# *Interim Update*: Global Automotive Power Electronics R&D Relevant To DOE 2015 and 2020 Cost Targets

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Project ID #
**APE032**

SYNTHESIS PARTNERS, LLC

# Overview

## Timeline

- Start: Oct. 2011
- Finish: Sept. 2012
- Percent complete: 40%

## Barriers Addressed

- Paths to radical reductions in automotive electric propulsion systems costs.
- R&D milestones required to achieve the DOE 2015 ($5/kW) and 2020 ($3.30/kW) power electronics-only cost targets
- Automated foreign literature search and analysis on power electronics and electrical machine activities of direct interest to DOE

## Budget

- Funding for FY12: $475K

## Partners

- Interactions/ collaborations:
  - OEMs, Tier 1 and 2 suppliers, USCAR, University of Maryland, ORNL, Ames Research Lab, VivoMind™ Research LLC
- Project lead: Synthesis Partners, LLC

# Study Objectives

- Global Automotive Power Electronics R&D Relevant to DOE 2015 and 2020 Cost Targets
  - Roadmap R&D milestones relevant to DOE 2015 ($5/kW) and 2020 ($3.30kW) cost targets.
  - Assess breakthrough technology developments needed to overcome core cost barriers that prevent achievement of DOE cost targets in 2015 and 2010.
  - Coordinate and collaborate with the USCAR Electrical/Electronics Technical Team (EETT).

- Foreign Literature Search on PEEM R&D Using Automated Methods
  - Apply integrated human and proprietary machine multi-lingual science and technology (S&T) literature search and analysis approach.
  - Rapidly and efficiently find and report relevant information from Asian-language texts concerning PEEMs of particular interest to DOE.

# Research Milestones

- Roadmap of Automotive Power Electronics R&D Relevant to DOE 2015 and 2020 Cost Targets
  - Sept. ’11 – May ’12: Coordination, Collection & Analysis
  - May – Aug.’12: Initial Results
  - Aug. – Sept. ’12: Report Findings
- Roadmap of Potential Breakthroughs in Automotive Power Electronics R&D Relevant to Core DOE Cost Target Barriers
  - Sept. ’11 – May ’12: Coordination, Collection & Analysis
  - May – Aug. ’12: Initial Results
  - Aug. – Sept. ’12: Report Findings
- Foreign Language Automated Literature Search
  - Sept. ’11 – May ’12: Coordination, Collection & Analysis
  - May – Aug. ’12: Initial Results
  - Aug. – Sept. ’12: Report Findings

