

“CalCars’ PRIUS+ Project”

Electric Automobile Association Silicon Valley Chapter

April 16, 2005

Technical aspects presented by
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Strategic/Advocacy/Promotional aspects presented by
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Slides available at link from
CalCars.org About page:
www.calcars.org/calcars-eaasv-16apr2005.pdf



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Why Pluggable or Gas-optional Hybrids?

- **Still no mass produced EVs in the U.S**
 - 36 years after first cross-continental EV race in 1968
 - 30 years after 1974 OPEC oil embargo/crisis
 - This year CA ZEV mandate demanded 10% of autos sold be ZEVs
- **Manipulated public perception of EVs as expensive, limited, and undesirable**
 - Ergo "You don't have to plug it in" hybrid marketing
- **Increasing need for alternatively fuelled vehicles: global warming & peak oil**
- **Hybrids becoming mainstream**
 - Prius is a runaway seller; all hybrids are selling beyond production capabilities
 - Reducing oil usage by up to 1/3
 - Enabled by & helping advance advanced batteries
 - Moving EV propulsion components into mass production

Advantages of ANY Battery Electric Propulsion

- **No local air pollution**
- **Well-to-wheel efficiency is higher than any ICE-based or fuel cell propulsion**
- **Greatly reduced overall air pollution**
 - Even coal-fired electric generation is cleaner than gasoline consumption
 - Major reductions in hydrocarbons, NOx, particulates, etc.
 - At minimum, significant reductions in greenhouse gasses
 - Natural gas electric generation, the major form in California, is cleaner yet
 - The cleanest, most efficient plants generate the electricity during normal off-peak charging times
- **Get cleaner as the power grid gets cleaner**
 - An ever-increasing proportion of our electricity supply will be, by law, from renewable energy -- very difficult to accomplish with gasoline
- **Eventual Vehicle-to-grid possibilities**
 - A power inverter can provide emergency power during power failures
 - A universe of PHEVs could eventually be tapped to provide regulation services and later, peaking power, for power utilities

PHEV Advantages

- **No range, refueling, or other limitations vs. existing ICE cars**
 - Gets around manipulated public perception about EVs
 - Will eventually change that perception to "you GET TO plug it in"
- **Reduce oil usage by at least another 1/3, to 1/3 of current usage or less**
 - . . . to less than oil imports; massive national security benefits
 - See below & papers by Andy Frank & EPRI for specifics
- **Can be mass produced now, and require only existing technology and infrastructure**
- **Even short-range PHEVs can be valuable and effective**
 - As EV components get cheaper, PHEVs can be designed to get an increasing proportion of their propulsion from stored electricity.
- **Transformation to availability of full EVs becomes an evolution rather than a revolution**
 - This may be THE key to the appearance of actual mass-produced EVs, especially as people realize that their 2nd PHEV is never used beyond its EV range!

Continuum from Partial to Maximum PHEVs

- **Partial PHEVs (e.g. PRIUS+)**
 - Capable of only partial EV propulsion (low speed and/or EV-assist)
 - Need engine sized for maximum hill-climbing (approx. 3x normal highway load)
 - Until batteries are depleted, can reduce gasoline usage
 - To as low as 1/3 that of a non-hybrid or 1/2 that of a hybrid
- **Maximum PHEVs**
 - Capable of full EV propulsion except during full acceleration or hill climbing
 - Engine sized for average vehicle load
 - Enough battery capacity required to climb the highest expected hill (using maximum engine output, too) – approx. same as for 40 mile EV range
 - Can *eliminate* gasoline usage except when
 - EV range is exceeded between charges
 - Maximum acceleration or hill climbing power is required

Why PRIUS+?

- **Purpose**

- To prove that an existing mass-produced car can easily become a PHEV
- To show people what is possible and gather excitement
- To get real-world experience and data, proving that a mass-produced PHEV
 - Is economically practical, with a life cycle cost below that of a standard car
 - Is even lower polluting and resource-eating than the best hybrid
 - Is highly desirable by a huge segment of car buyers
- To pressure automakers to add PHEVs to their offerings

- **Toyota's 2004-5 Prius**

- The first hybrid sufficiently advanced to become an effective PHEV without propulsion system modifications
 - Capable of pure EV propulsion (to 35 mph with the engine shut off)
 - Electric motor nearly as high powered (50 kW, 67 hp) as the engine (57 kW, 76 hp)
 - Room under the rear deck for extra batteries



