HYSTER-YALE GROUP

Port Equipment Electrification
The Challenges Ahead

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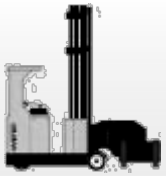
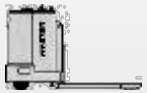
The Materials Handling Industry Background

1. Building Electric Vehicles since 1932
2. Until recently this industry was the largest Electric vehicle manufacturer in the world with over 300,000 vehicles produced globally.
3. Lead Acid Batteries have been the mainstay of our Industry but with Low voltages (24, 36, 48, 72, 80) From 10kWh to 128kWh
   a) Require high Maintenance
   b) Require dedicated ventilated charging areas.
   c) Limited to a max 0.3C charge rate but are pushed to 0.5C.
   d) Opportunity and Break Charging cant keep up with Energy Demand
      a) Battery Swapping – Special equipment needed to handle up to 3000 kg batteries
      b) Truck Swapping - Adds to the customer cost of acquisition and operation
   e) Battery Overheating occurs beyond a 2 shift operation.
   f) Opportunity and Break charging have increased connector maintenance.

The Hyster-Yale Product Range

Vehicle Product Range

Class I	Class II	Class III	Class IV	Class V
				
Electric Counterbalanced Rider Trucks	Electric Narrow Aisle Trucks	Electric Hand Trucks	Internal Combustion Engine (Cushion)	Internal Combustion Engine (Pneumatic)
1.0T to 5.5T Capacity	1.5T to 6.0T Capacity	1.5T to 8.0T Capacity	1.0T to 7.0T Capacity	1.0T to 52.0T Capacity

Electric CB

3 wheel Electric

4 wheel Electric

Warehouse Equipment

Reach Trucks

Order Pickers

Pallet Trucks

Very Narrow Aisle Trucks

Stackers

ICE CB

Internal Combustion Engine

Big Trucks

Empty Container Handlers

Reach Stackers

Forklifts

Laden Container Handlers

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A Brief Port Equipment History

- Hyster-Yale Group (HYG), or its predecessors, has been building Materials Handling Equipment for Ports all across the world for 80+ years
- In 2014 HYG acquired Nuvera (a Fuel Cell and Hydrogen generation company)
- Fuel Cell development and manufacturing – Class 1, 2, 3. Plans for future Big Truck options.

Key talking points:

- Environment requirements are coming for ports – is the industry ready?
- Electrification and its impact on reducing emissions
- Do you know the true environmental impact of port equipment?
- What is the latest unique technology coming to market?

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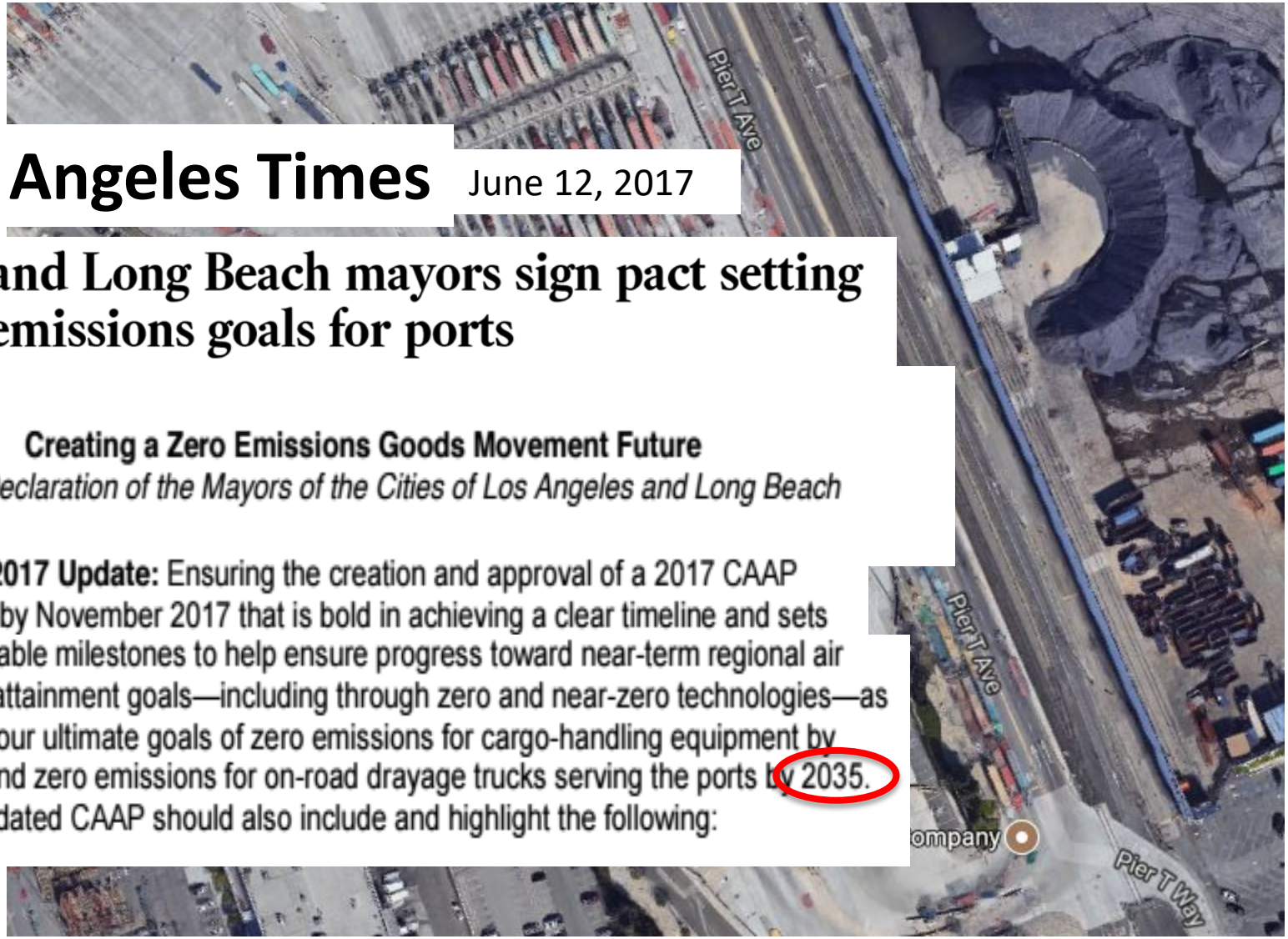
Towards Zero Emissions at the Ports



