National Renewable Energy Laboratory
Innovation for Our Energy Future

Thermal Management of PHEV / EV Charging Systems

U.S. Department of Energy
Annual Merit Review

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poster presented by
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APE029

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Overview

Timeline

- Project Start: FY 2010 (New Project)
- Project End: FY 2010
- Percent Complete: 5%

Barriers

- Cost & Performance
- Weight & Volume
- Thermal Management

Budget

- Total Funding (FY10-FY10)
  - DOE: $300K
  - Contract: $0K
- Annual Funding
  - FY10: $300K

Partners/Collaboration

- Electrical and Electronics Technical Team (EETT)
- USCAR Partners
- Oak Ridge National Laboratory
- Idaho National Laboratory
- National Renewable Energy Laboratory Grid Integration Task
- National Renewable Energy Laboratory Vehicle Systems Analysis Task

Objectives: Relevance (1/5)

- Multiple charging options available for PHEV and EV ranging from:
  - Off-vehicle high power rapid charge.
  - In-vehicle chargers as stand-alone and integrated systems.
- High power levels and limited vehicle package space present integration challenges.
  - How much heat?
  - Where should it go?
- Other proposed uses for grid electricity beyond charging.

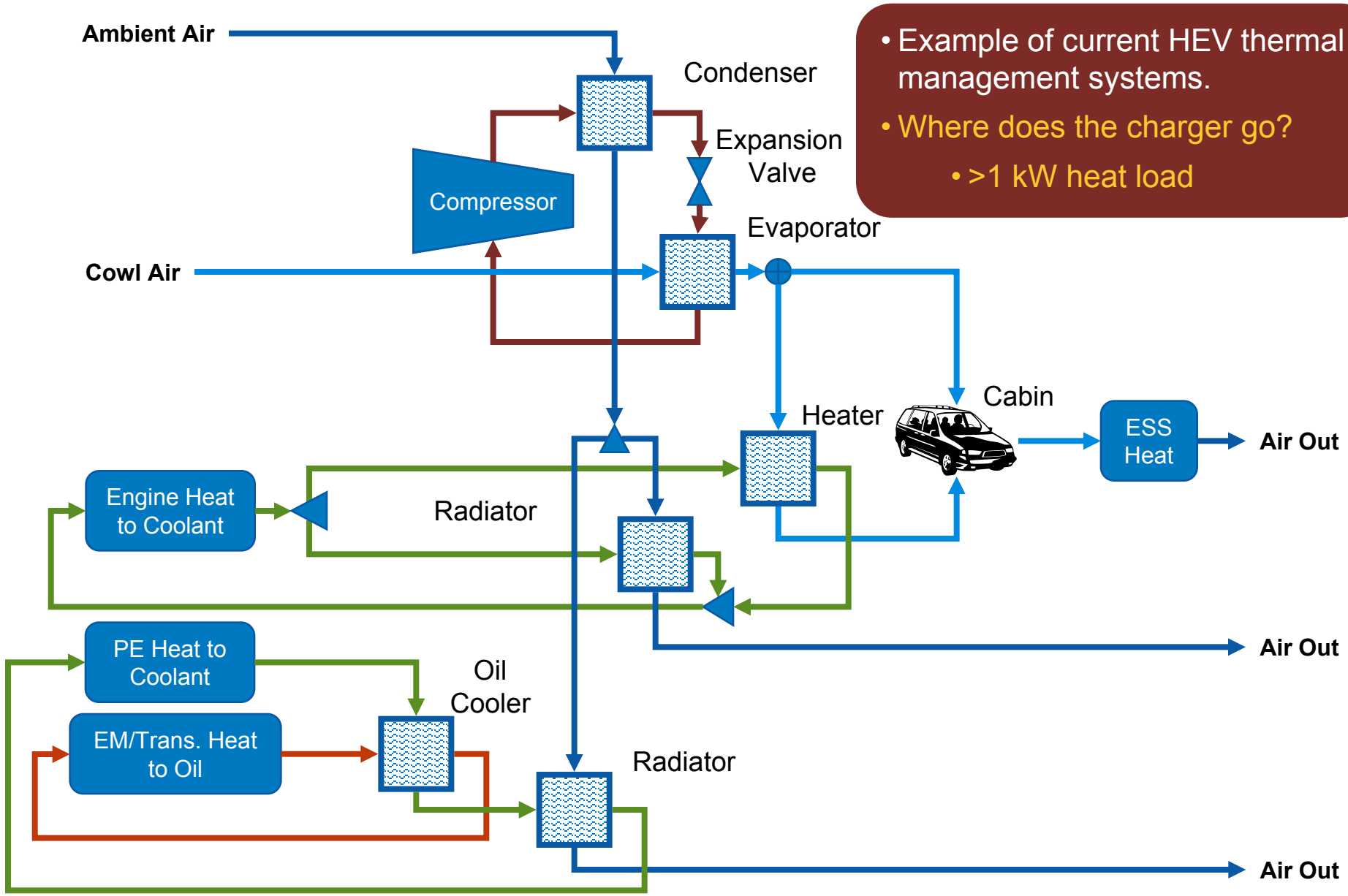
Level	Voltage	Current	Power	Power Loss*
1	120 V	12 A	1.44 kVA	**220 W** (85% Efficiency [1])
2	240 V	32 A	7.7 kVA	**1.2 kW** (85% Efficiency [1])
	240V		20kW [2,3]	**2 kW** (90% Efficiency [2,3])
3	480 V		Varies	

