

Hydrogen and Fuel Cells for Material Handling Applications

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- Leader in development and production of clean, commercial energy solutions for the material handling and industrial vehicle industry
- Plug Power Founded in 1997 in New York, USA
- Plug Power Europe was formed in 2012 as a joint venture to expand fuel cells for Industrial truck application.
- Plug Power Europe is a French registered company.
- Starting mid 2015, Plug Power Europe is a fully owned subsidiary of Plug Power
- Sales offices in France, Germany and UK to cover all of Europe.
- Service and operations center located in Belgium to cover all of Europe.
- Comprehensive European based service and engineering teams to support European product deployment.
- Over 450 employees worldwide.
- More than 14,000 units in the field
 - 121 million hours of runtime
 - >10000 Kg of Hydrogen used daily.
 - 150 fueling stations
- 180+ issued patents in Hydrogen technology.

Plug Power holds more than
90% of the fuel cell market
in the material handling
industry.

- Premier list of customers:
 - Colruyt, Belgium
 - Carrefour, FM Logistics, Prelocenter France
 - BMW, Daimler, Germany
 - Honda, UK
 - Walmart
 - Amazon
 - BMW, Daimler USA
- “One-stop-solution” option couples:
 - **GenDrive** fuel cell system
 - **GenFuel** hydrogen & fueling infrastructure
 - **GenCare** customer service

HONDA



Carrefour



Mercedes-Benz



colruyt

PRELOCENTRE

FM LOGISTIC

amazon

Walmart

**Increased Performance
leads to Economic ROI**

- **What are GenDrive fuel cells?**

- Complete fuel cell system in a box
- Superior alternative to industrial lead-acid batteries
- Proton Exchange Membrane (PEM) based hydrogen fuel cells, coupled with lithium ion battery to deliver DC power to the forklifts
- Small Li-ion battery provide energy for start up and help recuperate regenerative energy.

- **What do GenDrive fuel cells do?**

- Replace lead-acid batteries permanently
- Run on hydrogen gas and can be refueled in as little as 1- 3 min
- Produce no emissions except water and heat



- **High Throughput Food Distribution Centers**
 - Mix of reach and order picking trucks
 - High labor costs, High Energy costs
- **Consumer and Retail Distribution Centers**
 - Mix of counterbalanced, reach and order picking trucks.
- **Manufacturing Facilities**
 - A majority of counterbalanced and tugger trucks
 - Large labor forces, Large energy consumption

