Hydrogen Storage System Challenges

Advanced Composite Materials for Cold and Cryogenic Hydrogen Storage Applications in Fuel Cell Electric Vehicles

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THE FUTURE IS NOW ....

Production fuel cell vehicles are being produced or planned by every major automotive OEM

Toyota

Hyundai

Honda

Ford
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Why are we interested?

Key Importance Factors:

Alternative Fuel Vehicles

Energy Security: Alternative fuels offer renewable and domestic sources that reduce our offshore energy demands.

Environment: Alternative fuels can reduce the greenhouse gases, local air quality, and other smog-causing pollutants.

Cost of Ownership: Alternative fuels offer the opportunity for the use of low cost fuels and/or high efficient powertrains.

Zero Emission Vehicles

Environment: Zero emission vehicles offer the ultimate choice for reducing CO_2/mile and local air pollution on the road.

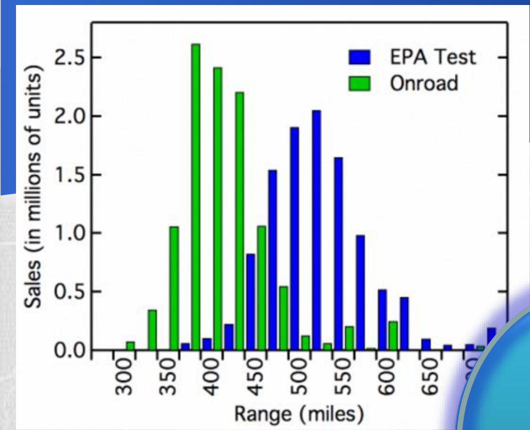
Regulatory: California Air Resources Board ZEV program requires OEMs to have ZEV credits to allow for vehicle sales in CA.

