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Evaluation of Hydrogen Storage System Characteristics for Light-Duty Vehicle Applications

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Objectives and Approach

Objectives

- Demonstrate an approach to evaluate hydrogen storage system characteristic trade-offs across several vehicle configurations
- Estimate the sensitivity of hydrogen storage system improvements on vehicle viability

Background

Hydrogen Storage Engineering Center of Excellence (HSECoE)

- Under Department of Energy (DOE) Fuel Cell Technologies Program within the Office of Energy Efficiency and Renewable Energy
- Complement the three materials-based hydrogen storage CoEs
- Research and develop onboard vehicular storage systems and components that will reach DOE targets while meeting vehicle related packaging, safety, cost and performance requirements

Approach

- Use an integrated system modeling approach by combining vehicle, cost and viability models to evaluate overall system performance
- Evaluate numerous vehicle combinations to take advantage of unique characteristics of individual storage systems

ADVISOR 2003 Advanced Vehicle Simulator

HSSIM

Hydrogen Storage SIMulator

Technical Targets

DOE Onboard Hydrogen Storage System Targets Considered

Storage Parameter	Units	2010	2015
System gravimetric capacity	kWh/kg	1.5	1.8
Storage system cost	$/kWh	TBD	TBD
Peak discharge rate	(g/s)/kW	0.02	0.02
Transient response (10% - 90%)	sec	0.75	0.75

Referenced previous 2015 target of $2/kWh for this analysis

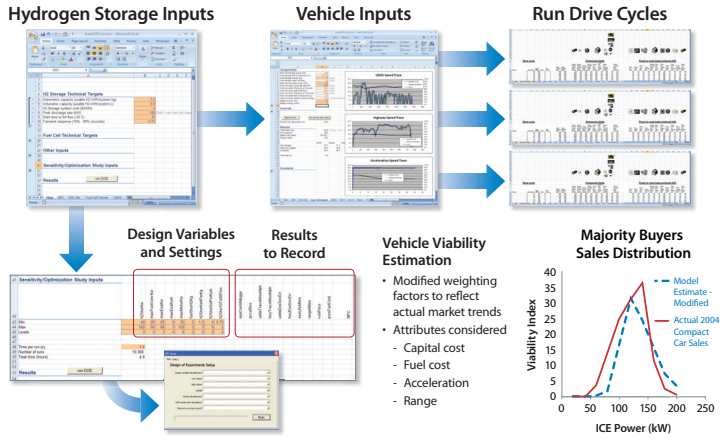
Source: www1.eere.energy.gov/hydrogenandfuelcells/storage/pdfs/targets_onboard_hydro_storage_explanation.pdf

Fuel Cell Power System Targets Considered:

Characteristic	Units	2005	2010	2015
Energy efficiency @ 25% of rated power	%	60	60	60
Energy efficiency @ rated power	%	50	50	50
Specific power	W/kg	500	650	650
Cost	$/kW	100	35	25
Transient response (10% - 90%)	sec	2	1	1

Source: www1.eere.energy.gov/vehiclesandfuels/resources/fcvt_plans_roadmaps.html

Model Framework



Experiment Design and Assumptions

Design of Experiments

Part 1: Target sensitivities for fixed component sizes

	Gravimetric Capacity (kWh/kg)	Transient Response (sec)	Cost ($/kWh)	Full Flow Rate (g/s)/kW
Minimum	0.5	1	$1.00	0.0025
Maximum	3.5	6	$12.00	0.025
Levels	7	6	12	10

Part 2: Target sensitivities capturing component sizing interactions

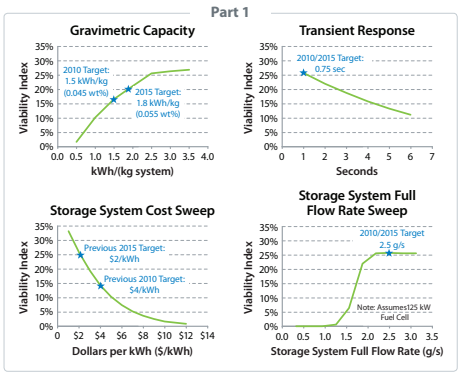
	Gravimetric Capacity (kWh/kg)	Fuel Cell Peak Power (kW)	Motor Peak Power (kW)	ESS Peak Power (kW)	ESS Energy (kWh)
Minimum	0.5	25	25	20	0
Maximum	5	175	200	80	3
Levels	10	4	8	7	4

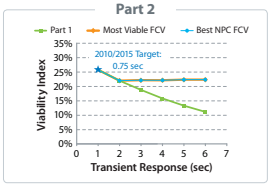
Assumptions

Attribute	Units	Conventional Vehicle[1]	Fuel Cell Vehicle
Fuel converter power	kW	126	125
Electric motor power	kW	-	100
Battery power	kW	-	-
Battery energy	kWh	-	-
Glider mass	kg	914	914
Frontal area	m^2	2.16	2.16
Coefficient of drag	-	0.28	0.28
Wheel radius	m	0.282	0.282
Tire rolling resistance	-	0.008	0.008
Fuel economy[2]	mpgge	25.9	49.9
Range	miles	479	304
0-60 mph time	sec	8.6	8.7
Capital cost[3]	$	19,395	27,419

[1] 2009 Toyota Camry
[2] EPA Combined based on post-2008 calculations
[3] Based on 2015 hydrogen storage and fuel cell cost targets as well as current high volume motor, power electronics and battery cost estimates

Results





"Part 1" Configuration

Power (kW)	Power (kW)	Energy (kWh)	Power (kW)
125	0	0	100

Fuel economy	(mpgge)	50
Range	(miles)	304
0-60 mph time	(sec)	8.7

"Most Viable FCV[1]" Configuration

Power (kW)	Power (kW)	Energy (kWh)	Power (kW)
25	80	1	100

Fuel economy	(mpgge)	55
Range	(miles)	337
0-60 mph time	(sec)	8.7

[1] Same as "Best NPC FCV configuration

Conclusions

- Estimated the sensitivity of hydrogen storage system improvements on vehicle viability
- Decreasing fuel cell power and increasing battery power can help preserve vehicle viability with slow transient response storage systems
- Using the "Most Viable" and "Best NPC" approaches provides similar results

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