2012 DOE Vehicle Technologies Program Review Presentation

Stand Alone Battery Thermal Management System

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Project ID: ES135

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Overview

Timeline

•Start: October 1, 2011
•End: September 30, 2014
•Percent Complete: 17%

Barriers

• Barriers Addressed
  - Cost
  - Reliability
  - Life

Budget

•Total Budget
  - DOE: $2,610,555
  - Contractor Share: $693,924
•Funding Received in FY11
  - $37,981
• Funding for FY12
  - $667,864

Partners

• National Renewable Energy Laboratory
• Chrysler Group LLC

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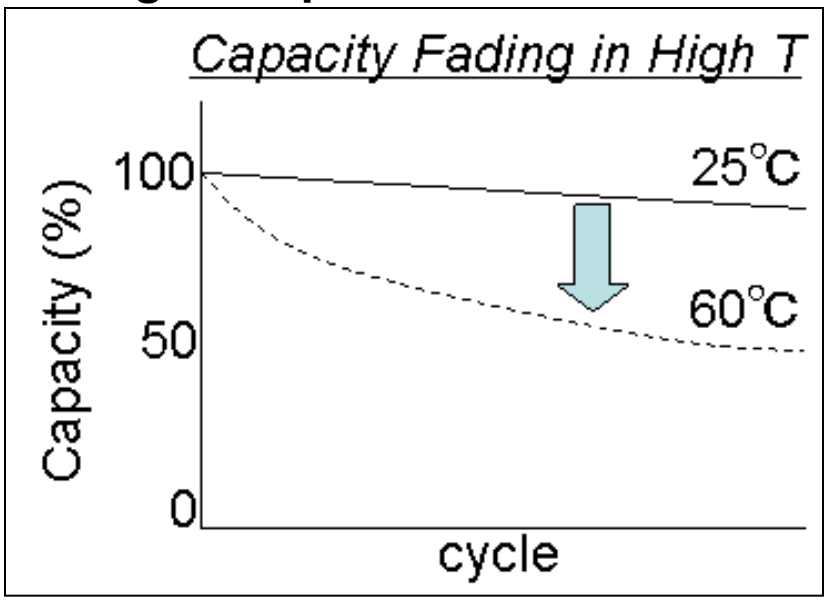
Relevance - Project Objective

Research, development, and demonstration of innovative thermal management concepts that reduce the cell or battery weight, complexity (component count), and/or cost by at least 20%.

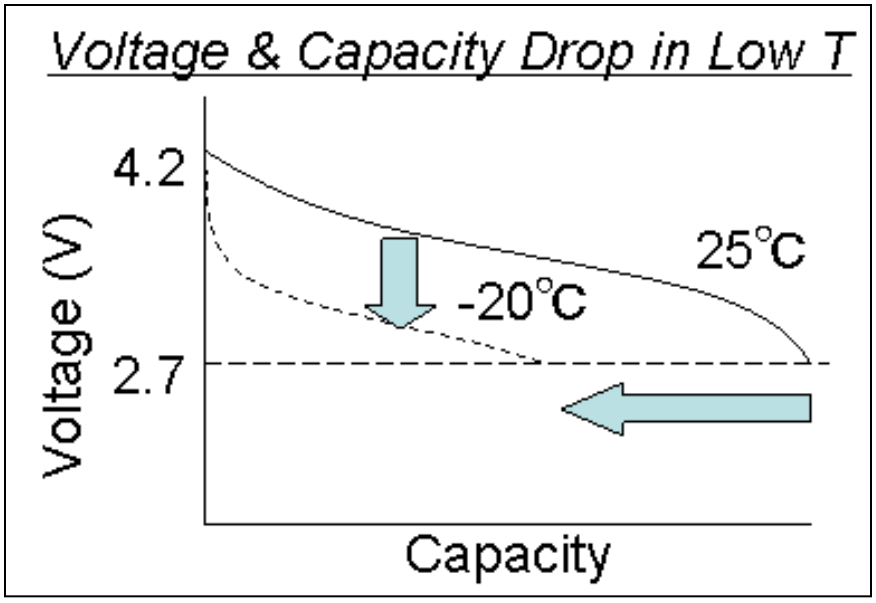
Relevance – Temperature Effect On Batteries

High Temperature Effect



The more time the battery is subjected to high temperatures, greater the capacity is reduced = reduced battery life.

Low Temperature Effect



Battery Voltage and Capacity is reduced at low temperatures = reduced driving range.

