Physical Hydrogen Storage

Physical storage is the most mature hydrogen storage technology. The current near-term technology for onboard automotive physical hydrogen storage is 350 and 700 bar (5,000 and 10,000 psi) nominal working-pressure compressed gas vessels—that is, "tanks."

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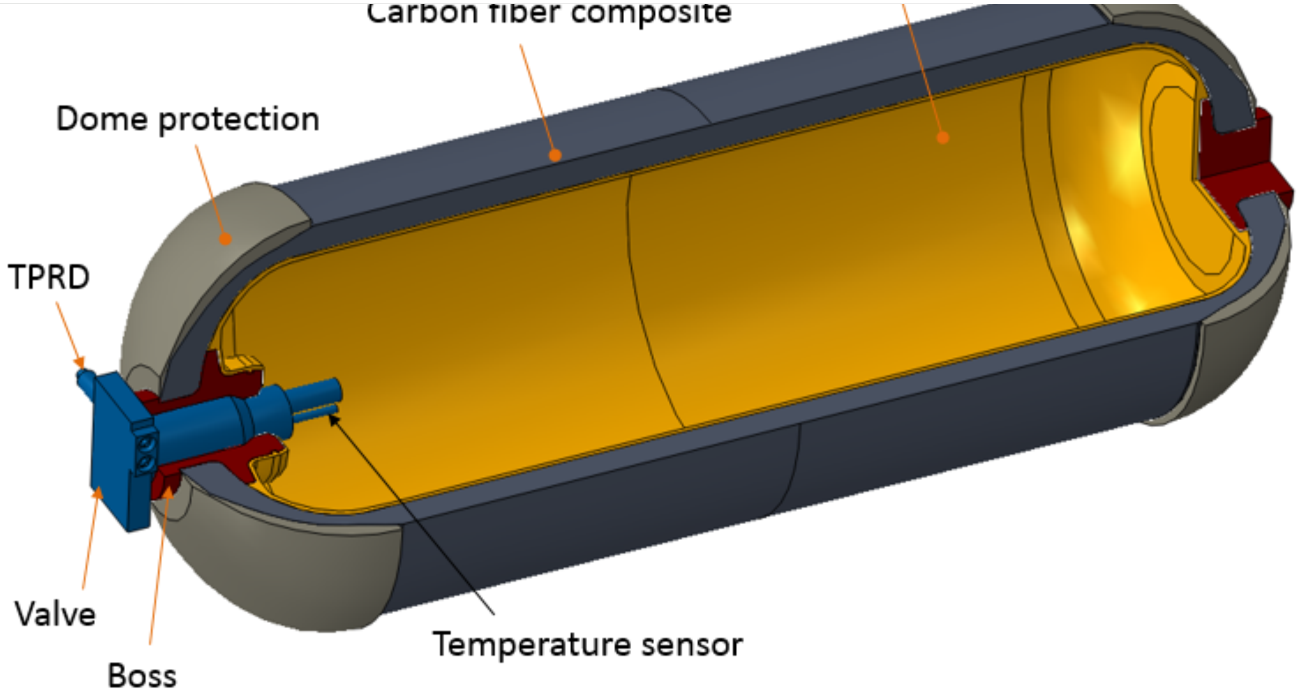

TPRD = Thermally Activated Pressure Relief Device
Credit: Process Modeling Group, Nuclear Engineering Division. Argonne National Laboratory (ANL)

Components of a pressurized hydrogen storage tank.

While low-pressure liquid hydrogen, near the normal boiling point of 20 K, is routinely used for bulk hydrogen storage and transport, there is currently little activity in developing it for onboard automotive use. While compressed hydrogen typically is stored at near-ambient temperatures, "cold" (sub-ambient but greater than 150 K) and "cryogenic" (150 K and below) compressed hydrogen storage are being investigated due to the higher hydrogen densities that can be achieved at reduced temperatures.

TECHNICAL TARGETS AND STATUS

Compressed hydrogen storage systems have been demonstrated in hundreds of prototype fuel cell vehicles and are available commercially at low production volumes. While physical storage has not yet met all of the U.S. Department of Energy (DOE) targets for onboard automotive storage, many targets have been achieved with only a few key areas requiring further improvement, including gravimetric density,

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of compressed hydrogen storage systems.

