



and  
H<sub>2</sub> Refuel H-Prize Competition  
Experience

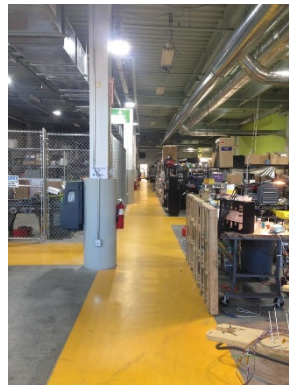
## Ivys' Role in the Hydrogen Industry

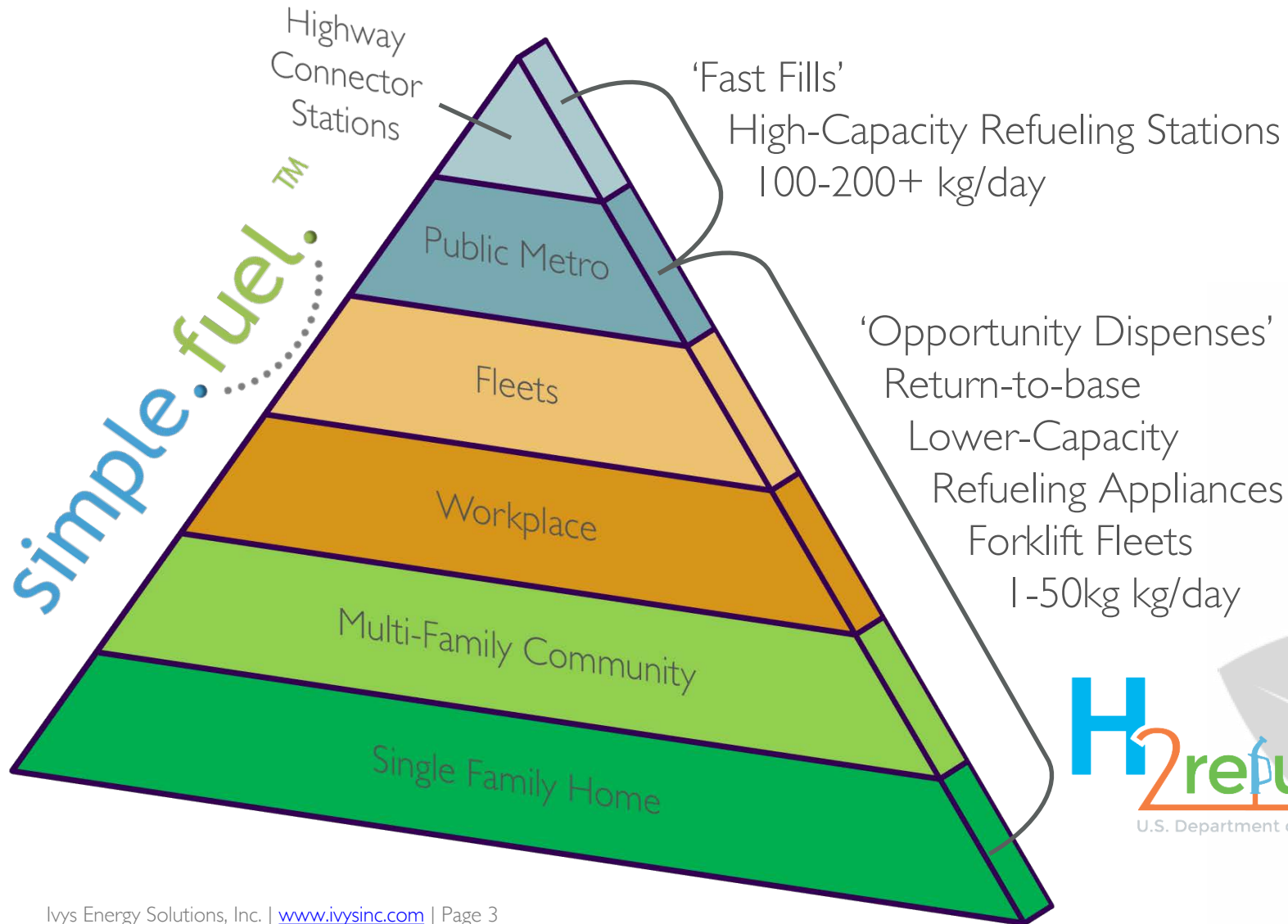
- Ivys' members led the development of a compact, on-site SMR appliance (Nuvera PowerTap™)
- Responsible for the safe deployment of 8 Nuvera H2 forklift stations (24/7 mission critical operations)
- Helped establish 1<sup>st</sup> H2 FCEV refueling station in Massachusetts (2009)
- Developing state-of-art H70-T40 dispenser systems (DOE Award #DE-EE0007273)
- Active Hydrogen Codes & Standards Participation

Ivys Energy Solutions, Inc., building on decades of experience in the hydrogen fuel cell industry, is developing innovative technologies and products to make a fundamental impact on automotive hydrogen refueling infrastructure, and enabling the successful near-term rollout of fuel cell vehicles.

