1^{ST} CASPIAN 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

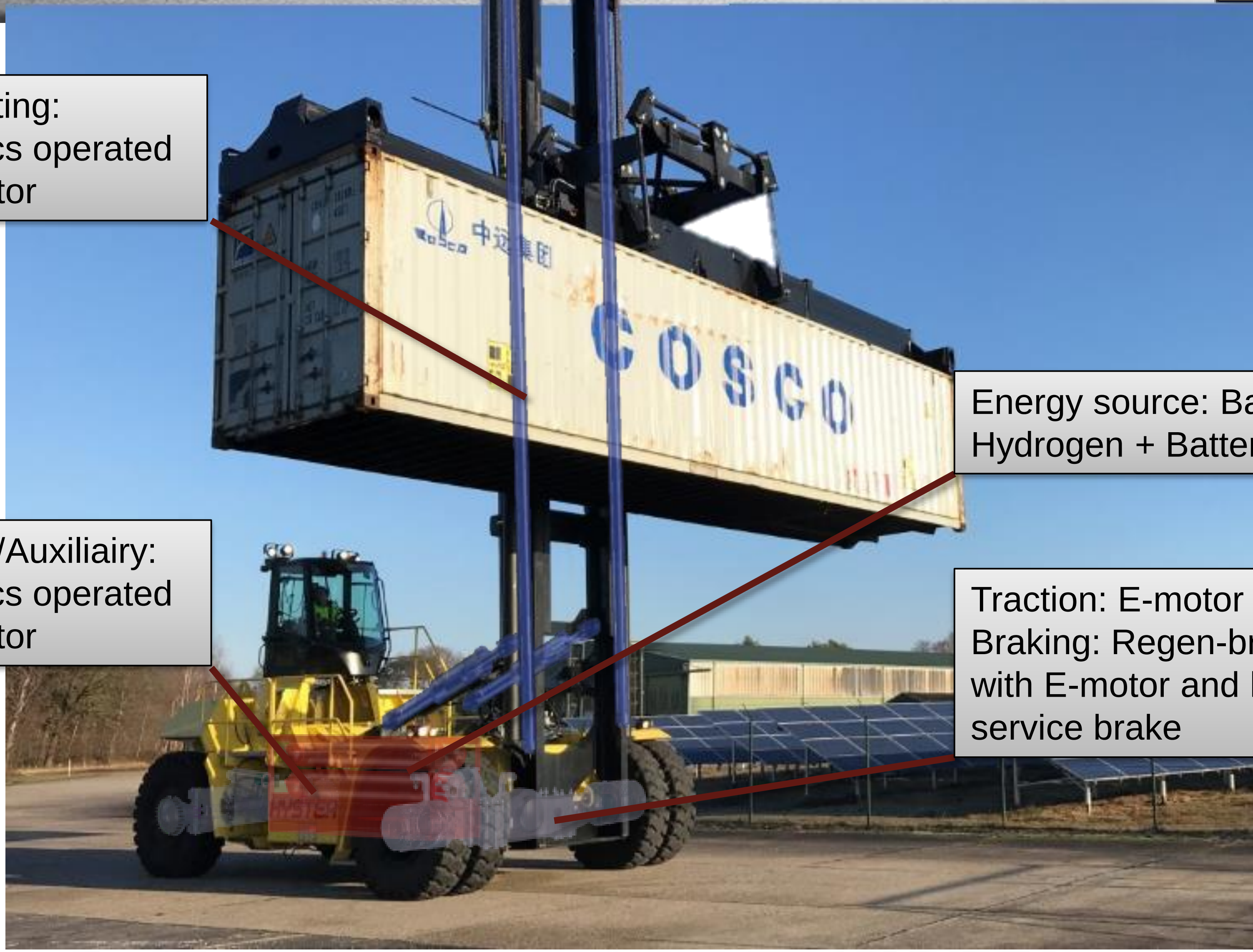
- Batteries: Li-Ion
  - 800 l Diesel (= 800 x 9,7) = 7760 kWh
  - 7760 kWh battery pack
    m3 for lead-acid), **97 tons**
- Fuel cell: hydrogen H2
  - 800 l Diesel = 7760/33 kg H2
    = **5.8 m**

