3RD BALTIC PORTS AND SHIPPING

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TECHNICAL INNOVATIONS FOR ZERO-EMISSION TERMINALS

STRONG PARTNERS. TOUGH TRUCKS.™

ZERO EMISSIONS

Technical challenge port equipment: 100% diesel fuel replacement

- Batteries: L… n
  - 800 l Di…el … = 800 x 9,7) = 7760 kWh
  - … ttery pack
    … m3 for lead-acid), **97 tons**
- Fuel cell: h…gen H2
  - 800 l Di…se… = 7760/33 … kg H2
    = **5.8 m** … @ … 00 l

What … nfigurati…

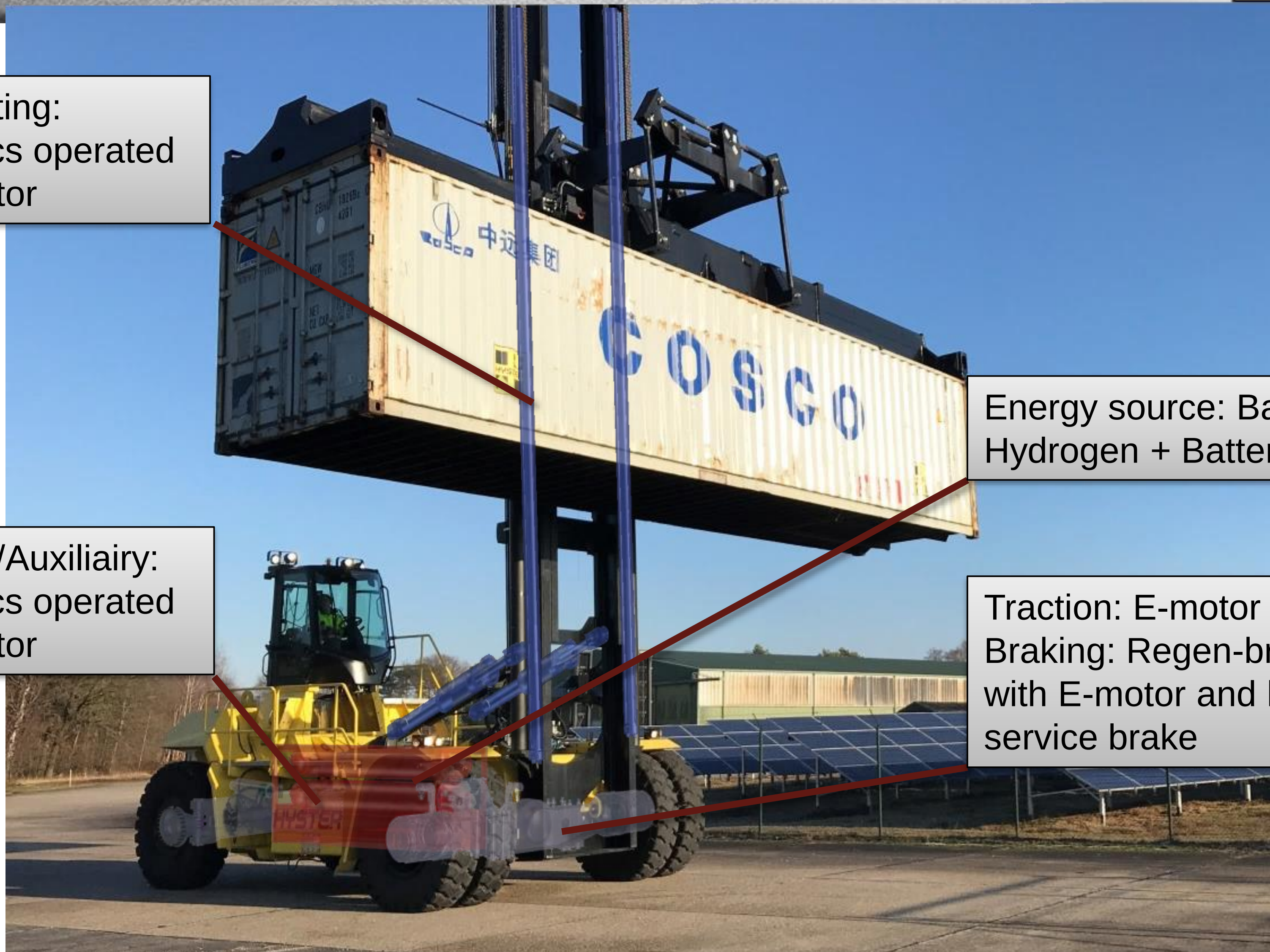
Optimized Siz… linked wit… ategy

Smart energy recov… maximum e…

ZERO EMISSIONS CONTAINER HANDLER

Lifting/tilting: hydraulics operated by E-motor

Steering/Auxiliairy: hydraulics operated by E-motor



Energy source: Battery or Hydrogen + Battery

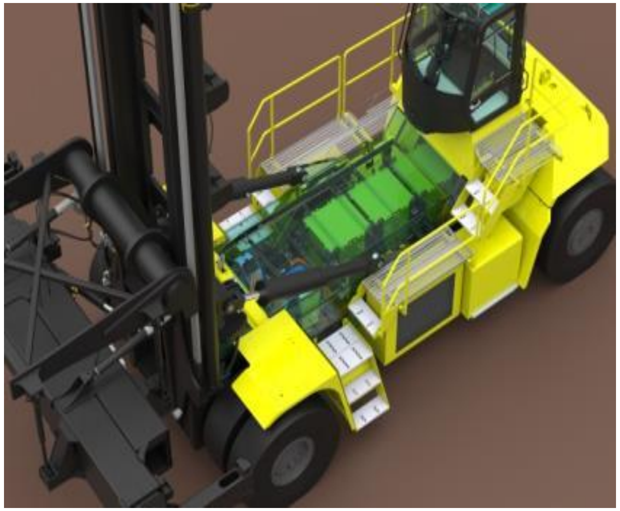
Traction: E-motor
Braking: Regen-braking with E-motor and hydraulic service brake