# General Approach

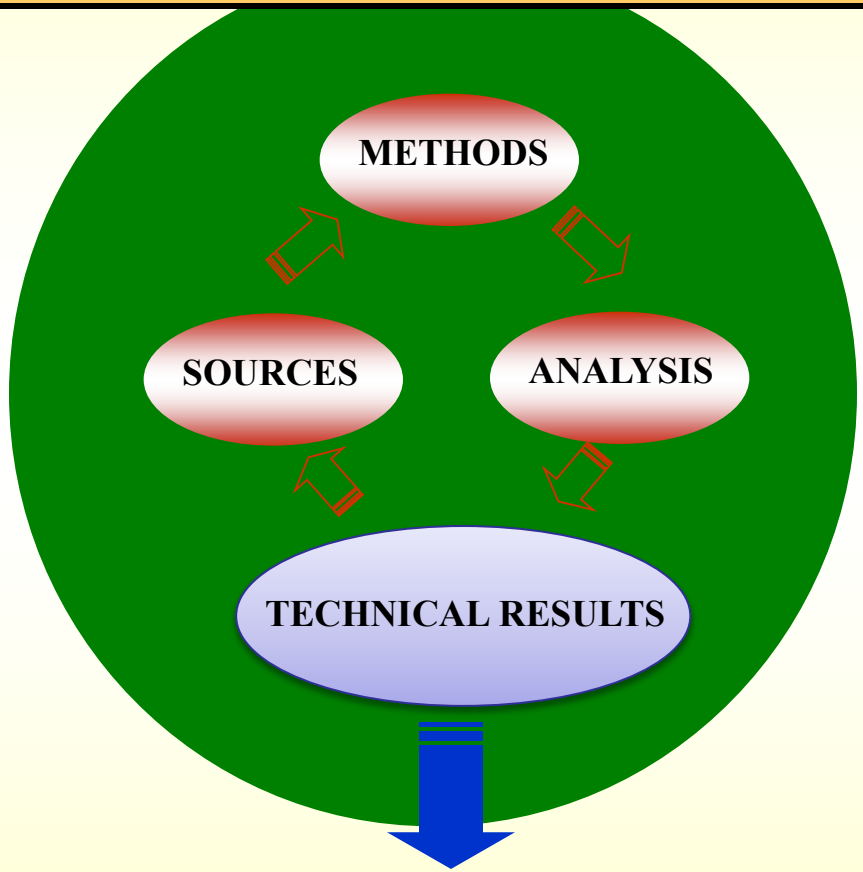
Iteration with DOE and USCAR EETT

Define

Qs

**Refine, Frame and Focus on Core Concerns**

Customized by Question, Domain and DOE Requirements

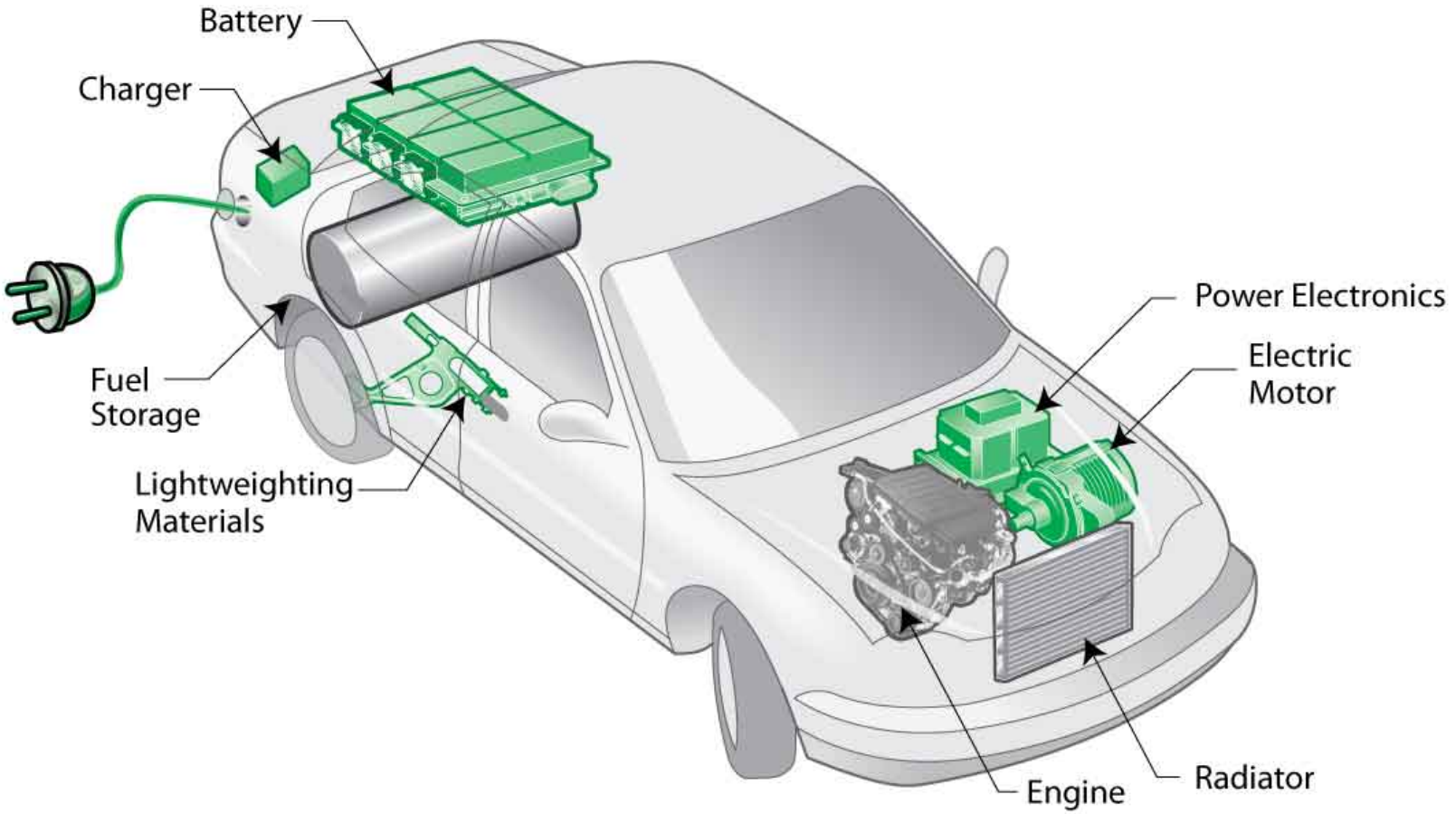



**R&D DECISION INTELLIGENCE**

# Interim Findings: Power Electronics Roadmap

- Detailed findings under development
