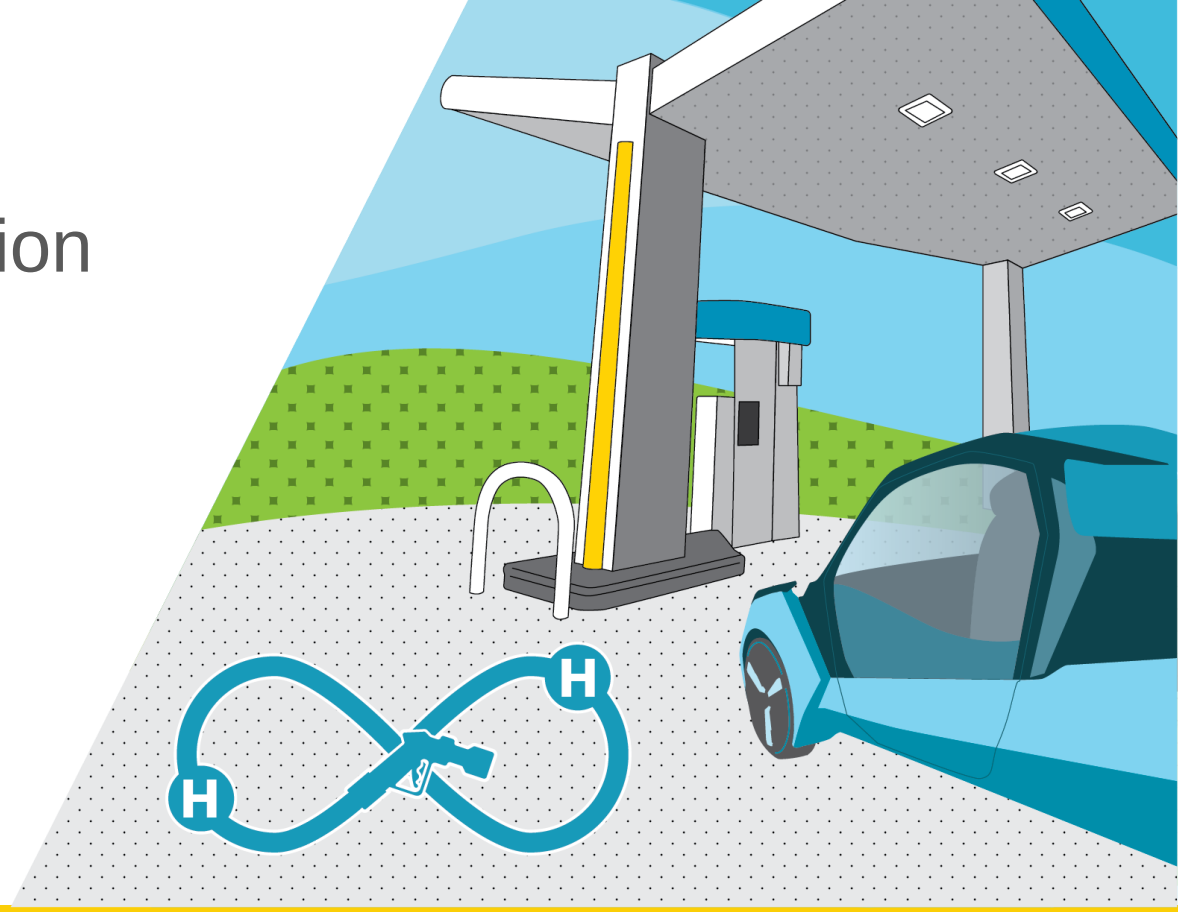
Shell Hydrogen Refueling Station Cost Reduction Roadmap