ONE SIZE DOES NOT FIT ALL

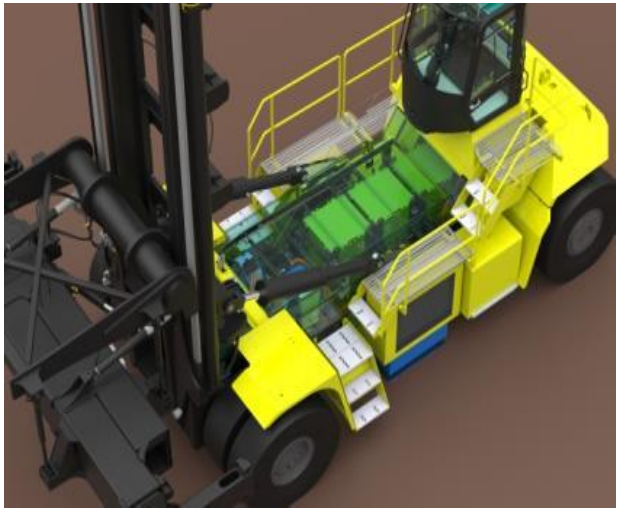
Application 1a
- Fixed break periods
- Normal power consumption

Application 1b
- Fixed break periods
- Normal power consumption
- Opportunity charging

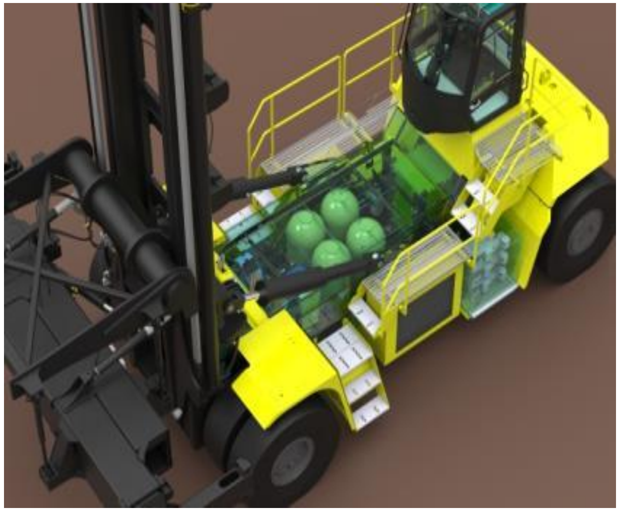
Application 2
- Irregular break periods
- Normal to High power consumption



OPTION 1a
- Large Li-Ion battery
- Conventional charging
- Low to Medium duty cycle



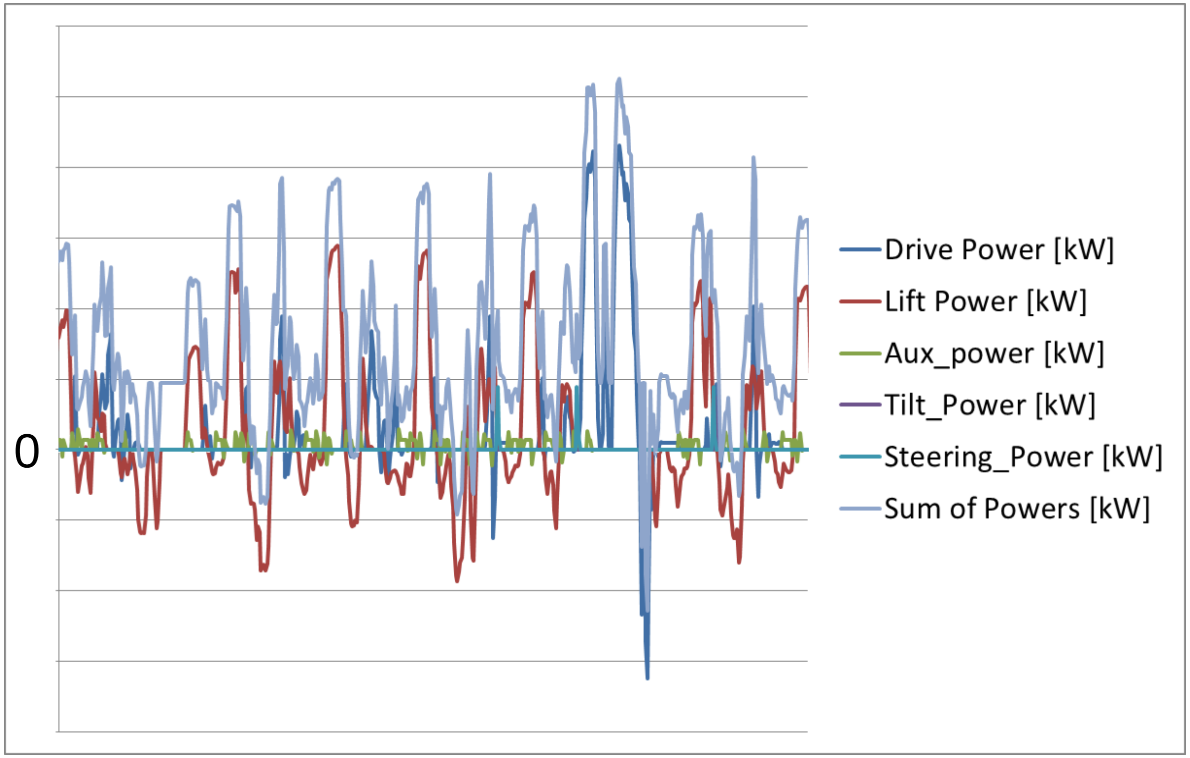
OPTION 1b
- Large Li-Ion battery
- Opportunity charging
- Medium duty cycle

