Hydrogen & Fuel Cells: Leading the Way to Zero Emissions

John Brazer Director of Sales

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Plug Power

Industry leader in hydrogen and fuel cell systems.
Facilitating and benefiting from paradigm shifts in the **Transportation** and **Energy** Industries.

Unmatched Accomplishments – Global Leader

Plug is building an end-to-end green hydrogen ecosystem to help its customers meet their business goals and decarbonize the economy. In creating the first commercially viable market for hydrogen fuel cell technology, the company has deployed more than 50,000 fuel cell systems and over 165 fueling stations, more than anyone else in the world, and is the largest buyer of liquid hydrogen. With plans to build and operate a green hydrogen highway across North America, Plug is building a state-of-the-art Gigafactory and multiple green hydrogen production plants that will yield 500 tons of liquid green hydrogen daily by 2025. Plug will deliver its green hydrogen solutions directly to its customers and through joint venture partners into multiple environments, including material handling, e-mobility, power generation, and industrial applications.

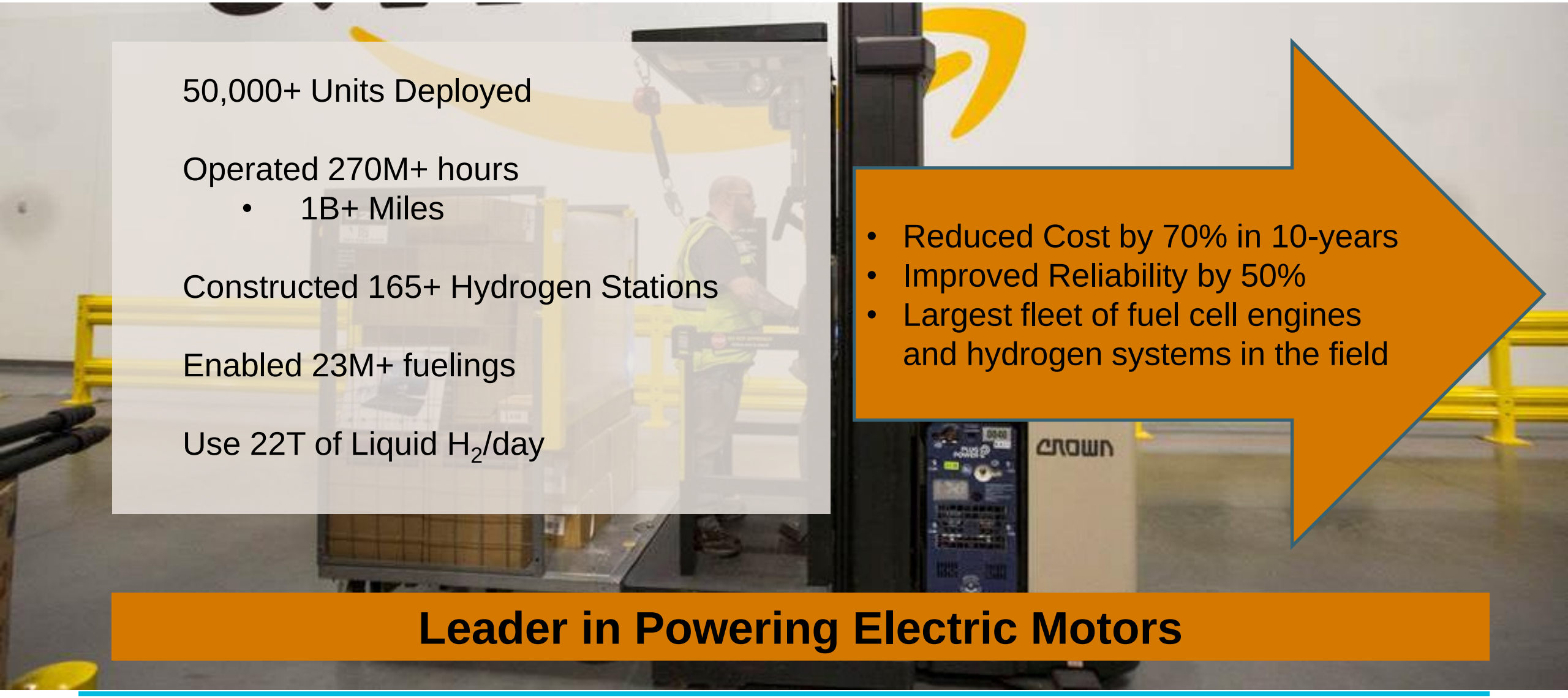
What is a fuel cell?

- **A fuel cell (FC) is a device that combines Hydrogen and Oxygen in an electrochemical process which generates electricity along with some heat and water as byproducts.**
- **The heat is dissipated into the air, the water is captured in a tank and emptied during the refueling process and the electricity is used to power the lift truck.**
- **While there are several different types of fuel cells, the type used in the GenDrive unit is known as a Proton Exchange Membrane (PEM) fuel cell. It is also known more technically as a Polymer Electrolyte Membrane (PEM) fuel cell.**

Hydrogen Safety

- Hydrogen is safer in many ways than gasoline, natural gas, or propane.
- Gasoline vapors, natural gas and propane do not disperse as readily as hydrogen. Because of this, when they leak, the gas tends to collect easily. When an ignition source comes into contact with these gases, explosive results often occur.
- Because hydrogen is 14 times lighter than air it immediately rises. Generally it disperses and escapes quickly even through the smallest openings and cracks but if not allowed to do so, then it will also collect in quantities that can result in an explosion if ignited.
- The likelihood of hydrogen collecting without dispersing however is much, much lower than the other gases collecting which is almost a certainty.
- The standard procedure for hydrogen leaks in a closed area is often simply to eliminate all sources of ignition, provide ventilation and allow the hydrogen to disperse.