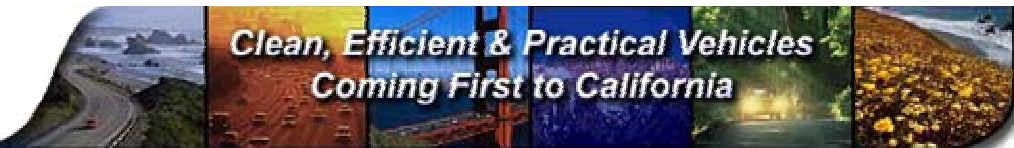


PRIUS+ Project Components

- **CalCars' founder, Felix Kramer**
 - PR, website, grant & help requests, and support
 - Full-time volunteer since CalCars' beginning
- **Technical lead, Ron Gremban**
 - Use of personal 2004 Prius
 - Research, design, construction oversight, and testing
 - Produced specs, battery spreadsheet, data log, etc.
 - Full-time volunteer since June 2004
- **Donations for parts and incidentals from an individual and a foundation**



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*Clean, Efficient & Practical Vehicles
Coming First to California*

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Donate Any Amount by Credit Card, PayPal or Check for PRIUS+ -- or Become a Charter Sponsor!

Several hundred thousand Americans have signed Clean Car pledges (about 25% came from California). Now, at this critical time, you get the chance to do more than express a general intention. Your actions will jump-start a historic change.

Of course, you can give any amount to give CalCars the resources to build the initiative and get the ball rolling on the [PRIUS+](#) campaign (and it's [tax-deductible](#)). See links below.

But if you can, we're asking you to donate \$95 to become a Charter Sponsor, prove there's a viable market for better cars and show we're en route to bringing motivated customers to a major car maker. This will:

- Enroll you as a **CalCars Charter Sponsor**;
- Enable us to **negotiate with car companies** (our claim that we represent serious buyers won't be credible with anything less than \$95 sponsors);
- Get you one of the the unique **bumper stickers** (below) that tells the world you'll soon be switching to a better, cleaner car -- display it on your car or collect it!
- Give you an early opportunity to **join the CalCars Buyers Club** for a plug-in hybrid vehicle -- produced by a car company from its line of compact SUVs;
- Subscribe you to our **email newsletter** with information about our campaign and important automotive, environmental and related developments.

Institutional Charter Sponsors for \$495 are also available.

As a Charter Sponsor, you get your choice of either 10x3-inch bumper sticker:



designed by [Kris Kiger](#)



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PRIUS+ Project Components (con't)

- **An internet discussion group for technical discussion and advice**
- **Extensive construction, debug, and equipment help from many people**
 - **Especially EAA members**
- **Free help from several vendors**
 - **EnergyCS: Redesign (well beyond what we paid for) of their CAN bus controller into a replacement for Toyota's Battery ECU**
 - **RabbitTool: Continuing NiMH D cell module design (for advanced battery pack)**
 - **AmondoTech: Donation of test batteries & charger; loan of battery tester**
 - **Others: Discounts and sample batteries (currently in transit)**

Yahoo! Groups : priusplus Messages : 96-129 of 192 - Mozilla Firefox


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Makers of Earth's first full hybrid SUV.

WHEN IT COMES TO HYBRIDS, THERE'S FULL, THEN THERE'S MILD.
LEARN WHY FULL IS BETTER BY FAR.



Learn about the advantages of a full hybrid system.>>

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<input type="checkbox"/>	102 Preliminary components list and budget: RFC (request for comment)	Felix Kramer	felixkramery	Thu 8/5/2004
<input type="checkbox"/>	103 PriusPlus Conversion Technical Group Is Open For Viewing	Felix Kramer	felixkramery	Thu 8/5/2004
<input type="checkbox"/>	104 Re: Preliminary components list and budget: RFC (request for comment)	Dan Kroushl	kroushdb	Fri 8/6/2004
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<input type="checkbox"/>	106 Where batteries can fit in the '04 Prius	Felix Kramer	felixkramery	Fri 8/6/2004
<input type="checkbox"/>	107 FYI: discussion about approving/denying membership in group	Felix Kramer	felixkramery	Sat 8/7/2004
<input type="checkbox"/>	111 Please keep list on-topic (was: CAN-Database for the new Prius 2004)	Felix Kramer	felixkramery	Mon 8/9/2004
<input type="checkbox"/>	113 Candidate Battery Packs updated: file available to all	Felix Kramer	felixkramery	Mon 8/9/2004
<input type="checkbox"/>	114 Comparison of possible PRIUS+ configurations: please comment	Ron Gremban	rgremban	Tue 8/10/2004
<input type="checkbox"/>	115 Re: Comparison of possible PRIUS+ configurations: please comment	Tom Stangl, VFAQman	talonts	Tue 8/10/2004
<input type="checkbox"/>	116 Re: Comparison of possible PRIUS+ configurations: please comment	Andy Frank	fonzfrank	Tue 8/10/2004
<input type="checkbox"/>	117 Re: Comparison of possible PRIUS+ configurations: please comment	Tom Stangl, VFAQman	talonts	Tue 8/10/2004
<input type="checkbox"/>	118 Re: Preliminary components list and budget: RFC (request for comment)	Ron Gremban	rgremban	Tue 8/10/2004