Los Angeles Times June 12, 2017

L.A. and Long Beach mayors sign pact setting zero-emissions goals for ports

Creating a Zero Emissions Goods Movement Future

A Joint Declaration of the Mayors of the Cities of Los Angeles and Long Beach

- **CAAP 2017 Update:** Ensuring the creation and approval of a 2017 CAAP Update by November 2017 that is bold in achieving a clear timeline and sets measurable milestones to help ensure progress toward near-term regional air quality attainment goals—including through zero and near-zero technologies—as well as our ultimate goals of zero emissions for cargo-handling equipment by 2030 and zero emissions for on-road drayage trucks serving the ports by 2035. The Updated CAAP should also include and highlight the following:

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Zero Emissions Benefits

- Environmental Improvements
  - Eliminate Fossil Fuel Emissions at all CA locations where ICE products are used
  - Powertrain Noise Elimination from Population areas
- Carbon Reduction per vehicle = 2.63 kg/l x liters used
  - the average fuel consumption of a top loader is around 16 L/hour => 42.7 kg/hour
  - 3000 h average per year => 128000 kg.
- Reduce the Cost of Operations
  - Lower Energy Costs
    - Target is > 35% Reduction
    - $0.65/ kWh for Diesel vs $0.15/ kWh for Electricity
    - Where possible use Energy Storage during Off Peak Hours
  - Reduced Maintenance
    - Electric Powertrain vs ICE Powertrain
    - Zero Maintenance Energy Storage – Li-Ion Batteries
    - Wireless charging to eliminate Cable and Connector Repair
  - Higher Productivity
    - Less Vehicle Downtime due to Maintenance
    - Wireless Charging reduces refueling time by eliminating wired charger connection times – typically 3-5 minutes per charge x 4 times per day x 3 shifts = 36 minutes / day/ truck Multiply that by the number of trucks in a fleet x the hourly rate of an operator

Zero Emissions Incentives

- In 2015 the State of California started offering financial grants for the development of Zero Emissions Port Equipment
- In 2016 HYG was successful in receiving a California Energy Commission (CEC) grant to build a 52 ton capacity Top Down Container Handler using only Batteries – Delivery September 2018
- In 2017 HYG applied for a California Air Quality Resources Board (CARB) grant to build a 52 ton capacity Top Down Container Handler using a combination of Battery and Fuel Cell technology Delivery December 2019

The Proposed Vehicle Conversion

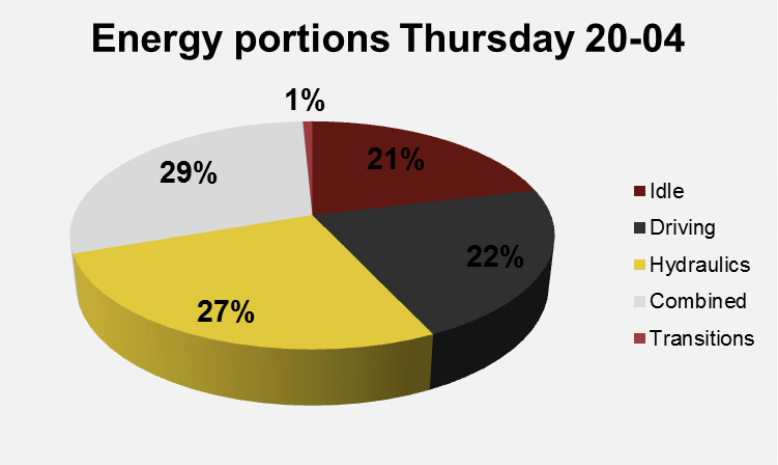
Hyster’ s prototype platform
Zero Emissions solution for Laden Container Handlers
based on the **H1150HD CH**
(H52XM-16CH)

Key characteristics:

- Load Capacity: 52 tons
- Vehicle weight: ~80 tons
- Lift height: 6 x 3 meter high containers
- 800 liter Diesel Fuel tank = 37 hours run time (assumes 40% efficiency)