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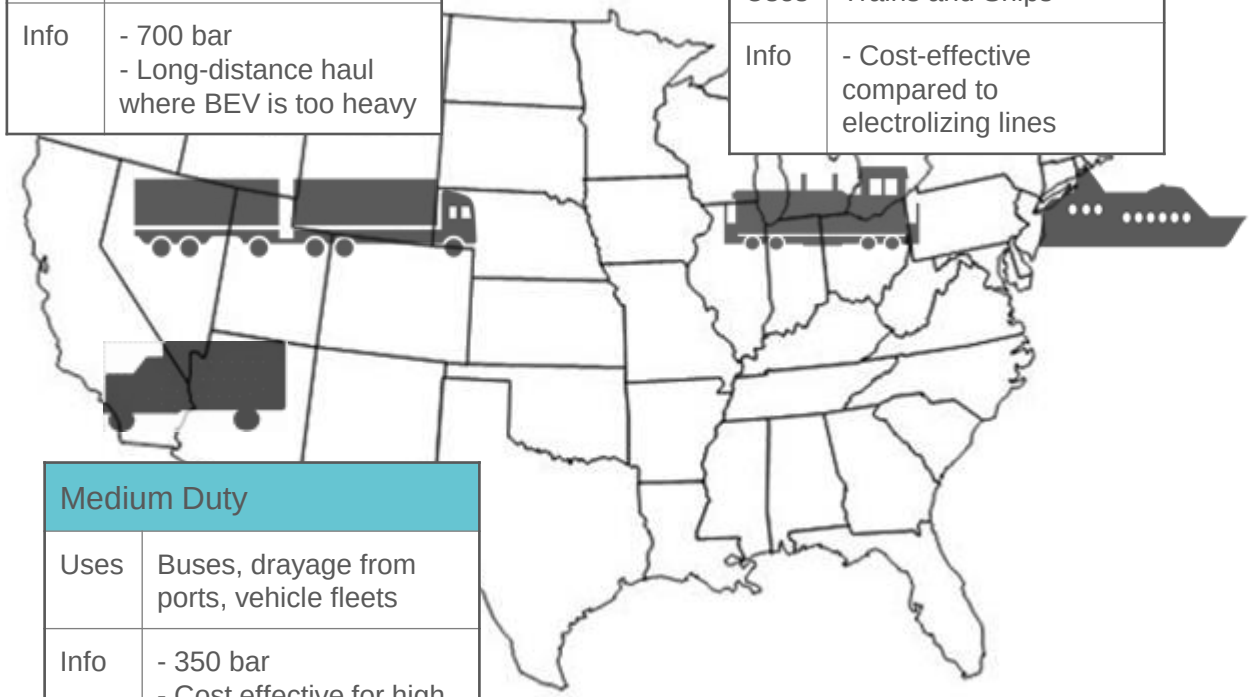
Shell Light Duty and Heavy Duty cost progression

Extracted Cost Savings		
	LD Station	**HD Station**
Total Vehicles	>100,000	>10,000
KG H_2/vehicle	4-10	35-100
<u>Delivered H2</u>	Higher volume of daily use yields **production savings** and **distribution efficiencies**	
KG/day	400	2000-4000
Tech Deployed		Liquifaction and Onsite SMR ***decreases delivery cost***
HRS Equipment and Tax	At-scale production of heavy equipment and cost learning	
		Liquifaction or on-site SMR ***slightly increases cost***
Construction	Cost learning & equipment efficiencies	
		Out-of-city construction **saves costs**

HD Cost Reduction Roadmap: Medium Duty and Heavy Duty

Heavy Duty	
Uses	Long haul transport
Info	- 700 bar - Long-distance haul where BEV is too heavy

Very Heavy Duty	
Uses	Trains and Ships
Info	- Cost-effective compared to electrolizing lines