Significant Heat Loads

* Power losses are approximated to illustrate magnitudes.

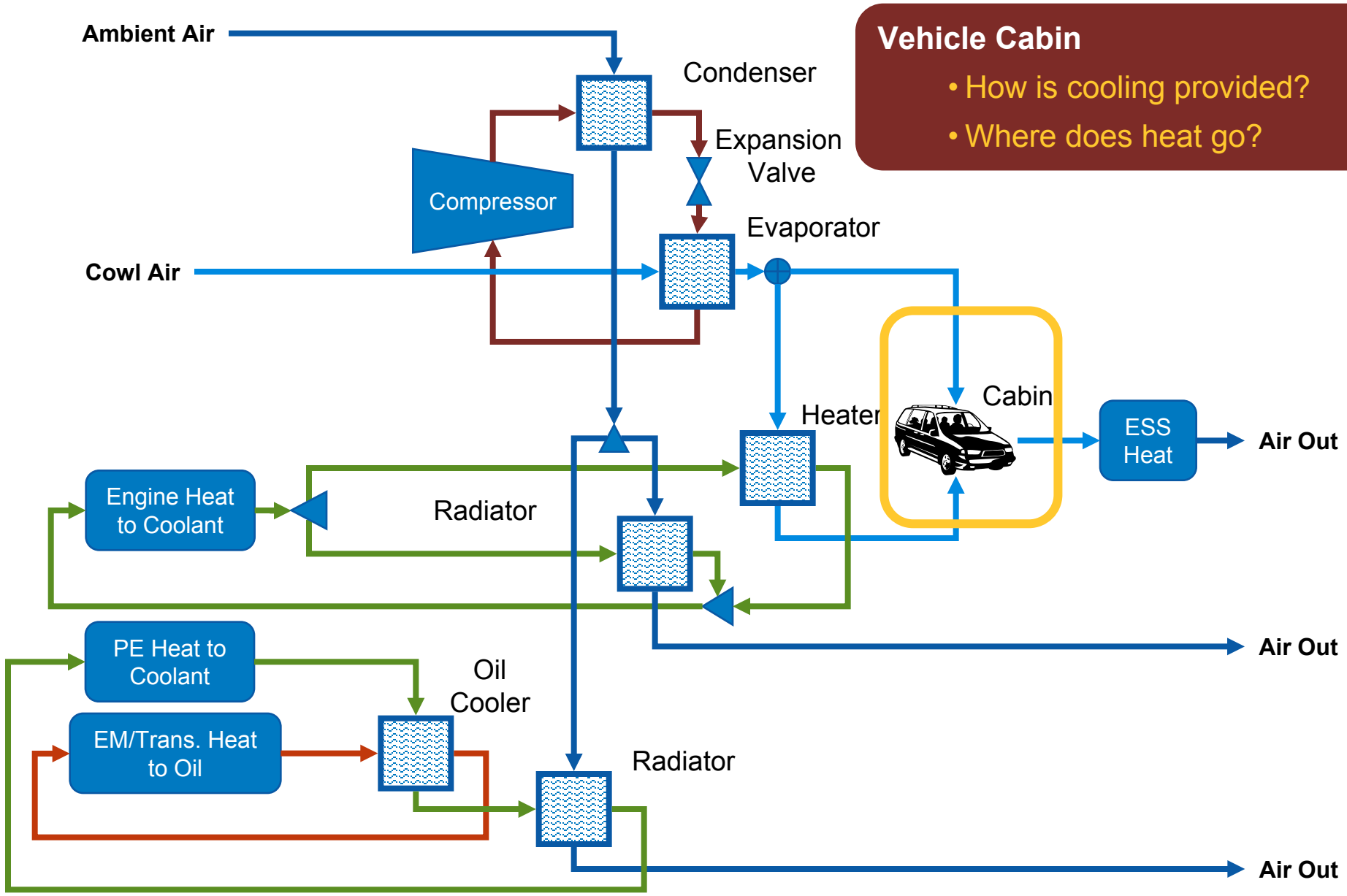
1. Lambert, Frank C., "IWC – Record of Consensus." PHEV WG Meeting, Palo Alto, CA, 2008. Available: http://et.epri.com/documents/12.11.08_IWC_PHEV_presentations/01_IWC_Actions_Lambert.pdf
2. AC Propulsion, "AC Propulsion Provides Power for 500 New Electric Vehicles." Available: http://www.acpropulsion.com/company/press-releases.php.
3. Su, Gui-Jia, "Utilizing the Traction Drive Power Electronics System to Provide Plug-in Capability for HEVs." DOE Vehicle Technologies Program Advanced Power Electronics and Electric Machines FY09 Kickoff Meeting, Oak Ridge National Laboratory, 2008.