Thermal Management is Required to Enable a Reduction in Battery Size
(Prevent over-size of battery pack to overcome temperature effects)

Milestones (FY11 & FY12)

Target Completion Date	Milestone	Status
April/2012	Testing Conditions for Simulation and Bench for Entire Project. Knowing the simulation and testing conditions is required up front.	On Track
May/2012	Thermal Characteristics of Battery Cells / Modules. This is needed so the simulation model created in the first year of the project matches the battery cells that will be used for testing later in the project.	On Track
January/2013	Go/No Go: Simulation Model Complete: Does it Match Vehicle Test Data? (Yes/No) Does the simulation model created in the first year match the actual battery in vehicle? This is required before moving to Phase 2 of the project.	On Track

Approach – Using DENSO Thermal Experience

- DENSO is the largest automotive supplier of thermal systems. (30% of Global Market)
- DENSO Recent Thermal Products:
  - 1996: DENSO introduced a condenser that integrated the condenser and subcooler.
  - 2002: CO_2 Car Air-Conditioning System (Replacing hydrofluorocarbon refrigerant with natural CO_2.)
  - 2002: DENSO introduced a new condenser featuring the world's thinnest tube (1 mm) and lowest fin height (5.4 mm)
  - 2002: DENSO introduced the thinnest evaporator of its kind in the world. This small and light evaporator (38 mm in width) has the world's thinnest tubes and thinnest tube plates.
  - 2003: DENSO launched the world's first small, light-weight electric compressor for hybrid electric vehicles.
  - 2003: DENSO unveiled the use of an Ejector for Refrigerator Truck cooling system and ECO-Cute CO_2 Hot Water Heater System
  - 2006: DENSO developed a unique double-pipe internal heat exchanger for a car air conditioning system, increasing cooling performance by up to 12 percent.
  - 2009: Passenger Vehicle Air Conditioning System Using an Ejector (Reduced power consumption up to 25%)

This project will utilize DENSO's strong thermal system technology portfolio

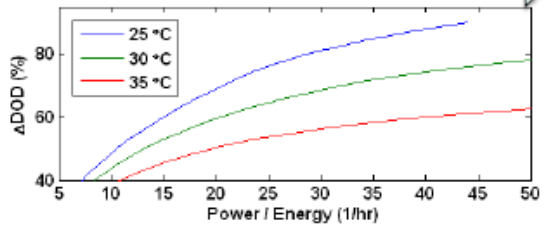
Approach – Review of Previous Studies

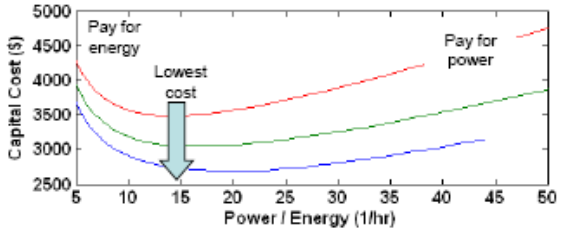
Example Trade-off Studies

Impact of requirements on battery size: Useable ΔDOD and cost

PHEV10: Assumed the battery has to last 10 years at various temperatures

Higher P/E increases useable ΔDOD

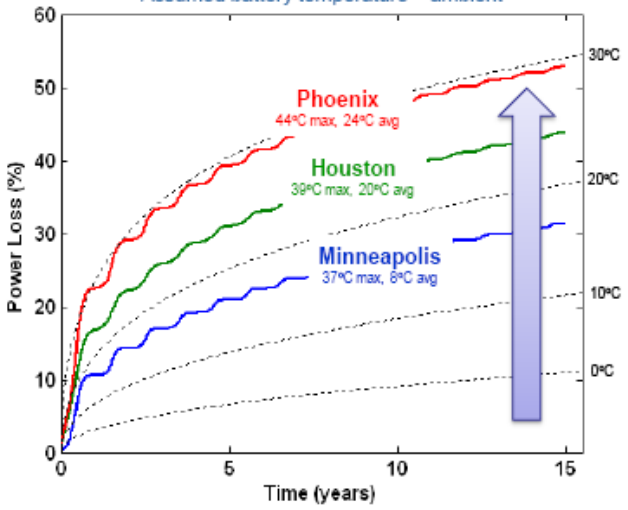




Reducing temperature exposure from 35°C to 25° reduces PHEV10 battery cost by $1000.

Impact of climate on power fade

Calendar fade model with Typical Meteorological Year (TMY) climate dataset
Assumed battery temperature = ambient



Some Li-ion technology must be sized with significant excess power to last 15 years.