**Team Leader of SimpleFuel™, winner of DOE's \$1M H2Refuel H-Prize competition**

**Development Location:**









# On-site Hydrogen Refueling Solution

## New class of *Refueling Appliance*

- 5 kg/day, 700 bar H<sub>2</sub> delivery solution
- 'Drop-in' installation, small footprint
- Modular & scalable for evolving market
- 'Opportunity Dispense' in 5-15 minutes
- Cost competitive to gas & liquid delivered
- Uses water & electricity ⇒ renewable H<sub>2</sub> option
- Serves both automotive and forklift markets



simple.fuel.™ is a partnership between Ivys Energy Solutions, McPhy Energy NA and PDC Machines Inc. to develop a compact, on-site hydrogen refueling solution

U.S. DEPARTMENT OF  
**ENERGY**

Energy Efficiency &  
Renewable Energy

## H-Prize created as part of the Energy Independence & Security Act of 2007

- Goal is “to advance the research, development, demonstration, and commercial application of hydrogen energy technologies.” (PLAW 110-140, Sec. 654)
- Initiative of DOE EERE Fuel Cell Technology Office
- Administered by the Hydrogen Educational Foundation, a 501(c)(3) non-profit organization
- Hydrogen infrastructure was focus of 2014-2016 round of H-Prize, titled “H2Refuel” targeting innovative solutions for home & community-based hydrogen refuelers for FCEVs
- Competition-based...promotes American Innovation!



## Tenets of SimpleFuel™ Design Approach:

- Safety First, Beyond Compliance
- Compact; Simple to Permit and Install
- Cost Effective
- Easy to Use, Friendly & Approachable
- Networkable; Enable Distributed Solutions
- Customer excitors!



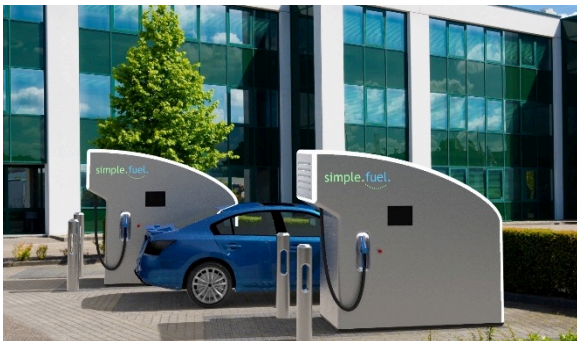
H-PRIZE CRITERIA (HOME)	WEIGHT	MINIMUM SCORE	MAXIMUM SCORE
Dispensing Pressure	3	350 bar or higher	700 bar or higher
Tested Availability	2	80% or higher	98% or higher
Installed System Cost	2	\$25k/kg or less*	\$5k/kg or less
Dispensing Time (1 kg)	1	10 hours or less	30 mins or less
Standard Fills per Day (1 kg)	1	1 or more	5 or more
Direct User Cost per kg	1	\$20 or less	\$8 or less

\*Home category allowed a maximum installed system cost of \$35k/kg if no team satisfied minimum score target



### Captive Fleets – Industrial Trucks

- >13,000 H2-powered forklifts in US today!
- ~60% market is less than 50kg/day H2
- Saves valuable real estate, enables incremental DC expansion & retail stores



### Tethered Fleets – On-Road Vehicles

- Up to 10-20 FCEVs per refueler
- Affords incremental, managed conversion
- State/Municipal, Workplace, Ride Share & University Programs
- 100 tonnes GHG/year savings possible with renewable grid-tie options



# Automotive Appliance Key Specifications



700 bar  
Automotive H2 Appliance

*Product suite can support a managed fleet of 10 to 20 FCEVs with 5-15 minute opportunity fills*

Dispense Pressure	Daily Capacity	Fueling Rate (typ.)	Hydrogen Quality
<b>700 bar</b>	<b>5 (or 10) kg H2/day</b>	<b>5 – 30 min/kg H2</b>	<b>Meets SAE J2719 / ISO 14687-2</b>

Power Consumption	RO Water Consumption	Noise	Dimensions
<b>19 (or 29) kWe max</b>	<b>3 (or 6) L/h</b>	<b>&lt; 70 dBa at 1m</b>	<b>2.03m W x 1.07m D x 2.08m H</b>

Installed System Cost	Direct User Cost
<b>&lt; \$35,000/kg</b>	<b>&lt; \$15/kg</b>

*Values in **bold** represent the tested 5kg H<sub>2</sub>/day H-Prize prototype of SimpleFuel™*



