Driving Rural Energy Storage: A Second Look at the Second-Life of EV Batteries

Hanjiro Ambrose[1,4]
Dimitry Gershenson[2,3,4]
Daniel Kammen[2,3,4]

[1] San Jose State University, San Jose, CA,
[2] Energy and Resources Group, University of California, Berkeley, CA
[3] Renewable and Appropriate Energy Laboratory, University of California, Berkeley, CA
[4] Berkeley Rural Energy Group, University of California, Berkeley, CA

Berkeley Rural Energy Group

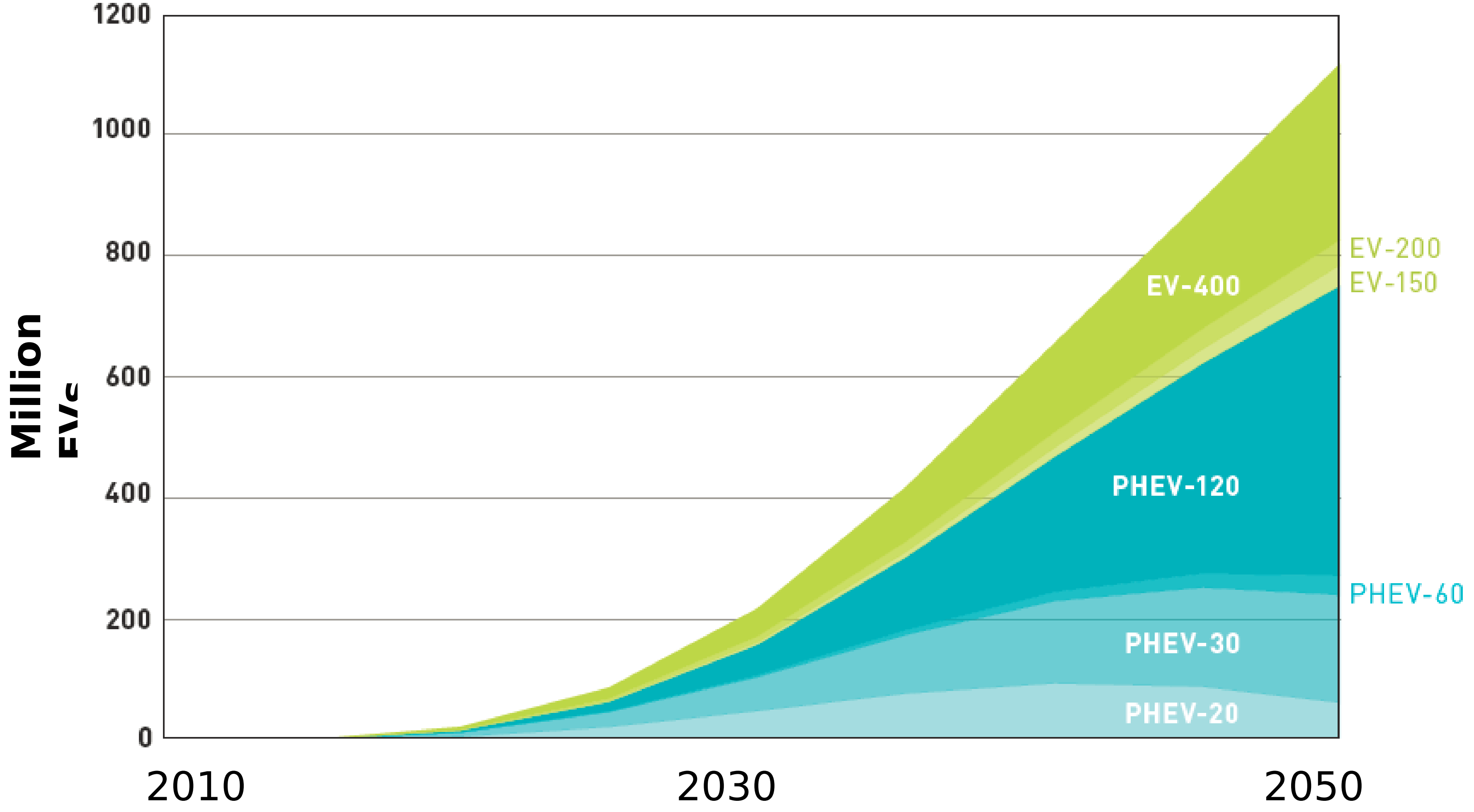
breg.berkeley.edu

Rural Electrification: Business As Usual

Storage: Primarily Deep Cycle Lead-acid Electric Storage Devices (ESDs)

