STRONG PARTNERS.
TOUGH TRUCKS.™

8TH BLACK SEA PORTS AND SHIPPING

› Rainer Marian

TECHNICAL INNOVATIONS FOR ZERO-EMISSION TERMINALS

ZERO EMISSIONS

Technical challenge port equipment: 100% diesel fuel replacement

- Batteries: l[illegible]n
  - 800 l Di[illegible]el = 800 x 9,7) = 7760 kWh
  - [illegible]kW [illegible]ttery pack
    [illegible] **m3 for lead-acid), 97 tons**

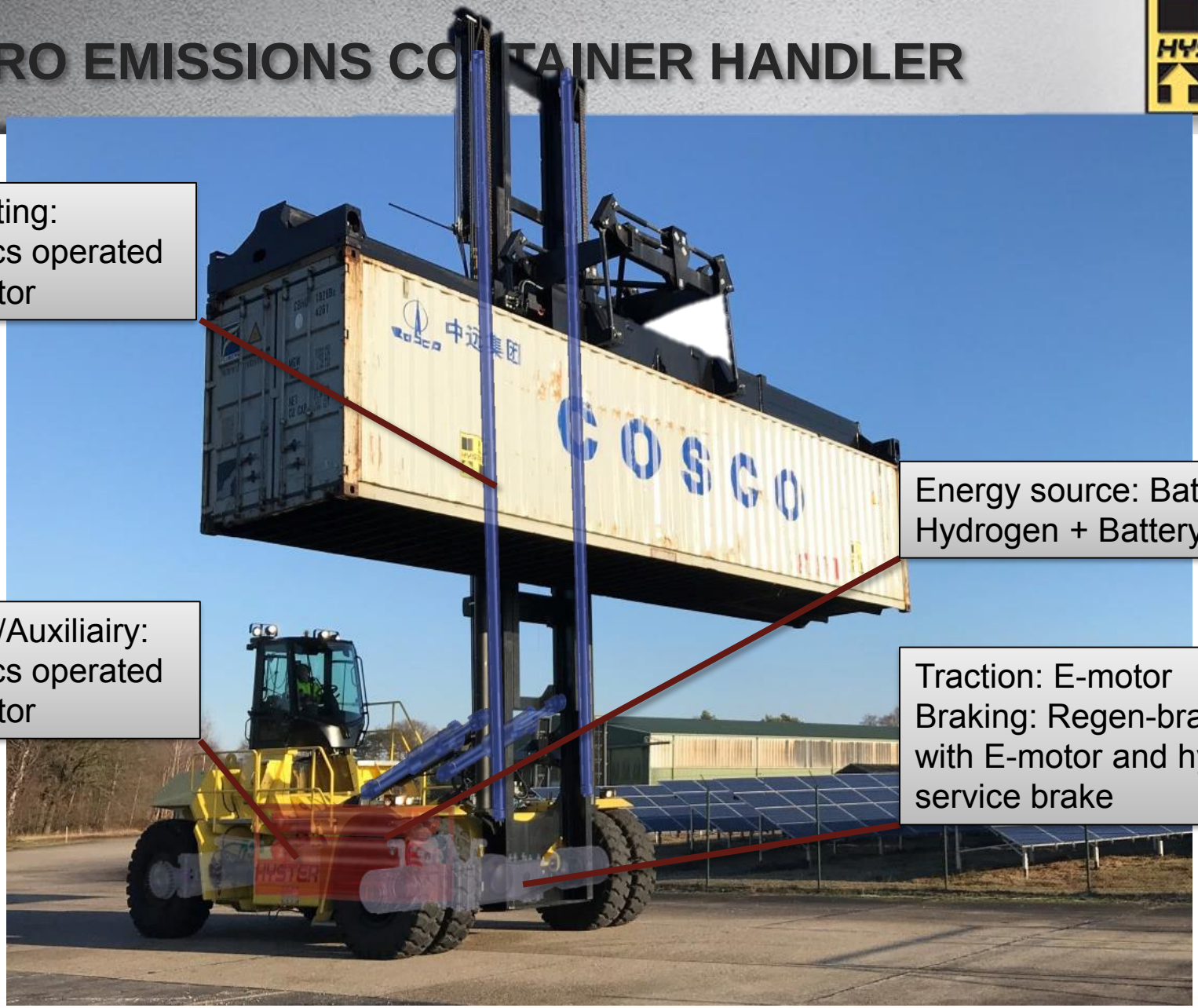
- Fuel cell: h[illegible]gen H2
  - 800 l Di[illegible]= 7760/33[illegible]kg H2
    = 5.8 m[illegible]@[illegible]00 l