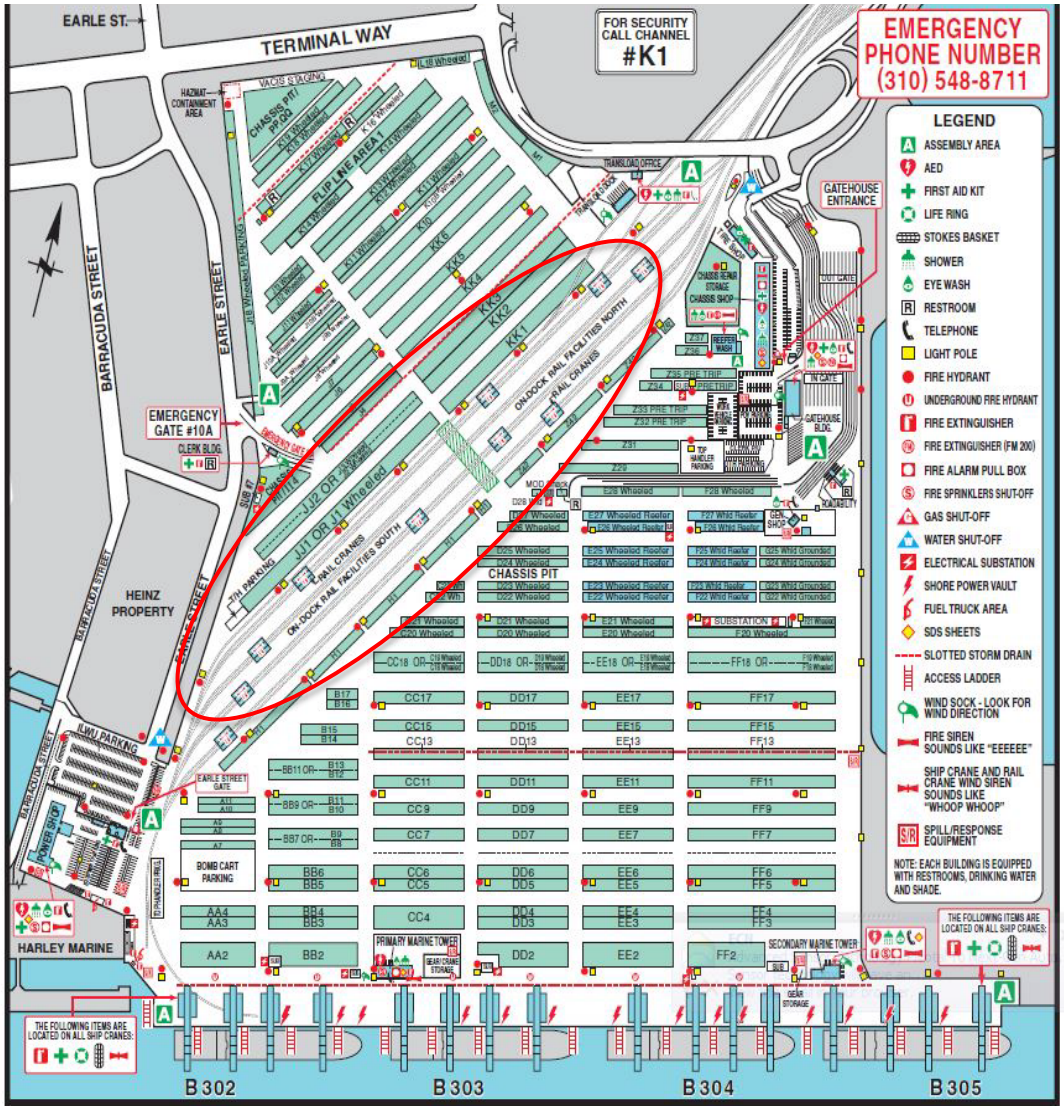
USA Port Duty Cycles

- Port Operations typically have 3 duty cycle types and operate these in 3 shifts in a 24 hour period
  - **Rail/ Yard/ Dock**
- **Yard** and **Dock** have a 15 minute + 1.5 hour + 15 minute break per 8 hour shift
  - Up to 21% fuel energy used during engine idle in a 24 hour Period.

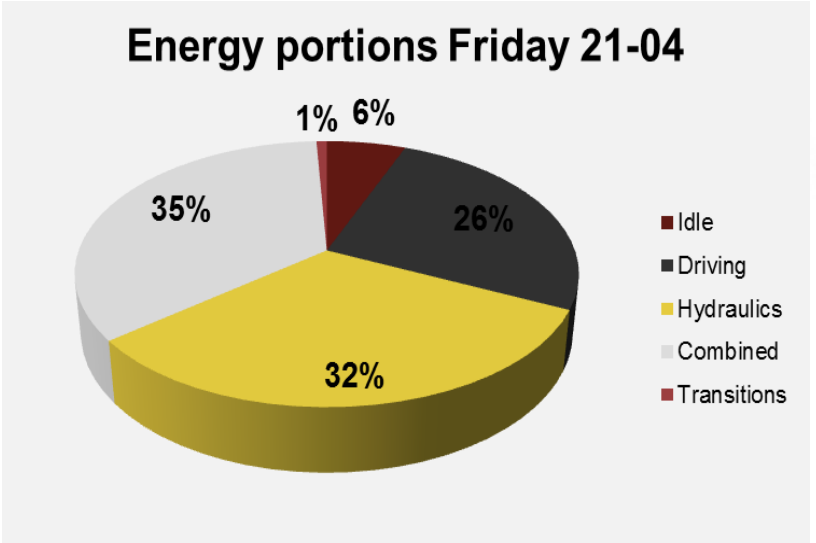


- **Rail** can operate for 7 hours with no break –
  - Only 3 to 6% fuel energy used during engine idle.

Port of LA Duty Cycle Energy Data



Location	Truck	Avg. power	Avg. Fuel cons.
APL	H117E01517M	84.3 kW	20.1 l/h



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The Onboard Energy Storage Challenge

- **Current Diesel Storage vs the equivalent Electric:**
  - *800 liters of Diesel (= 800 x 9.7kW/l) = 7760 kWh*
  - *7760 kWh battery pack*
    Lead Acid = **114 m^3, 291 metric tons**.
    Li-Ion = **57 m^3 , 97 metric tons**.

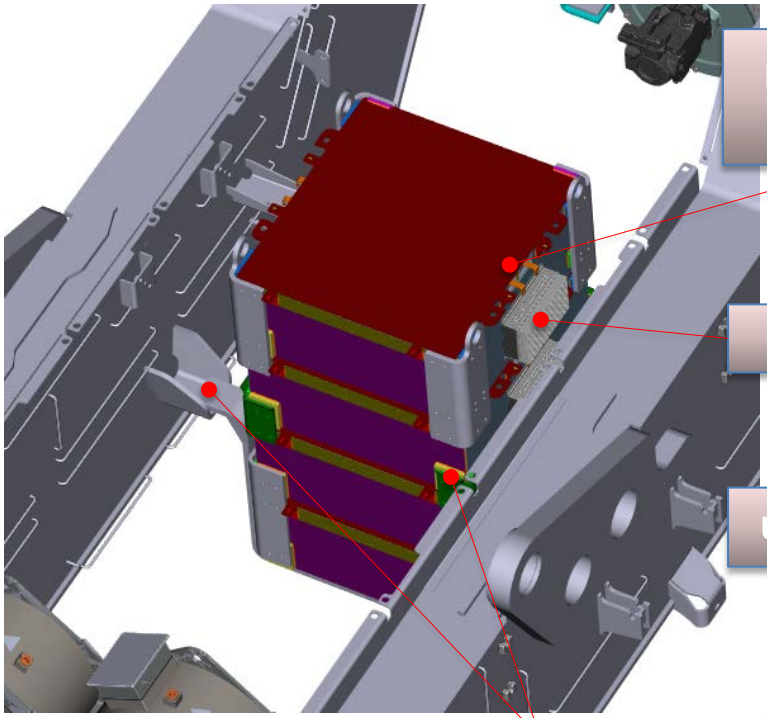
- **Usable Diesel Storage vs the equivalent Electric:**
  - *800 liters of Diesel (= 800 x 9.7kWh/l) = 7760 kWh x 40% = 3104 kWh battery pack = to about 37 hours of runtime*
  - *Lead Acid Battery =* ***46*** **m^3, 116.4 metric tons**.
  - *Li-Ion Battery=* **22.8 m^3, 38.8 metric tons**.

The Onboard Energy Storage Challenge

- **Battery Sizing for Typical usage:**
  - *20 Liters Diesel/ hour (= 20 x 4.2kWh/l) = 84 kWh x 8 hours = 672 kWh battery pack*
  - *Only 80% of the battery energy is usable so capacity needs to be increased by another 20% = 800kWh*
  - *Required Li-Ion Battery=* **2.2 m^3**, **4.2 metric tons**.

