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Plug-In-Vehicle Battery Secondary Use: Integrating Grid Energy-Storage Value

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UCLA Luskin Center EV Program Sampler

1. PEV regional planning for Southern CA Assoc. of Govts (DOE/CEC funding)
   - Modeling/mapping PEV demand, built environ. (e.g., multi-unit dwellings, workplaces, public charging), travel destinations, etc.
2. Analysis of charging challenges for multi-unit dwellings
3. Analysis of real-world use of PEVs by households
4. Battery secondary use (V2G and B2G)

Note: Symposium this year on locating, managing, and pricing charging infrastructure

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1.

2.

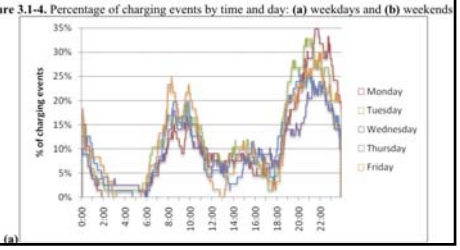
Electricity Markup

Installed Project Cost

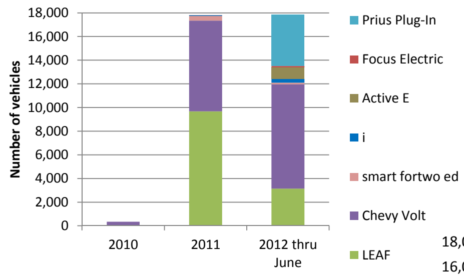
Project Cost	$ -	$ 0.10	$ 0.15	$ 0.20	$ 0.25	$ 0.30
$ 1,000.00	$ (195.72)	$ 2,038.45	$ 3,155.54	$ 4,272.63	$ 5,389.71	$ 6,506.80
$ 3,000.00	$ (2,603.77)	$ (369.59)	$ 747.49	$ 1,864.58	$ 2,981.67	$ 4,098.76
$ 5,000.00	$ (5,011.81)	$ (2,777.64)	$ (1,660.55)	$ (543.46)	$ 573.62	$ 1,690.71
$ 7,000.00	$ (7,419.86)	$ (5,185.68)	$ (4,068.60)	$ (2,951.51)	$ (1,834.42)	$ (717.33)
$ 9,000.00	$ (9,827.90)	$ (7,593.73)	$ (6,476.64)	$ (5,359.55)	$ (4,242.47)	$ (3,125.38)
$ 11,000.00	$ (12,235.95)	$ (10,001.77)	$ (8,884.68)	$ (7,767.60)	$ (6,650.51)	$ (5,533.42)
$ 13,000.00	$ (14,643.99)	$ (12,409.82)	$ (11,292.73)	$ (10,175.64)	$ (9,058.56)	$ (7,941.47)
$ 15,000.00	$ (17,052.04)	$ (14,817.86)	$ (13,700.77)	$ (12,583.69)	$ (11,466.60)	$ (10,349.51)
$ 17,000.00	$ (19,460.08)	$ (17,225.91)	$ (16,108.82)	$ (14,991.73)	$ (13,874.65)	$ (12,757.56)
$ 19,000.00	$ (21,868.13)	$ (19,633.95)	$ (18,516.86)	$ (17,399.78)	$ (16,282.69)	$ (15,165.60)

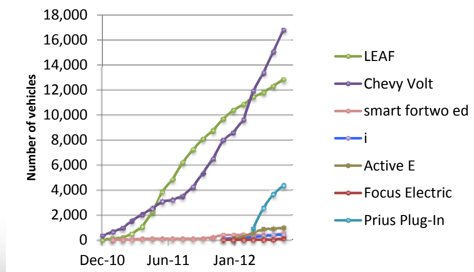
3.

Figure 3.1-4. Percentage of charging events by time and day: **(a)** weekdays and **(b)** weekends



U.S. PEV sales thru June by model: 1) annual, 2) cumulative





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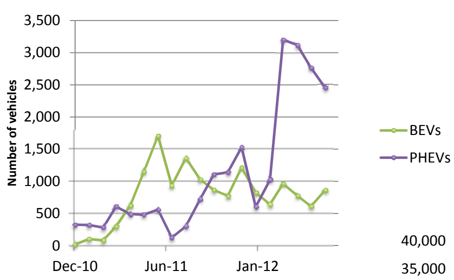
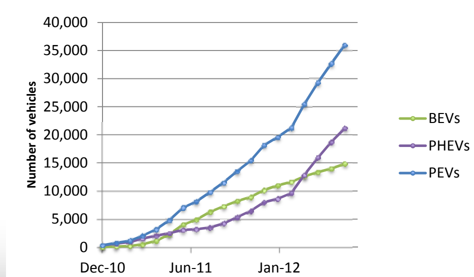
U.S. PEV sales by type (BEV vs. PHEV): 1) monthly, 2) cumulative





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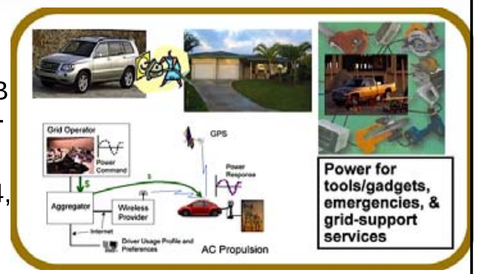
PEV battery secondary use (2U)

in first life (Mobile Electricity)

