Transportation Energy and Alternatives

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Modern Miracles

- Transportation and Energy use allows us to live and even thrive in harsh climates i.e. Arizona and Iceland.
- Even the poor among us have access to better nourishment and with more variety than the extremely rich just a few hundred years ago, all due to transportation.
- Fruits and vegetables can be eaten out of season due to transportation and refrigeration.

If we decrease transportation energy use do we decrease these real benefits?
Estimated U.S. Energy Use in 2009: ~94.6 Quads

Source: LLNL 2010. Data is based on DOE/EIA-0384(2009), August 2010. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports flows for non-thermal resources (i.e., hydro, wind and solar) in BTU-equivalent values by assuming a typical fossil fuel plant “heat rate.” The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 80% for the residential, commercial and industrial sectors, and as 25% for the transportation sector. Totals may not equal sum of components due to independent rounding. LLNL–MI–410527
Energy Pathways in Transportation

- Energy resource (typically chemical energy)
- Harvest
- Refining (if required)
- Transport to use location
- Convert to shaft power (Typically this goes through temperature to pressure to shaft power)
- Finally “The wheels on the bus (train, car, etc) go around and around”
What Primary Energy Resources Can be Used?

Some pathways have more obstacles than others.
Current status of transportation technology

- Fuels are presently dominated by liquids
  - Gasoline
  - Diesel
  - Jet A
- Conversion is dominated by the internal combustion engine for terrestrial applications and gas turbine engines for aircraft
- Why?
Characteristics of Fuel Production, Storage, and End use

- Availability (practical)
- Cost
- Ease of use
- Safety
- Power density
- Energy density
- Pollution and other externalities
Liquid vs Gaseous Fuels

- Safety
- Infrastructure
- Experience
- Ease of Conversion
Ease of Use

Hydrogen refueling in Munich, Germany

Gasoline Station in Indonesia

“You will never see widespread use of the fuel unless you can put it in a barrel”
Power Density of Engines

Figure 2.2 Aviation Engine Power Density

4 stroke engine
2 Stroke Engine

\[ C_4H_{18} + 12.5(O_2 + 3.76N_2) \rightarrow 8CO_2 + 9H_2O + 3.76(12.5)N_2 + \]
Energy Losses Analysis

2000 4WD Sierra/Silverado Pickup EPA Combined Cycle Fuel Energy

Indicated Work = Energy into Piston

Indicated Work Energy 37%

Exhaust & Coolant Heat Energy 63%

Fuel Heat Energy

Exhaust Heat Energy

Coolant, Convected, and Radiated Heat Energy
2000 4WD Sierra/Silverado Pickup EPA Combined Cycle
Indicated Energy Losses

- Engine Friction: 27%
- Aerodynamic Drag: 23%
- Vehicle Deceleration (Braking): 10%
- Driveline/Transfer Case: 10%
- Transmission: 11%
- Tire Rolling Resistance: 8%
- Generator: 4%
- Final Drive: 3%
- Power Steering: 2%
- Brake Drag: 1%
- Engine Driven Fan: 1%
Isn’t the IC Engine Dead yet?

Do you like…

• Transportation?

• Cheap food and water?
  – Pumped irrigation In Northern CA area there is about a 50/50 split between electric pumps and IC driven pumps
  – Off road transport ie tractors Harvesters etc

• Electricity? Not all generators are IC driven but some are.

Are we dead yet?
Future Alternatives

- Must attain technical specifications of current technology
  - Must have equal or better performance
  - Must have equal or lower cost
  - Must be largely transparent to user

“The stone age didn’t end because we ran out of stones”
Increasing Efficiency

Technical Specifications—utility, acceleration, top speed, lifetime, reliability, safety, visibility, comfort
Motivation for Alternative Fuel Use

- Energy Security/Economic Security
- Rising Cost of Fossil Fuels
  - Increasing demand
  - Decreasing supply
- Emissions

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Source: Exxon Mobil (2004) and own calculations.
What are the “alternative fuels” Potentially used for Transportation

- Biogas (primarily for onsite electrical generation) LFG, manure, etc
- Bioderived fuels (through fermentation) alcohols (energy crops displace food crops)
- Syngas derived fuels (CO+H2 catalytically reacting into liquids) primarily alcohols Wood, coal, Nat Gas or crop residue as a feedstock
- Hydrogen
Possibilities

- Hydrogen fuel cell vehicles
  - Hydrogen economy?
  - Electric economy?
- Biofuels and other Renewably Produced Fuels
  - land use?
  - Food vs Fuel?
- Hybrid Vehicles (commercial now)
- Plug in Hybrid
- Battery Electric Vehicles
  - Full scale
  - Neighborhood EV
  - E-bikes
- Grid connected vehicles (subways, trams, buses)
- HPVs and Bikes

Increasing Efficiency of Diesel and Otto cycles
Energy/cost is not always the bottom line

- Characteristics of End Use are Critical!
  sometimes but not always this is only for niche applications IE
  - Combustion stoves vs Electrical stoves
    (this has implications for developing countries)
  - Diesel emissions
  - Applications which require/prefer zero emissions (Forklifts golf carts etc)

- Infrastructure and previous investment IE
  - Liquid fuel infrastructure exists in many locations (gaseous infrastructure does not)
  - Capital in Place
  - Billions of dollars invested solely in tooling for mass production of the ICE

Trump Cards-
Safety, Health, Style,
Sound, Smell, Visible
Dirt, Reliability,
Performance.
29 Quad BTU per annum (2007) used for US Transportation

- 969 GW
- At 185 W/m² solar power (avg. US solar insolation not including Alaska) and 10% conversion efficiency
- $52.4 \times 10^9 \text{ m}^2$ or $52.4 \times 10^3$ sq km
- At 25% land use this increases to 209,636 sq km or 51.8 million acres
- Total Area in California= 424,000 sq km

But you can increase efficiency of Transport and Energy use, cover roofs etc with PV
Erickson’s Outlook

• Estimated 1 billion Cars in World.
• Everyone wants to live like a North American/European and why not?
• Average U.S. household owns 2.2 automobiles
• Its coming! lets deal with it!
  – Congestion (build roads parking traffic systems etc)
  – Increased Energy Use ( lets use what we have, increase fuel availability, domestically produce biofuels renewables etc)
  – Govt. Regulations (these will come where there are drastic problems. Can we preempt these through pollution controls etc?)
  – Encourage alternatives where appropriate (One size does not fit all ) auto transport is the desired alternative (mobility freedom, personal independence)
  – Best technology may be combinations Hybrid etc use strengths of each technology
The future

\[ C_4H_{18} + 12.5(O_2 + 3.76N_2) \rightarrow 8CO_2 + 9H_2O + 3.76(12.5)N_2 + \]