IVYS
Energy Solutions

and

H_2 Refuel H-Prize Competition Experience

Ivys Snapshot

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 1st H2 FCEV refueling station in Massachusetts (2009)
- Developing state-of-art H70-T40 dispenser systems (DOE Award #DE-EE0007273)
- Active Hydrogen Codes & Standards Participation

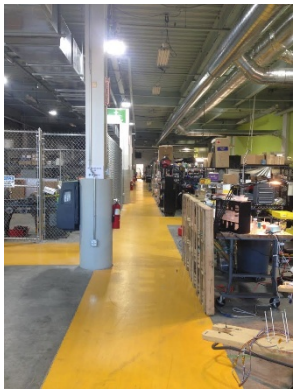
Ivys Energy Solutions, Inc., building on decades of experience in the hydrogen fuel cell industry, is developing innovative technologies and products to make a fundamental impact on automotive hydrogen refueling infrastructure, and enabling the successful near-term rollout of fuel cell vehicles.

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

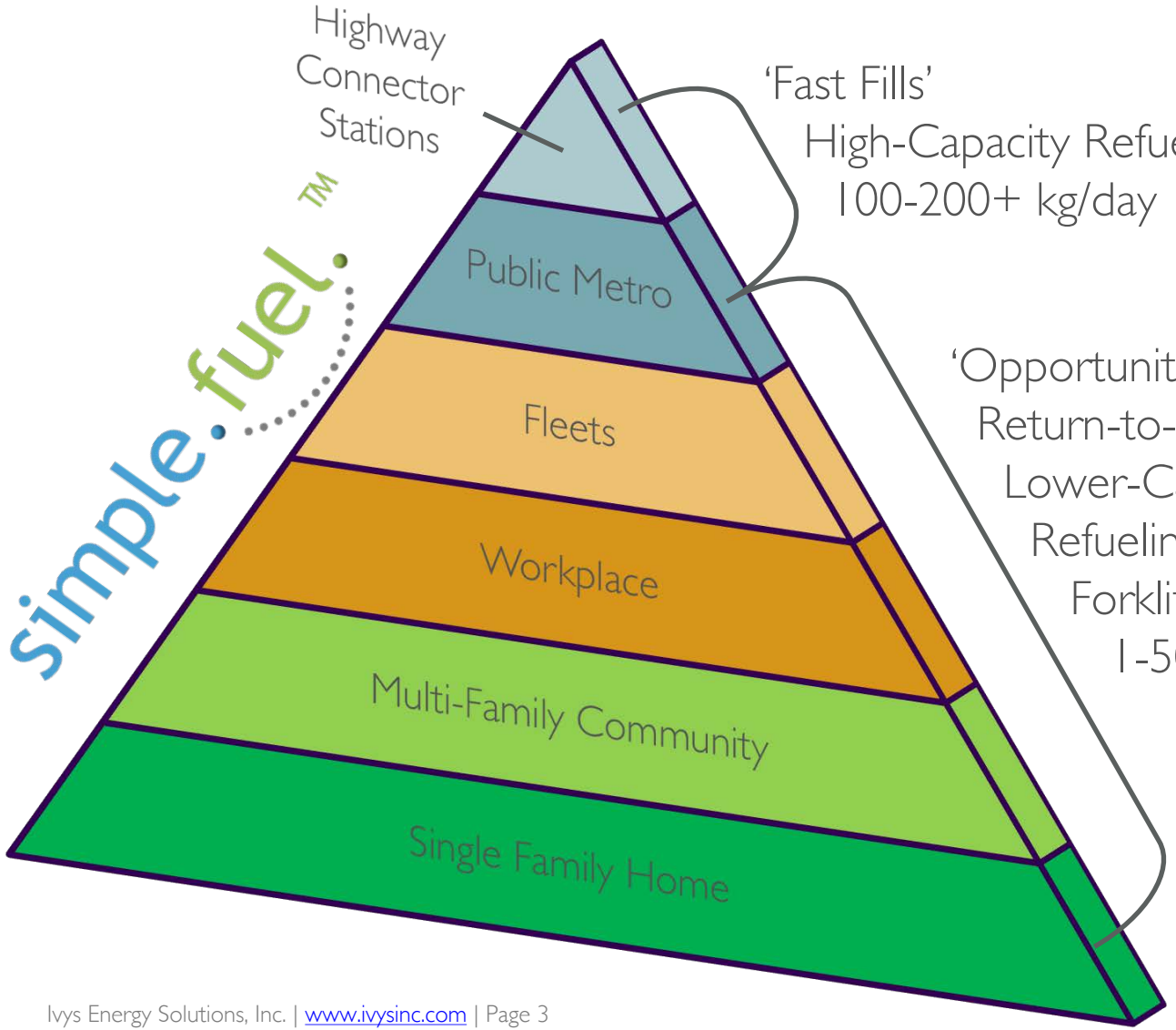
Development Location:

GREENTOWN LABS MEMBER COMPANY

H-PRIZE AWARDEE



Consumer Use Profiles



'Fast Fills'
High-Capacity Refueling Stations
100-200+ kg/day

'Opportunity Dispenses'
Return-to-base
Lower-Capacity
Refueling Appliances
Forklift Fleets
1-50kg kg/day

H2refuel
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On-site Hydrogen Refueling Solution

New class of *Refueling Appliance*

- 5 kg/day, 700 bar H2 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 H2 option
- Serves both automotive and forklift markets

IVYS Energy Solutions

McPhy energy

PDC MACHINES.COM

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

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Role of H-Prize Competition

U.S. DEPARTMENT OF ENERGY

Energy Efficiency & Renewable Energy

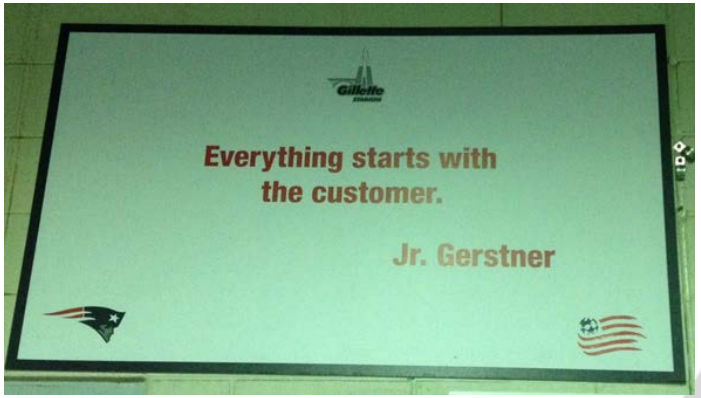
H-Prize created as part of the Energy Independence & Security Act of 2007

- 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!

Approach: Customer Focused

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 exciters!



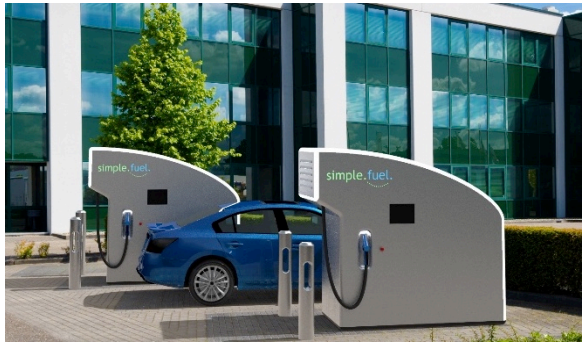
H-PRIZE CRITERIA (HOME)	WEIGHT	MINIMUM SCORE	MAXIMUM SCORE
Dispensing Pressure	3	350 bar or higher	700 bar or higher
Tested Availability	2	80% or higher	98% or higher
Installed System Cost	2	$25k/kg or less*	$5k/kg or less
Dispensing Time (1 kg)	1	10 hours or less	30 mins or less
Standard Fills per Day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

Target Entry Market Applications

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
700 bar	**5** (or 10) **kg H2/day**	**5 – 30 min/kg H2**	**Meets SAE J2719 / ISO 14687-2**

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

Installed System Cost	Direct User Cost
< $35,000/kg	**< $15/kg**

*Values in **bold** represent the tested 5kg H_2/day H-Prize prototype of SimpleFuel™*

