Hydrogen ICE Vehicles Powered by Ovonic Metal Hydride Storage

Presented to
2006 Air Innovations Conference
September 6, 2006

Ovonic Hydrogen Systems, LLC
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Energy Conversion Devices, Inc.’s Business Activities

ENERGY CONVERSION DEVICES, INC. (ECD)

ENERGY GENERATION
- SOLAR
  - United Solar Ovonic

- FUEL CELLS
  - Ovonic Fuel Cell Company

ENERGY STORAGE
- BATTERY
  - Ovonic Battery Company
- HYDROGEN
  - Ovonic Hydrogen Systems

INFORMATION TECHNOLOGIES
- Cobasys LLC (50%)
Outline

- Why Hydrogen
- Ovonic Metal Hydride Technology
- Ovonic Metal Hydride ICE Vehicles
- Ovonic Refueling Technologies
  - Ovonic Metal Hydride Dispensing Systems
  - Ovonic Metal Hydride Mobile Refueling Station
Hydrogen Economy: Key Drivers

- Energy Security
  - Dependence on imported fossil fuel leads to wars

- Growing demand over the depleted fossil fuels, cheap oil or natural gas will be history

- Climate Change – harm to our planet
  - CO₂ emissions from fossil fuels impose serious threat to our planet
  - In the US each vehicle, on average, will add 60 tons of CO₂ to the atmosphere

- Air Pollution
  - The annual expenditures for combating pollution and the related medical cost in the US is $45 billion
Global Energy Evolution

Hydrogen is the ultimate clean and sustainable form of energy.
Hydrogen Facts

- Sustainable Fuel, Local Resources
- No pollutants, No CO₂, No waste
- Hydrogen has the highest heat of combustion among all fuels
  - Hydrogen: 33.3 kwh/kg
  - Gasoline: 12.2 kwh/kg
  - Methane: 13.9 kwh/kg
- Hydrogen is the lightest gaseous fuel, it is very difficult to compactly store.
- Hydrogen is the most abundant element in our universe. On our planet, sustainable hydrogen will ultimately be derived from water.
- 3 gallons of water generate 1 kg H₂ (1 gallon of gasoline equivalent)
An Ultimate Energy Solution

Ovonic Solid Hydrogen Storage

Ovonic Solar

Electrolyzer

H₂

O₂

O₂

H₂

Ovonic NiMH Battery

Ovonic Fuel Cell / ICE

Ovonic Hydrogen solutions
Issues of Current Hydrogen Storage Options

- Compressed H₂
  - Bulky
  - Too high the stored potential energy

- Liquid H₂
  - Require ultra low temperature (-253°C)
  - High liquefaction energy

- Solid H₂
  - Ultimate solution
Ovonic Metal Hydrides

- Reversible
- Safe
- Compact

Design Requirements:
- Suitable MH Alloy
- Efficient Heat Exchanger
- Proper Powder Packaging
Compact

Material

OvMH: 125 g/liter
Liquid H₂: 71 g/liter
Compressed H₂ (5000 psi): 23 g/liter

System

Left: Ovonic Onboard Vessel, 3 Kg H₂ @ 1,500 psi
Right: Compressed H₂ Vessel, 0.78 Kg H₂ @ 5,000 psi
(One kg hydrogen = One gallon gasoline)
Ovonic Metal Hydride Storage Technology

**Special Features**
- Reversible
- Safe
- Compact
- Tailorable Pressure
- Fast Refilling
- Low Pressure Operation
- Cold temperature start-up
- Packaging flexibility
- Waste Heat for Desorption
  - The most energy efficient storage system

**Benefit**

**Vehicle:**
- Long Range
- Low Fuel Cost
- Safe Operation

**Stationary:**
- Small Footprint
- Directly refilled from an electrolyzer or Fuel Processor
Hydrogen ICE Vehicles
A Bridging Technology to Fuel Cell Vehicles