Objectives: Relevance (2/5)

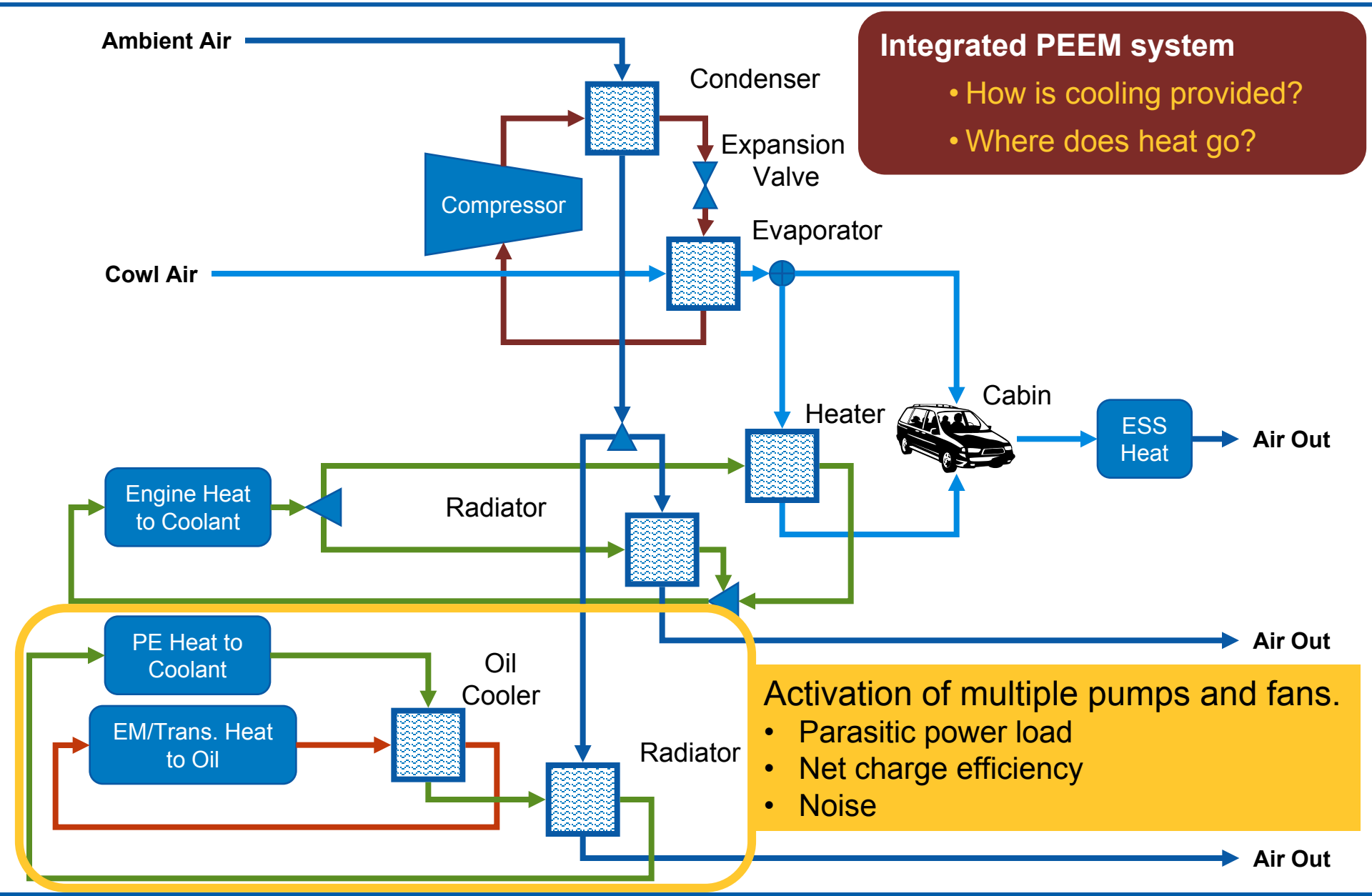


- Example of current HEV thermal management systems.
- Where does the charger go?
  - >1 kW heat load

Objectives: Relevance (3/5)



Objectives: Relevance (4/5)



Objectives: Relevance (5/5)

Objective

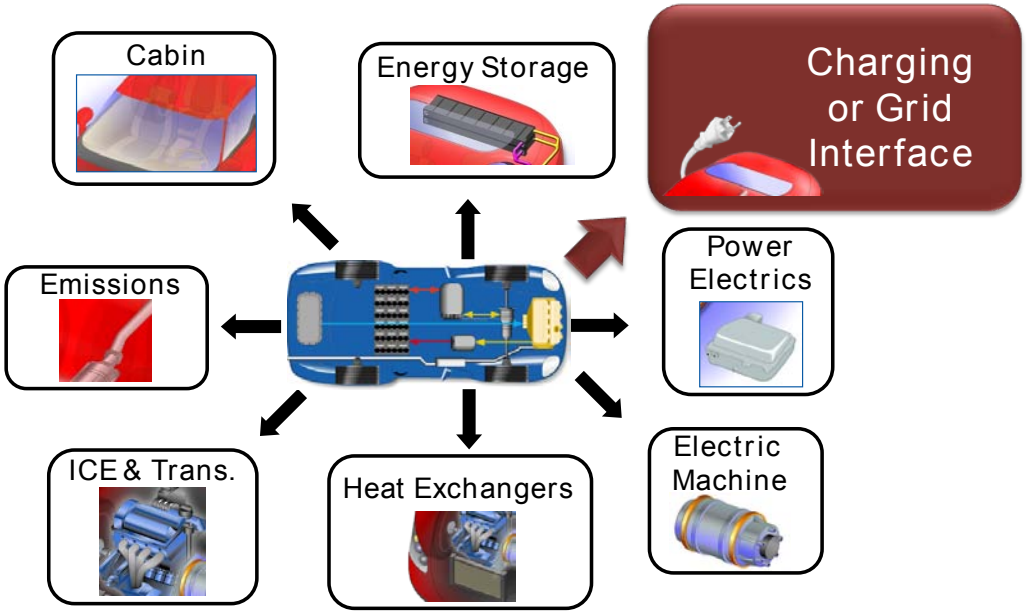
