Addressing America’s Energy Challenges

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America’s energy challenges (I)

- Energy security
  - Reliable and economic energy supply
  - Mostly about liquid hydrocarbons for transport
  - **Goal:** 3.5 M bbl/day reduction in crude use (~25% of daily transport use)
America’s energy challenges (II)

- Greenhouse gas emissions
  - Mostly about CO₂ from stationary sources (power and heat)
  - **Goal**: ~20% reduction by 2020, 80% by 2050

15 October 2009
America’s energy challenges (III)

- These goals require significant changes in energy sources, storage, transmission, and uses.

  Identify, develop, demonstrate, and deploy cost-effective, material, and timely solutions, and create jobs in the process.
The energy security problem

- Transportation is powered almost exclusively by crude-derived liquid hydrocarbons
  - Energy density (50 times better than the best battery), ease and economy of use, existing infrastructure, availability
US liquid fuel use

The diagram shows the historical and projected use of US liquid fuels from 1970 to 2030. The categories include:

- **History**
  - Total
  - Biofuels
  - Transportation
  - Industrial
  - Residential and commercial
  - Electric power

**Millions bbls per day**

- **Year**

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The energy security problem

- Transportation is powered almost exclusively by crude-derived liquid hydrocarbons
- The US imports a large fraction (~60%) of its crude supply
Import fraction of US liquid fuels

Oil imports have grown

Oil imports depend upon price
The energy security problem

- Transportation is powered almost exclusively by crude-derived liquid hydrocarbons
- The US imports a large fraction (~60%) of its crude supply
- Crude demand rising with global development
- “Easy” crude resources are increasingly concentrated geographically and politically
NOCs have most oil and gas reserves; OPEC < 40% of daily production

12 M bbl/day @ $70 = $250B/yr sent abroad
What can we do about transport?

- Encourage vehicle efficiency and conservation
  - CAFÉ standards
  - Vehicle downsizing, lightweighting, behavior
  - Make the cost of driving evident?
    (full amortization, fuel/road tax, insurance, …)
Average fuel economy of new light-duty vehicles

Fuel efficiency depends upon fuel price and vehicle technology.
What can we do about transport?

- Encourage vehicle efficiency and conservation
- Encourage novel/alternative vehicle technologies at cost
  - Improved internal combustion engines
    - HCCI, Exhaust Gas Recycling, Variable Valve Timing, selective cylinder deactivation, ...
  - Gradual electrification paced by battery development
    - Hybrids, plug-in hybrids, battery vehicles
  - DOE AVT and battery loan programs
What can we do about transport?

- Encourage vehicle efficiency and conservation
- Encourage novel/alternative vehicle technologies at cost
- Encourage (with consistency) a diverse portfolio of unconventional fuels
  - Biofuels
    - Lignocellulose, feedstocks, better molecules, algae?
  - What is the government doing?
    - Renewable fuel standards
    - Bioenergy centers, integrated biorefineries
Greenhouse gas emissions in 2000 by source

Transport is one of several sources

Non-energy emissions are significant

Total emissions in 2000: 42 GtCO2e.

Energy emissions are mostly CO₂ (some non-CO₂ in industry and other energy related). Non-energy emissions are CO₂ (land use) and non-CO₂ (agriculture and waste).

Source: Stern Review, from data drawn from World Resources Institute Climate Analysis Indicators Tool (CAIT) on-line database version 3.0
Mauna Loa CO$_2$ data, 1958-2004

Source: Oak Ridge National Laboratory, Carbon Dioxide Information Analysis Center

Increasing atmospheric CO$_2$
Challenges in stabilizing atmospheric CO$_2$

- The CO$_2$ concentration is rising at an accelerating rate; 550 ppm reached by 2050
- Global emissions are growing at ~2-3% per year
Growing Global CO₂ Emissions (1850-2004)

*from Fuel Burning, Cement Manufacture, and Gas Flaring
Challenges in stabilizing atmospheric CO\(_2\)

- The CO\(_2\) concentration is rising at an accelerating rate; 550 ppm reached by 2050
- Global emissions are growing at 2-3% per year
- The long CO\(_2\) lifetime means that the atmosphere accumulates the emissions
  - Drastic reductions in emissions are required implying large and major changes in energy production / use
The long CO₂ lifetime is highly problematic