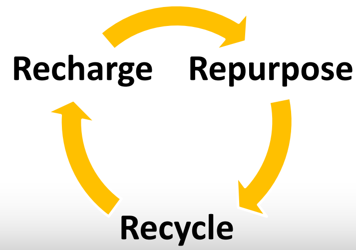
- Me- = mobile (untethered) power, vehicle-to building (V2B e.g., V2Home), and vehicle-to-grid (V2G) power
- (e.g., Williams & Finkelor 2004, Williams & Kurani 2007)



in second life (repurposing for second use)

– e.g., vehicular cascading/downcycling, repurposing as stationary energy storage (battery-to-grid or B2G)

- (e.g., Williams and Lipman 2009, 2011)



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Examining grid benefits with…

A spectrum of product lenses:

- traditional generation
- bulk energy storage
- distributed stationary energy storage
  – utility (e.g., CES)
  – behind the meter (residential, commercial, and industrial end users)
- smart charging
- vehicle-to-grid power

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Examining grid benefits with…

A spectrum of technologies:

- Combustion engines
- Pumped hydro
- Compressed air
- Flow batteries
- Batteries
  - New batteries
  - Used batteries
    - Refurbished stationary batteries
    - Vehicular batteries
      - Repurposed plug-in-vehicle (PEV) batteries

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Battery 2nd use in context: 6-project trajectory

Using a transportation lens to examine distributed energy-storage benefits and grid services:

1. 1997: pre-"V2G" fuel-cell Hypercar (RMI)
2. 2004: Rental-car parking-lot power plant (UCD)
3. 2006: Electric-drive vehicle-to-grid (V2G) net revenues and other "Mobile Electricity" value (UCD)
4. 2009: California Electric Fuel Implementation Strategies (CEFIS) project (battery 2nd life preliminary analysis for the CEC) (UCB)
5. 2011: CEC/UCD Battery 2nd Life project ("home energy storage appliances"), Task 3 (UCB)
6. 2012: NREL Secondary Use project, Task 4.1

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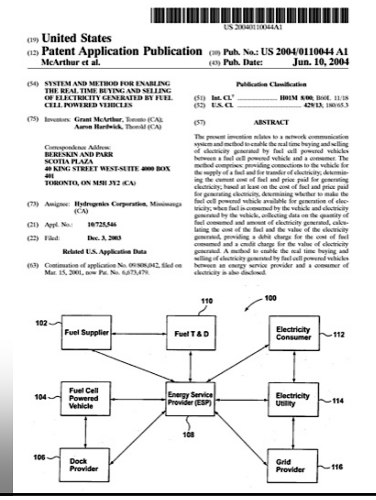
Mobile Energy

Mobile Electricity (Me-)


US 20040110044A1

(19) United States
(12) Patent Application Publication (10) Pub. No.: US 2004/0110044 A1
McArthur et al. (43) Pub. Date: Jun. 10, 2004

(54) SYSTEM AND METHOD FOR ENABLING THE REAL TIME BUYING AND SELLING OF ELECTRICITY GENERATED BY FUEL CELL POWERED VEHICLES

(75) Inventors: Grant McArthur, Toronto (CA); Aaron Hardwick, Thorold (CA)

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(73) Assignee: Hydrogenics Corporation, Mississauga (CA)

(21) Appl. No.: 10/725,546

(22) Filed: Dec. 3, 2003

Related U.S. Application Data

(63) Continuation of application No. 09/808,042, filed on Mar. 15, 2001, now Pat. No. 6,673,479.

