Hot Science Cool Talks

UT Environmental Science Institute

52

Our Energy Future

Dr. Michael E. Webber

February 22, 2008

Our Energy Future

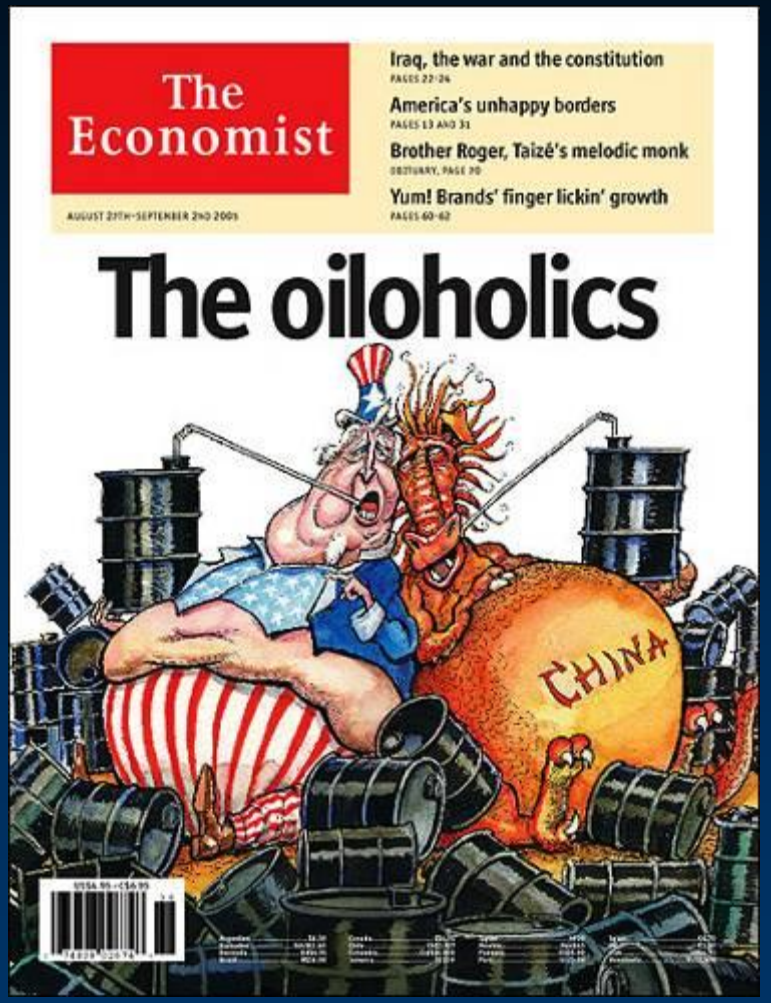
Dr. Michael E. Webber
The University of Texas at Austin

SECO
State Energy Conservation Office

ESI

America is the World's Energy Hog

- Largest consumer of energy per capita among large nations
- Largest consumer of energy overall
  - 1/4 of global total
- Largest emitter of carbon
  - 1/4 of global total



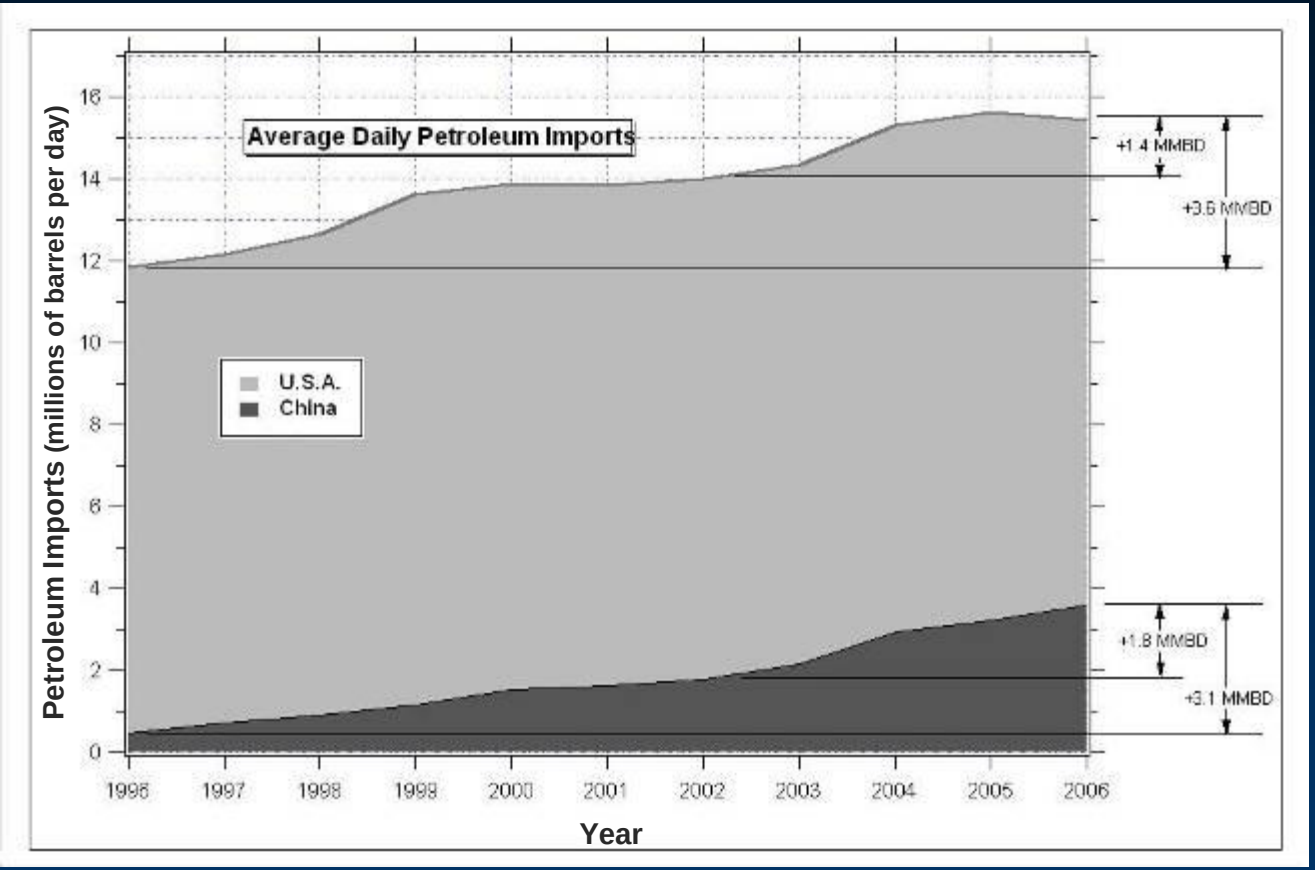
And, China is trying to catch up…

Our Energy Future

- Energy Introduction
- Energy Tradeoffs
- Energy Uses in America
- Challenges to our Energy Future
- Potential Energy Solutions
- Critical Energy Technologies of the Future
- America's Technological Breakthroughs
- Rethinking Economics for the Green Energy Era

American Energy Policy is Ridiculous

We blame China's demand for high oil prices



Source: EIA

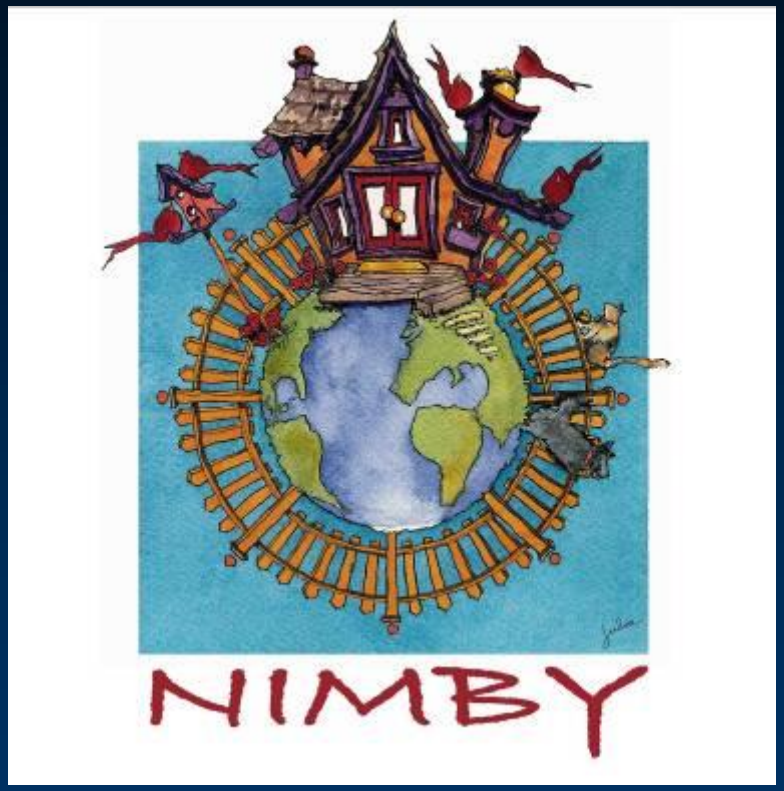
Americans Are Confused About What They Want from U.S. Energy Policy

