# Overview

## Timeline
- **Start:** November 2004
- **Finish:** December 2009
- **100% Complete**

## Partners
- BP
- Ballard/AFCC
- States of California & Florida
- City of Taylor, MI
- SMUD, Progress Energy & NextEnergy

## Budget
- **Total Project Funding**
  - DOE: $33M
  - Ford: $33M
- **Funding received in FY09** = $3.2M
- **Funding for FY10** = $0.7M

## Barriers
- Cost
- Freeze start
- Range
- Infrastructure
Objectives

• Ford Motor Company Objectives
  – Gain vehicle operational data in differing climate conditions, to direct and augment future design efforts
  – Provide input to the industry-government efforts to define a future hydrogen economy

• BP Objectives
  – Establish an initial retail compatible hydrogen infrastructure to fuel a small fleet of fuel cell vehicles
  – Evaluate emerging hydrogen technologies that have the ability to meet DOE cost and performance targets
  – Explore cost and commercial feasibility of renewable-based hydrogen generation
## 2009 Completed Milestones

| Demonstrated 700 bar Type IV/Next Gen IPT/Gen III FC Powertrain in vehicle package | - Successful integration testing of vehicles  
- Conducted fuel economy testing  
- Freeze start evaluation complete |
| Concluded Gen I Focus Fleet Operation | - Review EOL failure analysis  
- Fleet decommission complete  
- Tear down analysis |
1. Fleet Demonstration

18 Ford Focus Fuel Cell Vehicles
- Southern California (8)
- Orlando, Florida (5)
- Southeast Michigan (4)
- Reykjavik, Iceland (1)

2. Technology Advancement

Technology Demonstration Vehicles
- Fuel Cell Durability
- Increased operating range
- Cold start capabilities
1. Fleet Demonstration Accomplishments

2. Technology Demonstration Accomplishments

3. Infrastructure Demonstration Accomplishments
2005 Focus Fuel Cell Electric Vehicle

- 4 Passenger Sedan
- Curb Mass: 1600 kg (3520 lbs)
- Fuel Cell: Ballard Mark 902 FC STACK
- Peak Power: 65 kW (87hp)
- Powertrain: Integrated AC Induction
- Hybridized
- Series Regenerative Braking
- 50 Mi/Kg H₂
- Range: 200 mi/320 km
- Max speed: 80+ mph/128+ kph
- Fuel: 350 bar Compressed Hydrogen
- Emissions: Zero
2005 Focus Fuel Cell Electric Vehicle

14,000 Ft Altitude Testing

Mud Bath / Salt Water Fording

Sault Ste Marie Brake Testing -18 C

Cobblestone Roads
How would you rate the vehicle's performance?

- Acceleration
- Noise Level
- Braking
- Driving Range
- Handling
- Overall

Scale: Poor (0) to Excellent (10)

Comparison between 2006 and 2007.
I feel safer driving this vehicle than a gasoline vehicle. It is incredibly safe.

It handles very well.

I drive the car without hesitation and am very impressed by it.

It has great pick up off the line.

The car has been very reliable and a great addition to our fleet.

The car attracts a lot of attention and is fun to drive.

It has plenty of speed for getting down the highway.

I feel safer driving this vehicle than a gasoline vehicle. It is incredibly safe.
Fleet Demonstration Accomplishments

- **Focus Fuel Cell Fleet Milestones**
  - Accumulated over **1,300,000 miles to date**
  - Successful in-field operation past the original 36-month target with all vehicles in the field over 48 months
  - Demonstrated 50% higher fuel economy than gasoline vehicles
  - Confirmed >1000 hours fuel cell durability using on-road data
  - Validated vehicle fueling time of 5 minutes or less for a 5 kg tank
  - Fleet had a 94% up-time for user operation and availability
  - High customer satisfaction and feedback

