UTC Power

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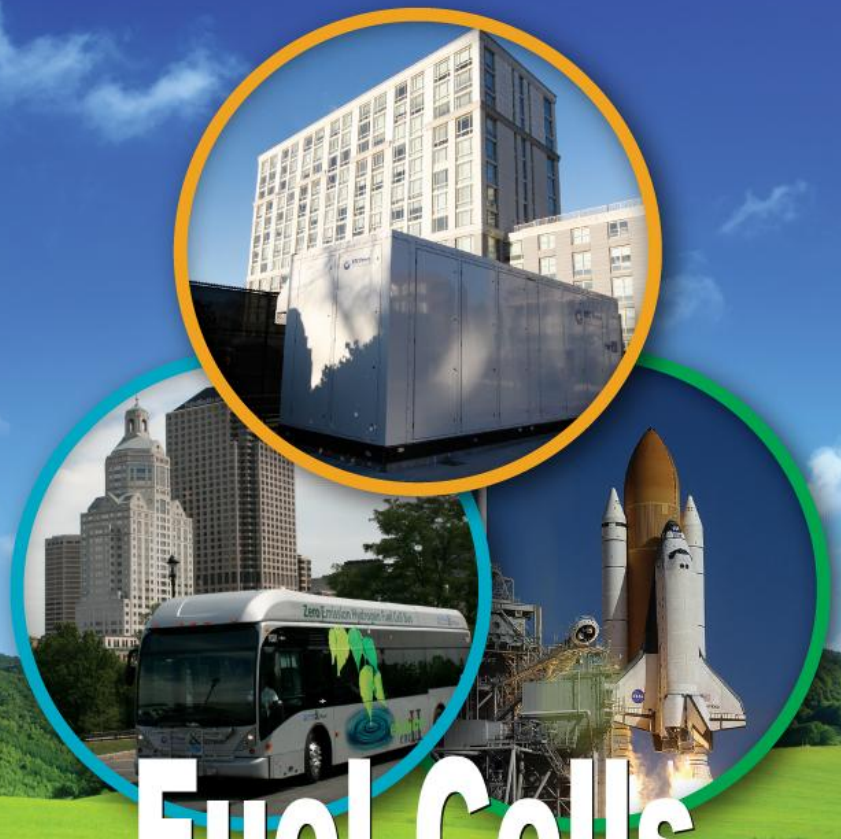
energy

Reinvented



Fuel Cells

Fuel Cell Power Electronics – Status & Challenges

Tejinder Singh – Engineering Manager

UTC Power is a world leader in developing and producing fuel cells that generate energy for buildings, transportation and space & defense applications.

Energy Productivity

Energy Security

Energy Responsibility

Agenda

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- UTC Power Overview
- Product Portfolio
- Stationary Applications
- Transportation Applications

United Technologies Corporation

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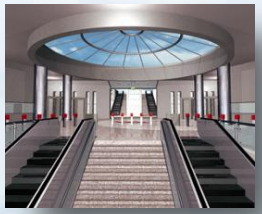
Fortune 50 corporation

$58.2B in annual sales in 2011

~60% of sales are in building technologies

Strong energy efficient & distributed energy product portfolio

UTC Power



OTIS

Carrier

Hamilton Sundstrand

UTC Fire & Security

UTC Power

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About Us

- Fuel cell technology leader since 1958
- ~ 450 employees
- 768+ active U.S. patents,
  258 additional U.S. patents pending
- Global leader in efficient, reliable, and sustainable fuel cell solutions