Fuel Cell Product Experience:



50,000+ Units Deployed

Operated 270M+ hours
- 1B+ Miles

Constructed 165+ Hydrogen Stations

Enabled 23M+ fuelings

Use 22T of Liquid H_2/day

- Reduced Cost by 70% in 10-years
- Improved Reliability by 50%
- Largest fleet of fuel cell engines and hydrogen systems in the field

Leader in Powering Electric Motors

Offering – Material Handling: Core Market

GENKEY®

GENDRIVE® GENFUEL® GENCARE®

Provider of Turn-Key Solutions Globally

GenFuel Full-service H2 System

GENFUEL®

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Molecule

Infrastructure
- Large Outdoor H_2 Pad
- Small Outdoor H_2 pad

Indoor & Outdoor Dispensers

Cost effective hydrogen is the critical enabler to be the full service provider – power, infrastructure, molecule & service

Hydrogen Solutions

- Hydrogen can be delivered
  - Liquid form [LH_2]
  - Gaseous form [GH_2]
- Hydrogen can be generated on-site
  - Steam Methane Reformer
  - Electrolyzer
- Hydrogen can be renewable/de-carbonized

GH2 Delivery

Electrolyzer

LH2 Delivery

Reformer

GenFuel for Stationary Markets

GENFUEL

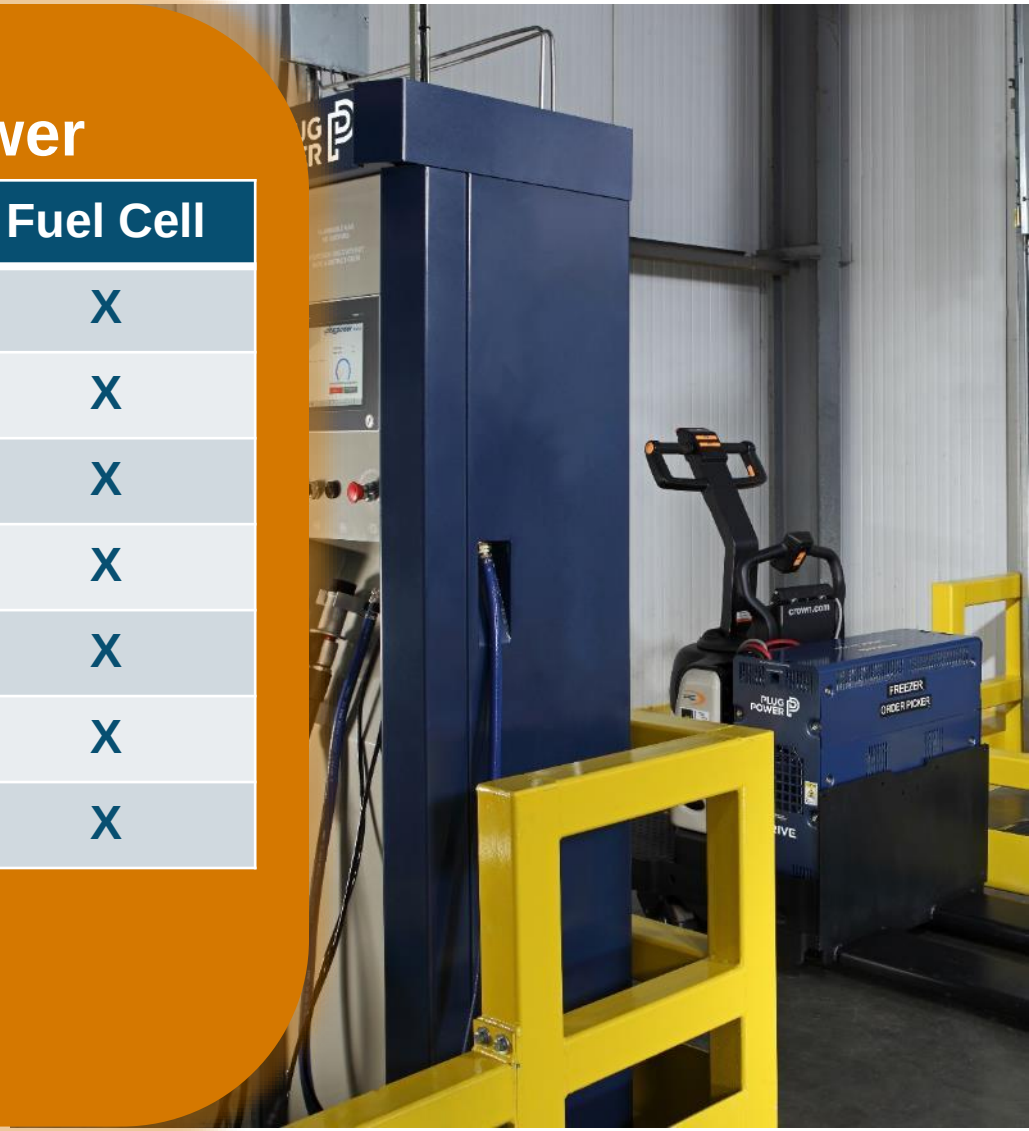
Complete Fuel Service Offering

- Complete support services
  - Initial fueling
  - Refueling
  - Disaster recovery
  - Preventive maintenance
  - Live call center 24x7x365
  - All fuel logistics handled for customer
- Disaster recovery support
  - Partnerships with service companies for delivery
  - Agreements in place for fuel sourcing
    - Leverage Plug Power assets where available
- Remote monitoring is available or Customer NOC dispatched
- Services offered driven by project commitment

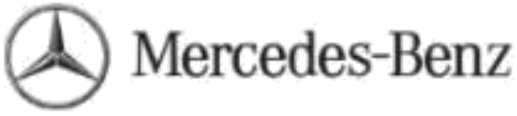
Fuel Cell Electric Checks all the Boxes

MHE Motive Power

Operational Criteria	ICE	Battery	Fuel Cell
Refuel/Recharge Time	X	---	X
Vehicle Cycle Performance	X	---	X
Work Force Productivity	X	---	X
Asset & Space Utilization	X	---	X
Emissions	---	X	X
Environmental Immunity	X	---	X
Total Cost of Ownership	X	---	X



Prestigious Customer List



Walmart: Long Term Strategic Partner
First Market Success

Plug Power's relationship with Walmart represents the largest hydrogen enabled fleet in the world

2014	• Initial agreement signed for multiple sites • GenKey installed in 6 distribution centers with 1,700 GenDrive units in 2014
2015	• 9 GenKey sites added • >1 million fuelings over the year
2018	• 8,000 GenDrive units deployed • Total of 38 GenKey sites deployed to date • > 10T on hydrogen usage per day
2019 and beyond	• Have over 150 NA distribution centers • Continuing to expand with Plug Power • Potential 35T per day of hydrogen usage • Expansion into delivery vans, drayage trucks

Amazon: Another Strategic Partner
First Market Success

**Amazon establishes multi-year,
multi-site customer agreement with Plug Power**

Background

- Plug Power and Amazon actively engaged in 2016
- Amazon recognized Plug's value proposition, including the ability to enhance productivity

First Site Success

- First site went live in Q4 2016
- Completed system installation in 8 weeks

Present Situation

- Over 20 GenKey sites deployed to date
- Using 4T on hydrogen per day
- Potential to Expand to 100 sites
  - 20T of hydrogen per day
- Focus on potential new applications