- **Battery Sizing for the available space:**
  - *Use the Highest Energy Density Li-Ion Chemistry = NMC*
  - *Operating Voltage = 700 to 800 Volts*
  - *Available Space=* **1.1 m^3**, **2.1 metric tons** = 400 kWh

Battery pack

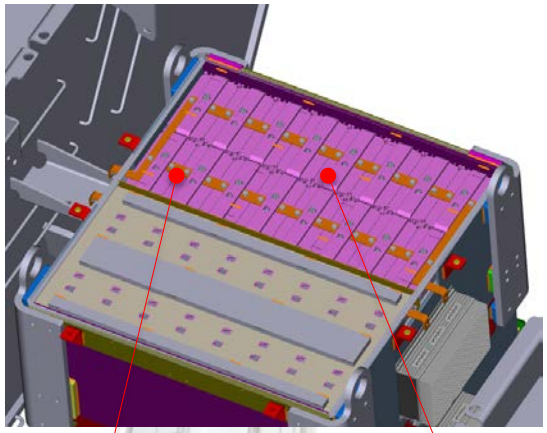


Battery pack c/o 8-9T ER

BMS

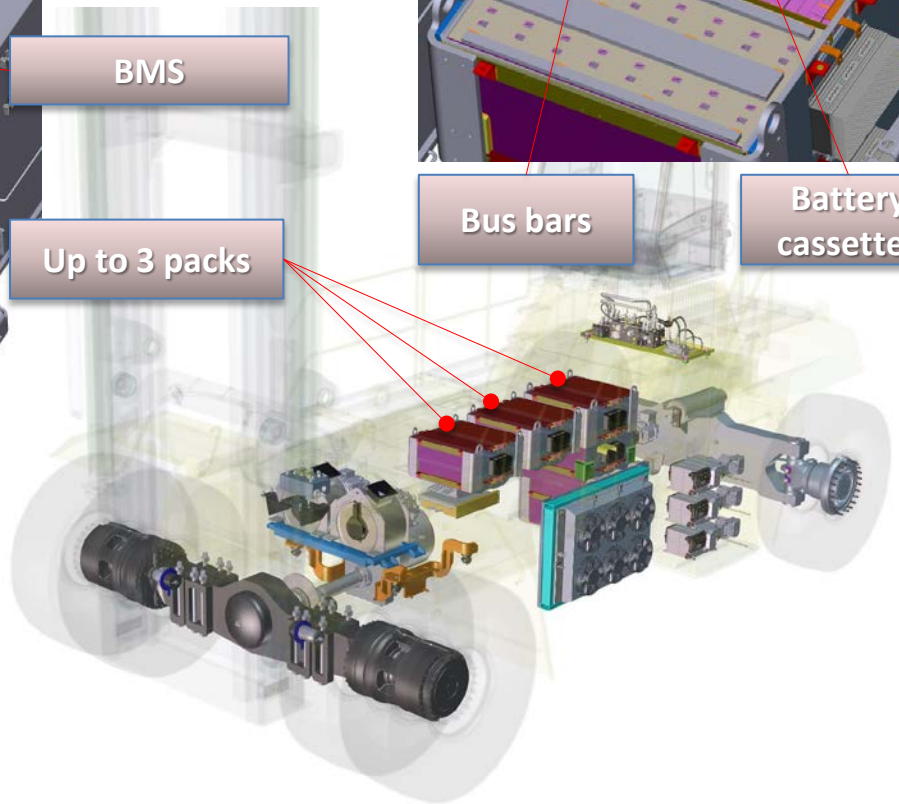
Up to 3 packs

Mounting brackets



Bus bars

Battery cassettes



Cooling required for high ambient temp areas

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USA Port Duty Cycles

- Port Operations typically have 3 duty cycle types and operate these in 3 shifts in a 24 hour period
- **Rail/ Yard/ Dock**
- **Yard** and **Dock** have a 15 minute + 1.5 hour + 15 minute break
  - Up to 21% fuel energy used during engine idle in a 24 hour Period. Plenty of time for Opportunity Charging
  - **Full electric operation is possible with a 400kWh battery**
- **Rail** can operate for 7 hours with no break –
  - Only 3 to 6% fuel energy used during engine idle in a 24 hour Period. No opportunity charging except at end of shift.
  - **Full Electric operation is not possible on just a 400kWh battery**

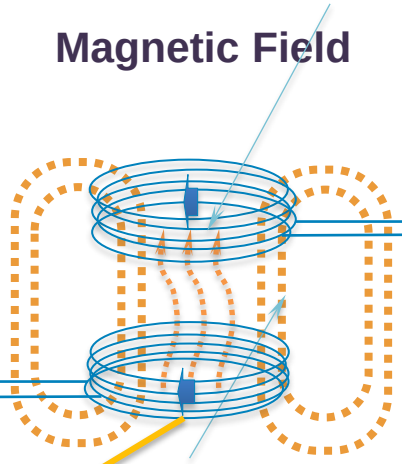
Charging the Vehicle
Connectors vs Wireless

- Connectors:
  - Medium Cost
  - Current and Voltage limited
  - High Maintenance
  - Port Labor Issues
- Wireless:
  - High Cost
  - No current and Voltage Limitation
  - Zero Maintenance
  - No Labor Issues

Charging the Battery

Input Power from Grid

Transmitter Electronics



Current

Receiver Electronics

Output Power to Vehicle

- 7.5” Air Gap, 10.5” Magnetic Gap
- Meets ICNIRP Guidelines and ISO/ANSI 14117 Standards (medical devices)

