• Sustainable Mobility
• Plug-In Vehicles (PEVs)
• PEVs & Architecture

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Transportation Dominates Oil Consumption

Transportation Dominates Oil Consumption... and a growing majority of oil consumed in U.S. is imported...

Gas & Diesel advantages:
- High Energy Density
- Energy Carrier and Storage
- Plentiful
- Pervasive & safe distribution
- Low Cost

Issues:
- CO2 Emissions
- Energy Security
- Stable supply
- Source Countries
- Trade Deficit

Source: Dr. Thomas Edgar
The University of Texas
Oil and the Trade Deficit

- The U.S. is losing its ability to generate export revenue from Advanced Technology.
- Advanced Technology thought to be the offset for importing goods such as oil.
- Normally, currencies would adjust to re-establish equilibrium.
  - Dollar not declining from “flight to safety” into U.S. Treasuries at this time.
The U.S. Transportation Situation
No Single Silver Bullet

- U.S. land mass is huge: mass transit can help in some urban areas.. But..

- Autos are a consumer durable: provide utility, enjoyment, fashion, convenience...
  - An emotional/aspirational consumer good

- Problems:
  - Emissions: the challenge now is \( \text{CO}_2 \)
  - Oil Imports: Energy Security, Trade Deficit
  - Congestion...

- How to achieve “Sustainable Mobility”
Sustainable Mobility

- The chemical process of burning hydrocarbons produces CO2
  - CO₂ emissions need to be reduced, but not to zero
    - NOTE: Humans emit CO₂, trees absorb CO₂

- 3 Basic methods to improve Fuel Economy (hence emissions)
  - Improve Powertrain Efficiency (or use a different fuel)
  - Lower weight of vehicle
  - Improve Aerodynamics
Internal Combustion Engines
Dominant & Still Improving

- Gasoline
  - SIDI
  - V.V.T.
  - Variable Displacement
  - HCCI
  - Turbo/Super-charging
  - Scuderi Split-Cycle
  - OPOC
  - Heat recovery

- Diesel:
  - Common-Rail Clean Diesels

- Even greater potential improvements when combined w/hybridization

- Perpetual concerns over cost & durability
Which Propulsion System has the most flexibility of Energy Resources?
Which Energy Carriers are likely to be low cost, secure, & wide spread?
Plug-In Vehicles (PEVs)
Earlier Attempts of Electric Vehicles

- Electric Vehicles predate gasoline vehicles
  - Early 1900s more EVs on the road than Gas powered cars
  - By late 1930s, EVs were dead
    - Superior energy density of liquid fuels
    - Electric Starter invented by Cadillac
    - Increasing range, speed, refueling advantages of gas powertrains
  - EV problems of range, speed, recharging not solved for most of 20\textsuperscript{th} century

- 1990s: CARB ZEV Mandate forced R&D
  - Modern electronics solved all problems (except Batteries)
    - Driven by advances in electronics by computer industry
    - AC conversion to DC for charging solved by modern electronics
  - Electronic controls: efficient, durable, lightweight, low cost
  - Electric Motors: highly efficient
  - ...but batteries still did not have sufficient energy storage...
Hybridization of Internal Combustion Engines

- Internal Combustion Engine + Electric Motors + Electronics + Batteries

- Hybrid Electric Vehicles (HEVs)
  - Toyota Prius, Ford Escape, Honda Insight, Civic, Accord, Chevy Tahoe
    - Also, “mild-hybrids”: Saturn Vue Greenline, Saturn Aura, Mercedes S-class

- Brake energy recapture, start/stop, variable displacement engine/motor combination

- Proved the viability of electrified vehicles: Electronics + Big Batteries + Motors
PEVs: Plug-In Electric Vehicles

- **Non-Range-Extended: BEV** (Battery Electric Vehicles)

- **Range-Extended vehicles: eREVs and PHEVs**
  - eREV: Extended Range Electric Vehicle, series hybrid, BEV w/range extender
  - PHEV: Plug-in Hybrid Electric Vehicle, parallel hybrid, blended mode operation
  - Electric + gas combination to solve traditional BEV “Range Anxiety” problem, displace petroleum use, and improve ICE Fuel Economy

Informative websites:
www.gm-volt.com
www.calcars.org
http://www.pluginamerica.org/vehicles/
The Potential of Plug-In Vehicles

- 70% of U.S. drivers travel less than 33 miles/day

- Li-Ion batteries
  - Driven by consumer electronics
    - “Tipping Point” technology now for PHEV
  - Safety, durability, cost challenges are surmountable