Industrial Appliance Key Specifications

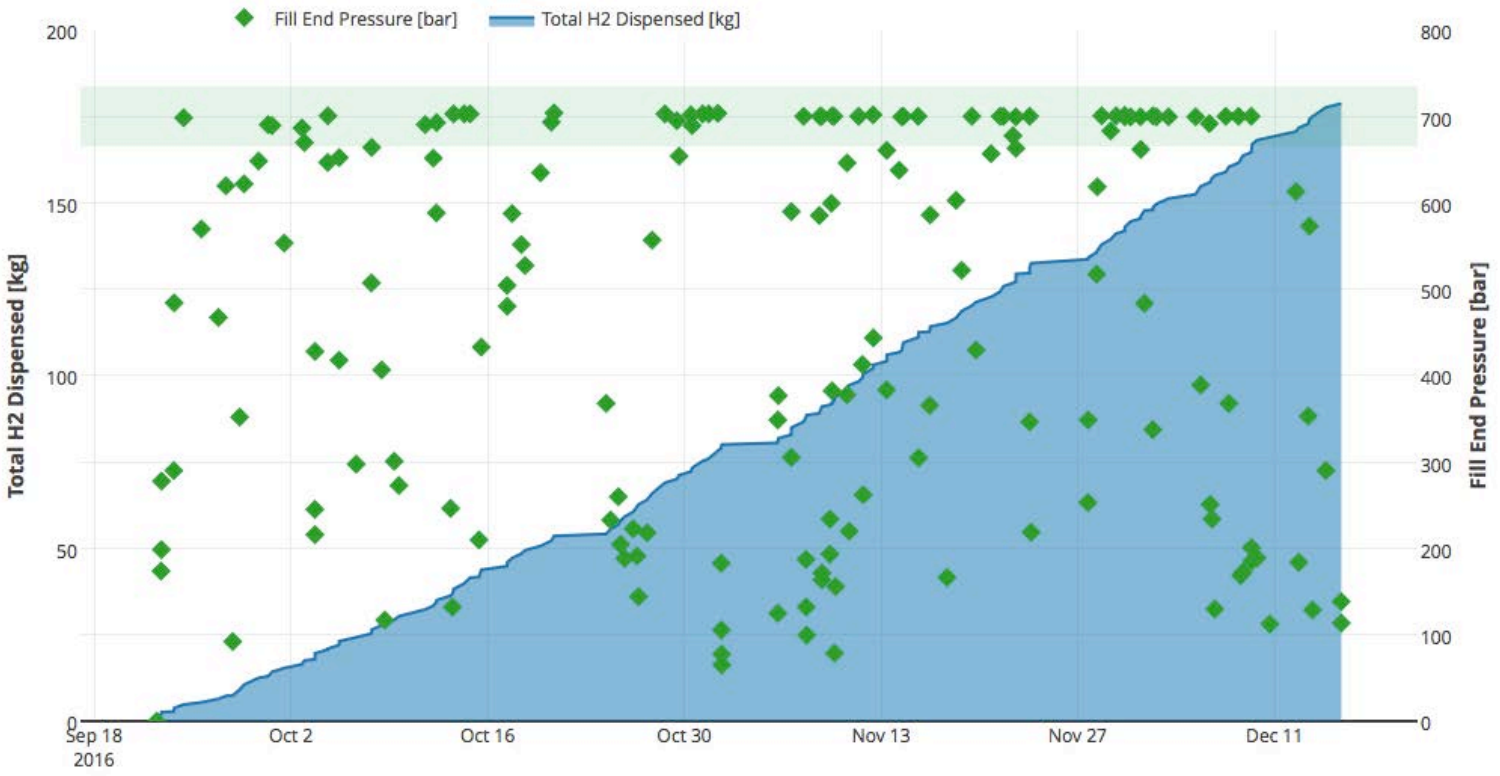
350 bar Industrial H2 Appliance

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

Validation Testing



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