- Two ideological camps for energy in the U.S.
  - High production and high consumption
  - Low production and low consumption
- American energy policy is the worst of both worlds
  - Low production and high consumption

Americans Are Confused About What They Want from U.S. Energy Prices

- High prices are good for:
  - Energy companies (and therefore jobs)
  - Saudi Arabia
  - Environment
- Low prices are good for:
  - Consumers
  - Our foreign policy stance towards Iran

American Attitudes About Energy Have Evolved Over Time from NIMBY to BANANA



Not In My Back Yard

Build Absolutely Nothing Anywhere Near Anyone

Energy Tradeoffs

Question: Paper or Plastic?

- Plastic
  - Good:
    - reusable, compact & consumes minimal material, does not use paper pulp
  - Bad:
    - not biodegradable, floats into ecosystems, uses primary energy resources

- Paper
  - Good:
    - reusable, renewable, biodegradable
  - Bad:
    - uses more materials, made from biomaterials

Answer: Canvas

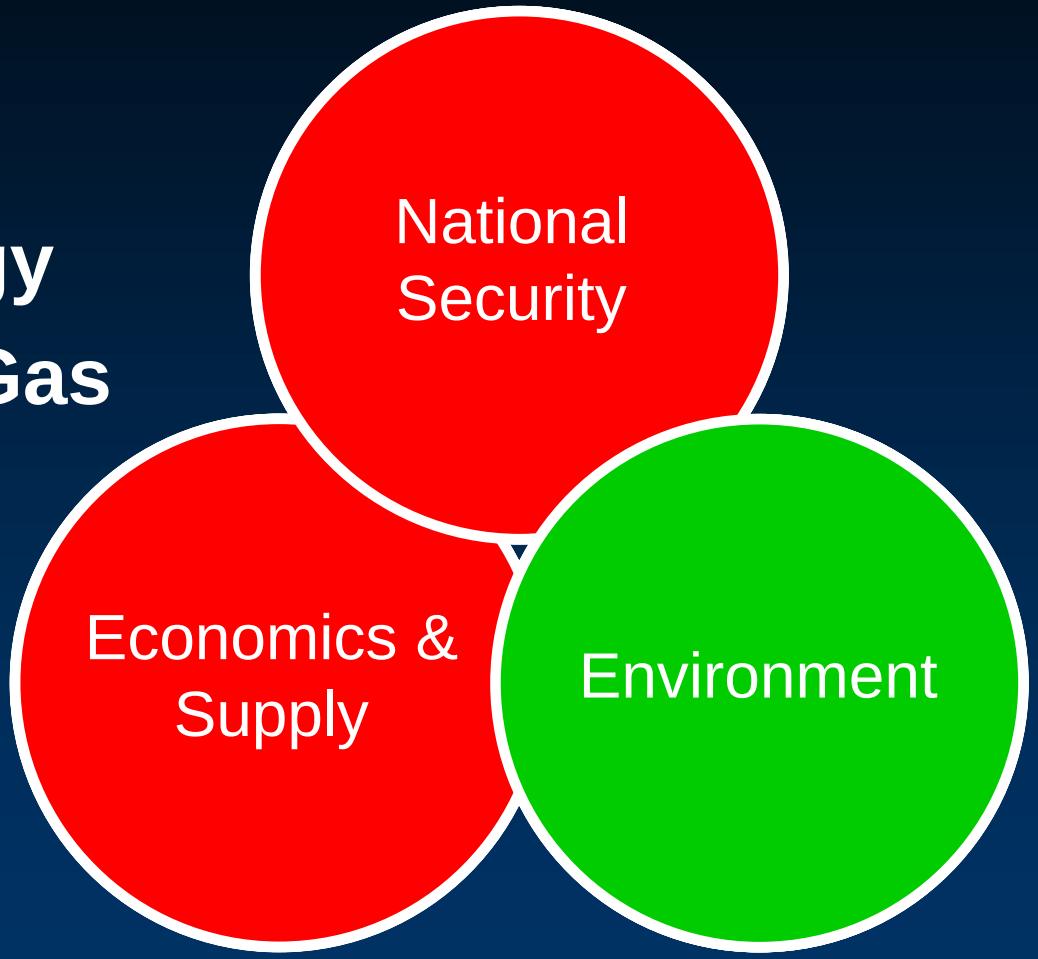
- Canvas bags have many merits
  - Reusable for many years
  - Won't float away
  - Renewable
  - Biodegradable
- "Paper vs. Plastic" is a typical energy conundrum
  - it's a false choice between only two options
  - a different option is often a better choice

The USA Must Balance Three Priorities While Addressing the Energy Problem

Oil

Bioenergy

Natural Gas

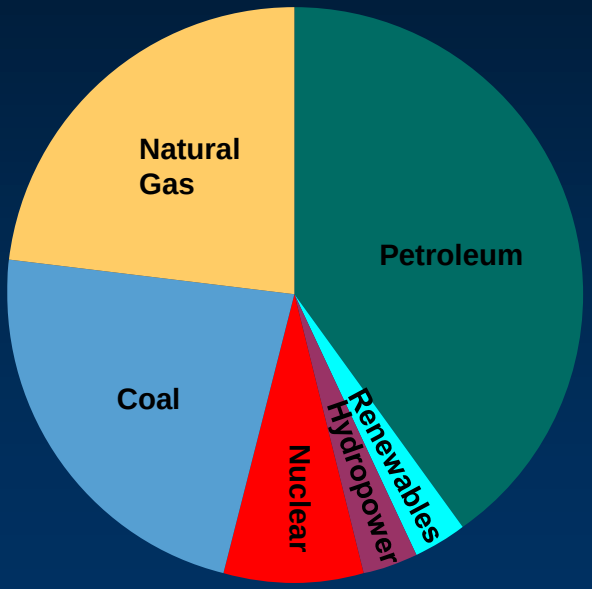


Most options for new fuels or technologies solve any one or two priorities, but not all three