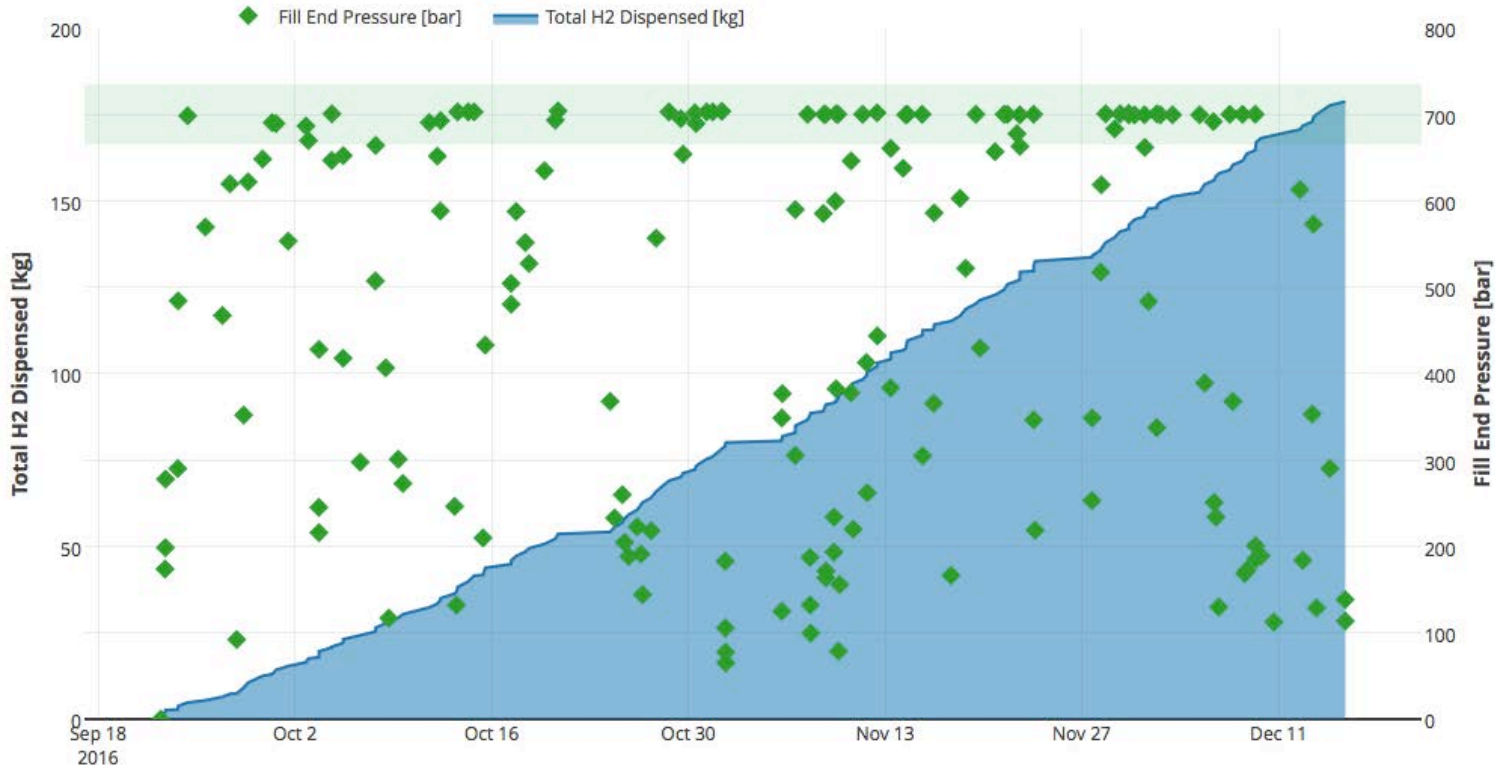


350 bar  
Industrial H2  
Appliance

*Support a multi-truck fleet with 2 minute fill times*

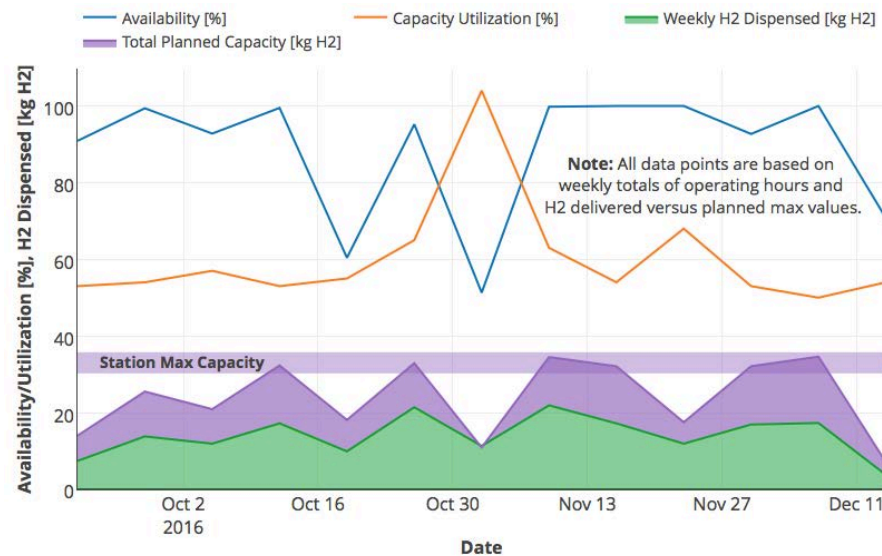
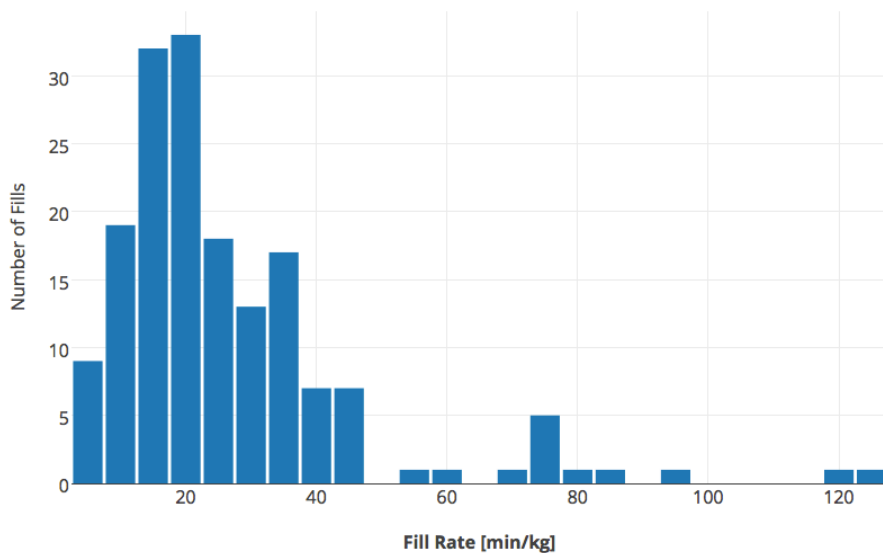
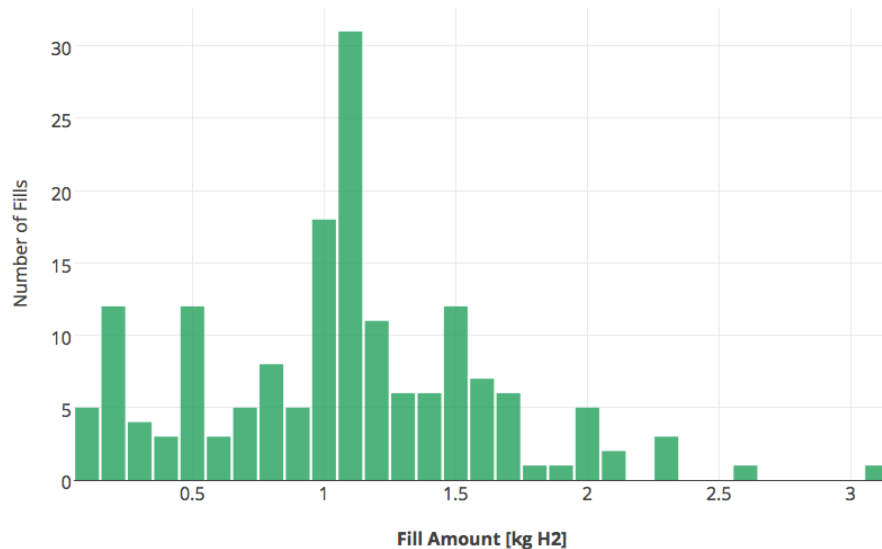
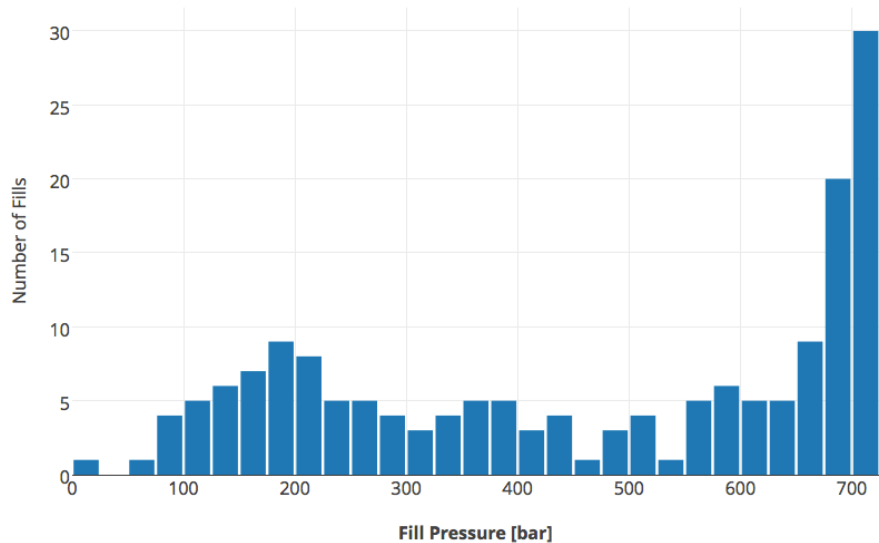
Dispense Pressure	Daily Capacity	Fueling Rate	Hydrogen Quality
350 bar	5 or 10 kg H2/day	2.2 – 10 min/kg H2	Meets SAE J2719 / ISO 14687

Power Consumption	RO Water Consumption	Noise	Dimensions
17 – 26 kWe max	3 – 6 L/h	< 70 dBa at 1m	2.03m W x 1.07m D x 2.08m H



