



Fuel Cell Electric Trucks For Ports Operational, Economic & Societal Benefits

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Hyster-Yale Group

Manufacturer
of materials
handling
equipment for
80+ years

3rd largest
lift truck
manufacturer
globally

(by units sold 2015)

Major
equipment
supplier to ports

Today offering
fuel cell systems
for Class 1, 2,
and 3 lift trucks



Goal: Full electrification of product range, including fuel cell options

**Fuel Cells Power
Manufacturing,
Warehousing and
Distribution** in
Multi-Shift Operations
Using Electric Sit-Down
Reach Trucks and
Pallet Riders



Fuel Cells Deliver on Six Value Drivers

In targeted applications for manufacturing, warehousing and distribution

PRODUCTIVITY



V
S



Elevate truck and labor utilization

WORKPLACE

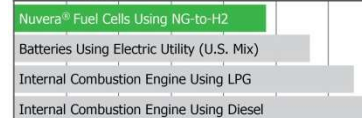


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Improve facility health

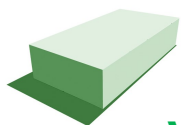
SUSTAINABILITY

Total Energy Use

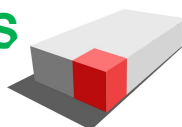


Advance corporate initiatives

SPACE SAVINGS

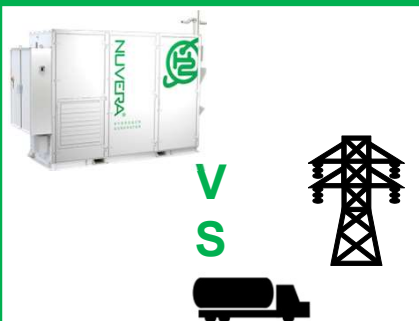


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Realize space savings

ENERGY SUPPLY

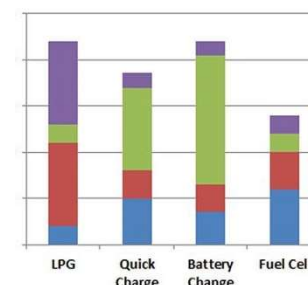


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Gain control over energy supply

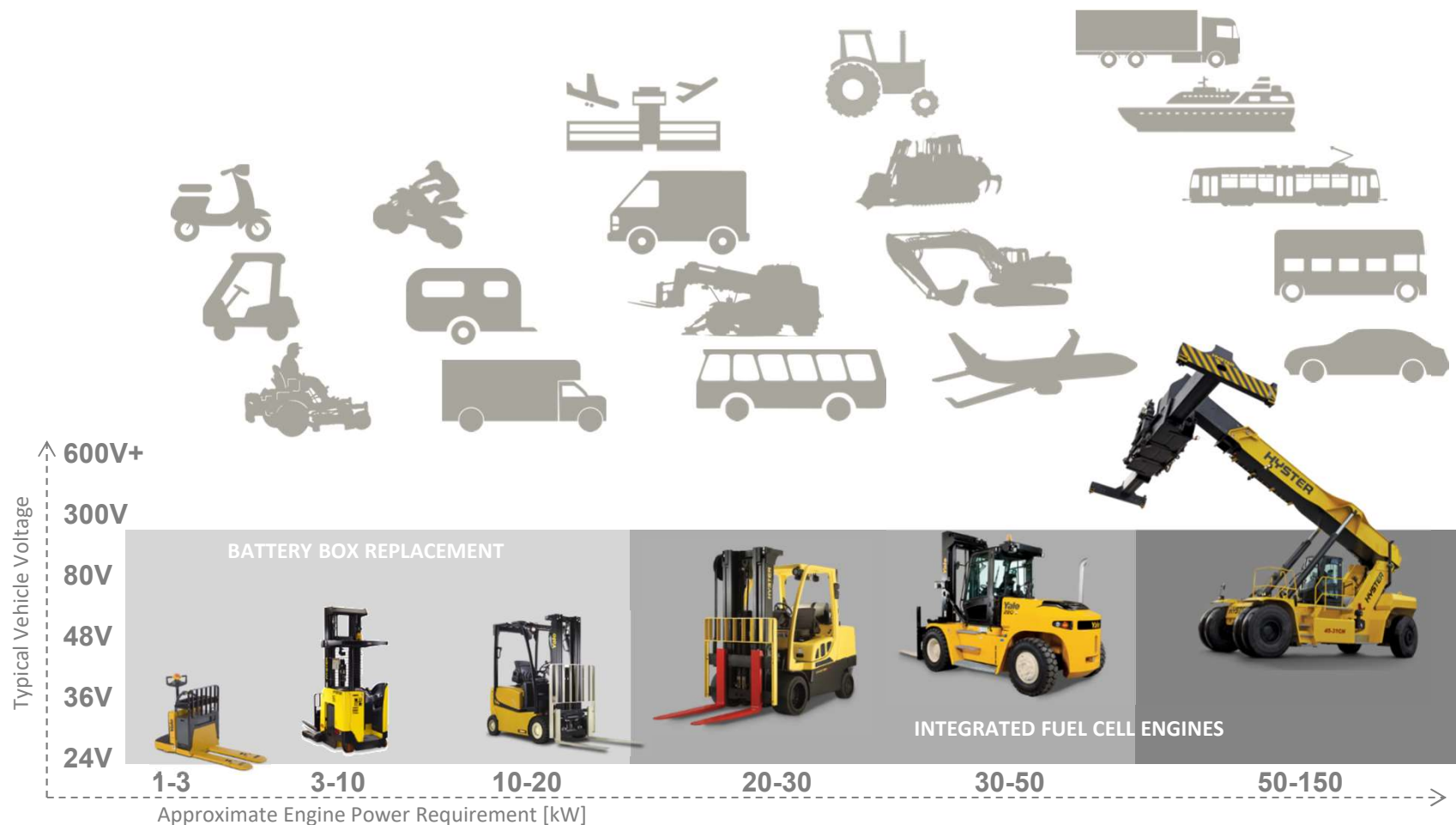
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TOTAL COST OF OWNERSHIP