USPS

- The Postal Service Pilot Project: February 2017 to March 2018
  - Replacing lead-acid batteries with hydrogen fuel cells to power fork lifts, tow motors, and pallet jacks at the Washington, DC, Network Distribution Center.
- Fuel Cells proved to be a viable alternative to lead-acid batteries for use with powered industrial vehicles.
- Financial highlights of the first year pilot:
  - $3.4 million total investment including capital and expense
  - $3.5 million annual cost avoidance and operational savings
  - 107% Return on investment
- Achieved through:
  - 27% increase in operator productivity as measured by containers handled/hour
  - Elimination of lead acid battery system costs
  - Electricity savings

GenDrive 1000 **GenDrive 3000**

Washington NDC Pilot Project
Financial Summary

- **$3.45 M Total Investment**
- **$18.8M Operational Savings in a 5-Year timeframe**
- **107% ROI with a 1.96 year payback.**

Source: https://about.usps.com/what-we-are-doing/green/emerging-technology.htm

Stationary Power

Value Proposition

- Smaller Footprint
- Higher Power Density
- Low TCO for 4G/LTE/5G Base Stations
- Noise Reduction
- Emission Reduction

Proven with the Southern Company – 500 sites deployed

Stationary Power for Government Agencies

U.S. Customs and Border Protection

Department of Defense

Washington State Patrol

U.S. Department of the Interior
Bureau of Reclamation

Federal Aviation Administration

FirstNet
First Responder Network Authority

Transportation 2.0: Electrification Already Underway

Why EVs

1. Design Simplicity
2. Higher Reliability
3. Lower Total Cost of Ownership
4. Self-Driven Vehicles / Autonomy
5. Climate Change

Why FCEVs

1. Power Density
2. Asset Utilization
3. Sharing Economy
4. Fast Fueling/Infrastructure
5. Range

FCEVs are ideal for asset-intense logistics applications.

EVs: electric vehicles
IC: internal combustion

Fuel Cell Electric Vehicles

Attributes of Fuel Cells

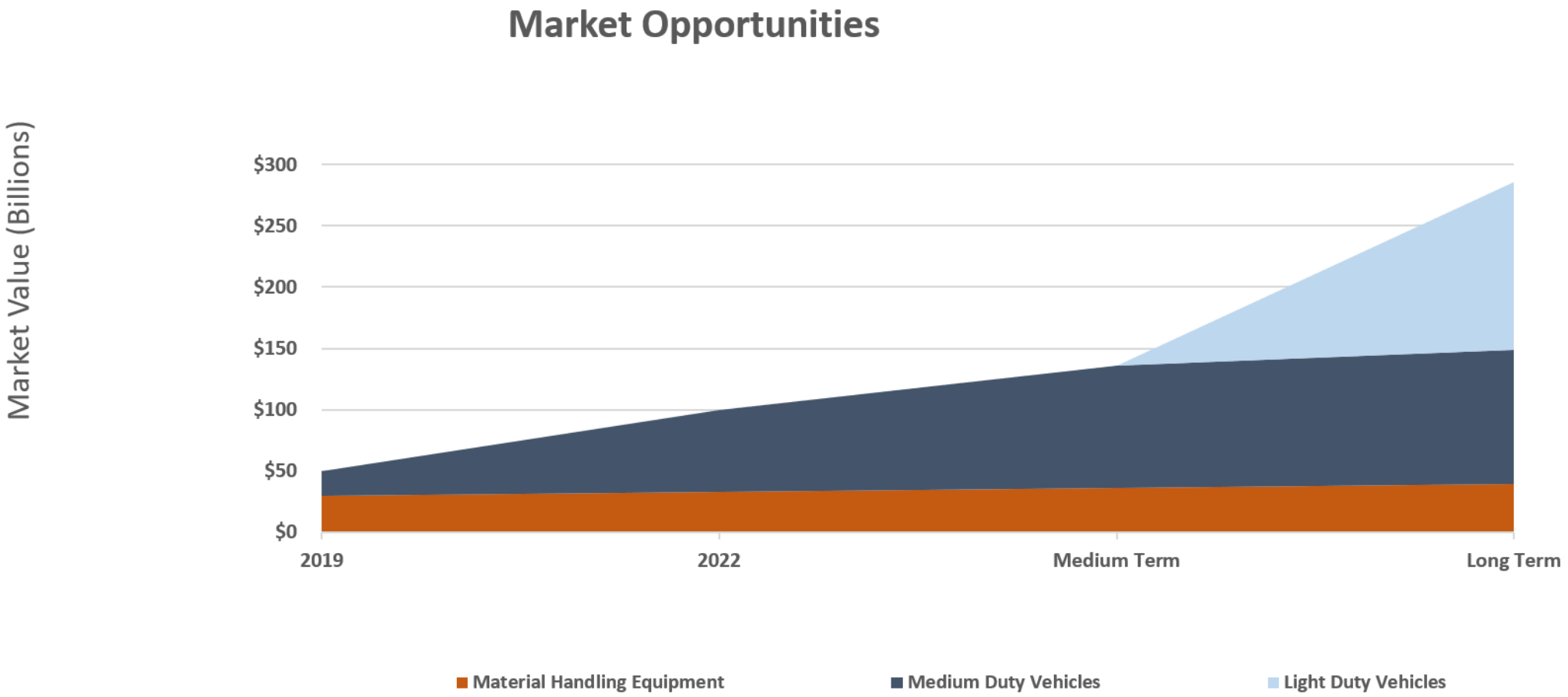
1. Energy Density is 10x BEVs
2. Asset Utilization
3. Sharing Economy
4. Fast Fueling
5. Range
6. Infrastructure

