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HTTP://NREL.GOV/TRANSPORTATION/

EXTREME FAST CHARGE AND BATTERY COST IMPLICATIONS

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Project Title: Extreme Fast Charging, Project ID: ES304

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OVERVIEW

Timeline

- Project start date: July 2016
- Project end date: January 2017

Barriers

Development of BEV batteries that meet or exceed DOE/USABC goals

- Cost
- Performance

Budget

- Total FY16 project funding: $775k
- Funding by Lab: $300k (ANL), $250k (INL), $225k (NREL)
- Funding for Battery Cost task: $75k
- Total FY17 funding: $0

Collaborations / Interactions

- Argonne National Laboratory, Idaho National Laboratory, National Renewable National Laboratory
- Automotive OEMs, Utilities, EVSE manufacturers & network operators, Battery developers

RELEVANCE, OBJECTIVES

RELEVANCE

- BEV owners would prefer recharging times to be similar to that of gasoline refueling in ICEVs
- Combination of fast charge and a network of high capacity chargers can minimize range anxiety
- Fast charge capability can promote the market penetration of BEVs and significantly improve the utility (or eVMT) of a BEV

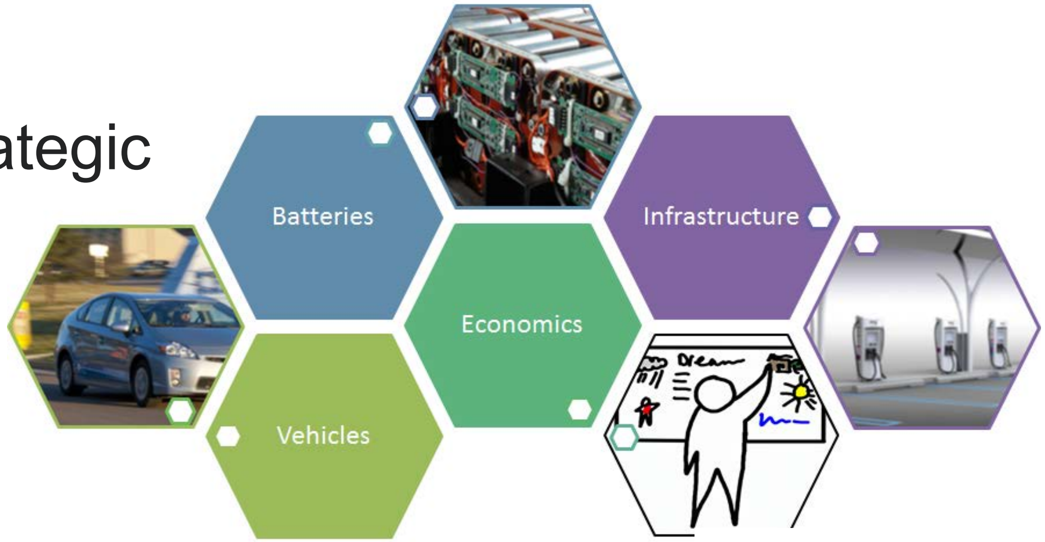
OBJECTIVES

Objectives

- Identify technical gaps in fast charging technology
- Assess the knowledge base of the fast charging capability of automotive batteries
- Identify R&D opportunities to improve fast charging ability