- Following slides provide initial findings
  - Data provided as of Mar. 16, 2012 and subject to change
- Discussion to clarify context of data and provide interpretation of chart information

# Power Electronics

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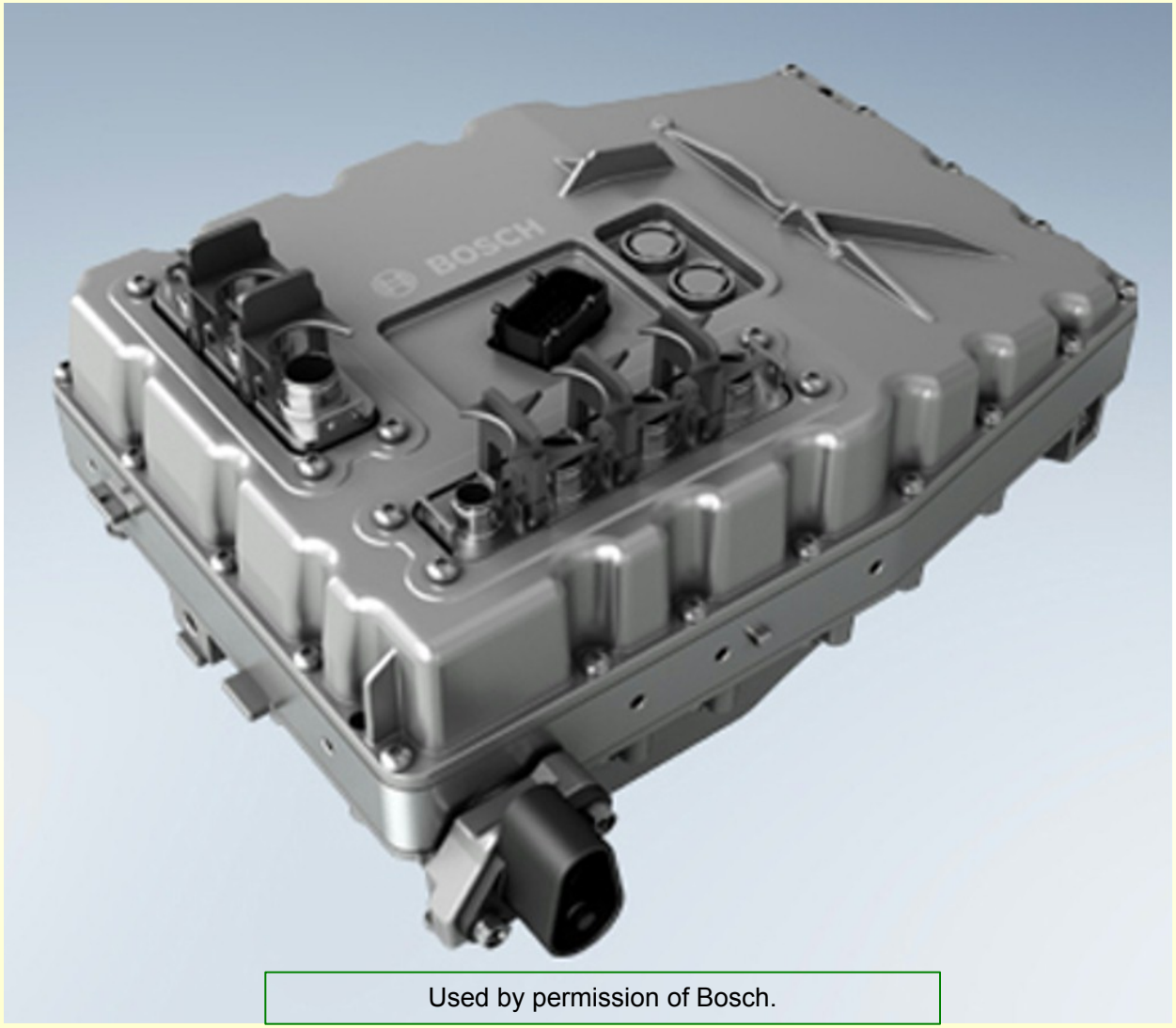
# Power Electronics

