

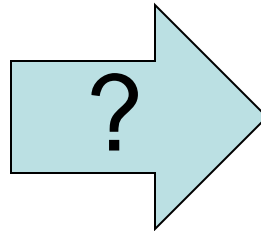
# Rapid Electric Vehicle Charging Workshop

**Amul D. Tevar, ARPA-E Fellow**  
**Wednesday, March. 28<sup>th</sup>, 2012**

# Could EV charging be made more convenient than filling a tank of gas?

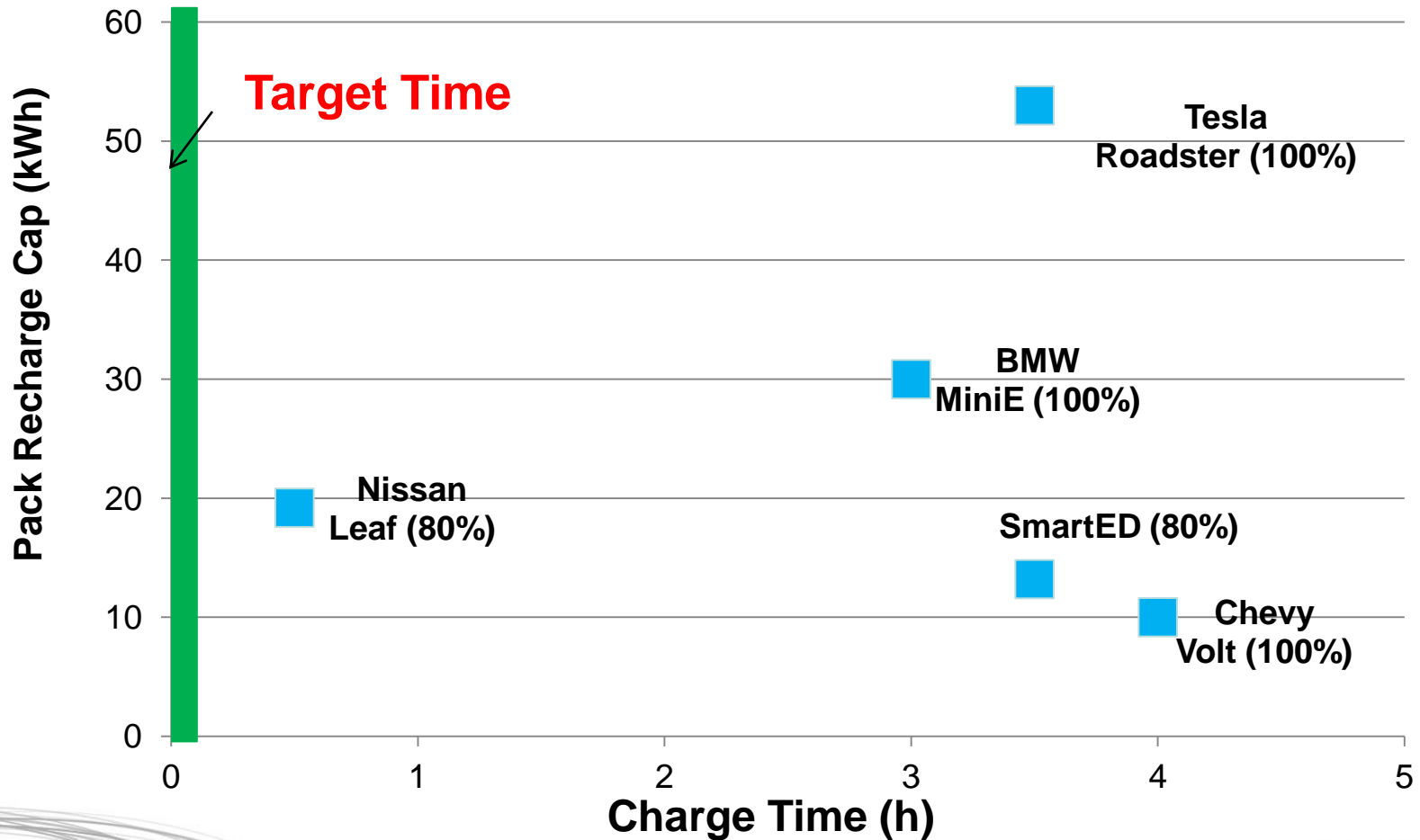
**‘I sure don’t want to sit around twiddling my thumbs for 30 minutes at a “charge station” waiting for an EV to charge...’**

