GATE Center for Automotive Fuel Cell Systems at Virginia Tech

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Project ID # ti_08_nelson

Outline

- Overview
- Objectives for FY2008 and FY2009
- Milestones
- Approach
- Accomplishments for 2008 - 2009
- Activities Planned for 2009 - 2010
- Summary
- Response to February 2008 review comments
- Additional Accomplishments for 2008 - 2009
- Publications 2008 - 2009

Overview

Timeline

- Start – Oct 2005
- Finish – Dec 2010
- 67 % Complete

Budget

- Total project funding
  - DOE - $499,000
  - Contractor CS - $166,000
- Funding received in FY08
  - $116,000 (total, includes CS)
- Funding received in FY09
  - $154,000 (total, includes CS)

Barriers

- Barriers addressed
  - Insufficient supply of graduate engineers with proper background
  - Need new knowledge in critical technologies
- Target
  - Provide industry with technical and human resources in interdisciplinary fuel cell and vehicle technologies

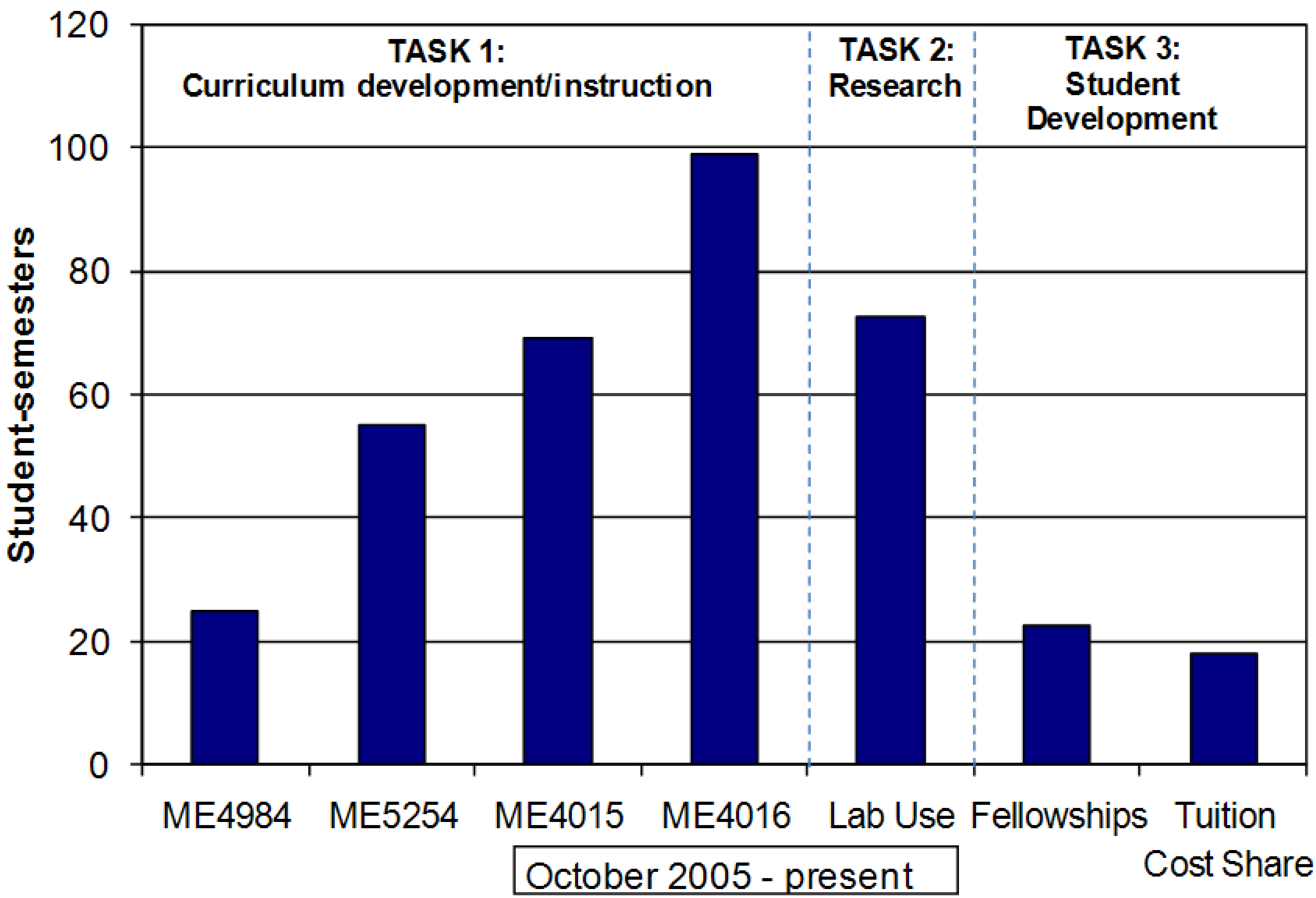
Partners

- Project Lead – Virginia Tech
- Industry Interactions –
  GM FCA, Fuel cell companies,
  Professional Development seminars,
  Conferences and Publications

