

Accelerating Vehicle Electrification

September 9, 2009
CEC Staff Workshop
SCAQMD, Diamond Bar, CA

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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



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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:

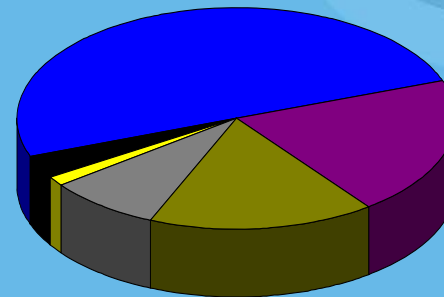
- **5.2 est. (73% better) for used light trucks** likely to be **candidates for plug-in conversion**
- **4.7 (57% better for EVs than 3.0) for passenger cars meeting 2009 CAFÉ standards**
- **3.6 (20% better) for passenger cars meeting 2020 U.S. / 2016 California CAFÉ standards**
- **2.8 for the 2004-9 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



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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

Technology
(demos)

Advocacy
(buyers)



Progress: 2004



2006



2009



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Unprecedented broad support & alliances

HYBRID CONVERSION COMPANIES



SUPPLIERS & COMPONENT-MAKERS



JOBS & FACTORY CONVERSIONS

Editorial: Minnesota lays a bet on cars of the future



ENVIRONMENTALISTS & EV FANS



UTILITIES & FLEET BUYERS



NEO-CONS / GEO-GREENS



RechargeIT



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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** Notice that this is *NOT* seen as a way to *EXCEED* existing future CAFÉ stds
- \$400 million for infrastructure deployment, regional deployment
- \$300 million federal purchases
- 30% tax credits advanced manufacturing investments
- **Goal: 1 million PHEVs by 2015**
- 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."



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Accelerating Vehicle Electrification

18+ carmakers interested; race to be first; few timetables
(see CalCars Carmakers page summary)



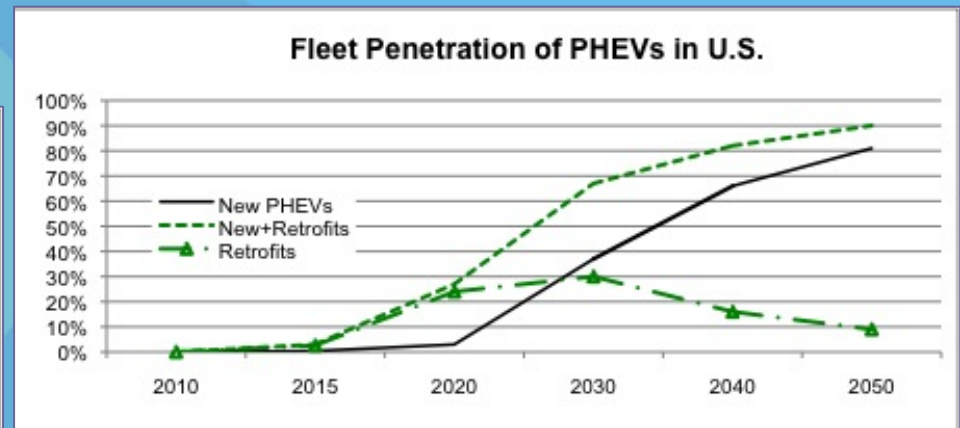
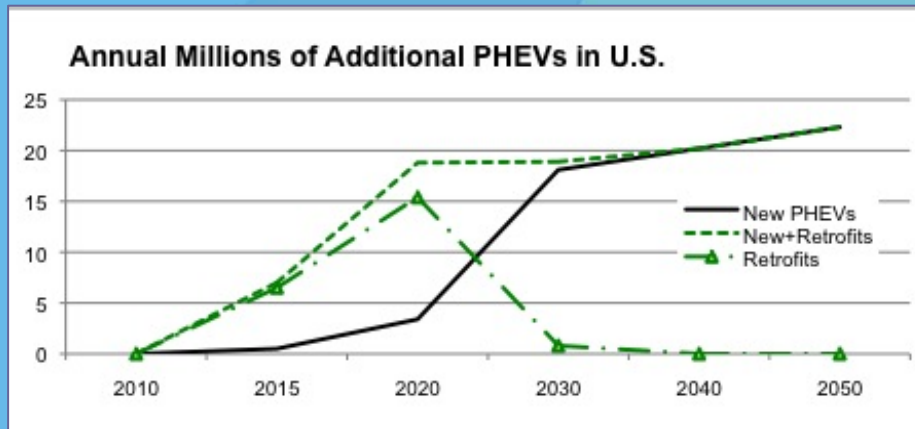
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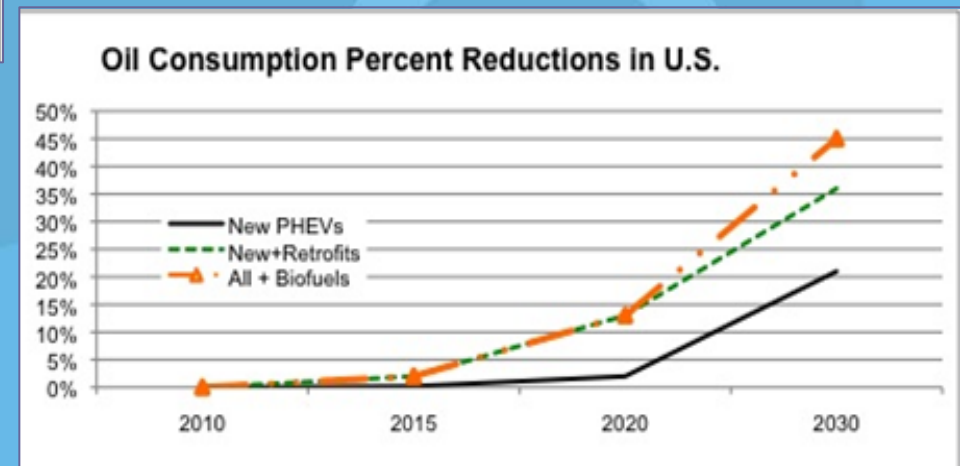
But for near- & mid-term impacts, retrofits are needed!