Stationary Fuel Cells

Transportation

Space & Defense

Grand Challenge : Cost

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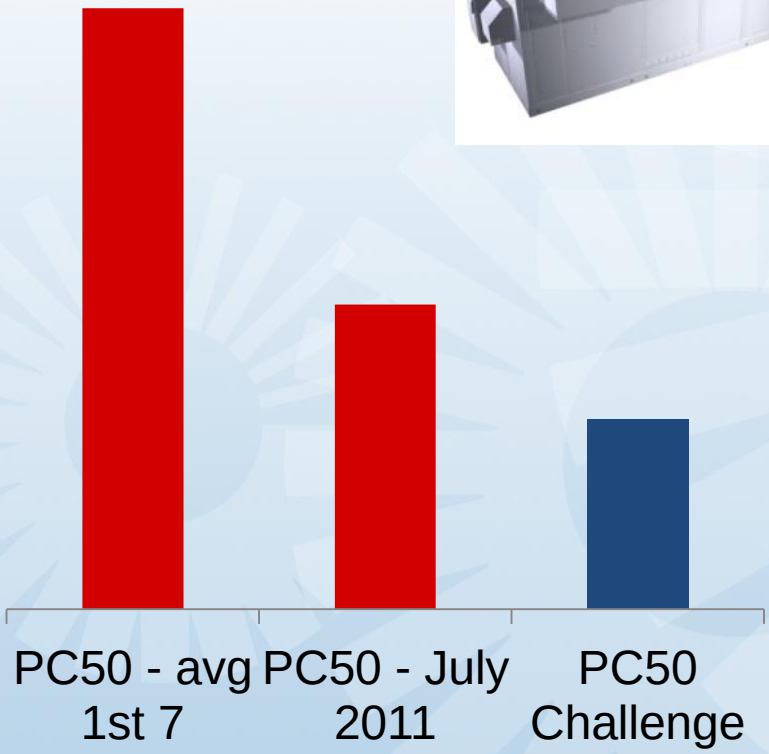
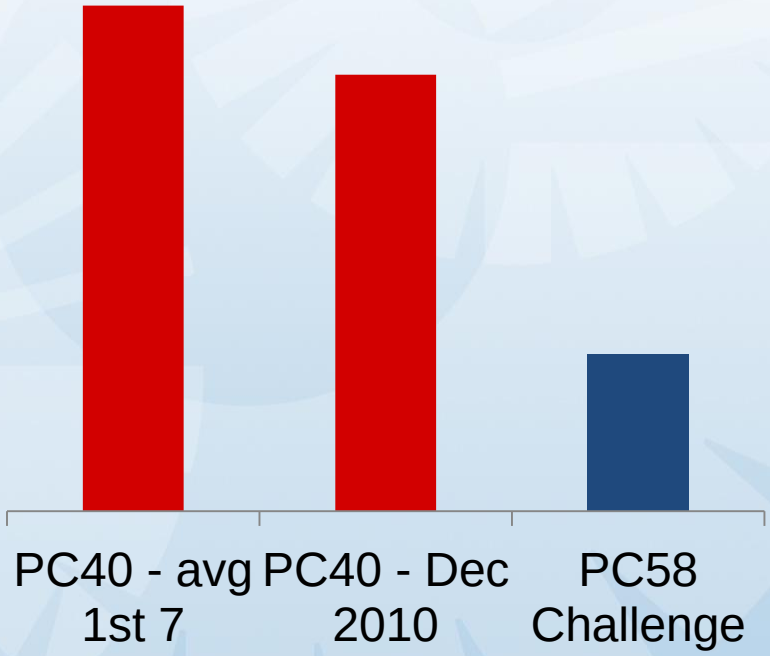
Stationary



Transportation



PureCell® Model 400 System

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Key Features

Output and Efficiency

- 400 kW net electric output
- 42% electrical efficiency[1]
- 1.5 MMBtu/hr heat output[1 2]
- Up to 90% system efficiency

Design Characteristics

- 10-year stack life
- Grid-independent capability
- Load following capability
- Natural gas fuel source
- Multi-megawatt capable[3]
- Certified to FC-1, UL, CARB 2007[4]

[1] 1st year average
[2] ~ 450 kW
[3] Through use of multiple Model 400 systems
[4] California Air Resources Board 2007 emissions standard