Modest emissions reductions will only delay, but not prevent, high concentrations
Drastic emissions reductions are required to stabilize concentrations
**CO₂ emissions and GDP per capita**

**CO₂ emissions and GDP per capita (1980-2005)**

**Per capita emissions must be quartered**

Today’s global average

Required for stabilization

Source: DOE EIA database (2008)
**CO₂ emissions, OECD and non-OECD, 1865-2005**

Total, 1865-2005:
- **OECD**: 730 GtCO₂ (64%)
- **Non-OECD**: 405 GtCO₂ (36%)

Total, 1993-2005:
- **OECD**: 158 GtCO₂ (51%)
- **Non-OECD**: 150 GtCO₂ (49%)

Most of this century’s emissions will come from the developing world.

Source: Adrian Ross, 10-06-08
Categories of US Energy Consumption

Buildings use about 40% of total US energy

- Buildings 40%
- Industry 32%
- Transportation 28%
- 22% Residential
  - Cooking 5%
  - Electronics 7%
  - Wet Clean 5%
  - Refrigeration 8%
  - Cooling 12%
  - Lights 11%
  - Water Heat 12%
  - Heating 31%
- 18% Commercial
  - Cooking 2%
  - Computers 3%
  - Refrigeration 4%
  - Office Equipment 6%
  - Ventilation 6%
  - Water Heat 7%
  - Cooling 13%
  - Heating 14%
  - Lights 26%
  - Other 13%
What do we do about heat and power?

- **Conservation and efficiency**
  - Make the price of electricity evident
  - Efficiency standards (appliances…)
    - ($190M ARRA to Ohio)
  - Regulatory incentives
    - (pay utilities for conservation)
  - Buildings, city design
    - (DOE weatherization programs)
    - ($267M ARRA to Ohio)
  - Smart grid and storage enable renewables, encourage efficiency, provide reliability
What do we do about heat and power?

- Conservation and efficiency

- **Set a price on carbon emissions**
  - Sources favored by technology and economics are:
    - Natural gas
    - On-shore wind
    - Small and medium hydropower
    - Nuclear fission
    - Carbon capture and storage (in demo soon)

- **Portfolio standards**
  - Renewable versus low-carbon
US power in 2008 (4,112 billion kWh)

- 48.5% Coal
- 21.3% Natural Gas
- 19.6% Nuclear
- 6.0% Conv. Hydropower
- 3.1% Renewable Energy
- 0.4% Other
- 1.1% Petroleum

U.S. Renewable Generation: 125 billion kWh

- 1.4% Biomass
- 0.4% Geothermal
- 0.1% Solar
- 1.3% Wind

Source: EIA
Other includes: pumped storage, batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, tire-derived fuels, and miscellaneous technologies.
* Includes on- and off-grid capacity.

Renewables are <4% of US power
US gas supply by source

Unconventional gas sources will grow
Renewables are small, but growing rapidly, especially wind.
Renewable electricity costs (2008)

Coal/gas-fired ~ 3-6 cents
Nuclear ~ 7 cents
Costs of CO$_2$ reduction

Technology development can reduce costs
Energy technologies change slowly

US energy supply since 1850

Source: EIA
IT technologies change rapidly

Sales of Personal Audio/Video since 2000
Because energy innovation is different

- **Energy Frontier Research Centers**
  - Find solutions to fundamental scientific roadblocks to clean energy and energy security

- **HUBS proposal**
  - Create sustained, tightly focused research centers with contributors from academia and industry

- **REgaining our ENERGY Science and Engineering Edge (ReENERGYSE) proposal**
  - Energy scientists (technology and policy)
  - Clean energy workers

- **ARPA-E**
  - Develop and deploy breakthrough energy technologies

- Coordination among many Federal/State agencies
Other aspects of the solutions

- **Technically informed, coherent, stable government policies**
  - Educated decision-makers and public
  - Focus on the most material/lowest-cost measures
  - For short/mid-term technologies
    - Avoid picking winners/losers
    - Level playing field for all applicable technologies
  - For longer-term technologies
    - Support for pre-competitive research
      - Hydrates, fusion, advanced [fission, solar, biofuels, storage]

- **Business needs reasonable expectation of “price of carbon”**
Questions/Comments?