GENDRIVE

Class 1 Suite
Sit-down Lift Trucks
11 kW, 12 kW



GENDRIVE

Class 2 Suite
Reach Trucks
11 kW,



GENDRIVE

Class 3 Suite
Rider Pallet Trucks
1.5 kW, 3.5 kW

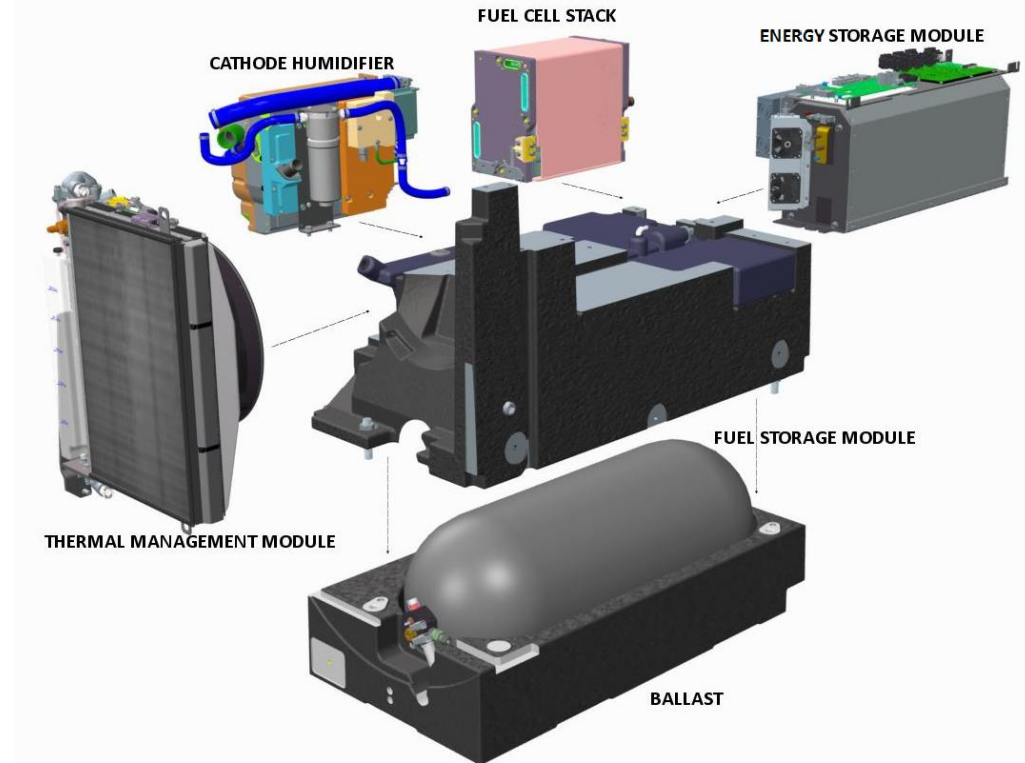


GenDrive Fuel Cell System

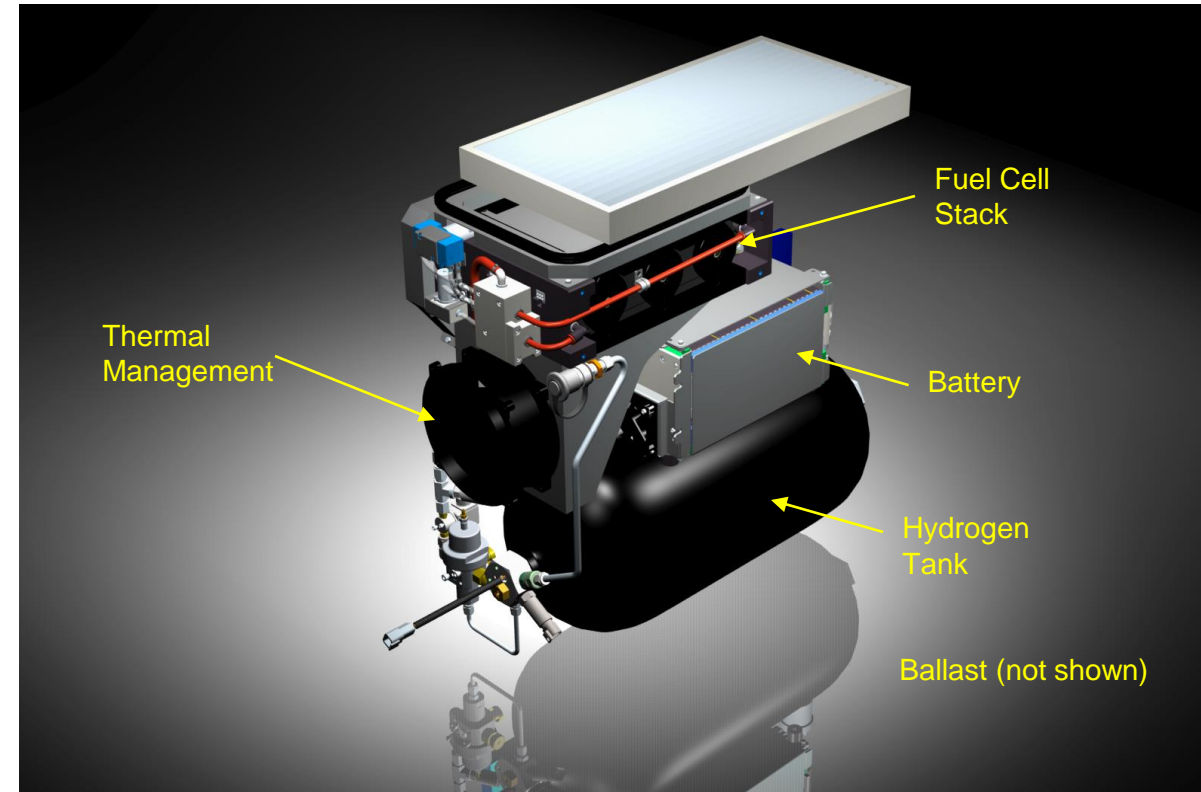
- Lead Acid battery replacement fuel cell system
- Available in 24, 36, 48, 80 voltage rating
- Uses industry leading Li-ion battery technology for peak power demand
- Meets Battery DIN Standard requirements for various OEM models
- Systems tested for freezer (-30C) application and high ambient (40C) applications
- Fully compatible with truck OEM standards and tested by OEMs
- Plug Power's GenDrives are CE certified:
 - Pressure Equipment Directive (2014/68/EU)
 - Machinery Directive (2006/42/EC)
 - Electromagnetic Compatibility Directive (2004/108/EC)