What figurati

Optimized Siz linked wit ategy

Smart energy recovery for maximum efficiency

ZERO EMISSIONS CONTAINER HANDLER



Lifting/tilting: hydraulics operated by E-motor

Energy source: Battery or Hydrogen + Battery

Steering/Auxiliairy: hydraulics operated by E-motor

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

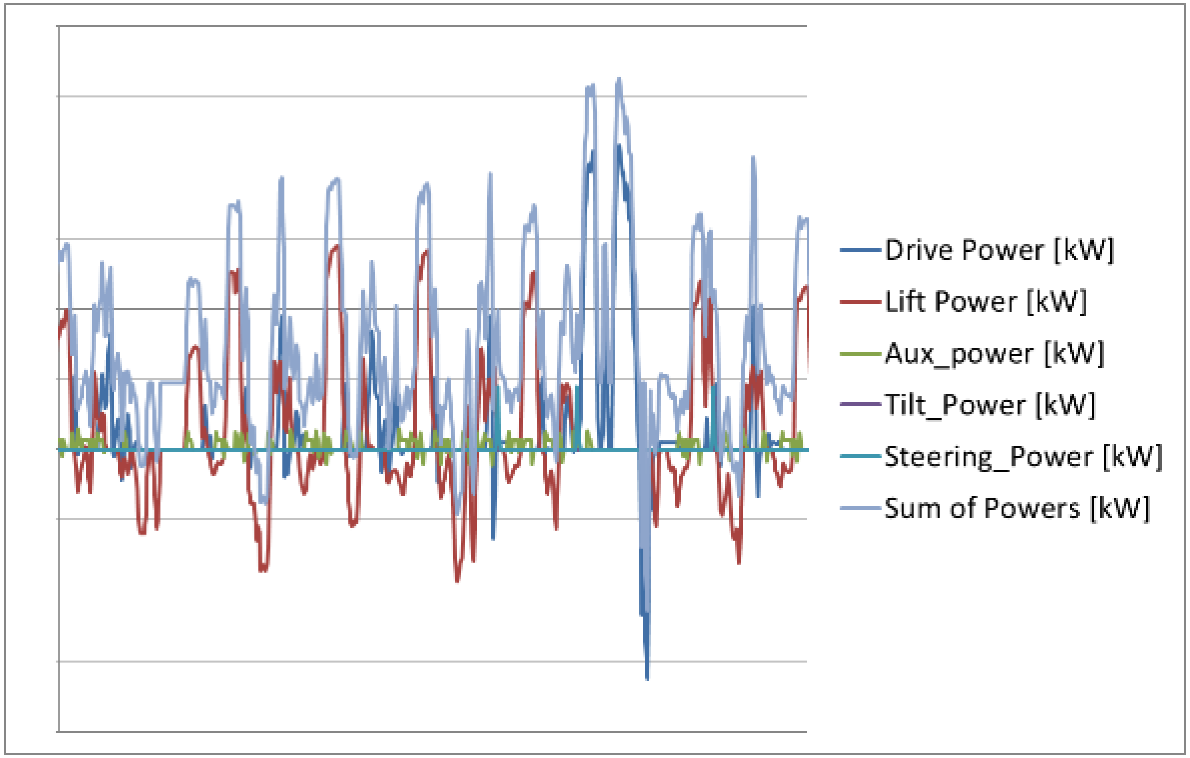
OPTION 1a
- Large Li-Ion battery
- Conventional charging
- Low to Medium duty cycle