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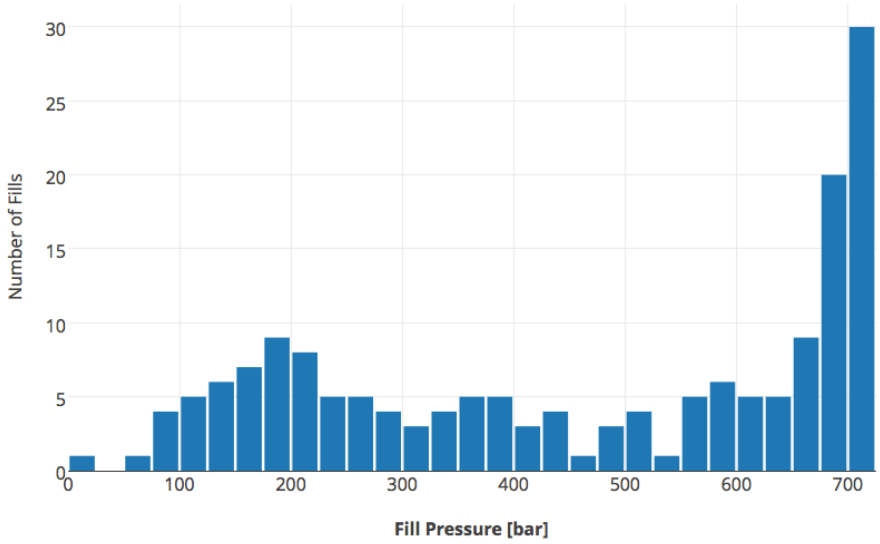
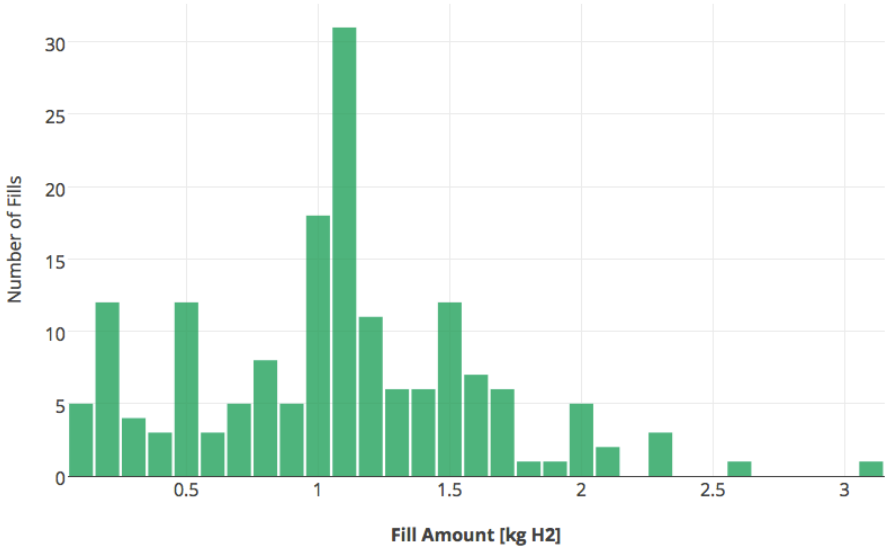
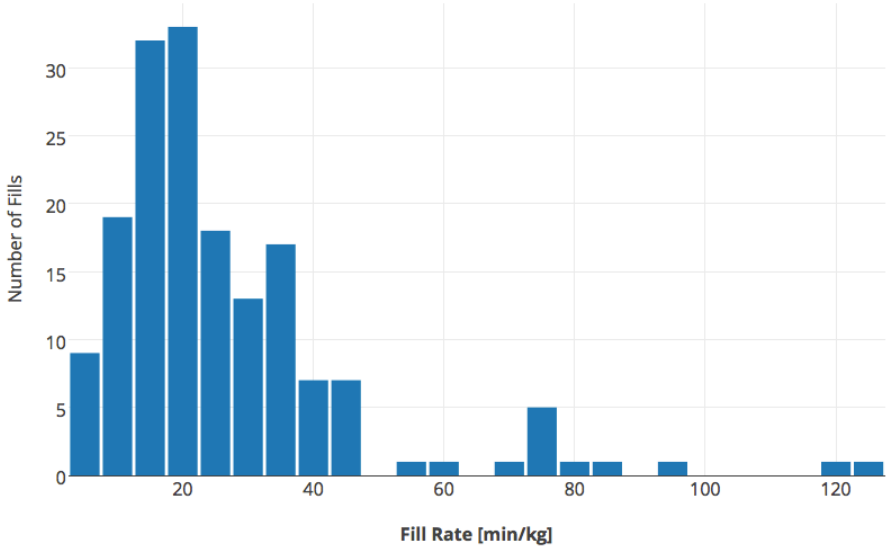
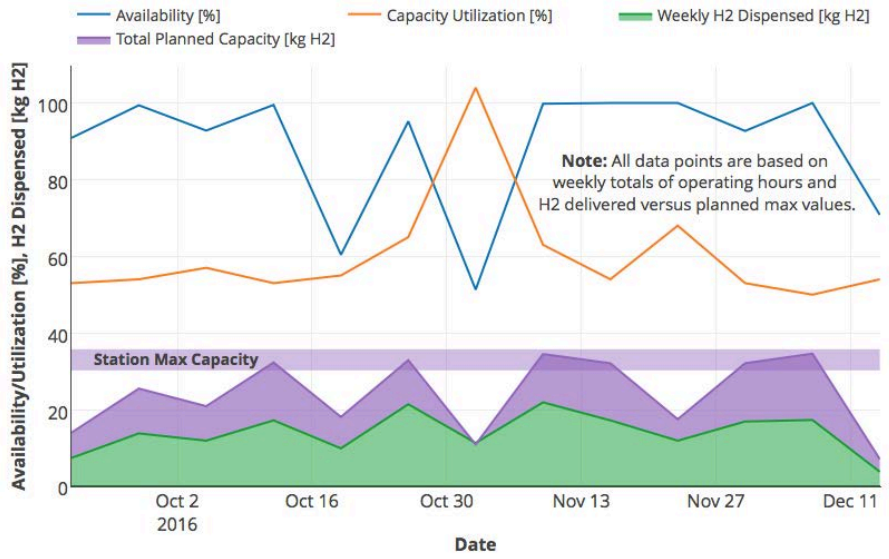
Validation Testing