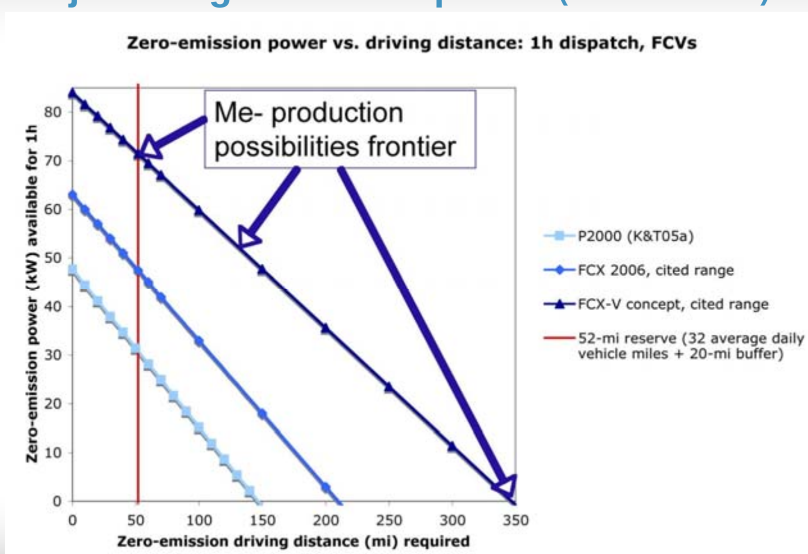
Publication Classification

(51) Int. Cl.[7] H01M 8/00; B60L 11/18
(52) U.S. Cl. 429/13; 180/65.3

(57) ABSTRACT

The present invention relates to a network communication system and method to enable the real time buying and selling of electricity generated by fuel cell powered vehicles between a fuel cell powered vehicle and a consumer. The method comprises: providing connections to the vehicle for the supply of a fuel and for transfer of electricity; determining the current cost of fuel and price paid for generating electricity; based at least on the cost of fuel and price paid for generating electricity, determining whether to make the fuel cell powered vehicle available for generation of electricity; when fuel is consumed by the vehicle and electricity generated by the vehicle, collecting data on the quantity of fuel consumed and amount of electricity generated, calculating the cost of the fuel and the value of the electricity generated, providing a debit charge for the cost of fuel consumed and a credit charge for the value of electricity generated. A method to enable the real time buying and selling of electricity generated by fuel cell powered vehicles between an energy service provider and a consumer of electricity is also disclosed.

Not just range?: Mobile power (Williams 2007)



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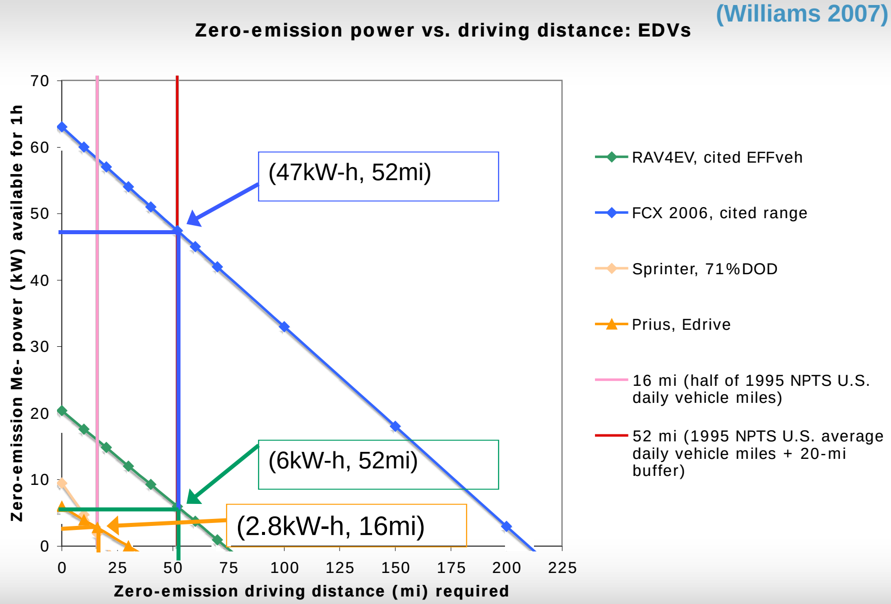
(Williams 2007)



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Vehicle-to-grid (V2G) power

(building on Kempton & Tomic 2005)

"Red line" bottom line: annual net revenues summary (Williams 2007)

	Pspin (kW)	Preg (kW)	NETrevSPIN	NETrevREG		Ppeak (kW)	NETrevPeak
RAV4EVfuellimit	6.0	17.9	-$8	$1,696		1.5	$8
edrive Priusfuellimit	2.8	8.3	-$96	$584	*	0.7	-$44
FCXfuellimit	47.4	33.9	$381	-$17		11.9	$385
FCX-Vfuellimit	71.5	51.0	$1,039	$440		17.9	$550
PFCXfuellimit	47.4	8.3	$421	$584	*	11.9	$426

*may be much lower e.g., $133

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Net Revenues: the whole gang (Williams 2007)

	NETrevSPIN	NETrevREG	NETrevPeak
RAV4EV (K&T05a)	$331	$2,532	
RAV4EV	-$24	$133	
RAV4EVfuellimit	-$8	$1,696	$8
RAV4EV	$92	$930	
RAV4EV	$86	$1,343	
RAV4EVmaxkW	$201	$4,859	
edrive Prius	-$24	$90*	
edrive Priusfuellimit	-$96	$584*	-$44
edrive PriusmaxkW	-$9	$1,262*	
P2000 (K&T05a) high	$175		-$145
P2000 (K&T05a) low	$261		$717
FCX	-$65	-$66	
FCX	$51	9.6kW: $43	$271
FCX	$308		
FCXfuellimit	$381	33.9kW: -$17	$385
FCXmaxkW	$809	$280	$444
FCX-Vfuellimit	$1,039	$440	$550
PFCX	-$24	$90*	
PFCX	$91	$699*	
PFCX	$86	$997*	
PFCX	$349		
PFCXfuellimit	$421	$584*	$426
PFCXmaxkW	$849	$1,262*	

(Please recall regulation caveats for PHEVs)