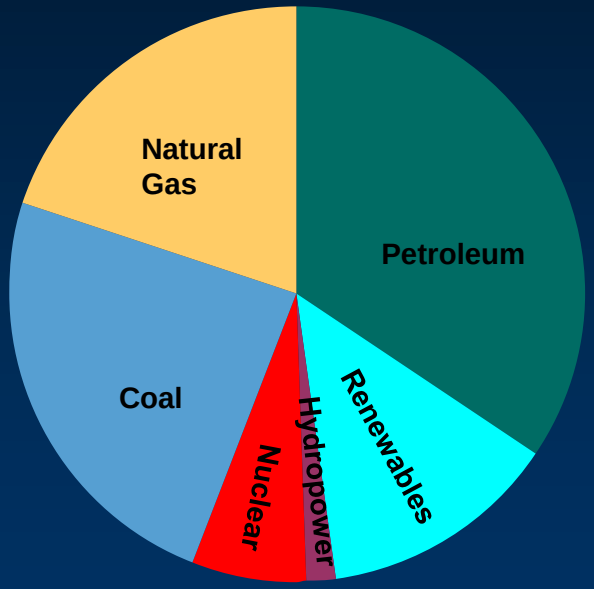
Energy Uses in America

2004 U.S. & World Energy Consumption

U.S. Energy Consumption by Fuel



World Energy Consumption by Fuel

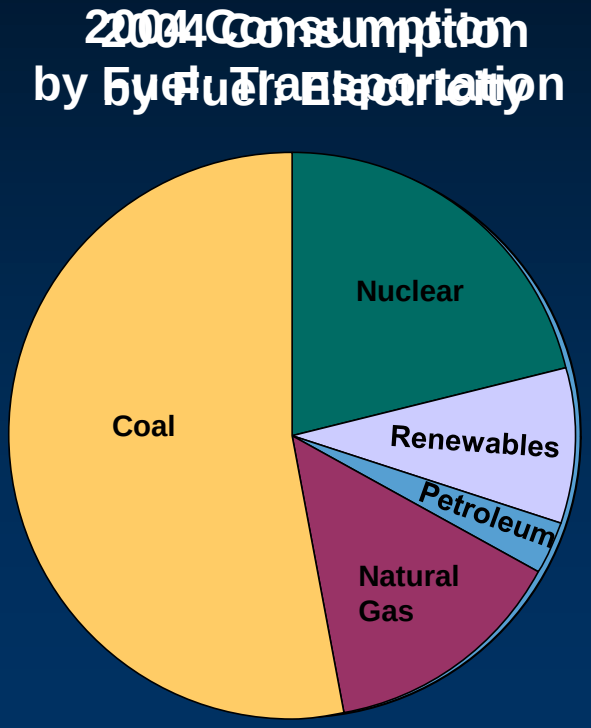


1 Quad = Quadrillion (1×10^{15}) British Thermal Unit (BTU)

Goldemberg, 2007
ESI & AEO, 2006

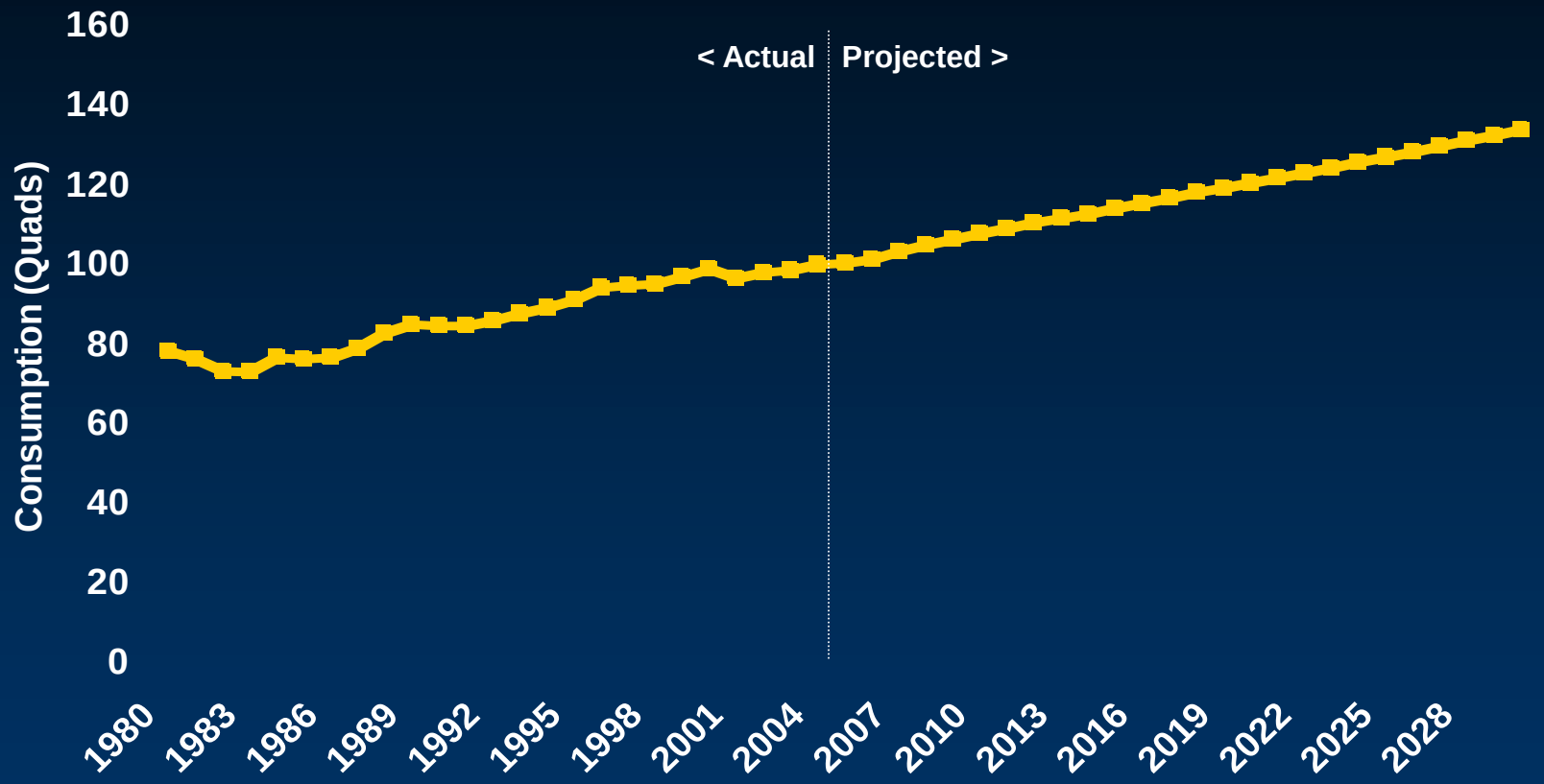
Energy Is Relevant to Many Sectors

- Transportation
- Electricity
- Food
- Water
- Industry & Manufacturing
- Residential & commercial: lighting, heating & cooling



Source: EIA & AEO, 2006

Analysts Expect Consumption Will Increase Steadily Over the Next 20 Years

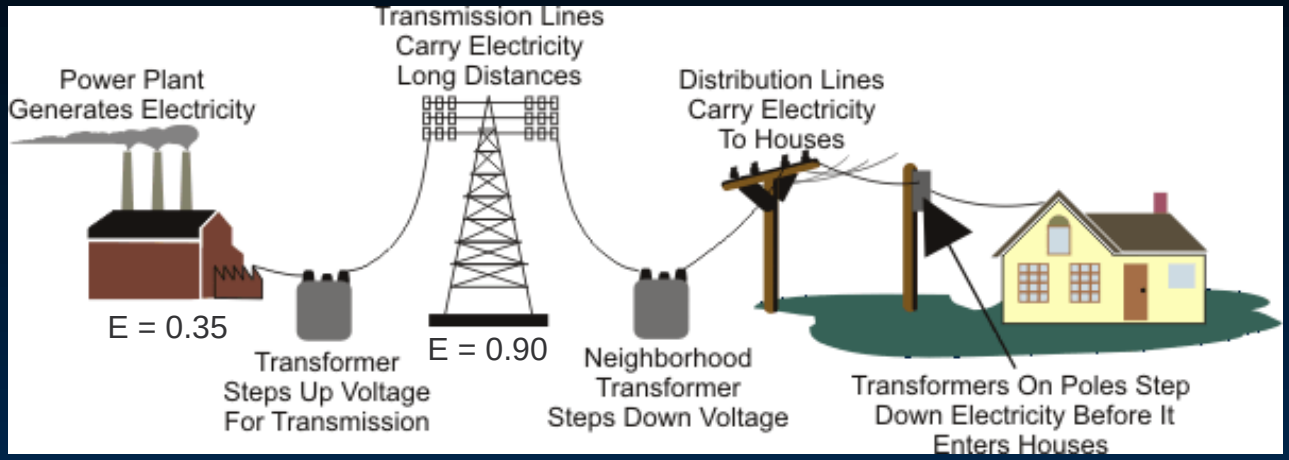


Sources of U.S. Energy Supply Are Expected to Change Very Little in the Coming 20 Years

1 Quad = Quadrillion (1×10^{15}) British Thermal Unit (BTU)

Source: EIA & AEO, 2006

The Electricity System Overall is Wasteful



- U.S. consumes ~40 quads of energy for electricity
- Lost Energy:
  - 26 quads lost from waste heat at the power plant
  - 1 quad lost from transmission
- Useful Energy:
  - 13 quads gets used as electricity (split evenly for residential, commercial, industrial use)
  - roughly 3,700 billion kWh

Source: EIA

Challenges to our energy future

Our Energy System Has Extensive Environmental Impacts

Water is used in power plants for cooling and agriculture. There are also risks of oil spills or other contaminants getting into the water supply.

Land impacts include areas for power plants and collecting fuels such as coal, uranium, biomass, and collectors for solar and wind energy.