Status and Targets for Gravimetric Density, Volumetric Density, and Cost —

Projected Performance and Cost of Compressed Automotive Hydrogen Storage Systems Compared to 2020 and Ultimate DOE Targets[a]

Storage System Targets	**Gravimetric Density** kWh/kg system (kg H_2/kg system)	**Volumetric Density** kWh/L system (kg H_2/L system)	**Cost** \$/kWh (\$/kg H_2)
2020	1.5 (0.045)	1.0 (0.030)	\$10 (\$333)
Ultimate	2.2 (0.065)	1.7 (0.050)	\$8 (\$266)
Current Status (from Argonne National Laboratory)	**Gravimetric Density** kWh/kg system (kg H_2/kg system)	**Volumetric Density** kWh/L system (kg H_2/L system)	**Cost[b]** \$/kWh (\$/kg H_2)
700 bar compressed (Type IV, single tank)	1.4 (0.042)	0.8 (0.024)	\$15[c] (\$500)

[a] Assumes a storage capacity of 5.6 kg of usable hydrogen.
[b] Cost projections are estimated at 500,000 units per year and are reported in 2007\$.
[c] Cost projection from Strategic Analysis (November 2015).

Performance Against All DOE 2020 Onboard Vehicle Storage Targets —

This system projections graph conveniently shows how a conventional 700 bar Type IV compressed hydrogen storage system at 300 K compares against all of DOE's 2020 onboard vehicle storage targets. The blue space indicates current performance and the white space indicates the areas in which 700 bar compressed systems currently fall short of DOE's 2020 targets.

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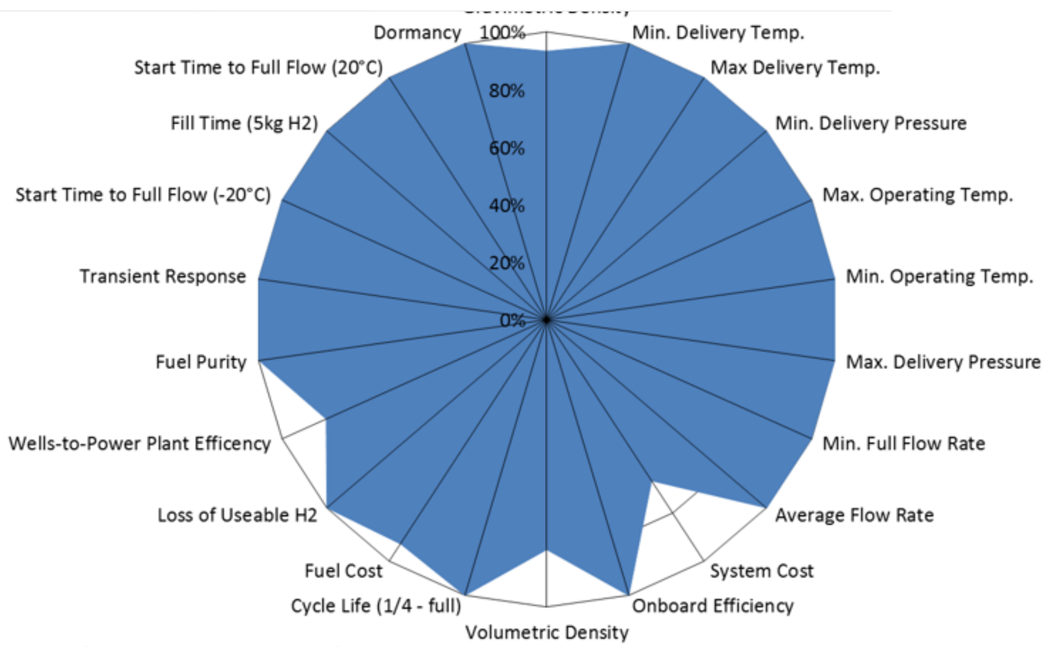

Note: Based on DOE FCTO Program Record 15013
Assumes 5.6 kg usable H_2
Fuel cost and well-to-power efficiency assume SMR delivered and dispensed

Distribution of 350 bar and 700 bar Compressed Hydrogen System Costs —

The cost of current compressed gas systems for automotive applications is dominated by the carbon fiber composite with a significant impact from balance of plant (BOP) components. Current physical storage research and development efforts focus on reducing the cost of the fiber reinforced composite portion of the pressure vessel to help meet DOE targets. These pie charts show cost distributions for 350 bar and 700 bar Type IV single-tank compressed hydrogen systems at 500,000 units. See DOE Fuel Cell Technologies Office Record 15013.