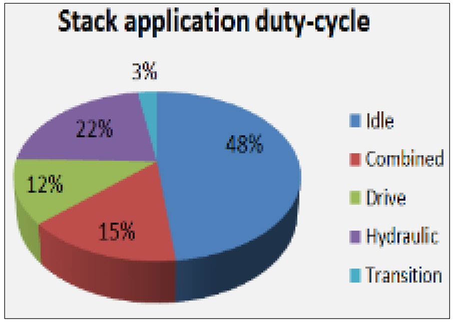
OPTION 1b
- Large Li-Ion battery
- Opportunity charging
- Medium duty cycle

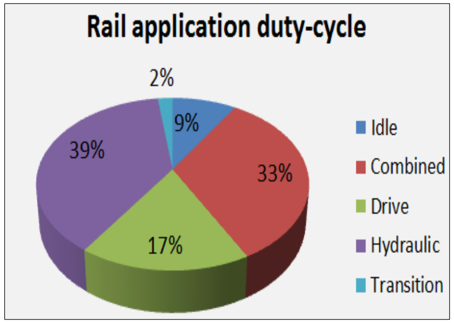
OPTION 2
- Fuel Cell with Small Li-ion battery
- Choice of charging system
- HD cycle: 1 day w/o refill

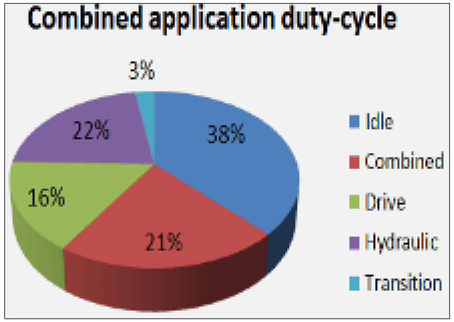