Applications

Strong Value Proposition

BEVs: battery electric vehicles

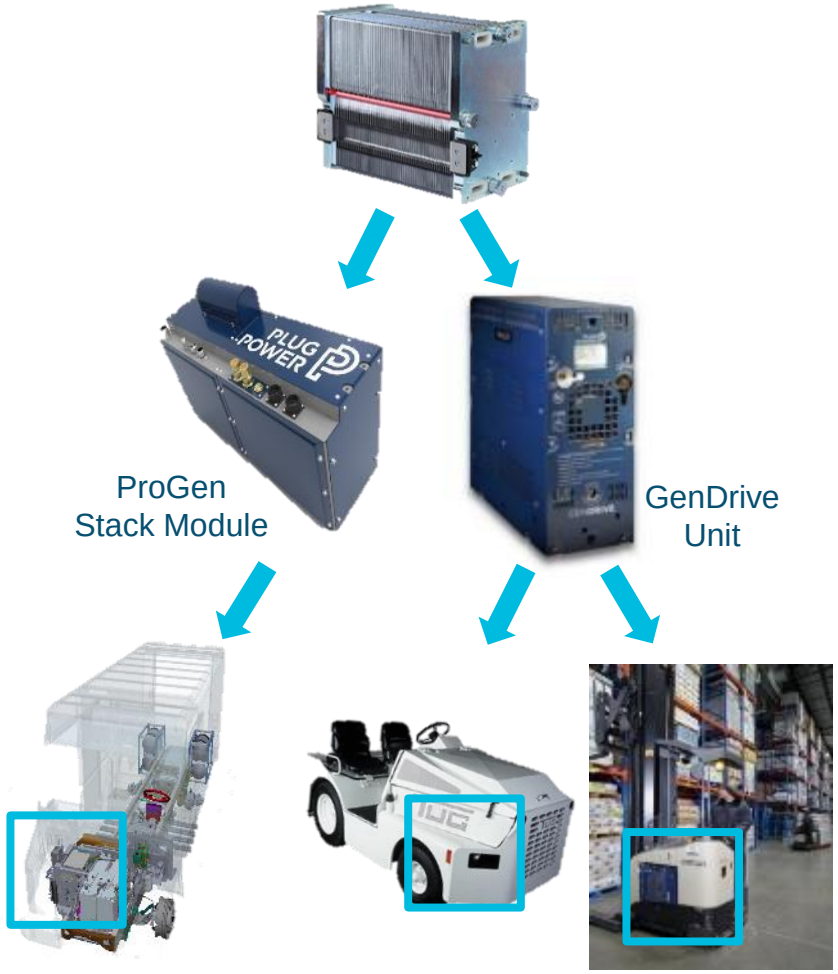
Market Size



~$300B Market Opportunity

ProGen Platform Unlocks a Vast Opportunity Set

ProGen Fuel Cell Stack



Modular Design Enables Mass Adoption

- Currently incorporated into our mobile and stationary products
- Scalability allows customers to adopt fuel cell power on their terms
- Original equipment manufacturers (OEMs) can easily integrate
- Flexibility drives penetration into new markets: Ground support, range extenders, commercial vehicles

A Proven Record Sets the Industry Standard

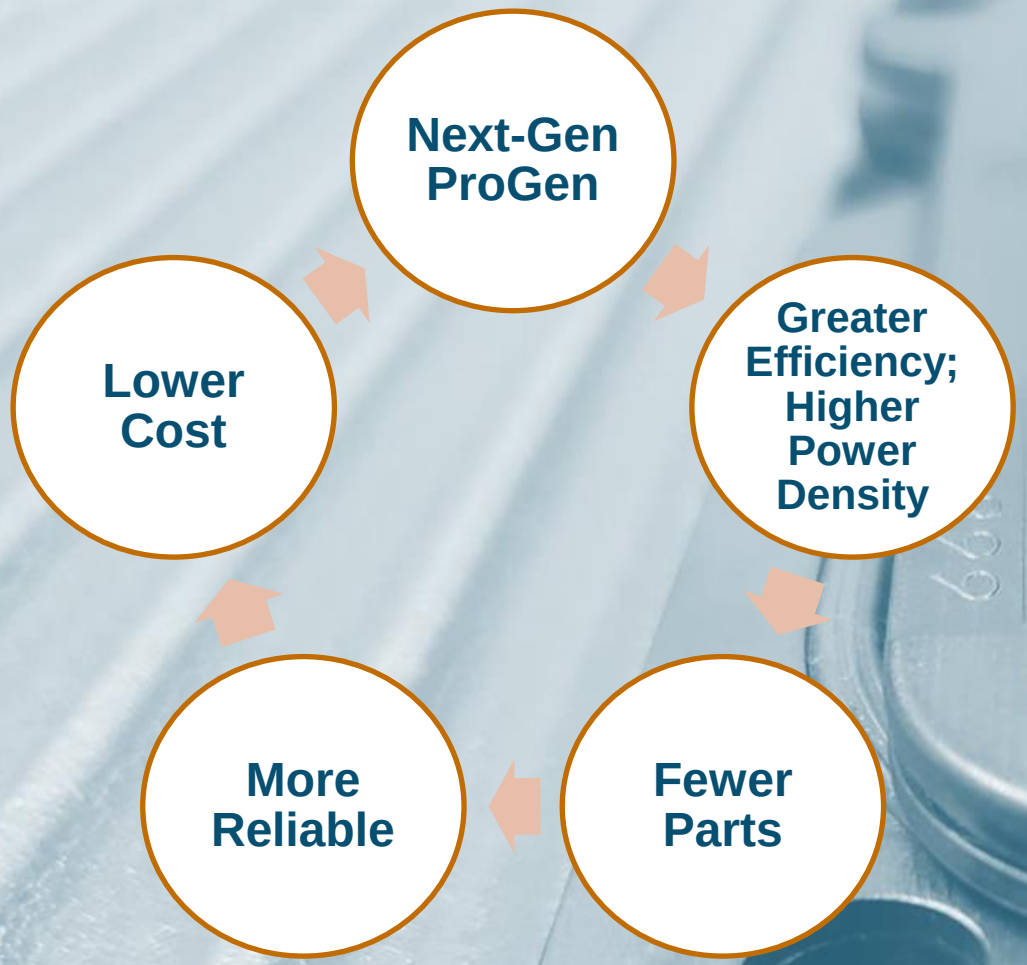
15% increase in fuel efficiency (relative to former engines)

15% increase in run-time (relative to former engines)

