Accelerating Vehicle Electrification

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For updated PDF of presentations:
www.calcars.org/downloads

2008: First preview of a new industry
Ali Emadi, Felix Kramer,
Andy Grove, & Andy Frank
at Plug-In 2008 in San Jose
A quick reminder: Electricity is better than gas!

I am about to publish a White Paper that uses EPA, CAFÉ, and Argonne National Labs data to establish that electric/gasoline-ICE Energy Economy Ratios (EERs) are actually much higher than the 3.0 that the CEC uses for all calculations of the value of electric propulsion:

- **5.2 est. (73% better)** for used light trucks likely to be candidates for plug-in conversion
- **4.7 (57% better for EVs than 3.0)** for passenger cars meeting 2009 CAFÉ standards
- **3.6 (20% better)** for passenger cars meeting 2020 U.S. / 2016 California CAFÉ standards
- **2.8** for the 2004-9 Prius which, at 64 mpg EPA, *already* meets 150% of 2020/2016 CAFE

1. **ECONOMICS: CHEAPER** --
   electric miles at a quarter the cost

2. **CLIMATE: CLEANER** --
   50% less CO2, even on the half-coal *national* power grid

3. **ENERGY SECURITY: DOMESTIC** --
   Only 1.5% of U.S. electricity comes from oil
Nonprofit Startup: CalCars’ successes & challenges

- In 2004, no one believed PHEVs were viable, and auto manufacturers claimed that no one would ever want to plug in a car.
- CalCars:
  - Demonstrated low-tech conversions of a mass produced hybrid into a PHEV,
  - Aggressively pursued public awareness, education, and partnerships with environmental, national security, technology, and other advocacy groups
  - Worked to build grassroots consumer pressure on industry and government
  - Created an open-source technology exchange
### Unprecedented broad support & alliances

#### HYBRID CONVERSION COMPANIES
- Plug-In Conversions Corporation
- Green Gears
- Hymotion
- Hybrido

#### JOBS & FACTORY CONVERSIONs
Editorial: Minnesota lays a bet on cars of the future
- Apollo Alliance

#### UTILITIES & FLEET BUYERS
- Become A Plug-In Partner
- Southern California Edison
- Pacific Gas and Electric Company
- SMUD

#### SUPPLIERS & COMPONENT-MAKERS
- Coulomb Technologies
- A123 Systems
- EDTA

#### ENVIRONMENTALISTS & EV FANS
- Plug In America
- Friends of the Earth
- Rainforest Action Network
- Repower America

#### NEO-CONS / GEO-GREENS
- Center for Security Policy
- Securing America's Future Energy

#### RechargeIT
- Enterprise
- Google
President Obama/Congress on PHEV Policies

Stimulus Package and Since

- $2,500-$7,500 tax credit: 200,000 new plug-ins from each manufacturer
- 10% tax credits up to $4,000 for plug-in conversions
- $2 billion advanced battery research
- Plug-in cars as way to meet higher CAFE MPG standards
- $400 million for infrastructure deployment, regional deployment
- $300 million federal purchases
- 30% tax credits advanced manufacturing investments
- Goal: 1 million PHEVs by 2015

Notice that this is NOT seen as a way to EXCEED existing future CAFÉ stds

Key element of Waxman-Markey global warming solutions bill

Nov ’07 Googleplex; March ’09 SoCalEd. ’06: “When it becomes possible in the coming years, we should make sure that every government car is a plug-in hybrid.”
18+ carmakers interested; race to be first; few timetables
(see CalCars Carmakers page summary)

Chevy Volt: 2009 demo, 2010 production; Opel Ampera; blended PHEV SUV 2011

2009: small demo fleet
But for near- & mid-term impacts, retrofits are needed!

New plug-ins, even at a 10x faster rate than hybrids (21% vs. 2.2% in 10 years) won’t be a significant percentage of fleet until 2025-2030

- This penetration rate of new plug-ins extrapolates from Obama’s goal of 1M by 2015; up to a decade faster than CEC’s maximum-EV Scenario 3
- This conversion rate requires no more battery manufacturing capacity than for new PHEVs alone (though the factories are needed sooner)
- Both may be optimistic. In any case, retrofits can accelerate effectiveness by at least a decade!

Note: biofuel penetration rate is a broad estimate

Source: CalCars white paper (see last slide)
But can ICE vehicles be converted en masse?

Once again, CalCars has begun a campaign for something crucial but not yet seen as viable. This time, for proof-of-concept demonstrations, we have discovered several start-up companies that have applied known technologies in innovative ways.

• Converting gas guzzlers -- the nearly 50% of light vehicles classified as trucks -- is easiest, saves the most gasoline, and is the most economically viable.

• Conversions to PHEVs have the highest market appeal, but conversions to BEVs are easier and can still satisfy many specific fleet requirements.

• Several companies are demonstrating ICE-to-PHEV conversions that *add to, instead of replacing*, the existing drivetrain, thus radically reducing costs.

• Batteries are the concern and the enabler
  
  – Volume Li-ion pack costs are already safe, long-lived (though needing road testing), and approaching $600/useful-kWh in high volume, or $300 per mile of light truck electric range, so a 20-EV-mile PHEV-20 light truck’s battery would cost just $6000.

  – Several non-Li-ion chemistries are viable, too: NiMH is mature, and carbon-foam lead-acid may soon better NiMH at much lower cost; either can power PHEV-20s.
But can ICE vehicles be converted en masse (con’t)?