Benefit to DOE

- Aid in development of strategic program plan for fast charge applications



APPROACH

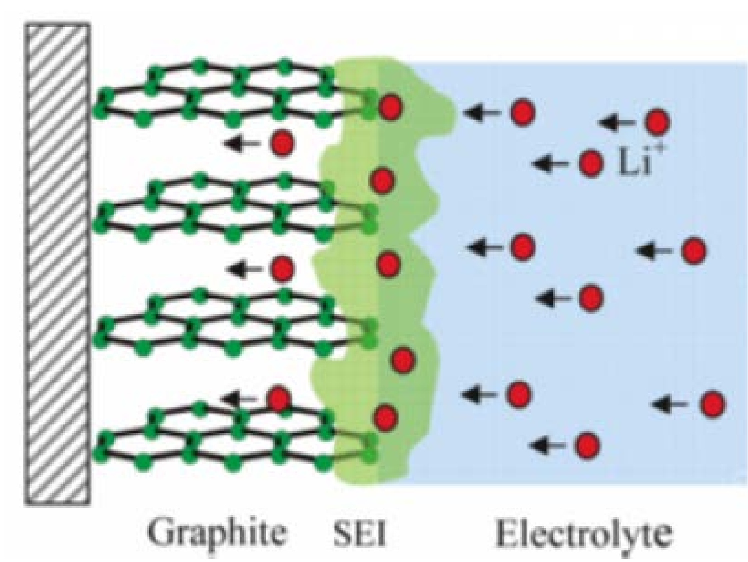
APPROACH

- Convened an industry stakeholder meeting to capture direction of fast charge technology and product readiness
- Extensive review of the literature
- Battery Cost Analysis
  - The spreadsheet model BatPaC has been used to design the battery pack and to estimate its cost in large volume manufacturing
  - Explore the effect of design and properties
  - Identify opportunities for improvement and R&D needs

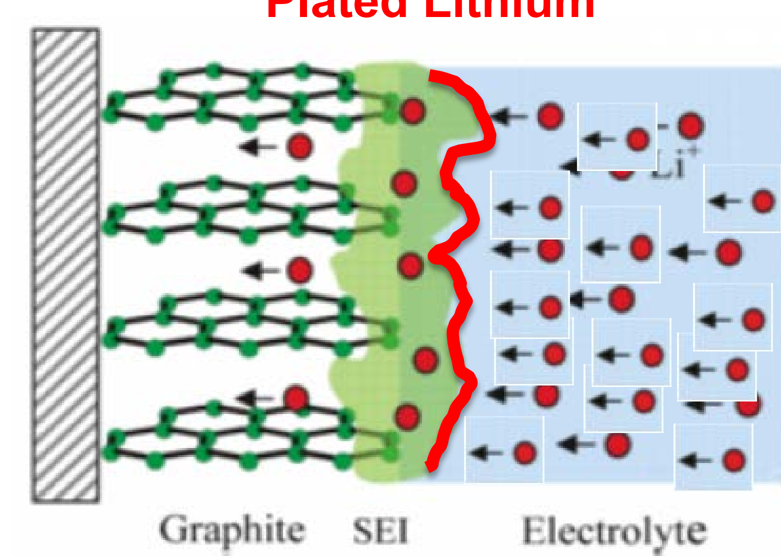
TECHNICAL ACCOMPLISHMENTS AND PROGRESS

ISSUES AND CHALLENGES WITH FAST CHARGING

- Lithium plating / deposition occurs on the anode above a threshold current density
- Cell temperature rise during charge can be an issue
- Durability of cells are likely to be affected



Plated Lithium



Defining a baseline battery pack and performance

Non Fast-Charging Battery: Increasing the State of Charge (SOC) by 80% in 60 minutes

Pack Requirements / Design Specification	
Cathode – Anode Chemistry	NMC622-Graphite
Pack Energy, kWh	85
Pack Rated Power (10-s burst), kW	300
Pack Voltage, V	900
No. of cells in battery pack	240
Maximum Allowable Current Density (MACD)*, mA/cm^2	4
Charging Time, ΔSOC=80%, min	60
Cell Temperature before Charging, °C	10
Charging Time, ΔSOC=80%, min	**60**