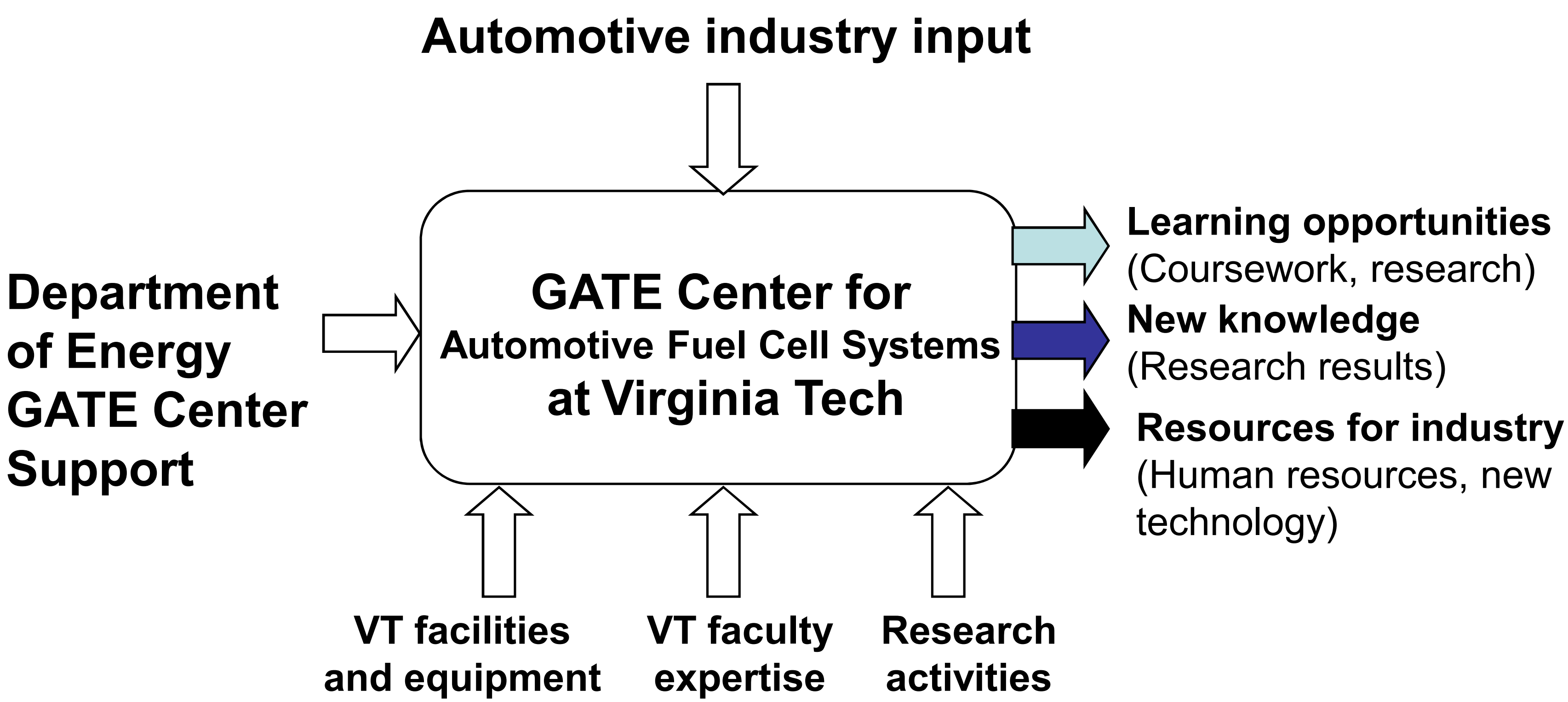
Objectives for FY2008 and FY2009

- Task 1 – Curriculum development
  - Develop new materials and enhance existing courses for a fuel cell and hydrogen systems curriculum
- Task 2 - Engage students in research
  - Provide research opportunities for students that support the goals of the GATE Center
- Task 3 – Recruit students for GATE Fellowships
- Task 4 – Dissemination and scholarship
- Task 5 – Industry interaction

Milestones
Tasks 1-3: Curriculum, Research, Student Development



Concept for DoE/VT/Industry Interaction

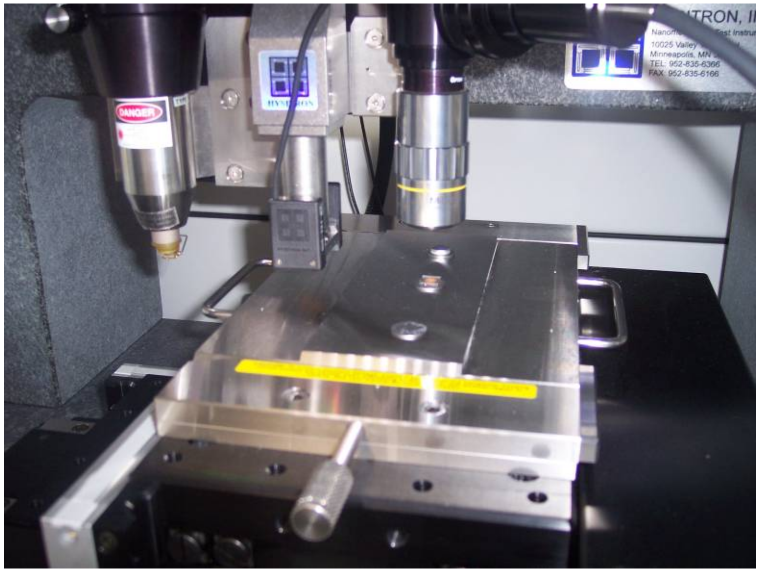


Approach: Collaborative Education and Research Across Disciplines and Academic Levels

