Outline

- Situational Analysis & Suggested Actions
- Technology “Road Map”
- Key Technology Objectives
- Proof Points from 2004 and 2005
  - Catalyst development
  - Understanding membrane failure
  - Continuous Gas Diffusion Media
- Summary

Status: Key Drivers & Government Support

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- Policy drivers:
  - energy supply and security concerns ("addiction to oil")
  - emissions, pollution and climate change
- Government support:
  - emissions regulations (California ZEV)
  - demonstration programs (US DOE / DOT, CUTE, China, STEP, Canada)
  - but somewhat limited and diffuse R&D support available (for basic, applied and industrial)
- Barriers for transition to hydrogen economy still exist:
  - perceived cost of displacing incumbent technologies and fuels
  - concern re: "black" hydrogen / alternative fuels explored (ex. ethanol)
  - some view hybrids (& plug-in hybrids) as solutions and not interim step
- Why Hydrogen Fuel Cell Vehicles?:
  - only comprehensive, long term solution that fully addresses all policy drivers (with ICE functionality equivalence at higher overall efficiency)
  - other technologies (HEV, PHEV, H2-ICE) help transition but not solution

How Government Can Help

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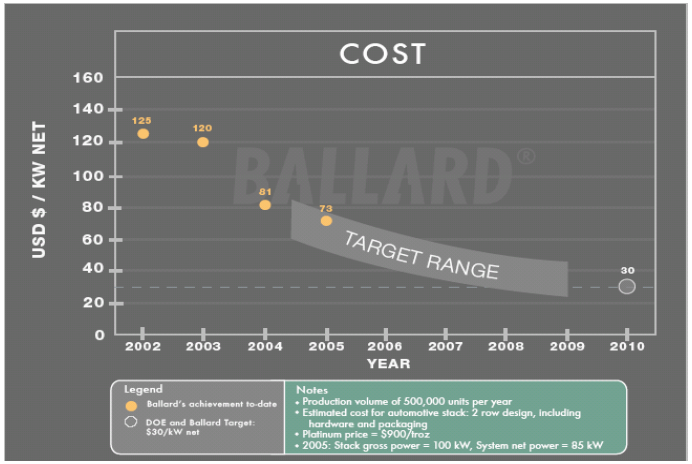
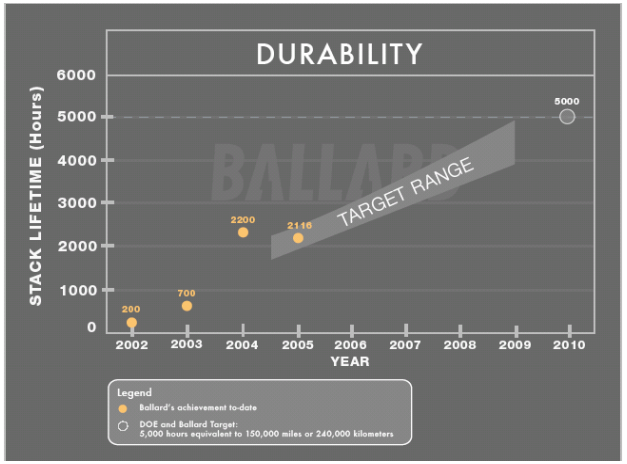
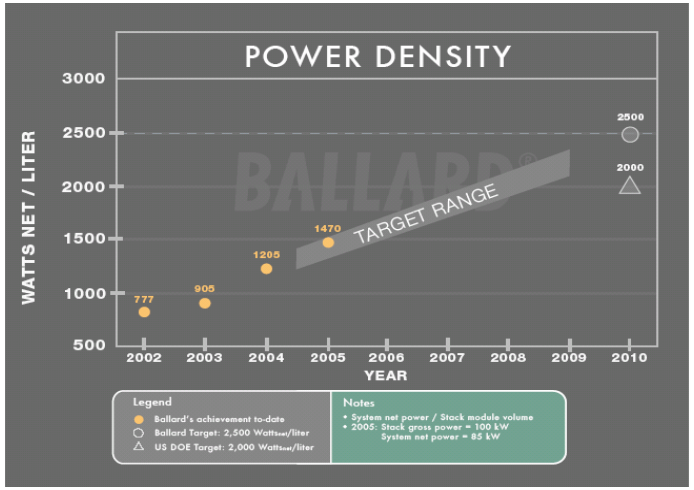
Current support and growing international cooperation is helpful (and greatly appreciated) but, considering resistance to transition more can be done, including:

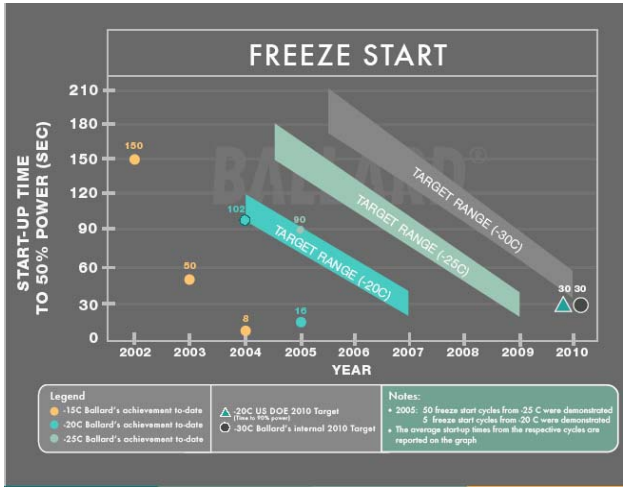
- Greater investment and effort to overcome challenges that could slow commercialization (ex. fuel storage solutions, cost and durability of fuel cells & infrastructure development, build consumer confidence for hydrogen as a safe fuel)
- Greater commitment to "volume" fuel cell deployments (ex. mandates, commercial deployment programs etc.)
- Incentives to key component suppliers to reduce costs during volume ramp-up
- Initiatives to allow sector to remain sustainable until 2009-2015

Technology "Road Map" Summary









Technology Imperatives

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- Execute Technology "Road Map" to demonstrate a commercially-viable fuel cell technology by 2010
  - Stimulate commercialization
- Enhance strategic relationships with key unit cell component suppliers
  - Supply based needs to be encouraged to keep spending R&D dollars and to break the price/volume paradigm
- Accelerate emerging technologies; e.g.
  - Hydrocarbon composite membranes
  - Catalyst-loading reduction – with enhanced voltage efficiencies
  - Metal plate technologies

Key Technology Development Objectives

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- Understand failure mechanisms resultant from water management challenges in the unit cell
  - Develop materials and design solutions, coupled with operational strategies that drive improved system efficiencies
- Accelerate design selection through improved “tools” and related modeling & simulation expertise
  - Structure/property relationships for key materials functionality; accelerated tests to define durability issues
- Engineered electrocatalyst layers
  - Facilitate further loading reduction with improved polarization curve; mitigation of known failure mechanisms

Catalyst Technology Advancements

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Platinum

1994	2004	Already Lab Demonstrated	>2010
8-10 mg/cm²	1.0 mg/cm²	0.3-0.5 mg/cm²	< 0.3 mg/cm²

Processes

hand coating	screen printing spraying	roll coating (knife, comma bar)	CVD nanoparticle dispersion

Catalyst Structure

No catalyst support	Carbon Support	Carbon Support	Corrosion-free Support
Pt Metal	Pt and Pt alloys	Pt and Pt alloys	Non-PGM or low Pt content alloys

Key Technology Development Objectives

- Low-cost composite membranes
  - Increased ionic conductivity and x-y plane dimensional stability
  - Introduce hydrocarbon ionomers
- Low-cost, continuous GDL deployment
  - Facilitate continuous manufacturing process development for volume and cost reduction