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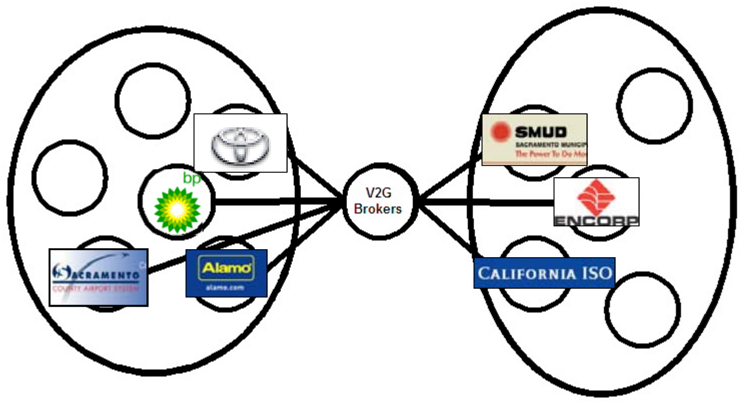
Building Community: Partnerships (Williams & Finkelor 2004)

- Avoiding the Farnsworth trap: Build key partnerships (Hargadon 2004)



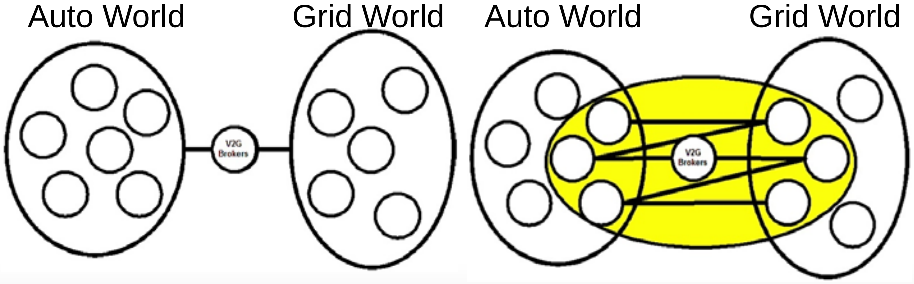
Automotive World

Electricity Grid World

Giving Away the Keys to the Kingdom or Integrating Disparate Worlds?

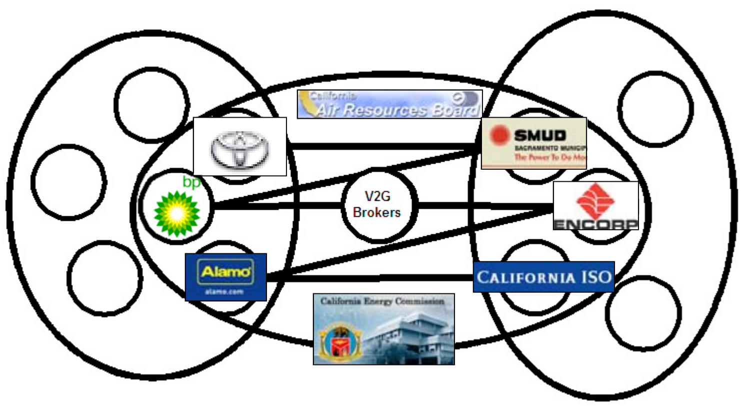
- Wanting control of their innovations, innovators often form self-defeating bottlenecks rather than encouraging the necessary interactions (e.g., Beta vs. VHS, Apple vs. IBM) (Hargadon 2004)

Auto World | Grid World | Auto World | Grid World



Stable Brokerage Position | Building Redundant Ties

Building Community: Partnerships (Williams & Finkelor 2004)



Automotive World Electricity Grid World

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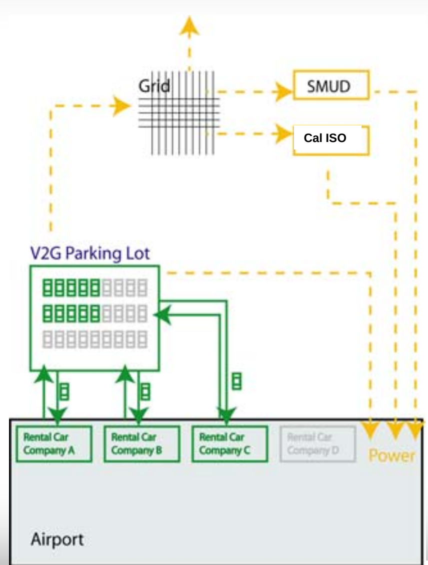
V2G Aggregation

- Can aggregation help lower costs, accrue benefits?
- Cell-phone, other companies manage relatively low margins on large numbers of complex *transactions*
- Even easier: *physical* aggregation: "parking-lot power plants"
- Williams & Finkelor NHA 2004:



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V2G, smart charging, & repurposing

- No matter how you design it, V2G is a complex challenge
- Eventually, the rolling stock of battery storage will be hard to ignore
- In the meantime, automakers have to introduce and sell cars with nascent batteries: “hands off”
- Smart charging (G2V) potentially offers less complexity, similar benefits
  - Shouldn’t giving up control be rewarded (provider benefits)?:
  - Yellow button: charge me now
  - Green button: give my plug-in hybrid as little as you want, when/how you want, but reward me for providing system benefits…
- Even easier?: storage paid in part for transportation, but that doesn’t disconnect and drive away, thereby limiting potential benefits
- Indeed, rather than getting in the way of vehicle commercialization, can we help by creating residual value for propulsion batteries?