- Characterize and **match EV/PHEV charging configurations to thermal management technologies** and vehicle integration applications.
- Support technology development beyond charging to support other applications for electric vehicle support equipment.

Addresses Targets

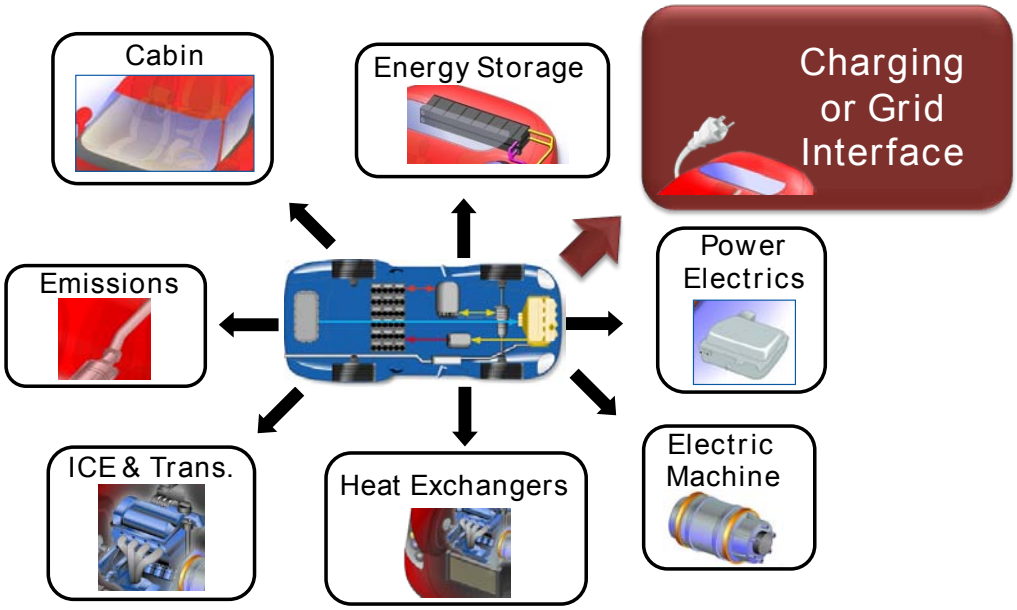
- Results are guided towards reducing **cost, weight, size, and energy losses.**