Membrane Degradation

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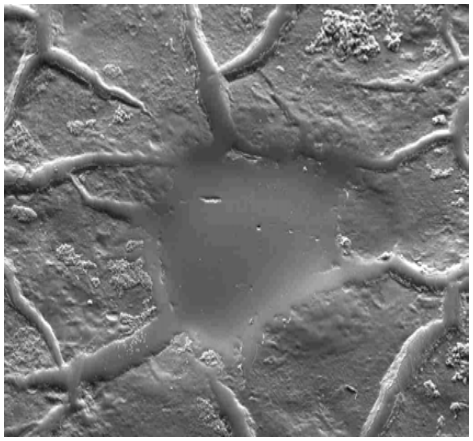
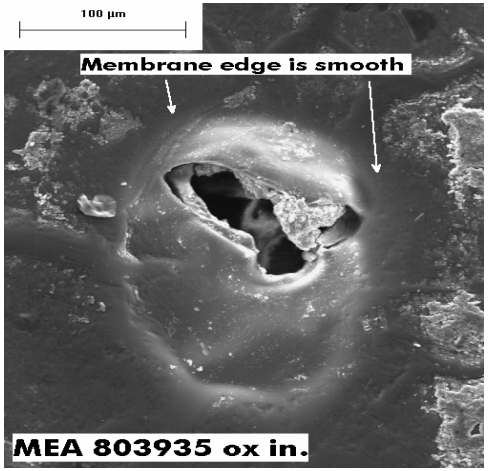
- Understanding failures:
  - Accelerated tests development and mechanistic understanding.
  - Mitigation and design improvements



Membrane is thinning in discrete areas



Reduced physical strength – leads to rupture

GDL on a Roll – Ballard Material Products

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Ballard's 2004 Technology Demonstration

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Achieved significant improvements in three key fuel cell stack performance metrics – in a single stack design…

Freeze Start	Durability	Cost Reduction
▪ Performed 50 consecutive freeze starts from -20° C (100 sec)	▪ Demonstrated stack lifetime of more than 2,000 hours	▪ Reduced platinum loading to 0.7 mg/cm^2 from 1 mg/cm^2

…with no loss in voltage efficiency and while increasing power density.

Ballard's 2005 Technology Demonstration

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Achieved further improvements in three key fuel cell stack performance metrics – in a single stack design…

Freeze Start	Durability	Cost Reduction
▪ Performed 50 consecutive freeze starts from -25° C (90 sec)	▪ Demonstrated stack lifetime of more than 2,000 hours	▪ Reduce cost by 10% over 2004 technology

…while increasing stack power density and operational flexibility by running the durability test at reduced inlet Relative Humidity

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Commercialization Strategy

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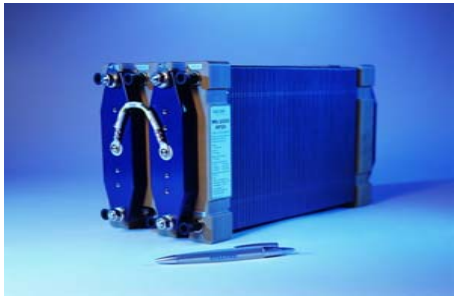
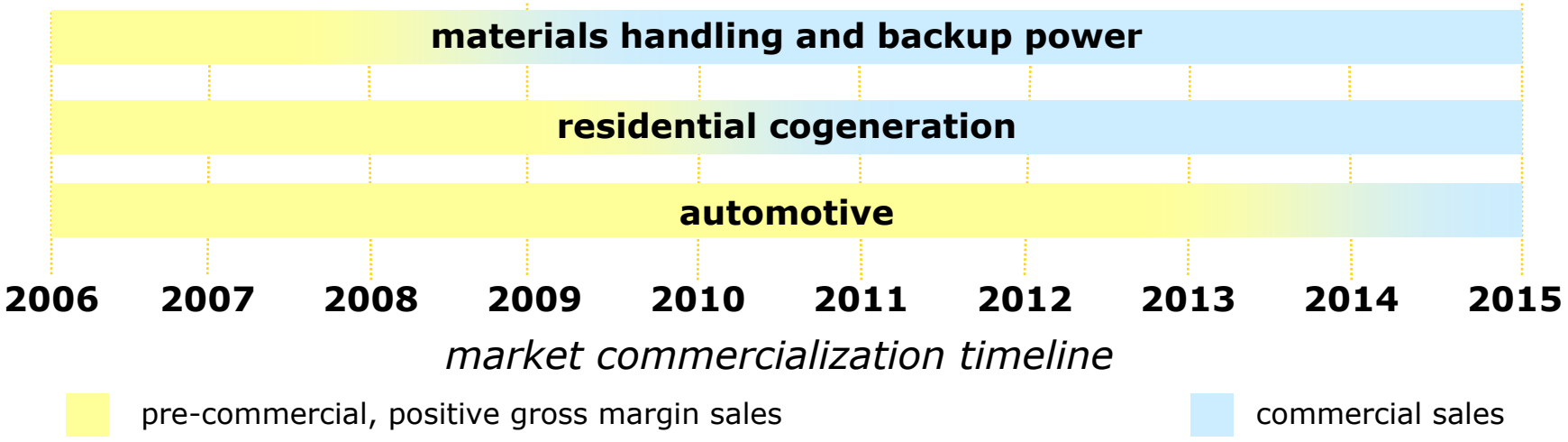