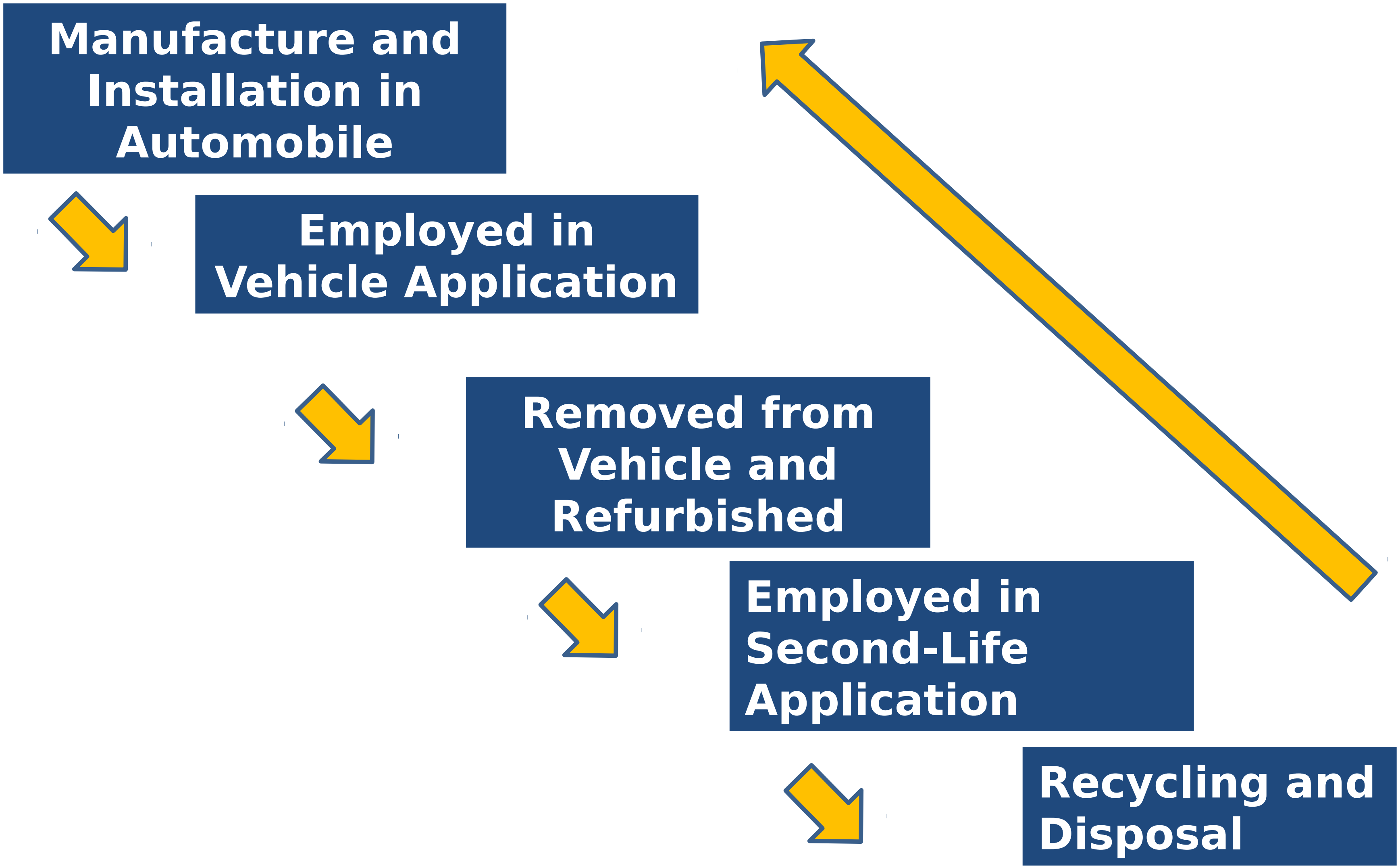
- Low initial capital cost (75 - 300 $/kWh)
- Low energy density (30 - 40 Wh/kg)
- Short lifetime (3 - 5 years)
- Maintenance requirements
- Environmental impact