- A Liquid-Cooled GenDrive unit contains six main components
 - The fuel cell stack is the heart of the system and converts hydrogen and oxygen to electricity and water
 - An energy storage module (lithium-ion battery) handles startup and peaks in the load
 - Humidification ensures long life of the fuel cell stack
 - Thermal management is provided by a liquid cooling unit consisting of a radiator, fan and pump.
 - The fuel tank stores hydrogen compressed to 350 bar nominal pressure
 - A cast-iron ballast ensures that the GenDrive meets the minimum weight requirements



- An Air-Cooled GenDrive unit contains five main components
 - The fuel cell stack is the heart of the system and converts hydrogen and oxygen to electricity and water
 - An energy storage module (lithium-ion battery) handles startup and peaks in the load
 - Thermal management is provided by fans
 - The fuel tank stores hydrogen compressed to 5000 psig
 - A cast-iron ballast ensures that the GenDrive meets the minimum weight requirements
 - Humidification is not required in air-cooled systems



GenDrive Solves the Retrofit Problem

- GenDrive is designed to retrofit existing electric forklift trucks with no modifications required. Simply remove the battery and install GenDrive. The lift is now hydrogen capable with no need for battery changes.
- Up to 75% of the weight of the GenDrive is ballast added to meet truck requirements. The GenDrive must weigh as much as a battery made almost entirely of lead
- Lift trucks require 24, 36, 48 and 80V and a wide range of power. GenDrive achieves this with a variety of stack options and technologies
- Lift trucks require many different shapes. GenDrive is available in more than 70 different form factors



Key Benefits of GenDrive® Systems Implementation

Increased Productivity

- Forklifts operate at **consistent full speed** & power at all times
- Refuel in **less than 3 minutes** versus 10 – 20 minutes per battery change
- Increase **floor space** for product storage

Reduced Operational Expenses

- Economic lifetime up to **1.5x – 2.0x** longer than lead acid batteries
- Proven **productivity gains and operational savings**
- Higher throughput or repurpose /reduction of workforce

Environmental Benefits

- **Zero emissions**, recyclable
- **85% reduction** in Greenhouse Gases
- Elimination of personnel contact with toxic materials

Increased Commercial Efficiency

- **Battery rooms eliminated – more room for revenue generating activities**
- Drop in replacement solution

15%

Increase
productivity
up to 15%

>50%*

Greenfield IRR
Payback < 1 yr
~\$3M in savings

Reduce
carbon
footprint up to
80%

85%

ProGen Modular Architecture



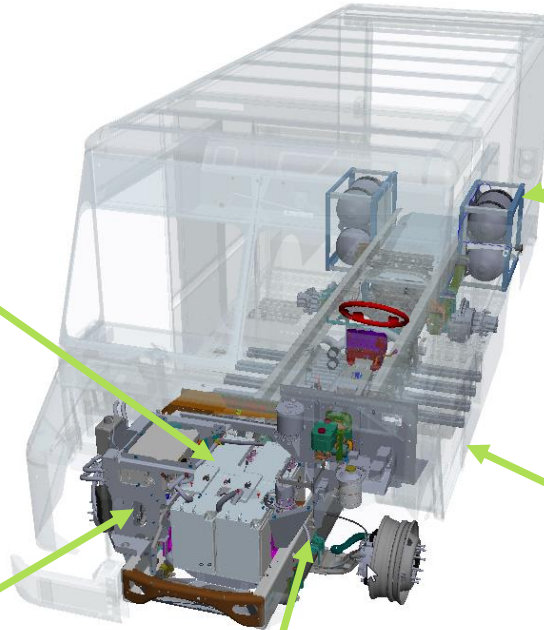
Stack Module

- 15, 20, 30 kW Stack
- Air Blower/Compressor
- Humidifier
- H₂ Regulator
- Sensors
- Control Electronics
- CAN communications



