

DOE Targets for On-Board Hydrogen Storage Systems for Light-Duty Vehicles
 Current R&D Focus is on 2015 Targets with Potential to Meet Ultimate Targets

Technical System Targets: On-Board Hydrogen Storage for Light-Duty Vehicles

Storage Parameter	Units	2010	2015	Ultimate
System Gravimetric Capacity: Usable, specific-energy from H ₂ (net useful energy/max system mass) ^a	kWh/kg (kg H ₂ /kg system)	1.5 (0.045)	1.8 (0.055)	2.5 (0.075)
System Volumetric Capacity: Usable energy density from H ₂ (net useful energy/max system volume)	kWh/L (kg H ₂ /L system)	0.9 (0.028)	1.3 (0.040)	2.3 (0.070)
Storage system cost ^b (& fuel cost) ^c	\$/kWh net (\$/kg H ₂) \$/gge at pump	4* (133) 2-3	2* (67) 2-3	TBD 2-3
Durability/Operability <ul style="list-style-type: none"> Operating ambient temperature^d Min/max delivery temperature Cycle life (1/4 tank to full)^e Cycle life variation^f Min delivery pressure from storage system; FC= fuel cell, ICE= internal combustion engine Max delivery pressure from storage system^g 	°C °C Cycles % of mean (min) at % confidence Atm (abs) Atm (abs)	-30/50 (sun) -40/85 1000 90/90 4FC/35 ICE 100	-40/60 (sun) -40/85 1500 99/90 3FC/35 ICE 100	-40/60 (sun) -40/85 1500 99/90 3FC/35 ICE 100
Charging/discharging Rates <ul style="list-style-type: none"> System fill time (for 5-kg H₂) Minimum full flow rate Start time to full flow (20°C)^h Start time to full flow (-20°C)^h Transient response 10%-90% and 90% -0%ⁱ 	min (Kg H ₂ /min) (g/s)/kW s s s	4.2 min (1.2 kg/min) 0.02 5 15 0.75	3.3 min (1.5 kg/min) 0.02 5 15 0.75	2.5 min (2.0 kg/min) 0.02 5 15 0.75
Fuel Purity (H ₂ from storage) ^j	% H ₂	99.99 (dry basis)		
Environmental Health & Safety <ul style="list-style-type: none"> Permeation & leakage^k Toxicity Safety Loss of useable H₂^l 	Scc/h - - (g/h)/kg H ₂ stored	Meets or exceeds applicable standards		
		0.1	0.05	0.05

*The storage system costs are currently under review and will be changed at a future date
 Useful constants: 0.2778kWh/MJ, ~33.3kWh/gal gasoline equivalent.

Note: Above targets are based on the lower heating value of hydrogen; targets are for a complete system, including tank, material, valves, regulators, piping, mounting brackets, insulation, added cooling capacity, and/or other balance-of-plant components. Unless otherwise indicated, all

targets are for both internal combustion engine and for fuel cell use, based on the low likelihood of power-plant specific fuel being commercially viable. Also note that while efficiency is not a specified target, systems must be energy efficient. For reversible systems, greater than 90% energy efficiency for the energy delivered to the power plant from the on-board storage system is required. For systems generated off-board, the energy content of the hydrogen delivered to the automotive power plant should be greater than 60% of the total energy input to the process, including the input energy of hydrogen and any other fuel streams for generating process heat and electrical energy.

Footnotes to Table 1

- ^a Generally the 'full' mass (including hydrogen) is used, for systems that gain weight, the highest mass during discharge is used.
- ^b 2003 US\$; total cost includes any component replacement if needed over 15 years or 150,000 mile life.
- ^c 2005 US\$; includes off-board costs such as liquefaction, compression, regeneration, etc; 2015 target based on H₂ production cost of \$2 to \$3/gasoline gallon equivalent untaxed, independent of production pathway.
- ^d Stated ambient temperature plus full solar load. No allowable performance degradation from -20C to 40C. Allowable degradation outside these limits is TBD.
- ^e Equivalent to 200,000; 300,000; and 300,000 miles respectively (current gasoline tank spec).
- ^f All targets must be achieved at end of life.
- ^g For delivery *to* the storage system, in the near term, the forecourt should be capable of delivering 10,000 psi (700 bar) compressed hydrogen, liquid hydrogen, or chilled hydrogen (35 to 77K) and up to 5,000 psi (350 bar). In the long term, it is anticipated that delivery pressures will be reduced to between 50 and 150 atm for solid state storage systems, based on today's knowledge of sodium alanates.
- ^h Flow must initiate within 25% of target time.
- ⁱ At operating temperature.
- ^j The storage system will not provide any purification, but will receive incoming hydrogen at the purity levels required for the fuel cell. For fuel cell systems, purity meets SAE J2719, Information Report on the Development of a Hydrogen Quality Guideline in Fuel Cell Vehicles. Examples include: total non-particulates, 100 ppm; H₂O, 5 ppm; total hydrocarbons (C₁ basis), 2 ppm; O₂, 5 ppm; He, N₂, Ar combined, 100 ppm; CO₂, 1 ppm; CO, 0.2 ppm; total S, 0.004 ppm; formaldehyde (HCHO), 0.01 ppm; formic acid (HCOOH), 0.2 ppm; NH₃, 0.1 ppm; total halogenates, 0.05 ppm; maximum particle size, <10 μm, particulate concentration, <1μg/L H₂. These are subject to change. See Appendix on Hydrogen Quality in the DOE EERE Hydrogen Fuel Cells and Infrastructure Technologies Program Multiyear Research, Development and Demonstration Plan (www.eere.energy.gov/hydrogenandfuelcells/mypp/) to be updated as fuel purity analyses progress. Note that some storage technologies may produce contaminants for which effects are unknown; these will be addressed as more information becomes available.
- ^k Total hydrogen lost into the environment as H₂; relates to hydrogen accumulation in enclosed spaces. Storage system must comply with CSA/HGV2 standards for vehicular tanks. This includes any coating or enclosure that incorporates the envelope of the storage system.
- ^l Total hydrogen lost from the storage system, including leaked or vented hydrogen; relates to loss of range.