- Research collaboration among academic departments
  - Mechanical Engineering – system modeling, nano-/meso-scale modeling, testing and materials characterization
  - Material Science and Engineering Department –material characterization related to fuel cell electrodes
  - Engineering Science and Mechanics Department – durability modeling and membrane characterization
- Research collaboration with undergraduate researchers
  - NSF Research Experience for Undergraduates (REU)
  - 10 summer students working with faculty and graduate mentors on various aspects of fuel cell materials and processes (ME, MSE, ESM, ChE, Chemistry)
- Educational collaboration across departments and academic levels for student projects and classes
  - Mechanical engineering, electrical engineering, MSE
  - Graduates, seniors, juniors

Accomplishments

Task 2: Automotive Fuel Cell Research - Durability

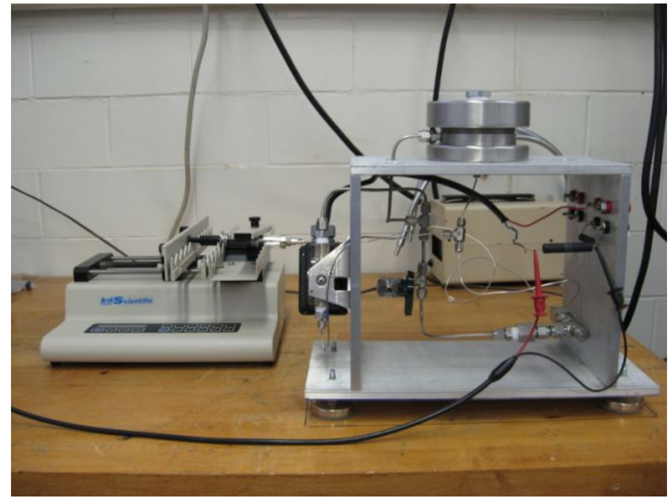


Nano-indenter used for measurement of out-of-plane membrane properties

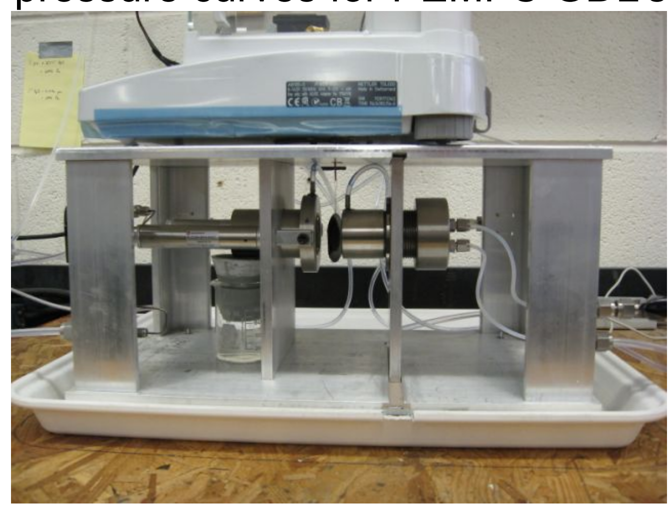
- Improvement of membrane durability requires an understanding of membrane mechanical properties and their relationship to membrane failure
- Research by students that have completed GATE center coursework, used GATE labs, or received GATE center funding (denoted by *) has addressed
  - Characterization of the viscoelastic properties of PFSA membranes (linear and non-linear)
  - Development of a constitutive model for PFSA viscoelastic properties
  - Characterization of the fracture energy of PFSA membranes using a knife slit test
  - Evaluation of the biaxial strength of PFSA membranes using pressure-loaded blister tests
  - Simultaneous measurement of water uptake and strain in PFSA membranes*
  - Development of techniques for evaluation of the resistance of PFSA membranes to shorting*
- Research has been conducted in conjunction with industrial sponsorship
- Dissemination
  - 7th International Conf. on Fuel Cell Science, Engineering, and Technology, June 2009
  - 6th International Conf. on Fuel Cell Science, Engineering, and Technology, June 2008
  - 5th International Conf. on Fuel Cell Science, Engineering, and Technology, June 2007