Uniqueness and Impacts

- Applies developed power electronics thermal technologies to **support use of grid electricity in EV/PHEV applications.**
- Interfaces with other Vehicle Technologies Program areas.



Approach/Strategy (1/4)



1. Understand uses and applications

2. Quantify thermal loading and efficiency impacts

3. Vehicle thermal integration

Approach/Strategy (2/4)

Vehicle Technologies Program Collaboration Areas

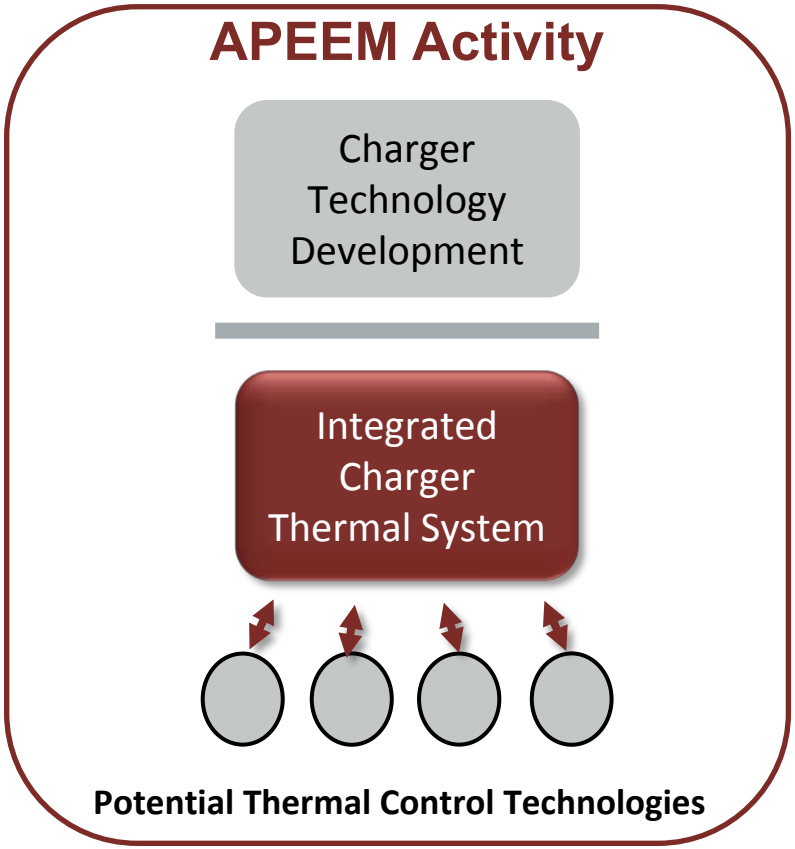
Energy Storage Systems (ESS)
Thermal Management