ENERGY EFFICIENCY BY ENERGY RECOVERY

- 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

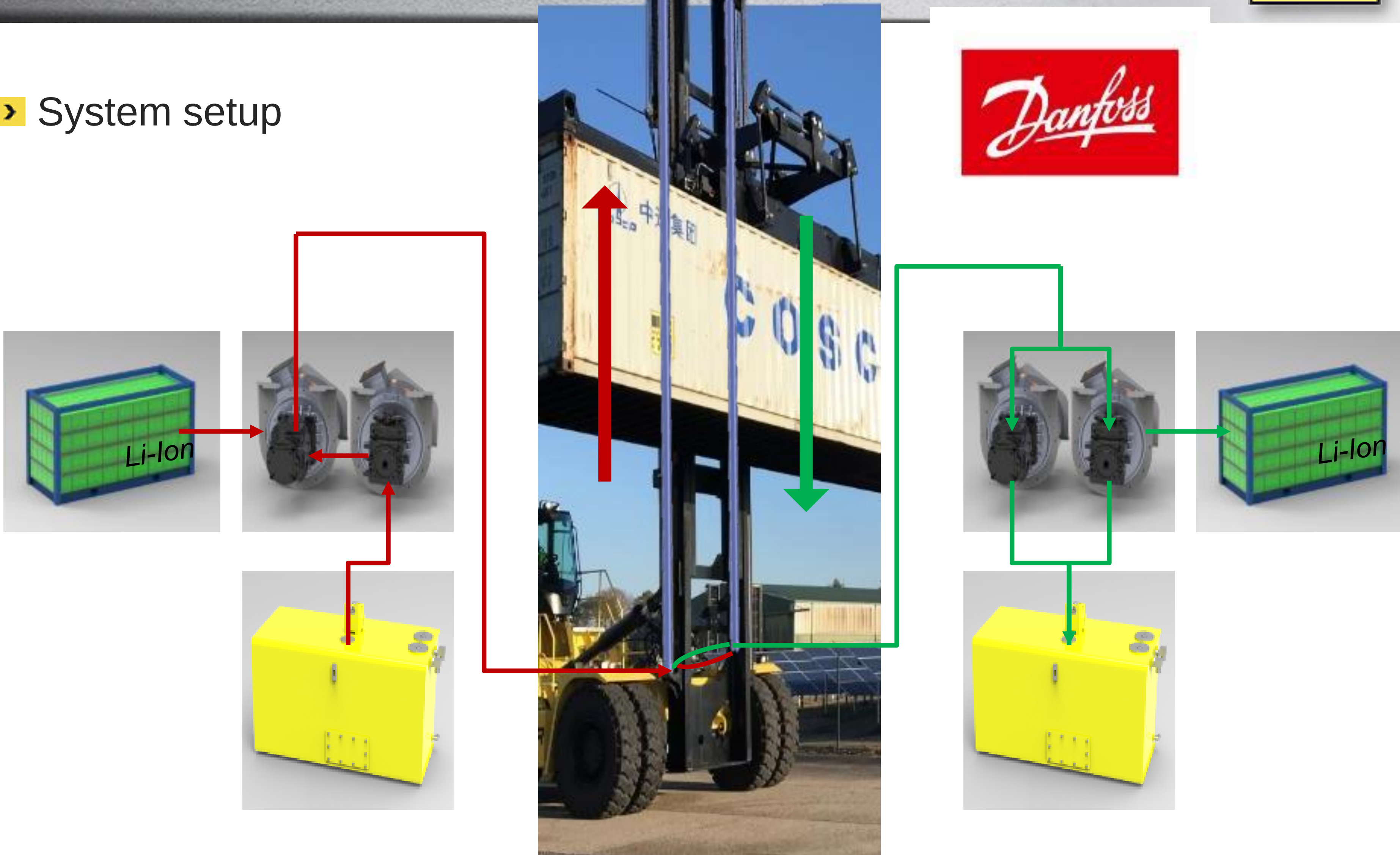
LIFT ENERGY RECOVERY

- 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

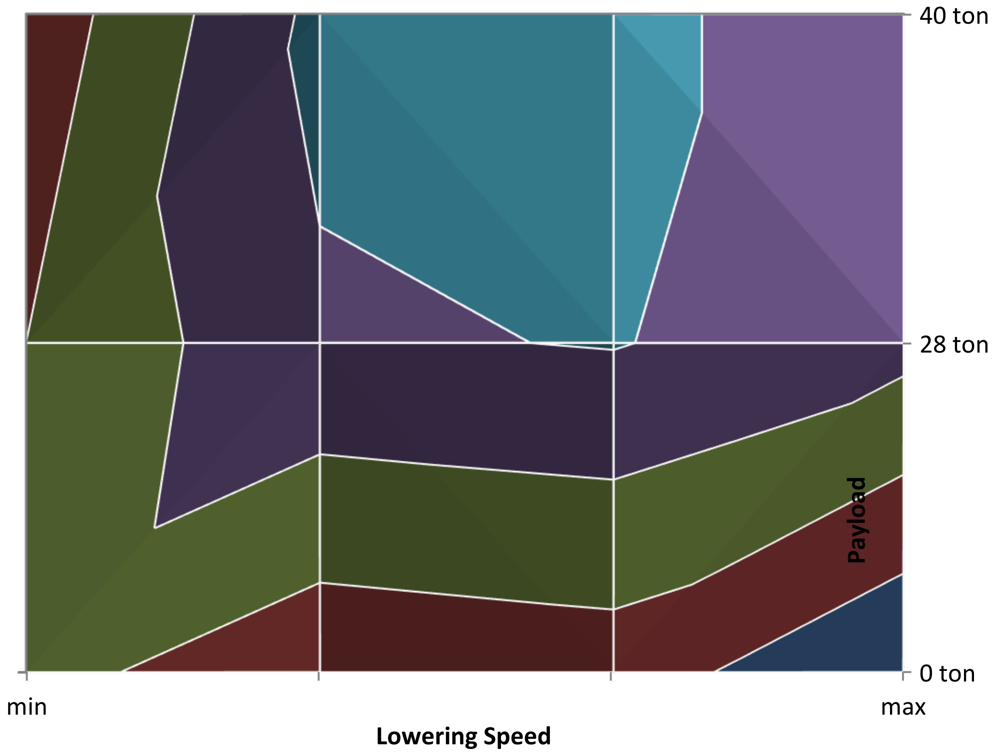
LIFT/LOWER SYSTEM

- System setup