What[illegible]nfigurati[illegible]

Optimized Siz[illegible]linked wit[illegible]ategy

Smart energy recov[illegible]aximum e[illegible]

ZERO EMISSIONS CONTAINER HANDLER



Lifting/tilting: hydraulics operated by E-motor

Steering/Auxiliairy: hydraulics operated by E-motor

Energy source: Battery or Hydrogen + Battery

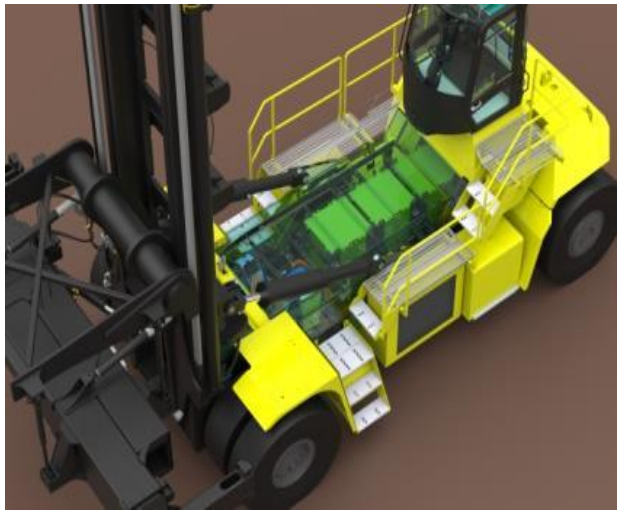
Traction: E-motor
Braking: Regen-braking with E-motor and hydraulic service brake

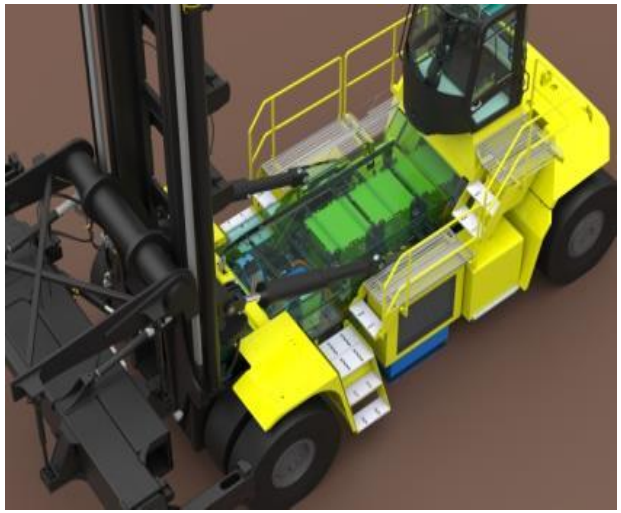
ONE SIZE DOES NOT FIT ALL

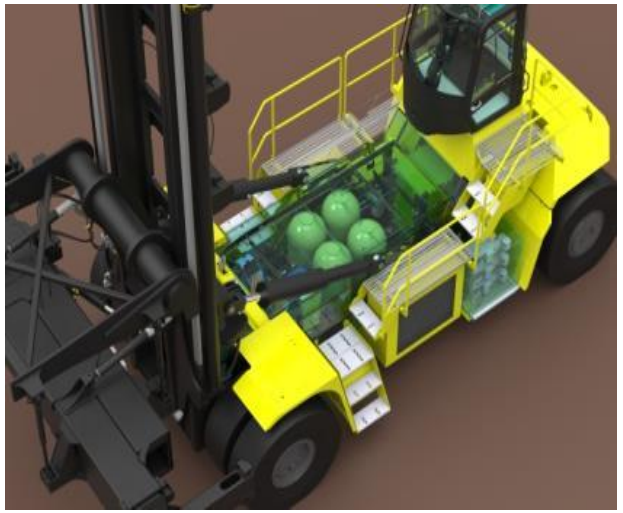
Application 1a
- Fixed break periods
- Normal power consumption