PRIUS+ Functional Spec

- **Yes Not require internal modifications to Toyota's HSD**
- **Yes Not compromise or overstress the HSD or mechanical systems, or reduce safety, reliability, or expected lifetime**
- **Not Yet Not measurably reduce hybrid (non-plug-in) mileage**
 - Advanced battery should accomplish this
- **Not Yet, Almost Not require special driving techniques or non-automated actions**
 - Must press EV-only button at appropriate times; soon to be automated
- **Yes Have all components (except a display) hidden outside the passenger and cargo areas**
- **Yes Be fully rechargeable in 8-12 hours**
- **Yes Run in EV-only mode (up to 35 mph) for at 12-20 miles**
- **Yes If possible, use electric power at higher speeds, too**
- **Yes Automatically stop discharging the battery when optimally depleted and change to ordinary hybrid operation**
- **Not Yet Include automatically recording instrumentation**
 - Expected upgrade to EnergyCS' CAN bus controller

PRIUS+ Configurations

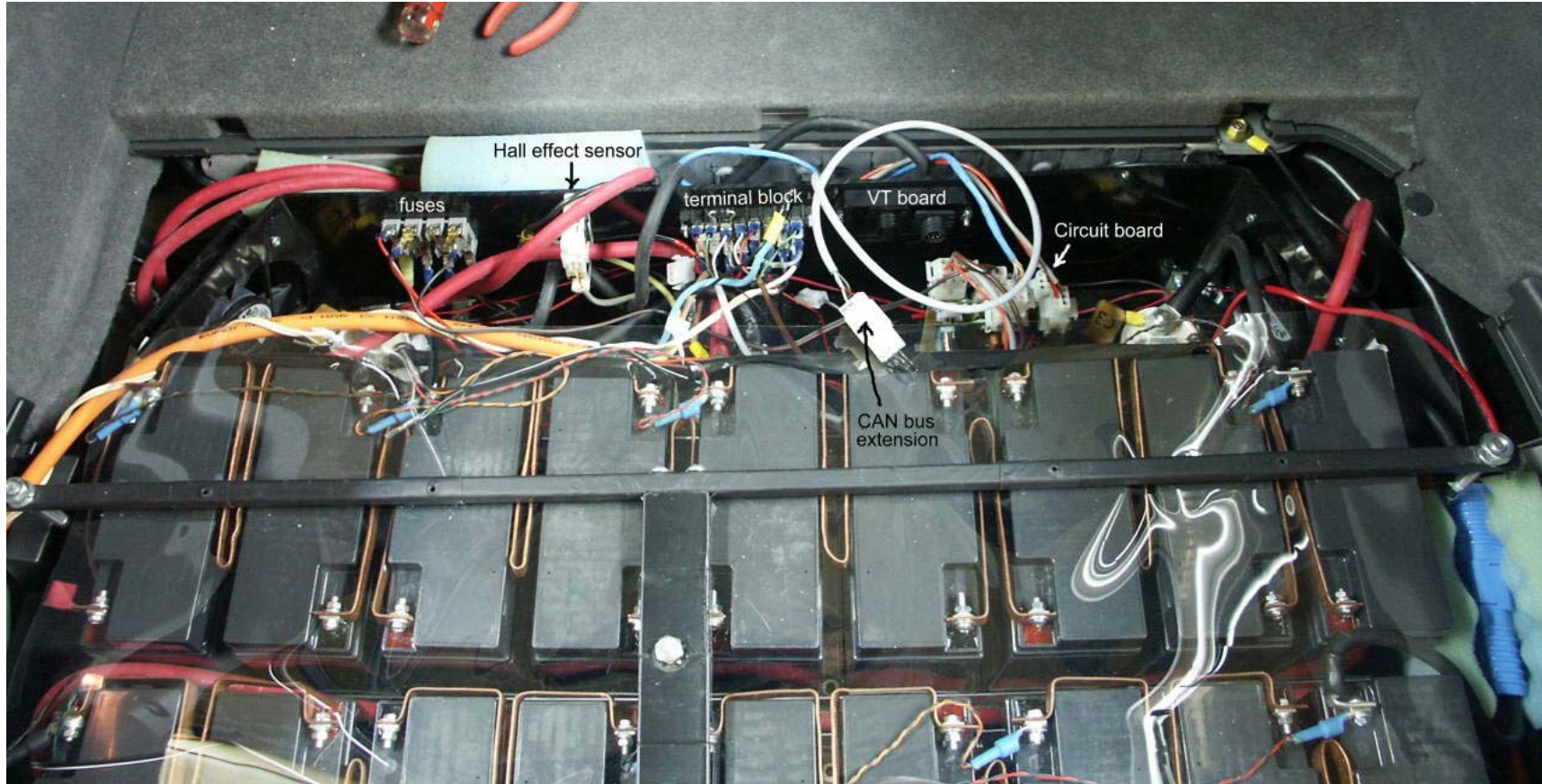
- **Failed**
 - Put added battery in parallel with OEM battery only during discharge (using an SCR)
- **Working**
 - Replace both battery and Toyota's Battery ECU
- **May work with NiMH only**
 - Put higher voltage added battery in parallel with OEM battery only during driving
 - Replace OEM battery with higher voltage battery (do not replace Battery ECU)