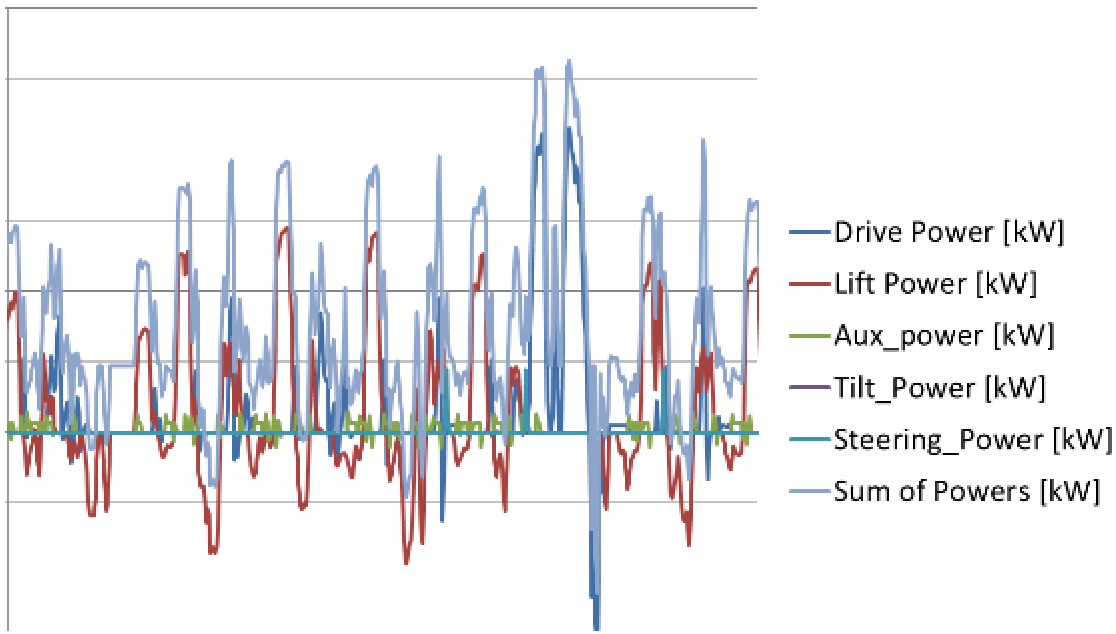


LIFT/LOWER EFFICIENCY

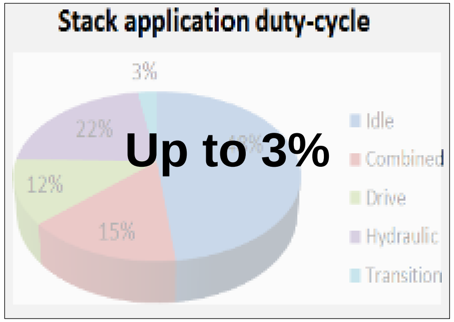
- Measurements performed at 0, 28 and 40 ton payload
  - Up to 64% energy recovery
  - Higher payload results in higher recovery percentage
  - Energy recovery still possible with 0 payload