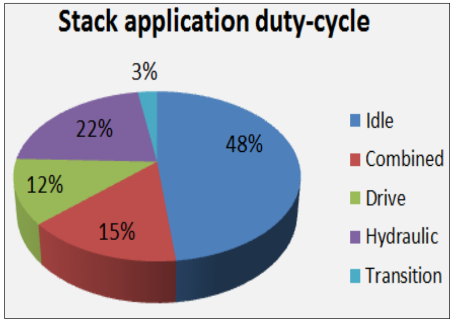


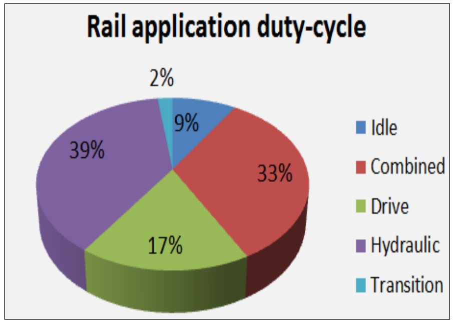
OPTION 2
- Fuel Cell with Small Li-ion battery
- Choice of charging system
- HD cycle: 1 day w/o refill

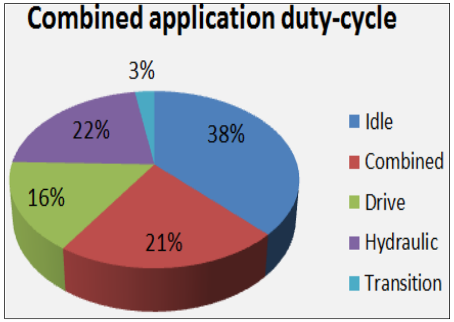
ENERGY EFFICIENCY BY ENERGY RECOVERY

- Typical applications show a theoretical energy recovery potential of 15% over the duty cycle





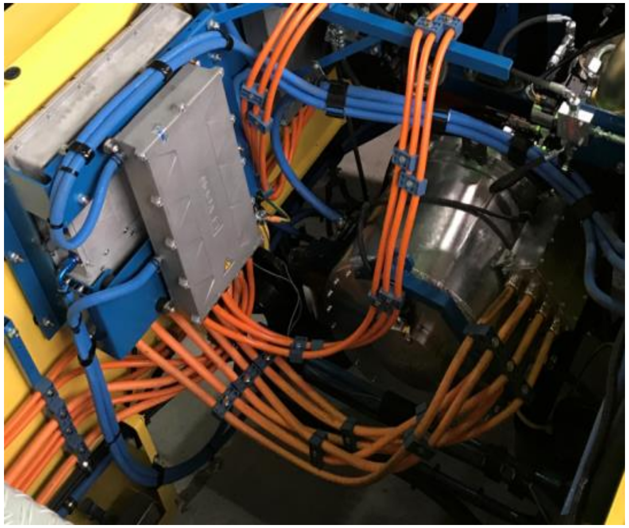




BRAKE ENERGY RECOVERY

- Energy recovery on braking
  - 80 ton vehicle travelling at 23 km/h
    → Kinetic Energy = 0.45 kWh
  - 6 seconds to stop: 272 kW of theoretical stopping power available (Energy = Power x Duration

- System solution
  - Traction motor acts as generator
  - Regenerative braking first, additional hydraulic braking only when needed