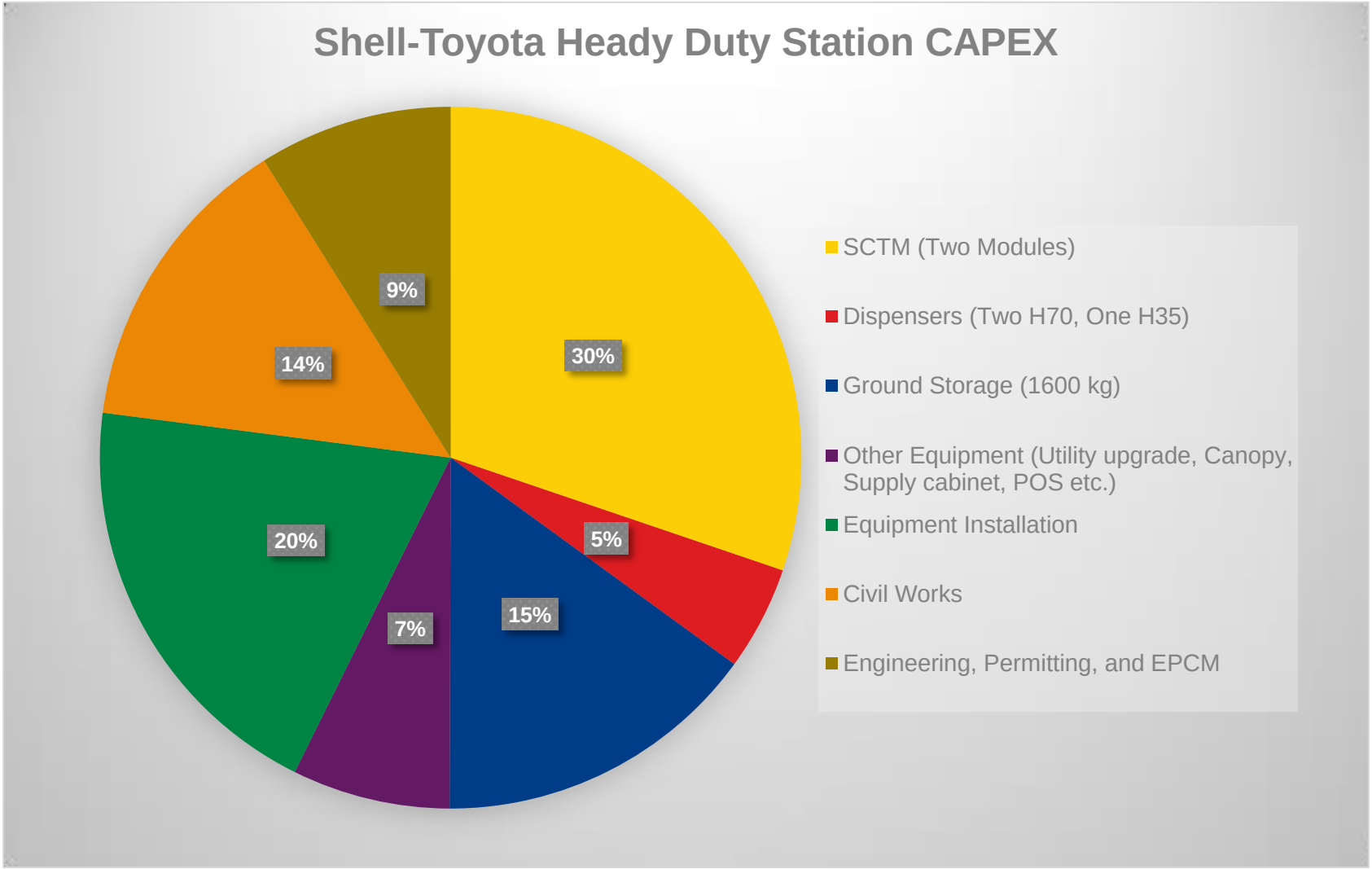


Medium Duty	
Uses	Buses, drayage from ports, vehicle fleets
Info	- 350 bar - Cost effective for high duty-cycle vehicles

Distribution Technology Progression		
Tech	**Use Case**	**Technical Requirement**
Efficient On-Site SMR	- 5 tons daily Steam Methane Reformation on or near site - Extremely low distribution costs	- High volume of purchase at heavy-duty stations
H_2 Liquifaction	- Transporting and distributing hydrogen over long distances - **Cost reductions** in distribution, but **cost increases** in production	- Cryogenic pumps at refueling stations to pressurize and gasify H2 - Robotic refueling and onboard LH2 use for heavy duty
H_2 Pipeline transport system	- Large scale transport of hydrogen 2+ decades from now - Distribution costs go from dollars per kg to cents per kg	- Kilotons per day usage in cities across the country required for effective capital efficiency

