

IMPACTS OF ZERO-EMISSION CONTAINER HANDLING EQUIPMENT IMPLEMENTATION

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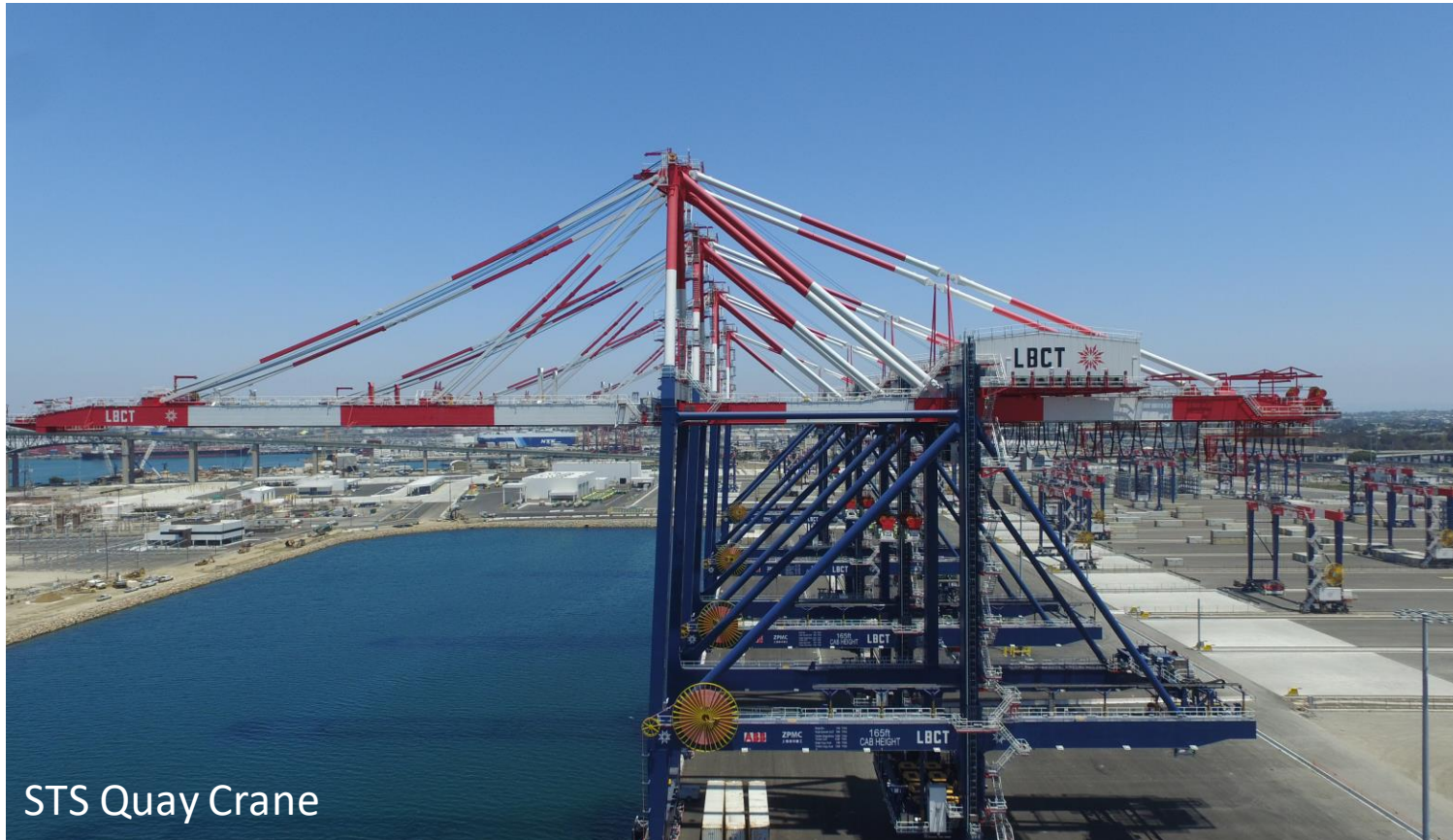
Introduction

- ▶ Growing trend to implement Zero Emission/Near Zero Emission (ZE/NZE) technologies for container handling equipment (CHE).
- ▶ There are many types of CHE with varied terminal operating roles.
- ▶ Some types of CHE fit well with proven ZE/NZE technologies
- ▶ Other CHE types create challenges to conform to proven technologies
- ▶ This presentation will describe the types of CHE and the opportunities and challenges of implementing ZE/NZE technologies for container terminal operations.
- ▶ Finally, a cost comparison for initial costs and energy costs of the lifetime of diesel and electrified equipment is also presented.