Thermal Module

- Radiator
- Cooling Fan
- Coolant Pump
- CAN communications



DC/DC Converter

- 15, 20, 30 kW
- 350-700V
- CAN communications



H₂ Storage Module

- Tanks
- Sensors
- Fueling Receptacle
- CAN communications



Battery Pack

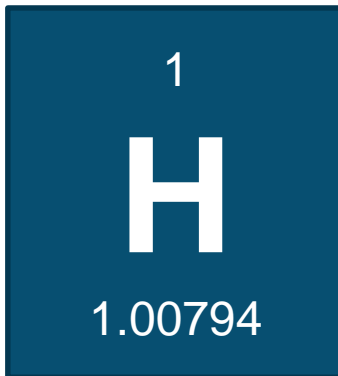
- 350-700V
- Battery Management System
- CAN communications

- GenDrives are qualified by the truck OEMs.
- We have close working relationship with all major truck OEMs
 - Linde MH
 - Still Gmbh
 - Jungheinrich
 - Crown Europe
 - Toyota Europe
 - Yale / Hyster
- Enables ease of integration of GenDrive.
- OEMs perform necessary truck safety verification.
- GenDrive has an option to communicate via CAN



- GenDrive integrated Design for safety:
- Active ventilation monitoring via tachometry feed back sensor
- High pressure Hydrogen Safety Devices:
 - High Pressure tank thermally activated relief valve
 - High pressure tank solenoid valve, Manual tank valve
- Low pressure hydrogen safety devices:
 - Low pressure relief valve, Low pressure shutoff valve
- Hydrogen leak monitoring: Hydrogen sensor, Pressure decay
- Continuous Battery temperature and voltage monitoring
- Several subsystem level safety sensors
- Dual redundant safety circuit to monitor system level safety
- Field return of experience is utilized in product design for improvements.

GENFUEL®



Molecule



Infrastructure

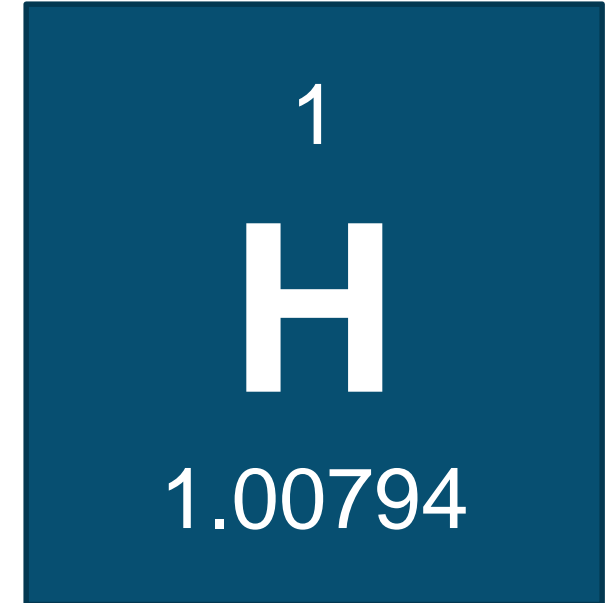
- Large Outdoor H₂ Pad
- Small Outdoor H₂ pad



Indoor & Outdoor
Dispensers

Plug Power proprietary dispensers: intelligent dispensers that gather and communicate fuel and fuel cell data