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# Analyzing Barriers to Cost Reduction

- Top-level findings:
  - Differences in architecture (dual vs. single inverter, integrated functions vs. individual components) make accurate comparisons difficult
  - Obtuse or inadequate common vocabulary makes it very difficult to compare public data on costs!
  - Nascent automotive power electronics industry has opportunity to build database for “apples-to-apples” comparisons of key costs and cost drivers
  - Systematic comparison between best-available cost analyses is needed on periodic basis to drive healthy debate

# Analyzing Barriers to Cost Reduction

| Source | Methodology | Component | Estimated Volume | Manufacturing Cost Estimate* |
|---|---|---|---|---|
| SP Analysis (2011) | Analysis of current market prices and cost drivers, third party analyses of inverter systems, and analysis of the effect of varying production levels provided by the inverter industry | Single inverter/DC converter unit | 100K<br><br>400K | $614.50<br><br>$484 |
| Tier 1 Manufacturer (2011) | Real world example | Single inverter | 100K | $600 |
| FEV Analysis (2011) | Component teardown / comparisons with databases for materials, labor, manufacturing overhead, and mark-up costs and proprietary modeling system | Power Electronics/ Inverter & Controls Subsystem<br><br>Voltage Inverters/ Converters Subsystem. | 450K | Power Electronics/ Inverter & Controls Subsystem $263.03 – 298.11<br><br>Voltage Inverters/ Converters Subsystem $111.86 – 177.59 |

* Baseline definition of manufacturing costs varies by source.

# Selected Global Roadmap Activity

| Title | Source | Date |
|---|---|---|
| Automotive Australia 2020: Technology Roadmap | Automotive Australia 2020 | June 2010 |
| Electrical and Electronics Technical Team Roadmap | US Department of Energy | December 2010 |
| Technology Roadmap: Electric and plug-in hybrid electric vehicles | International Energy Agency | June 2011 |
| Electrification Roadmap: Revolutionizing Transportation and Achieving Energy Security | Electrification Coalition | November 2009 |
| International Technology Roadmap for Semiconductors | ITRS | 2011* |
| Power Technology Roadmap Trends 2010 - 2015 | Power Sources Manufacturers Association | 2011 |

* Completely revised during odd-numbered years with an update in even-numbered years

# Technology Roadmap Elements

- Many types of Technology Roadmaps (TRMs)
  - Multi-layered time-based charts to enable technology developments to be aligned with market trends, technology and market drivers and decision needs
- TRMs have similar core objectives
  - If it does not support investment decisions, it is not a good or effective TRM!
  - TRMs need to be useable, flexible and targeted to decisions
- Technology-driven innovation drives constant re-alignment of TRMs
  - Pragmatic benefit depends on continuous refresh and re-alignment, as the cost, complexity and pace of power electronics technology change only increases

"All information is perishable."