PureCell® Model 400 System

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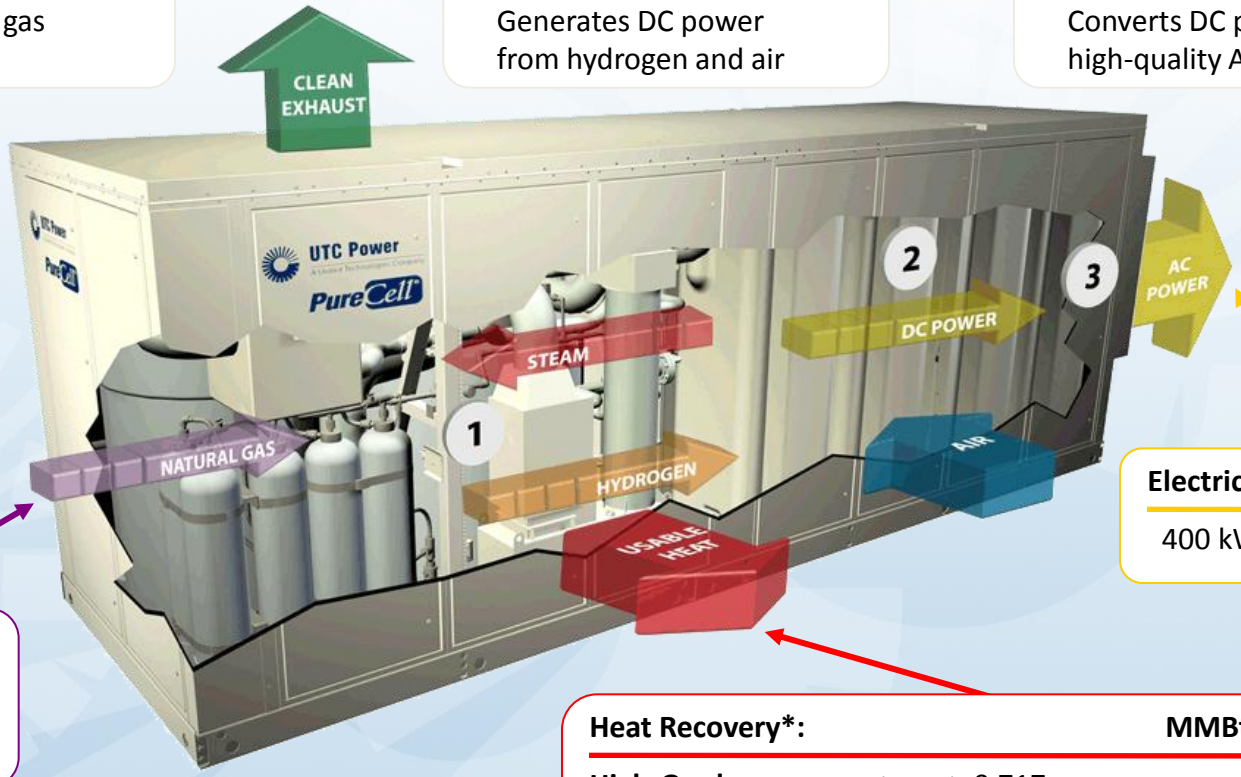
Process Overview

1 Fuel Processor
Converts natural gas fuel to hydrogen

2 Fuel Cell Stack
Generates DC power from hydrogen and air

3 Power Conditioner
Converts DC power to high-quality AC power



Fuel Input* (LHV):
Natural gas
3.79 MMBtu/hr

Electric Output:
400 kW, 480V, 60 Hz

Heat Recovery*:	MMBtu/hr
High-Grade up to 250°F (120°C)	0.717
Low-Grade up to 140°F (60°C)	1.017

* Beginning-of-life values

PureCell® Fleet

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Model 200

- 270+ systems installed across 19 countries on 6 continents
- 9.7+ million hours of field operation
- More than 1.6 billion kWh of electricity generation
- Average availability 2008 – present: **96%**
- Demonstrated 10 year cell stack life (design life of 5 years)
- Fleet Leader – Casino in Uncasville, CT with 85,181 hrs or 15,609 MWHRS

Model 400

- In production since 2010
- 42 systems in commercial operation
- Over 410,000 hours of field operation
- More than 150 million kWh of electricity generation
- 2011 Fleet availability: > **96%**
- 10-year stack design life
- Delighted customers placing additional orders

