Energy Storage Systems for Heavy Duty Transport

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ISE has pioneered in electric drive transit vehicle development

What does ISE do?

ISE's Partners & Suppliers

ISE sources complementary components from market-leading partners

- **Engine** — Cummins, Ford
- **Drive Motor and Inverter** — SIEMENS
- **Ultra-capacitors, Batteries** — Maxwell Technologies, COBASYS, Altairnano
- **Fuel Cells** — BALLARD, UTC Fuel Cells
- **Electrical Components** — Carrier, SUTRAK, Thermo King

ISE: Leader in Integrated Hybrid Drive Systems

ISE designs, integrates, installs and services its own energy management systems, accessories and control software with third party components into a complete **series hybrid-electric drive system** optimized for heavy duty vehicles

Fuel Type/ Technologies Supported

Gasoline Hybrid	Diesel Hybrid	Hydrogen Fuel Cell	All Electric

Customers & Markets

ISE systems are designed into and sold with the platforms of heavy duty vehicle OEMs

Operators & OEMs

Transit Buses

High Duty Cycle Commercial Vehicles

- Refuse
- Port
- Local haul

Specialized Vehicles

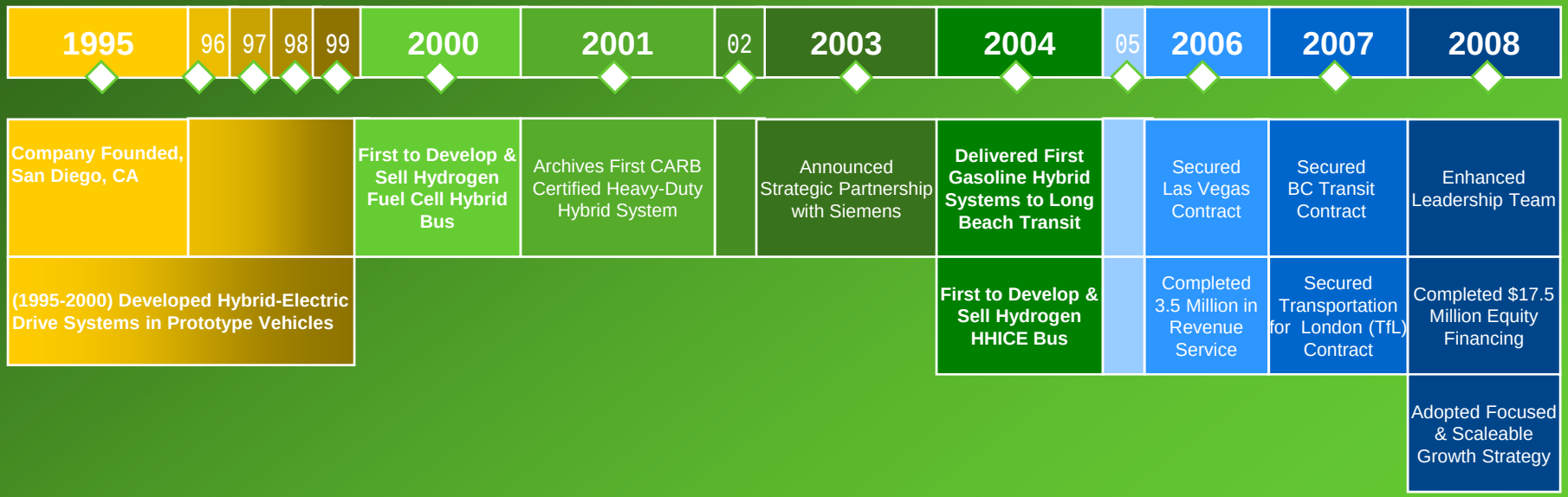
Other Commercial

- Delivery
- School bus
- Airport

ISE offers hybrid-electric drive systems for heavy duty transportation applications

–Wide Range of Heavy Duty Hybrid Configurations / fuel types

–Pioneer in Hybrid Technology for Heavy Duty Vehicles



ISE - a leader in hybrid-electric drive systems

- ISE has dominant share in gasoline, hydrogen hybrid electric buses
- Strong experience across all major fuel technologies and vehicle applications

North America		Market Leader	Strongly Positioned Competitors	Aspiring Entrants
Buses	Gasoline	ISE Transportation recharged.	NONE	Proterra, esignLine
	Diesel	BAE SYSTEMS, Allison Transmission	ISE Transportation recharged.	MAN, ZF
	Zero Emissions*	ISE Transportation recharged.	NONE	ebus
Trucks		EATON Powering Business Worldwide, BOSCH	NONE	ISE Transportation recharged., MAN, ZF

*Hydrogen Fuel Cell and Electric

ISE Vehicle Development Status:

- Gasoline Hybrid Bus, 35-45’ –

  A commercial product, 250 delivered and in revenue service, in excess of 11 million miles on the Long Beach buses alone. Available from New Flyer, NABI (Gillig in 3 months)
- Diesel Hybrid 60’ Articulated –

  50 to enter service in Las Vegas next year
- Hydrogen fueled buses – fifth generation design in commissioning, 6 in service, expect 30 in service next year.
- Battery electric – prototype to be delivered next year.
- All but battery electric have full performance (65mph speed, hill climb, range in excess of 250 miles)

Showing the fuel cell end of the BCT bus:

- Range in excess of 300 mi (500 km) on 45 kg hydrogen,
- Certified to Canadian road and safety standards
- This bus carries up to 70 passengers, speed to 65 mph (105km/h)

GHG Reduction Outlook

- Hybrid drive, with regenerative braking, electric accessories, offers up to 50% reduction in fuel use and GHG emissions (more commonly, 20-30%)
- A hybrid-electric CNG bus should be better… not yet proven, certification of a suitable small engine is needed.
- Both battery and FC vehicles offer large efficiency gains, and about a 50% reduction in WTW GHG using fuel from HC sources (Conventional generation mix for BBus, NG to hydrogen for FCB).
- Both offer a direct path to near zero GHG with deployment of solar/wind electricity or zero emission bio sources of electricity or methane.