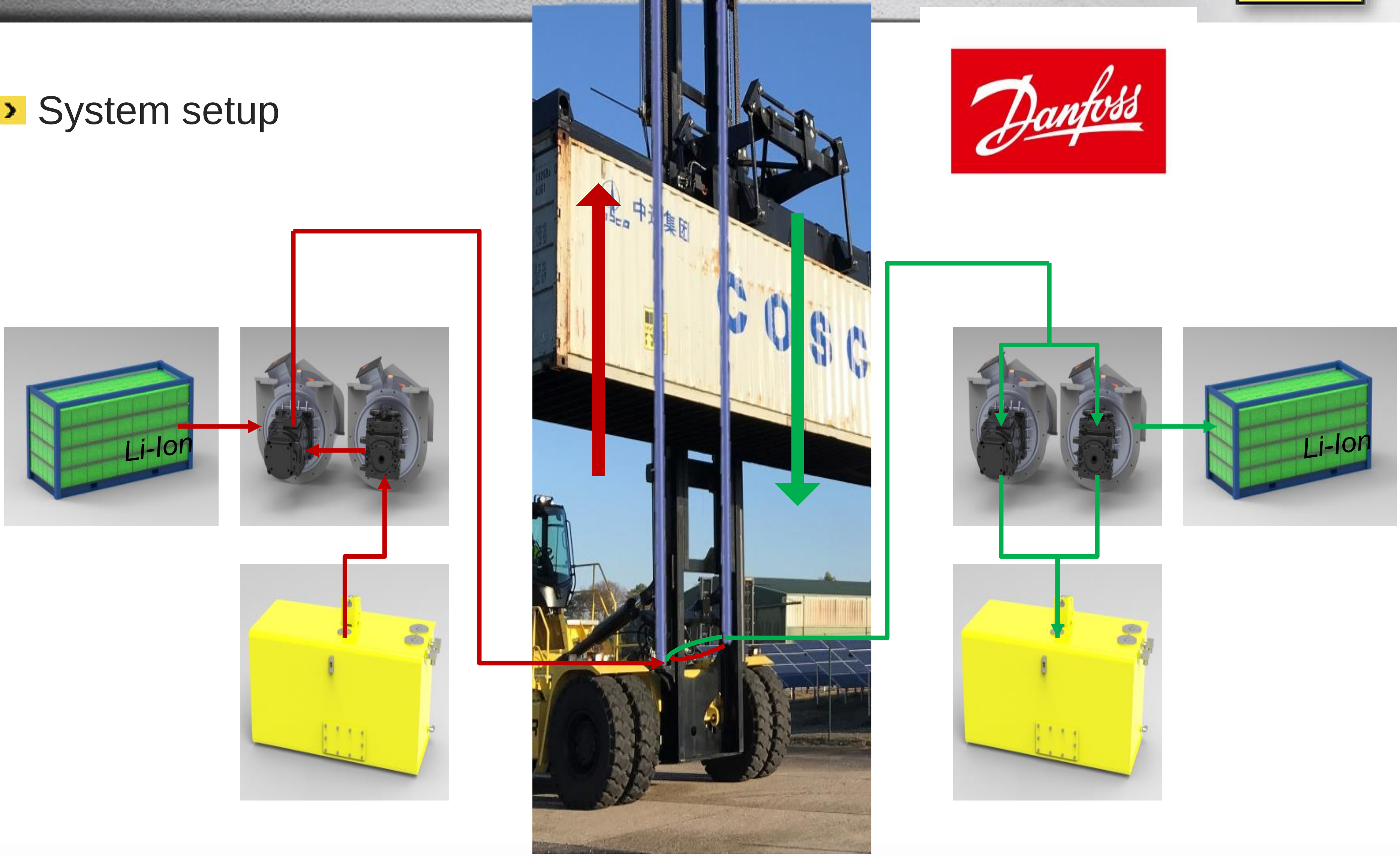
LIFT ENERGY RECOVERY

- Energy recovery on lowering
  - 5-high mast: 13 meters of lifting with 52 ton total load
    → Potential Energy = 1.8 kWh
  - 26 seconds to lower: 255 kW of theoretical power available

- System solution
  - Patent pending hydraulic full flow recovery system for lifting/lowering of the load
  - High efficiency system for other hydraulic functions