- Lightest and smallest element
- Odorless, colorless and tasteless
- Non-toxic and non-poisonous, renewable energy source, unlike methane and gasoline
- Rapid dispersion in case of a leak
 - Rises at a speed of ~ 20 meters/second
- 3 times the energy content of gasoline (by weight)
- When used in energy production:
 - Hydrogen is at least 60% efficient; Gasoline is 33-35% efficient.
- Industrialized countries produce hydrogen for various applications:
 - Chemical, food and electronics industries
 - Source of Energy



Outdoor Equipment Pad

- Redundant system capable of expansion, growth and seasonal demand
- Sub-Assemblies are built at Plug Power and tested prior to shipment for prompt deployment
- Pad layout is generally a 15 m x 20 m area for a horizontal tank, and slightly smaller for a vertical tank, and can be installed in a typical trailer parking area
- All hydrogen tubing and utilities are run underground to the building

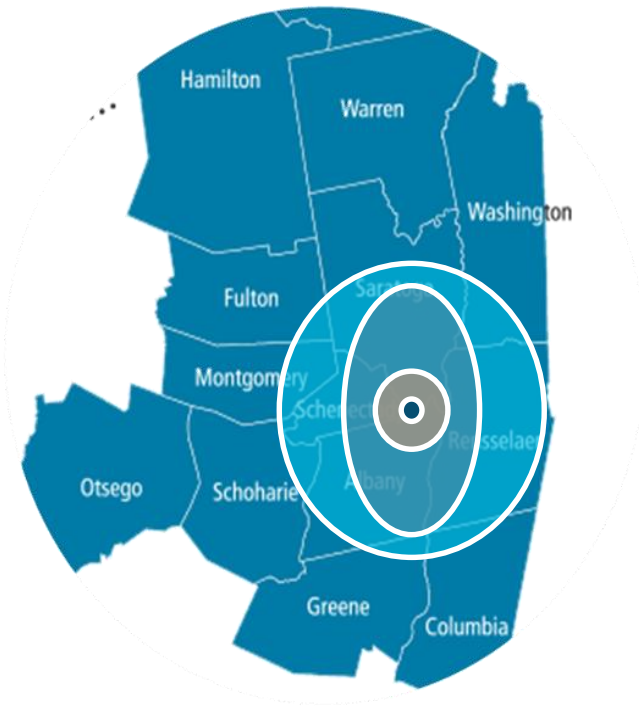


- No H2 is released inside the building during a refuel
- Plug Power's Dispenser is CE certified, to the following
 - ATEX Equipment Directive (94/9/EC)
 - Pressure Equipment Directive (97/23/EC)
 - Electromagnetic Compatibility Directive (2004/108/EE)
 - Low Voltage Directive (2006/95/EC)
 - Machinery Directive (2006/42/EC)
 - ISO/TS 19880-1:2016 Gaseous Hydrogen Fuel Stations
 - SAEJ2601-3: Fueling Protocol for Gaseous Hydrogen
- Mandatory Safety Measures built in station
 - H2 Detection [Triggers at 25% LEL of H2]
 - 5 m radius safety zone.
 - Fire Extinguisher and Alarm Pull Station
 - Fueling Protocol to identify leak check
 - Emergency stops present to stop H2 flow during emergency
- Plug Power Dispenser offers additional safety
 - Depowering of the electric forklift during refill
 - Monitoring of hydrogen tank temperature
 - Safety pressure mat: operators do not leave fueling stations during fill