Task 2: Automotive Fuel Cell Research - Water Transport

- Improvement of fuel cell performance, particularly at high current density, requires an understanding of liquid water transport in gas diffusion media
- Research by students that have completed GATE center coursework, used GATE labs, or received GATE center funding (denoted by *):
  - Development of characterization techniques for capillary pressure – saturation curves for materials of mixed wetability (Sole*)
  - Development of characterization techniques for relative permeability in gas diffusion media (Sole*)
  - Development of analytical models of the GDL that incorporate experimentally determined liquid transport characteristics (Sole*)
- Research has been conducted in conjunction with industrial sponsorship
- Dissemination
  - Sole (2009), 7th International Conf. on Fuel Cell Science, Engineering, and Technology, June 2009
  - Sole (2008), 6th International Conf. on Fuel Cell Science, Engineering, and Technology, June 2008
  - Sole (2007), 5th Int. Conf. on Fuel Cell Science, Engineering and Technology, June 2007



Apparatus for measuring saturation pressure curves for PEMFC GDL's



Apparatus for measuring relative permeability of PEMFC GDL's

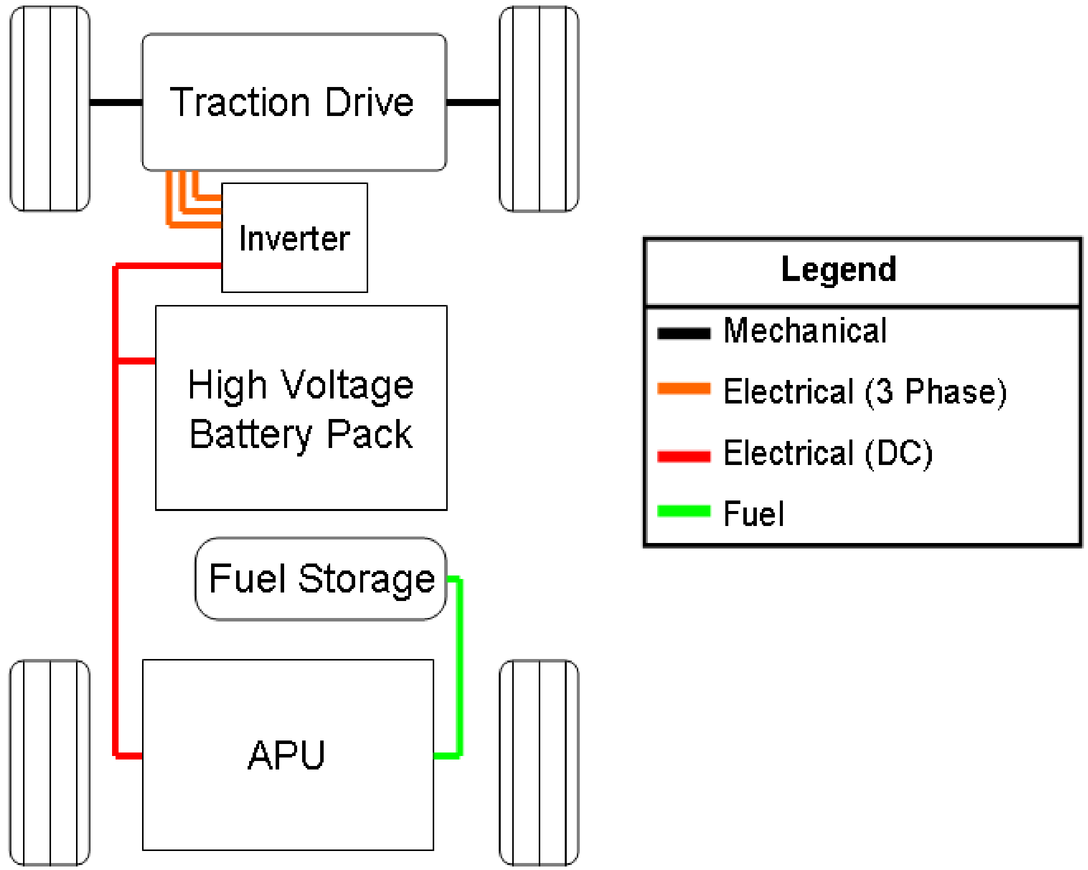
Series plug-in hybrid electric vehicle (SPHEV)

The SPHEV is propelled by an electric drive.

The high voltage battery pack provides energy for all electric range (AER), when no onboard fuel is consumed.

The auxiliary power unit (APU) converts onboard fuel to electrical energy to continue propelling the vehicle after the battery energy is used.

The SPHEV is designed to never run as a blended plug-in, having a battery large enough to provide full performance.



Compare efficiency, petroleum energy use and GHG impact for Hydrogen, E85 and Grid Electricity energy sources