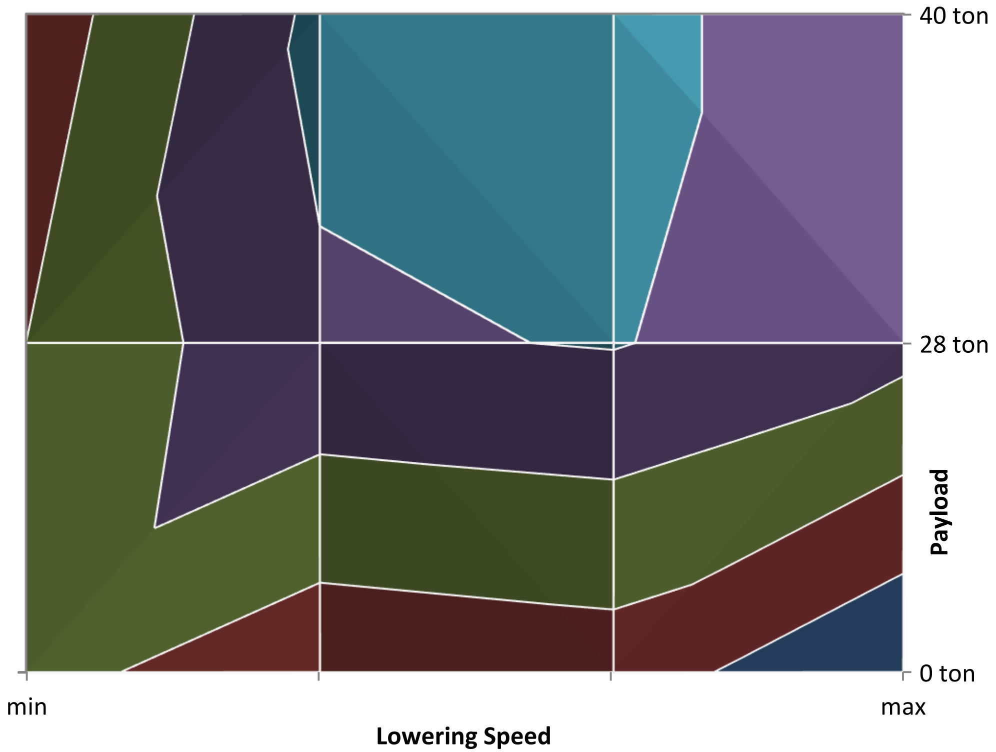
LIFT/LOWER SYSTEM

- System setup



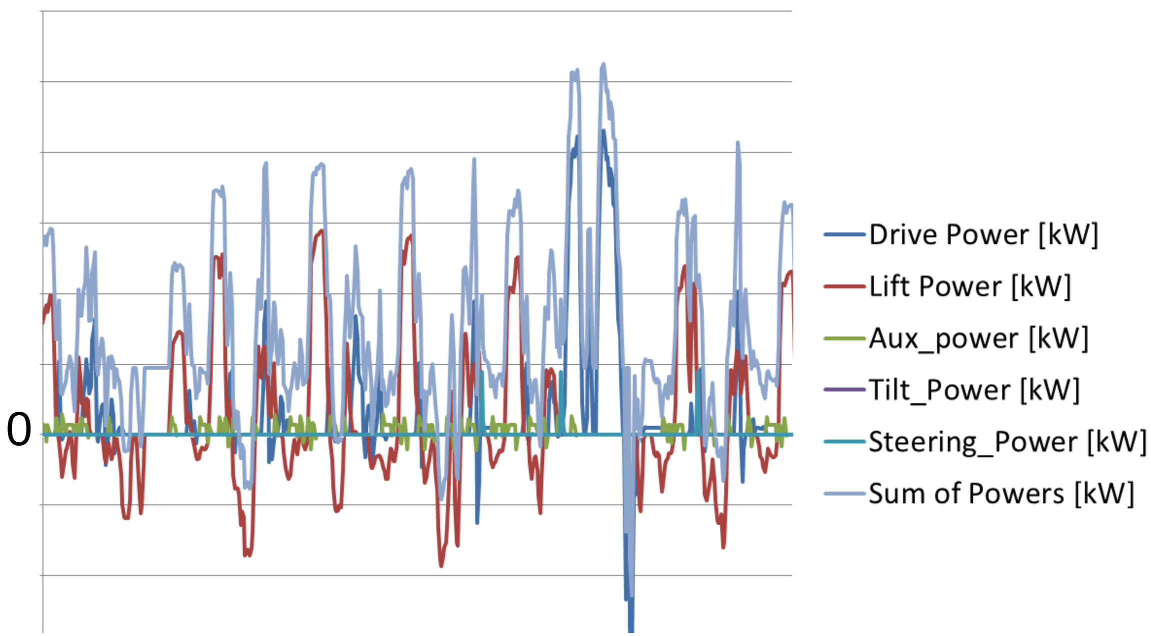
LIFT/LOWER EFFICIENCY

- Measurements performed at 0, 28 m/s and 40 ton payload
  - Up to 64% energy recovery
  - Higher payload results in higher recovery percentage
  - Energy recovery still possible with 0 payload



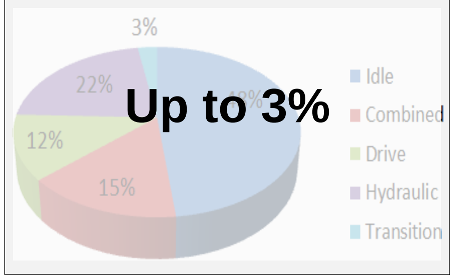
IMPACT ON ENERGY CONSUMPTION

- Calculated energy consumption reduction based on current system efficiencies for hydraulic functions:
- This is compared to the same electric truck without the hydraulic energy recovery.