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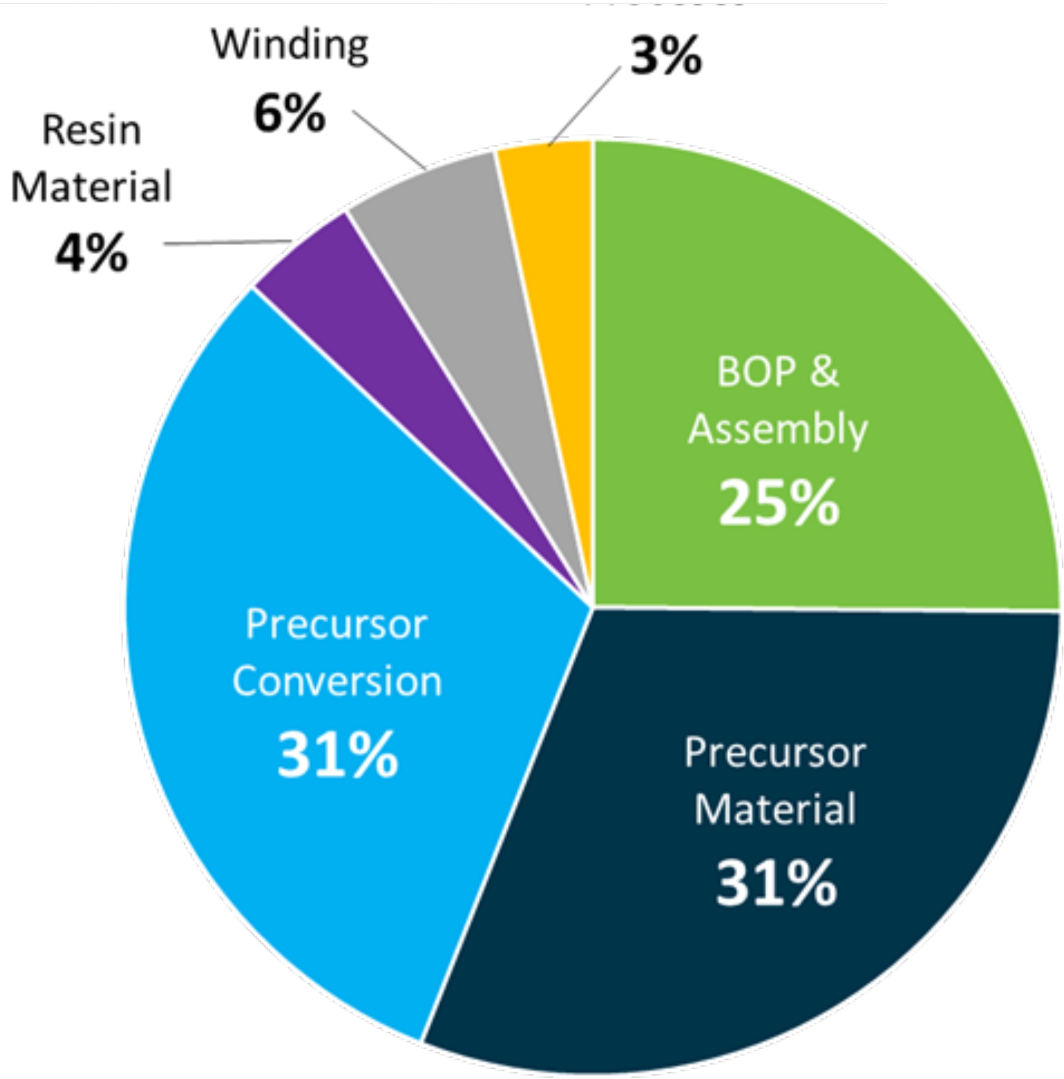

700-bar compressed hydrogen storage system cost breakout (single tank system) from 2015 DOE FCTO Record #15013.

System Cost Based On Production Volume

The Fuel Cell Technologies Office also has conducted analysis to determine the cost for the low volumes that are expected during the initial ramp up of fuel cell electric vehicles. These bar charts show how the estimated system costs vary based on

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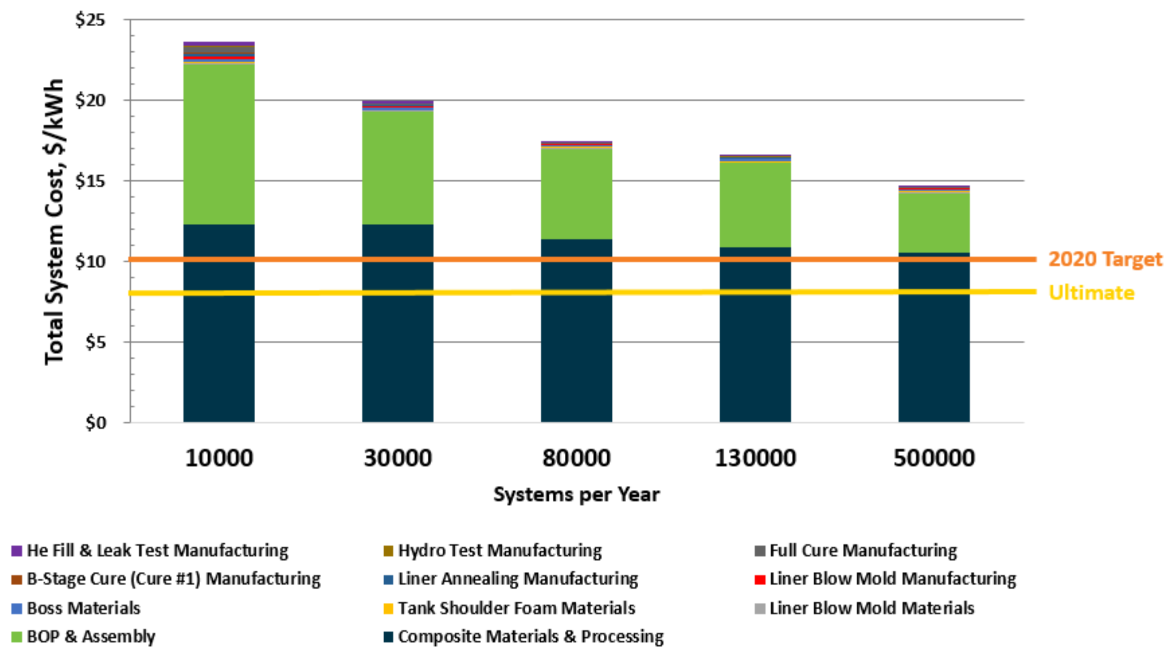