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

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







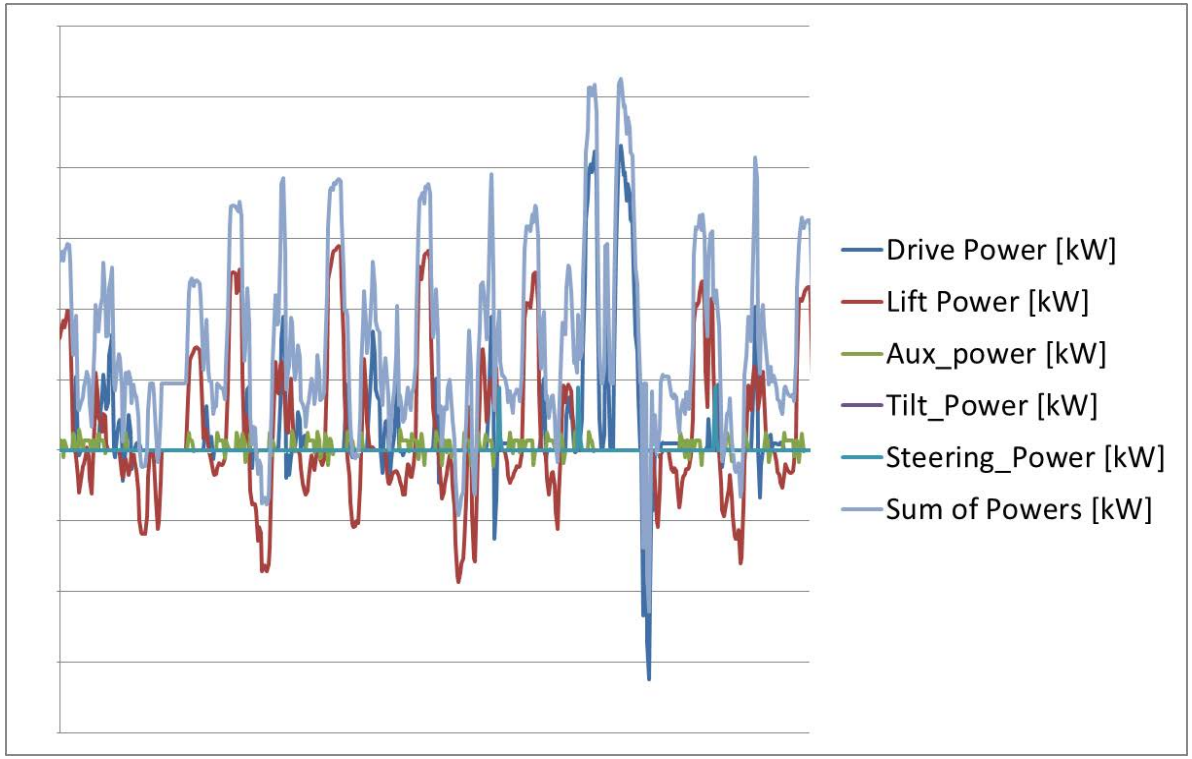
OPTION 1a
- Large Li-Ion battery
- Conventional charging
- Low to Medium duty cycle

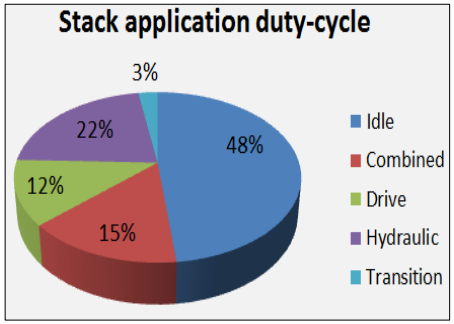
OPTION 1b
- Large Li-Ion battery
- Opportunity charging
- Medium duty cycle

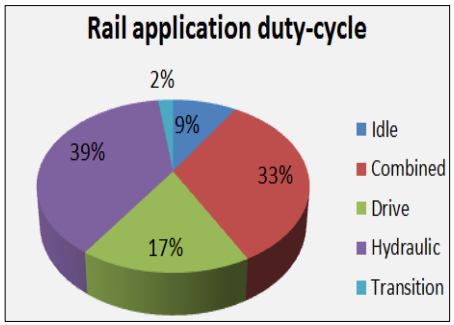
OPTION 2
- Fuel Cell with Small Li-ion battery
- Choice of charging system
- HD cycle: 1 day w/o refill