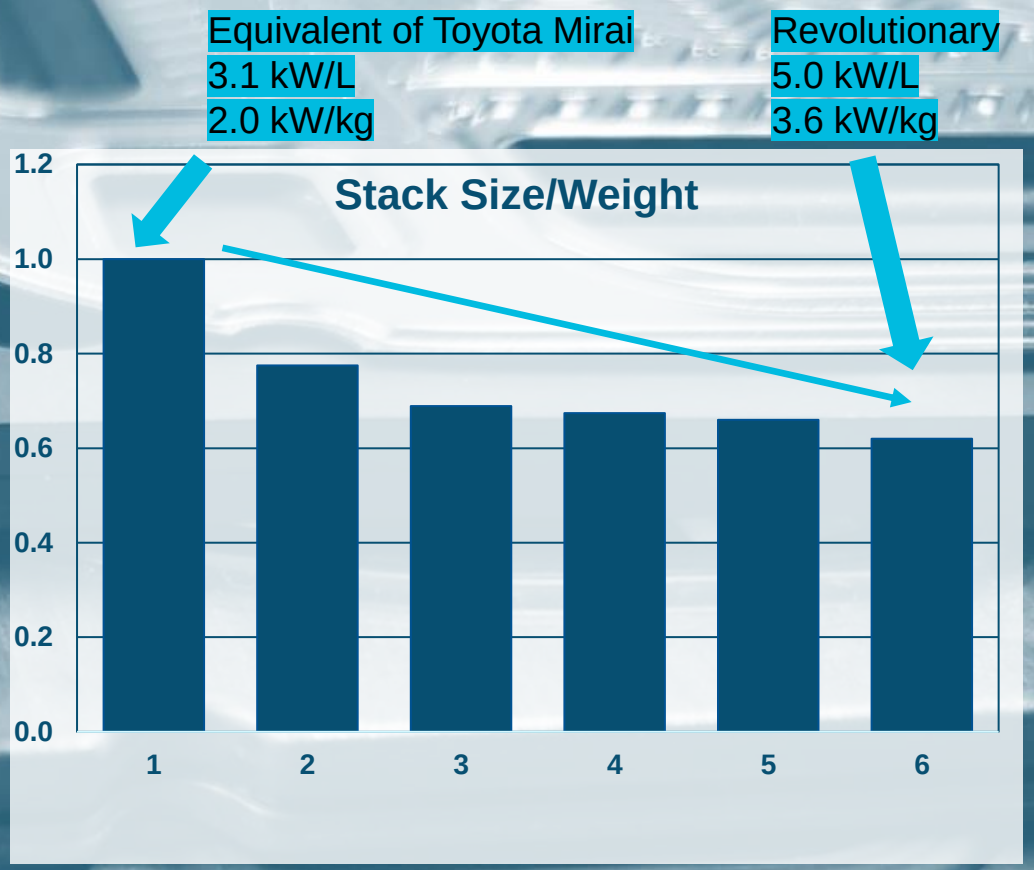
2 million hours of run-time across GenDrive units

6,000 ProGen stacks used across stationary and mobile

Continual Evolution of ProGen



We've already been through this loop 5 times.