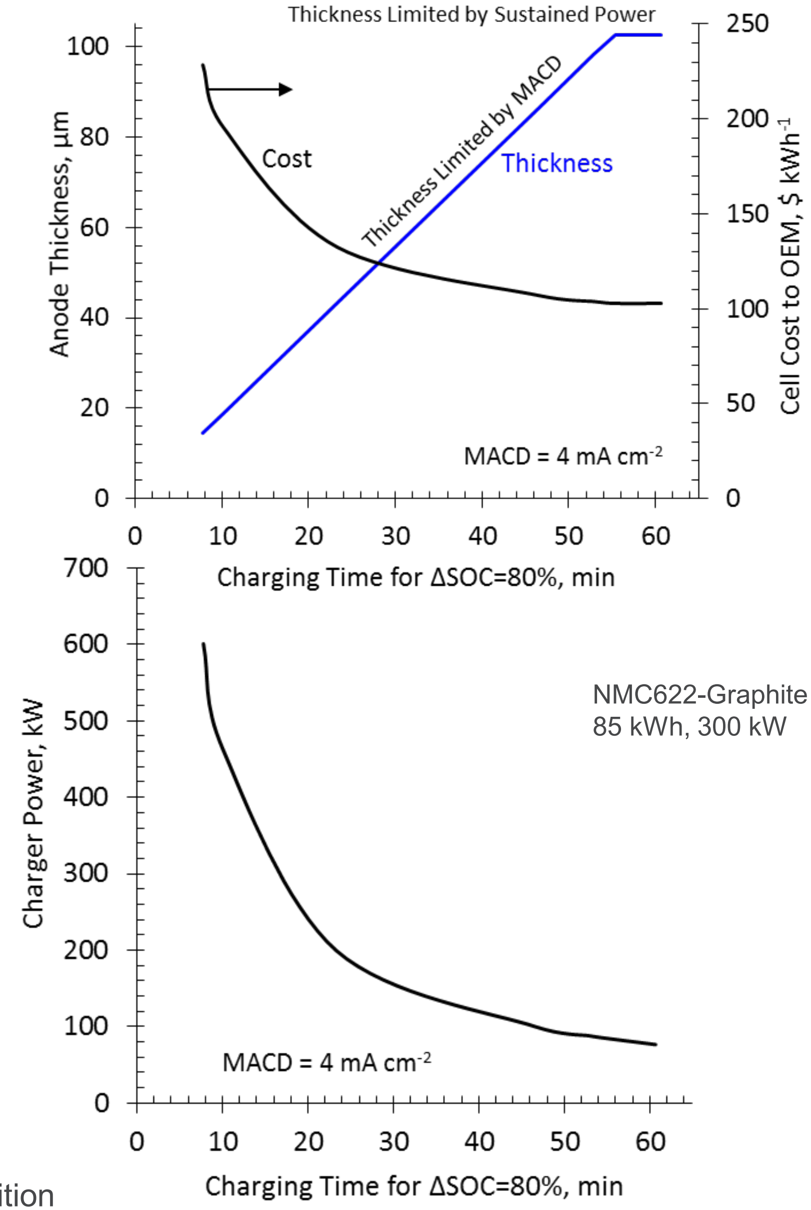
Calculated Results	
Minimum Charger Power Needed, kW	77
Anode Thickness**, µm	103
Heat Generated during Charging (battery pack), kWh	1.45
Post-Charge Cell Temperature, Δ80% SOC (no cooling) °C	25
Cell Cost to OEM, $ / kWh	$103

* To avoid lithium deposition, Gallagher et al, J. Electrochem. Soc. 163(2) A138 (2016)
** Anode/Cathode thickness ratio = 1.12

Fast charge limits anode thickness, increases cost

Cost increases sharply for charge times faster than 15 min

- The maximum anode thickness of 103 µm is limited by sustained power requirement
- Charging faster than 55 min is limited by MACD=4, requiring thinner anodes
- A 460 kW charger is needed for the selected battery to be charged ΔSOC=80% in 10 min