700-bar compressed hydrogen storage system cost breakout by volume from 2015 DOE FCTO Record #15013.

Pathways to Reduce Cost

Finally, DOE has determined potential pathways to reduce the cost of compressed tanks. This includes reducing the cost of carbon fiber composites and/or developing lower cost alternative fiber reinforced composites, better utilizing and therefore reducing the amount the fiber reinforcement included in the tank, and reducing the amount and cost of balance of plant components. This chart shows one potential cost reduction strategy for 700 bar compressed systems.

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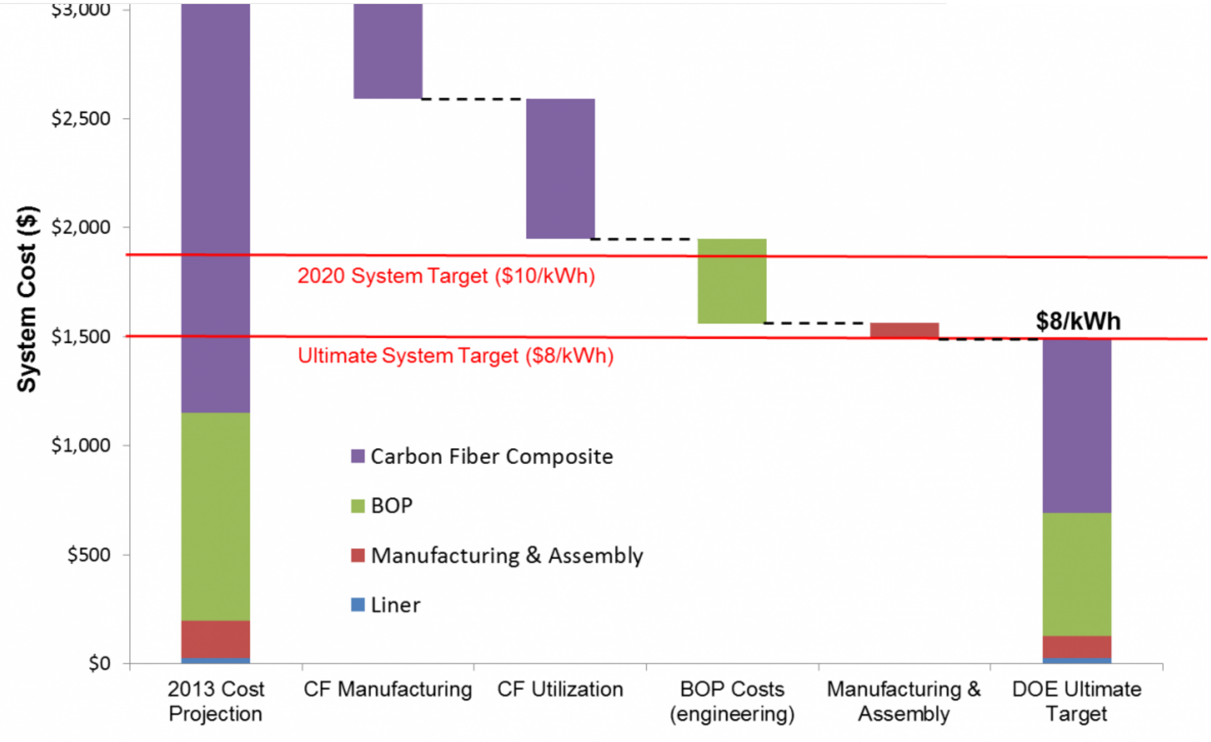

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