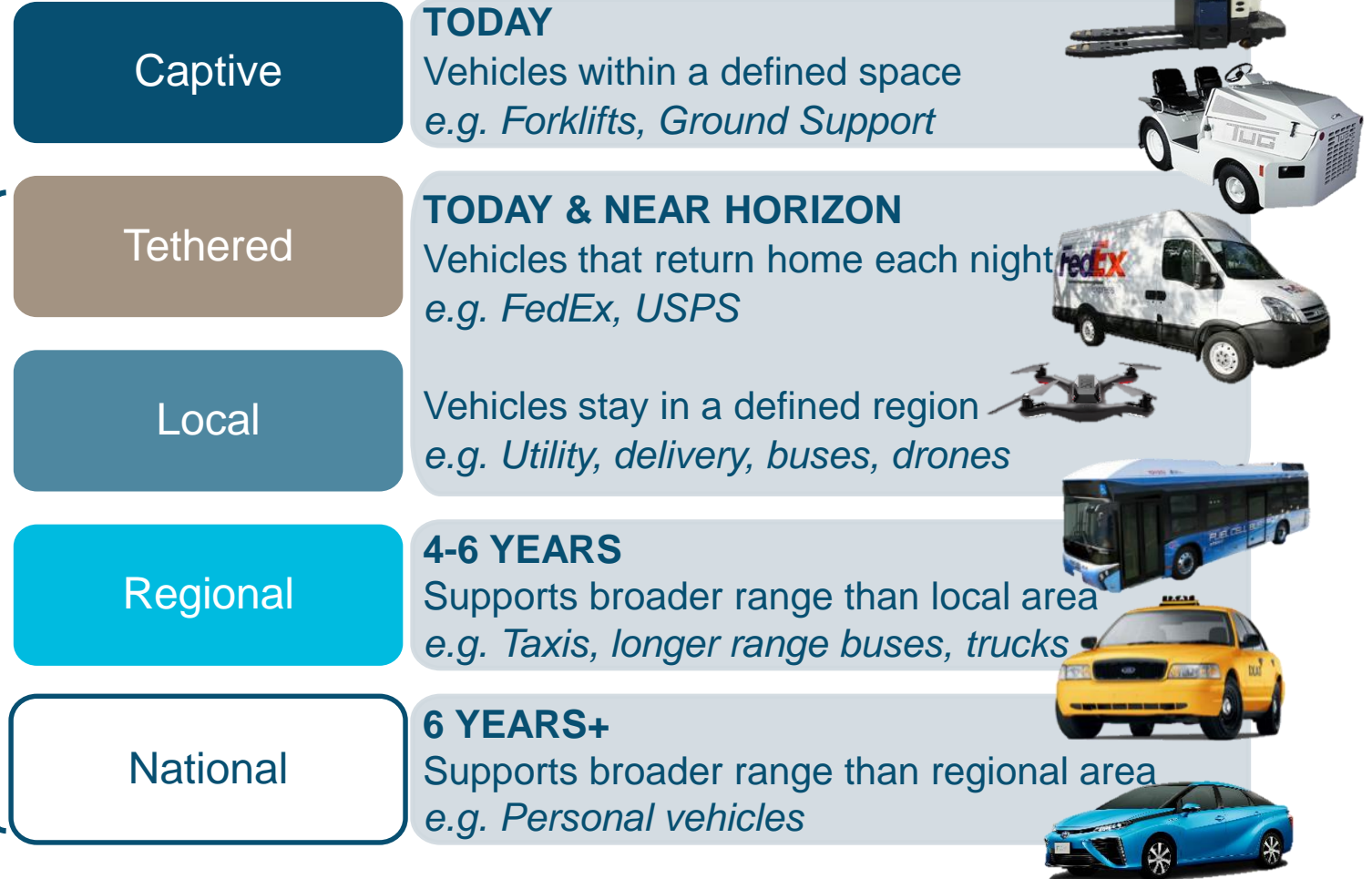


Hydrogen Port City Concept

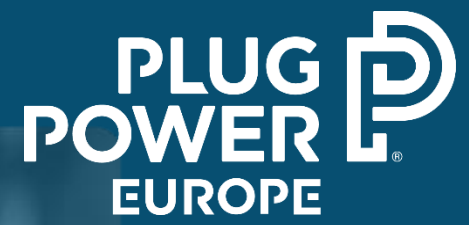
Example: H2 Port City



Leveraging existing technology to
increase range & power



- Hydrogen energy and fuel cells are not a research project anymore. Several companies for 3 shift operations are fully dependent on Hydrogen energy.
- Hydrogen fuel cell product safety is achieved through design, testing, production and continuous monitoring.
- Hydrogen fuel is a clean, safe alternative fuel that is widely used in industrial truck application in Europe and North America.
- Refuelling stations both indoor and outdoor safely operating in North America providing hydrogen for GenDrive.
- Hydrogen fuel is not only a green energy, it is providing a reliable, safe, cost effective alternative to conventional batteries.



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