- Share the same refueling infrastructure
- Adopt the same codes and standards
- Provide the consumer with the same hydrogen safety awareness
- A near term affordable solution
Ovonic Converted Hydrogen Powered Toyota Prius Hybrids

2005 Model ▶

2002 Model ▼

2004 Model ▼
Hydrogen Storage System mounted underbody
2004 Model ▼

2002 Model ▲
Hydrogen Storage System inside the trunk
Liquid pump
Heat Exchanger
Metal Hydride Storage Vessels
# Hydrogen Prius Test Results
*(Measured by Quantum’s Advance Vehicle Division)*

**Grams per Mile**

<table>
<thead>
<tr>
<th></th>
<th>HC</th>
<th>CO</th>
<th>NOx</th>
<th>CO2</th>
<th>MPK-city</th>
<th>MPK-hwy</th>
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</thead>
<tbody>
<tr>
<td>2005 Ovonic™ Hydrogen Prius</td>
<td>0.001</td>
<td>0.002</td>
<td>0.014</td>
<td>1.6</td>
<td>54-56</td>
<td>50-52</td>
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<tr>
<td>2005 Prius (Gasoline) Baseline</td>
<td>0.004</td>
<td>0.386</td>
<td>0.004</td>
<td>176.5</td>
<td>52 mpg</td>
<td>48 mpg</td>
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<tr>
<td>SULEV / PZEV standard</td>
<td>0.010</td>
<td>1.0</td>
<td>0.020</td>
<td>na</td>
<td></td>
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## Hydrogen Vehicle Comparisons

<table>
<thead>
<tr>
<th></th>
<th>Fuel Tank (kg H2)</th>
<th>ZEV / SULEV</th>
<th>CO₂ (g/mi)</th>
<th>Fuel Economy Miles/kg H2</th>
<th>Range (mile)</th>
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<tbody>
<tr>
<td>H₂ FC vehicle @ 5,000 psi (Toyota)</td>
<td>3.2</td>
<td>yes</td>
<td>no</td>
<td>60</td>
<td>180</td>
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<td>Ovonic H₂ Prius (2002) OHS MH vessel</td>
<td>3</td>
<td>yes</td>
<td>no</td>
<td>45</td>
<td>135*</td>
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<tr>
<td>Ovonic H₂ Prius (2004) OHS MH vessel</td>
<td>3.5</td>
<td>yes</td>
<td>no</td>
<td>57</td>
<td>200*</td>
</tr>
</tbody>
</table>

* Real World Drive Range
Ovonic Metal Hydride Dispensing Systems

- Design and built according to Class I, Div. II
- Pressure regulated flow
- IrDA communication
- Temperature and strain monitoring as safe guards
Transportations
Two- and Three-Wheelers
Huge market in Asia, Africa, etc.
Renewable Energy Applications

Grid

Renewable Energy Facility

Water Supply

Electrolyzer

O$_2$ Gas

H$_2$ Gas

H$_2$ Pipeline

ICE Generator / Fuel Cell

Ovonic Bulk Hydrogen Storage

Clean Power to Grid

Peak Shaving

Local Loads

Local H$_2$ Users

Ovonic H$_2$ Trucking

Clean H$_2$ Fuel Dispensing
Hydrogen – The Ultimate Freedom Fuel

- Sustainable – enhance energy security
  
  Renewable energy → Water electrolysis → Hydrogen

  3 gallons water generate 1 kg H₂ (1 gallon of gasoline equivalent)

- Clean – by-product is water

  No harmful pollutants to the environment, to human health

  No harmful CO₂ to our planet

- While the growing demand exceeds the unstable oil supply, we will repeatedly see record high oil prices

- While the mandatory limits on CO₂ are being implemented globally

- While the world is fighting over the limited oil reserves

- The time is now – We can replace all combustible fuels with H₂, making a clean, healthy, and safe society

- *It leads to a basic profitable industry and job creation.*