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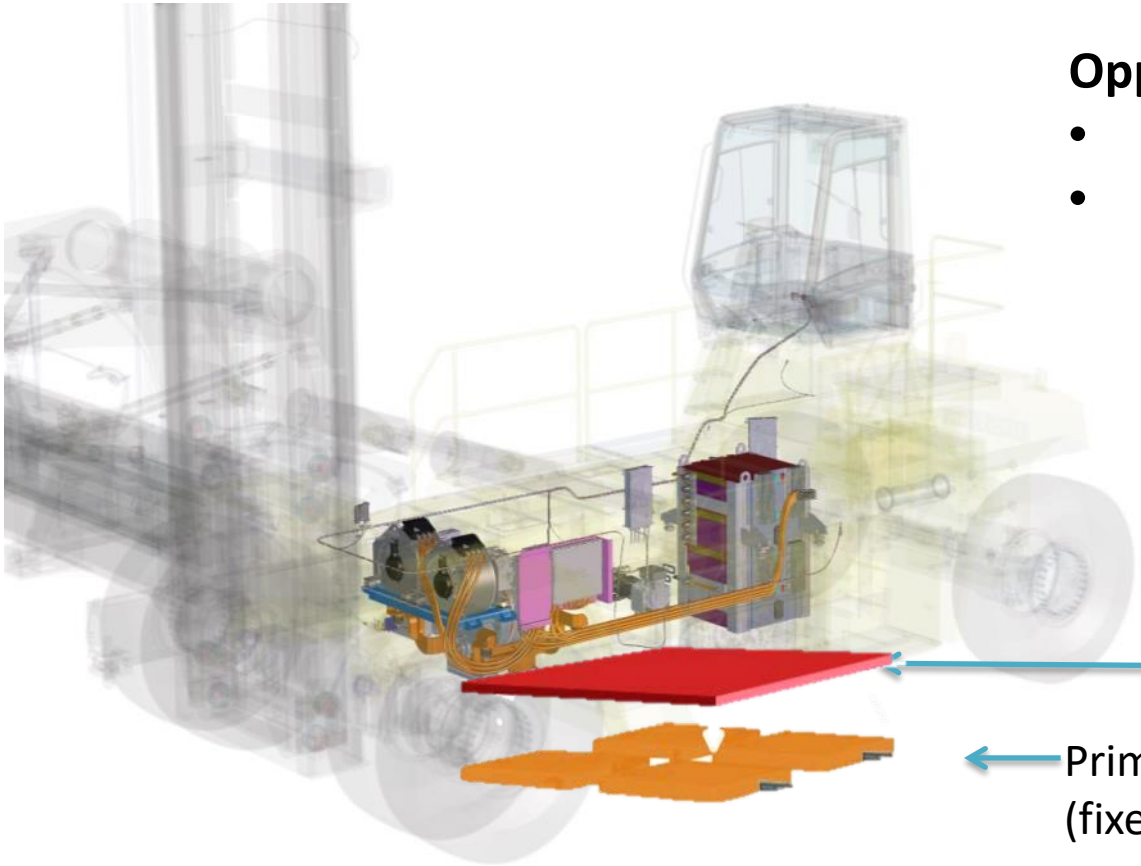
Wireless Charging



Opportunity charging options:

- Wireless (inductive)
- 250 kW delivered to the battery allowing for 93% energy transfer

Defining the right configuration

Battery pack calculation model

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Inputs:

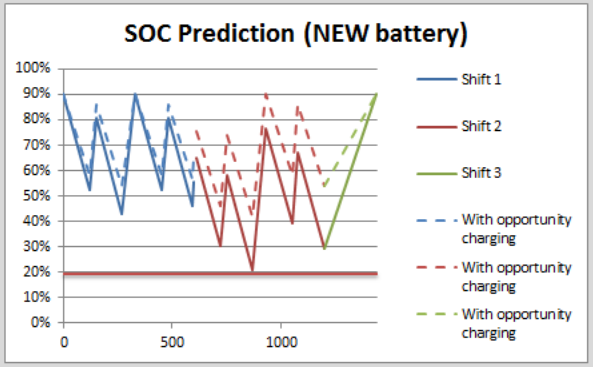
Average energy consumption	84	[kW]	Average energy consumption based on continuous driving according to prescribed pattern, calculated in virtual model
Opportunity charging	250	[kW]	Max charge rate during short stops on wireless charging system (max. 15 min.)
Normal charging	250	[kW]	Long term charging rate for overnight / lunch break charging
Annual operating hours	4000	[hr]	

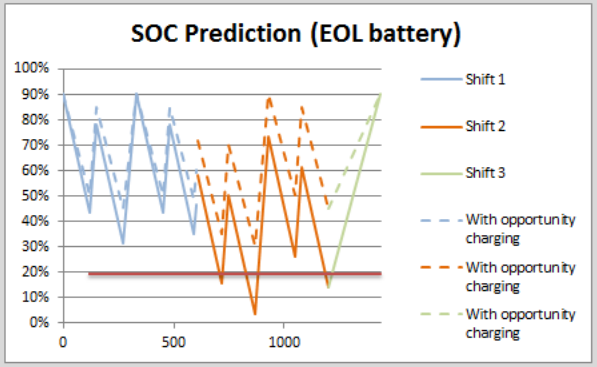
			Capacity when New	*Max charge*	*Max charge*	*Min charge*	*Useable range NEW*
Battery config	448	[kWh]	Based on 9T battery configuration (1 pack is 28 kWh)	***448***	*90%*	*403.2*	*88.6*	***313.6***
Cycles to 80% capacity (EOL)	5000		Based on 9T NMC type batteries	***Capacity when EOL***		*Max charge*	*Min charge*	*Useable range EOL*
C-rate	1		Rated C-rate for number of cycles	***356.4***	*90%*	*322.56*	*71.68*	***250.88***

Shift pattern	Shift start	Drive 1	Break 1	Drive 2	Break 2	Drive 3	Break 3	Drive 4	Break 4	Drive 5	Shift End	Total min	Total hrs
Shift 1	0	120	30	120	60	120	30	110			10	600	10
Shift 2	10	110	30	120	60	120	30	120			0	600	10
Shift 3			240									240	4

% opportunity charging	5	[%]	Amount of time available during the drive part of the shift

Results:





Battery life:

Number of full cycles per day:	4	estimated from SOC prediction
Number of shifts per day:	2	
Working days per year	250	based on annual operating hours and number of shifts

Months before battery EOL **60**

		Shift start	Drive 1	Break 1	Drive 2	Break 2	Drive 3	Break 3	Drive 4	Break 4	Drive 5	Shift End
SOC prediction (NEW battery)	Shift 1	90%	53%	80%	43%	90%	53%	80%	46%	46%	46%	55%
	Shift 2	65%	30%	58%	21%	76%	39%	67%	29%	29%	29%	29%
	Shift 3	29%	29%	90%	90%	90%	90%	90%	90%	90%	90%	90%
SOC prediction (EOL battery)	Shift 1	90%	43%	78%	31%	90%	43%	78%	35%	35%	35%	47%
	Shift 2	58%	15%	50%	3%	73%	26%	61%	14%	14%	14%	14%
	Shift 3	14%	14%	90%	90%	90%	90%	90%	90%	90%	90%	90%

- APM Terminal Rail (84kW average)
- Coffee and Lunch breaks used for charging
- Large battery pack for range, low C-rates due to size of pack and Battery Chemistry

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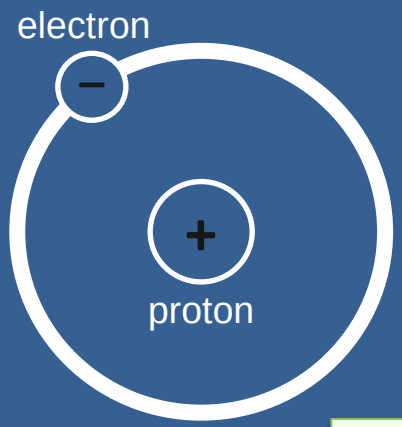
Why Hydrogen and Fuel Cells?