SAMSUNG
Coca-Cola
COX COMMUNICATIONS
New York Power Authority
Price Chopper
WHOLE FOODS MARKET
Stop&Shop
SUPERVALU

PureCell® Model 400 Solution

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Flexible Fuel Cell Application and Varied Experience

Price Chopper
New York

St. Helena Hospital
California

The Octagon
New York

Coca-Cola Enterprises
New York

Samsung/GS Power
South Korea

World Trade Center (Freedom Tower)
New York

Fuel Cells: Power Through the Storm

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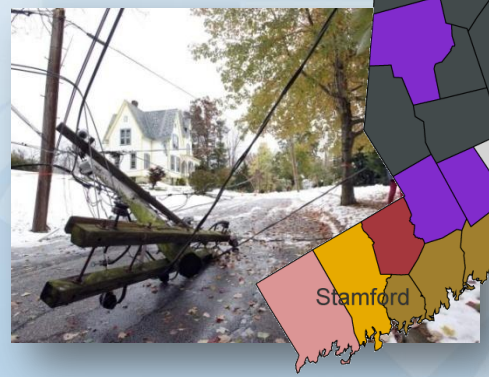
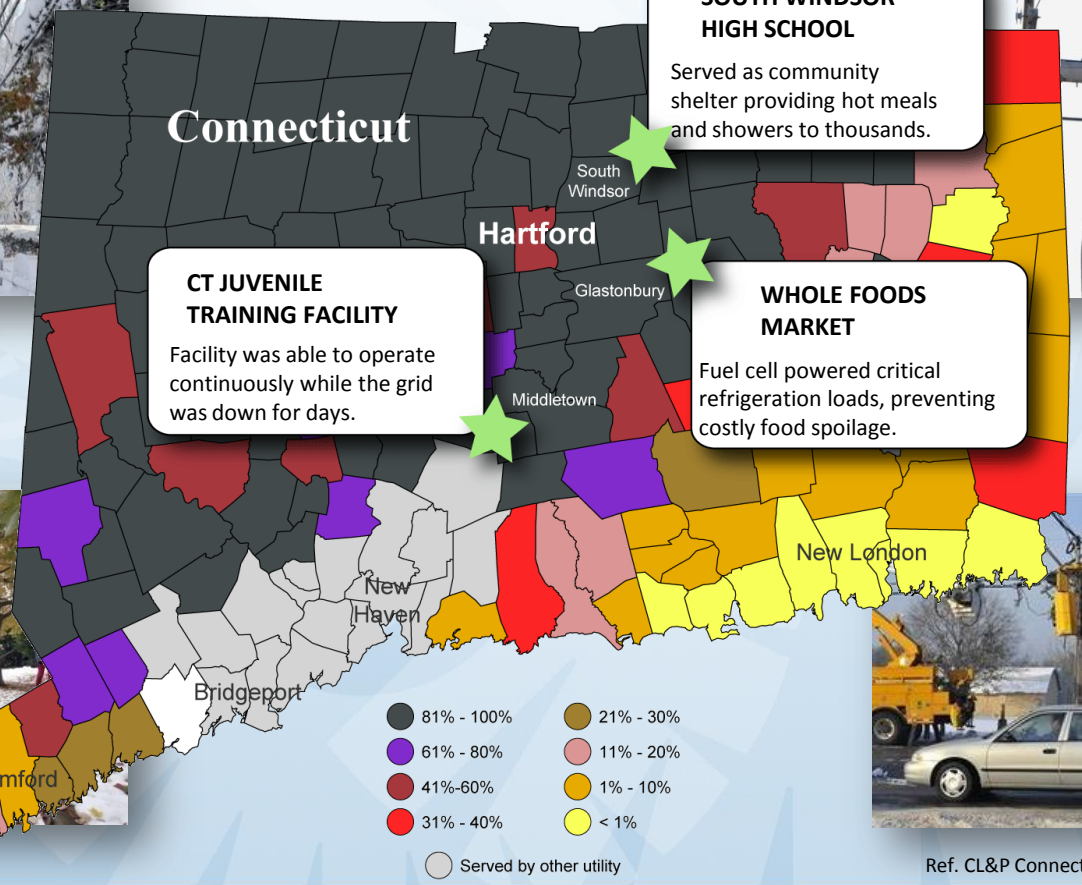
PureCell® systems keep CT businesses and shelters running through prolonged power outages resulting from the October 2011 winter storm.