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Center for Sustainable Energy CALIFORNIA

"Second Life Applications and Value of 'Traction' Lithium Batteries"

"Tasks":
(1) Identify potential second life applications
(2) Acquire and test used PEV battery packs
(3) Analysis of the Combined Vehicle- and Post-Vehicle-Use Value of Lithium-Ion Plug-In-Vehicle Propulsion (TSRC)

Center for Sustainable Energy CALIFORNIA

tsrc

SDGE
A Sempra Energy utility

UCDAVIS
PLUG-IN HYBRID ELECTRIC VEHICLE RESEARCH CENTER

pier

California Energy Commission

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Battery-second-life report outline

1. Introduction: background, scope, glossary
2. 1st life: vehicle-specific battery specs and lease costs
3. Repurposing & distributed energy storage appliance (DESA) costs for each vehicle-battery type
4. 2nd life: look through DESA product lens at various energy storage benefits
5. Integrating 2nd-life net benefit into the battery lease, bounding estimates, uncertainty/sensitivity analyses, and alternative scenarios
6. Conclusions, directions for future work

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Plug-in-vehicle model
(old, partial—i.e., inaccurate—for illustration only)

Plug-in vehicle	Manufacturer	Battery rated kWh	Available (%)	Available kWh	CD fuel econ (kWh/100mi)	Electric mi - active	kWh avail /mi - active	Battery Supplier	Neg electrode	Battery Chemistry	alpha-discharge	alpha-charge	Cell cost factor
Baseline	(BDW)	5.2	65%	3.4	39	11	0.32	Hypothetical	C	LFP	1.0	1.0	1.00
Prius PHV	Toyota	5.2	75%	3.9	36	13	0.30	Panasonic EV Energy (Panasonic/Toyota)	C	NCM	1.2	1.2	0.89
Accord PHV	Honda	6.0	65%	3.9	39	12	0.32	Blue Energy Co.	C		#N/A	#N/A	#N/A
Chef's choice	(BDW)	6	80%	4.8	39	15	0.32	Hypothetical	LTO	LFP	0.4	0.4	2.03
Escape PHEV	Ford	10	65%	6.5	39	20	0.32	JCS (Johnson Controls-Saft)	C	NCA	1.2	1.2	0.87
(Quallion City EV design)	(Quallion)	11.3	65%	7.3	39	23	0.32	Quallion	C	NCA	1.2	1.2	0.87
(Lithium Technology/GAIA)	unnamed	12	65%	7.8	39	24	0.32	(Lithium Technology/GAIA)	C	LCO	3.0	3.0	0.88
F3DM	BYD	13.2	65%	8.6	39	27	0.32	BYD	C	LFP	1.0	1.0	1.00
Chevy Volt	GM	16	65%	10.4	36	35	0.30	LG Chem Power	C	LMO	3.0	3.0	0.71
i	Mitsubishi	16	80%	12.8	36	43	0.30	Lithium Energy Japan (GS Yuasa/Mitsubishi)	C		#N/A	#N/A	#N/A
smart fortwo electric drive (ed)	Daimler	16.5	85%	14.0	39	63	0.22	Tesla	C	NCA	1.2	1.2	0.87
F6DM	BYD	20	65%	13.0	39	41	0.32	BYD	C	LFP	1.0	1.0	1.00
Caliber ReEV (conv.)	FEV	21	65%	13.7	39	43	0.32	EIG	C	LFP	1.0	1.0	1.00
500EV	Chrysler-Fiat	22	80%	17.6	39	55	0.32	SB LiMotive (Samsung SDI/Bosch)	C	LMO	3.0	3.0	0.71
Karma	Fisker	22.5	65%	14.6	39	46	0.32	A123	C	LFP	1.0	1.0	1.00
Focus Electric	Ford	23	80%	18.4	39	58	0.32	LG Chem Power	C	LMO	3.0	3.0	0.71
City	Th!nk	23	80%	18.4	39	58	0.32	EnerDel	C	LMO	3.0	3.0	0.71
ie:3 concept	JC	23	80%	18.4	39	58	0.32	JC	C	NCA	1.2	1.2	0.87
LEAF	Nissan	24	85%	20.4	34	73	0.28	AESC (NEC/Nissan)	C	LMO	3.0	3.0	0.71
Crestline	(BDW)	24	85%	20.4	34	73	0.28	Hypothetical	C	LFP	1.0	1.0	1.00
Transit Connect Electric	Azure/Ford	28	80%	22.4	39	70	0.32	JCS (Johnson Controls-Saft)	C	NCA	1.2	1.2	0.87
ActiveE	BMW	32	80%	25.6	39	80	0.32	SB LiMotive (Samsung SDI/Bosch)	C	NCM	1.2	1.2	0.89
Coda Sedan	Coda	34	80%	27.2	39	85	0.32	Lio Energy Systems (Lishen)	C	LFP	1.0	1.0	1.00
Cooper MINI-E	BMW	35	80%	28	39	88	0.32	SB LiMotive (Samsung SDI/Bosch)	C	NCM	1.2	1.2	0.89
SUT	Phoenix	35	80%	28.0	39	88	0.32	Altairnano	LTO	LMO	0.6	0.6	1.05
RAV4EV	Toyota	35	80%	28.0	39	88	0.32	Tesla (Panasonic 18650?)	C	NCA	1.2	1.2	0.87
Edison Panel Van	Smith EV	36	80%	28.8	39	90	0.32	Valence	C	LFP	1.0	1.0	1.00
Model S	Tesla	42	80%	33.6	39	105	0.32	Panasonic	C	NCA	1.2	1.2	0.87
Roadster	Tesla	53	86%	45.6	39	143	0.32	Panasonic	C	NCA	1.2	1.2	0.87
e6	BYD	72	80%	57.6	39	180	0.00	BYD	C	LFP	1.0	1.0	1.00
(Dow Kokam)	(Dow Kokam)	80	80%	64.0	39	200	0.32	Dow Kokam	C	NCM	1.2	1.2	0.89
C-Max Energi	Ford		65%	#N/A	39	#N/A	#N/A		C		#N/A	#N/A	#N/A
Sonata Plug-In Hybrid	Hyundai		65%	#N/A	39	#N/A	#N/A	LG Chem, SK Energy, SB LiMotive	C	LFP	1.0	1.0	1.00
Minicab MiEV	Mitsubishi		80%	#N/A	39	62	#N/A	Toshiba	LTO	LCO	1.1	1.1	1.68
Demio (Mazda2 in Japan)	Mazda		65%	#N/A	39	120	#N/A		C		#N/A	#N/A	#N/A
i3	BMW		65%	#N/A	39	#N/A	#N/A	SB LiMotive (Samsung SDI/Bosch)	C	NCM	1.2	1.2	0.89
[to be released]	"major n.a. OEM"		65%	#N/A	39	#N/A	#N/A	A123	C	LFP	1.0	1.0	1.00