NMC622-Graphite
85 kWh, 300 kW

MACD = Maximum allowable current density to avoid lithium deposition

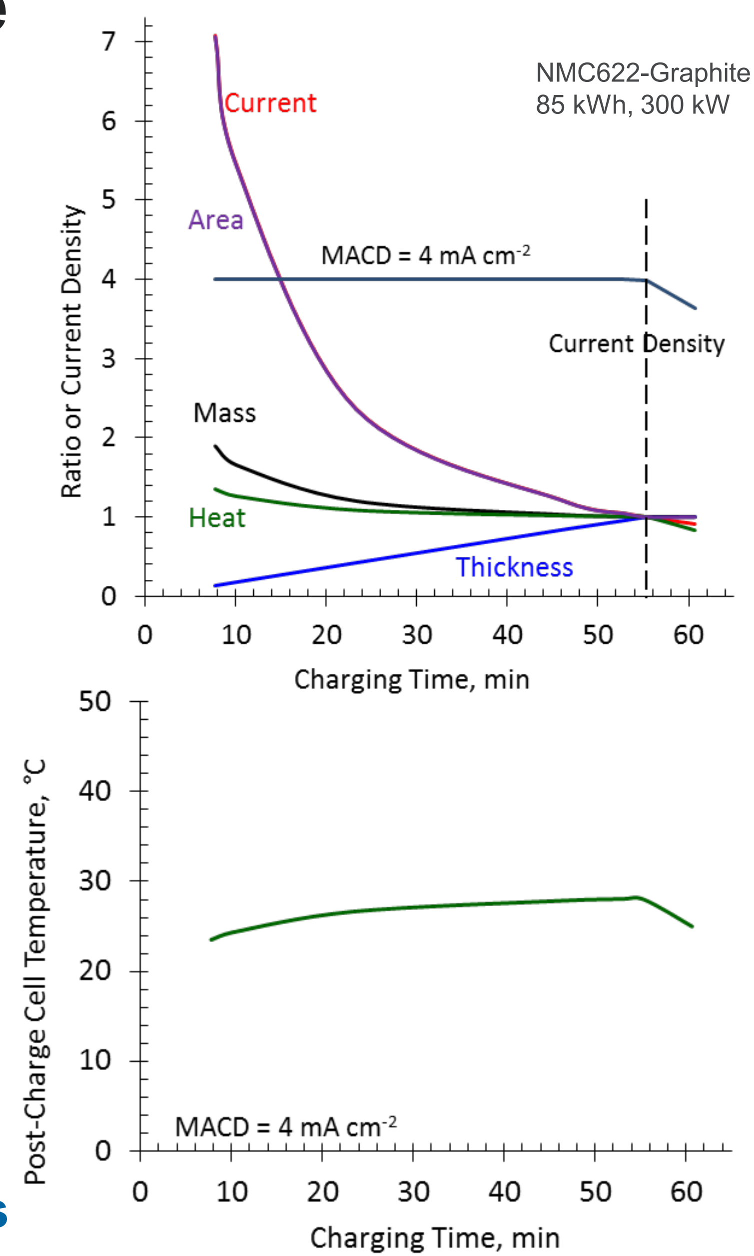
Heat generated during charge raises the cell temperatures

With faster charging, current through the cell increases
- More heat is generated
- Cell temperature increases

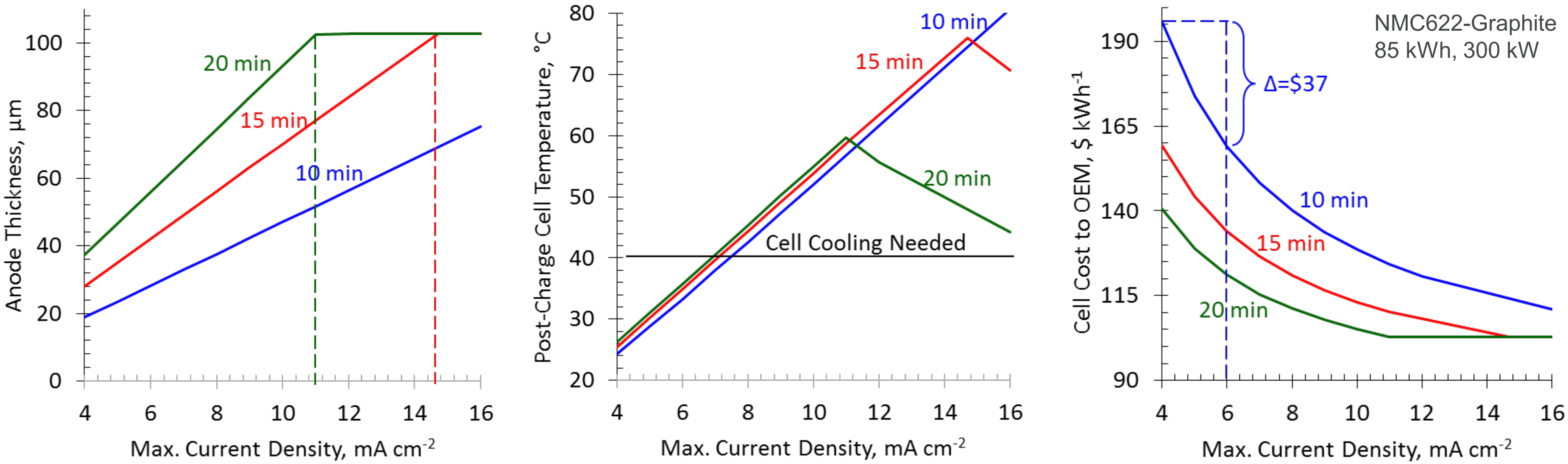
- At charging times less than 55 minutes
  - Current density capped at 4 mA/cm^2
  - Thinner electrodes needed
  - Cell area increases
  - Cell mass (inactive materials) increases more than increase in heat generation
  - Post-charge cell temperatures are lower