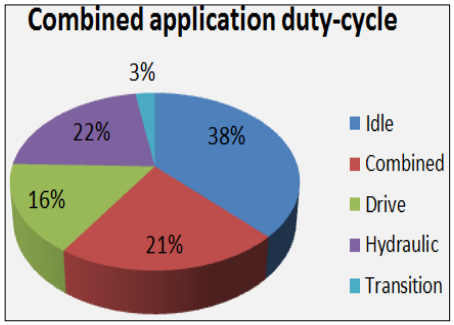
ENERGY EFFICIENCY BY ENERGY RECOVERY

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





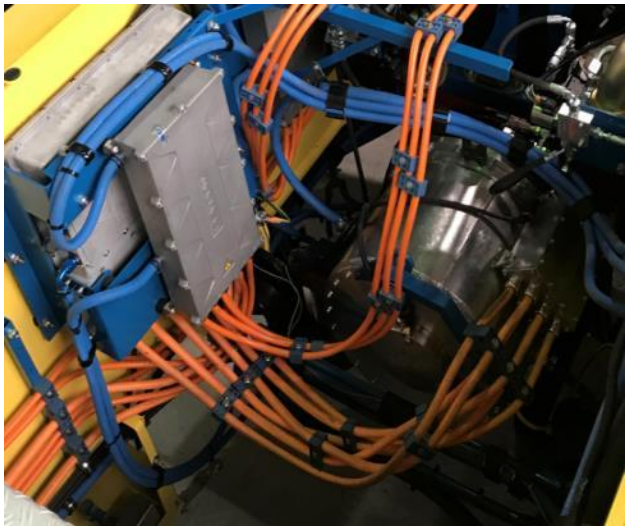




BRAKE ENERGY RECOVERY

- 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

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