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PEV assumptions, early 2011

Battery=modules+ MMS	Prius PHV	Volt	LEAF
Battery rated kWh	5.2	16	24
Available kWh	3.9	10.4	20.4
Battery type	Panasonic NCM	LG Chem LMO	AESC LMO
Re-rated for 2nd life (kWh)	4.2	12.8	19.2
"Battery" cost	~$4,200	~$8,100	~$15,000
8-y battery lease payment (per mo.)	$64	$122	$225

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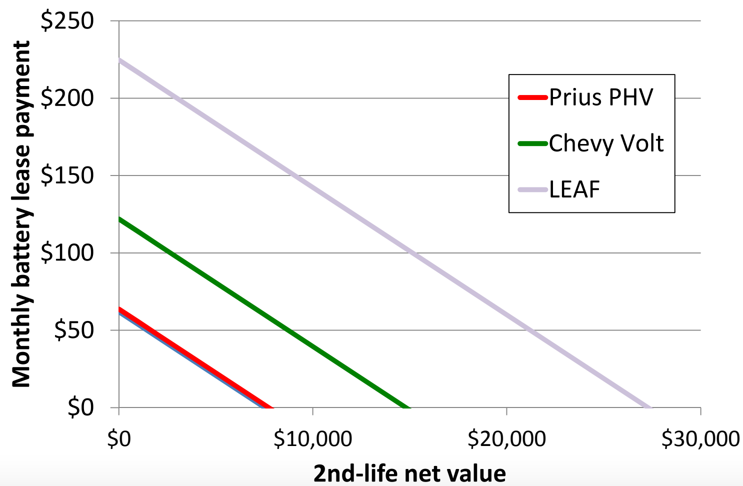
Monthly battery lease by residual value



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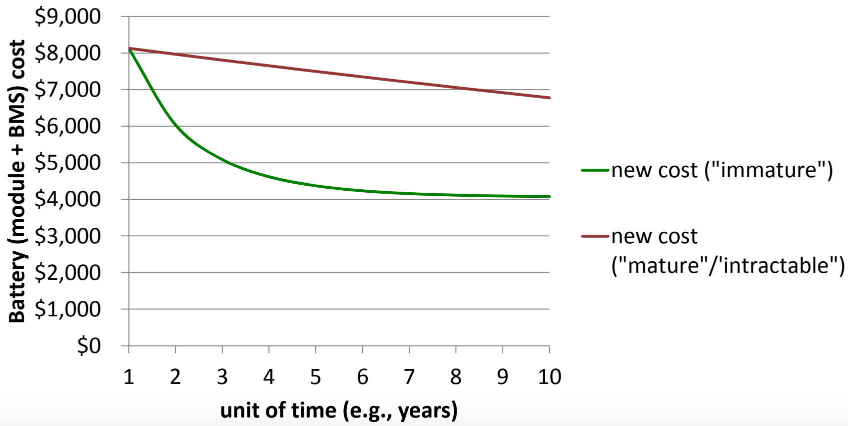
Chapter 3: Repurposing

Distributed Energy Storage
Appliance Costs

Max. allowable repurposing costs (Volt)

Mature- vs. immature-market cost reductions per y



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Distributed Energy Storage Appliance (DESA) costs