Types of CHE

- ▶ Categorized based on operational focus
 - Vessel operation equipment
 - Horizontal Transport Equipment
 - Container Yard (CY) Equipment
 - Intermodal Yard (IY) Equipment

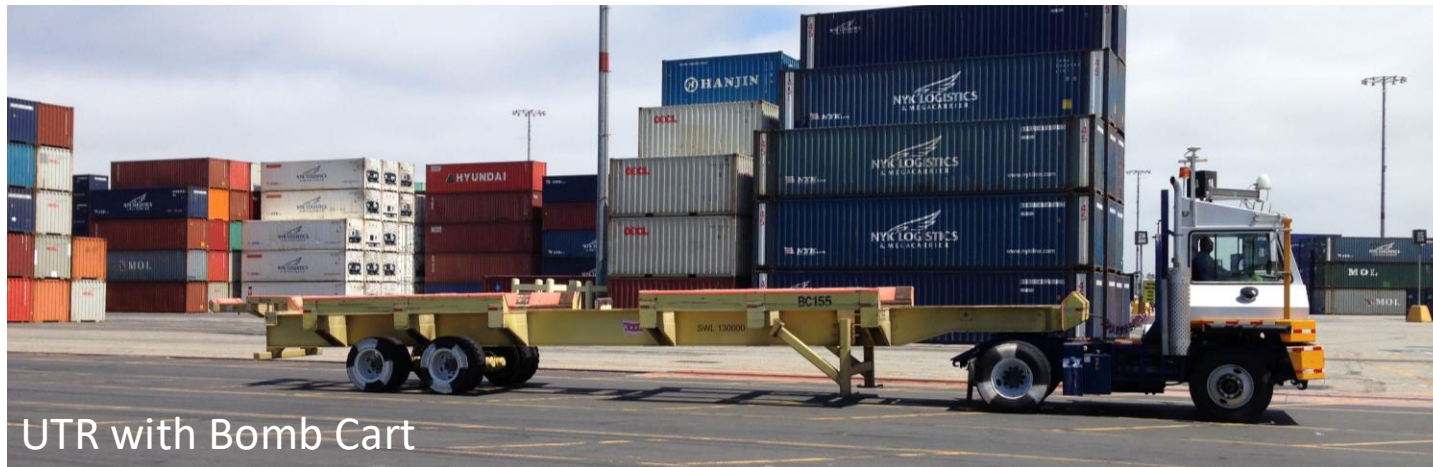
Vessel Operation Equipment



Horizontal Transport Equipment



Automated Guided Vehicle (AGV)



UTR with Bomb Cart



Shuttle Carrier

CY and IY Equipment

Rubber Tired Gantry Crane (RTG)



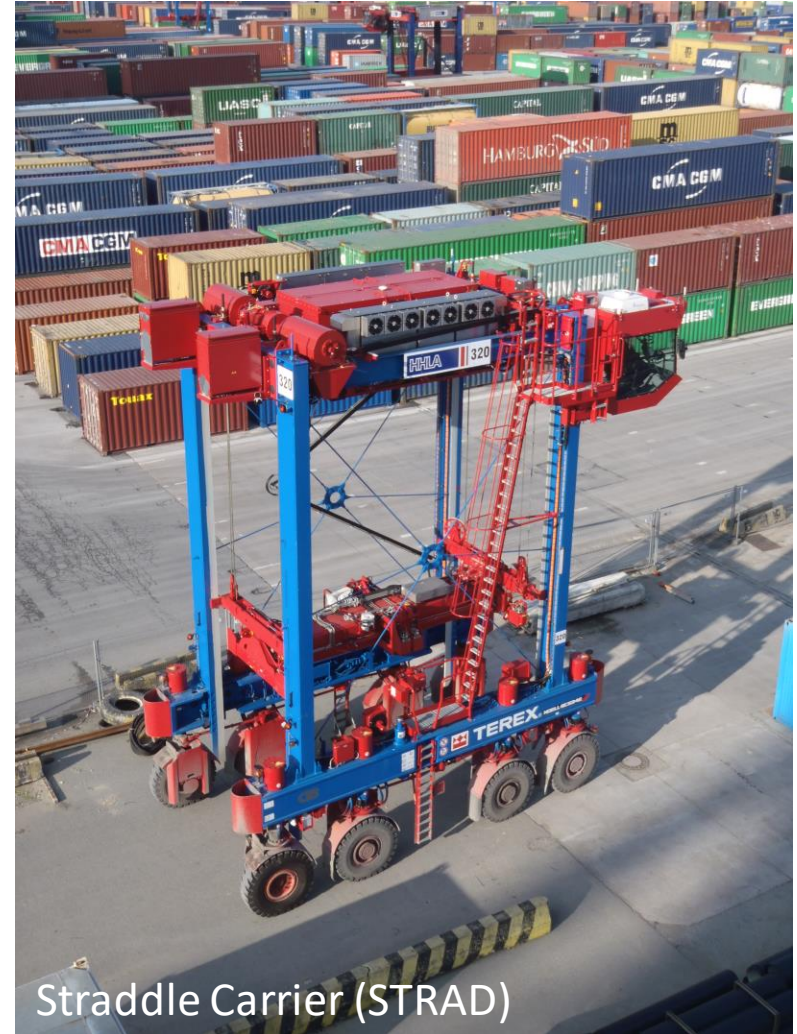
Rail Mounted Gantry Crane (RMG)
Automated Stacking Crane (ASC)



CY and IY Equipment



Top Pick



Straddle Carrier (STRAD)

NZE Equipment Opportunities and Challenges

- ▶ NZE CHE is in prototype testing
- ▶ Organizing LNG and CNG refueling inside the terminal
- ▶ Storing LNG and CNG on terminal.
 - Delivery of fuel by truck is preferred method.
- ▶ Availability of LNG/CNG locally.
- ▶ Diesel-electric CHE with re-generated energy and batteries for storage
 - Fuel savings and emission reductions are significant.