World EV Stock



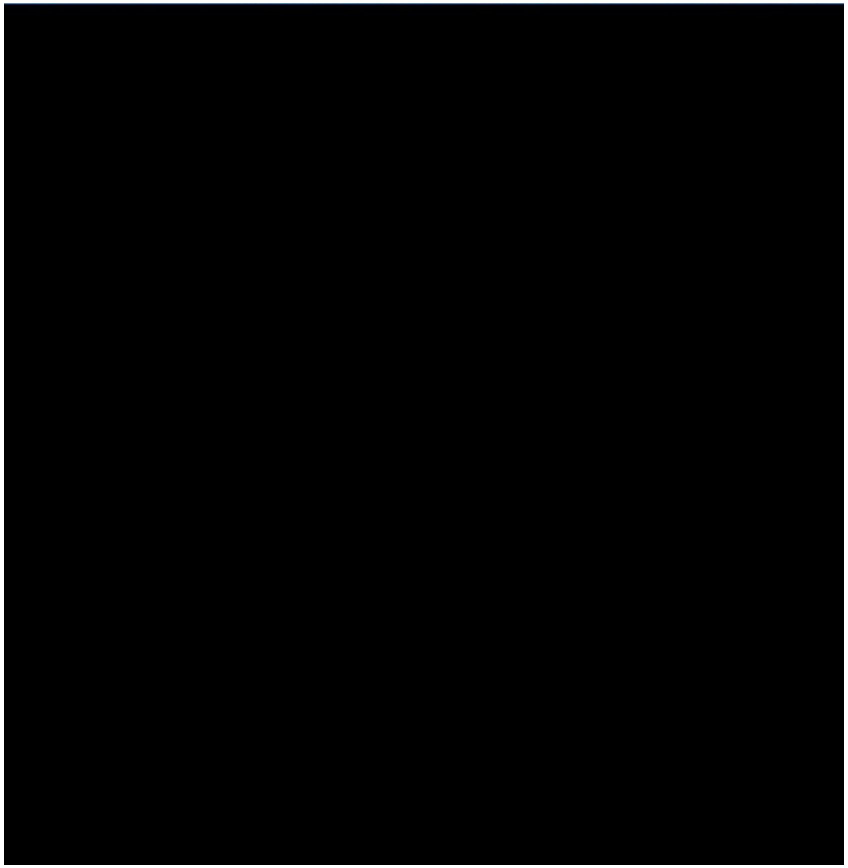
IEA. EV City Casebook. 2011.