- No cooling is needed if 40°C is tolerable (initial cell temperature at 10°C)

Cooling is not needed for the designed cells



Anodes with higher allowable current densities will lower the cost of fast charge batteries



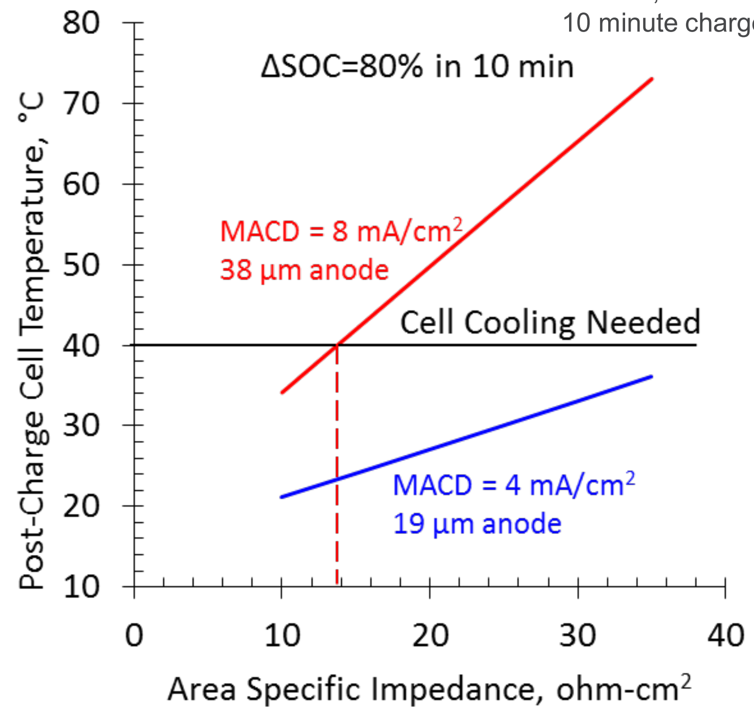
- For a 20 min charge
  - At < 11 mA/cm^2 , thinner electrodes needed, cost increases
  - At > 7 mA/cm^2, cooling is required
- A 15 min charge raises the threshold to 14.8 mA/cm^2
  - At < 15 mA/cm^2 , thinner electrodes needed, cost increases
  - At > 7 mA/cm^2, cooling is required
- A 10 min charge requires thinner electrodes, costs more, cooling above 7 mA/cm^2

For a 10-min charging battery, \$37/kWh cell cost savings is possible, if the MACD can be increased from 4 to 6 mA/cm^2

Lower area specific impedance (ASI) will reduce heat generation and cell temperature rise

NMC622-Graphite
85 kWh, 300 kW
10 minute charge

- At MACD = 4 mA/cm^2
  - No cooling is needed
    - Current is low, heat generated can be absorbed by cell thermal mass
    - Thin electrodes, high cost
- At MACD = 8 mA/cm^2
  - Cooling is needed if ASI > 14 Ω-cm^2
    - More current, more heat generated
    - Thicker electrodes, lower cost



- Effect of ASI on cell cost is very small
  - May add cost to meet cooling needs