Hydrogen is abundant, simple, **clean**



Hydrogen **stores** energy

Hydrogen is electricity…

…with the **convenience** of fuel

*Hydrogen is **portable** electricity*

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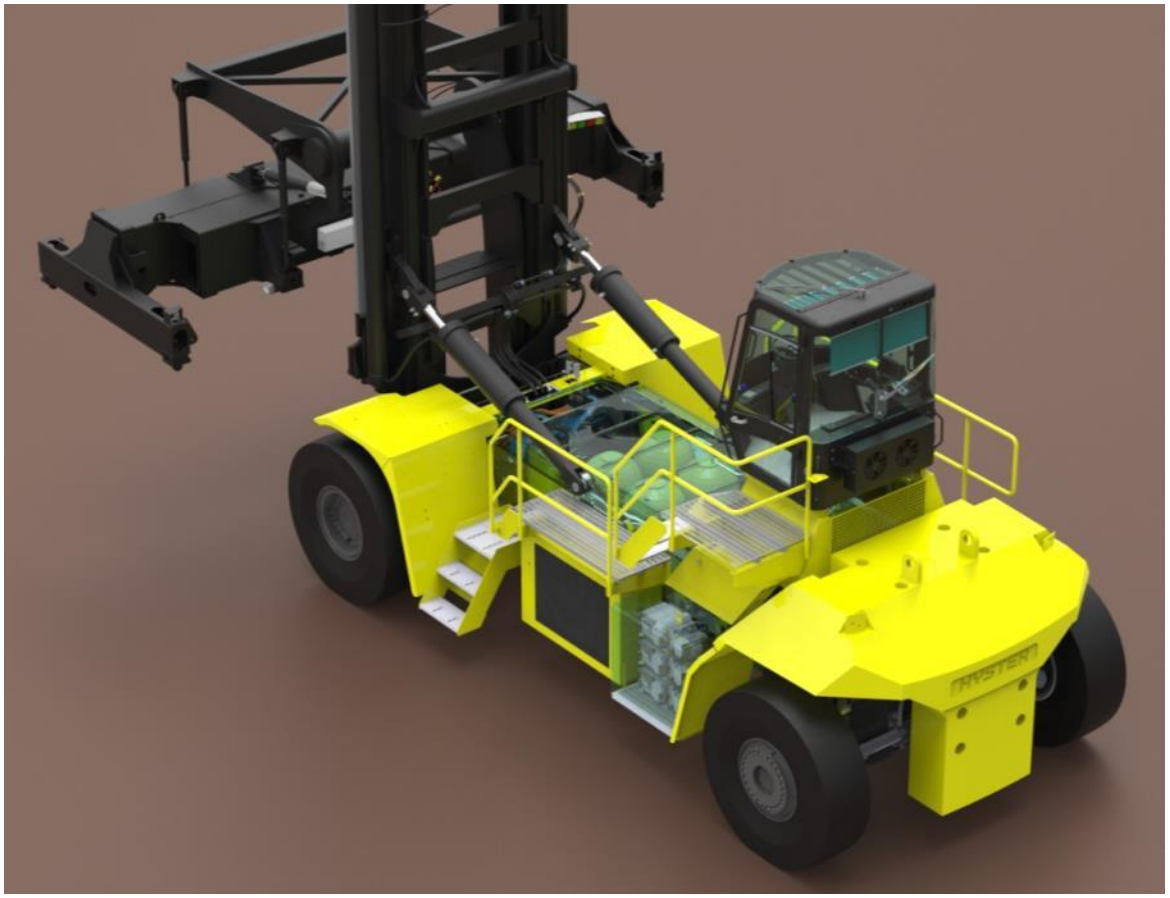
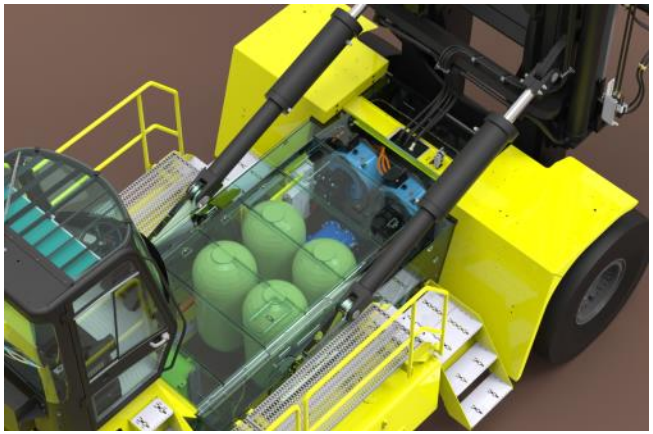
Solving the Energy Crisis

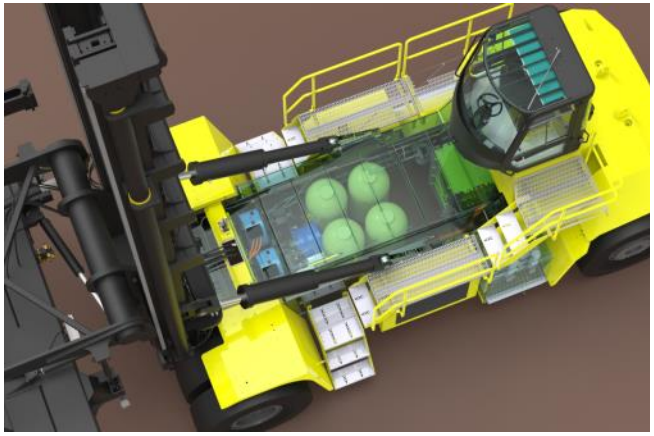
- **Fuel cell: hydrogen H2**
  - *800 l Diesel (= 7760/33.3) = 233 kg H2*
    =5.8 m^3 @ 700 bar. = no space
- **Batteries:**
  - *Li-Ion Battery*= **1.1 m^3**, **2.1 metric tons**= 400kWh
  - Reducing the Battery by 50% = **0.55 m^3**, **1.05 metric tons** = 200kWh = $100K

- **Fuel cell: hydrogen H2**
  - 600kWh of H2 = 600/ 33.3 = 18 kg of H2 = 0.45 m^3 @ 700 bar
  - Hydrogen to electricity conversion efficiency is about 50% so we need to double the amount of stored hydrogen. 36kg of H2 = 0.9 m^3
  - Currently we are only able to store H2 on board @350 bar because of the cost of higher pressure tanks and fuel delivery pressure so we need to double our space to 1.8 m^3
  - Eliminating some of the Battery modules it is still only possible to fit 20 kg of Hydrogen on board = 660 kWh x 50% = 330kWh usable so some H2 refueling is required to complete an 8 hour shift.