H2 Refuel H-Prize Winner
Satisfied all technical and cost criteria
including 3 month performance test
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Clean H2O Emissions
hydrogen EV
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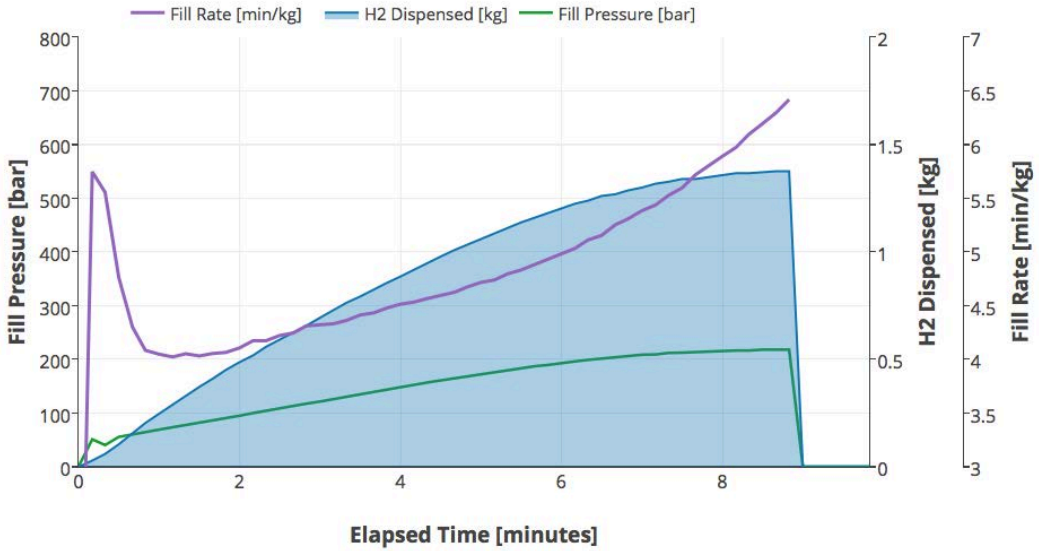
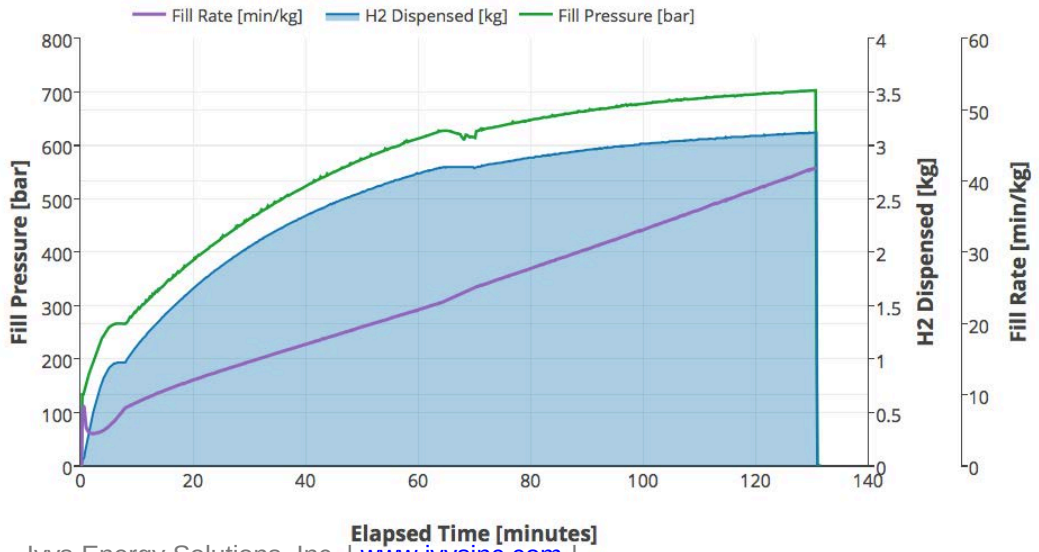
Automotive Refueling Scenarios

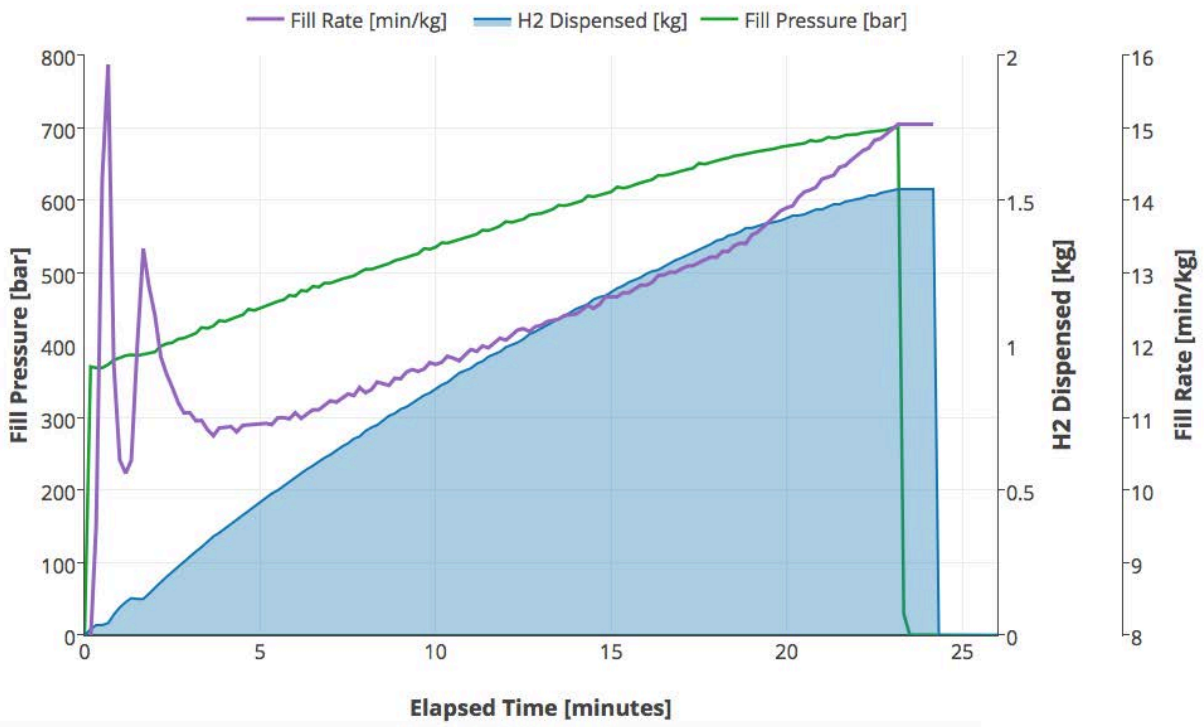


‘Opportunity’ Dispense
Smaller Mass Dispensed **Lower Final Pressure** **Fastest Fill Rates** Target application: Quick range addition, managed fleet fueling