SOUTH WINDSOR HIGH SCHOOL

Served as community shelter providing hot meals and showers to thousands.

CT JUVENILE TRAINING FACILITY

Facility was able to operate continuously while the grid was down for days.

WHOLE FOODS MARKET

Fuel cell powered critical refrigeration loads, preventing costly food spoilage.

Ref. CL&P Connecticut Outage Map for October 2011

Supermarket Open During Blackout

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Reliable Power During Grid Outages (San Diego Albertsons)

- Albertsons supermarket operates throughout September 2011 San Diego power outage
- Was one of the only retail stores in the valley operating during the crisis
- Despite the sweltering heat outside, Albertson's perishable inventory protected thanks to the continued operation of their fuel cell

"When you drive down the neighborhood and the only thing lit is Albertsons, it attracts people,"

-Rick Crandall, Director of Sustainability, SuperValu Inc.

Evolution from PC25 to PC50

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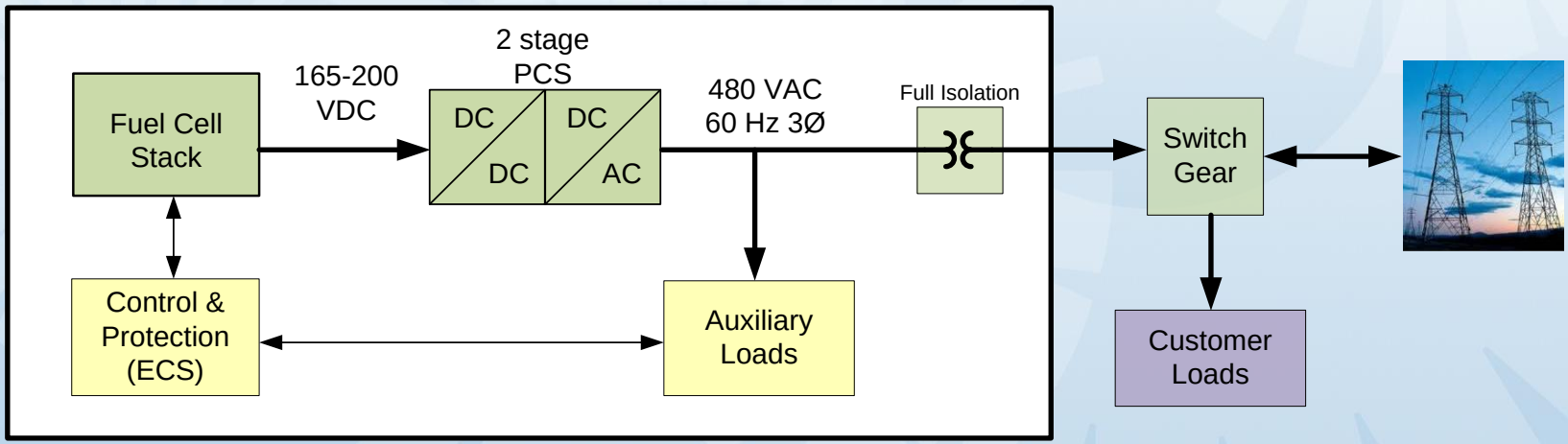
- **PC25**
  - Single Cell Stack Assembly – grounded
  - 2 stage 200kW converter
    - DC/DC converter to boost voltage
    - 3 phase grid connected Inverter
  - Full Isolation transformer for grid connection
    - Capable of Grid Independent Operation
  - PCS is ~93% efficient



