- **Point of Use Energy**
  - Photovoltaic + Advanced Materials+ Optics
- **Central Power Generation**
  - Solar Thermal + Advanced Materials + Energy Transfer Techniques
- **Biomass - Wildcard**
  - Life Science (GMO) + Solar + Nano
- **Niche Markets**
  - Wind - random times and limited locations
  - Wave - complex transmission to users
  - Geothermal - cost of a deep well

NOTE: Compare Price at Point of Use

Fission

Fusion

Renewable Conclusion

- Abundant, Inexpensive Resource Base of Fossil Fuels (always 40 years oil left + 200+ years coal)
- Renewables will not play a large role in primary power generation

unless/until:

– technological/cost breakthroughs are achieved, and / or

– unpriced externalities are introduced (e.g., environmentally-driven carbon taxes)

- [or politically created supply restrictions]

Source: Professor Lewis of Caltech
<http://nsl.caltech.edu/energy.html>

Other CleanTech

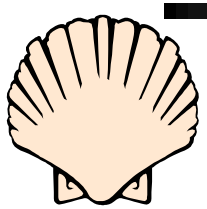
- **Energy Storage** (TW-Hr.)
  - Batteries + Advanced Material
  - Advanced Materials + UltraCaps
- **Energy Efficiency - Opportunities**
  - Lighting and Semiconductors (> 85% @120V AC)
  - Solid Oxide Fuel Cells (> 50% natural gas joules)
  - Others - Dynamic HVACs - Pumps - etc.
  - **Lightweight Electric-motors on Auto Wheels**
- **Municipal Water / Waste Treatment**
  - Advanced Materials for Molecular Separation

Entrepreneur Opportunities

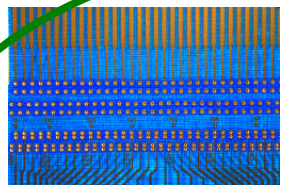
This Startup Cycle is Different

- Very early stage capital tighter than late
- Investors expect to see tech demo
- **Huge global market** longer and **more expensive to penetrate**
- **Total capital required** to reach exits (M&A or IPO) growing faster than PPI or CPI
- **Global competition - Intense**
  - Smart and educated people everywhere
  - Capital less expensive than US in some countries
  - IP - more difficult path to achieve value
  - Method IP frequently copied without recourse

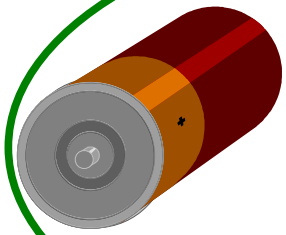
Technologies Needed



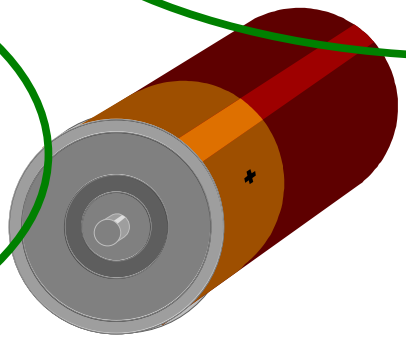
1 - Long-term safe storage of CO2 mimicking nature such as seashells *(possible in 10-20 years)*



2 - Photovoltaic panels selling for $0.33/watt with 25-year lifetime *(possible in 10 years)*

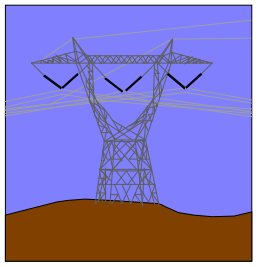


3 - Batteries with > 3x LiIon energy density for electronics & autos *(possible in 5 years)*



4 - Efficient energy storage of gigawatt hours of electricity *(possible in 30 to 100 years)*

5 - Fuel cell at $1/Watt producing electricity at 50% and hot water at 35% efficiency *(possible in 5 years)*



6 - Very low loss electricity transmission using superconducting wires *(possible in 10 to 30 years)*

Focus US/CA Startup on Strengths - Minimize Weaknesses

Strengths

- Entrepreneurial risk taking
- Science/ Engineering multidisciplinary skills
- **Workforce with diverse thinking** - variety of Edu
- **Partnership opportunities** for efficient / effective development and sales channels
- Specialized skill sets and **service infrastructure available on demand**

Weaknesses

- High cost of capital
- Difficult capital market for seed companies
- Extensive local competition for capital
- Complex government regulations
- High cost of labor

Customers & Investors Demand Results

- Promise less
  - product performance, schedule, costs, etc.
- Deliver and
- **Deliver more**