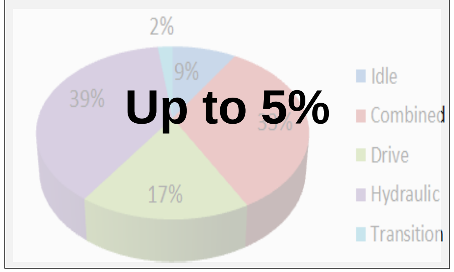


- theoretical energy recovery potential of 15% for all systems

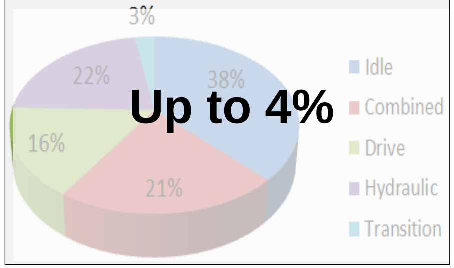
Stack application duty-cycle



Rail application duty-cycle



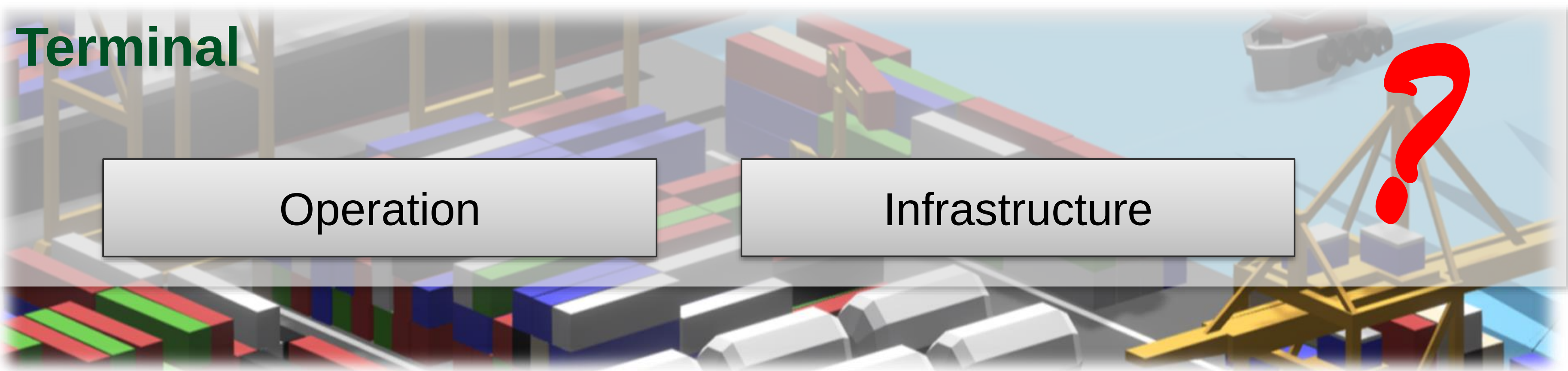
Combined application duty-cycle



CHALLENGES

- The three challenges of electrification

1. Operational planning of charging
2. Charging infrastructure
3. Total peak power consumption from the grid

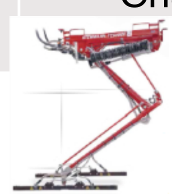


CHARGING SOLUTIONS

Wireless charging vs. Conductive charging

	Wireless charging	Conductive charging (Auto)	Conductive charging (Manual)
Efficiency	90%-94%	>94%	>94%
Operation	Automatic	Automatic	Manual
Maintenance	++	+	o
Available Power range	< 250 kW	< 900 kW	< 350 kW
Cost	-	o	+
Infrastructure	Charger installation partly in ground – major roadworks needed	Pantograph/Pin/Shoe connector Charger cabinet	CCS2/Mode 4 standardized charging – Charger cabinet CCS3 in preparation for higher charging powers