EV Battery Life Cycle

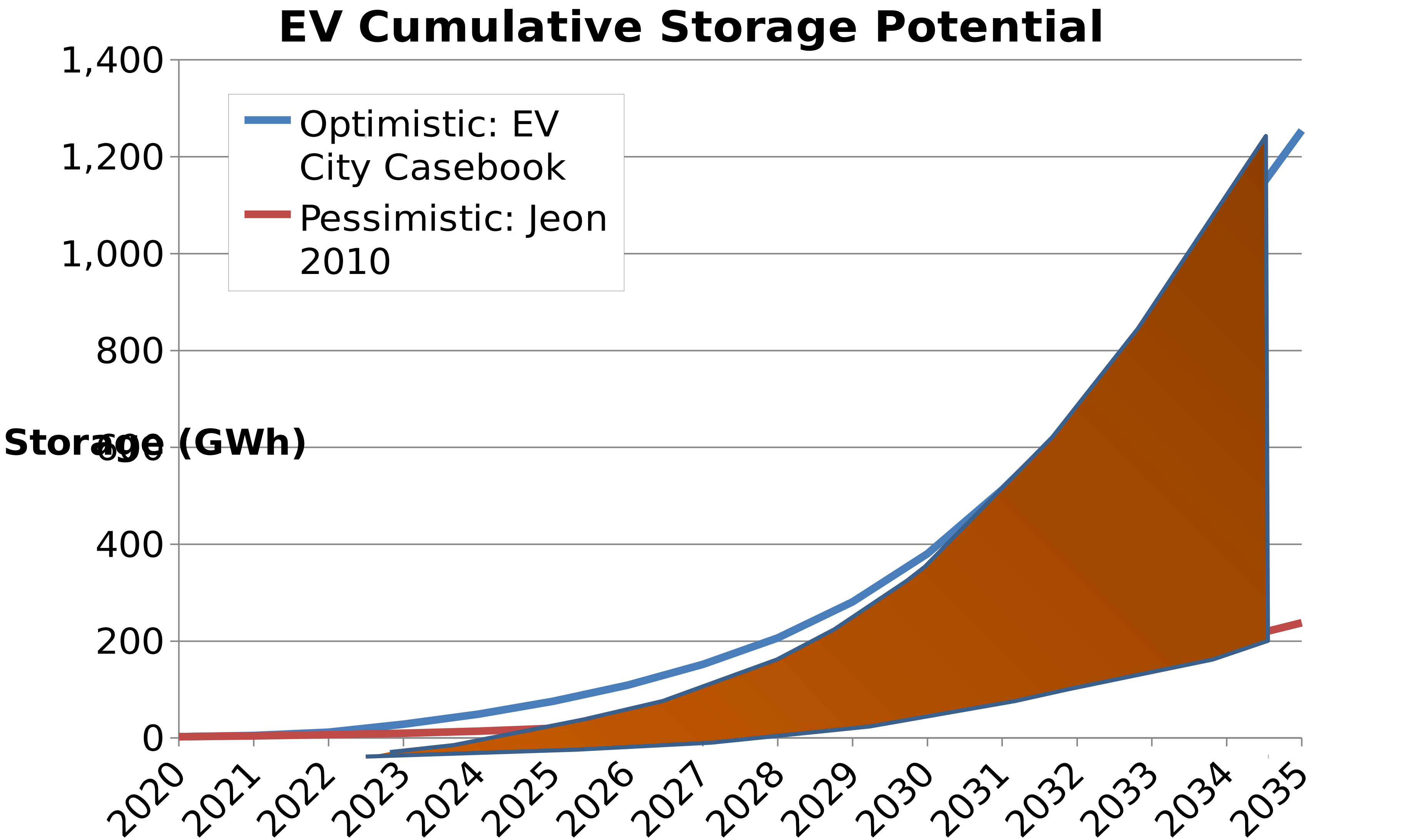


Second-Life Applications

- **Off-Grid:** Backup, Remote Installations
- **Grid:** Renewable Firming, Service Quality and Reliability, Load Shifting
- **Mobile:** Transportation, Recreational Vehicles, Commercial Idling Support