Electric Vehicle Grid Integration
Electric grid interface

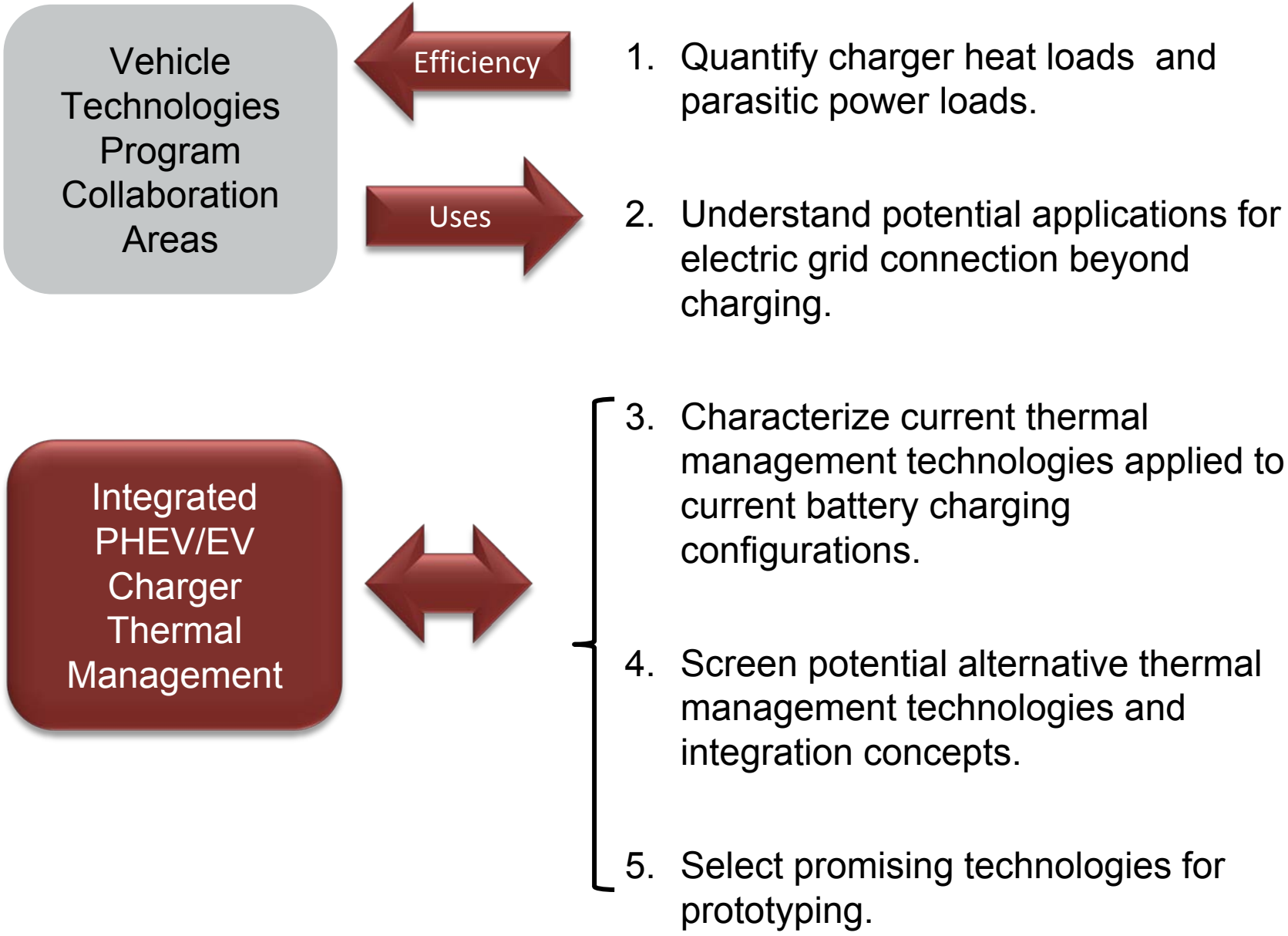
Vehicle Systems Analysis
Thermal Preconditioning

Uses/Loading

Efficiency/Heat



Approach/Strategy (3/4)



Approach/Strategy (4/4) - Milestones

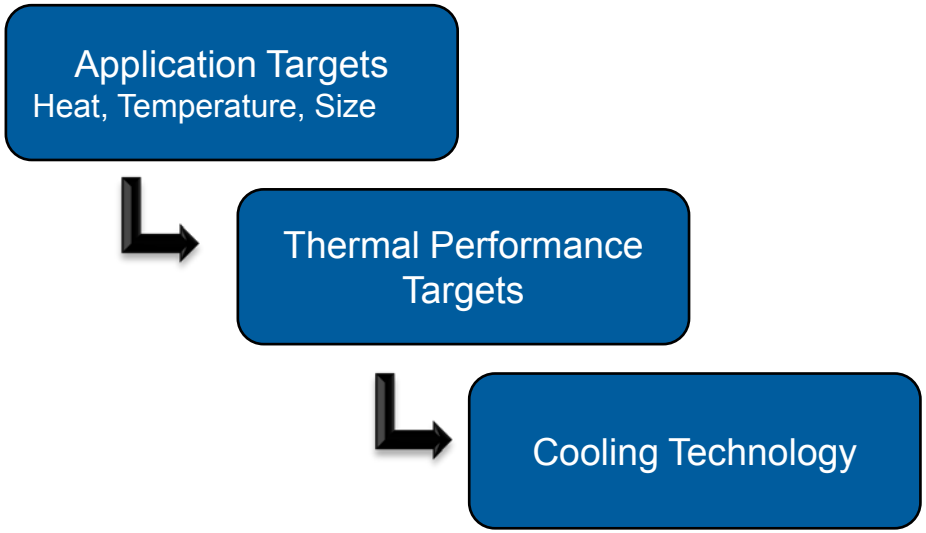
FY10 (Scheduled)