### Rigorous Product Evaluation:

- ✓ 700 bar, 5 kg/day SimpleFuel appliance testing with Hyundai Tucson FCEV
- ✓ More than 200 fills demonstrated to 4 – 7 kg class automotive tanks
- ✓ Furthering collaboration from multiple OEMs to validate product
- ✓ Supporting ISO/SAE Ambient-Class Standards Development





*H2 Refuel H-Prize Winner*  
*Satisfied all technical and cost criteria*  
*including 3 month performance test*  
[www.hydrogenprize.org](http://www.hydrogenprize.org)



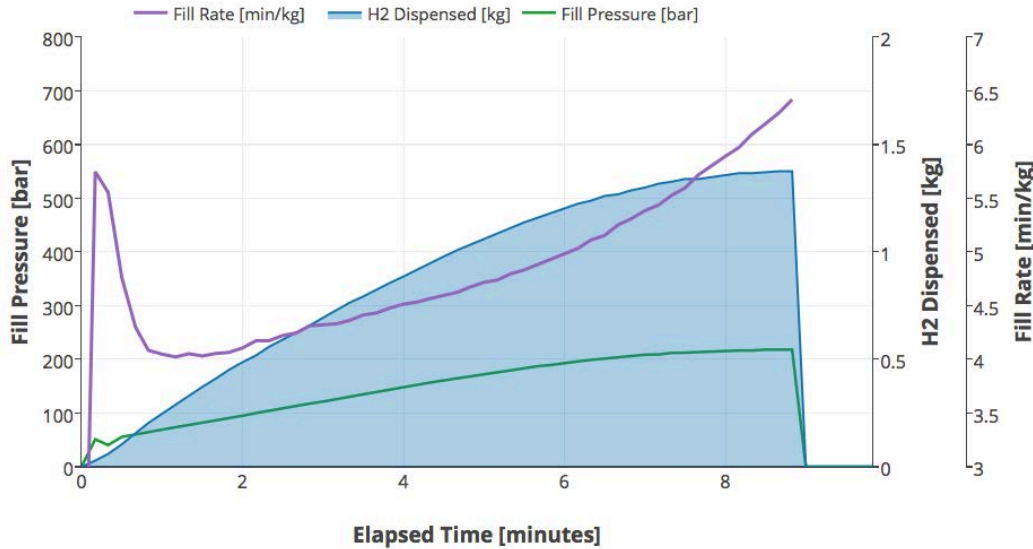
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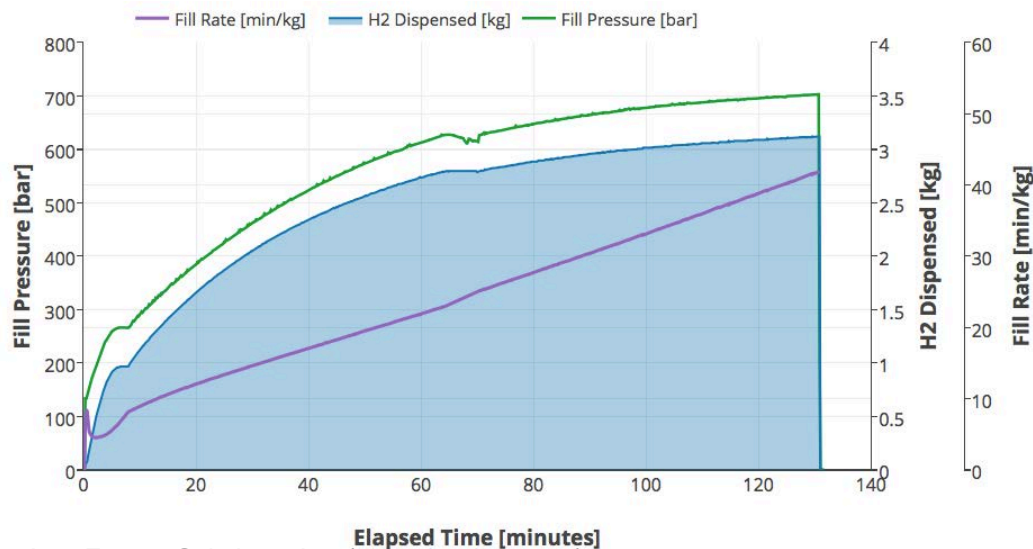
# Automotive Refueling Scenarios