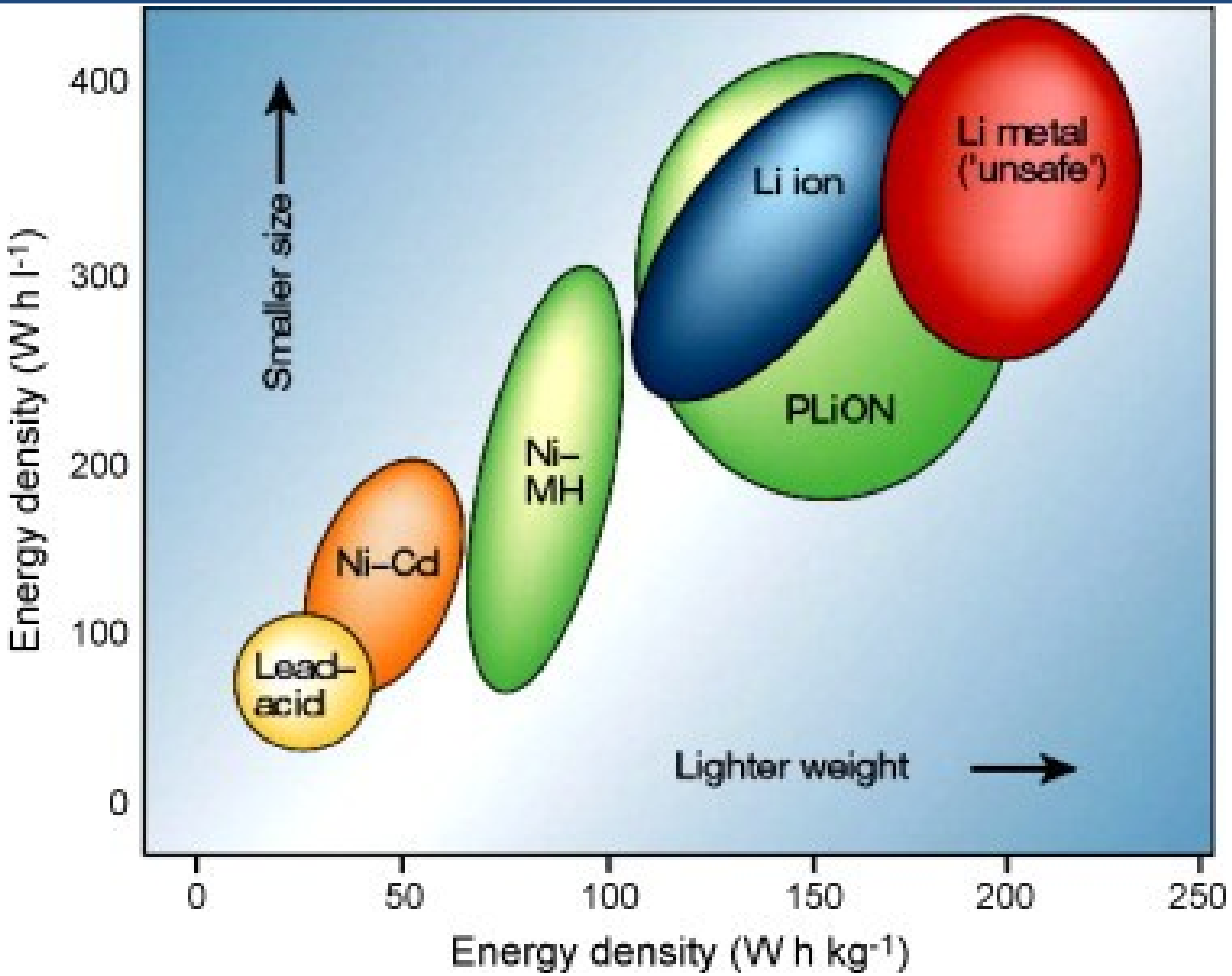


Projected Storage



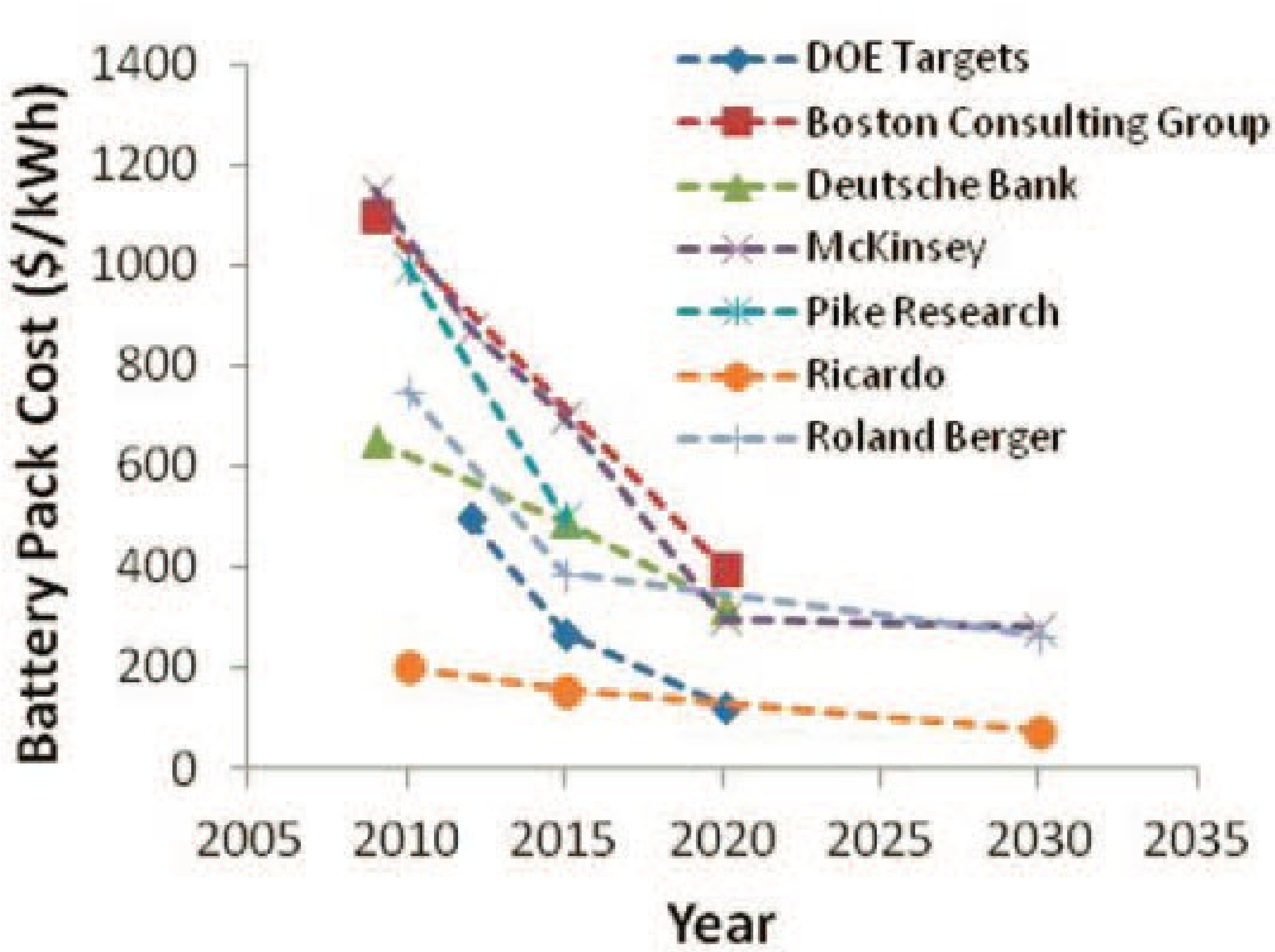
BEVs with average 200km range (45kWh), 30% capacity loss.