Air impacts include smog and carbon dioxide.

Energy and the Economy

Energy Imports Are Expensive

- 14 MMBD @ $80/barrel = $1.1 billion deficit
  - every single day

- Energy Expenditures Are a Substantial Portion of Individual Expenses
  - Average family paid $2,277 for gasoline in 2006
    - a new record
  - Higher energy prices show up in
    - food
    - plastic & chemical products
    - pharmaceuticals

Keeping our addictions affordable…

Our Energy System Has National Security Impacts

Countries are in the headlines for reasons that are intertwined with energy

one new coal power plant every week.

and wants to help Iran build nuclear power plants.

The Oil Crises in the 1970s caused long lines for gasoline

1973 Arab
oil embargo

The oil weapon is used by producing nations to inflict economic pain on consuming nations

1979 Iranian Revolution

Gas weapon still works in some countries…

- Gas is a regional commodity because pipelines are land-based
- Russia has cut off gas supplies to Europe on multiple occasions
- It is not possible to rapidly replace gas supplies
  - LNG terminals cost billions of dollars and years to build

Energy Trends That Give Rise to National Security Concerns

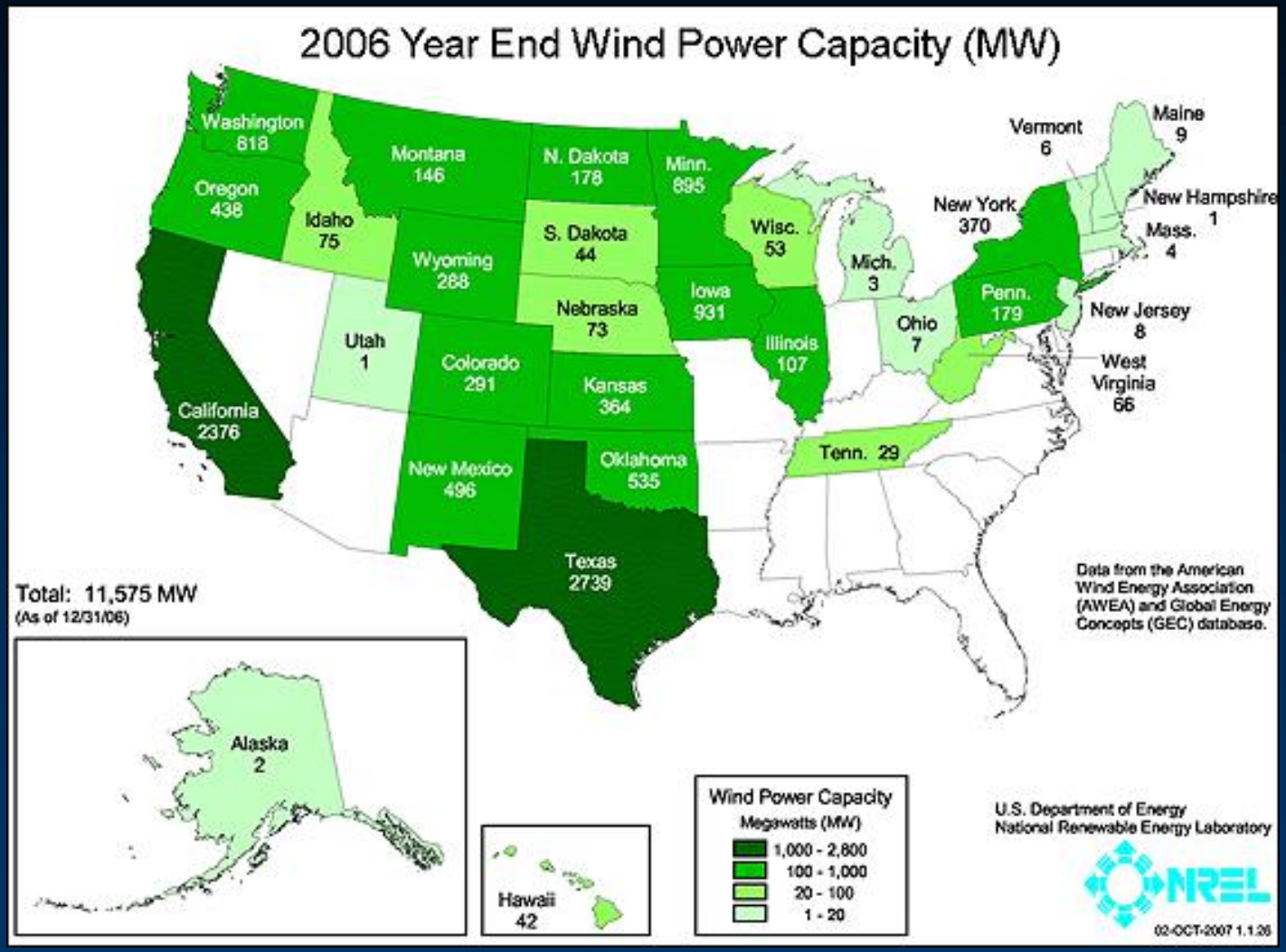
- Potential for major energy supply disruptions and market instability
- Adverse consequences of large payments to foreign oil and gas producers
- Nuclear proliferation potential with added nuclear plant investment

There Are Many Potential Energy Solutions

Wind Energy: A Success Story

- Benefits:
  - profitable
  - growing quickly
  - no emissions
- Problems:
  - intermittent wind affects overall capacity factor
    - mismatched with peak demand
  - wind is where people aren’t
  - land intensive (but dual-use)
  - noise
  - looming concerns about impacts on birds/bats

