Electric Drive Vehicle Climate Control Load Reduction




John P. Rugh
National Renewable Energy Laboratory
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Project ID: VSS090

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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

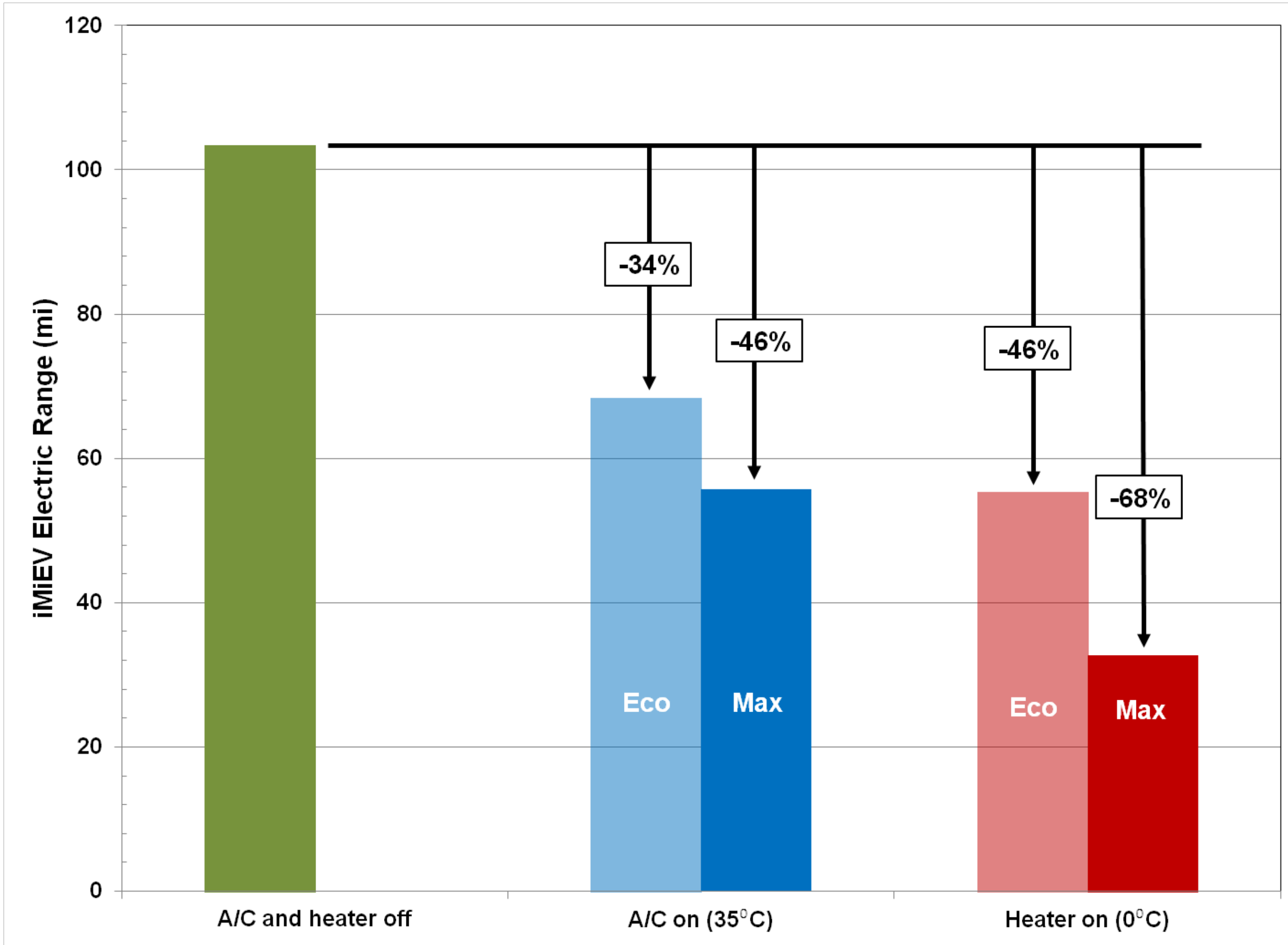
Barriers

- **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

Relevance – Overcoming the Risk Barrier

- **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**

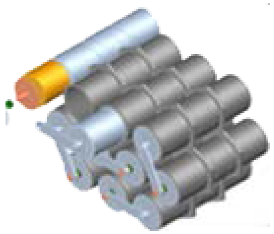
Relevance – Overcoming the Cost Barrier

- **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
    - Leveraged what worked in previous vehicles
    - Used air temperatures and limited subjective testing to validate designs
    - 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**