# Technology Roadmap Elements

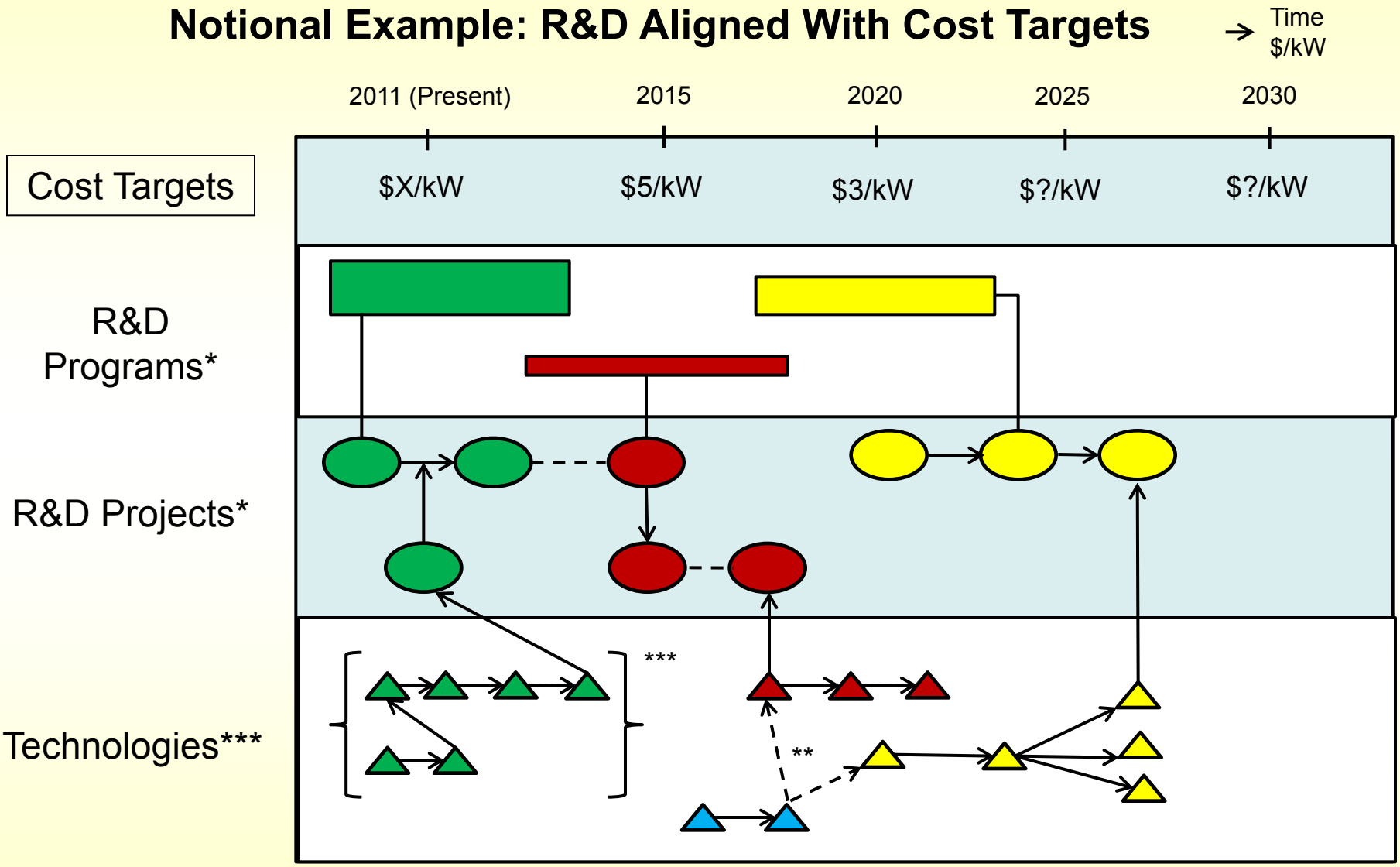
- Technology Components: 2015-2020
  - R&D related to core components in P/HEV power electronics systems
  - R&D related to systems-level design approaches in P/HEV power electronics

- Systems Engineering Elements: 2015-2020
  - Systems and systems-of-systems addressed in the design and manufacture of P/HEV power inverters, power electronics and electrical machines
  - Core trade-offs to be considered in P/HEV power electronics system development

- Cost Analysis Elements: 2015-2020
  - Relative importance of cost drivers, by components (or category) in P/HEV power electronics
  - Cost trend lines for key components or systems in P/HEV power electronics
  - Projected impact of major cost barriers (those cost thresholds that prevent achievement of major cost reductions), and their impact on key components in P/HEV power electronics