Installed Wind Capacity is Growing Quickly

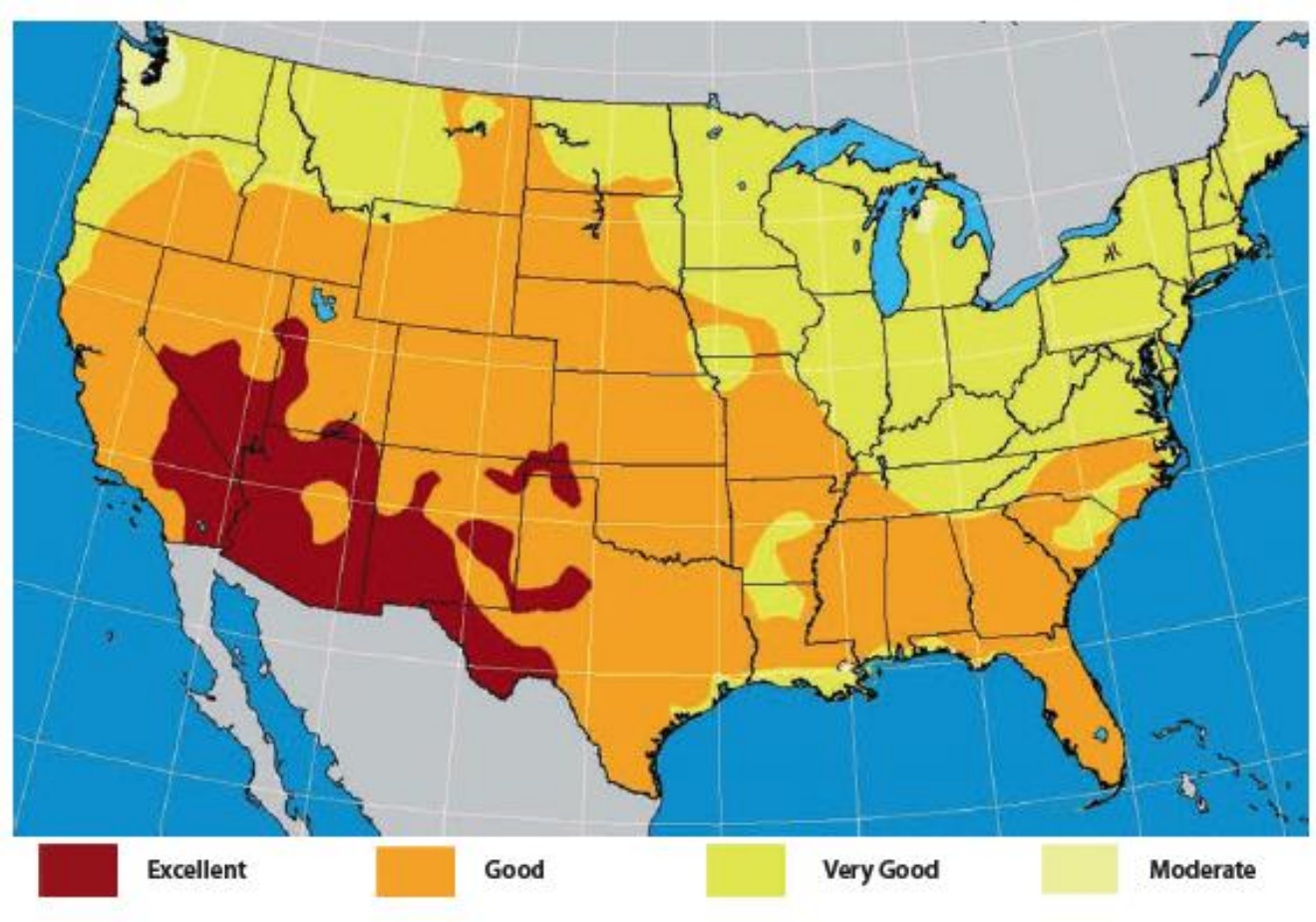


Next step: off-shore wind

Solar Energy

- Benefits:
  - the fuel is free
  - renewable
  - inexhaustible
  - matches well with peak demand
- Problems:
  - expensive capacity
  - intermittent (but somewhat predictable)
  - much of the sun is where people aren't
  - land intensive but, dual-use with urban rooftops
- Breakthroughs:
  - More efficient Direct conversion to electricity (PV = photovoltaics)
  - More efficient Concentrating Solar Power (CSP) to create steam
    - Nano-materials and thin-films
  - Cost-effective PV manufacturing
    - merging the glass and semiconductor worlds

Solar Potential is Greatest in the Southwest



Source: NREL, 2007

Nuclear Power Has Several Advantages and Drawbacks

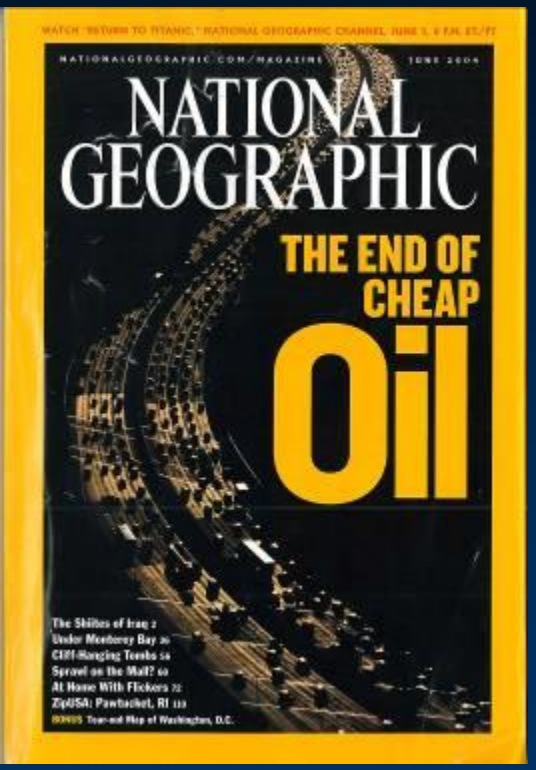
- Advantages
  - Supreme energy density
  - Minimal waste generation per kWh
  - Excellent capacity factor, maintenance & safety records
  - Domestic or friendly sources of uranium
- Disadvantages
  - Waste is radioactive and long-lived
  - Public safety (accidents, attacks)
  - Concerns about weapons proliferation

The Future of Nuclear Is Unclear

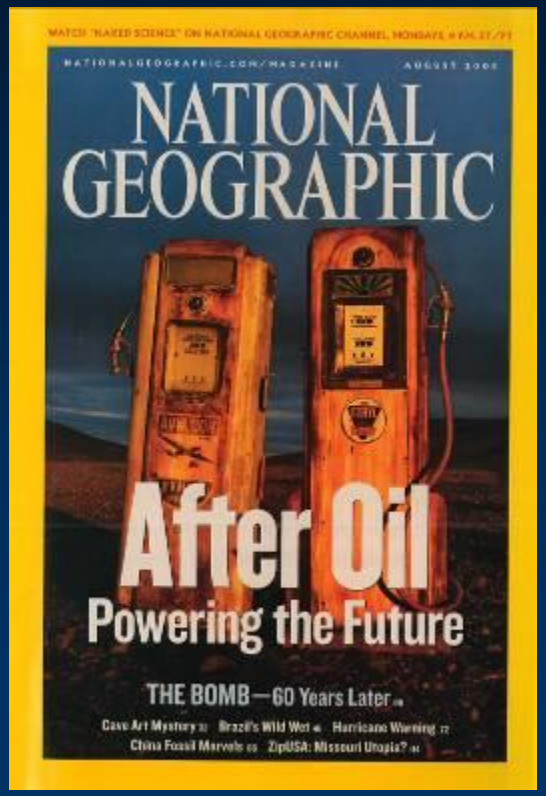
- Many have declared a nuclear renaissance is underway, but
  - 25 nuclear plants are being built
  - 76 nuclear plants are planned
  - 162 nuclear plants are proposed
- Costs of uranium have risen: $11/lb (2003) to $138/lb (2007)
- Need 3000 new nuclear reactors for world electricity demand
  - 1 new reactor per week for 60 years
- Will industrialized nations
  - allow nuclear permits to expire?
  - build more nuclear to mitigate CO2 emissions?

Source: DoE, UK Guardian

Prominent Media Attention to Oil Has Raised Questions About Resource Depletion, Costs, and Reliability of Supplies



June 2004



August 2005

May 2005

October 2003

But, the U.S. prefers to find an alternative fuel

- Hydrogen
- Biofuels
- Electricity

The Hydrogen Economy

The Hydrogen Economy as an Antidote

- We’re promised that the Hydrogen Economy will
  - reduce our dependence on fossil fuels, especially oil
  - reduce our greenhouse gas emissions
- Is it true?
- The Hydrogen Economy Calls for a few ambitious shifts in our energy use
  - Use hydrogen for a significant portion of our stationary power (e.g. electricity)
  - Use hydrogen as the primary fuel for transportation

Hydrogen Advantages

- The Key Technological Component of the Hydrogen Economy is the Fuel Cell
- Hydrogen is already manufactured globally

Hydrogen Disadvantages

- We Will Need a Lot of Hydrogen
- You Can't Mine Hydrogen
- Hydrogen Production is Energy Intensive
- Pipeline Delivery of Hydrogen is Inefficient
- Road Delivery of Hydrogen is Energy Intensive
- Hydrogen does not necessarily reduce CO2 emissions
- The Hydrogen Economy is Likely to Require Vast Amounts of Water
- Even With Aggressive Market Penetration Rates, Hydrogen Use Will be Small