Tools to Compare TCO

Opportunities for Fuel Cell Motive Power



Integrated Fuel-Cell Hybrid Truck

Nuvera® Fuel-Cell Engine



Battery (Li-Ion)



Laden Container Handler Applications

Duty Cycle*	Average Power	Fuel Cell Range Extender Power
Mild	55-70 kW	1 x 50 kW / 2 x 30 kW
Heavy	70-85 kW	2 x 30 kW / 3 x 30 kW
Severe	85-110 kW	3 x 30 kW/ 2 x 50 kW

* Duty cycle assessments based on load monitoring of terminal operator at Port of LA

The Electrification of Port Equipment

- ▶ Eliminate burning of fossil fuel by port equipment
- ▶ Eliminate diesel fuel handling and support operator health and safety
- ▶ Lower noise in population centers
- ▶ Reduce equipment maintenance costs
- ▶ Lower the cost of regulatory compliance

CARBON REDUCTION

26.3 kg of CO₂ are produced for every liter of diesel burned

Average fuel consumption of a top loader:

≈ 16 liters/hour

→ 42.7 kg CO₂/hour

At 3000 hours per year, each diesel top loader produces:

≈ 128,000 kg CO₂/yr

Additional FC Value Drivers for Ports

PRODUCTIVITY



A yellow Hyster forklift with a crane attachment is lifting a yellow container at a port. The forklift has "HYSTER" and "45-3TCH" written on it. The container has "HYSTER" and "45-3TCH" written on it. In the background, there are other containers and a large crane structure.