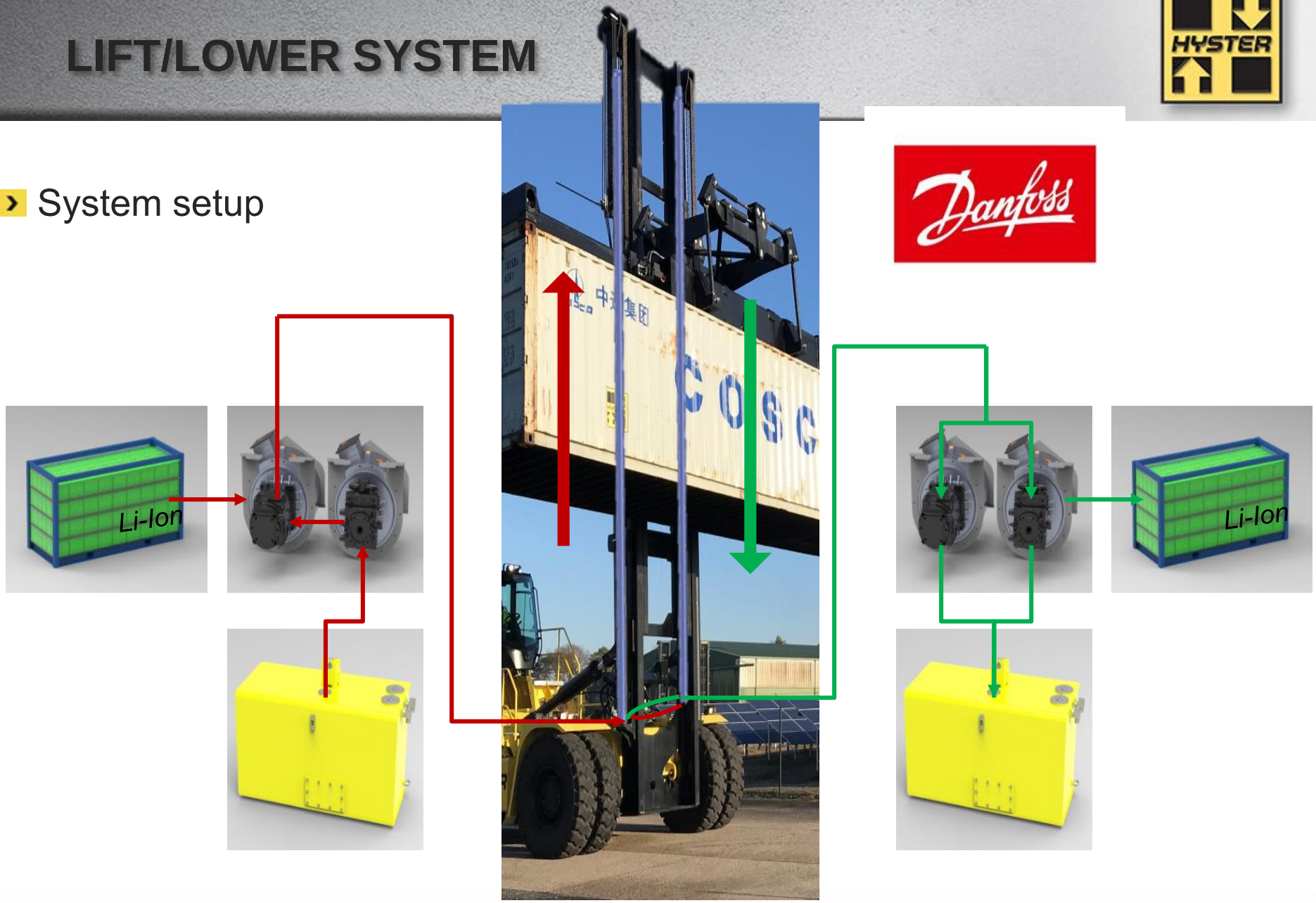


LIFT ENERGY RECOVERY

- 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

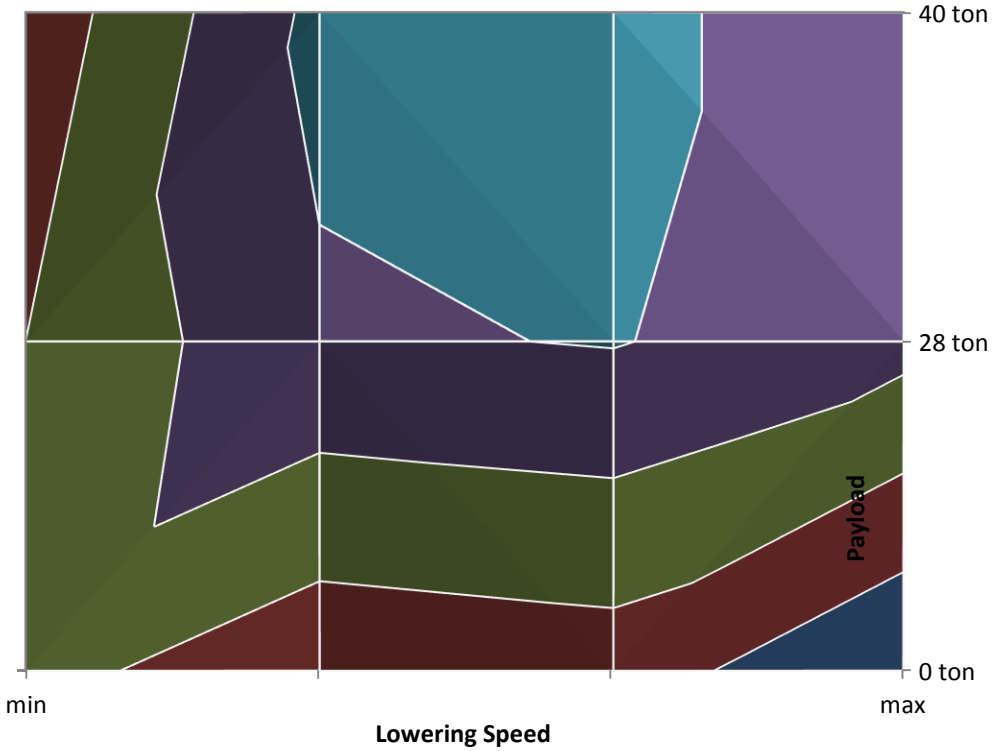
LIFT/LOWER SYSTEM

- System setup



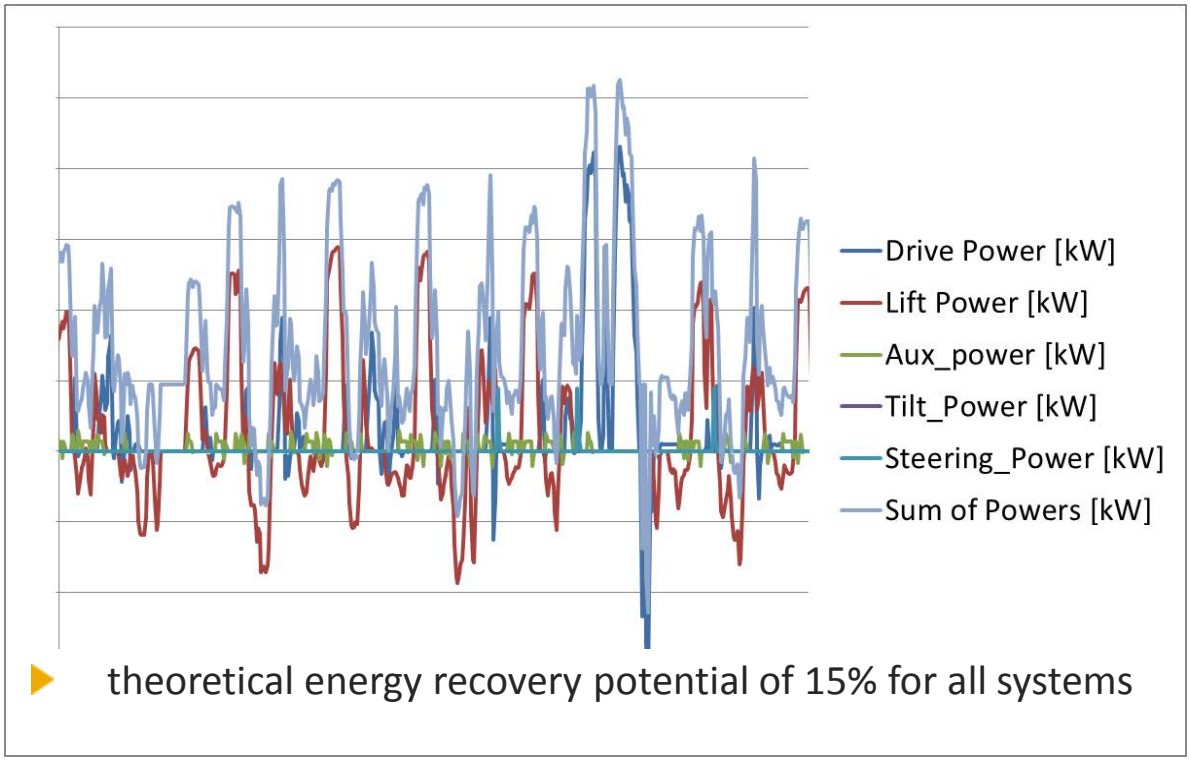
LIFT/LOWER EFFICIENCY