- 50-70% lower cost per mile to operate: electricity cheaper than gas

- Synergy with the electric grid
  - Charge during valley when grid is underutilized & wind is strongest
  - Centralized & remote emissions
  - V2G: massive energy storage for the grid

- Lower CO2 emissions

- Reduced oil imports
Alternative Powertrain Adoption Outlook

2007 ZEV Panel vehicle projections

Year (Approximate)

HEV
PHEV
FCEV
FPBEV
H2ICV
CEV
NEV

Vehicle Technology Status (Global Volume):
Demo (100’s/year)
Pre Commercial (1000’s/year)
Low Volume Commercial (10,000’s/year)
Mass Commercialization (100,000’s/year)

Source: CARB 2007 ZEV Technology Review
Achieving Sustainable Mobility

- No one solution fits all customers’ requirements
- Some solutions beneficially solve some problems (but not all)
- Consumer behavior matters the most
- Technology based improvements viable, but even larger gains can be derived by consumer preference/behavior changes
  - Powertrain efficiency + mass reduction + aerodynamics
- U.S. unwillingness to tax motor fuels to encourage efficiency (and sufficiently maintain infrastructure)
- Inexpensive Fuels + efficient vehicles = more vehicles + more miles/year
Consumer Behavior

- Vehicle selection (horsepower, size, features), maintenance
  - (e.g. tire pressure), Driving Habits: speed, trip-grouping, carpooling

- Technologies & Policy create new alternatives
  - Exciting technologies under development

- Customer willingness to accept increased costs/trade-offs for Clean Diesels, Hybrids, eREVs/PHEV, BEV, FCV, lower rolling resistance tires, lighter materials, underbody aerodynamics...
Plug-In Vehicles and implications to architecture
PEVs and Architecture

- PEV charging (refueling) is a different paradigm
  - Gasoline station: fast refill
    - But typically a place you don’t want to spend much time
  - PEV charging: Could be nearly as fast as gas station
    - but also new paradigms:
      - Charge where you will naturally be (i.e. home, work)
      - Charge where you WANT to be (Movies, shopping)

- Can only site gas stations in select locations
  - But can potentially re-charge a PEV at any building (but at different rates/speed)
PEV Charging Locations

Home

Work

Public

Fleet
Where Are the Cars?

Fleet Distribution during week

Source of Data - 2001 National Household Travel Survey; GM Data Analysis (Tate/Savagian) - SAE paper 2009-01-1311
Charging Infrastructure

- **Public**
  - High Visibility
  - Commercial/Retail
  - Public Education and Outreach

- **Workplace**
  - Corporate, Municipal Parking Lots

- **Residential** *(majority)*
  - Satisfying consumer-driven home installation process
  - Permits, electricians, inspections, meters, rates

Sources: GM, Nissan, Ford, Toyota
Electric Vehicle Supply Equipment (EVSE)

Level-1 Charger
(120 Volts AC)
Fits in trunk, plug in anywhere with an standard 120V outlet

Level-2 Charger
(240 Volts AC)
Twice as fast, permanently mounted to garage wall at home

Public Charging Station
(120/240 Volts AC)
Includes secure payment capability

DC Ultra-Fast Charging Station
(up to 500 Volts DC)
Near gas station- equivalent recharge time, expensive, not for homes
Solar panels + PEV storage

- Charge PEVs from local renewable sources (Solar)
  - Save excess in (large) PEV battery
  - Excess stored energy to power house at night
  - Carbon Neutral Residence improve solar economics

- Use PEV as residential emergency generator

Source: NREL TR-640-41410: Costs and Emissions Associated with Plug-In Hybrid Electric Vehicle Charging in the Xcel Energy Colorado Service Territory
PEVs as Emergency Power Source

Coordinated PEVs as power source for Mobile Hospitals, Rescue or Command centers
Charging Station Installation
Other Considerations

Owner Occupied Home EVSE is the least complicated to install

Multifamily & public locations more complicated
- Ownership: Renter vs Owner
- Parking: Assigned vs unassigned
- Building Codes, Covenants, and Restrictions
- Decision Makers: Property Owner, Mgmt, HOA?
- Service Scenarios:
  - Common or individual Charging Stations
  - Un-metered or common meter or pay-as-you-use
  - Fairness, scheduling, reservations, exclusion

Building Codes for future PEV charging stations
- Conduit/panels/electrical equipment
- parking architecture to support future PEV charging stations
Questions??

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