PRIUS+ Components

- **Temporary lead-acid (PbA) battery**
 - 18 12V electric bicycle batteries, 216V
 - 12Ah at existing high rates, forced air cooled
 - 270 lb, less than \$900
- **Brusa NLG5 charger**
 - Capable of up to 12.5A and 500V
 - Programmable for any battery chemistry
 - Very expensive (\$4k)
- **EnergyCS CAN bus controller and input sensors**
 - Replaces Toyota's Battery ECU as BMS
 - Displays useful data graphically and numerically
 - Expected to be upgraded for data gathering to a CompactFlash
 - Expected to be upgraded to automatically enter EV-only mode
- **Misc. wiring, relays, contactors, meters, etc.**



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PRIUS+ Results

- **Approx. 300 lb total additional weight reduces hybrid city mpg (after battery depletion) by approx. 5 mpg but does not effect hybrid highway mileage**
- **Example runs**
 - Under 10-mile all-electric propulsion (at under 35 mph), infinite mpg (i.e., no gasoline use) plus 262 grid Watt-hours/mile vs. 50-60 mpg as a normal HEV.
 - 14 mile round trips, including approx. 10 miles on hilly freeways: 58-105 mpg + 185-226 Wh/mi from the grid, compared to 34-38 actual HEV mpg on the same course, driving with the extra battery weight -- otherwise maybe 37-41 mpg.
 - 26-28 mile trips with lots of surface streets: 55-65 mpg +124-164 grid Wh/mi.
 - Beyond 20 miles per day (40 miles per day with NiMH or 60 miles/day with Li-ion battery), normal HEV mileage -- except better mileage on long descents due to ability to store more recovered energy -- and no further electricity use.
- **Operating costs**
 - All-electric: Electric power, approx. 1.25 cents/mile @ 250 Wh/mi and \$0.05/kWh (off-peak rate), not amortizing battery cost
 - As a regular hybrid: Approx. 4.5 cents/gasoline mile (\$2/gallon, 45 mpg)



PRIUS+ Future

- **Batteries**
 - **NiMH battery pack**
 - **Approx. 30 Ah at high rates, 201-216V**
 - **Expected to**
 - **Double EV range to 20 EV-only miles or 40 mixed driving EV assisted miles**
 - **Bring city hybrid mileage back up to Prius' original**
 - **Possibly make configurations that don't replace Toyota's Battery ECU viable**
 - **Ongoing research and search since January 1**
 - **Have not found available right-sized cells**
 - » **Even potentials are double our \$7k budget and/or have other problems**
 - **D cells are most available, but must be paralleled for sufficient capacity**
 - » **Problematic with NiMH cells**
 - » **Dangerous unless carefully fused & monitored**
 - » **Coolable modules and thermal management must be designed**
 - » **Cells with low enough internal resistance not yet found**
 - **Supercapacitors may be able to reduce high power battery requirements**
 - » **Maxwell D cell (350F, 2.5V) caps are \$17 each and may be economically viable**
 - **NiZn pack is a possible alternate**
 - **Same specific energy as NiMH but higher internal resistance**
 - **1/4 the price, but manufacturer (Evercel) is not in production**
 - **Lithium battery pack**
 - **Already done by EnergyCS (see next slide)**
 - **Digital data logging and automated EV-only entry (EnergyCS upgrade)**

Other Possibilities for PHEV Conversion

- **Toyota Highlander hybrid**
- **Lexus 400**
- **Ford Escape hybrid (EV-only up to 25 mph)**
- **Other vehicles using or duplicating Toyota's HSD**