Clean energy is hard to store!

- Diesel/ethanol including tank – (one gallon gasoline = 127MJ) 18→ 32 MJ/kg
- CNG incl. tank 18MJ/kg
- Hydrogen in tank 6MJ/kg
- Battery, including BMS, cooling 0.4MJ/kg

Limited range capability is thus the major limitation for BEVs

HDVs – more emissions reductions/dollar inv.

- HD vehicle is used 80 -120 hours/week, with possibility of reductions of fuel use by 12,000 gallons/year and more (equivalent to 40 cars!)
- Innovation in the bus/truck space moves more quickly than LDV, presently half of bus replacements are electric drive hybrids.
- One dollar of state funds will do five times the emissions reductions if used for buses than for LDVs.

Zero Emission: All-Electric Bus

ISE Battery Electric Drive System Advantages:

- Uses large lithium battery pack with standard ISE drive system
- Zero Emissions
- Quiet operation
- No engine certifications, no traps, no filters, no fuel,
- Up to 50% reduction in GHG emissions compared to liquid fueled hybrid bus
- Inexpensive operation - @ $0.13/kwh, one third the cost of diesel (but CNG is competitive in cost)
- Grid power comes from largely domestic sources
  - *Challenges:*
    - **Funding the development** of a reliable high-energy battery pack for heavy duty transit
    - Installation and support of electric infrastructure
    - Battery cost
    - Range!

Next big challenge:

Zero Carbon Fuel at Acceptable Cost

AQMD funded program illustrated above demonstrated feasibility, projected that renewable (wind) hydrogen in megawatt (50+ buses) scale may be lower cost than diesel. Confirmed by GE, NREL

- Many pathways to sustainably sourced hydrogen – “Made in USA”
- Directly charge vehicle batteries as means of storing solar/wind electricity?

Projections for next 3 years:

- Gasoline hybrid is majority of ISE production – hundreds per year
- FC hybrid very dependent on overseas orders or domestic investment, performance of 2010 buses in Canada, London – single order for 100 would be pivotal in bringing down price.
- Limited number of battery buses… possible 3 in 2010, ten in 2011, future very dependent on capital investment, experience, battery prices, charging breakthroughs
- Guesses @ relative 2011-2015 pricing for basic 40’ bus:
  - Gasoline hybrid $500,000 - $450,000
  - NG hybrid $550,000 - $500,000
  - Hydrogen full service (BCT) $1,500,000 - $1,000,000
  - H_2 “battery intensive”, reduced performance $1,000,000 - $900,000
  - GICE, HHICE “battery intensive”, reduc. perf. $600,000
  - Battery electric, 120 mi range $900,000 - $700,000
  - Opportunity charging Battery Electric $700,000 - $600,000

Why the Battery Electric Buses are more expensive:

- For 150 mile range 12 year transit battery bus, battery/drive train cost is $500,000 above that of gasoline electric, *plus* added commercial risk.
- For 100 mile range premium is down to about $300,000 +
- Battery price projections suggest reductions, but can they be believed?
  - Extremely dependent on volume, experience both in automotive and in utility applications
  - HD vehicles demand a premium battery (high voltage, high energy and power density, packaging suitable to mobile application)

ISE Manufacturing Capabilities:

- Present facilities limited to approximately 300 vehicle drives/yr, can be easily expanded
- Manufacturing capability increasingly focused to components, such as electrical energy storage systems
- Cost reduction opportunities have dictated some cross-border manufacturing,90% of value added in CA (ISE employs 140)
- Significant cost reduction is possible with $4M investment required for redesign of some components and for earlier stages of cost reduction.
- Costs could be reduced, volume tripled with $60M investment in new manufacturing plant.
- Venture capital, public monies virtually frozen at this time.

Federal monies only significant sources of AB118 match funds, however…:

- Recent experience follows earlier, DOE funds have never been accessible to ISE.
- Lack of support of Senators, Governor has been reflected in failure to access DOE funding.
- ISE structure, intentions, not suited for effective marketing to military.
- Canada, Europe more friendly to new energy transport development than USA, more appreciative of GHG saving technologies
- DOT funds do support bus purchases, however agencies are now so strapped for cash they are cutting service, have little interest in new projects or purchases unless fully funded.
- ISE is investing modest amounts of equity funds in electric drive development, hence can offer very limited in-kind cost share.

Possibly powerful incentives:

- Team with ARB to maintain the ZEB rule, modify only to provide early adoption incentives for ZEB purchase – penalties for 2010, 2011 purchase of more vehicles than 2009.
- Use of state funds for purchase of *only* gaseous &/or battery electric fuel vehicles, (DGS has fleet of 52,000 vehicles, thousands of MD & HD vehicles)
- Similar rules or incentives for University/College purchases? All vehicles purchased with tax funds?
- Provide award preferences for firms developing renewable gaseous fuels and committing to large investments as required for dropping price of renewable hydrogen to a guaranteed below $5/kg, renewable methane to below $1/therm compressed at dispenser.
- NZEV approaches may allow best use of vehicle development funds, with some limited performance compromise. (Would CARB support?)
  - Gasoline hybrid but with large battery, small engine?
  - HHICE, either full performance or small engine, large battery?