Superior Useful Energy Density and Cell Potential



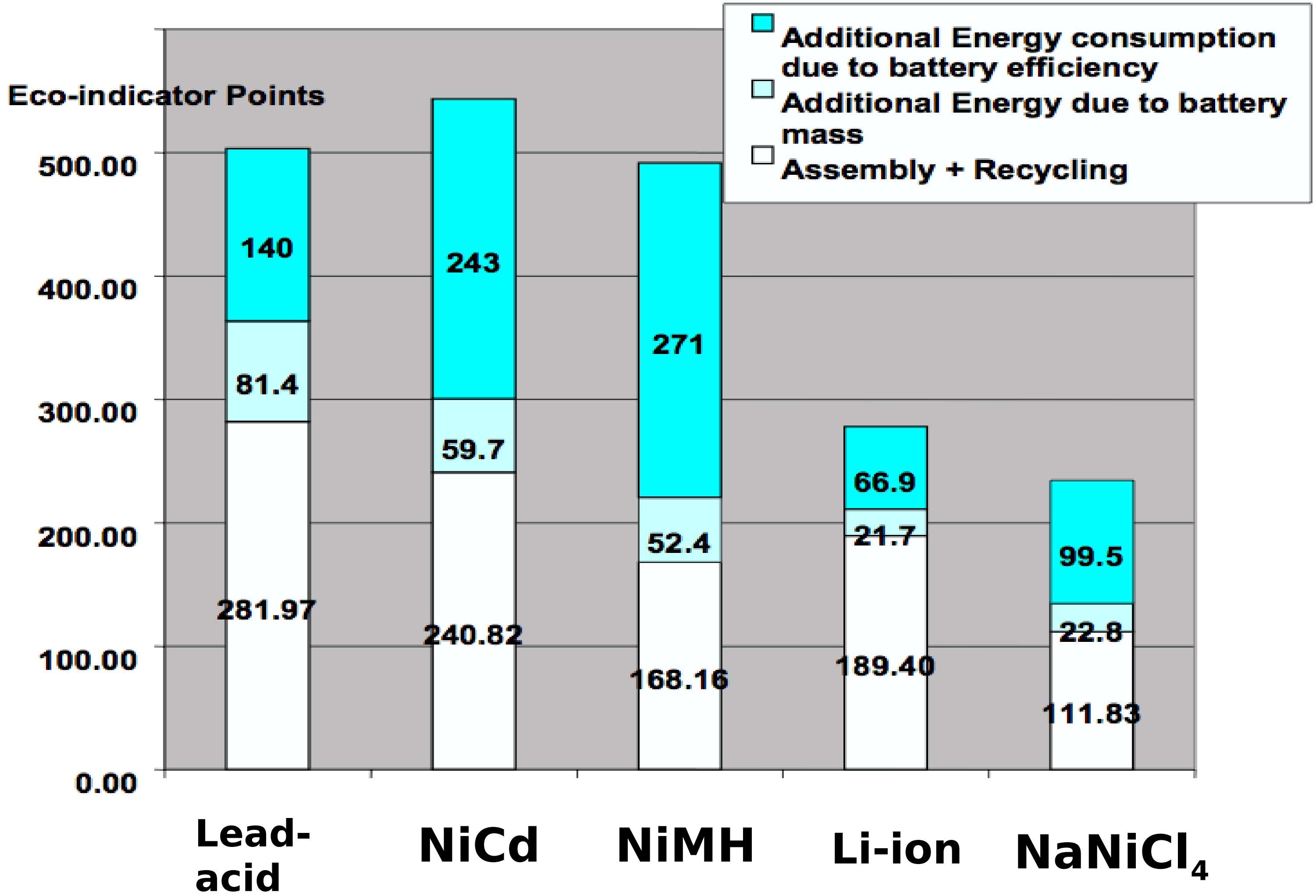
Amjad et al. Renewable and Sustainable Energy Review. 2010. p. 1104-1110

Lower Lifetime Cost



Neubauer et al. Proc. of SAE International. 2012.