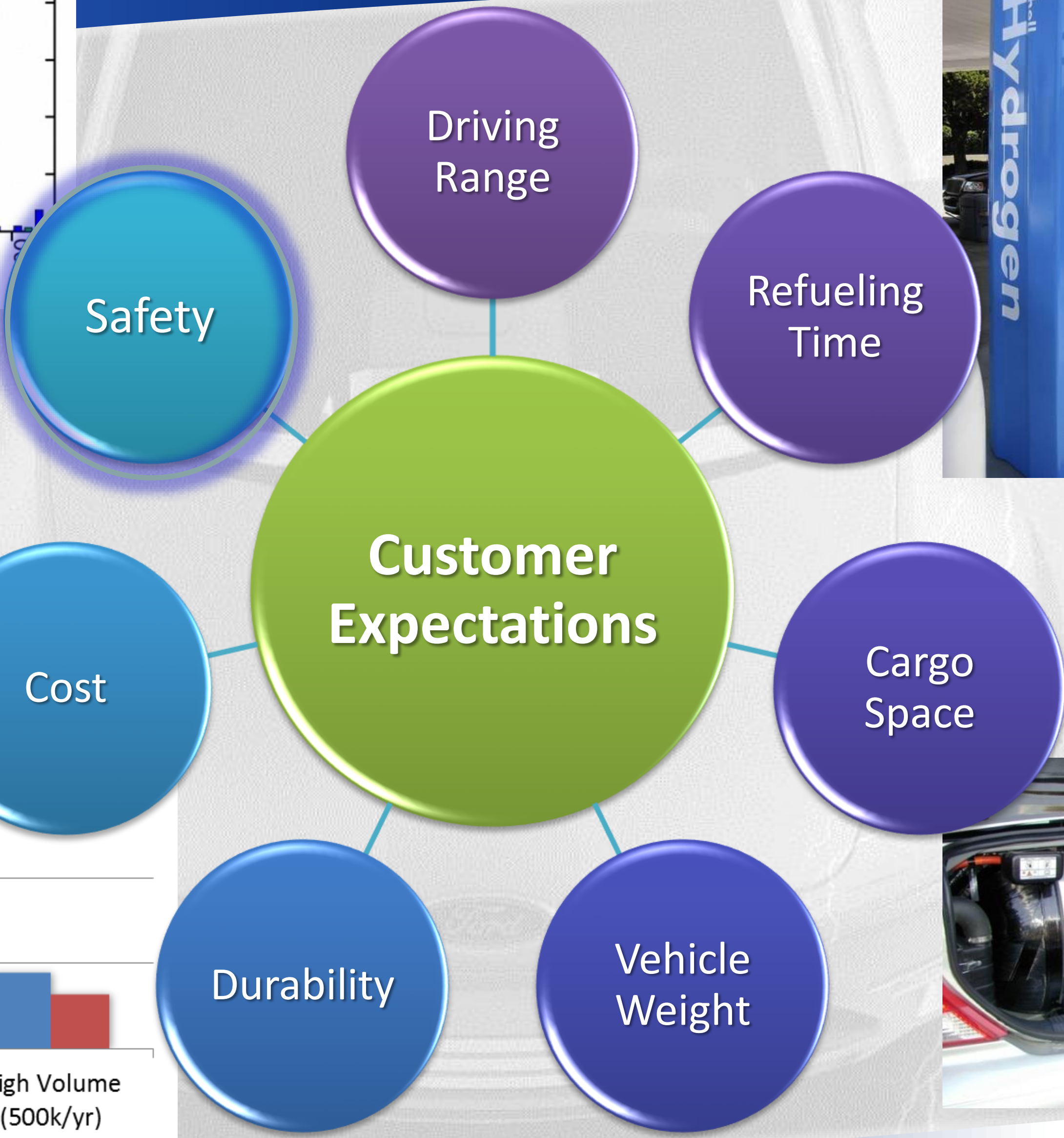
Fuel Cell H_2

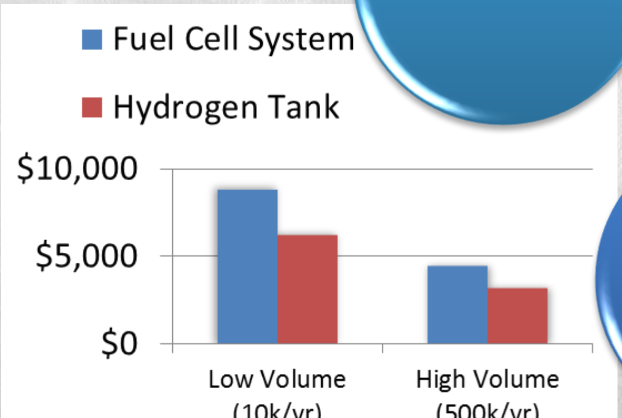
Driving Range: Fuel cell vehicles provide driving range 2 to 3x greater than typical BEVs and near conventional gasoline vehicles.

Fueling Time: Fuel cell vehicles provide fueling times in 3 to 5 minutes similar to conventional gasoline vehicles rather than hours for BEVs.