*- Comment from hybridcars.com forum*



# Current Li-Ion pack charging times are long

Sample of US Current & Future EV Charging



Sources: Manufacturer Spec Sheets

# Why is rapid charging of EVs important?

- Deloitte survey of international consumer views on consumer EV demands and concerns found that:

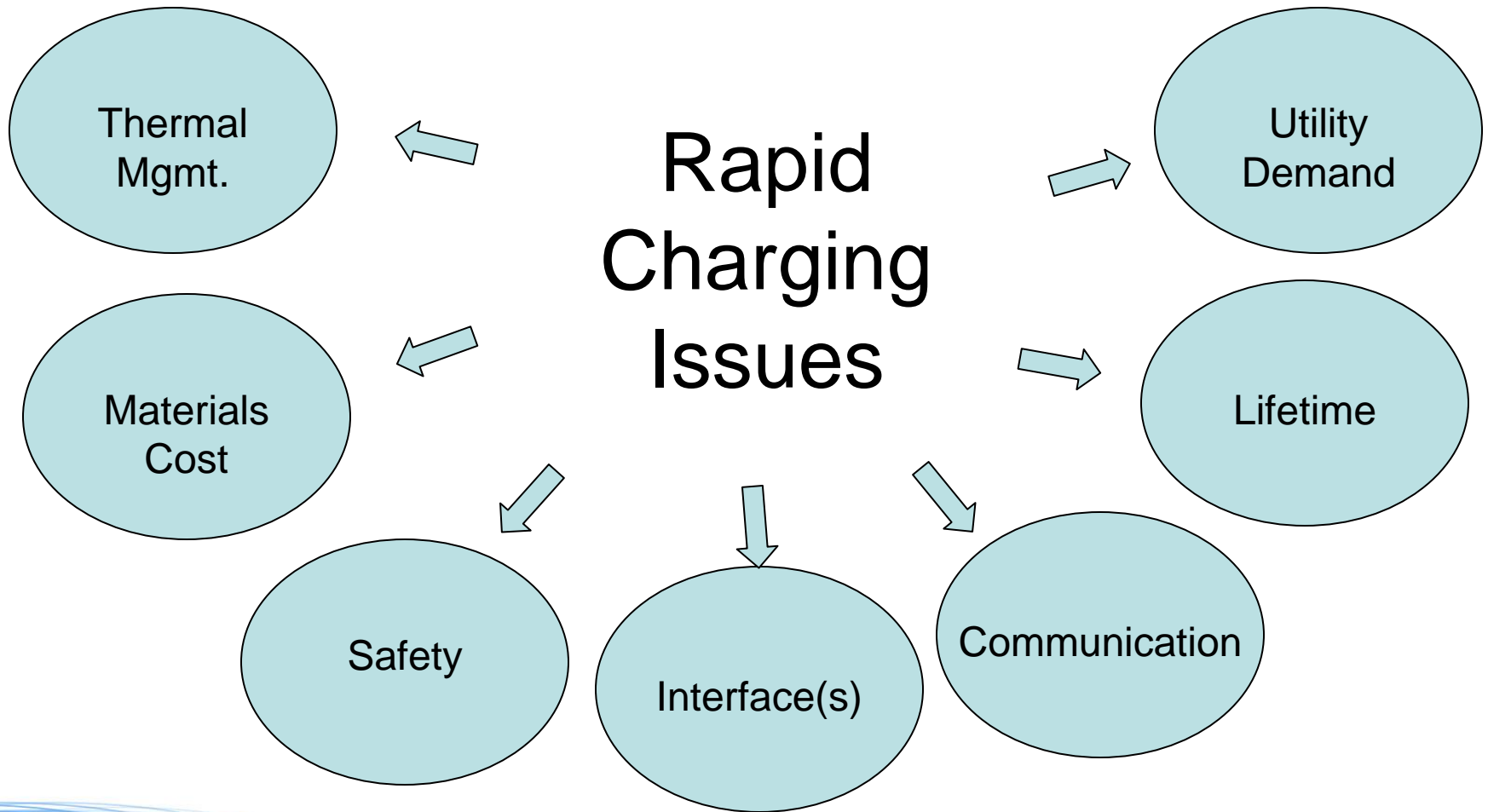
*“For more than 85 percent of the survey respondents, range, convenience to charge, and cost to charge were all “extremely important”*