Environmental Impact (Comparison to Lead-acid)



Matheys et al. Proc. of LCE. 2006. p. 97-102

Li-ion VS BAU

	Used Lithium-Ion	Lead-Acid
Useful Lifetime (Years)	6 - 10	3 - 5
Energy Density (Wh/kg)	100-180	30-50
Environmental Impact (Eco-indicator 99)	278	500
Cost ($/kWh)	? < $150	$75 - $300
Maintenance Required	NO	YES

500 GWh of Storage

$$500\ GWh * 50\% * \frac{system}{100\ W * 6\ h} \approx 400\ Million\ Systems$$

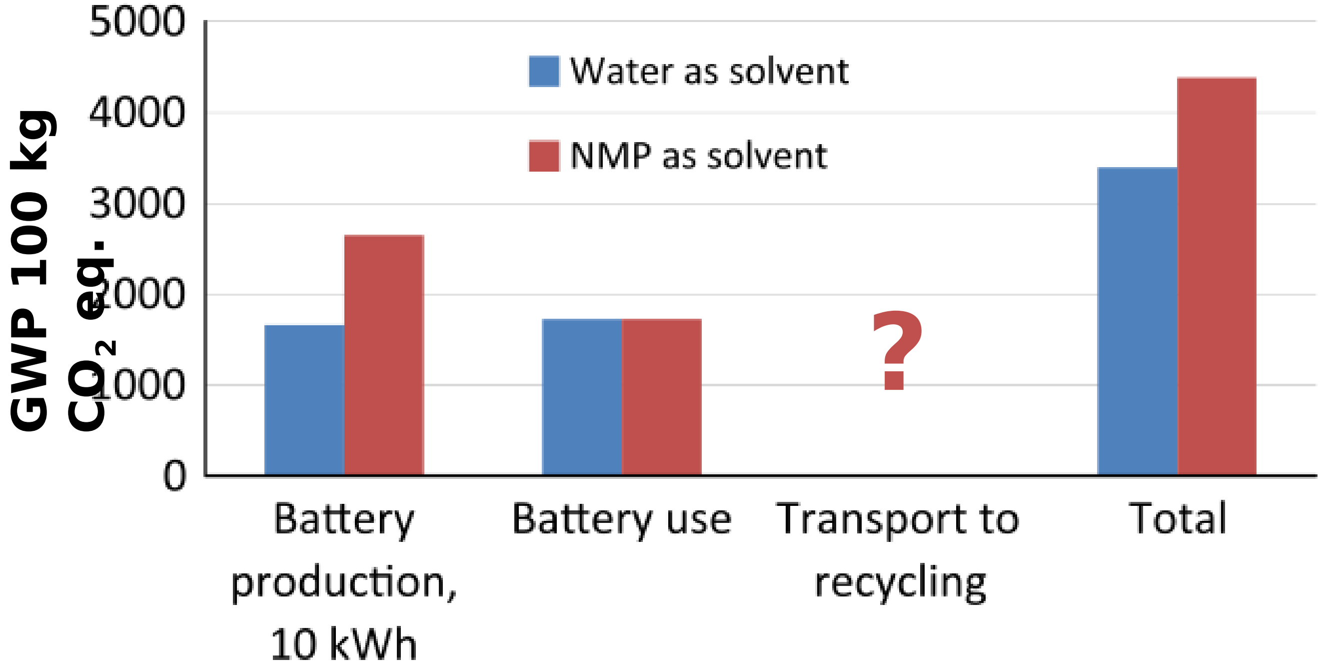
Implementation Issues

- Charge regulation
- Thermal management
- Repurposing costs
- Local technical capacity

Further Research

- Cost/impact of transport between point of origin, second-life, and end-of-life (EOL)

Impacts from two 10kWh Li-ion batteries with different solvent types



Zackisson et al. Journal of Cleaner Prod. 2010. p. 1519-1529

Further Research

- What is the expected value of recovered materials and real cost of recycling/processing?
- What are the environmental/health impacts of unrestricted disposal in rural areas?
- What is the actual field lifetime of an average Li-ion ESD

THANK YOU

Hanjiro Ambrose
(hanjiro@me.com)

Dimitry Gershenson
(d.gersh@berkeley.edu)

Daniel Kammen
(kammen@berkeley.edu)

Lithium Resources

Resource constraints on the battery energy storage potential for grid and transportation applications

Cyrus Wadia[a,b,1,2], Paul Albertus[c,*,1], Venkat Srinivasan[d,3]