Evolution from PC25 to PC50

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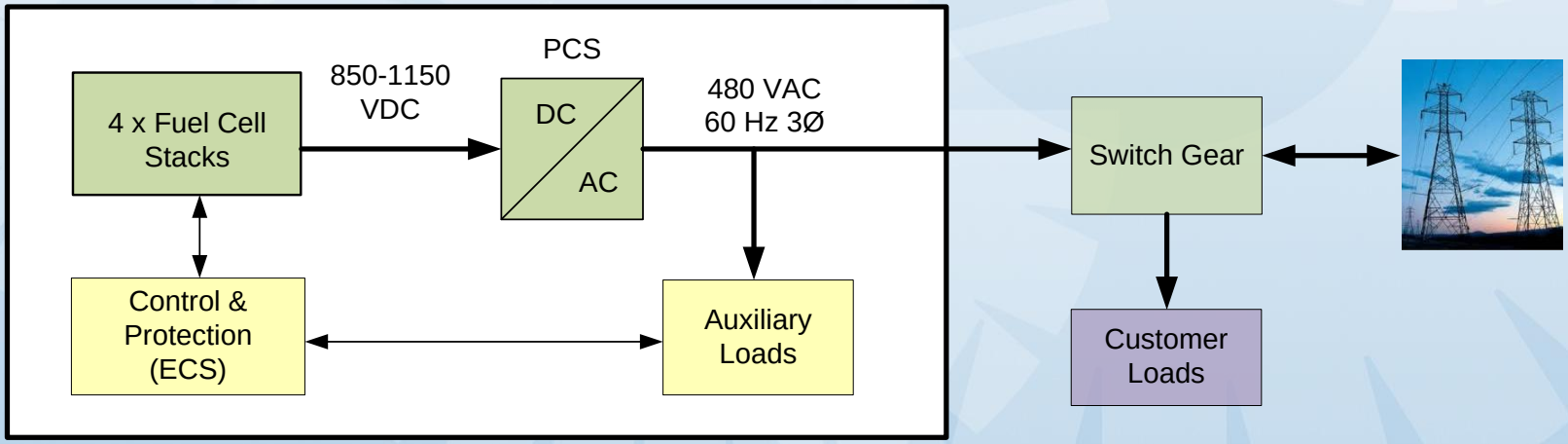
- **PC50**
  - Four Cell Stack Assemblies in series to achieve >850V @ base load
  - 400kW / 470kVA inverter
  - Directly connected to grid
    - No isolation transformer
    - Capable of Grid Independent
      - Interruption during transition
  - PCS is ~97% efficient



Next steps

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- Flexible architecture
- Core module system leveraging COTS PCS
- Multiple Unit Load Sharing (MULS)
- Seamless GC/GI transitions
- Microgrid Integration & Secure Communication

Transportation

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Electrical drive train with FC as a primary source of propulsion power

World class performance

- Primary propulsion is UTC's Puremotion™ 120kW proton exchange membrane (PEM) fuel cell
- Fleet experience of more than 600,000 miles
- Fleet leader at a record 12,000 hours and counting
- Additional fleet buses demonstrating similar durability – 7,200 hours
- 18 quiet, zero-emission fuel cell buses are currently in service in the United States
- 2010 and 2011 fuel cell availability is greater than 95% surpassing 85% for conventional engines
- >2x more efficient than diesel powered bus

Transportation

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- UTC Power content on PC40 includes:
  - Fuel cell assembly
  - Balance of plant
    - sensors, actuators, blowers, pumps, etc
  - Digital electronic controller
    - Protection
    - Control of cell stacks
    - Communication with external systems
- Utilizes modular inductor, dc dc converter and inverter modules
  - Integrated by bus manufacturer

Transportation Challenges

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- PC58 in Conceptual Design phase
- PC40 vs PC58
  - Cost reduction
  - Reduced envelope
  - Increased power
    - 120kW -> 150kW

- Opportunities for improved integration with external systems
  - Battery management and Optimization
  - Power system flexibility to accommodate different cell stack configurations
  - Use of ultra capacitors for load transients

- Questions / Discussion