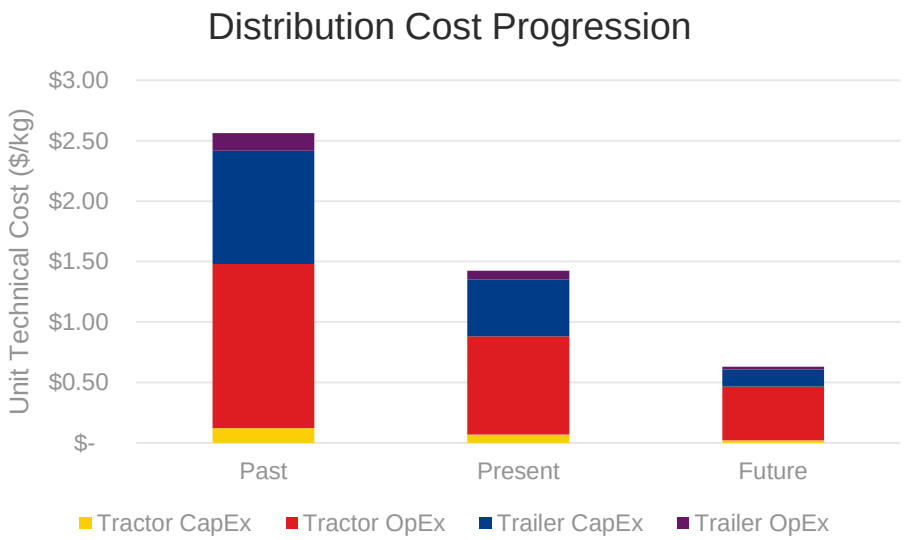
Potential Future Cost Reduction Technologies		
Tech	**Use Case**	**Technical Requirement**
Solid Oxide Fuel Cells	- Potentially higher efficiencies - Ability to deal with lower quality fuel	- Technology is very far from deployment
Liquid Hydrogen Fuel Carriers	- Potential distribution cost reductions - Potential uses in HD refueling	- Efficient use requires on-board heating and H_2 extraction

First Generation Heavy Duty Cost Breakdown



First-Gen HD Refueling: Major Cost Drivers	
SCTM	*Storage, compression, and thermal management* On-site H2 production requires compression from 30 bar to 700 bar requires several stages of compression 700 bar compressor technology is still young, the markets for these compressors is still small, and the products are thus not mass-produced and are expensive
Construction, Permitting, Installation	California is more expensive to permit and construct in than most states or countries This is a first-build refueling station with requirements to support two upcoming stages of technology change Cost-learning, standardized protocols and construction, and building in other parts of the country will drastically reduce cost by shrinking line items representing ~70% of current costs

Hydrogen Distribution Progression and LH_2 vs. GH_2



Trailer Capacity (kg)	600	→	1200
Trailer Pressure (Bar)	450	→	517

Increasing demand raises numbers of stations and utilization rate

This yields increasing network efficiency

Liquid H_2 Transport and Refueling

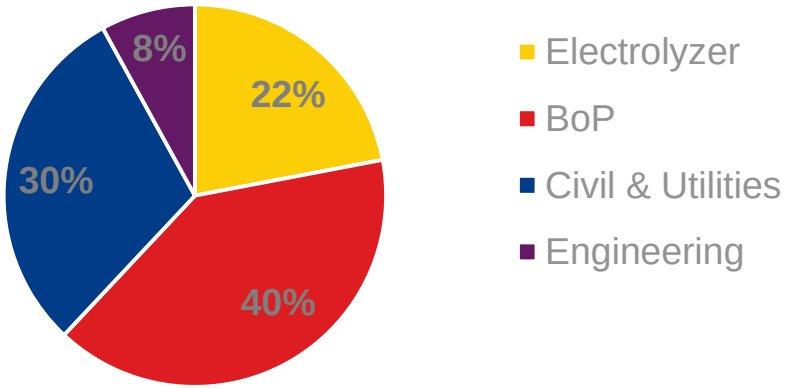
Capital and Risk Intensive	:	Economies of scale at massive size require build-out that is out-of-phase with demand Difficult to economically supply small-scale systems
Station Tech and Protocol Issues	:	Current stand-off distance requirements create issues for liquid HRS (NFPA2) In the absense of on-board LH_2 use, current dispensers and compressors are *cost prohibilitive* and have *short uptime between required maintenance*
Opportunities as Technology Progresses	:	Distribution costs relative to GH_2 become attractive with larger volume stations (est. >1T per day) or longer distribution lines (est. >250m radius) Very likely to be the solution to future shipping opportunities, especially cruise liners