- Only 2 – 4% of consumers have their expectations met with current EVs

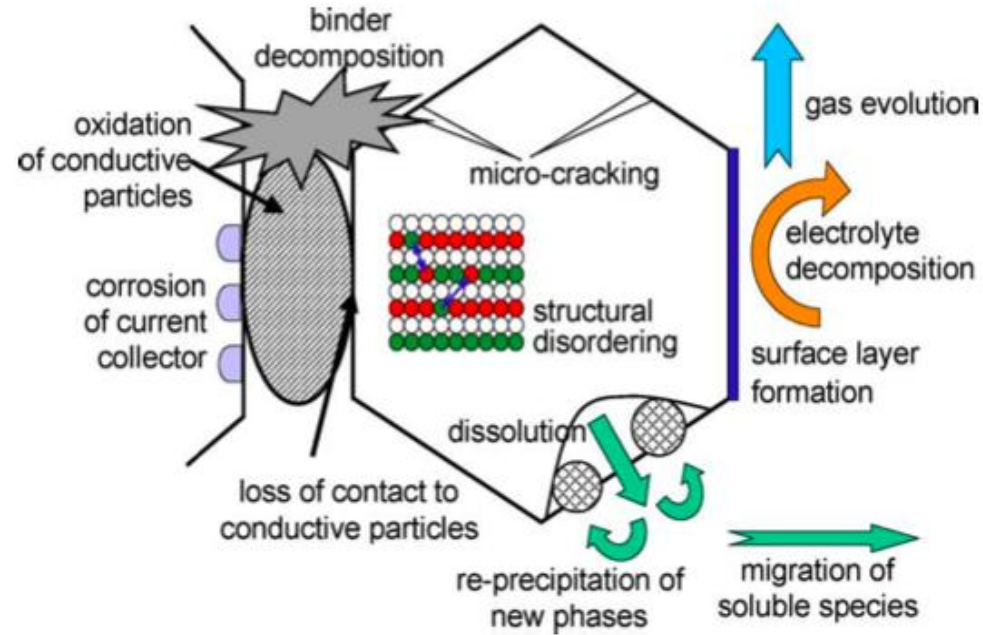


2 hr: Consumer charge time expectations  
10 min: Could we achieve this?

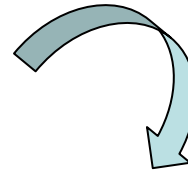
# Significant technical issues with rapid charging