wireless



pantograph

pin

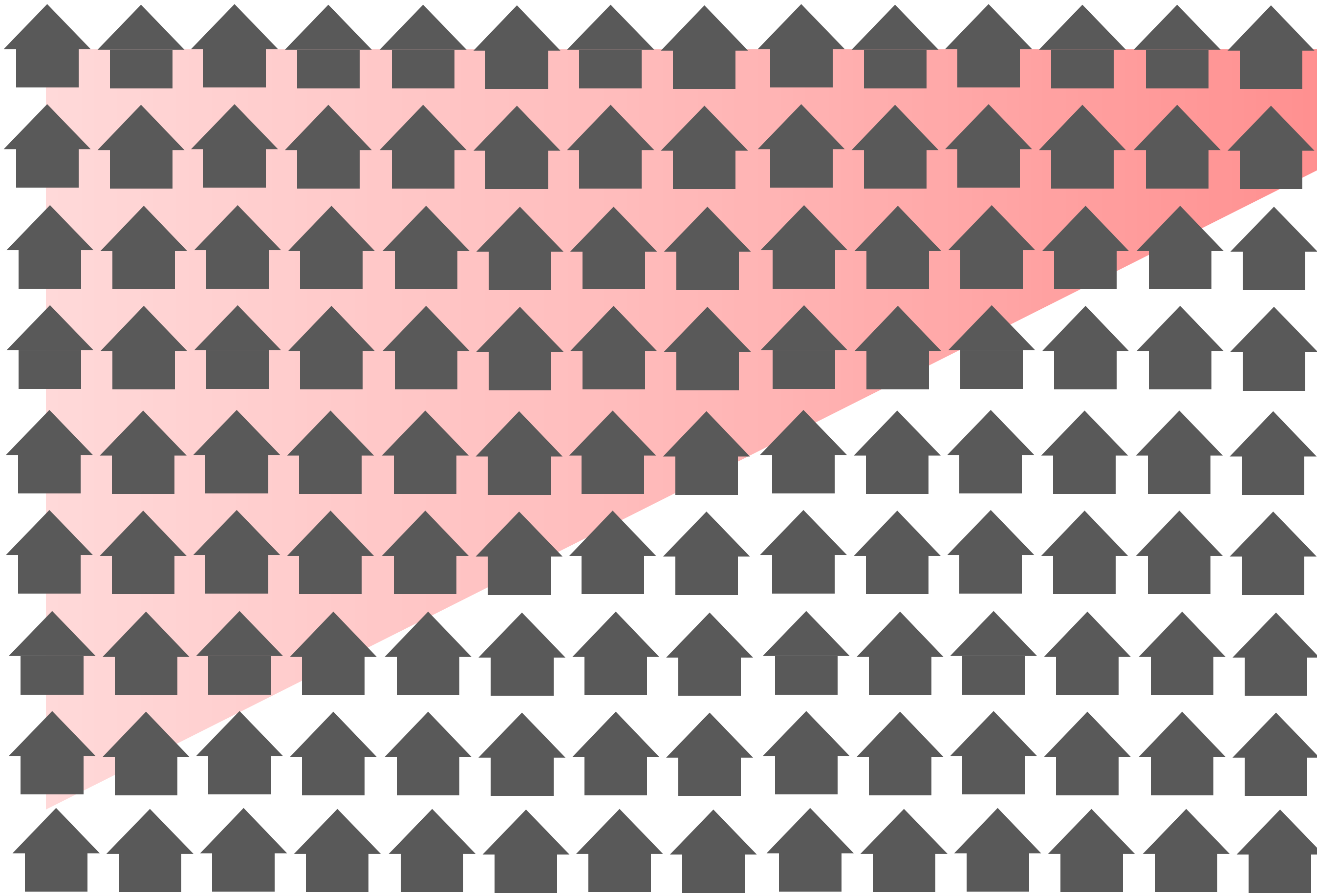
connector

Source: WAVE IPT www.wabtec.com http://ec.staubli.com www.phoenixcontact.com

ELECTRIFICATION OF PORTS - CHARGING

- Simultaneous battery charging of 20 trucks at 200 kW requires 4 megawatts

20 Trucks



- Grid power not sufficient in many locations

REFERENCE: http://shrinkthatfootprint.com/average-household-electricity-consumption

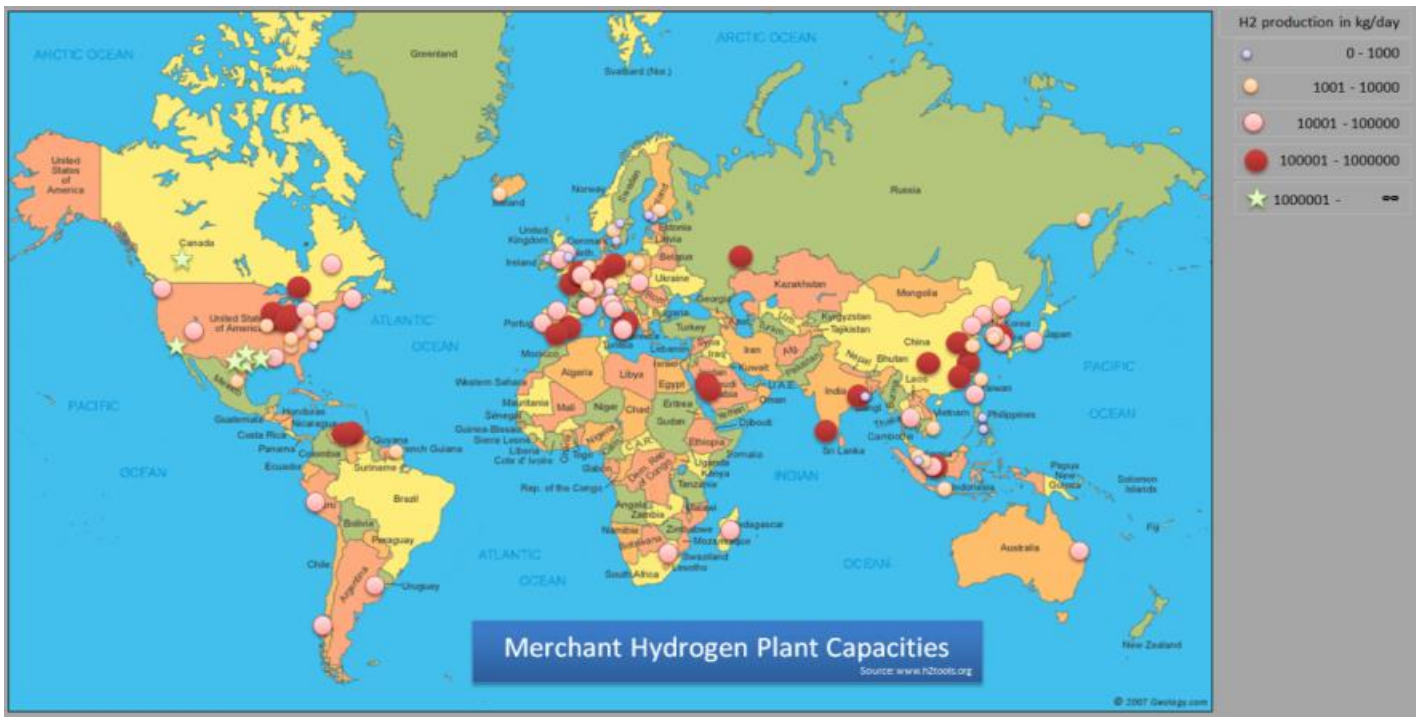
INFRASTRUCTURE CHALLENGE

- Hydrogen enables fast fueling of vehicles and avoids placing large electricity demands on the grid from battery charging

