



**STRONG PARTNERS.
TOUGH TRUCKS.™**

CREATING HYDROGEN DEMAND AT PORTS AND TERMINALS

LAUNCH ALASKA

SEPT 13, 2023

HERMAN KLAUS, DIR APPLICATION SOLUTIONS

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*Transforming the way the world moves
materials from Port to Home*



Hyster-Yale Materials Handling, Inc. (NYSE: HY)

- 2021 revenue = \$3.1B
- ~8000 Employees worldwide
- Global HQ in Cleveland, OH

- **Hyster** = Full Line MH supplier
- **Nuvera** = H2 Fuel Cell manufacturer

HYSTER FULL RANGE OF MATERIAL HANDLING EQUIPMENT



Class 1

Electric counterbalanced
1-5.5t

Class 2

Electric narrow aisle
1.5-3.0t

Class 3

Electric hand trucks
1.5-8t

Class 4

ICE cushion tire
1-8t

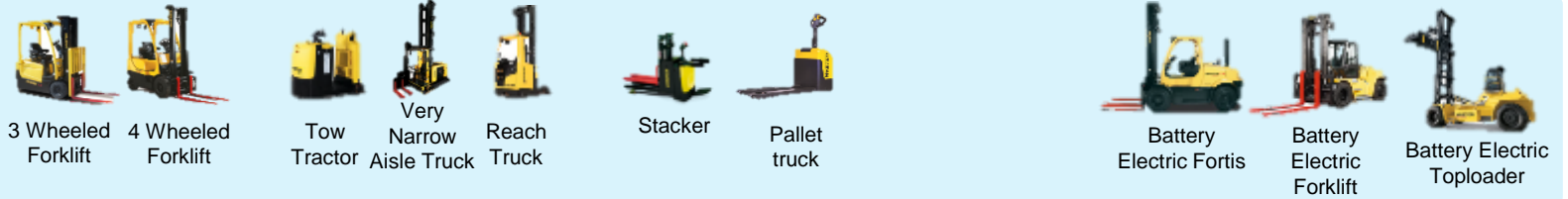
Class 5

ICE pneumatic tire
1-58t

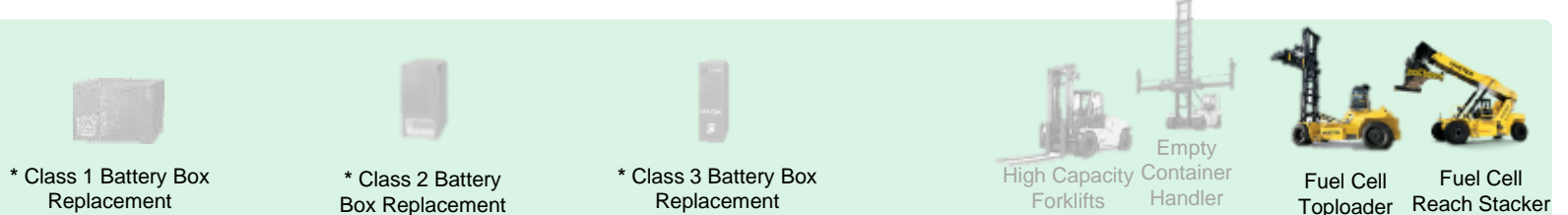
Diesel



Electric



Fuel Cell



ZERO EMISSIONS: BATTERY OR H2

Technical challenge port equipment: 100% diesel fuel replacement

- ▶ Batteries: Li-Ion
 - ▶ 800 l Diesel Tank
 - ▶ 7760 kWh battery pack
= **57 m³** (114 m³ for lead-acid), **97 tons**



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- ▶ Fuel cell: hydrogen H2
 - ▶ 800 l Diesel (= 7760/33.3) = 233 kg H2
= **5.8 m3** @ 700 bar.



