Electric Drive Vehicle Climate Control Load Reduction

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## Overview

### Timeline
- Project Start Date: FY12
- Project End Date: FY15
- Percent Complete: 5%

### Budget
- Total Project Funding: $800 K
- Funding Received in FY11: $0 K
- Funding for FY12: $800 K

### Barriers
- Risk – customer acceptance of electric-drive vehicles (EDVs)
- Cost – cost premium for EDVs
- Life – battery and temperature
- Human thermal comfort is difficult to quantify, but critical to climate control energy use

### Partners
- Interactions/collaborations
  - Automobile manufacturer
    - CRADA is in approval process
- Project lead: NREL
Relevance – Passenger Compartment A/C and Heating Significantly Impact Electric Vehicle (EV) Range

- **Vehicle**: Mitsubishi iMiEV
- **Drive Cycle**: 10-15
- **Impact on range**
  - A/C: -34% to -46%
  - Heating: -46% to -68%

Data Credit: Kohei Umezu and Hideto Noyama, Mitsubishi, Presented at the 2010 SAE Automotive Refrigerant and System Efficiency Symposium
• **Barrier: Risk Aversion**  
  – Manufacturers build EVs but sales are low

• **Contributors to potential low sales**  
  – Consumer EV usage learning curve  
  – Range anxiety – will I get home?  
  – Challenge – *some trips will be at maximum range capability*

• **Climate control usage exacerbates range concerns**  
  – Reduces range  
  – Can cause predicted range on dashboard display to change dramatically  
    – Adds uncertainty – consumers do not like uncertainty

• **The choice automobile manufacturers do not want consumers to have to make:**  
  – Use the climate control system and be stranded or  
  – Get home while shivering or sweating excessively

• **Work with automobile manufacturers to minimize the impact of climate control on range**
Relevance – Overcoming the Cost Barrier

• **Barrier: Cost**  
  – Price premium for EVs

• **Contributor to higher cost**  
  – Electric drive components such as the battery

• **Climate control usage influences cost**  
  – The battery size is determined by the range desired  
  – Climate control impacts the range and therefore the battery size

• **What if the battery size (and initial cost) could be reduced due to lower energy consumption of the climate control system?**

• **Work with automobile manufacturers to reduce the size of the battery by minimizing the energy consumption of vehicle climate control**
Relevance – Overcoming the Life Barrier

• **Barrier: Life**
  – Li-ion battery life is sensitive to temperature
  – Higher temperatures lead to degradation (reduced state of charge)
  – Reduced life

• Depending on where the battery is located and the cooling strategy, the cabin climate control system can impact battery temperature
  – E.g., Prius uses cabin air to cool the battery
  – Heat transfer between the warm cabin and battery during a thermal soak leads to higher battery temperatures

• Designing battery size to account for high temperature degradation leads to a larger (and higher cost) battery

• Work with automobile manufacturers to minimize amount the time the battery exceeds the desired temperature and reduce the size of the battery
Relevance – Overcoming the Thermal Comfort Barrier

• **Barrier: Thermal Comfort**
  – Historic climate control system design and control
    o Leveraged what worked in previous vehicles
    o Used air temperatures and limited subjective testing to validate designs
    o Had little regard for energy use (heating was “free”)

• **EVs cannot afford excessive energy use for climate control**

• **A new way of looking at climate control system design with a focus on thermal comfort is required**
  – Analysis [digital humans in computational fluid dynamics (CFD) analyses]
  – Testing (manikin)

• **Work with automobile manufacturers to develop new strategies for thermal comfort evaluation and optimization in vehicles**
Relevance – The EV Heating Challenge

- **Challenge: Cabin Heating**
  - Cabin heating has been provided by waste heat from the engine in conventional vehicles
  - EVs do not have an engine

- **Stored energy used for cabin heating takes valuable energy away from propulsion**