Zero emissions
Fuel Cell Hybrid Option







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Zero emission
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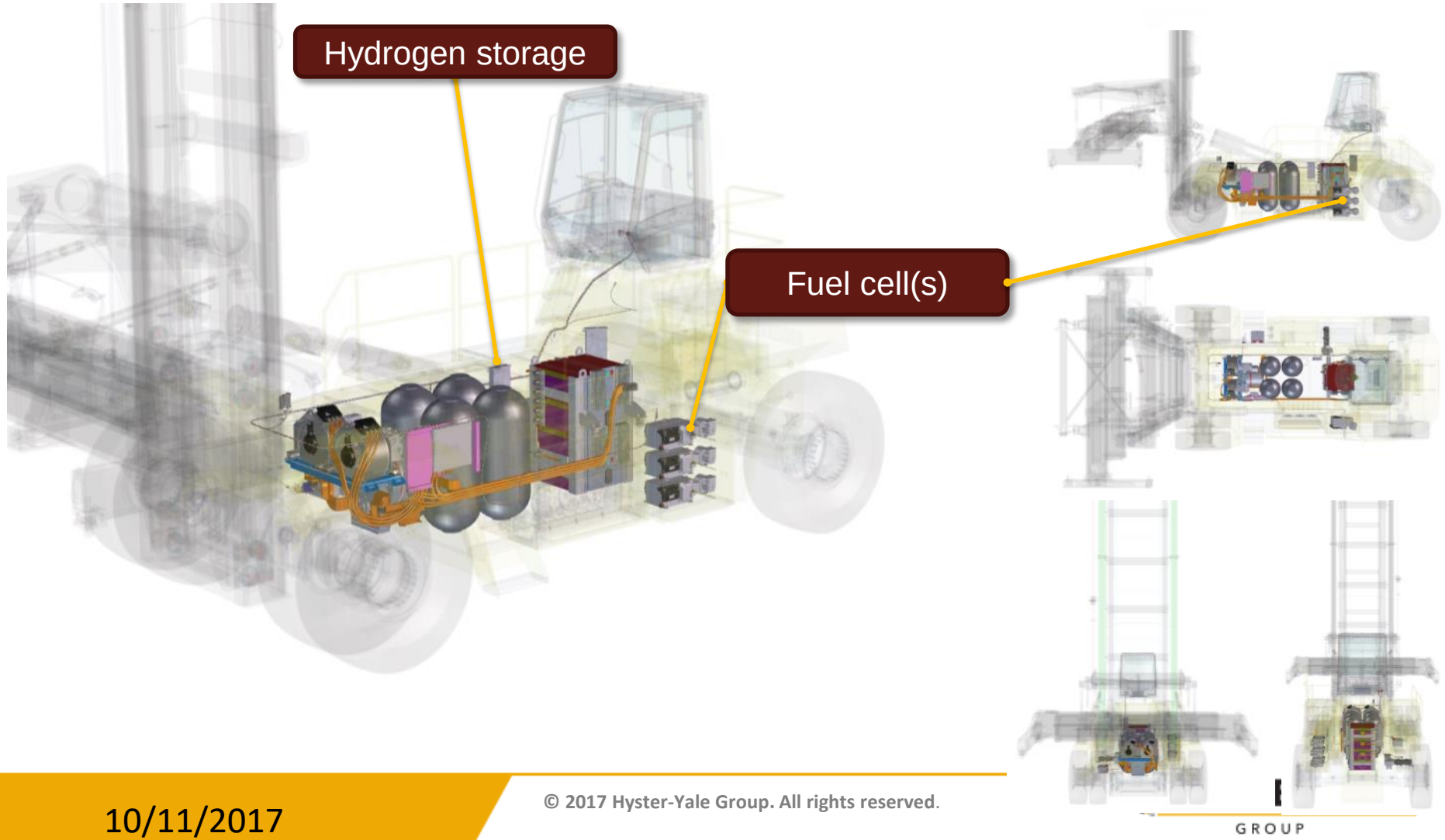

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Defining the right configuration

Battery pack calculation model

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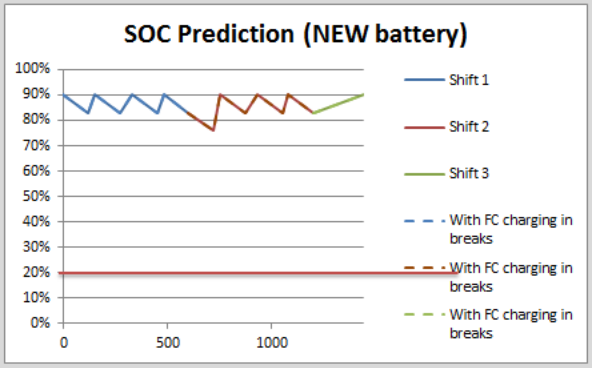
Inputs:

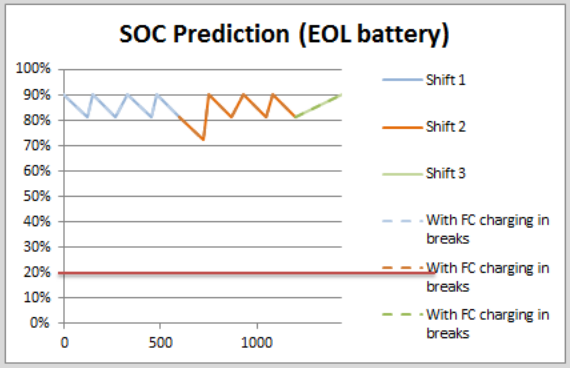
Average energy consumption	84	[kW]	Average energy consumption based on continuous driving according to prescribed pattern, calculated in virtual model
Opportunity charging	0	[kW]	Max charge rate during short stops on wireless charging system (max. 15 min.)
Normal charging	120	[kW]	Long term charging rate for overnight / lunch break charging
Annual operating hours	4500	[hr]	

			Capacity when New	*Max charge*	*Max charge*	*Min charge*	*Useable range NEW*
Battery config	112	[kWh]	Based on 9T battery configuration (1 pack is 28 kWh)	*112*	*90%*	*100.8*	*22.4*	*78.4*
Cycles to 80% capacity (EOL)	5000		Based on 9T NMC type batteries	*Capacity when EOL*		*Max charge*	*Min charge*	*Useable range EOL*
C-rate	1		Rated C-rate for number of cycles	*83.6*	*90%*	*80.64*	*17.92*	*62.72*
Fuel Cell	80	[kW]						