Fuel cells offer means to operate longer periods without disruption

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without disruption

LABOR



Fuel cells offer same refueling characteristics as diesel

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Hydrogen Supply

Mobile Fueler
<20 kg/day



75 kg Storage

On-Site Generator
50-150 kg/day



**Steam Methane
Reformer**

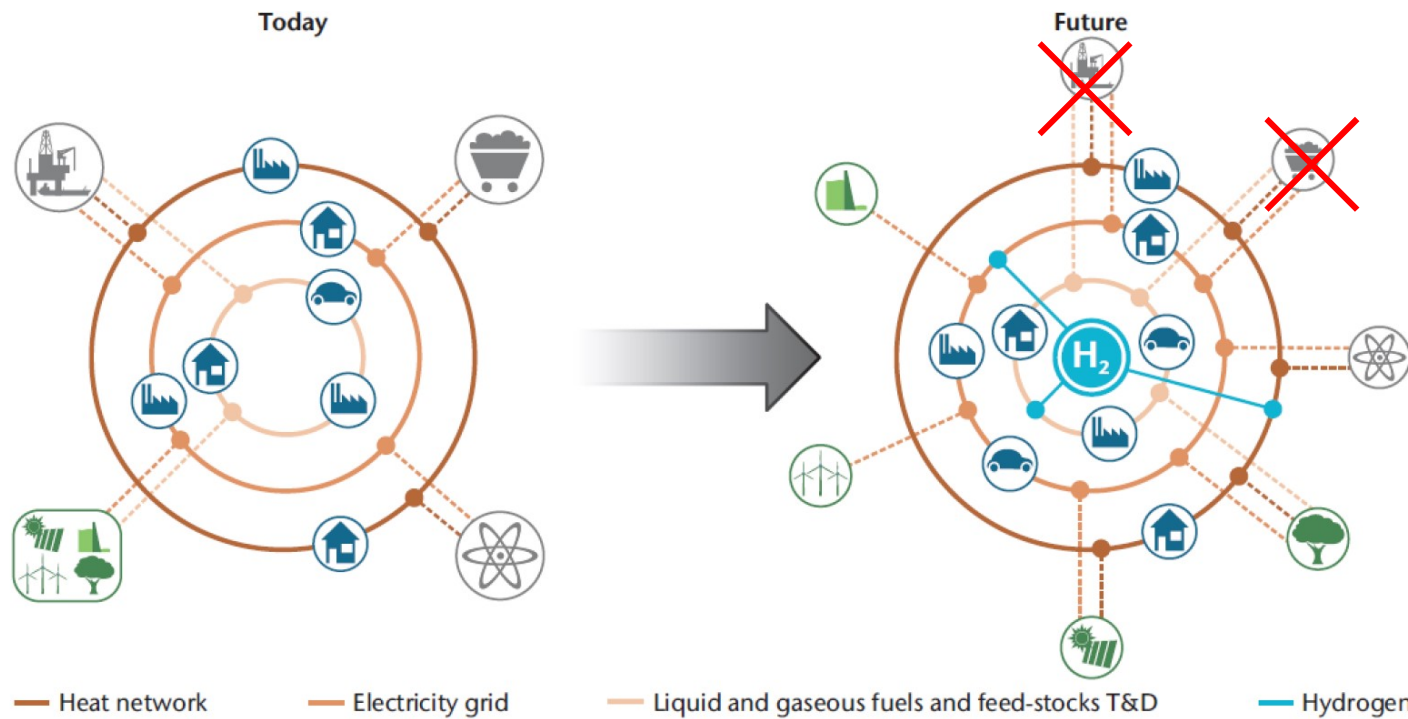
Delivered Liquid H₂
>100 kg/day



On-Site Storage

H₂ Supply: Team Up with Power Grid

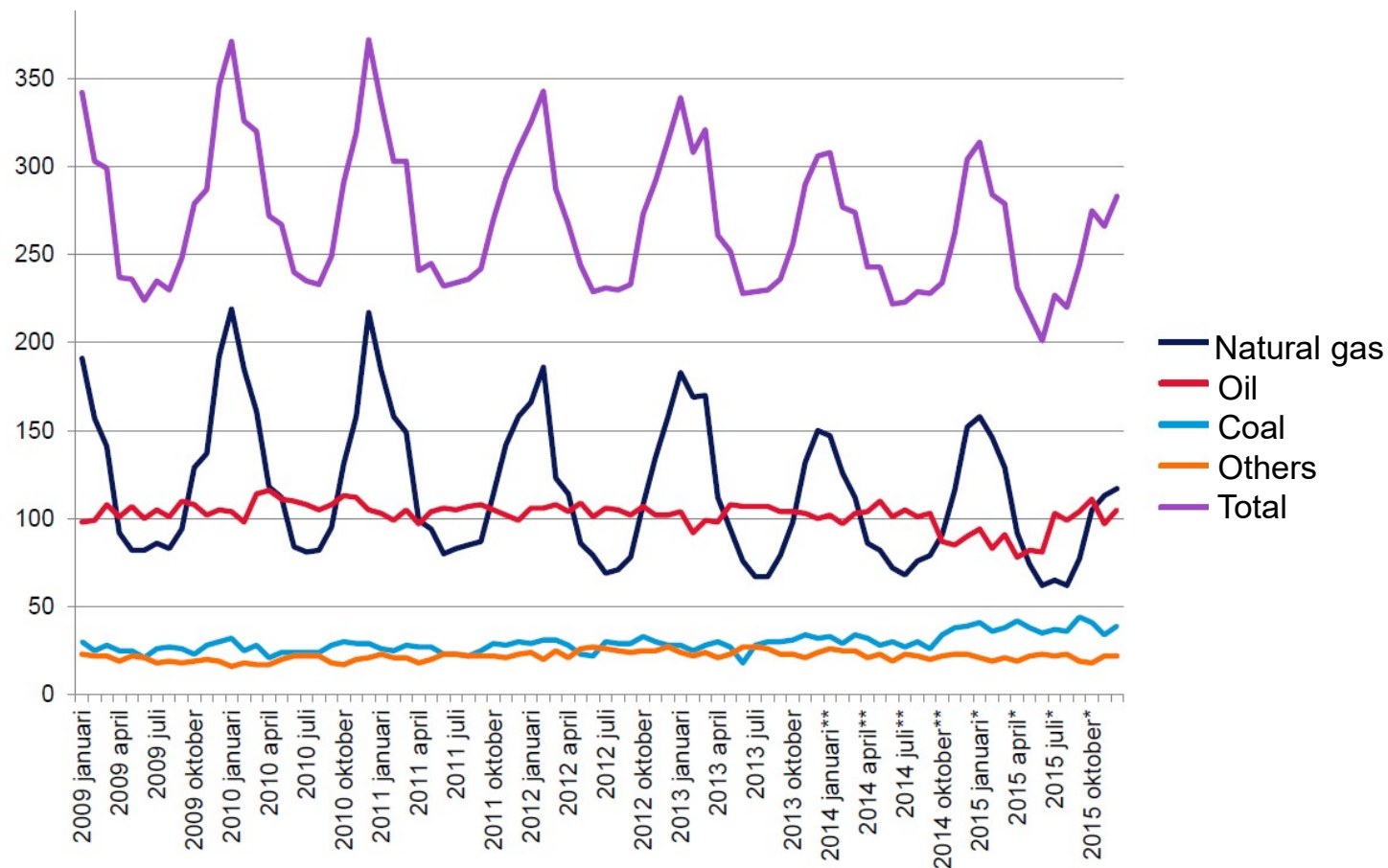
Energy storage needed



Source: Technology Roadmap – Hydrogen and Fuel cells; IEA, 2015

Seasonal Energy Storage Buffer Required

Energy Feedstock Usage in the Netherlands, 2009 - 2015



Source: HAN University

Hydrogen can be used to store energy produced renewably for use when needed.

Voice of the Customer

Hydrogen fueling should mimic current diesel fueling operations

- Fuel is transported to the equipment
- Fueling is performed by dedicated personnel, not equipment operator
- Labor may perceive hydrogen as unsafe

There may be multiple duty cycles within a single terminal operator's business

- Some duty cycles may support opportunity charging
- Other duty cycles require that the equipment operate continuously through one or more shifts

Fueling infrastructure is critical

- Siting and permitting is an issue, for mobile refuelers as well as stations
- Safety protocols need to be developed
- Minimal footprint for fueling infrastructure is required

Fleet operators want equipment, parts and service from established OEMs

Summary

The more quickly hydrogen and fuel cell technologies are commercialized, the sooner both customer and societal benefits will be realized

- Provides the means for vehicle electrification at big truck scale
- Affords benefits to fleet operations that also further public policy goals
- Energy storage requirements driven by the increased adoption of renewables are synergistic with the increased adoption of fuel cell-powered equipment

Summary

Hydrogen supply is critical

- Hydrogen is already widely available as an industrial gas
- Hydrogen fuel infrastructure must be established as fuel cell powered vehicles are introduced
- Multiple supply options make its use in ports practical

Summary

Partnerships are needed at every level!

- OEMs and technology providers cannot succeed without customer involvement in the development stages
- Hydrogen is an ideal partner for a new and changing power grid
- Governments should support the increased use of hydrogen in all applications to meet air quality, carbon reduction, and renewable energy storage objectives

Thank you!

For more information, visit:

- www.hyster-yale.com
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