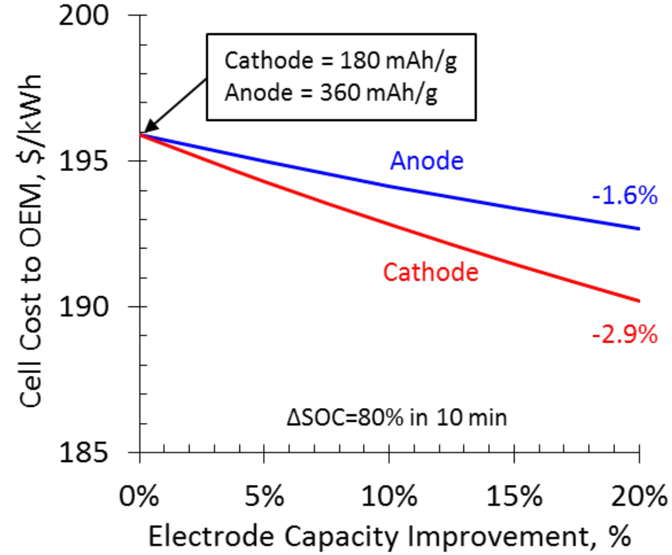
	35 Ω-cm^2	10 Ω-cm^2	Δ
4 mA/cm^2	$196.1 / kWh	$195.8 / kWh	0.2%
8 mA/cm^2	$140.4 / kWh	$140.0 / kWh	0.3%

NMC622-Graphite, 85 kWh, 300 kW, 10 minute charge

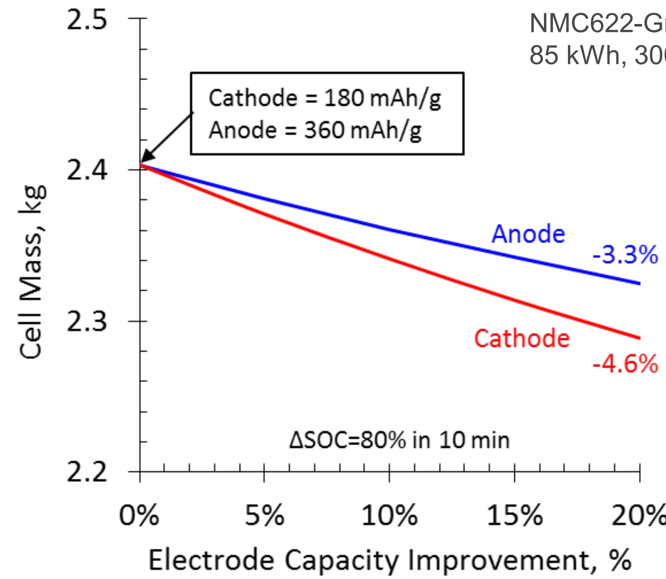
NREL INL Argonne

Higher capacity electrodes will lower cost, improve specific energy, energy density

- 20% improvement in electrode capacity
  - Lowers cost by 1-3%
  - Lowers cell mass by 3-5%
  - Lowers cell volume by 5%



NMC622-Graphite
85 kWh, 300 kW



PROGRESS

Milestones / Status

✓ Participate in meeting with collaborators and stakeholders
  – Status: Complete, September 2016

✓Report on fast-charging capabilities and path forward
  – Status: Report has been compiled

COLLABORATION

COLLABORATION

- ANL, INL and NREL worked to assess state of technology
  - Battery, infrastructure, vehicle, and market analysis teams
- Participated in information exchange with stakeholders
  - Automotive OEMs, utility, government agencies, battery developers, EVSE manufacturers & network operators

SUMMARY

- Fast charging battery packs have been modeled to show
  - Lithium plating limits the anode thickness and increases the pack cost
  - Cell cost increases nonlinearly with decreasing charging times
  - Cooling may be needed during charging, especially if the constraint on lithium plating can be relaxed with improved electrodes
  - Improved electrodes will lower the cost of battery packs

PROPOSED FUTURE WORK

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- Adapt BatPaC to incorporate design constraints for fast charge
- Analyze case scenarios to identify opportunities that facilitate fast charge
- Incorporate new experimental data from battery tests
- Support R&D teams with projections using new data

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PUBLICATIONS

- Enabling Fast Charging – A Battery Technology Gas Assessment, manuscript to be submitted to J of Power Sources