**'Opportunity' Dispense**

**Smaller Mass Dispensed**  
**Lower Final Pressure**  
**Fastest Fill Rates**

Target application: Quick range addition, managed fleet fueling

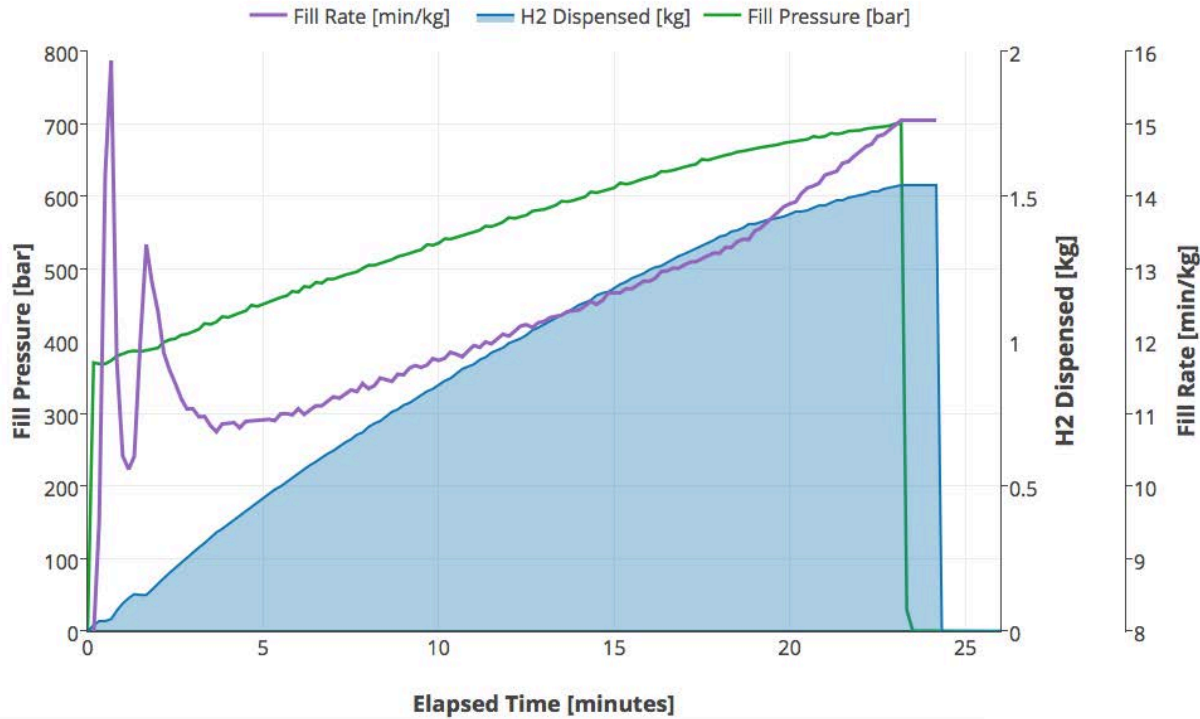


**'Full Fill' Dispense**

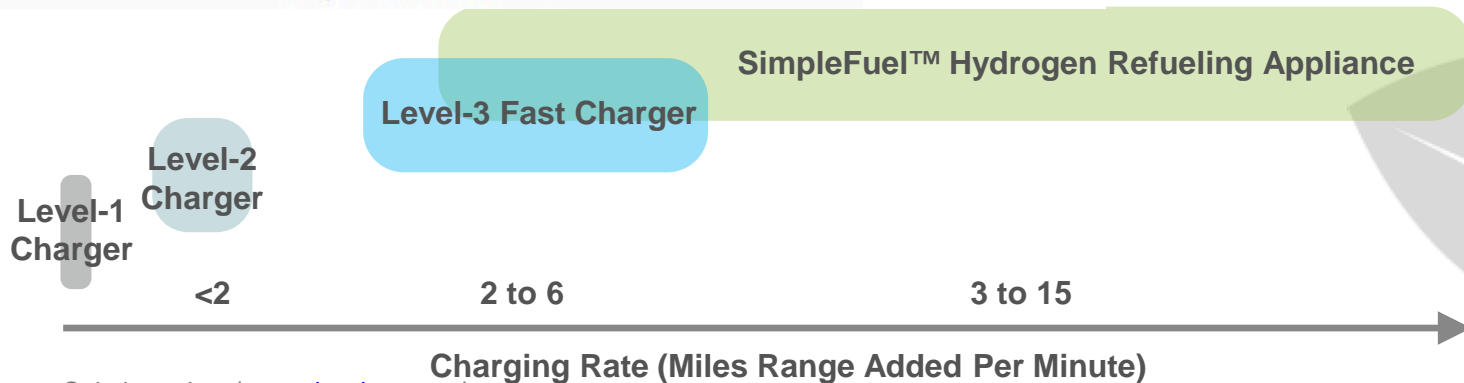
**Large Mass Dispensed**  
**Full Tank to 700 bar**  
**Fill Rate Slows During Fueling**