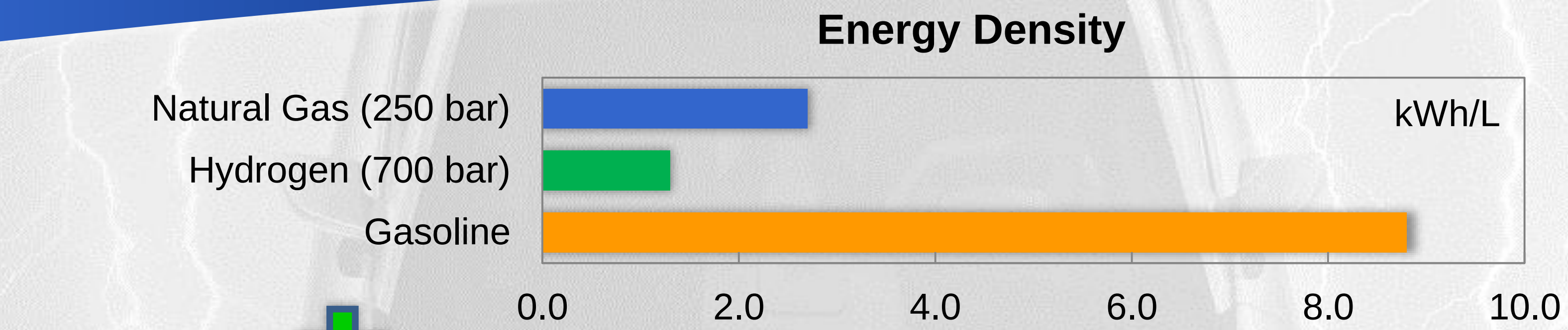
meeting customer expectations

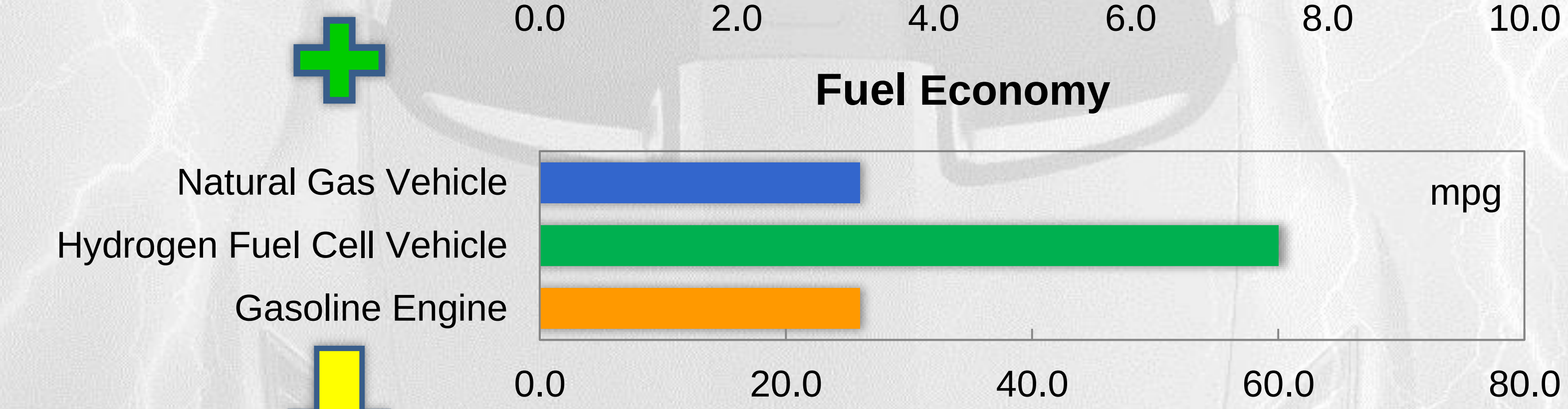


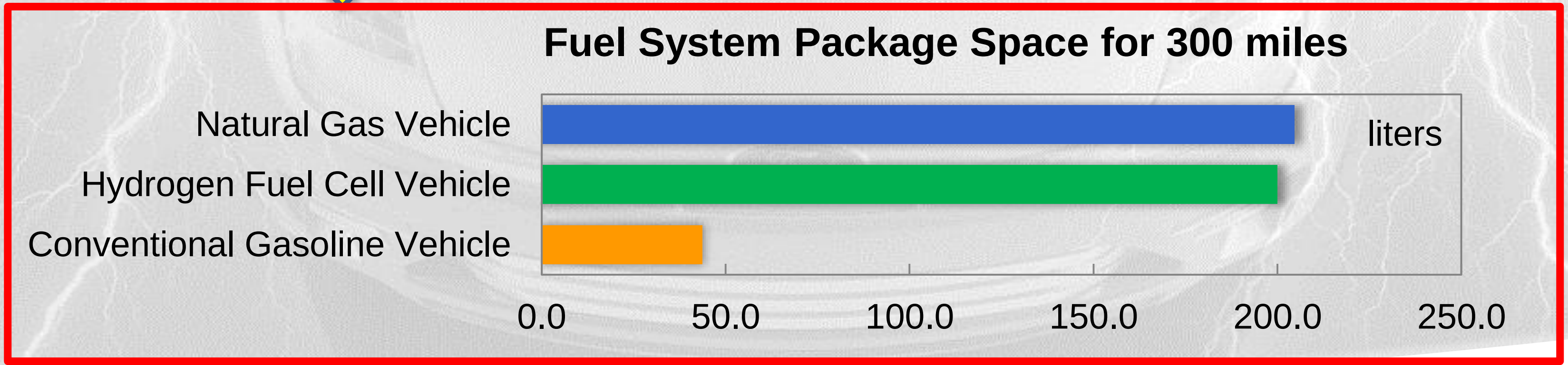




(credit: SA / ANL)