Shift pattern	Shift start	Drive 1	Break 1	Drive 2	Break 2	Drive 3	Break 3	Drive 4	Break 4	Drive 5	Shift End	Total min	Total hrs
Shift 1	0	120	30	120	60	120	30	120			0	600	10
Shift 2	0	120	30	120	60	120	30	120			0	600	10
Shift 3			240									240	4

Results:





Battery life:

Number of full cycles per day:	4	estimated from SOC prediction
Number of shifts per day:	2	
Working days per year	281.25	based on annual operating hours and number of shifts

Months before battery EOL **53**

SOC prediction (NEW battery)	Shift start	Drive 1	Break 1	Drive 2	Break 2	Drive 3	Break 3	Drive 4	Break 4	Drive 5	Shift End
Shift 1	90%	83%	90%	83%	90%	83%	90%	83%	83%	83%	83%
Shift 2	83%	76%	90%	83%	90%	83%	90%	83%	83%	83%	83%
Shift 3	83%	83%	90%	90%	90%	90%	90%	90%	90%	90%	90%

- EMS Rail (84 kW average)
- Battery pack sized to keep C-rates within limits of the battery specification
- Fuel Cell delivers close to the average power (80 vs. 84 kW)

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The Hydrogen Supply (1st Solution)

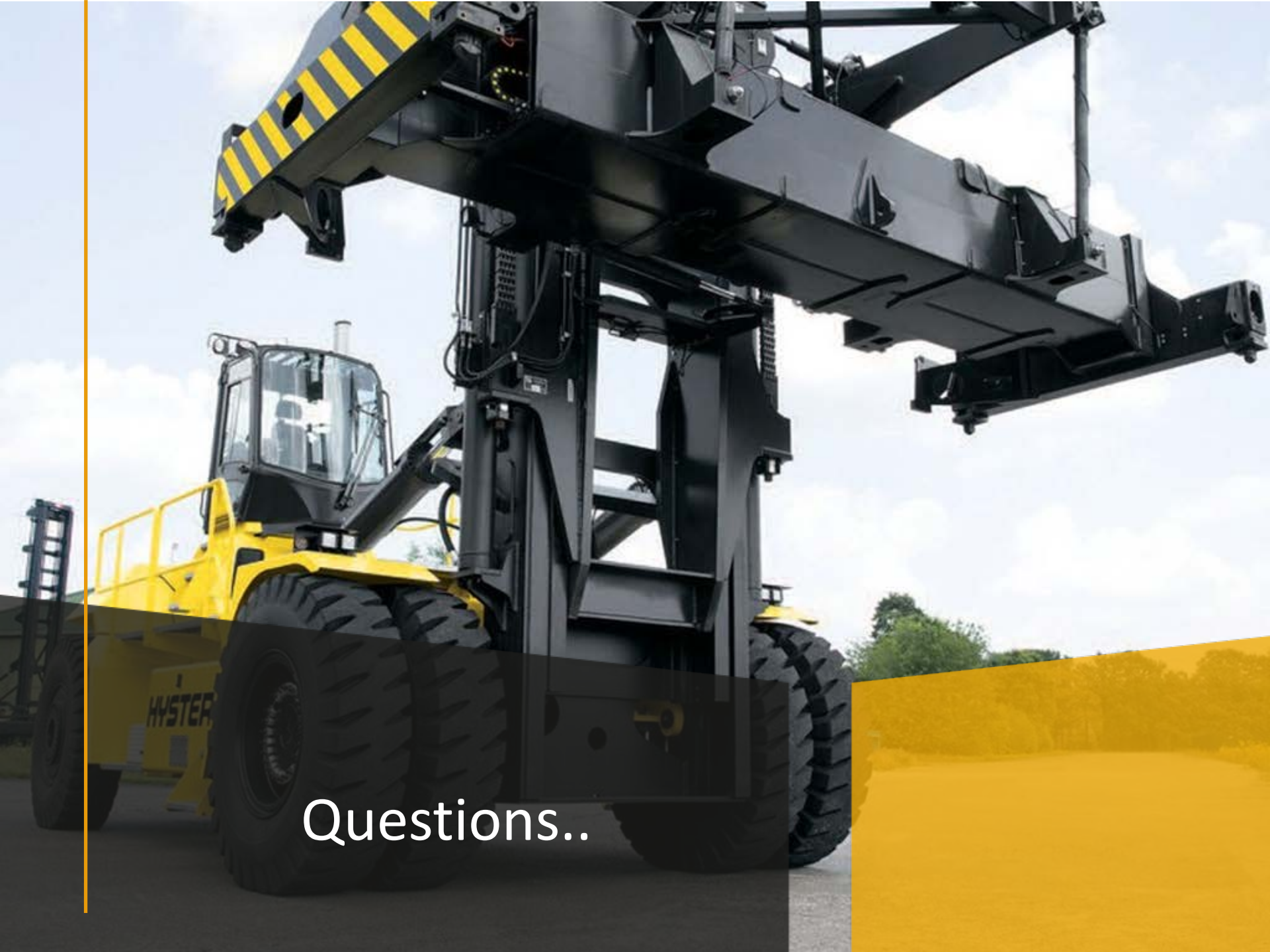
- Hydrogen is brought in by tanker but fuel needs to be transferred to storage vehicle with compressor that is in a fixed location
- Complete refuel in 15 minutes but Forklift could need to be driven up to 1.21 Km (0.75) miles to refuel

The Hydrogen Supply (2nd Solution)

- Compressed Hydrogen is delivered to wherever the truck is located. (same as current Diesel delivery)
- Need to Double the refueler capacity

Summary

- Using a Battery/ Fuel Cell hybrid Energy Source it is possible to operate a zero emissions Top down Container handler vehicle continuously, for a 3 shift duty cycle not exceeding 8 hours per shift.
- However the Battery and Fuel Cell cannot independently meet the Power and Energy needs of the current shift cycle for a RAIL operation.
- The Battery represents a maintenance free power source for its life in the vehicle to 80% EOL SOC.
  On a Battery only vehicle, periodic maintenance is extended from every 500 hours to every 2000 hours compared with a Diesel Powertrain.
- The cost of new technology Battery storage is continuing to fall and in some cases matches Rapid Charge Lead Acid.
- The Fuel Cell up time is an unknown, but is targeted to achieve 10,000 hours between stack replacements.
- Fuel Cell Filters will require more regular maintenance at about every 200 Hours. However operating in a NaCL / NOX environment may prove to be a challenge.
- Fuel Cell costs are still at a premium, but will fall, the same as Batteries, with the wider adoption /utilization in the car industry.
- Electrical Energy is already provided at the port but Hydrogen has to be trucked in on a daily basis.



Questions..