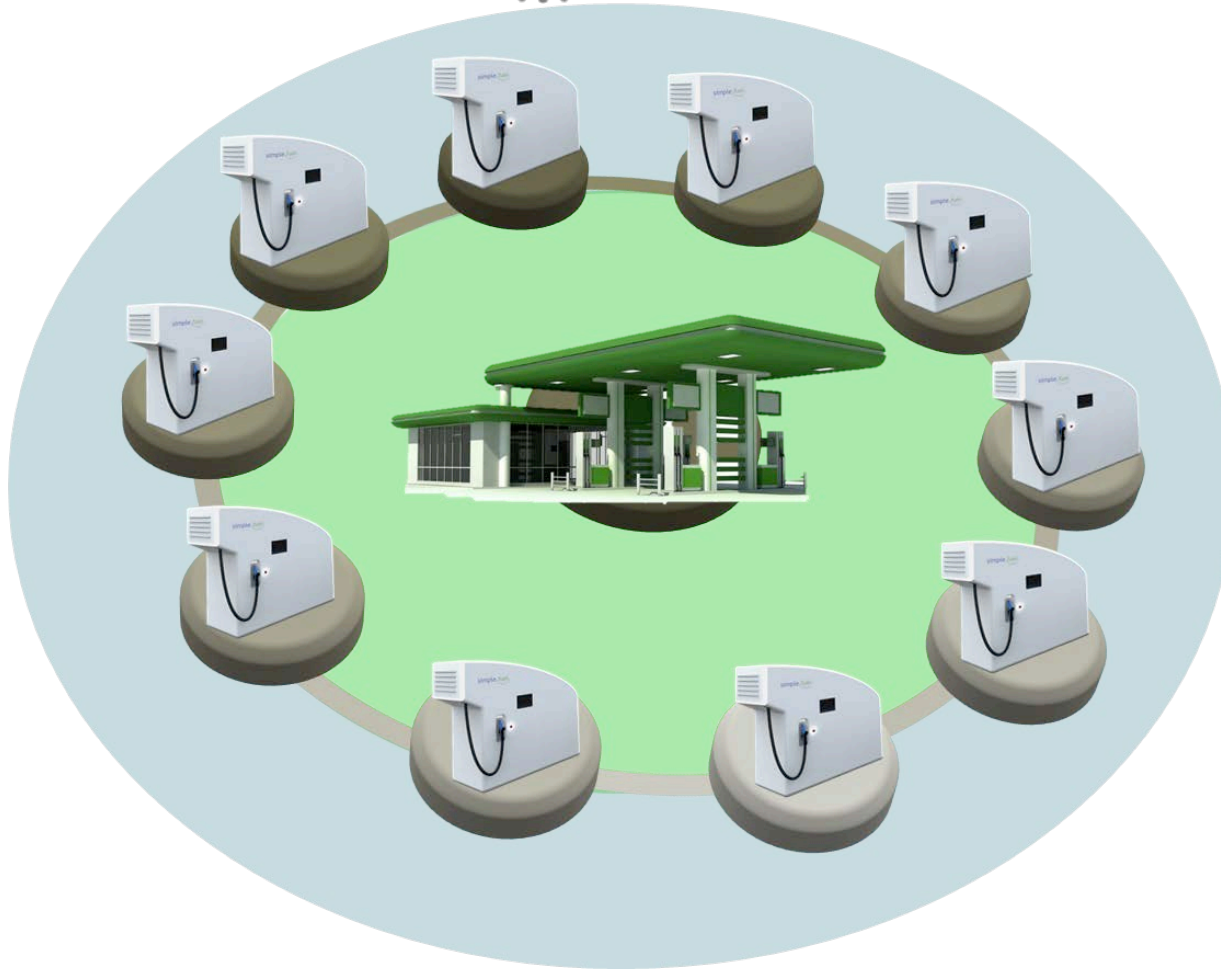
Target application: 'Slow charge' complete fill, overnight/shop fueling

# simple.fuel<sup>TM</sup> Unique Zero-Emission Vehicle Refueling Solution



*The SimpleFuel<sup>TM</sup> appliance provides a competitive vehicle range fill-time to that of the fastest BEV chargers*





Network of 10-20  
SimpleFuel™  
Refuelers

*AND*

'Fast Fill' Central  
Hub Station

= *Same  
Investment*

- For early markets, reduce total time to fuel (including travel time) by distributing many smaller refueling locations
- Network of SimpleFuel™ refuelers can optimize utilization via direction of vehicles to optimal refueling point
- Fast and simple permitting and installation process is of critical importance to this model

## Engagement with Automotive OEMs

- Ivys team helping to develop SAE ambient-class H2 fueling standard, for publication this year
- H-Prize competition drove interest from OEMs in this class of fueling equipment

## Initial Customer Deployments

- In discussions with multiple US fleet customers
- Market pull to accelerate OEM adoption of small-scale refueling / standards development
- Cost-effective solution without subsidies

## Demonstration and Outreach

- Continuing demonstration with Hyundai FCEV
- MA funded project for fully renewable SimpleFuel™ installation (solar + energy storage) with Hyundai vehicles in late 2017



Greentown Labs Global Center for Cleantech Innovation & 200kW Solar Array



MA Soul EV / Hyundai Tucson FCEV

- Landmark Demonstration of Commonwealth Leadership on H2
- \$320k Total Budget (\$170k cost share/\$150k Grant)!
- 18-Month Term | 12-Month Test/Data Collection Period!
- 10 Tonnes GHG Reduction (100 Tonnes possible)!



# Thank you

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# Supplemental Material

## Basic site installation requirements for drop-in install:

- ✓ Power per specification
- ✓ RO Water Supply – sized for single or multiple systems
  - ✓ Vents: H<sub>2</sub> and O<sub>2</sub> per specification
  - ✓ Vehicle Impact Protection – Bollards
- ✓ Detail design review by U.S. Hydrogen Safety Panel Members
- ✓ Standard home install/cost provided by expert panel member(s)

## Commercialized product is under-going an appliance certification



Valued Quality. Delivered.