Energy Density
Natural Gas (250 bar)
Hydrogen (700 bar)
Gasoline
kWh/L
0.0
2.0
4.0
6.0
8.0
10.0


Fuel Economy
Natural Gas Vehicle
Hydrogen Fuel Cell Vehicle
Gasoline Engine
mpg
0.0
20.0
40.0
60.0
80.0


Fuel System Package Space for 300 miles
Natural Gas Vehicle
Hydrogen Fuel Cell Vehicle
Conventional Gasoline Vehicle
liters
0.0
50.0
100.0
150.0
200.0
250.0

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Technical System Targets: Onboard Hydrogen Storage for Light-Duty Fuel Cell Vehicles [a] (updated January 2015)			
Storage Parameter	**Units**	**2020**	**Ultimate**
System Gravimetric Capacity: Usable, specific-energy from H_2 (net useful energy/max system mass) [b]	kWh/kg ($kg\ H_2$/kg system)	1.8 (0.055)	2.5 (0.075)
System Volumetric Capacity: Usable energy density from H_2 (net useful energy/max system volume) [b]	kWh/L ($kg\ H_2$/L system)	1.3 (0.040)	2.3 (0.070)
Storage System Cost :	\$/kWh net (\$/kg H_2)	10 400	8 266
• Fuel cost [c]	\$/gge at pump	2-4	2-4
Durability / Operability:			
• Operating ambient temperature [d]	°C	-40/60 (sun)	-40/60 (sun)
• Min/max delivery temperature	°C	-40/85	-40/85
• Operational cycle life (1/4 tank to full)	Cycles	1500	1500
• Min delivery pressure from storage system	bar (abs)	5	5
• Max delivery pressure from storage system	bar (abs)	12	12
• Onboard Efficiency [e]	%	90	90
• "Well" to Powerplant Efficiency [e]	%	60	60
Charging / Discharging Rates:			
• System fill time (5 kg)	min ($kg\ H_2$/min)	3.3 (1.5)	2.5 (2.0)
• Minimum full flow rate	(g/s)/kW	0.02	0.02
• Start time to full flow (20°C)	s	5	5
• Start time to full flow (-20°C)	s	15	15
• Transient response at operating temperature 10%–90% and 90%–0%	s	0.75	0.75
Fuel Quality (H_2 from storage) [f]:	% H_2	SAE J2719 and ISO/PDTS 14687-2 (99.97% dry basis)	
Environmental Health & Safety:		Meets or exceeds applicable standards	
• Permeation & leakage [g]	-		
• Toxicity	-		
• Safety	-		
Loss of useable H_2 [h]	(g/h)/kg H_2 stored	0.05	0.05