Gaseous H_2 Transport

Flexible Stations	:	Enables very low-cost 35MPa medium duty and heavy duty refueling Allows for use of both small and large distribution options as demand shifts and grows
Technology Requirements	:	Requires high capacity (1000kg+) and low cost (<$1000/kg) transportation and storage

Renewable H_2 Production and Requirements for Success

Present Electrolyzer CapEx Cost Stack



Path to Diesel-Competitive Renewable Electrolyzer H_2

Cost Reduction	:	Current costs of over $1MM / MW capacity for electrolyzers need to be at least halved Electricity costs are the major driver of electrolyzer H_2 costs, requiring $0.04 per kwh at half the current CapEx to break-even with On-Highway diesel prices in the Midwest
Utilization Rate	:	CapEx efficiencies can only be realized at near-full utilization rates, requiring high-capacity factor renewables or massive over-sizing of variable renewable resources

Steam Methane Reformation (SMR) is the current workhorse of hydrogen production

While SMR provides the easiest path to cost-competitive H_2, the energy intensity of the process and leaks in the natural gas production and transport can result in greenhouse gas emissions on par with diesel vehicles.

Path to Green SMR-produced H_2

Capital Efficiency	:	SMR is a very mature technology, and is capital-efficient New efficient SMR designs in sized from 100-20,000 kg/day are capable of producing H_2 from low-cost natural gas feedstock
Efficient Trading Structures	:	SMR H_2 production on-site of biogas production locations will likely not yield production and distribution efficiencies of SMR from a natural gas pipeline. *→ Efficient and traceable RIN trading is thus a likely pre-prequisite of large-scale green SMR in the near term*

Shell Global Hydrogen – a Growing Presence in the US

Shell Global Hydrogen Projects and Expansions		
Station Type	**Description**	**Learnings and Challenges**
Torrance	Our first-generation hydrogen refueling stations is one of the longest operating Hydrogen Refueling Stations in California	- High maintenance costs and early-stage technology decrease reliability - Understanding of technology needs led to better current-gen stations
Northern California	Shell Hydrogen is building and branding seven current-generation stations in Northen California with major reliability improvements	Current generation of technology, better use of reliable and low-cost distribution systems, and efficient use of redundancy will result in ***reduced costs*** and ***increased reliability***
Next Generation California Expansion	Shell Hydrogen has leveraged large-scale opportunities to improve performance across the entire value chain	- We have worked with partners to procure and engineer the next-generation systems and components to reduce cost and increase reliability - Our next generation refueling stations have a contractual pathway to ***decrease CapEx***, ***increase uptime*** and ***decrease maintenance costs***
Heavy Duty Refueling Stations	We are working with Toyota and California to develop three heavy-duty refueling stations	- Shell and others are developing demonstration heavy-duty refueling stations in stages - The progressive stages will increase station refueling capacity, truck refueling speed, and number of heavy duty stations - These stations will help inform heavy duty refueling protocols
Dealer Value Proposition	Shell Global Hydrogen is using our learnings from our stations to strategically license our technology	- Shell has created an offering to work with partners to strategically expand consumer access to hydrogen in markets outside of our core strengths - Partners can license our latest-generation technology and brand reliability to be leaders in their markets ***while expanding consumer access to hydrogen***