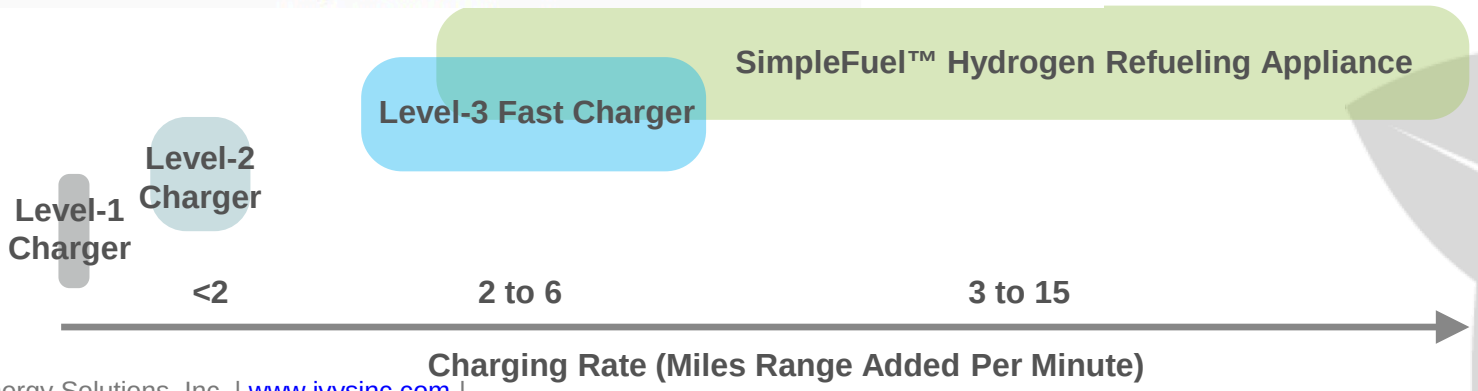


‘Full Fill’ Dispense
Large Mass Dispensed **Full Tank to 700 bar** **Fill Rate Slows During Fueling** Target application: ‘Slow charge’ complete fill, overnight/shop fueling

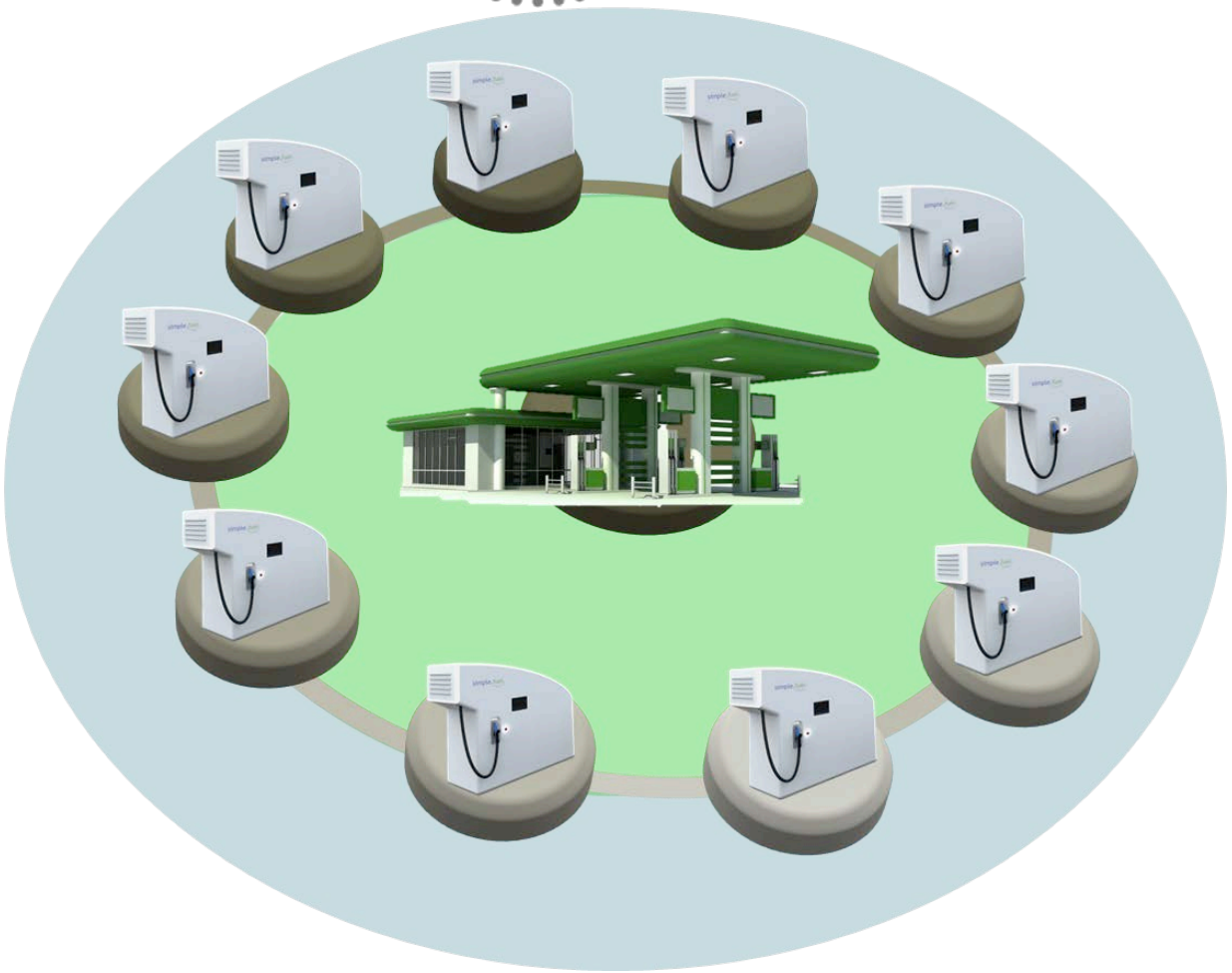
Unique Zero-Emission Vehicle Refueling Solution