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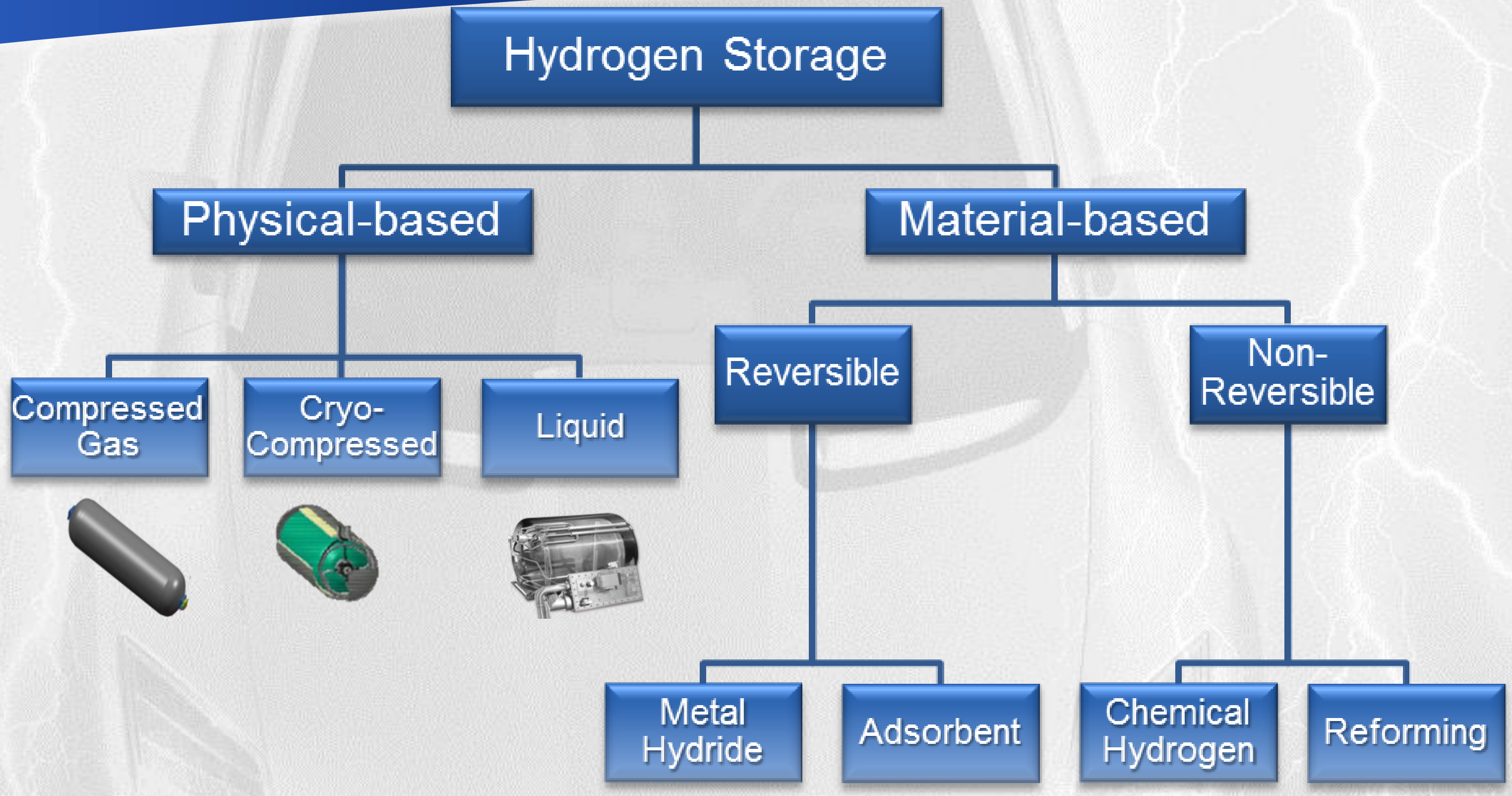


DOE Target	2020	Ultimate
System Gravimetric Density	5.5% (1.8 kWh/kg)	7.5% (2.5 kWh/kg)
System Volumetric Density	40 g/l (1.3 kWh/l)	70 g/l (2.3 kWh/l)
Storage System Cost	$333/kg ($10/kWh)	$266/kg ($8/kWh)

Material-based hydrogen storage systems have higher potential to meet the DOE targets but have increased complexity over physical-based storage options

700 bar compressed tanks can meet the DOE targets except:
cost, volumetric capacity, and weight