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

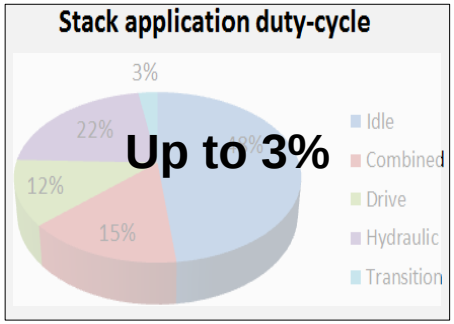


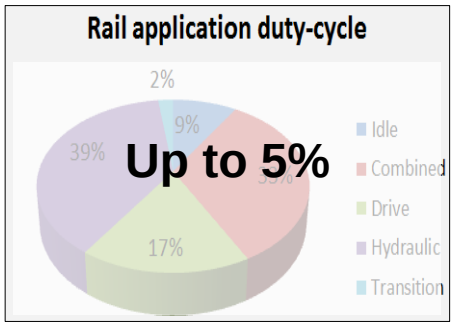
IMPACT ON ENERGY CONSUMPTION

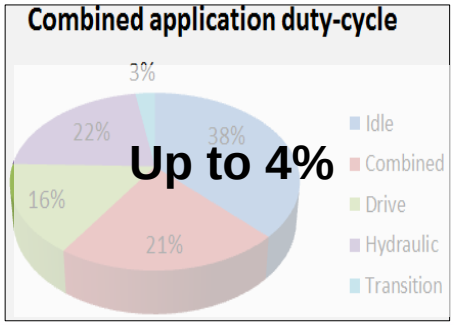
- Calculated energy consumption reduction based on current system efficiencies for hydraulic functions:



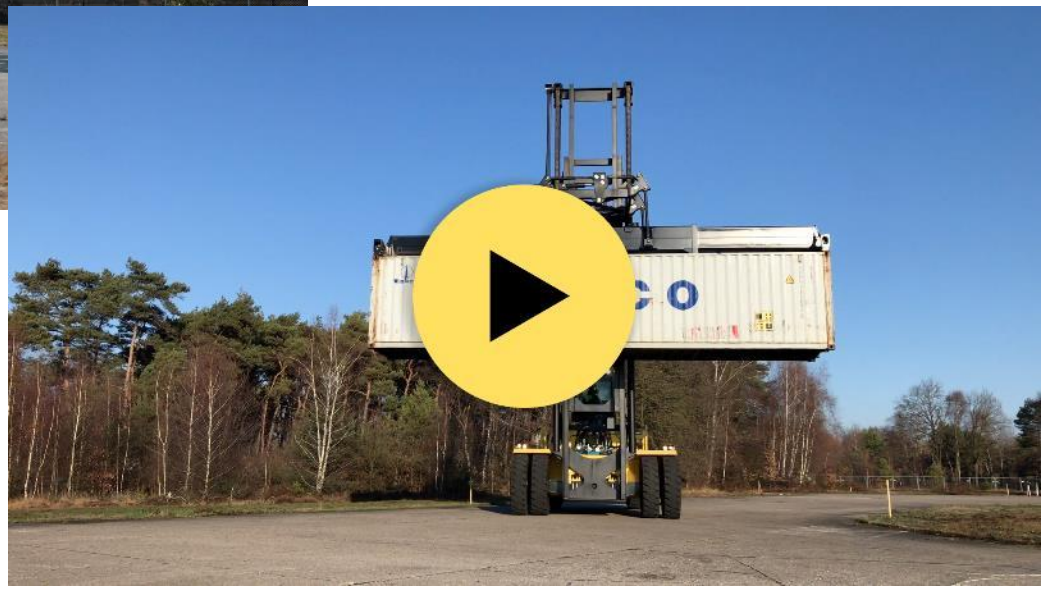
- theoretical energy recovery potential of 15% for all systems