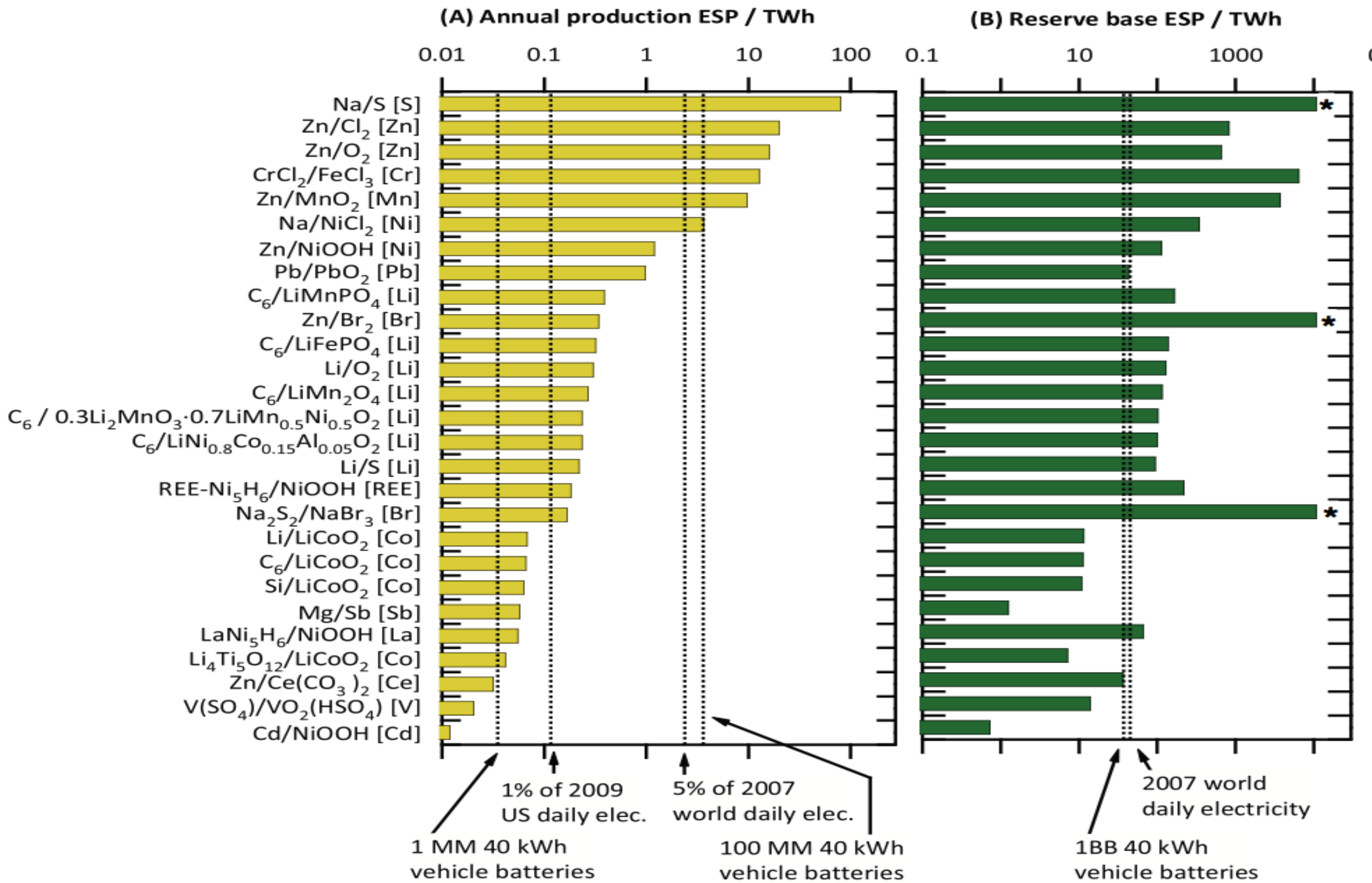


Table 1: World total lithium resource and reserve estimates (Mt. Li), (Paul Gruber 2010).

Li Resources	Deposits Included	Reference	Li Reserves	Deposits Included	Reference
19.2	15	Tahil (2008)	**4.6**	11	Tahil (2008)
25.5	8*	USGS (2010)	**9.9**	8*	USGS (2010)
29.9	24	Evans (2008)	**29.4**	40	Yaksic/Tilton (2009)
64.0	40	Yaksic/Tilton (2009)	**39.4**	61	Clarke/Harben (2009)**