ESA cost component	Basis	PHV 3kWh/6kW	Volt 8kWh/16kW	LEAF 16kWh/32kW
Battery (modules+mgt. system)	Repurposing cost	$744	$1,150	$1,780
Power conditioning, controls, interfaces	Inflated $442/kW=CreadyEtAl'02 max. for fully-capable bulk storage	$3,310	$8,830	$17,300
Accessories, facilities, shipping, catch-all	Inflated $117/kWh=CreadyEtAl'02 for load leveling, arbitrage, and transmission deferral facility at Chino	$442	$1,170	$2,290
10-year operation and maintenance	NPV($18/kW-y)=Chino facility. Compare to $102/y for residential load following	$828	$2,210	$4,330
Installation, residential circuitry	EVSE-style installation costs (sans charger), based on max. power	$800	$2,000	$4,300
	Total HESA cost	**$6,120**	**$15,400**	**$30,000**

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Chapter 4: 2nd-life gross benefit

Grid-related energy-storage value

Applications (Eyer&Corey/Sandia'10)

Application	Discharge Duration, Low (h)	Discharge Duration, High (h)
Electric Energy Time-shift	2	8
Electric Supply Capacity	4	6
Load Following	2	4
Area Regulation	0.25	0.5
Electric Supply Reserve Capacity	1	2
Voltage Support	0.25	1
Transmission Support	0.00056	0.0014
Transmission Congestion Relief	3	6
T&D Upgrade Deferral 50th percentile**	3	6
T&D Upgrade Deferral 90th percentile**	3	6
Substation On-site Power	8	16
Time-of-use Energy Cost Management	4	6
Demand Charge Management	5	11
Electric Service Reliability	0.083	1
Electric Service Power Quality	0.0028	0.017
Renewables Energy Time-shift	3	5
Renewables Capacity Firming	2	4
Wind Generation Grid Integration, Short Duration	0.0028	0.25
Wind Generation Grid Integration, Long Duration	1	6

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Menu of 2nd-life 10-y benefit (kW=2*kWh)

Application	PHV	Volt	LEAF
Electric Energy Time-shift	$330	$880	$1,720
Electric Supply Capacity	$320	$850	$1,670
Load Following	$800	$2,130	$4,180
Area Regulation	$8,720	$23,250	$45,610
Electric Supply Reserve Capacity	$280	$750	$1,470
Voltage Support	$2,870	$7,670	$15,040
Transmission Support	$1,200	$3,190	$6,270
Transmission Congestion Relief	$60	$150	$300
T&D Upgrade Deferral 50th percentile†	$2,390	$6,470	$12,490
T&D Upgrade Deferral 90th percentile†	$3,760	$10,020	$19,660
Substation On-site Power	$600	$1,600	$3,130
Time-of-use Energy Cost Management	$730	$1,960	$3,840
Demand Charge Management	$220	$580	$1,140
Electric Service Reliability	$3,700	$9,860	$19,340
Electric Service Power Quality	$4,170	$11,120	$21,820
Renewables Energy Time-shift	$230	$620	$1,220
Renewables Capacity Firming	$810	$2,160	$4,240
Wind Generation Grid Integration, Short Duration	$4,680	$12,480	$24,480
Wind Generation Grid Integration, Long Duration	$380	$1,000	$1,970

* lifecycle benefit over 10 years, with 2.5% escalation and 10% discount rate
† converted here to approximate 10 years of benefit to be comparable to other applications, but this is not likely at a single location

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Regulation: not the focus here

- Hotly contested by other products, technologies
- Would take ~44,000 Volt-based DESAs to provide the 2006–2008 average CAISO regulation up+down requirement of 732MW/y
- Would take 3–4 years to process 44k top-candidate batteries using 4 CA repurposing centers
- GM hoped to produce 45k Volts in U.S. in 2012, a fraction of which would produce top-candidate batteries in CA
- Regulation requirements could rise, but could be provided (if not optimally) by 20 GW of existing regulation-certified capacity in the near-to-mid-term (e.g., up to 20% RPS) (CAISO 2010, p.23)

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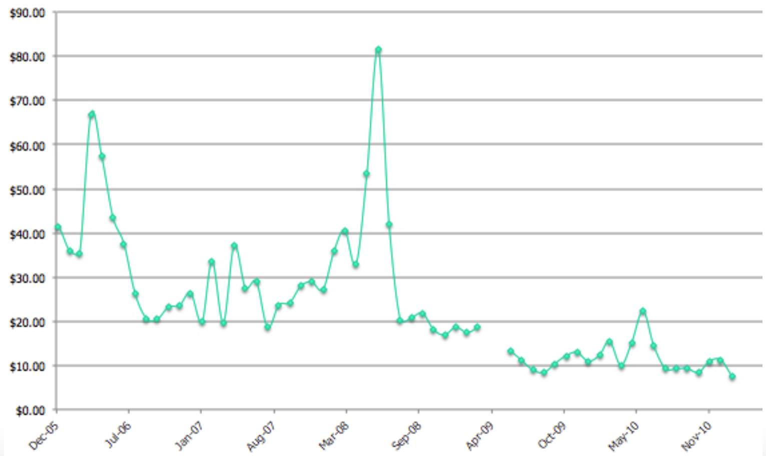
CAISO regulation (up+down, $/MW)



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Multi-app. value propositions (10-y benefit): Volt