OPTIONS

Material Selection

Reduce material cost

Increase performance

Tank Design and Manufacturing

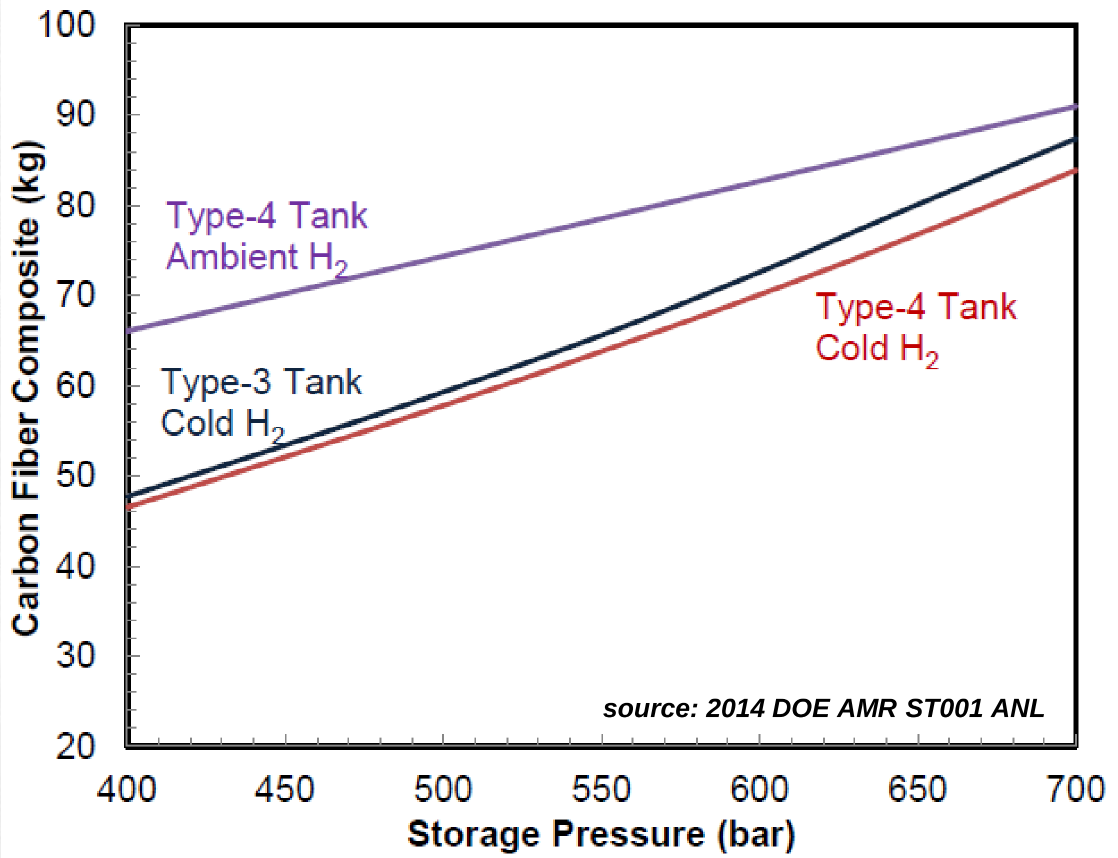
Better material use

Improve efficiency

Operating Conditions

Reduce pressure

Increase density


Carbon Fiber Composite (kg)
100
90
80
70
60
50
40
30
20
400
450
500
550
600
650
700
Storage Pressure (bar)
Type-4 Tank
Ambient H_2
Type-3 Tank
Cold H_2
Type-4 Tank
Cold H_2
source: 2014 DOE AMR ST001 ANL


Reduction in
wall thickness
with pressure

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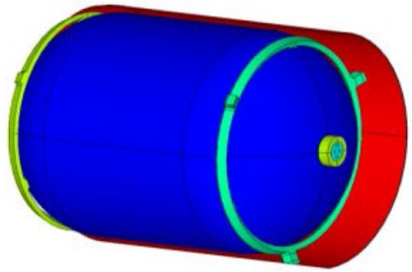
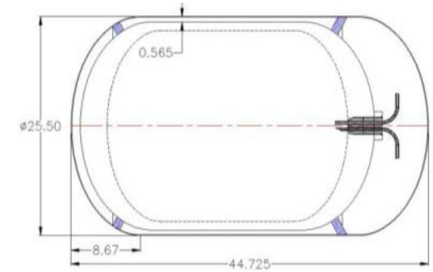
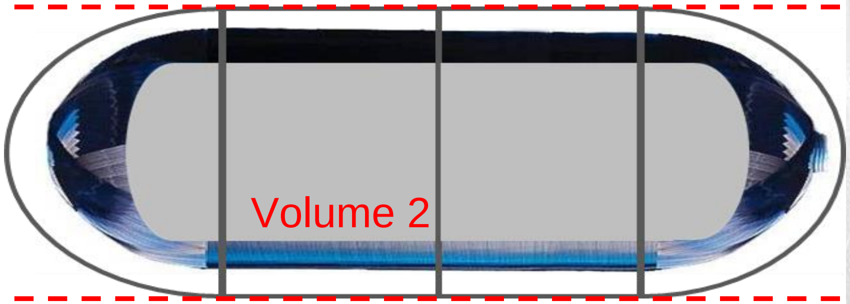
Credit: LLNL





Compressed Hydrogen Tank

Cold Gas Hydrogen Tank



Thermal insulation needs to maintain 5-7 W maximum heat leakage performance over 15 years with minimal additional weight, volume and cost to the storage system.

- ***Degradation of insulation results in lose of fuel and inconsistent fueling.***

Great Products
Strong Business
Better World

THANK YOU

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