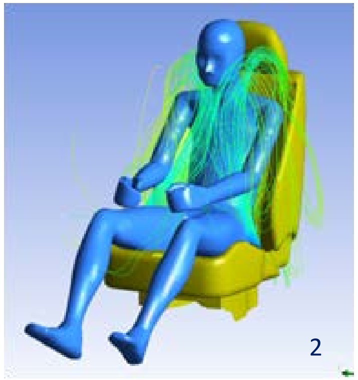
Objectives

- **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

Optimize thermal comfort

Thermal load reduction

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**

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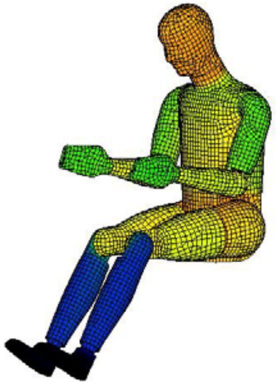

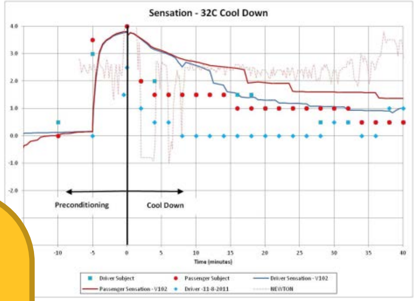

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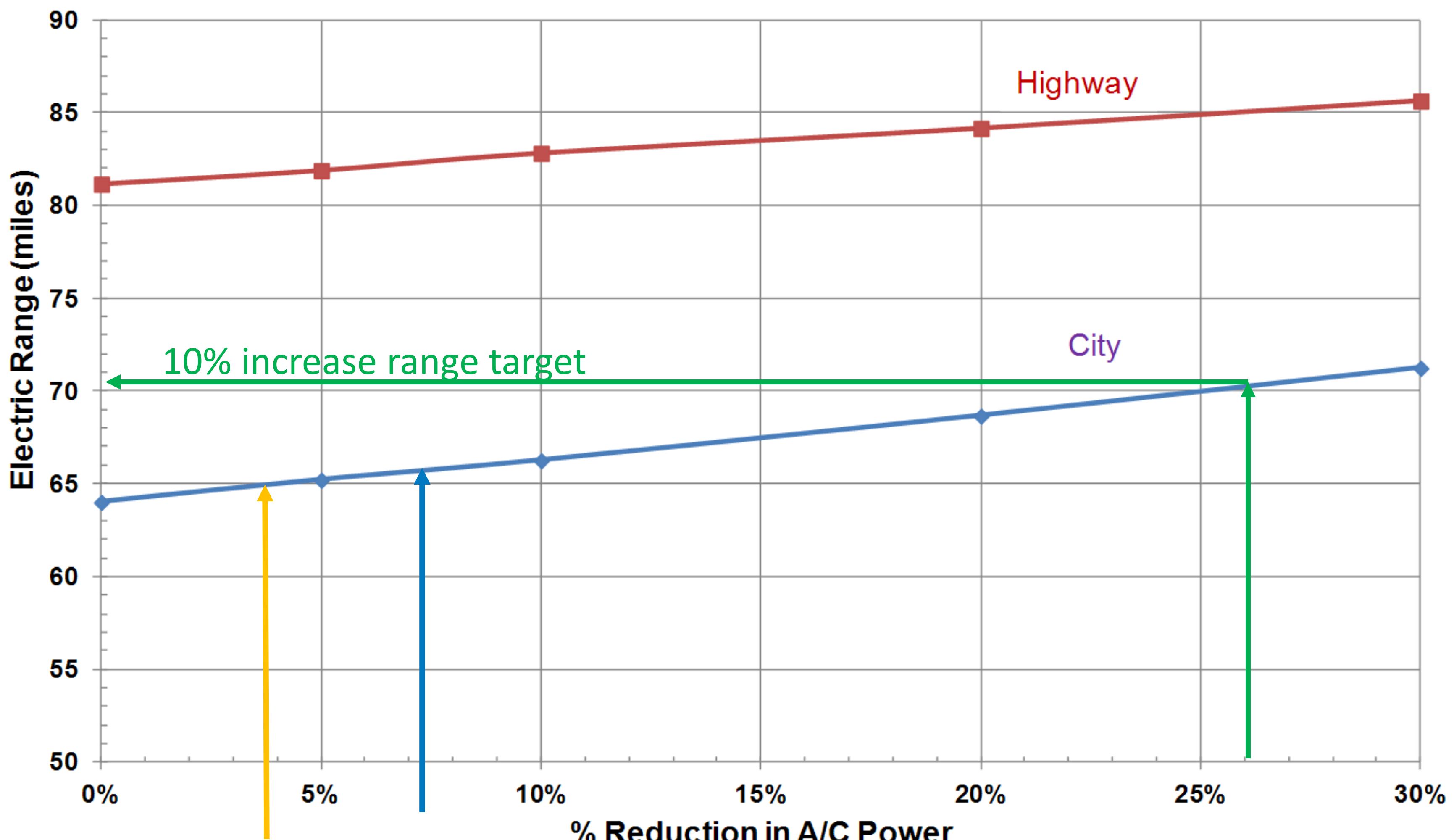
From vehicle design to build, optimize thermal comfort with minimum energy use

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:

Task Leader and PI:
John P. Rugh
National Renewable Energy Laboratory
John.rugh@nrel.gov
303-275-4413

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