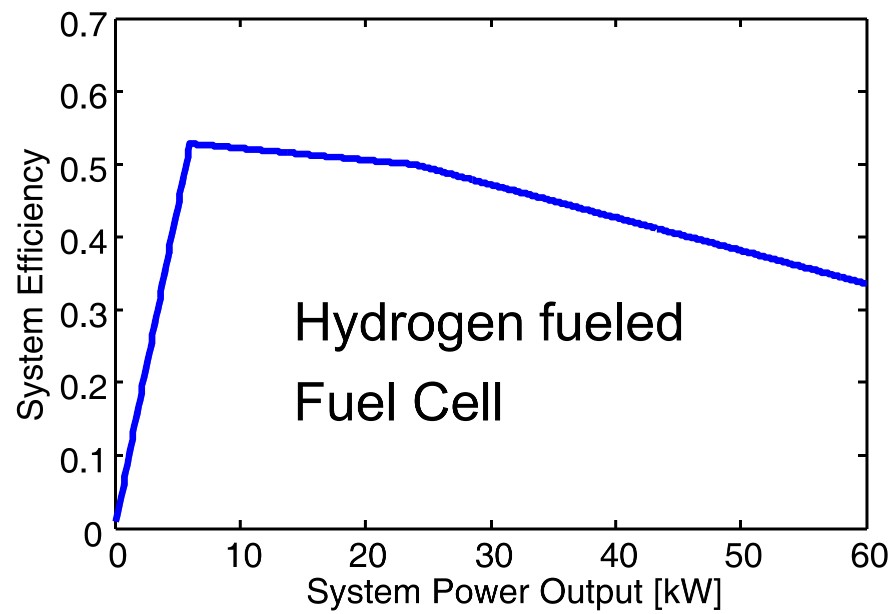
Fuel conversion

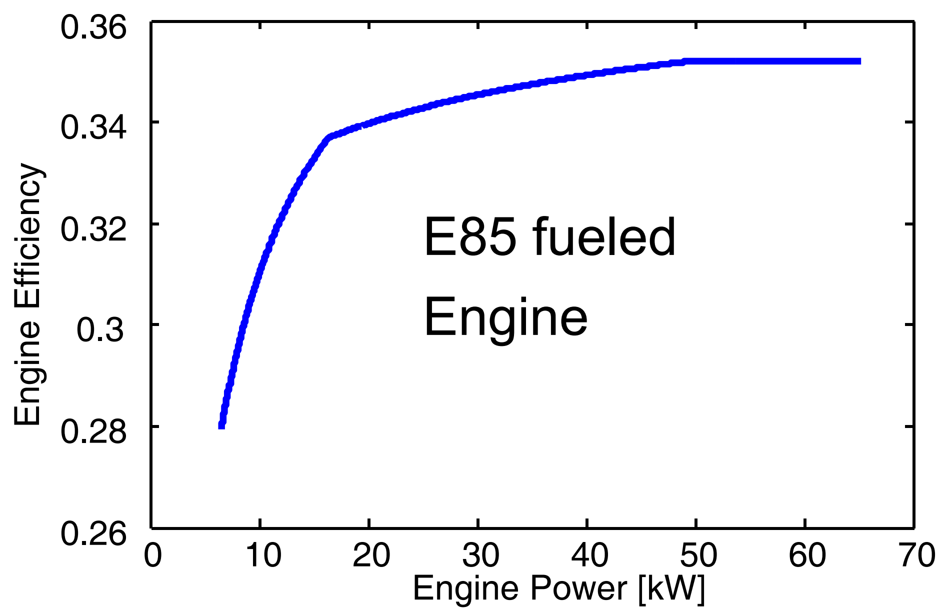
Two fuel converter models were made- a fuel cell (Hydrogen) and an internal combustion engine (ICE, E85).

Fuel cell efficiency is a function of system power.

Engine efficiency is a function of engine torque. A constant generator efficiency is used to simulate the conversion of engine power to DC bus power.

Fuel converter (FC) efficiency is used to determine the fuel energy input from the FC output





Comparison of Energy Source Impact

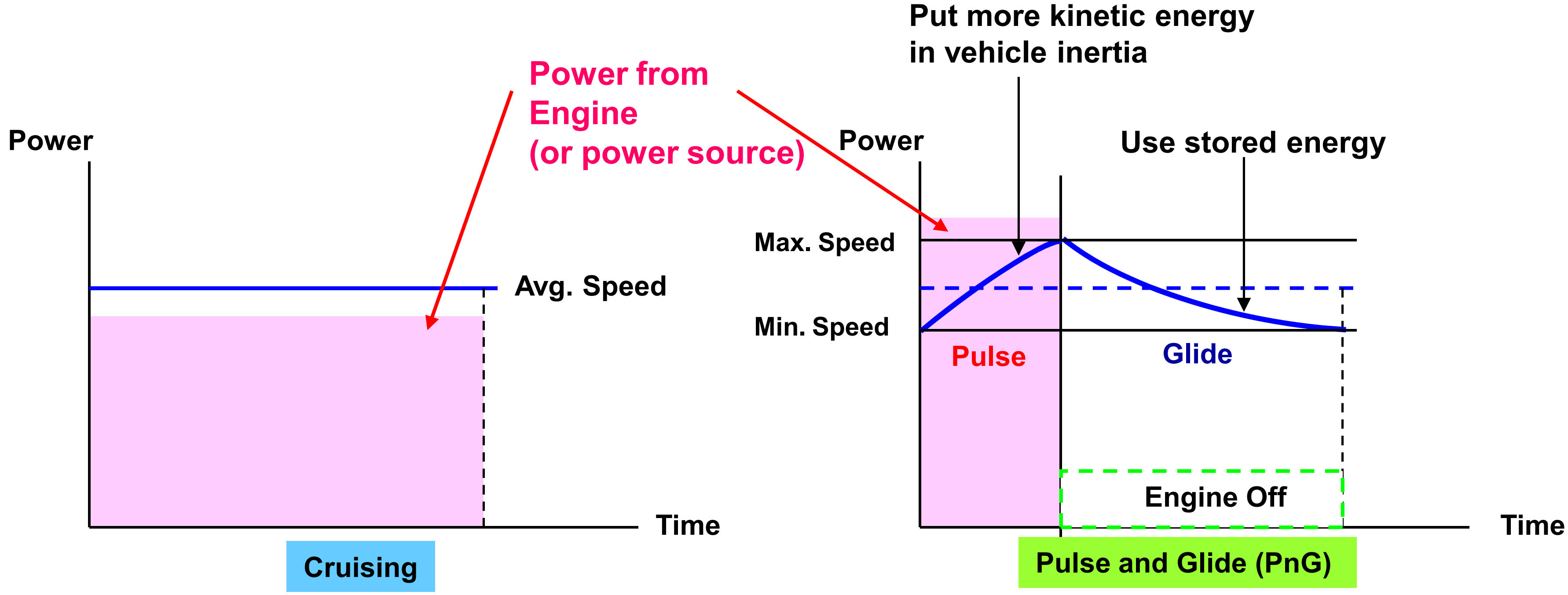
The SPHEV model results show that the stock vehicle using RFG is very efficient on the highway for WTW energy and even GHG emissions. The other energy sources are superior for WTW petroleum energy use and city GHG emissions.