Intertek

Service Interval / Service Type	6 Mo. Inspection/ Clean/ Replace as Needed	1-Year Inspection/ Clean/ Replace as Needed	1-Year Replacement	5-Year Replacement
<b>Electrolyzer</b>				
Inlet Water Filter	X		X	
Pressure Equalizers	X		X (Internal Seal)	
Electrolyte Solution		X		X
Cell Stack				X
<b>Compressor</b>				
Oil System	X		X (Filter)	X (Oil)
Diaphragms			X (QTY 2)	
<b>Gas Purification &amp; Dispensing</b>				
Dryer Guard Filter		X		
Dispenser Filter		X		
Water Separator Filter	X		X	
Ventilation Air Filter	X			

Service cost typically  $\leq$  2-4% of capital cost per year; year-5 involves stack replacement



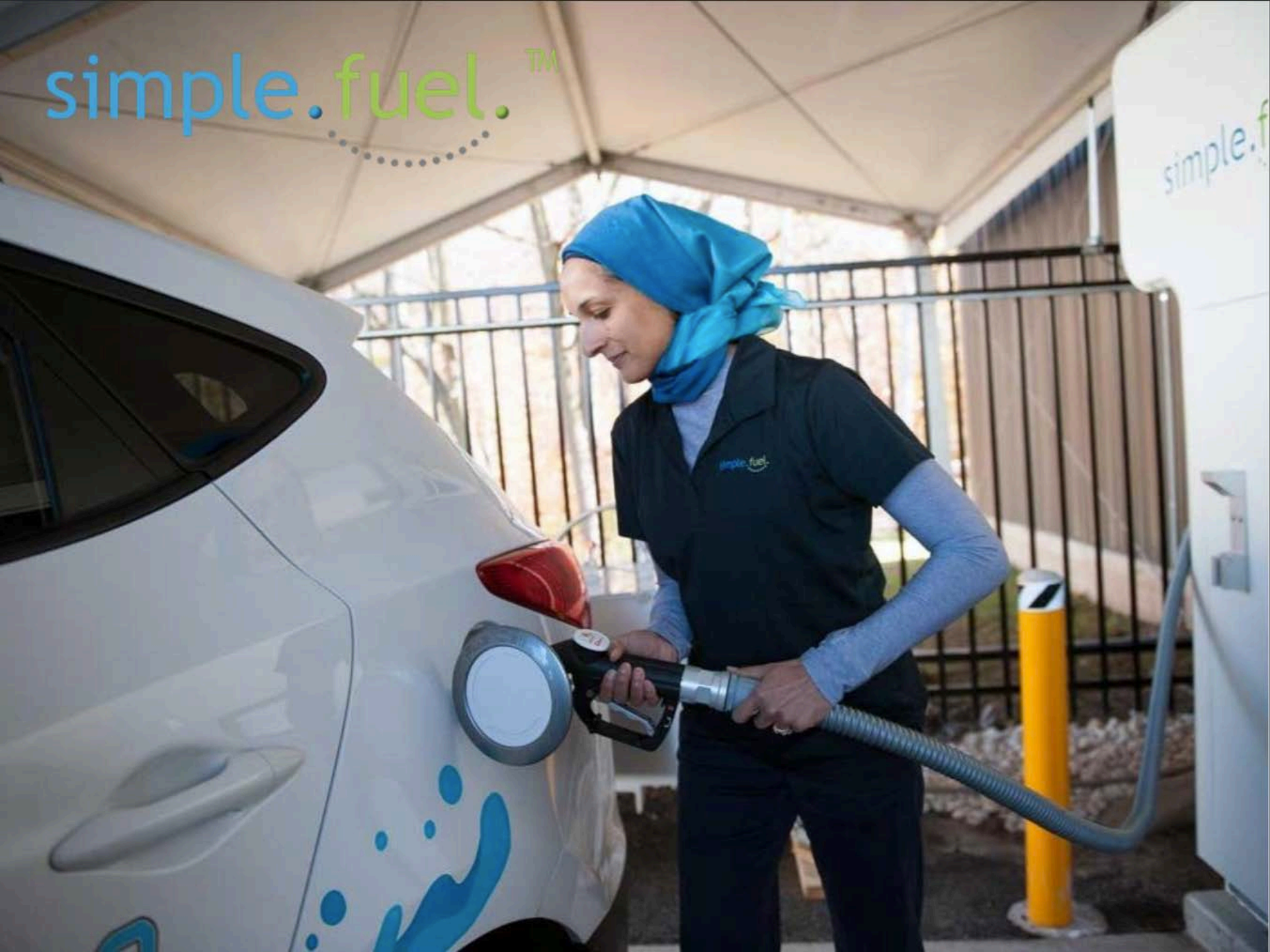
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*Community Outreach  
Warwick-Bucks County First  
Responder Visit (Aug. 23  
2016)*





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*The SimpleFuel<sup>TM</sup> Team would like to thank:*

U.S. DEPARTMENT OF  
**ENERGY**

Energy Efficiency &  
Renewable Energy