# What needs to be addressed?



**Interface**



**Safety & Warranty**

Source: Vetter, J. Power Sources, vol. 147, 2005



# What could be enabled with rapid charging?

## Rapid Charge Stations



**Removes cost of at-home charging units**

## Inductive/Wireless Charging

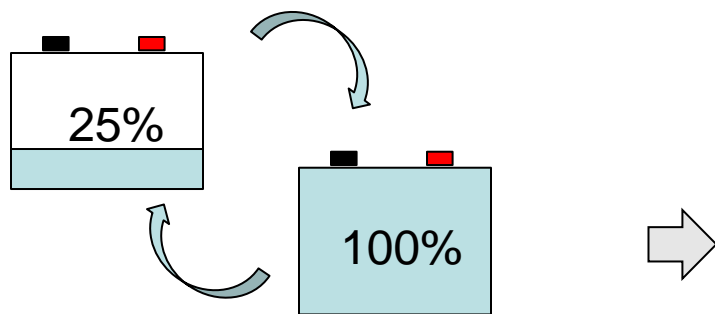


**Charging without cables**

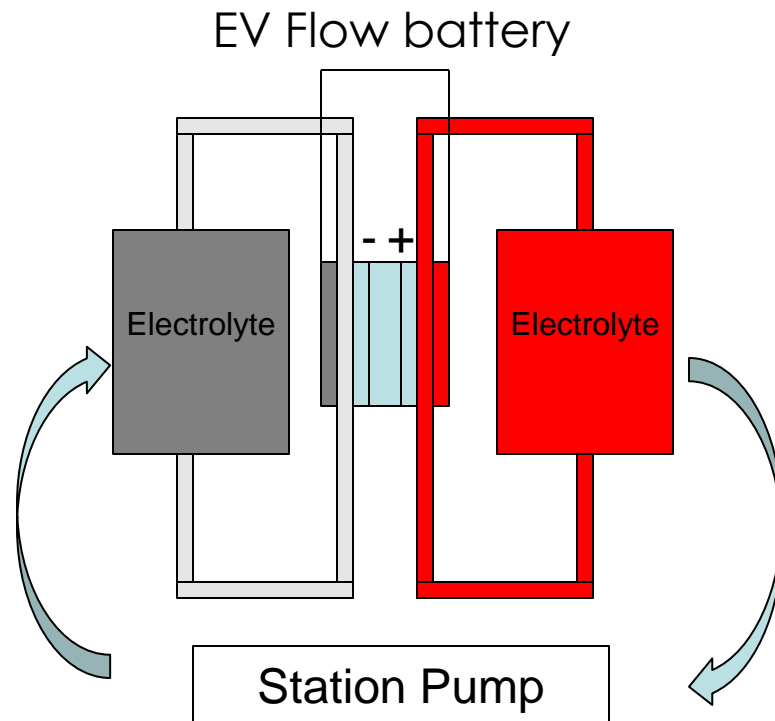
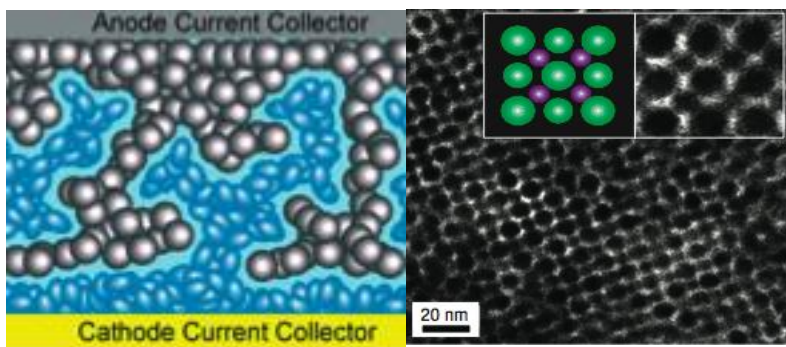
Source: Botsford, C. & Szczepanek, A. *Intl Batt, Hybrid and Fuel Cell EV Symposium, 2009.*

# What about easily replaced systems?

Battery Swapping. . . but this does not solve rate issue



EV Self-assembled battery



Use active materials hard, and change at station when capacity has been reduced

Sources: Adv. Funct. Mater. 2007, 17, 379–389  
Nature Mats, vol. 6, 2007,



# What would the solution look like?



- How can we avoid traditional battery issues or limitations?
- Are there advances from other fields?
- Are there secondary issues that may make high rates intractable?

Image: Wired.com

# Rapid EV Charging Goals

**Workshop purpose:** Identify technological whitespace, new research directions, and opportunities that could enable rapid charging battery packs with the following characteristics:

- 1. Ability to achieve a charging rate of >30 driving miles/min charge
- 2. Inherent system stability during interaction with grid and charger

## **Ground Rules**

In the interest of time, the following topics will not be discussed:

- Existing Battery swapping approaches
- Regulations and policy
- Charger port specifications
- Demonstration projects with existing technologies

# Discussion #1 - System Level Aspects

## ARPA-E's goals are to:

- Validate or improve our strawman metrics to be technically audacious but possible with sufficient stretching for the system around a battery that would enable rapid charging
- Identify and understand potential new designs, materials, and processes that could result in dramatically faster charging 5-10 years from now.



# Discussion #1 - System Level

- What infrastructure system advances are needed? How would a system interact with the grid?
- What are smaller, overlooked areas that are minor in systems at lower rates that may become major, compounding issues at higher rates?
- What would the ideal system be? How would the ideal system to overcome thermal issues? Other issues? Would new sensors be needed for rapid charging?
- What type of efficiency could be achieved? Where do the limitations originate from?
- What are the major technical and economic barriers?
- What novel/unique approaches could be enabling for this technology? What materials and engineering challenges, if overcome, would make this possible?
- Would communication between cell-pack-grid be necessary? What are possible approaches and would they need uniformity?

# Discussion #1 - System Level

- What would the cost of a possible charging station be? Would energy storage be needed?
- How would system *value* change with the addition of rapid charging? Is it worth it?
- Would a rapid charging EV system enable new infrastructure? How would a potential utility approach it?
  
- Summary Questions- What are the high level techno-economic metrics necessary for commercial adoption? What fundamental materials and process performance metrics are necessary for success?

## Discussion #2- Battery Level

- Can this be solved with existing systems? What are the current limitations? What modifications are needed? What will the effects be?
- Are there new systems or non-traditional approaches that could enable rapid charging? Would they have new or different fundamental limitations? What approaches offer the greatest opportunity?
- What safety steps are necessary to allow >30 miles/min charge? Could the same system rapidly and safely discharge for use and emergencies? Is rapid charging radically different than rapid discharging?



# Discussion #2- Battery Level

- What would the ideal battery be? What would its performance, lifetime and cost be?
- Could one battery allow both high energy density and high charging rates? Are there fundamental limitations?
  
- Summary Questions- What are the high level techno-economic metrics necessary for commercial adoption? What fundamental materials and process performance metrics are necessary for success?