- **Electric heaters are a lower cost option but only have a coefficient of performance (COP) = 1**

- **Heat pumps have higher COPs and could potentially use waste heat from the energy storage system and advanced power electronics and electric motors cooling loops**

- **Work with automobile manufacturers to investigate advanced cabin heating strategies for EVs**
Objectives

• Minimize the impact of climate control on plug-in hybrid electric vehicle (PHEV) and EV range

• Reduce the size of the battery by minimizing
  – Energy consumption of vehicle climate control
  – Time the battery exceeds the desired temperature range

• Investigate new strategies for thermal comfort evaluation

• Increase electric range by 10% during operation of the climate control system through improved thermal management
  – Maintain or improve occupant thermal comfort
Approach

• Work with automobile manufacturers to assemble a team that may include suppliers for glazings, seats, insulation, EDV thermal systems, and HVAC systems

• Conduct thermal analyses (CFD, RadTherm®, human thermal comfort)
  – Evaluate the effectiveness of potential strategies to reduce the climate control loads

• Evaluate promising techniques in outdoor vehicle thermal soak tests
  – Transient and steady-state thermal tests will be conducted using the standard vehicle onboard thermal systems and an offboard vehicle climate control load hardware emulator system

• Consider thermal effects on the trade-off between electric range and initial battery energy/cost

• Leverage DOE’s thermoelectric HVAC projects and the zonal climate control approach
Approach – Initial Focus Areas

- Zonal approach
- Thermal load reduction
- Optimize thermal comfort
- Advanced seating concepts
- Secondary fluid loop options
- Unique EDV thermal needs of the battery and power electronics
- Intelligent HVAC control to minimize energy use
Proposed Future Work

• **FY12**
  – Develop CRADAs with automobile manufacturers
  – Conduct vehicle thermal analyses and tests to evaluate the effectiveness of potential strategies to reduce the climate control loads

• **FY13**
  – Continue testing and analyses to determine value proposition of reducing climate control loads (range and battery size)

• **FY14-15**
  – Work with automobile manufacturers to incorporate most promising technologies into a development vehicle
Accomplishments / Collaboration

• CRADA with an automobile manufacturer
  – Currently in approval process
  – Automobile manufacturer will provide vehicles and engineering support
Accomplishments – Thermal Comfort

- Supported DOE’s thermoelectric HVAC project
- Worked with a manikin manufacturer (MTNW) and software company (ThermoAnalytics) to improve thermal comfort assessment in vehicles

From vehicle design to build, optimize thermal comfort with minimum energy use
Accomplishments – Solar Control Glass and Range Target

~26% reduction in A/C power required to attain range target for the city cycle

Solar-Control Configuration 1 (4% A/C reduction)  
Solar-Control Configuration 2 (7.2% A/C reduction)  
~26% reduction in A/C power required to attain range target for the city cycle
Summary

• **DOE Mission Support**
  – Reduced EDV climate control energy use may reduce costs and improve range, which would accelerate consumer acceptance, increase EDV usage, and reduce petroleum consumption

• **Overall Approach**
  – Work with automobile manufacturers to assemble a team that may include suppliers for glazings, seats, insulation, EDV thermal systems, and HVAC systems
  – Conduct thermal analyses (CFD, RadTherm, human thermal comfort)
  – Evaluate promising techniques in outdoor vehicle thermal soak tests
  – Consider thermal effects on the trade-off between electric range and initial battery energy/cost
  – Leverage DOE’s thermoelectric HVAC projects and the zonal climate control approach
Summary (cont.)

• **Projected Benefits**
  – Increase in-use electric vehicle range by minimizing climate control energy requirements
  – Increase customer acceptance of PHEVs and EVs by reducing range anxiety and improving thermal comfort
  – Reduce battery size/cost by minimizing the battery exposure to high temperatures

• **Collaborations**
  – Automobile manufacturer
Acknowledgments and Contacts

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For more information:

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