			E85 - CS	GH2 - CS	Electricity - CD	Stock - RFG
PTW Fuel Energy Consumption	City	kJ/km	2259	1146	546	2789
	Hwy	kJ/km	2030	1205	622	1037
WTW Fuel Energy Consumption	City	kJ/km	5133	1996	1440	3494
	Hwy	kJ/km	4615	2099	1640	1299
WTW Petroleum Energy Consumption	City	kJ/km	629	18	48	2765
	Hwy	kJ/km	566	19	55	1028
WTW GHG Emissions	City	g CO2/km	155	109	101	262
	Hwy	g CO2/km	139	114	116	98

Vehicle Inertia Impact on Fuel Consumption using Pulse and Glide (Acceleration and Coast) Driving Strategy

SAE Paper 2009-01-1322 to be presented April 2009

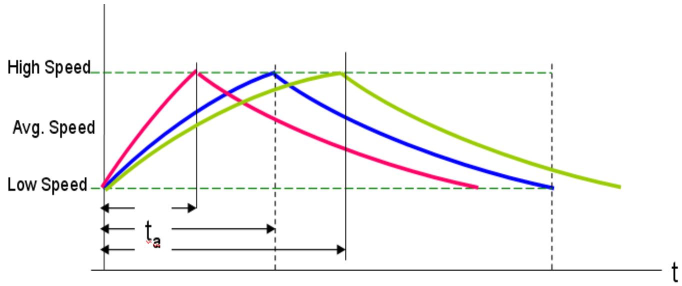
Objective: Quantify vehicle kinetic energy storage impact on fuel consumption of conventional and hybrid electric vehicles



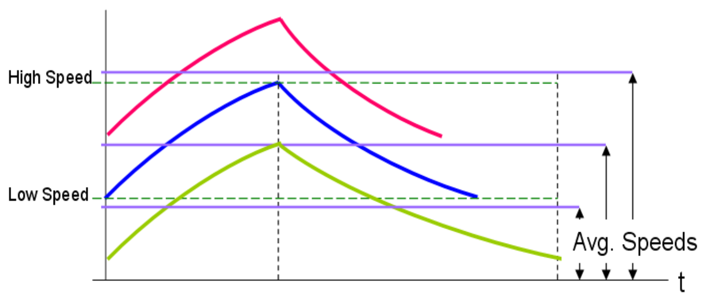
In this study, many parameters that affect fuel economy are considered for pulse and driving strategy such as **acceleration time**, **speed range** and **speed difference**.