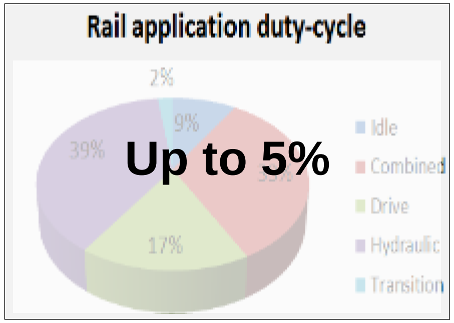


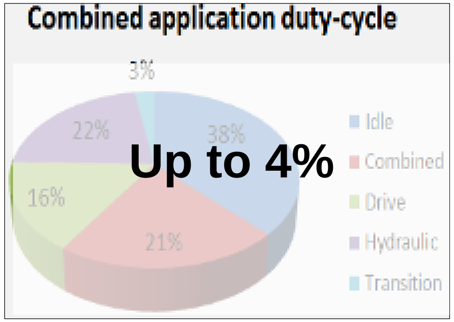
- Calculated energy consumption reduction based on current system efficiencies for hydraulic functions:



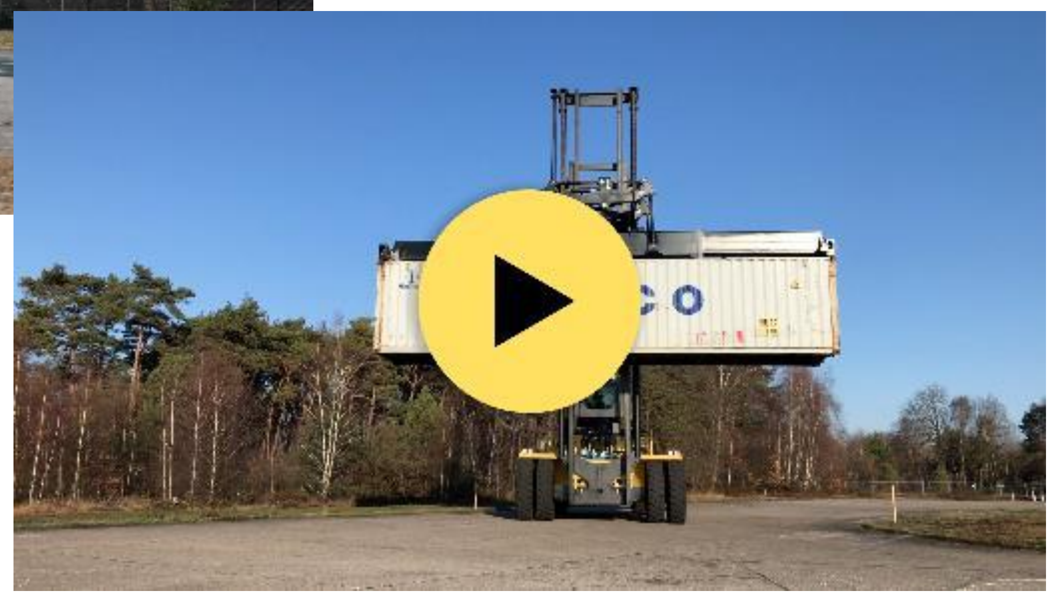
- theoretical energy recovery potential of 15% for all systems







LIFT/LOWER DEMO



CHALLENGES

- The three challenges of electrification

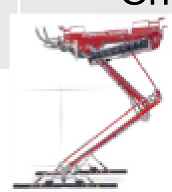
1. Operational planning of charging
2. Charging infrastructure
3. Total peak power consumption from the grid