Residential Cogeneration: Mark 1030

Automotive: Mark 902

Materials Handling & Backup Power: Mark9 SSL™



market commercialization timeline

pre-commercial, positive gross margin sales

commercial sales

Commercialization Strategy

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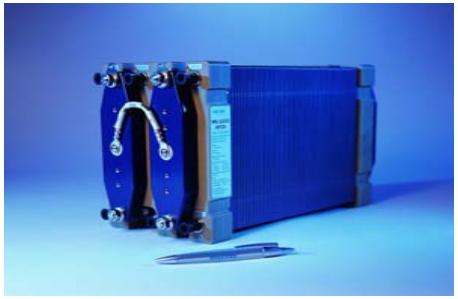

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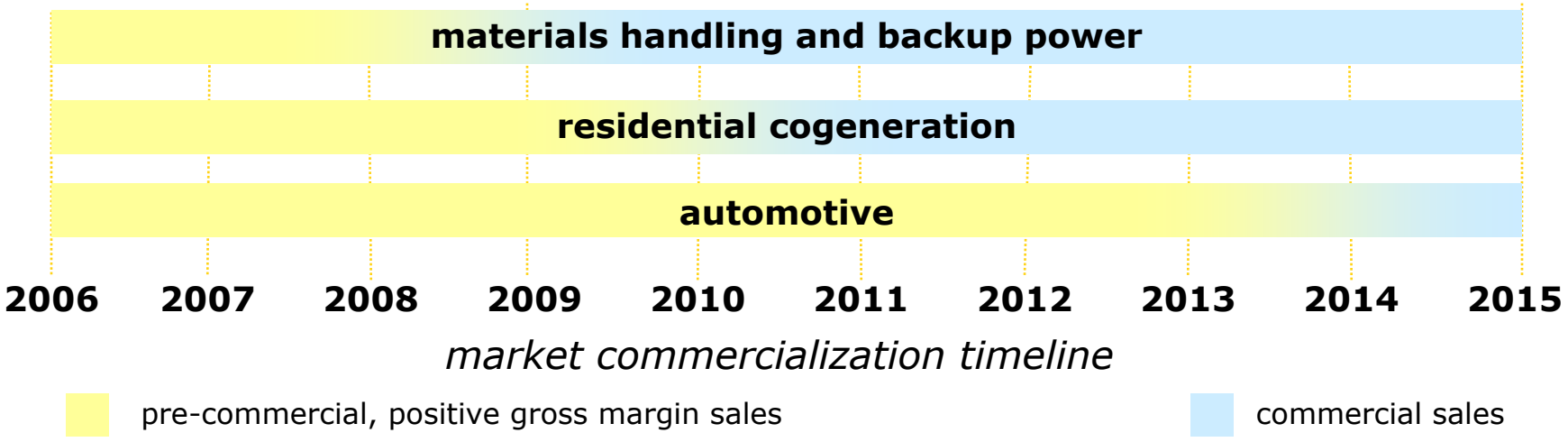

market commercialization timeline

pre-commercial, positive gross margin sales

commercial sales

Summary

- Execute the Technology "Road Map" to deliver fuel cell stack technology by 2010 that meets commercial targets when produced in high volume
- Enhance strategic relationships with unit cell components suppliers
- Reduce design cycle time: accelerated testing, fundamental understanding, simulation & modeling
- Continue to leverage data from "real-life" field demonstrations
- Accelerate the introduction of emerging technologies
- Provide stack products that meet customer needs to create a sustainable, growth business for Ballard