- Annual milestone report - status update (October)

Technical Accomplishments & Progress (1/4)

- Met with researches at other research organizations within DOE and outside of DOE to understand potential uses, configurations, and control of electric vehicle support equipment which includes chargers.
- Developed collaboration with Idaho National Laboratory (INL) to include charging thermal data from light-duty vehicle PHEV test fleet supported by the Vehicle Technologies Program.
- Charger efficiency data provided by ORNL on high power charging concept developed as part of the APEEM activity that is integrated within the existing electric drive system.
- Working with grid integration activity within NREL to obtain charging efficiency and thermal data.

Technical Accomplishments & Progress (2/4)



Developing process to evaluate cooling technologies for electric vehicle support equipment.

Technical Accomplishments & Progress (3/4)

Application Targets
Heat, Temperature, Size

Thermal Performance Targets

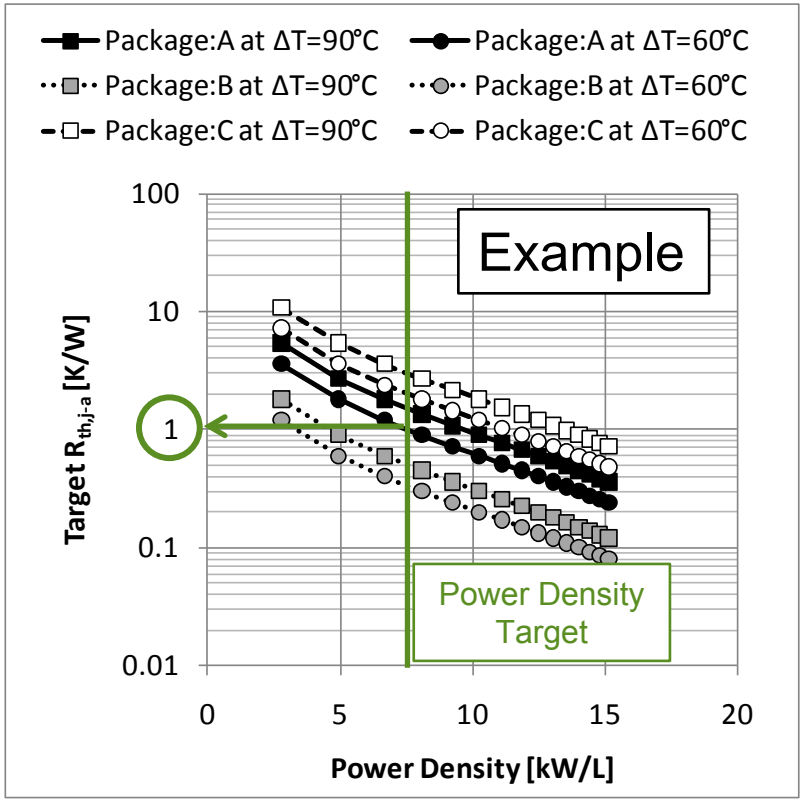
Cooling Technology

Developing process to evaluate cooling technologies for electric vehicle support equipment.

Technology Target to Thermal Resistance Target

1. Identify Application Technology Targets (Power Density)
2. Identify Temperature Specifications Targets
3. Define Component Geometry

System Thermal Resistance Target [$R_{th,j-a}$]



Technical Accomplishments & Progress (4/4)

Technology Target to Thermal Resistance Target

1. Identify Application Technology Targets (Power Density)
2. Identify Temperature Specifications Targets
3. Define Component Geometry