What is needed: Application specific truck configurations + Intelligent Design
Optimized Sizing of batteries and hydrogen system linked with Smart charging/Refill strategy
Smart energy recovery for maximum efficiency

Fleet size



- ▶ Amount of trucks
- ▶ Ability to plan charging/refilling

Operation & Application



- ▶ Number of shifts
- ▶ Duty cycle

Infrastructure capabilities



- ▶ Electrical grid connection
- ▶ Electric grid stability
- ▶ Hydrogen availability

TRUCK FLEET SELECTION



Fuel Cell Helps Completing Shift

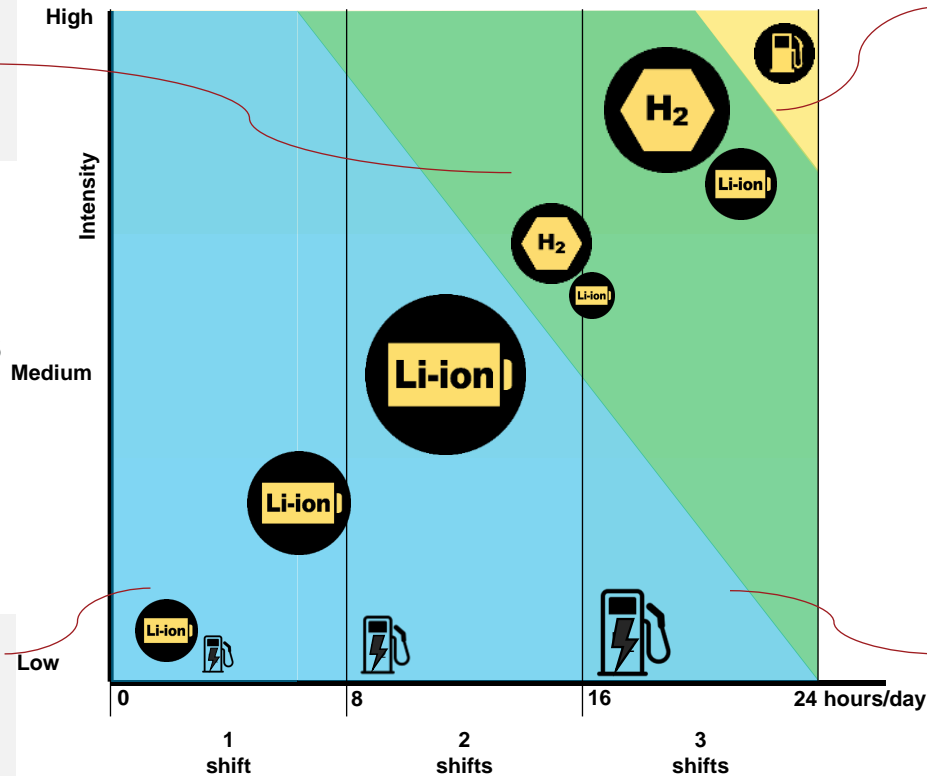
When continuous operation is required

Battery Powered for Light Applications

- Modular setup battery pack matches with the application
- Charger size to fit the application

Battery & Charger Size Modularity

To determine the best fit with the application



Diesel for Extreme Applications

Additional truck when possible
Backup for peak days
Remote applications

Fuel Cell Powered for Tough Applications

- Hydrogen fuel cell powers the truck
- Battery pack flattens the peaks in power demand

Battery & Fuel Cell Possible

Battery with a large charger, since charging time is limited
Hydrogen when preferred e.g. supply already available at the location

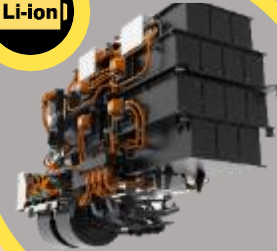
HYSTER® PORT EQUIPMENT



HYSTER® DEVELOPS FULL LINE ZERO EMISSION OFFERING FOR PORTS:

- FULL ELECTRIC (LITHIUM-ION)
- FUEL CELL HYBRID (HYDROGEN — LI-ION)

Li-ion



H₂



PROJECT TEAM AND ORGANIZATION



Project Sponsor



Demonstration Site



Prime Contractor / Project Manager



Commercial Fleet Partner and Operator



Hydrogen Fuel Cell System Provider/Integrator



Vehicle OEM/Integrator



Mobile H2 Fueling Provider



Wireless Charging System Provider/Integrator

VEHICLE OVERVIEW



- Electric Top Loader (ETL)
- Hyster-Yale Group, Inc. (HYG) vehicle
 - Hyster H1150HD-CH class
 - Drive System: AC Motors (4) + 130 kWh Li-ion Battery
- Fuel cell and hydrogen storage system
 - 2 x 45 kW Nuvera fuel cell engines
 - 30 kg of hydrogen storage @ 350 bar



WALLENBERG
STOCKHOLM
9731640

NO SMOKING

MAX LOAD 320T
BOX 12.2' x 7'14.6" x 43'6.0"