Source: BMW, DoE, Webber, Bossel, 2003

Hydrogen Fuel Cell Vehicle

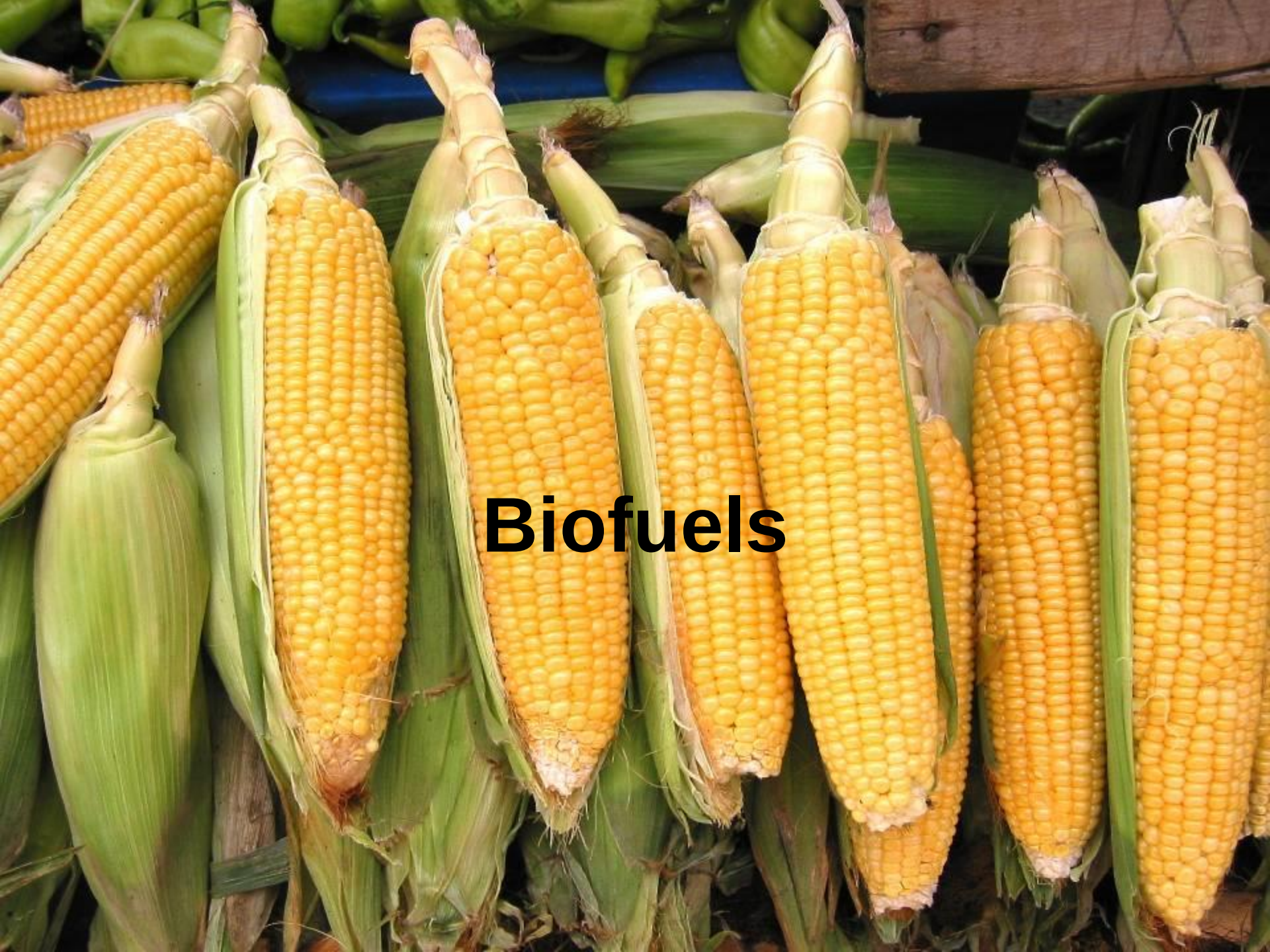
- Mercedes-Benz F-Cell
  - Range: 110 miles
  - Miles per Kilogram (City/Hwy): 57/58
  - Limited lease proof of concept

- BMW also has a hydrogen car for ~$1M
  - combustion engine

- UT is building a hydrogen fueling depot and a hydrogen bus at the Pickle Research Center
  - starts with natural gas for on-site production of hydrogen!

Hydrogen Big Picture

- Hydrogen will not make sense unless it’s produced by renewable energy and/or new direct biological or photological techniques that do not exist
- Drawbacks: lack of infrastructure, energy losses, more competitive storage technologies
- Advantages: clean at its end use, compatible with fuel cells (which have many advantages)


Biofuels

Biofuels have several advantages

- Crop-based biofuels consume CO2 during the creation of the raw fuel source because of photosynthesis
  - Can reduce well-to-wheel CO2 emissions ~25%
- Residue-based biofuels reduce demand for new fuels and bring value to waste products
- Renewable
- Feels “natural”
- Domestically grown - better to enrich Iowa farmers than autocratic regimes that are linked to terrorism

Source: DoE (EERE), GREET 1.7

Corn-Based Ethanol is Problematic

- Requires about as much energy to make as it yields
- Consumes vast amounts of fossil fuels
  - natural gas-based fertilizers
  - petroleum-based herbicides and pesticides
  - heat for fermentation from natural gas or coal
- Consumes vast amounts of water: 6 gal H2O/gal ethanol
- Expedited topsoil erosion
- Negatively impacts the nitrogen cycle
  - growing dead zone in the Gulf of Mexico

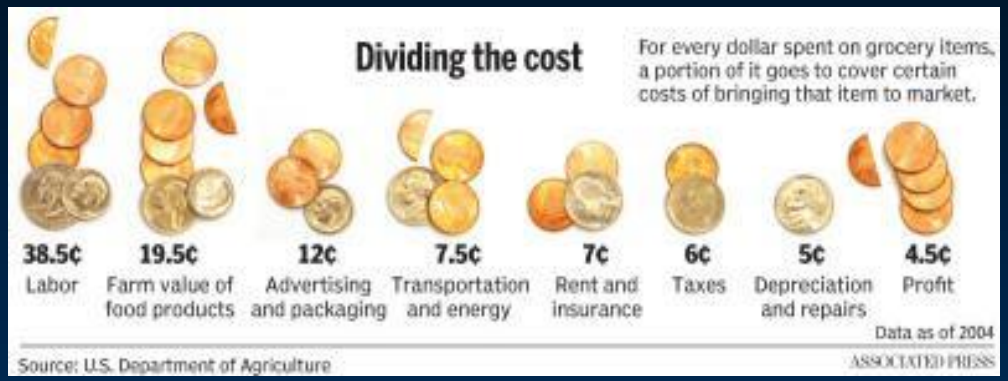
Source: DoE,Cook

Corn-Based Ethanol is Problematic, cont'd

- Worsens air quality
- Sparse refueling and distribution infrastructure
- Max U.S. capacity for corn ethanol is ~15-20B gal/year
  - today we consume ~140B gallons of gasoline
- Ethanol has lower energy content than gasoline by ~30%
- Ethanol corrodes pipelines, so it must be trucked (with Diesel)
- Corn cannot be piped, so it must be trucked (with Diesel)

Source: DoE, Cook, Jacobson

In the Competition of Food vs Fuel, Food Wins



- Using food crops for fuel will inevitably drive up the prices of food
  - already causing price increases
  - ranchers are pushing back
  - riots over tortilla prices in Mexico