# Technology Roadmap Analysis

## Notional Example: R&D Aligned With Cost Targets

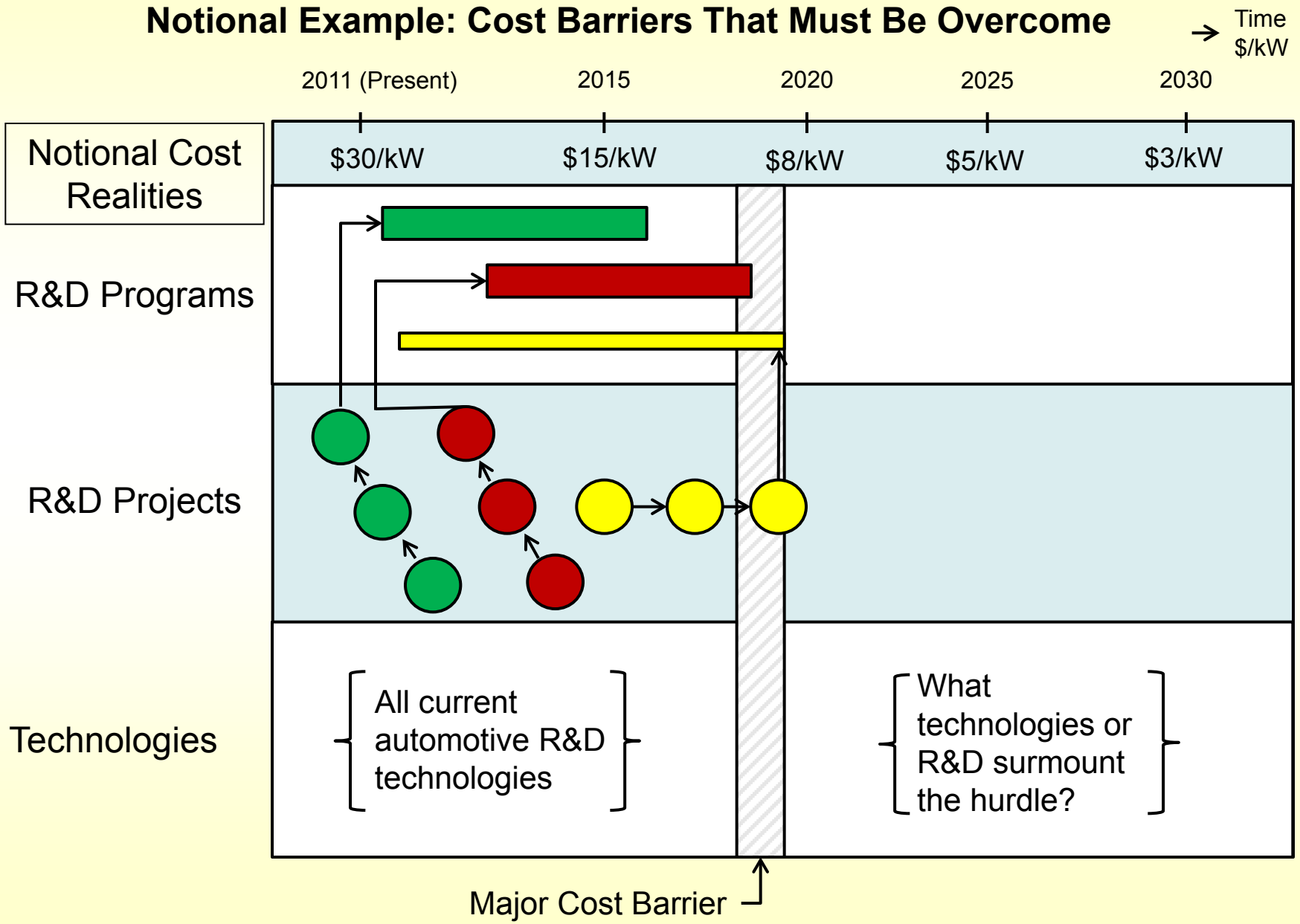



*Size = Resources
Color = Institution

**Solid Line = Dependency
Dotted Line = Potential Dependency

***Linked Technologies = System View

# Technology Roadmap Analysis



# Foreign Literature Search Results

- Detailed findings under development
- Assessment of global data sources in progress as of Mar. 16, 2012
- Discussion today to clarify progress, data availability and early findings

# Collaborations

- Close coordination and involvement with USCAR Electrical/Electronics Tech Team
- Close coordination with industry, universities, federal laboratories, and subject matter experts on both public and proprietary basis
- Collection from sources outside the DOE-Vehicle Technologies Program to identify low-cost technology development opportunities in support of DOE goals
- Industry: Global OEMs, Tier 1 and 2 suppliers, technology developer networks, VivoMind™ Research
- Federal Research Labs: ORNL, Argonne, Ames Research Lab and international S&T labs (TBD)

# Proposed Future Work

- Discussions with DOE are ongoing.

# Summary

- Research findings are under development
  - Roadmap of Automotive Power Electronics R&D Relevant to DOE 2015 and 2020 Cost Targets
  - Roadmap of Potential Breakthroughs in Automotive Power Electronics R&D Relevant to Core DOE Cost Target Barriers
  - Foreign Language Automated Literature Search findings