---

1/ Includes DOE and non-DOE Focus Fleet Vehicles
<table>
<thead>
<tr>
<th>Vehicle Attributes</th>
<th>Robustness Demonstrator</th>
<th>700 bar Demonstrator</th>
<th>Designed Around Hydrogen Demonstrator</th>
<th>Plug-In Technology Demonstrator</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vehicle</strong></td>
<td>TDV 1</td>
<td>TDV 9</td>
<td>TDV 2</td>
<td>TDV 3.2</td>
</tr>
<tr>
<td><strong>Platform</strong></td>
<td>Modified Focus</td>
<td>Focus</td>
<td>Explorer</td>
<td>Explorer</td>
</tr>
<tr>
<td>Fuel Cell Generation</td>
<td>Gen 1 modified</td>
<td>Gen 1 carryover</td>
<td>Gen 1</td>
<td>Gen 2</td>
</tr>
<tr>
<td>Range (miles)</td>
<td>200</td>
<td>250</td>
<td>150</td>
<td>175</td>
</tr>
<tr>
<td>Hydrogen Storage (bar)</td>
<td>350</td>
<td>700</td>
<td>350</td>
<td>350</td>
</tr>
<tr>
<td>STACK Life Target (miles)</td>
<td>30,000</td>
<td>15,000</td>
<td>45,000</td>
<td>45,000</td>
</tr>
<tr>
<td>Unassisted Cold Start</td>
<td>2°C</td>
<td>2°C</td>
<td>&lt;0°C</td>
<td>-15°C</td>
</tr>
<tr>
<td>Assisted Cold Start</td>
<td>2°C</td>
<td>2°C</td>
<td>-15°C</td>
<td>n/a</td>
</tr>
<tr>
<td>Fuel Efficiency</td>
<td>50</td>
<td>50</td>
<td>30</td>
<td>35</td>
</tr>
<tr>
<td>(mpge)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Technology Demonstration Vehicles
TDV 1 Accomplishments

<table>
<thead>
<tr>
<th>Demonstration Objective</th>
<th>TDV 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Next Generation Fuel Cell</td>
<td>▲</td>
</tr>
<tr>
<td>Over 300 Mile Range</td>
<td></td>
</tr>
<tr>
<td>700 bar Hydrogen Storage</td>
<td></td>
</tr>
<tr>
<td>STACK Life (30,000 mile)</td>
<td>X</td>
</tr>
<tr>
<td>Unassisted Cold Start &lt; 0°C</td>
<td></td>
</tr>
<tr>
<td>Fuel Efficiency (mpg) (*normalized to Focus)</td>
<td>X</td>
</tr>
<tr>
<td>FCS Peak Noise (dBA)</td>
<td></td>
</tr>
</tbody>
</table>

▲ Advancements, improvements or new concepts

Accomplishments

- Developed a novel humidity sensor
- Developed a novel gas conditioner
- Characterized fuel cell stack interfaces
- Improved Humidification of Anode
- Applied next generation H2 recirculation blower
- Demonstrated improved stack lifetime and reliability
- Completed 30,000 mile dynamometer endurance test
- No stack performance or durability issues
- Thermal characterization of anode and cathode gases
### TDV 9 Accomplishments

<table>
<thead>
<tr>
<th>Demonstration Objective</th>
<th>TDV 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Next Generation Fuel Cell</td>
<td></td>
</tr>
<tr>
<td>Over 300 Mile Range</td>
<td>▲</td>
</tr>
<tr>
<td>700 bar Hydrogen Storage</td>
<td>X</td>
</tr>
<tr>
<td>STACK Life (30,000 mile)</td>
<td></td>
</tr>
<tr>
<td>Unassisted Cold Start &lt; 0°C</td>
<td></td>
</tr>
<tr>
<td>Fuel Efficiency (mpg) (*normalized to Focus)</td>
<td>X</td>
</tr>
<tr>
<td>FCS Peak Noise (dBA)</td>
<td></td>
</tr>
</tbody>
</table>

▲ TDV9 demonstrated progress toward this objective, extending range in the same vehicle packaging allowance.

**Accomplishments**

- Demonstrated new 700 bar technology through durability and real-world customer cycles
- Provided the capacity improvement pathway to the 300-mile driving range goal
- The high-pressure system improves volumetric density by about 1.5x while maintaining the same weight ratio
- Successful fueling trials have been conducted providing experience that is similar to the Focus Fuel Cell Vehicle fleet with 350 bar systems
- Achieved industry certification and Ford’s internal validation
Accomplishments

- Under hood packaged stack and system
- Full electric All Wheel Drive
- Improved vehicle current control
- Hydrogen Storage Architecture for extended range
- NVH treatment for silent operation
- 1556 miles distance record for 24 hr run on test track
- Demonstrated Technology in hundreds of drives for government and public officials
- Displayed at 2006 LA Auto Show
- TDV2 is still in operation in Iceland with in excess of 25,000 operating miles
### Accomplishments

- Demonstrated unassisted freeze start capability (greater than 40 freeze starts conducted)
- Cold start time significantly reduced
- Improved Efficiency to nearly 40 miles/kg
- Fuel cell system Lifetime of 2000+ hours
- Improved power output: 90 kW peak
- 700 bar fuel storage of 9.5kg H2 for a feasible range over 300 miles with no compromise vehicle package

<table>
<thead>
<tr>
<th>Demonstration Objective</th>
<th>TDV 3.2</th>
<th>TDV 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Next Generation Fuel Cell</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Over 300 Mile Range</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>700 bar Hydrogen Storage</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>STACK Life (30,000 mile)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unassisted Cold Start &lt; 0°C</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Fuel Efficiency (mpg) (*normalized to Focus)</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>FCS Peak Noise (dBA)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### TDV 7 Accomplishments