Technology Development

Membrane: Largest US Manufacturer

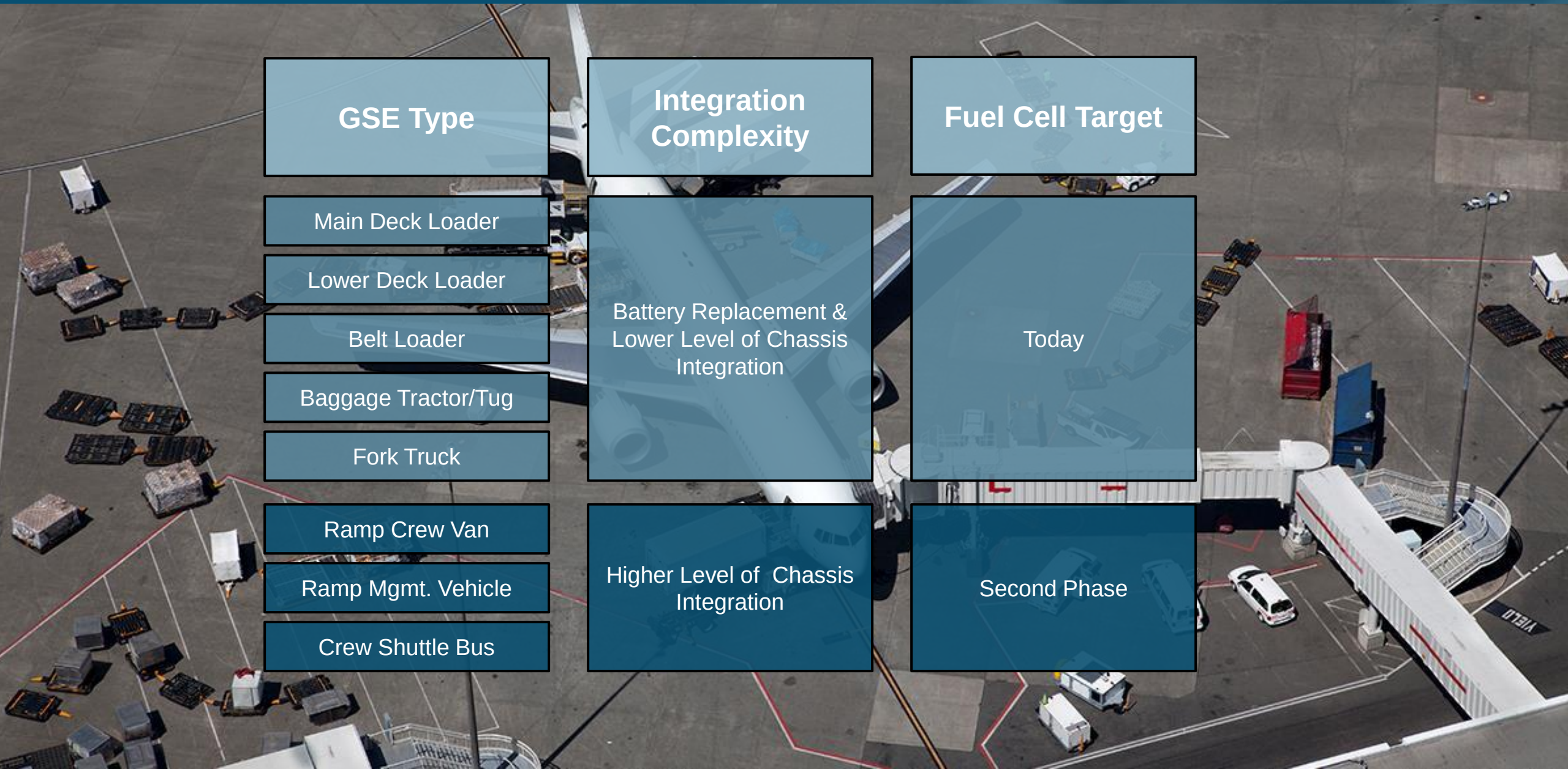
Stacks: Industry Leading Technology

ProGen: Complete Fuel Cell Engine

Skid: Modular Hydrogen System

Rich Technology Set

Electric Ground Support Equipment



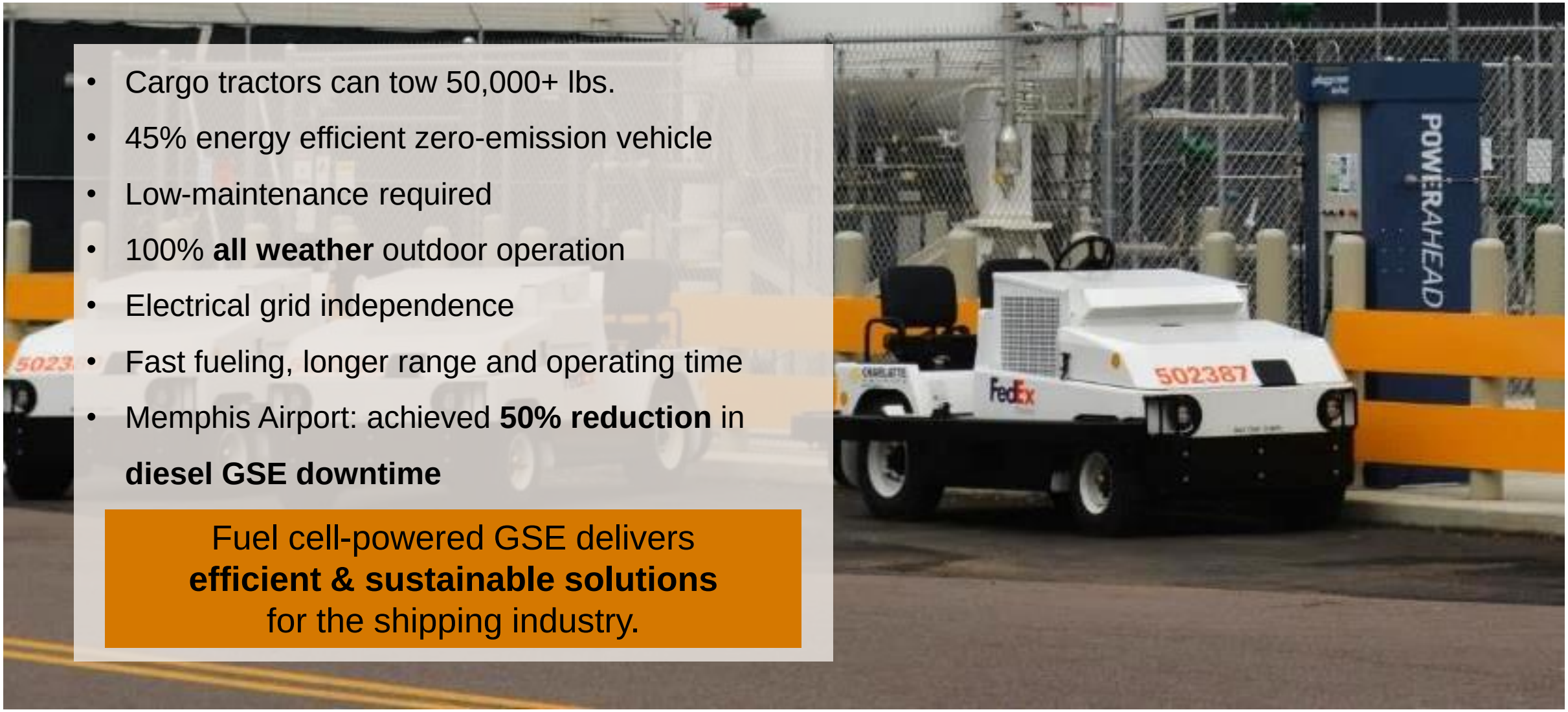
GSE Type	Integration Complexity	Fuel Cell Target
Main Deck Loader	Battery Replacement & Lower Level of Chassis Integration	Today
Lower Deck Loader		
Belt Loader		
Baggage Tractor/Tug		
Fork Truck		
Ramp Crew Van	Higher Level of Chassis Integration	Second Phase
Ramp Mgmt. Vehicle		
Crew Shuttle Bus		

Hydrogen Electric Ground Support Equipment

PLUG POWER

Main Deck Loader	Lower Deck Loader	Belt Loader	Baggage Tractor/Tug
			
• 66,000 lbs lift • 224” lift height	• 20 ft. ULD • 15,500 lbs lift	• 30-170” door height • Common components	• 4000 lbs drawbar tow • Common components
Diesel • CAT 4 cyl - 105kW, Tier 3 • Options: Deutz 4 cyl - 120kW or Cummins 4 cyl - 97kW	Electric • 160V – 2 X 80V Batteries, est. 1200-1500Ahr • reGen using Supercapacitors	Electric • 72 or 80V Battery, 375-450Ahr • 72 or 80V 40 HP drive motor	Electric • 72 or 80V Battery, 500-700Ahr, 3500-4100 lbs • 72 or 80V 40 HP drive motor
ProGen FCHED • 1 or 2 X 30 kW • 10 kWhr battery • 80 or 160 V	ProGen FCHED • 1 or 2 X 30 kW • 10 kWhr battery • 80 or 160 V	GenDrive/ProGen FCHED • 20 kW • 3-5 kWhr battery • 80 V	GenDrive/ProGen FCHED • 20 kW • 3-5 kWhr battery • 80 V

Hydrogen Fuel Cells for GSE



- Cargo tractors can tow 50,000+ lbs.
- 45% energy efficient zero-emission vehicle
- Low-maintenance required
- 100% **all weather** outdoor operation
- Electrical grid independence
- Fast fueling, longer range and operating time
- Memphis Airport: achieved **50% reduction** in **diesel GSE downtime**

Fuel cell-powered GSE delivers **efficient & sustainable solutions** for the shipping industry.

Charlatte CT5E – Fuel Cell Program

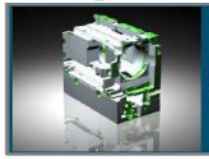
- Fuel Cell Solution: replaces batteries, fits in box
- Usage Profile: Intense towing, constant stop/go
- Voltage: 80V
- Power: 22 kW (handles 50k lbs.)

Accomplishments | Fuel Cell Design

Drop-in-Place Replacement For Battery

Fuel Cell System
- Stack (power)
- Battery (transients)

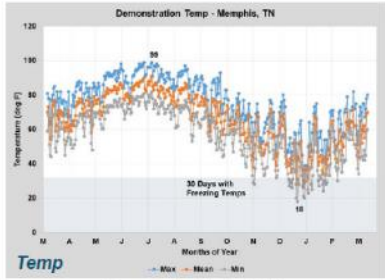
H2 Tank
- Energy (run time)

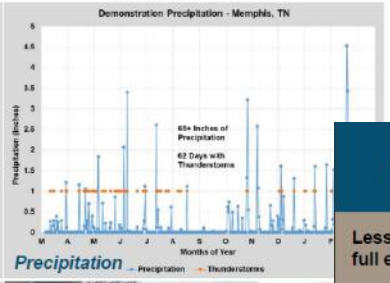


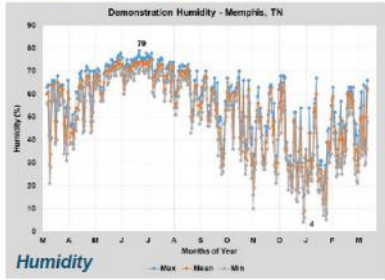
Ballast
- Weight (traction)

- Drawbar: 5,000 lbs.
- Towing Capacity: 40,000 lbs.
- Voltage: 80VDC
- Power: 22 kW
- 100% Outdoor Operation
- H2 Storage: 3.6 kg
- Hybrid PEM FC / Li-Ion Battery
- 4,000 lbs.