20 Trucks

HYDROGEN AVAILABILITY

- Commercially produced H_2
  - Local production with renewable energy with electrolysis
    → $2\ H_2O(l) \rightarrow 2\ H_2(g) + O_2(g)$
  - Deriving H_2 from methane/biogas (SMR)
    → $CH_4 + H_2O \rightleftharpoons CO + 3\ H_2$



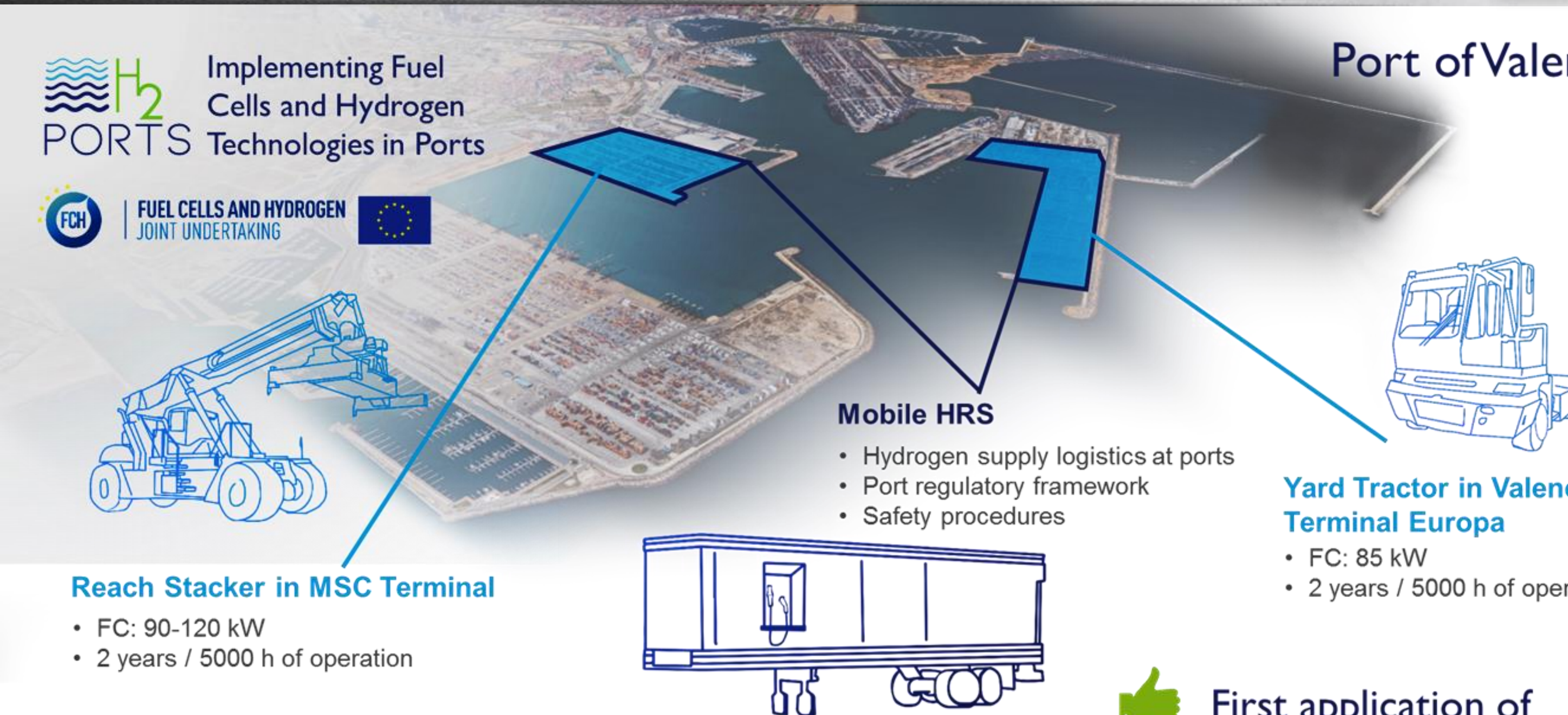
Source:
www.h2tools.org

HYSTER DEVELOPS REACHSTACKER WITH FUEL CELL

HYSTER

H2 PORTS Implementing Fuel Cells and Hydrogen Technologies in Ports

FCH | FUEL CELLS AND HYDROGEN JOINT UNDERTAKING



Port of Valencia

Mobile HRS

- Hydrogen supply logistics at ports
- Port regulatory framework
- Safety procedures

Yard Tractor in Valencia Terminal Europa

- FC: 85 kW
- 2 years / 5000 h of operation

Reach Stacker in MSC Terminal

- FC: 90-120 kW
- 2 years / 5000 h of operation

General features

- Total Budget: 4,117,197.5 EUR
- Duration (4 years): 2019-2023

First application of hydrogen technologies in port handling equipment in Europe

Partners: Fundación Valenciaport, valenciaport Autoridad Portuaria de Valencia, GRIMALDI GROUP, MSC Terminal Valencia S.A.U, HYSTER-YALE GROUP, BALLARD, ATENA, Centro Nacional del Hidrógeno, enagas

TO SUM UP

1. Electrification is ready to happen – also for (more efficient) port equipment

2. Energy source decision depends on local conditions and application

3. Hydrogen and Grid power can be complimentary solutions for ports

4. Standardization (charging/hydrogen) is needed

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TOUGH TRUCKS.™

ANY QUESTIONS?