<table>
<thead>
<tr>
<th>Demonstration Objective</th>
<th>TDV 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Next Generation Fuel Cell</td>
<td>▲</td>
</tr>
<tr>
<td>Over 300 Mile Range</td>
<td>▲</td>
</tr>
<tr>
<td>700 bar Hydrogen Storage</td>
<td></td>
</tr>
<tr>
<td>STACK Life (30,000 mile)</td>
<td>▲</td>
</tr>
<tr>
<td>Unassisted Cold Start &lt; 0°C</td>
<td></td>
</tr>
<tr>
<td>Fuel Efficiency (mpg) (*normalized to Focus)</td>
<td>X</td>
</tr>
<tr>
<td>FCS Peak Noise (dBA)</td>
<td>X</td>
</tr>
</tbody>
</table>

▲ TDV 7 utilized a specially designed, smaller fuel cell stack based on the Mk902 stack technology that was used to generate power at two fixed levels during operation. Using the plug-in feature daily, the average range can be extended.

### Accomplishments
- NVH & Freeze Start improvements
- Reduction of FCS weight
- Modular FC APU design
- Less reliance on H2 Infrastructure
- Reduce System complexity
- Flexible Vehicle Design
- Increased Fuel Economy
Infrastructure Demonstration

Sacramento
- Sept. ’05 CaFCP Station
- Mar. ’06 APCI Mobile Refueler
- Mar. ’08 SMUD Station
- 8 Vehicles

SE Michigan
- Oct ’05 BOC Partial Refueler
- Oct ’06 City of Taylor Station
- July ’08 Dearborn 700 bar Station
- 4 Vehicles

Florida
- Sept ’05 APCI Mobile Refueler
- Dec ’07 Jamestown Station
- 5 Vehicles

Reykjavik
- 1 Car
## Infrastructure Accomplishments

<table>
<thead>
<tr>
<th>Location</th>
<th>Dearborn, MI</th>
<th>Taylor, MI</th>
<th>Jamestown, FL</th>
<th>SMUD, CA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology</td>
<td>Liquid Delivered</td>
<td>Liquid Delivered</td>
<td>Electrolysis</td>
<td>Electrolysis</td>
</tr>
<tr>
<td>Service Pressure</td>
<td>13,200 psig</td>
<td>6,600 psig</td>
<td>6,600 psig</td>
<td>6,600 psig</td>
</tr>
<tr>
<td>Daily Capacity</td>
<td>60 kgs/day</td>
<td>96 kgs/day</td>
<td>24 kgs/day</td>
<td>24 kgs/day</td>
</tr>
<tr>
<td>Fill Types</td>
<td>Wireless RF</td>
<td>Wireless RF</td>
<td>Wireless RF</td>
<td>Wireless RF</td>
</tr>
<tr>
<td></td>
<td>Wired Comm</td>
<td>Wired Comm</td>
<td>Wired Comm</td>
<td>Wired Comm</td>
</tr>
<tr>
<td></td>
<td>Non-Comm</td>
<td>Non-Comm</td>
<td>Non-Comm</td>
<td>Non-Comm</td>
</tr>
<tr>
<td>Safety Training</td>
<td>100 emergency responders/fleet operators</td>
<td>40 emergency responders 25 fleet operators</td>
<td>90 emergency responders 60 fleet operators</td>
<td>200 emergency responders/fleet operators</td>
</tr>
<tr>
<td>Data Collection</td>
<td>Obtained fueling data from vehicles</td>
<td>Obtained fueling data from vehicles</td>
<td>On-site electronic data collection</td>
<td>On-site electronic data collection</td>
</tr>
</tbody>
</table>
Collaborations and Coordination

Thanks to our Project Partners and Customers ...
Future Work

• Submitted final report
• Completed decommission and deployment of vehicles
• Continue internal research of hydrogen and fuel cell system technology to progress towards commercial viability
This project addressed the following technical barriers identified in the Technology Validation Program Plan:

1. Lack of Fuel Cell Vehicle Performance and Durability Data
   - Submitted 270 gigabytes of operational data
   - Developed predictive analysis of fuel cell degradation with NREL
   - Exceeded lifetime expectancy of the fuel cell stack

2. Hydrogen Storage
   - Demonstrated 350 bar with high reliability in the field
   - Developed advanced 700 bar storage system to optimize capacity

3. Lack of Hydrogen Refueling Infrastructure Performance Data
   - Implemented multiple customer stations and trained over 500+ personal

4. Maintenance and Training Facilities
   - Created new Technician Repair Order System for 3 external facilities

5. Codes and Standards
   - Conducted 4 annual C&S conferences and no reported safety incidents