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

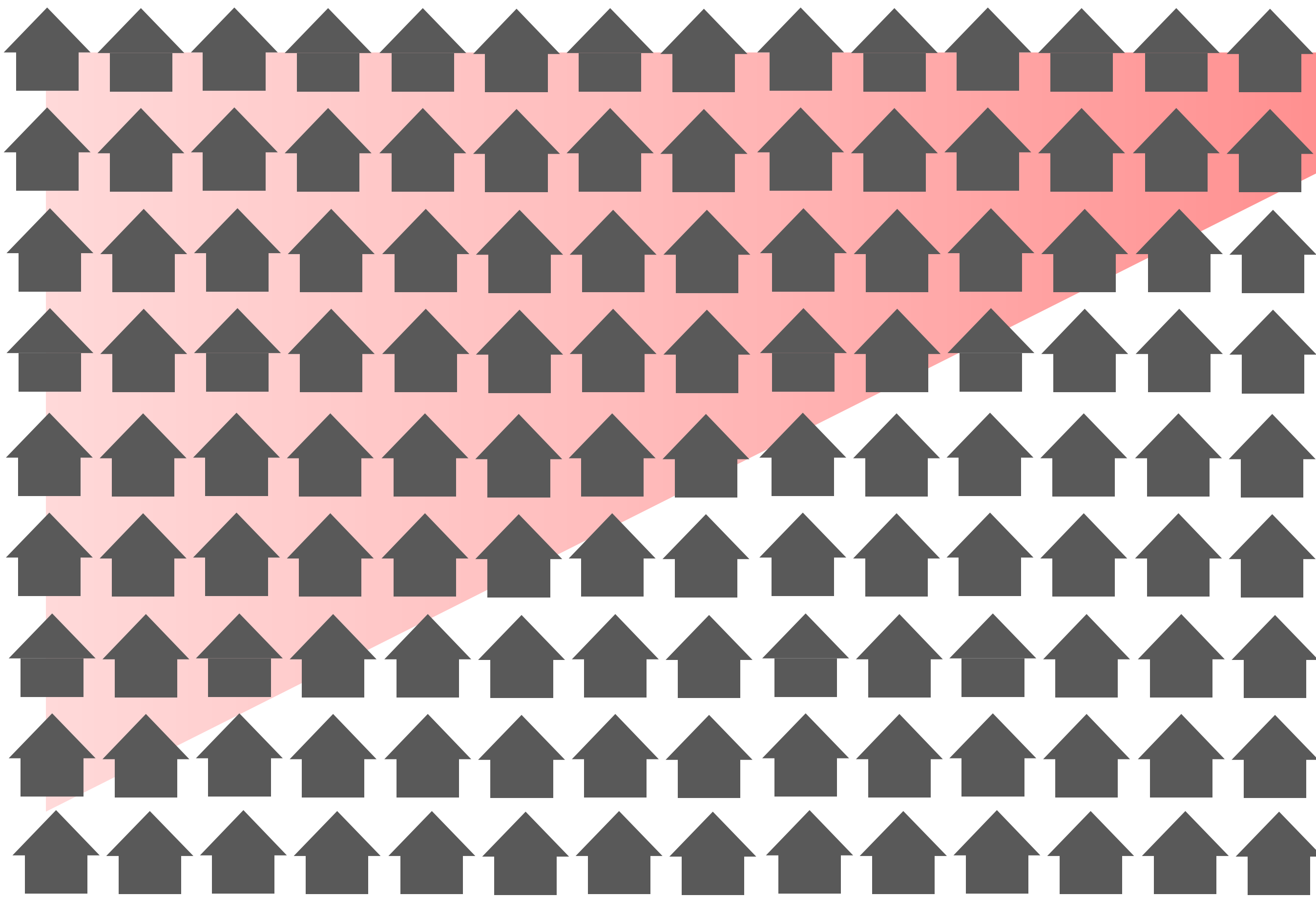
pin

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



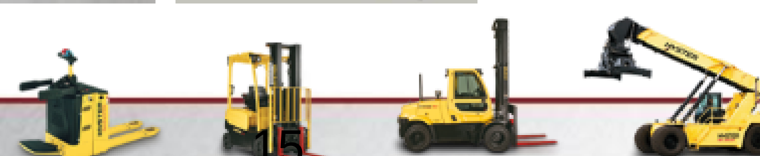
- Grid power not sufficient in many locations

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?