Task 2: Vehicle Technologies – Hybrid Vehicle Control

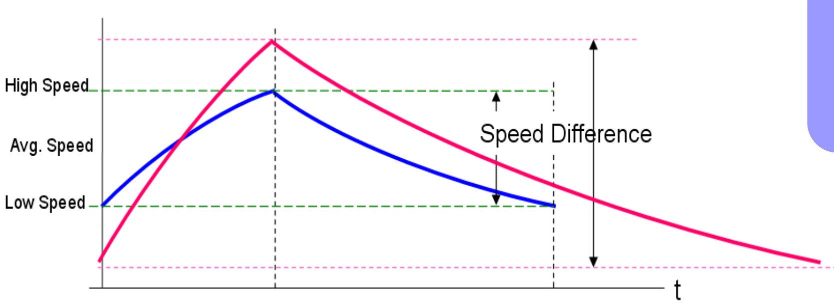
Determination of Parameters



Acceleration Time: 10 – 30 sec

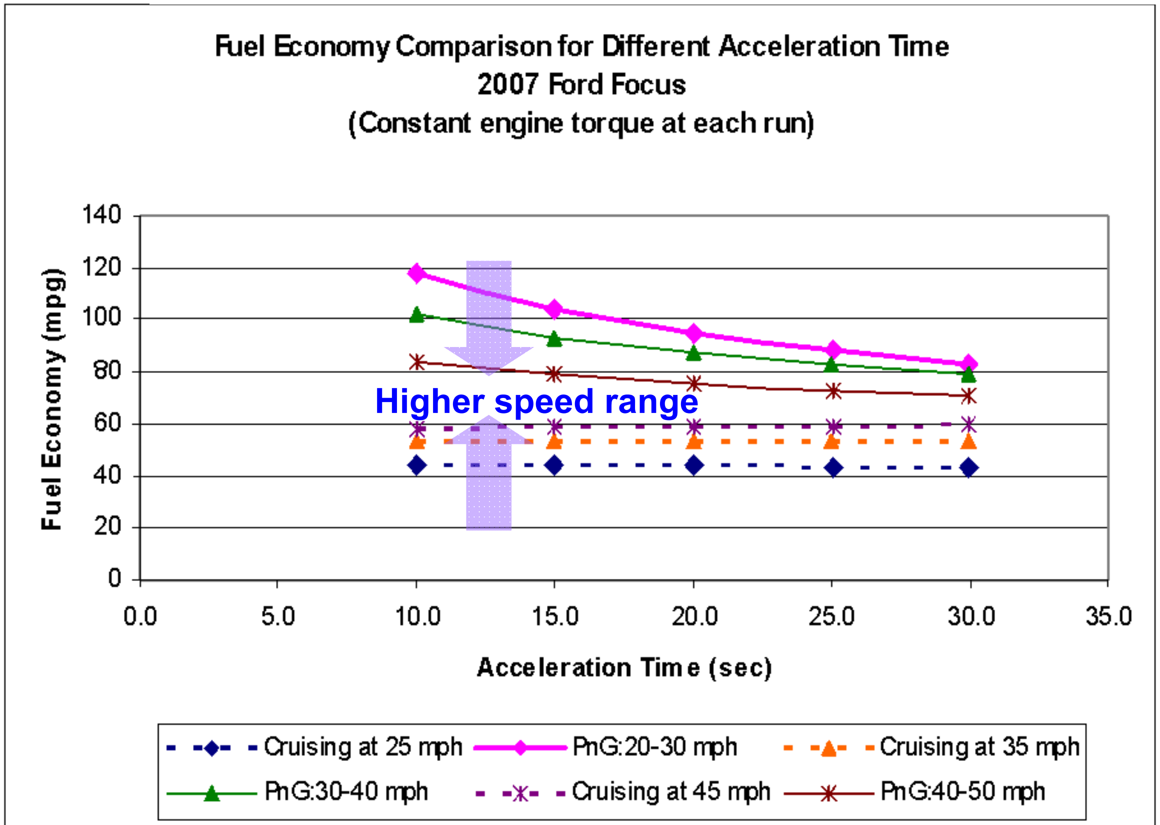


Speed Range: 20 – 50 mph



Speed Difference: 10 and 20 mph

2007 Ford Focus results from simple vehicle model



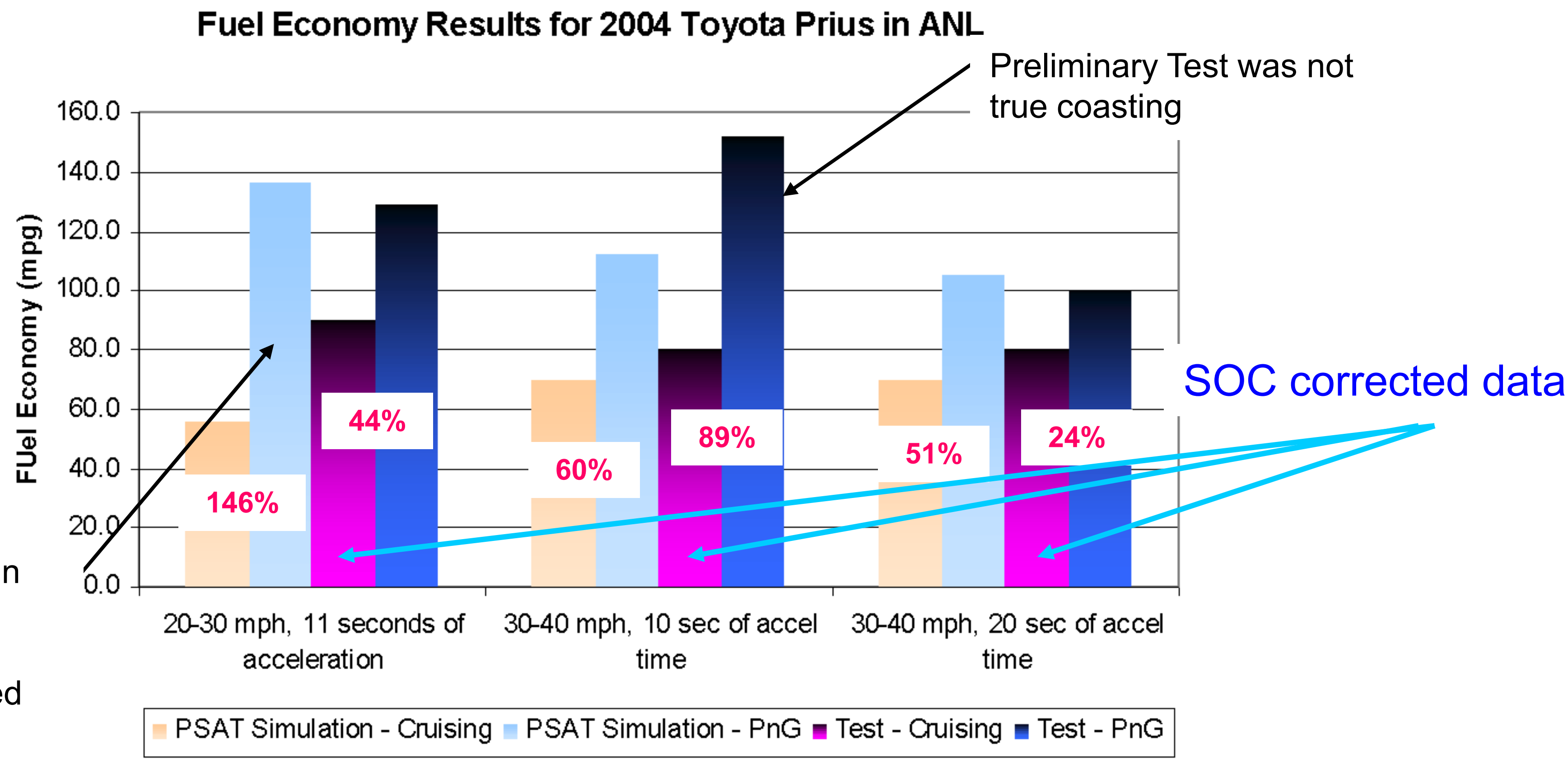
Shorter acceleration time
Lower speed range