Accomplishments | Experience





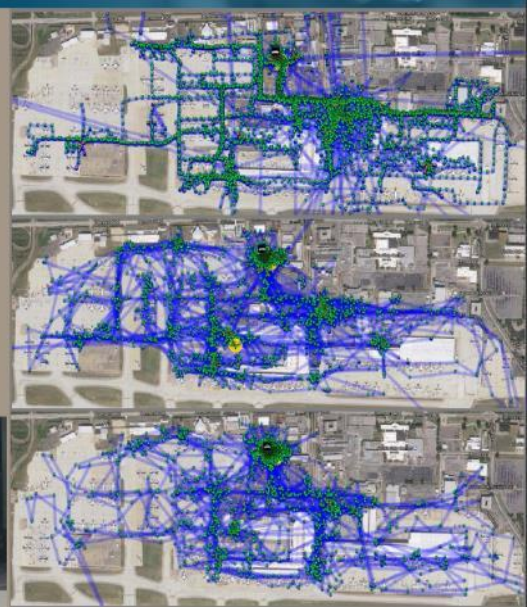


Challenges | Lessons Learned – MHE/GSE

Lesson #1: Tractor is able to handle the full extent of the application

Usage throughout airport / all applications
- Prep 4-dolly strings
- Tow 40,000 lbs. from planes to sort
- Input cans into sorting facility
- Tow 40,000 lbs. from sort to planes

Takeaways
- No issues operating outdoors 24/7
- Operate worst route for full shift without needing to refuel
- Weatherproofing is successful



80V 20kW – 6510 GenDrive Unit A
Available to Start Production in 2Q18

Hamburg Airport Baggage Tractor

- Mulag Comet 4E
- Plug Power 1600-80CE fuel cell

- Completed successful 2 month test at Hamburg Airport

Fuel Cell System Architecture

Power: Fuel Cell / Li-Ion Battery	Energy Storage: H2 Tank	Tractor Traction: Ballast

Market Expansion: Commercial Fleet Vehicles

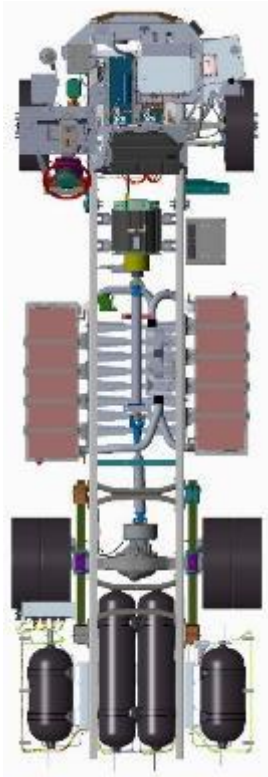
PLUG POWER

Fuel Cells:
Zero Emission
Technology of
Choice

- Extended Range
- High Asset Utilization
- Increased Payload
- Fast Fueling
- Lower Cost Infrastructure at Scale

Doubled Range of BEV
No Impact to Cargo Space
2X Fuel Efficiency over Diesel

FedEx Delivery Truck



FC / H2 Specifications

- Towing Capacity: 50,000 lbs.
- Voltage: 80 VDC
- Fuel Cell Power: 20 kW
- H2 Storage: ~156 kWh (11.6 kg)
- Hybrid PEM FC / Li-Ion Battery
- FC Efficiency: 45% (15 kWh/kg)

Truck Specifications

- GVW: 16,500 lbs.
- Voltage: 430 VDC
- Motor Power: 268 hp
- Motor Torque: 1620 ft-lbs
- Batt Energy Storage: 80 kWh
- Truck Efficiency: 0.9 kWh/mile

Market Expansion: Commercial Fleet Vehicles

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500 Kilometer Range
100 Vans in 2020
Express or City Routes

***"80 to 90 percent** of the express fleet can ultimately only be covered by vehicles with a box body and hydrogen."*
~Markus Reckling, DHL

Ships and Long Haul Vehicles

- Hydrogen is **the ideal solution** for heavy duty long haul
- Over **10x energy density** of batteries
- Refill times and range **similar** to diesel
- **Avoid** expensive grid charging infrastructure
- **Full payload** capability
- More **reliable** and less maintenance
- **Lower** operating and ownership costs

Lower Total Cost of Ownership than Batteries with Better Performance

Hydrogen & Fuel Cells at Ports

The Project Portal "Beta" truck under test runs at the Ports of Long Beach and Los Angeles. Source: Toyota USA

Photo of the hybrid fuel cell-battery-powered container handler under development by Hyster for use in California. Source: Hyster

- **HFC provide the long run time, quick refueling, and quiet, efficient power required to meet the fast-paced and constantly moving demands of ports**
- **The port also provides an ideal environment for hydrogen energy and fuel cells, offering centralized, large-scale production, storage and refueling sites for various applications**

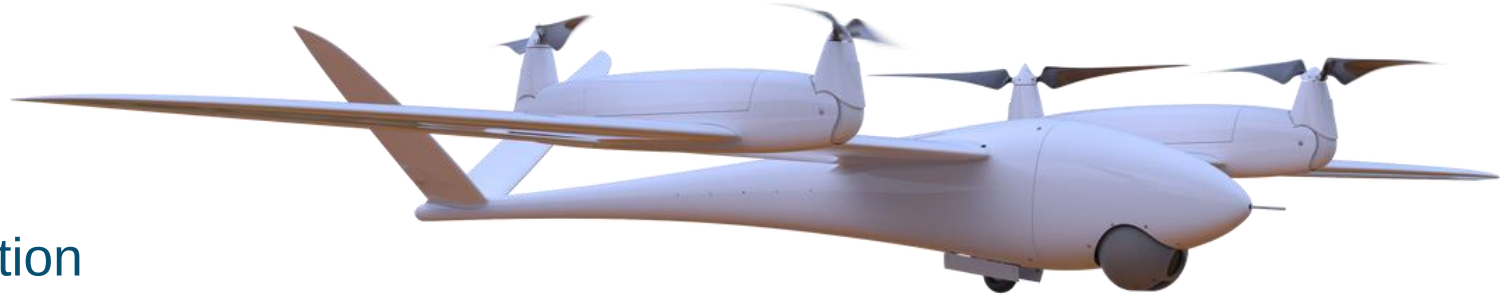
UAVs

- 10x **Range** and **Runtime** of Lithium Batteries
- Higher power density
- Fast refills (**minutes**)
  - Eliminates re-charging of batteries
- Up to **10 times the life** of lithium batteries
- Significant **value** for drone applications