Austin American Statesman, October 9, 2007

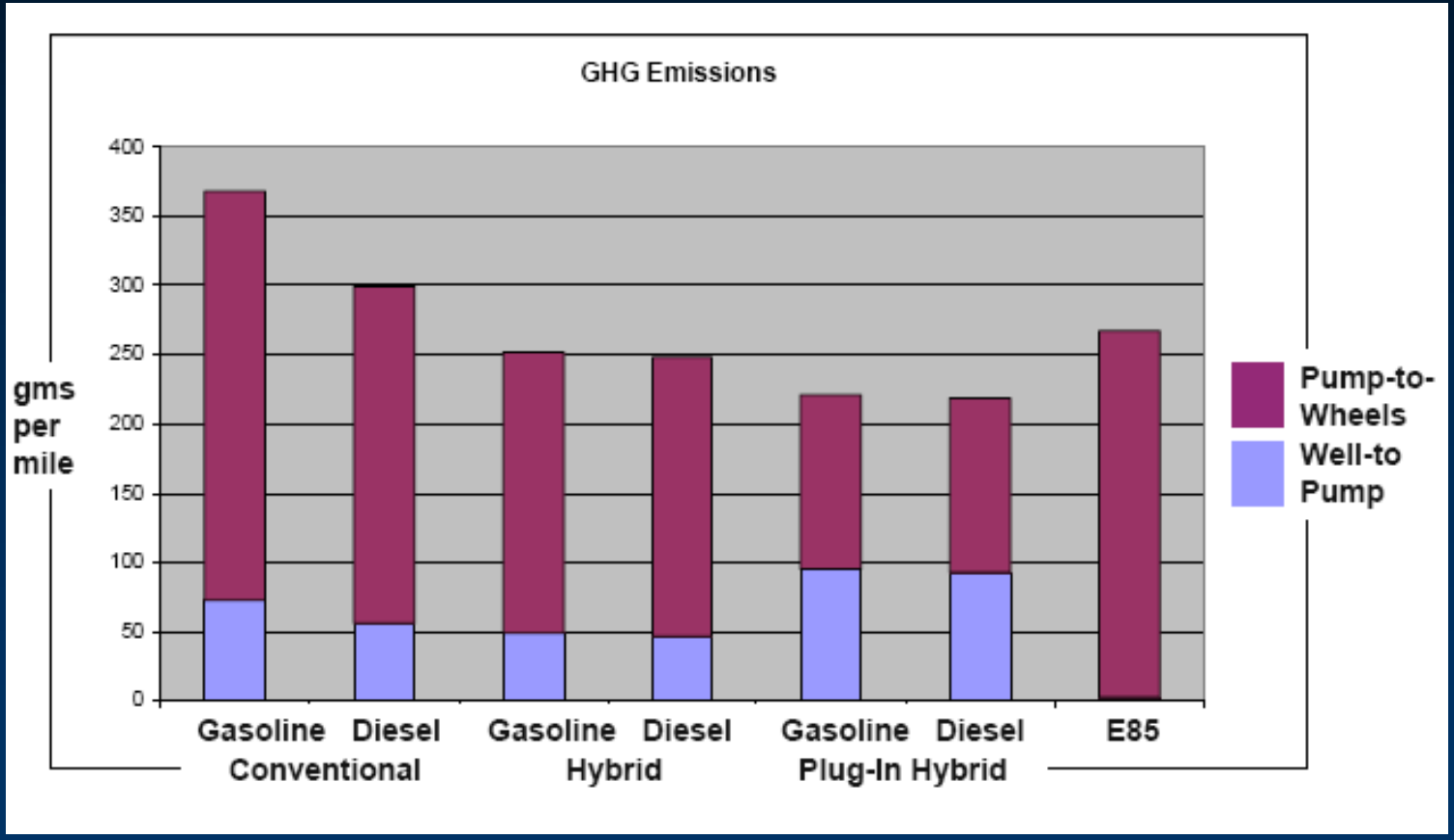
From Dot Com to Dot Corn

Plug-In Hybrid Electric Vehicles

By coupling transportation to the power grid, plug-in hybrids and electric vehicles introduce many advantages

- Easier to manage emissions of pollutants and greenhouse gases at thousands of power plants rather than hundreds of millions of autos
- Load leveling with off-peak battery charging
- Reduced petroleum consumption

Summary of Greenhouse Gas Emissions: Plug-in Hybrids Look Very Appealing



Source: Argonne National Labs

PHEVs Are a Very Promising Solution, But Have Their Own Drawbacks

- Requires vast amounts of cooling water for thermoelectric power
- Does not necessarily reduce air pollution--just shifts it
- Hazardous mining tails from battery production

Source: Toyota, EPA, Webber, PNNL

The Promise of Algae

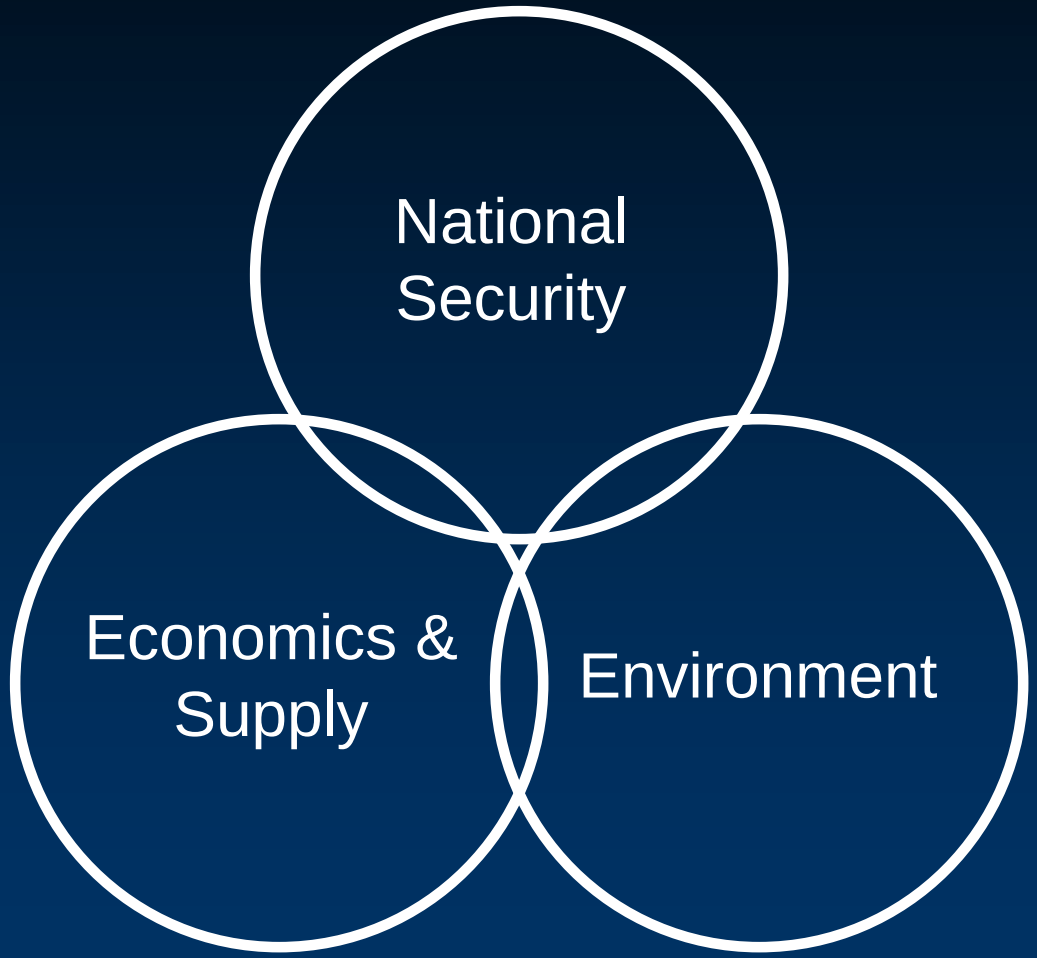
- Algae has grown for billions of years….whether you want it to or not
- Algae only needs three ingredients to grow
  - lots of sunlight
  - lots of CO2
  - lots of bad water
  - TEXAS has all three!
- “The Pondscum Project”
  - growing algae with brackish water in W. Texas for biodiesel and CO2 capture

Critical Energy Technologies of the Future

The Energy Problem Is Comprised of Three Converging Crises

- Three energy crises:
  - Climate Change
  - Resource Depletion
  - National Security & Violent Extremism
- All three are related to and amplify each other

The USA Must Balance Three Priorities While Addressing the Energy Problem



Most options for new fuels or technologies solve any one or two priorities, but not all three

Defining the Critical Technologies

- Which technologies allow us to either

  1. develop domestic resources (coal, wind, solar), or
  2. import energy from “friendly” nations

  …without causing environmental problems, or running into supply shortages

- Which technologies can bridge the gaps and enable win-win solutions?

The Three Critical Technology Barriers to the Green Energy Transition

- Energy Storage
- Carbon Capture and Sequestration
- Supergrids

Small Scale Energy Storage Enables Electrified Transportation

- Electrified transportation can use abundant domestic resources
  - including renewable sources such as wind and solar
- It is easier to minimize/mitigate the environmental impact of ~1500 power plants rather than 200+ million autos
- Key parameters that determine deployability
  - gravinometric density (energy storage per unit mass)
  - volumetric density (energy storage per unit volume)

There Are Many Different Small-Scale Energy Storage Technologies

- Capacitors
- Inductors
- Flywheels
- Batteries (static and flow)
- Carriers: hydrogen and other liquid fuels

Large Scale Energy Storage Enables Greater Use of Intermittent Renewable Sources

- Intermittency is the limiting factor for domestic renewable sources such as wind and solar
- Key parameters that determine deployability
  - Volumetric density (energy storage per unit volume)
  - Total volume or total capacity