The SimpleFuel™ appliance provides a competitive vehicle range fill-time to that of the fastest BEV chargers



Distributed Fueling Infrastructure Model



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

Next Steps

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

Thank you

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Supplemental Material

Installation Requirements

Basic site installation requirements for drop-in install:

✓Power per specification
✓RO Water Supply – sized for single or multiple systems
✓Vents: H2 and O2 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

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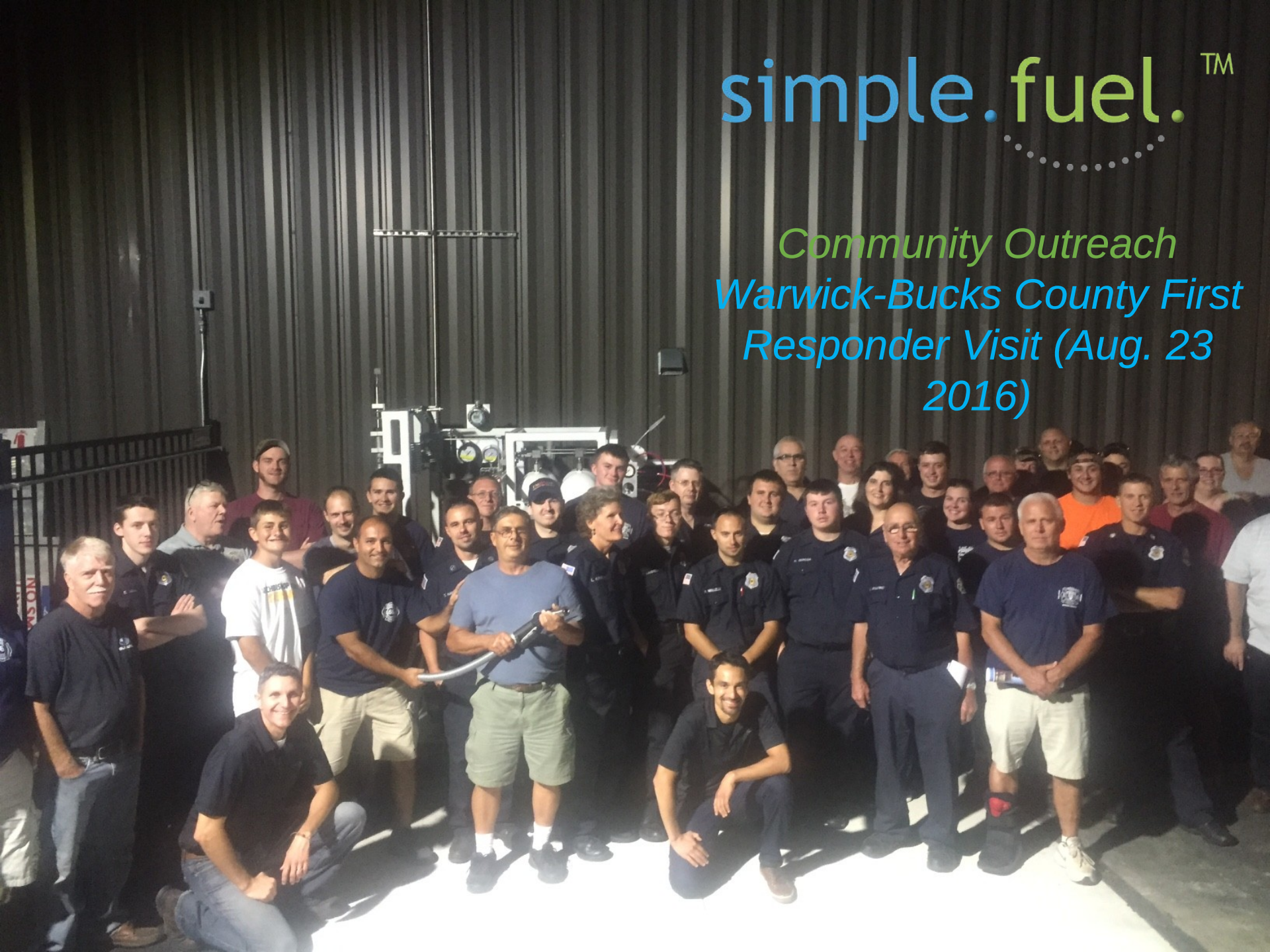
Periodic Inspection & Maintenance