Larger improvement of fuel economy than steady speed case

Conventional vehicle improved FE comes from engine load leveling, similar to HEV (expected)

2004 Toyota Prius

Fuel cut off during coasting



Electric only drive in the beginning is excluded so FE is lower than expected

Pulse and glide driving strategy shows potential of improving fuel economy through simulation and test results for both conventional and hybrid electric vehicles.

Why does this strategy show improvement in a hybrid vehicle that already has battery energy storage and engine load leveling control strategy?

Students that have received one or more semesters of GATE support for 2008-2009

Charles Smith: continuing Ph.D. on “Hydrogen storage on carbon nanotubes using quantum thermodynamics”.

Andrew van Dyke: continuing Ph.D. on water management in PEMFC, expected graduation 2012.

Jeongwoo Lee: continuing Ph.D on “Vehicle Inertia Impact on Fuel Consumption using Pulse
and Glide Driving Strategy”, expected graduation December 2009.

Josh Sole: completed PhD dissertation on, “Investigation of Water Transport Parameters and Processes in the Gas Diffusion Layer of PEM FuelCells”, June 2008.

Kurt Johnson: completed MS thesis on “A Plug-in Hybrid Electric Vehicle Loss Model to Compare Well-to-Wheel Energy Use From Multiple Sources, July 2008.

Chris Fox: completed MS thesis “Evaluation of Penetration Shorting in PEM Fuel Cells”, completed February 2009

Students recently hired in fuel cell and automotive fields 2008 – 2009

- Bryan Shevock (MS): GM, HEV integration, March 2008
- Kurt Johnson (MS): GM, HEV Controls, July 2008
- Yongquiang Li (Ph.D.): GM FCA, 2008

Additional information for accomplishments on tasks are provided after the summary:

- Task 2: Automotive Fuel Cell Research - Modeling
- Task 4: Dissemination - Theses and Dissertations
- Task 5: Industry Interaction 2008-2009
- Publications for 2008 - 2009

Activities Planned for 2009 - 2010

- Task 1 – Curriculum development
  - Continue to offer and update courses for fuel cell systems, hydrogen energy technologies, vehicle technologies
  - Refine laboratory experience in fuel cell courses
  - Develop doctoral level course in fuel cell materials and processes
- Task 2 - Engage students in research
  - Provide research opportunities for students
  - Continue 3 Ph.D. students:
    - Charles Smith
    - Jeongwoo Lee
    - Andrew van Dyke
- Task 3 – Recruit 1 or more students for GATE Fellowships
  - Jessica Wright (PhD)
- Task 4 – Dissemination and Scholarship
  - Publications, conferences, short courses
- Task 5 – Industry Interaction
  - Shared research projects, visits, graduating student hires, industrial advisory board

Summary: GATE Center for Automotive Fuel Cell Systems at Virginia Tech

- DoE objectives – Produce graduate degree engineers for industry with background in fuel cell, hydrogen and vehicle technologies research
- Approach – Develop courses and research projects to benefit students and industry needs
- Accomplishments – Courses, fellowships, projects, graduates, and publications
- Collaborations – Industry projects, student hires
- Plan for 2009 - 2010 – Progress on goals and tasks

Questions ?