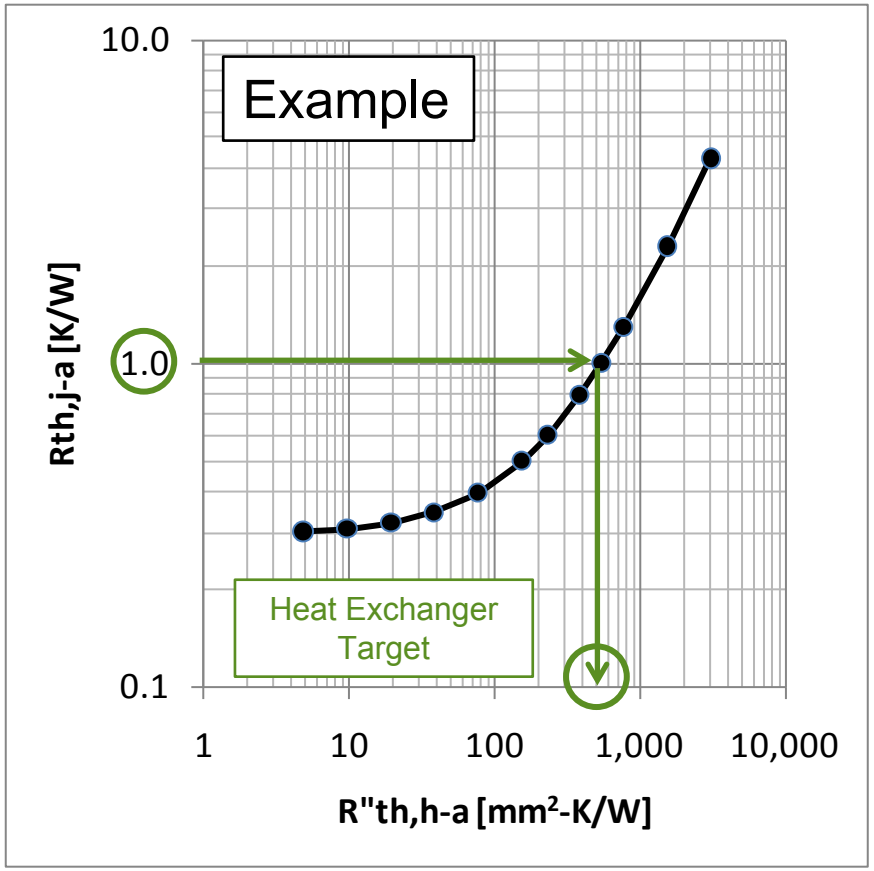
System Thermal Resistance Target [$R_{th,j-a}$]

Heat Exchanger Technology Selection

1. Define Package Geometry
2. Develop 3D Parametric FEA Model
3. Characterize Thermal Package Performance

Heat Exchanger Target Thermal Resistance [$R''_{th,h-a}$]

Developing process to evaluate cooling technologies for electric vehicle support equipment.



Collaboration and Coordination

Industry

- Electrical & Electronics Tech Team: Partner
  - Input on plans and accomplishments.

Other Government Laboratories

- Oak Ridge National Laboratory: Partner
  - Charger development work within the APEEM activity.
  - Grid integration.
- Idaho National Laboratory: Partner
  - In-use charger efficiency data for PHEV fleets.
- National Renewable Energy Laboratory (Outside of APEEM): Partner.
  - Applications for electric vehicle support equipment.

Proposed Future Work

- The project is scheduled to end in FY2010

Summary

Relevance

- Characterize and match EV/PHEV charging configurations to thermal management technologies and vehicle integration applications.
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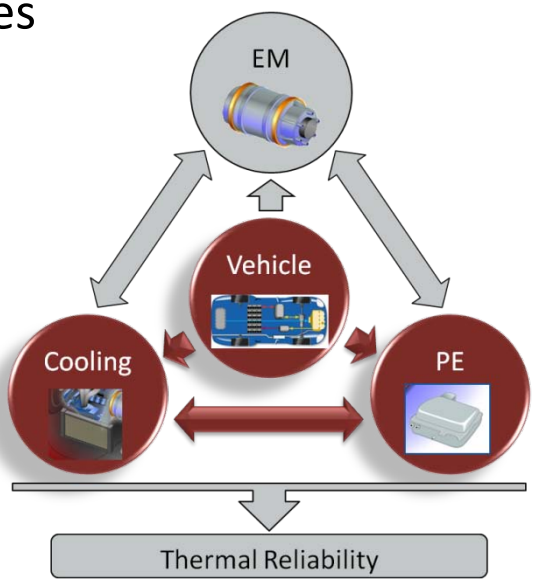

Approach/Strategy

- Apply developed power electronics thermal technologies to support use of grid electricity in EV/PHEV applications.
- Interface with other Vehicle Technologies Program areas.
- Quantify charger heat loads and screen potential alternative thermal management technologies and integration concepts.

Summary

Technical Accomplishments

- Established collaborations with other research partners to obtain thermal data on EV/PHEV charging systems.
- Developing process to link appropriate thermal management technologies to charging applications.

Collaborations

- Collaborations established with R&D partners.
  - Idaho National Laboratory
  - Oak Ridge National Laboratory