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

Source: CalCars white paper (see last slide)



- 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



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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.



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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**



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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.



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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.**



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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



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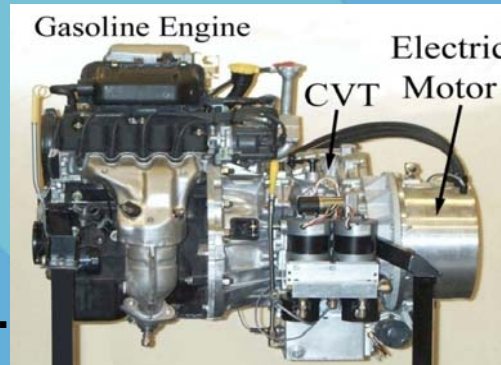
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Efficient Drivetrains Inc.

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.



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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.



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CalCars: a resource for a broad new campaign

- Watch News-Archive & ICE-conversions Pages

04/29/09: [Read Our Analysis & Think Differently About Scrapping and Converting Gas Guzzlers](#)

03/27/09: [Our New Guzzler Video; Other Media; Apply for US Billions; GM Book; Correction](#)

01/21/09: [Our Testimony on Conversions Bolstered by 140+ Thoughtful Appeals](#)

11/12/08: [Multiple PHEV Conversion Solutions Gain Momentum](#)

10/03/08: [Should We Crush Gas-Guzzlers? Or Convert Them to Plug In? An Analysis](#)

09/20/08: [Another F-150 Conversion company](#) (Envia Rapid Electric Vehicles)

08/04/08: [Andy Grove's Ambitious Conversions Goals at Plug-In 2008](#)

07/28/08: [PI-08: Company News: GM/V2Green/Coulomb/Google/HEVT/PlugInSupply](#)

07/13/08: [Andy Grove in Washington Post; Volt, Tesla Other Reports](#)

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- And thanks for all you've done—and will do!



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Get snapshots of issues & emerging companies

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

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PLUG OK

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POPULAR: [Convert Big Gas-Guzzlers to Plug In](#) | [Research Analysis: Scrap Or Retrofit Clunkers](#)

Plug-In Hybrids Use Cheaper, Cleaner, Domestic Energy

Quick Takes
[How to Get a PHEV](#)
[Where PHEV Conversions Are](#)

Our latest video: March 12, 2009: "[Converting Gas Guzzlers:](#)" explaining the reason we're working to launch a major effort to

Watch our 1:45-minute video
calcars.org/audio-video.html



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