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NREL National Renewable Energy Laboratory

Based on previous work from NREL, it is clear that thermal management of some type is needed to help reduce the size of the battery pack.

Information Source: National Renewable Energies Laboratory
Presented at the 2009 U.S. DOE Hydrogen Program and Vehicle Technologies Program Annual Merit Review & Peer Evaluation Meeting held 18-22 May 2009 in Arlington, Virginia

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Approach – Project Strategy

Based on previous studies, this project is set up into three phases.

Phase 1: (1 Year) Study previous research and establish battery simulation model using software that can also simulate thermal systems.

Phase 2: (1 Year) Simulation work to evaluate various thermal management concepts and study their effectiveness to enable the reduction of the battery size.

Phase 3: (1 Year) Actual bench testing with the thermal management concepts identified in Phase 2.

As the title of the project shows, the thermal system being developed is one that is dedicated to the battery pack which has high efficiency and high reliability for the thermal needs of the battery pack only to enable the size reduction of the pack.

Approach – Phase 1 Overview

Phase 1: October 2011 → January 2013

For Phase 1, the project will create a battery simulation model in LMS AMEsim software package.

- Simulate battery cell dictated by Chrysler
- NREL to help characterize battery cell thermal characteristics
- NREL will also support creation of the battery model
- Correlate simulation model to actual vehicle test data from Chrysler

Battery Simulation Model will be Created In Phase 1

Approach – Phase 2 Overview

Phase 2: January 2013 → January 2014

For Phase 2, the project will analyze various thermal management concepts using LMS AMEsim software. (Using the battery model created in Phase 1)

- This will use DENSO previous and on-going research into high efficiency vapor-compression cycles to be used for active battery thermal management.
- Other technologies will be studied which will provide passive thermal management.

The optimal thermal management system will be chosen based on many simulation iterations with various technologies.
This simulation model should be able to prove that the battery temperatures can be controlled to a point which would reduce the cell or battery weight, complexity (component count), and/or cost by at least 20%.

Approach – Phase 3 Overview

Phase 3: January 2014 → September 2014

For Phase 3, the project will create prototype samples of the technologies identified in Phase 2, and do actual bench testing.

Bench testing will be done at DENSO in Southfield, MI in a new EV thermal system test bench.

This testing will show with actual samples that the battery temperatures are able to be controlled in such a way to achieve the project goal of reducing the cell or battery weight, complexity (component count), and/or cost by at least 20%.

Technical Accomplishments

In the first 6 months of the project, the following are the main technical accomplishments:

- Study of methods to simulate battery characteristics.
- Voltage characteristic simulation of battery cell established in AMEsim.
- Vehicle Drive Cycles used for simulation identified.
- Thermal system heating and cooling rough heat transfer requirements identified. (Used to narrow the scope of technology for the project)

Because the project just started, accomplishments are limited; however the project is on track to meet the milestones.

Collaborations

National Renewable Energy Laboratory : During FY11, much time was spent getting an approved non-disclosure agreement between NREL and DENSO. Also, establishing the terms & conditions for the project between DENSO and NREL. Now that the relationship between NREL and DENSO is complete, FY12 work will include thermal characterization of battery cell using a calorimeter and support creating the battery simulation model.

Chrysler: FY11 and FY12 they will provides target battery temperatures, drive cycle and testing conditions. Also provides overall guidance.

DENSO Corporation: DENSO Corporation in Japan has a support role to DENSO America on this project. This includes sharing research information and supporting the simulation work. For FY11, work done by DENSO Corporation was only 6% of the total amount of work done for the project.

Proposed Future Work

FY12

• Identify the thermal characteristics of the target battery cell for this project.
• Create a battery simulation model in AMEsim
• Confirm the battery simulation results match vehicle and bench test data
• Construction of EV thermal system test bench

FY13

• Using the battery simulation model created during FY12, analyze various thermal management concepts using AMEsim software to find the optimal thermal system that will enable 20% cost reduction of the battery pack.

FY14

• Create prototype samples of the thermal system components identified in the simulation work during FY13.
• Perform bench testing in the EV thermal system test bench to demonstrate the effectiveness of the thermal system.

Summary

- The project will use the theoretical expertise of NREL, the real world application experience of Chrysler, and the experience of DENSO, the worlds largest automotive thermal system supplier, to create a vehicle battery thermal system that will enable a 20% cost reduction of the battery pack.
- Milestones are on track
- Our approach uses detailed simulation models followed by actual bench testing to demonstrate the project goal was realized.
- We are well positioned for the scope of the work to be completed next year