Eyer&Corey'10 Value Proposition [6]	Sum (double counting)	Total: 90% of biggest, 50% of rest	Total -10% aggregation fee
e- energy time-shift + T&D upgrade deferral + e- supply reserve capacity	$11,800	$9,900	$8,900
TOU energy cost management + demand charge mgt	$2,500	$1,800	$1,800
renewables energy time-shift + e- energy time-shift + T&D upgrade deferral	$11,500	$9,800	$8,800
renewables energy time-shift + e- energy time shift + e- supply reserve capacity	$2,400	$1,500	$1,400
T&D upgrade deferral (10 years of value)† + e- service power quality + e- service reliability (equivalent here to Eyer&Corey "distributed storage for bilateral contracts with wind generators" proposition)	$31,000	$20,000	$18,000
storage to service small A/C loads = voltage support + e- supply reserve capacity + load following + transmission congestion relief + e- service reliability + e- service power quality + renewables energy time-shift	$32,400	$20,700	$18,600

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Chapter 5: Results

Integrating results; sensitivity analysis; alternative scenarios

Findings Overview

- Modest potential benefits of incorporating post-vehicle grid value from distributed energy storage into battery lease
  - E.g., "Volt" 8-y battery-only lease reduced 22% (3–30%) by providing multi-app combo related to servicing local A/C loads
- Regulation most valuable distributed energy storage appliance (DESA) application explored, but might provide limited impetus; multi-application duty-cycles likely needed
- Monte Carlo uncertainty analysis indicates reductions estimated might need significant downward adjustment
- Large sources of variance:
  - how much value from non-priority DESA applications: deeper investigation into capturing multi-app value needed
  - DESA costs related to power conditioning; co-locate with PV?

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Additional thoughts

- Unclear if potential system benefits embodied in the lease metric will provide enough impetus
- However, to the extent the prospects for energy storage in general are improved, repurposed energy storage may still be interesting
  - Repurposing burden not yet the weakest link
- Regardless, need to find appropriate and valuable uses for plug-in-vehicle batteries
- Proceed, but proceed with caution
- Evolving future context may change picture

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Battery 2nd use in context: 6-project trajectory

Using a transportation lens to examine distributed energy-storage benefits and grid services:

1. 1997: pre-"V2G" fuel-cell Hypercar (RMI)
2. 2004: Rental-car parking-lot power plant (UCD)
3. 2006: Electric-drive vehicle-to-grid (V2G) net revenues and other "Mobile Electricity" value (UCD)
4. 2009: California Electric Fuel Implementation Strategies (CEFIS) project (battery 2nd life preliminary analysis, CEC)
5. 2011: CEC/UCD Battery 2nd Life project ("home energy storage appliances"), Task 3
6. 2012: NREL Secondary Use project, Task 4.1

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End-User Product: Small Commercial/Industrial Q&R, DC, and TOU
(Neubauer, Williams, et al. 2012)

- Power quality + reliability aggregate easily
  - Avoided UPS cost (Eyer&Corey'10) yields $136/kW-y value
- Demand charge + TOU aggregate easily
  - ~$37k max annual savings from demand charge mitigation
  - Southern California Edison's TOU-GS-3-SOP rate structure
- All four do not: What happens when you have a reliability need immediately following a DC/TOU discharge?
- To conservatively address this, we set aside a Q&R capacity reserve that is maintained at all times.

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End-User Product: Small Commercial/Industrial Q&R, DC, and TOU (Neubauer, Williams, et al. 2012)

Scenario	Q&R % of system power	DC/TOU % of system power	Annual Revenue	Payback period*
1	100%	0%	$27,200	6.9 y
2	100%	13%	$33,600	7.5 y
3	100%	36%	$44,600	10.3 y
4	0%	100%	$48,900	>15 y

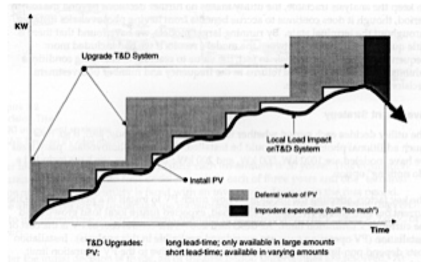
- Annual revenue increases as amount of DC/TOU capacity increases
- But payback period is best without DC/TOU (fewer kWh to buy)

Conclusion (Neubauer, Williams, et al. 2012)

- The use of repurposed PEV batteries for end-user quality and reliability needs appears financially sound
  - The financial case could improve significantly if new PEV battery prices fall below $440/kWh

Utility Product:
Transportable Trans. & Distrib. Upgrade Deferral
(Neubauer, Williams, et al. forthcoming)

- Site at T&D congestion points for 1 or so years to avoid investment in upgrade
- Device called on rarely (hours per year), often during relatively well known peak-use hours
- When used, charges at night, provides a deep discharge (like a vehicle's CD mode)
- The rest of the year, layer on Regulation Energy Management (new regulation service) (like a vehicle's CS mode)
- (Details in development)



(from an old RMI report)

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5. 2011: CEC/UCD Battery 2nd Life project ("home energy storage appliances"), Task 3
6. 2012: NREL Secondary Use project, Task 4.1
7. Translate second use back into V2G or smart charging??
8. Charging business models robust to demand charges and road tax

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