WALLENS
WALLENS

July 28, 2022
Port of Los Angeles



IN-SERVICE DEMONSTRATION



- Fenix Marine operating the ETL in routine service at POLA.
 - Project Team providing technical support
- Focus on maintaining optimal reliability, efficiency, and performance
- Data plan was constructed prior to this period
 - Means of data collection and analysis
- Data collected will be provided to CARB



H2 FUELING



Bayotech/IGX	GTM 1500
Max Pressure	6,500 psig
Total Capacity (@ 6,500 psi)	146.6 kg
Dispensing Capacity (@ 5,000 psi)	30 kg
Outlet Connection/Nozzle	TK16-50
Fuel Quality	SAE J2719

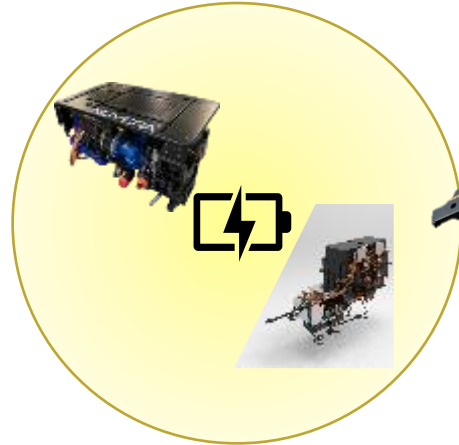
Preliminary findings:

- 3+ kg/hr (duty cycle dependent)
 - Diesel truck uses 4.5 gal/hr
- 15% regeneration (braking and lowering load)
- Close coordination for infrastructure deployment re: timing
- Drivetrain and individual component technology is established
 - Development challenges are associated with controls and efficiency improvements and application specific nuances
- Cost of hydrogen, especially at this entry level scale remains expensive

FULL ELECTRIC PORT OFFER COMING TOGETHER



MODULAR DESIGN / COMMON SYSTEMS



FUEL CELL ELECTRIC TERMINAL TRACTOR



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Capacity Trucks links with Hyster-Yale

News 16 Dec 2020 by WCN Editorial

The US companies are joining forces to develop battery-electric and hydrogen fuel cell electric terminal tractors and initial prototypes are targeted to be available for field-testing during 2021



A Capacity Trucks' T2 Series diesel terminal tractor

The collaboration leverages each company's product expertise in the global mobile material handling solutions market, bringing together Capacity's terminal tractor platform and Hyster-Yale Group's experience in lift truck electric powertrain technology and hydrogen fuel cell technology developed by it.

On top of that the parties are looking at autonomous drive vehicles, and VDL Automated Vehicles, the port AGV developer that is part of VDL Groep BV in the Netherlands, is designated as the preferred integration partner and supplier for automation.

The agreement includes exclusive manufacturing and supply



BOTH ELECTRIC & FUEL CELL HYBRID POWERTRAIN

- Tractor ready for testing end 2023
- Performance equal to or better than ICE TT*
 - H₂ ETT able to run at least 8-hr shift

* Truck autonomy depends on amount of on-board energy (i.e. Batteries or Hydrogen). Space limitations requires more frequent recharging / refueling compared to diesel. Actual recharging needs depend on operational parameters. The H₂ capacity is designed to suffice for a full shift for 97% of existing customers based on telemetry data

FUEL CELL ELECTRIC EMPTY HANDLER

HHLA



- Full-shift capability
- Fast refilling
- Status: In development

FUEL CELL ELECTRIC REACHSTACKER

Port of Valencia



- 2 x 45kW Nuvera Fuel Cell
- ~ 30 kg H₂
- ~ 130 kWh Li-ion Battery
- Full-shift capability
- Fast refilling
- Status: User testing underway

SEAPORTS AS DRIVERS FOR HYDROGEN ADOPTION



Port Side:

- Cranes
- Rubber-Tire-Gantries
- Reachstackers
- Empty Container Handlers
- Terminal Tractors
- Drayage Trucks
- Commercial Vehicles
- Buses



Ship Side:

- Ship-to-Shore Power
- Auxiliary Power
- Pilots
- Ferries
- Special Port Vessels
- Short Sea Shipping
- Ocean-Going Vessels

Hydrogen Infrastructure

- Transport Pipes
- Industrial Usage
- Industrial Production
- Fueling Systems

Many of the critical use cases 'meet at the port'
Public-private collaboration to accelerate further

Thank You

Herman Klaus

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Port of Los Angeles

Funded by California Climate Investments