Pumped Hydroelectric

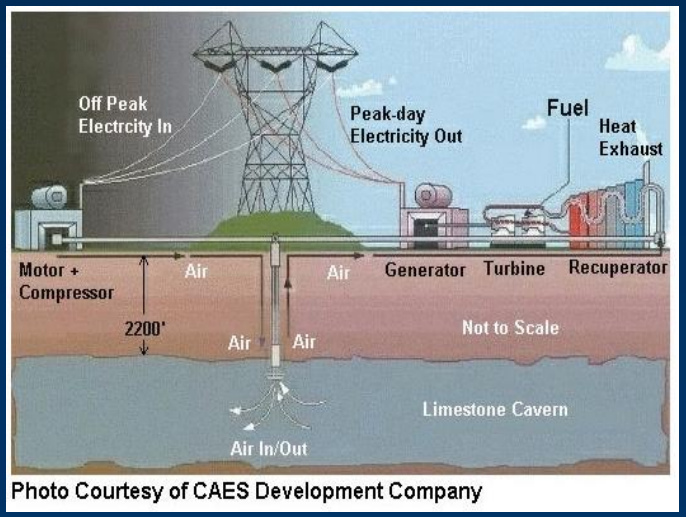


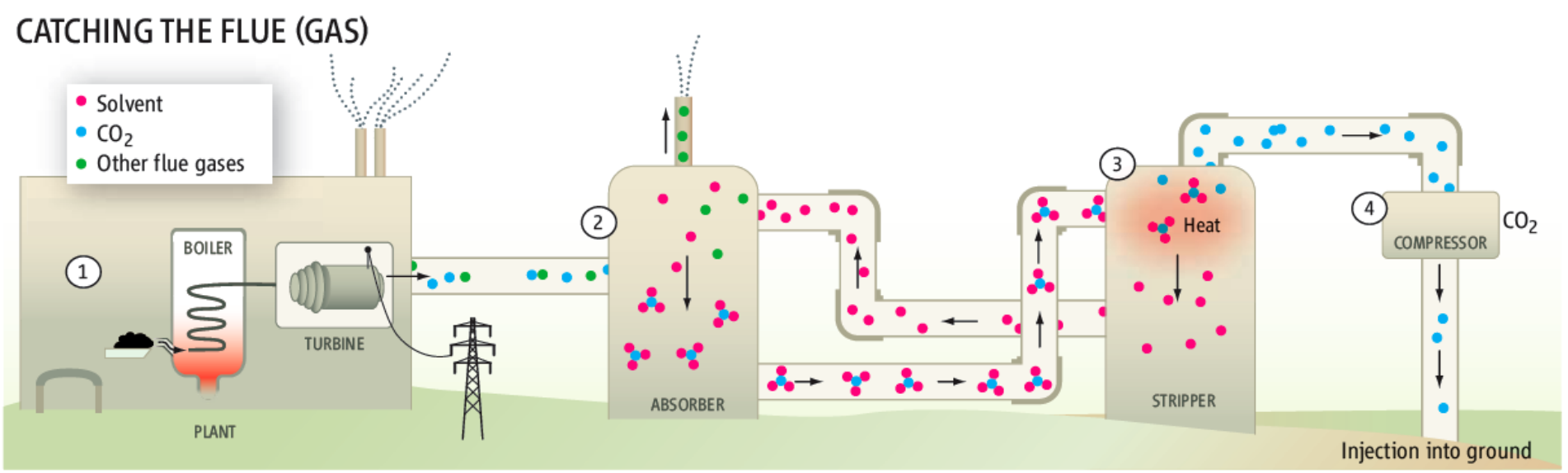
Photo Courtesy of CAES Development Company

Compressed Air Energy Storage (CAES)

Carbon Capture and Sequestration is a Critical Technology

- CCS enables the use of domestic solid fuels to make electricity and liquid fuels
  - coal and oil shale
- Key questions
  - What is the best capture method:
    - post-combustion: stripping, algae,…
    - pre-combustion: IGCC,…
  - What is the best sequestration method:
    - geological, ocean,…
    - embedded in products,…

Chemical Absorption & Stripping Is a Leading Approach For Post-Combustion CO_2 Capture



- Requires significant materials & heat input
  - capturing 90% of the CO_2 lowers output by ~30%
- Absorbing chemicals
  - Monoethanolamine (MEA) binds with CO_2
    - already used industrially to separate CO_2 & natural gas
  - Chilled ammonium carbonate

Science, July 2007

Growing Algae Is Another Method for Post-Combustion Carbon Capture

Carbon capture with algae in Arizona

- CO_2 + H_2O + sunlight gives algae
- 10-30x more productive per acre than palm oil
- Only grows during the day, which is when you want maximum capacity
- NOT really sequestered
  - re-used for fuels

What is a Supergrid?

Super efficient grid operating over long distances

Supergrids Are A Critical Technology

- Supergrids can connect remote sources of renewable power with locations of demand
  - It’s always windy and sunny somewhere
- Supergrids can connect remote large-scale storage
  - with locations of demand
  - with sources of intermittent renewable power
- Supergrids can create a global market for electricity

The American Love Affair With Technology

Americans Believe Technology Will Save the Day

"…there is excessive confidence in the potential of particular technical fixes that are seen to hold (often near-magical) solutions to our problems and whose early commercialization is forecast to bring prosperous future."

Vaclav Smil, "Energy at the Crossroads"

Don’t Bet the House on Technological Breakthroughs

There Is No Technical Solution

- “The Tragedy of the Commons”
  - Garrett Hardin, *Science*, 1968
- During the nuclear arms race, both sides invested heavily in newer technologies that simultaneously increased military power and decreased national security
  - conclusion: “this dilemma has no technical solution”
- There are a class of problems that have no technical solution:
  - population
  - nuclear war
  - energy & environmental corruption

Non-Technical Solutions Are Likely to Be More Effective Than New Technologies

- Behavioral Shifts
- Cultural Shifts
- Removing policy barriers
- Innovative Markets
  - Real-time pricing
  - Environmental dispatching
  - Including market externalities
    - environmental impacts
    - national security implications

There are many “Green” behaviors, cultural forces, and personal choices available

- Maintain proper tire pressure
  - air is practically free!
  - can save ~0.25 MMBD of petroleum in the U.S.
- Lower the speed limit
  - can save ~1 MMBD of petroleum in the U.S.
- Reduce trips
- Use mass transit
- Compressed workweek

Source of oil savings estimates: IEA 2005

Rethinking Economics for the Green Energy Era

There is a cultural sense that our economy's current approach to energy isn't working

Current Economic Thinking Is Antiquated

- Growth is the only goal of economic theory
  - personal, city, state, national
  - implies more resource use, more impacts, more destruction of natural assets
- More population and more consumption is the key to economic growth

Towards a New Economic Theory

- Old Economics yielded the Industrial Revolution
  - Nature is abundant and people are scarce, so increase labor productivity
    - automation, mechanization
- Need New Economics for the next Industrial Revolution
  - People are abundant and nature is scarce, so increase resource productivity
    - efficiency, resource reuse

Source: Hawken, Lovins & Lovins, Natural Capitalism

Questions?

END

Michael E. Webber, Ph.D.
University of Texas at Austin
webber@mail.utexas.edu
http://www.webberenergygroup.com

Associate Director
Center for International Energy & Environmental Policy
Jackson School of Geosciences

Assistant Professor
Thermal Fluids Area
Mechanical Engineering

Fellow
Strauss Center for International Security & Law
LBJ School of Public Affairs

Dr. Michael E. Webber

Michael Webber is the Associate Director of the Center for International Energy and Environmental Policy in the Jackson School of Geosciences, Fellow of the Strauss Center for International Security and Law at the LBJ School of Public Affairs, and Assistant Professor of Mechanical Engineering at the University of Texas at Austin, where he trains a new generation of energy leaders through research and education. Prior to joining UT Austin, Michael was a principal investigator for analytical studies of policy issues relevant to energy, innovation, the U.S. industrial base, and national security at the RAND Corporation. Previously, he was a Senior Scientist at Pranalytica, a startup making high-fidelity sensors for homeland security, industrial and environmental monitoring applications. Michael has published more than a dozen peer-reviewed scientific articles; been awarded two patents; and given dozens of lectures, speeches, and invited talks in the U.S. and Europe, including briefings for members of Parliament, senior decision makers in Government, and executives in the private sector.

Michael's educational background includes a B.A. with High Honors(Plan II Liberal Arts) and B.S. with High Honors (Aerospace Engineering) from UT Austin, and an M.S. (Mechanical Engineering)and Ph.D. (Mechanical Engineering, Minor in Electrical Engineering) from Stanford University, where he was a National Science Foundation Fellow from 1995-1998. In 2005, Michael was recognized by the College of Engineering at UT Austin as an Outstanding Young Engineering Graduate. Michael was selected as a Next Generation Fellow of the American Assembly in 2006 and a Marshall Fellow for 2007. From 2004 to 2006 he was a board member for the Hope Street Group, which is a non-profit bi-partisan national organization for young professionals interested in promoting policies that expand opportunity and economic growth.