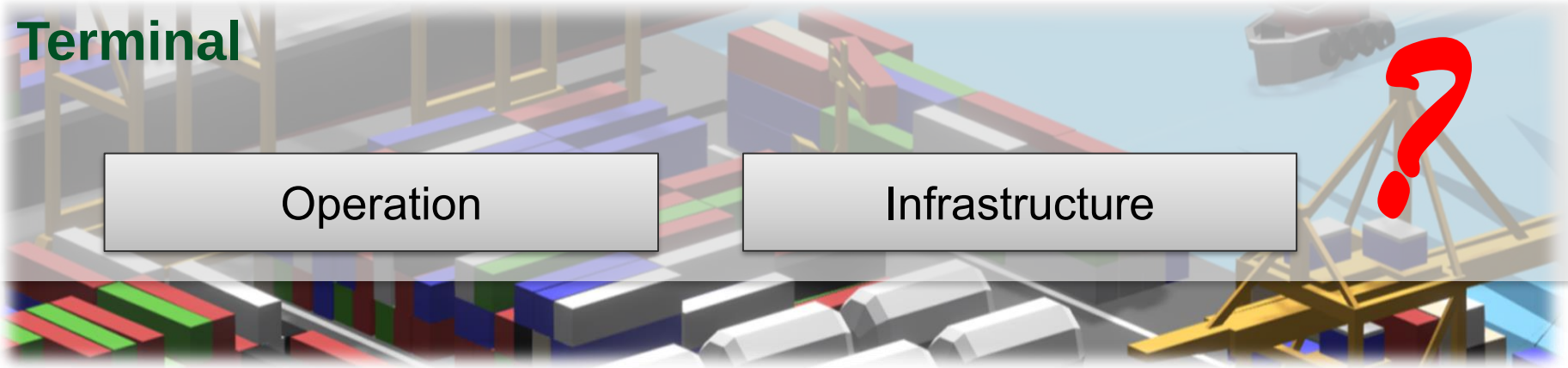
LIFT/LOWER DEMO



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

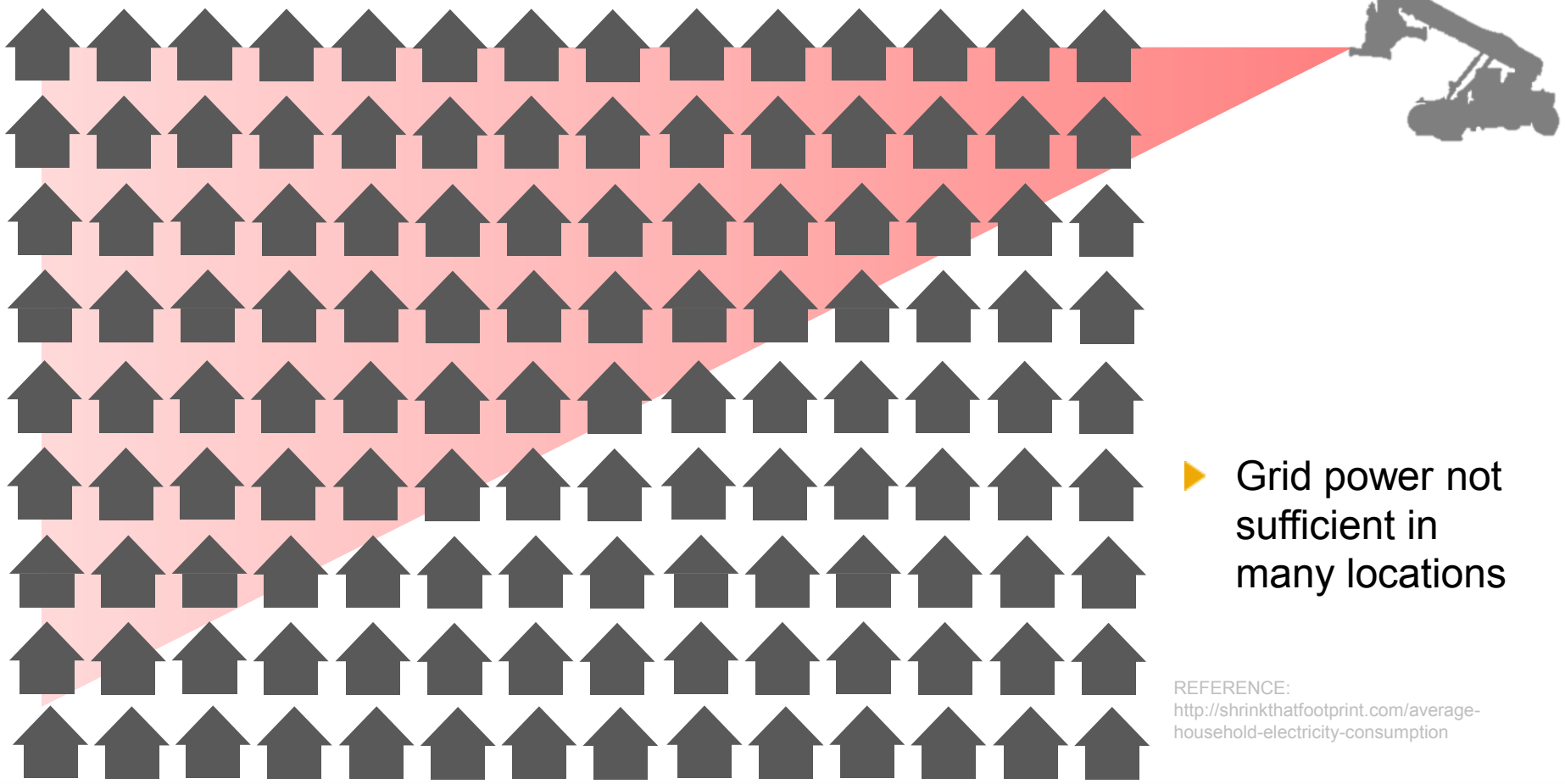
pin

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



- 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 H2
  - Local production with renewable energy with electrolysis
    → $2\ H_2O(l) \rightarrow 2\ H_2(g) + O_2(g)$
  - Deriving H2 from methane/biogas (SMR)
    → $CH_4 + H_2O \rightleftharpoons CO + 3\ H_2$

Source:
www.h2tools.org

HYSTER DEVELOPS RS WITH FUELCELL

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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ANY QUESTIONS?