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

Service cost typically ≤ 2-4% of capital cost per year; year-5 involves stack replacement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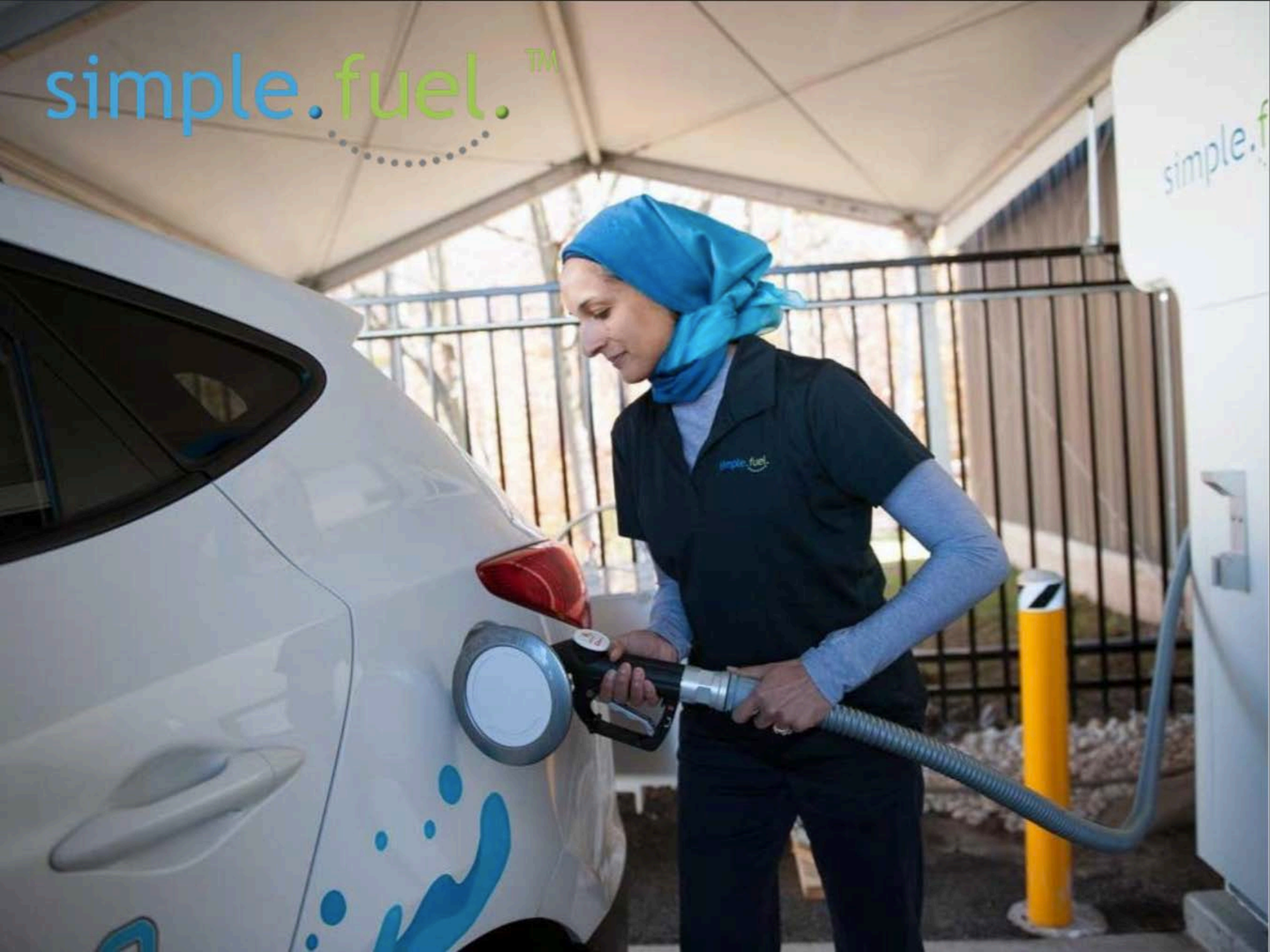
Community Outreach
Warwick-Bucks County First Responder Visit (Aug. 23 2016)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Acknowledgements

The SimpleFuel™ Team would like to thank:

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U.S. Department of Energy

HYDROGEN EDUCATION FOUNDATION

H2 HYDROGEN Safety Panel

HYUNDAI

NREL
NATIONAL RENEWABLE ENERGY LABORATORY