- As with new vehicles, **automotive-volume production can lower costs dramatically**
  - The CEC Investment Plan can help achieve that
  - HEV-to-PHEV-20 conversion costs, already $10-14k for the Prius with just 100’s built, **should sink below $6k -- $8k for larger sedans and $10k for light trucks** -- in “minimum automotive” quantities of tens of thousands

- There is a cost of creating custom conversions for each vehicle model and production series (several model years), but this is already figured in and will first be done for high-volume vehicles with millions of each on the road.

- Further costs for **ICE-to-PHEV conversions** that retain the OEM drivetrain are limited to
  - The cost of the motor/generator, its control and power electronics, its mechanical connections and mounting, and their installation
  - One-time R&D expertise, time, and expense required to perfect the admittedly-difficult ICE/electric control system
  - We project installed prices of **$10k for sedans and $16k for light trucks** in “minimum automotive” quantities

- **ICE-to-BEV conversions** do not need the tricky ICE/electric control system of PHEV conversions, but do need bigger, more expensive batteries as well as electrification of power steering, brakes, and cabin heating/cooling.
  - We project **BEV conversions** to sell in “minimum automotive” volumes for
    - $17k for sedans with 50 mile EV range; $27k for 100 miles
    - $25k for light trucks with 50 mile EV range; $40k for 100 miles
But *can* ICE vehicles be converted en masse (con’t)?

- Auto manufacturers, their supply chains, and their dealers could *develop new revenue streams*, increase customer loyalty, create green jobs, and help the environment, our economy, and national security — all by:
  - Providing their customers with upgrade paths for the products they own, like most other high-tech industries.
    - Computers, smart-phones, etc, are all upgradeable with additional and/or improved parts (e.g. more RAM, higher-capacity disk drives, next-generation optical drives, additional software applications).
    - Software manufacturers routinely make more money selling upgrades than the original program.
    - Why not treat automobiles, too — which remain in customer hands far longer than most products, long enough to become hopelessly obsolete without an upgrade path — as a revenue stream throughout their lifetime?
  - Using shut-down factories and laid-off workers to manufacture conversion kits that dealers can then earn income by installing

- The California Air Resources Board is proving, with its pioneering new standards for certification of HEV-to-PHEV conversions, that vehicle conversions can be safe, low-emissions, and affordable.

- The CEC can help provide the seed funds and paradigm legitimacy to create a new automotive business model, move small-scale ICE-to-PHEV innovators into volume production and partnership with auto manufacturers, and launch a new industry.

- The start-up conversion businesses up next have each developed a valuable conversion, but have not yet found the funding for third-party validation and production tooling.
Hybrid Electric Vehicle Technologies, Inc.

World’s First Plug-in Hybrid Electric Pickup Truck, hevt.com Chicago IL
• Founder: IIT Prof. Ali Emadi, leading power electronics expert.
• 40 million trucks/buses in U.S; 2 million added annually.
• F-150 prototype design scales to F-250, 350, school and transit buses.
• Simple payback: 2-5 years.

- Uniquely converting America’s most popular pickup truck, the Ford F-150, to a plug-in hybrid; more than 15 months of testing.
- Up to 30 miles all-electric range; up to 40% MPG improvement as a hybrid (beyond all-electric range).
- Up to 180,000 pounds of CO2 savings in 12 years; V2G capability; increased low-speed torque for better towing.
- ESTIMATED COST IN VOLUME PRODUCTION: $15,000 OR LESS.
- Seeking investment funding.
Rapid Electric Vehicle Technologies, Inc.

rapidelectricvehicles.com
Vancouver British Columbia

- Developing partnerships with Canadian dealers.
- All-electric and PHEVs starting with Ford trucks and SUVs.
- Contracts pending with public and private fleets.
- Seeking investment funding.

REV 300ACX
Pure Electric

Vehicle Details

Max Speed: 100mph / 160 kmh
Range: Up to 200 km's
Acceleration: 0-100 <7 seconds
Charge time: 3.5 hrs at 240V
Efficient Drivetrains Inc.
efficientdrivetrains.com
San Francisco-Sacramento region

• CoFounder & CTO Prof. Andy Frank, UC Davis, inventor of modern PHEV.

• Working with car/truck OEMs, conversions, first-tier suppliers to embed innovative drivetrain system designs, components -- parallel, series, and retrofit technologies.

• Patent portfolio: hybrid fundamentals, continuously variable transmissions, energy management systems.

• Projects in U.S., Europe, and Asia: two-wheeler, V2.0 parallel PHEV drivetrain for light and medium duty, inline CVT, CVT integration, and controllers.

• 2008/2009 operations funded from customer revenues.

• Seeking $2-3M in expansion funding now.
Poulsen Hybrid, LLC

poulsenhybrid.com  Shelton, CT

$8,600 suggested retail price (before tax incentives) for complete Poulsen Hybrid System installed with 4.5 kWh Lithium-ion batteries, wheel motors and brackets.

- Conversions for the most popular compact cars & SUVs.
- 20-30 mile battery assisted range matches 70% of US daily commutes.
- Mechanical connection to drivetrain is via 2 hub motors that replace hubcaps.
- Business model scales to convert tens of thousands/year.
- Creates green authorized installer jobs in communities everywhere.
CalCars: a resource for a broad new campaign

- Watch News-Archive & ICE-conversions Pages

- Subscribe to CalCars-News
- Print/distribute PDFs from Downloads Page
- And thanks for all you’ve done—and will do!
Follow our White Paper on ICE Conversions including news, photos; links to pioneering companies

[calcars.org/ice-conversions.html]

Download eight-page White Paper with links to CalCars Tech Lead Ron Gremban’s spreadsheets and analyses

[calcars.org/scrap-or-retrofit.html]

Watch our 1:45-minute video

[calcars.org/audio-video.html]