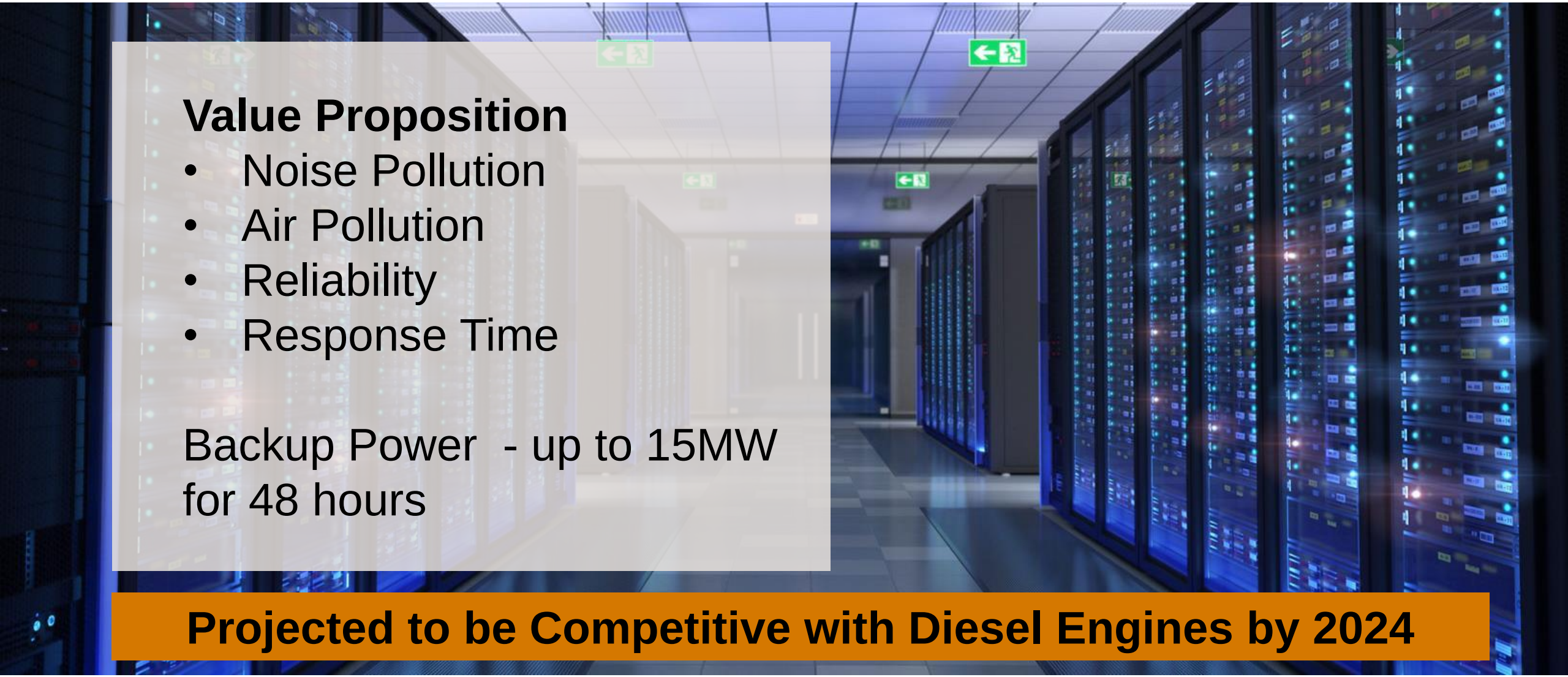
The Ideal Application for Fuel Cells

Small Scale Technology Platform:

- EnergyOR: Acquired by Plug Power
- Target applications
  - UAV, Robotics, UUV, AGV, etc
- Demonstrated performance in application
  - Long duration drone flights
- Developed light weight air cooled fuel cell system
  - 370/500W, 1kW
- Best in class specific power
  - Achieves 450-600Wh/kg
- Patented plate technology
  - Graphite foam (Grafoil)
  - Die cut flow fields



Future Data Centers – Large Scale Backup Power



Value Proposition

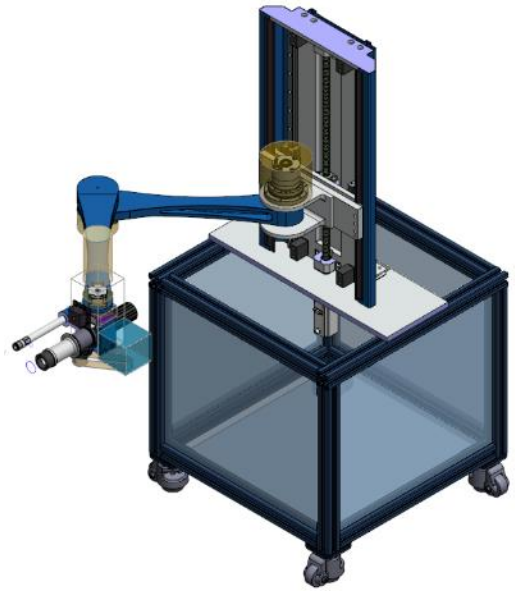
- Noise Pollution
- Air Pollution
- Reliability
- Response Time

Backup Power - up to 15MW for 48 hours

Projected to be Competitive with Diesel Engines by 2024

Technology: Automated Fueling

- DOE Budget Period 1 (Mar 2019 – Mar 2020)
  - Design, assemble and test prototype fueling dispenser for Autonomous Guided Vehicles
  - Research requirements and specifications for automotive fueling (primarily NREL)
- Work done to date
  - Implemented vision system using QR codes to locate nozzle
  - Created concept design for scara-type robotic fueling arm
  - Prototype assembly starts January 2020
  - WalMart has agreed to host customer demonstration in 2021
- Budget Period 2 (Mar 2020 – Mar 2021)
  - Design, assemble and test commercial-intent fueling dispenser for Autonomous Guided Vehicles. Testing to be performed at customer site for 16 weeks.
  - Demonstrate capabilities needed to fuel vehicles with off-the-shelf robot in a lab environment (primarily NREL)
- Budget Period 3 (Mar 2021 – Mar 2022)
  - Design and demonstrate autonomous fueling of hydrogen vehicle using off-the-shelf robot



Summary

- **PLUG Power** is the leading the way to zero emissions providing solutions to meet unfolding vehicle electrification and expanding hydrogen economy
- Substantial Growth opportunity in core market
- Strong Technology platform
- Opening multiple new mega markets
- Clear path to $1B in revenue and $200M in EBITDA, still less than 1% of addressable opportunity
- Hydrogen strategy a source of potential upside
- Team, Technology and Platform in place to execute!

PLUG POWER

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