Another PRIUS+, by EnergyCS

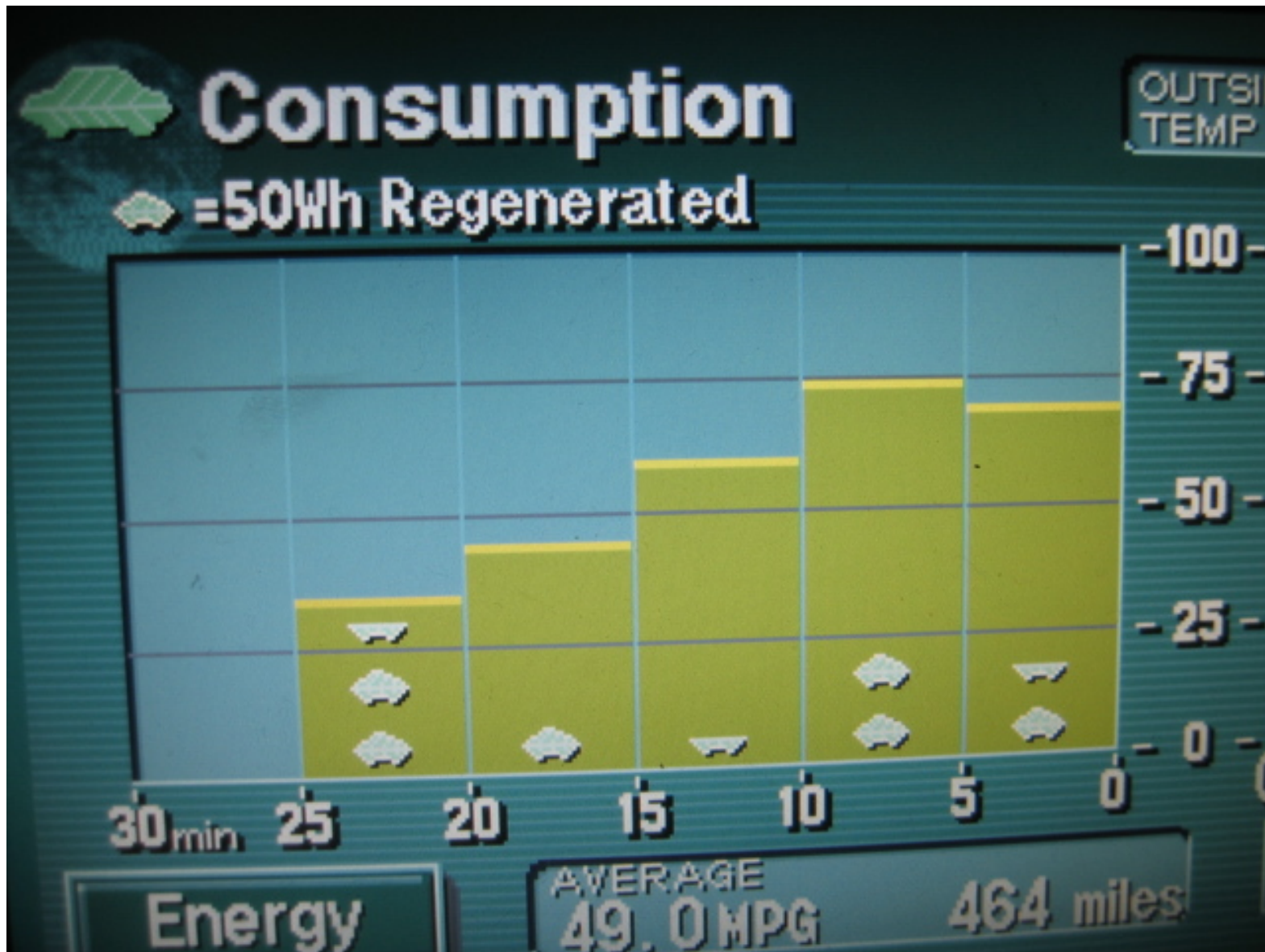
- **17 Valence U1 lithium-ion modules**
 - 45 Ah, 12V, 15.4 lb each
 - Thermal runaway and explosion resistant
 - Long cycle life (manuf. Claims 2000 deep cycles)
 - \$15k retail, but maybe less for conversions
- **EnergyCS' CAN bus controller & Li-ion battery management unit**
- **30 mile EV-only or 60 mile EV assisted range**
- **120-180 mpg mixed-mode driving**
- **Batteries are not yet hidden beneath the cargo area floor**





PRIUS+ strategies, advocacy, promotion





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