ZE Challenges for Free Range CHE



- ▶ Horizontal Transport and Select CY CHE
 - Fixed utility connection is impossible in practice.
 - Energy recharging of battery-operated vehicles.
 - Recharge Time
 - Quantity and location of charging stations
- ▶ Operating Range of Batteries
 - UTR battery products
 - Range of 160-220 kWh with average consumption estimated to be 15kW/hour.
 - Top Pick / STRAD battery products
 - Range of 600-1000 kWh, with average consumption estimated close to 60kW/hour.
 - As battery capacity increases, charging time also increases
 - Select strategy for battery sizing and charging.

ZE Challenges for Free Range CHE

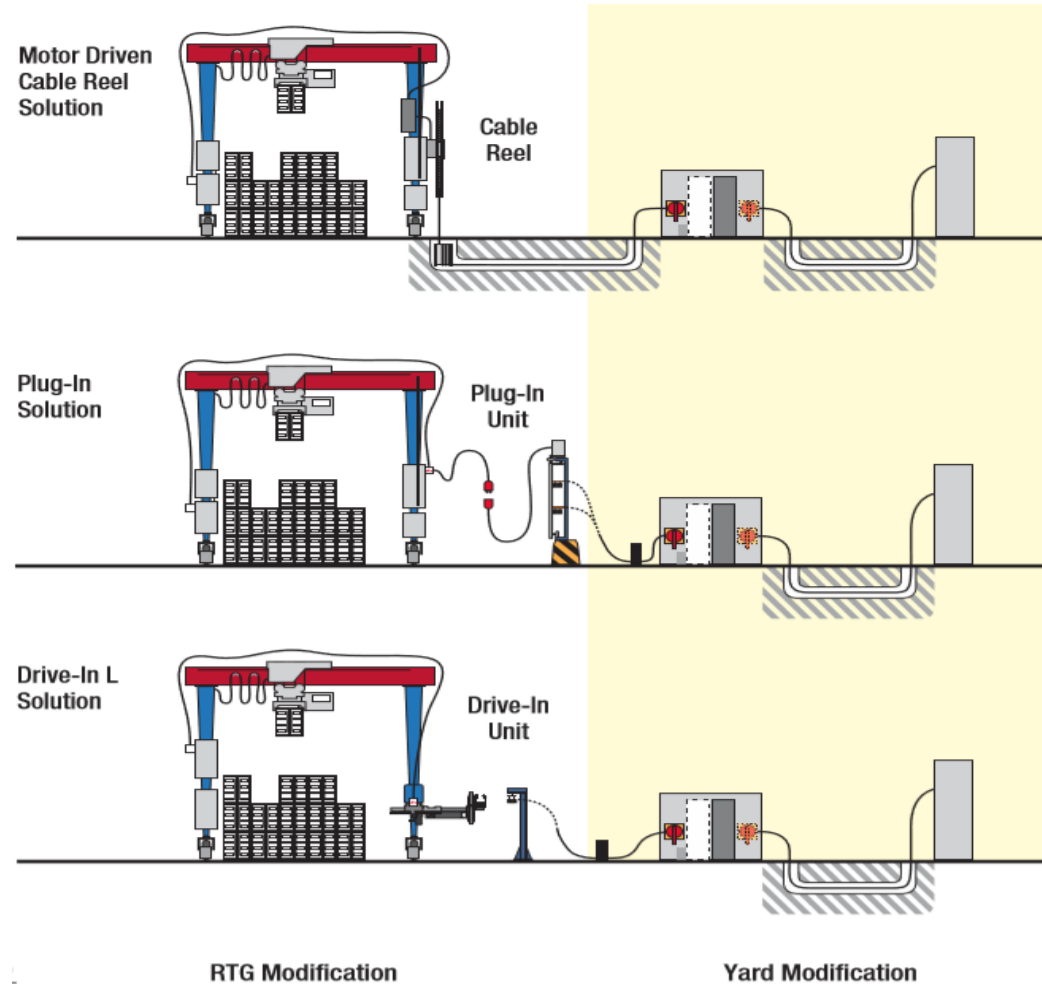


▶ Battery Charging Strategies

- Charge during non-operational times for a full work shift
 - Requires many highly utilized charging locations
 - Requires large battery capacity
- Provide excess equipment that charges during work shift
 - Results in a 25% increase in fleet size
 - Cost savings with less charging stations and lower battery capacity
 - Requires convenient switching between charged and spent CHE
- Use opportunistic charging during work shift cycle
 - Quick charge to operate 0.5 to 2 hours
 - Re-charge stations positioned at key locations in work area

ZE Opportunities for Select CHE

- ▶ Electric Ready CHE
 - STS Quay Crane
 - Mobile Harbor Crane
 - RTG
 - RMG/ASC



Cost of ZE/NZE CHE

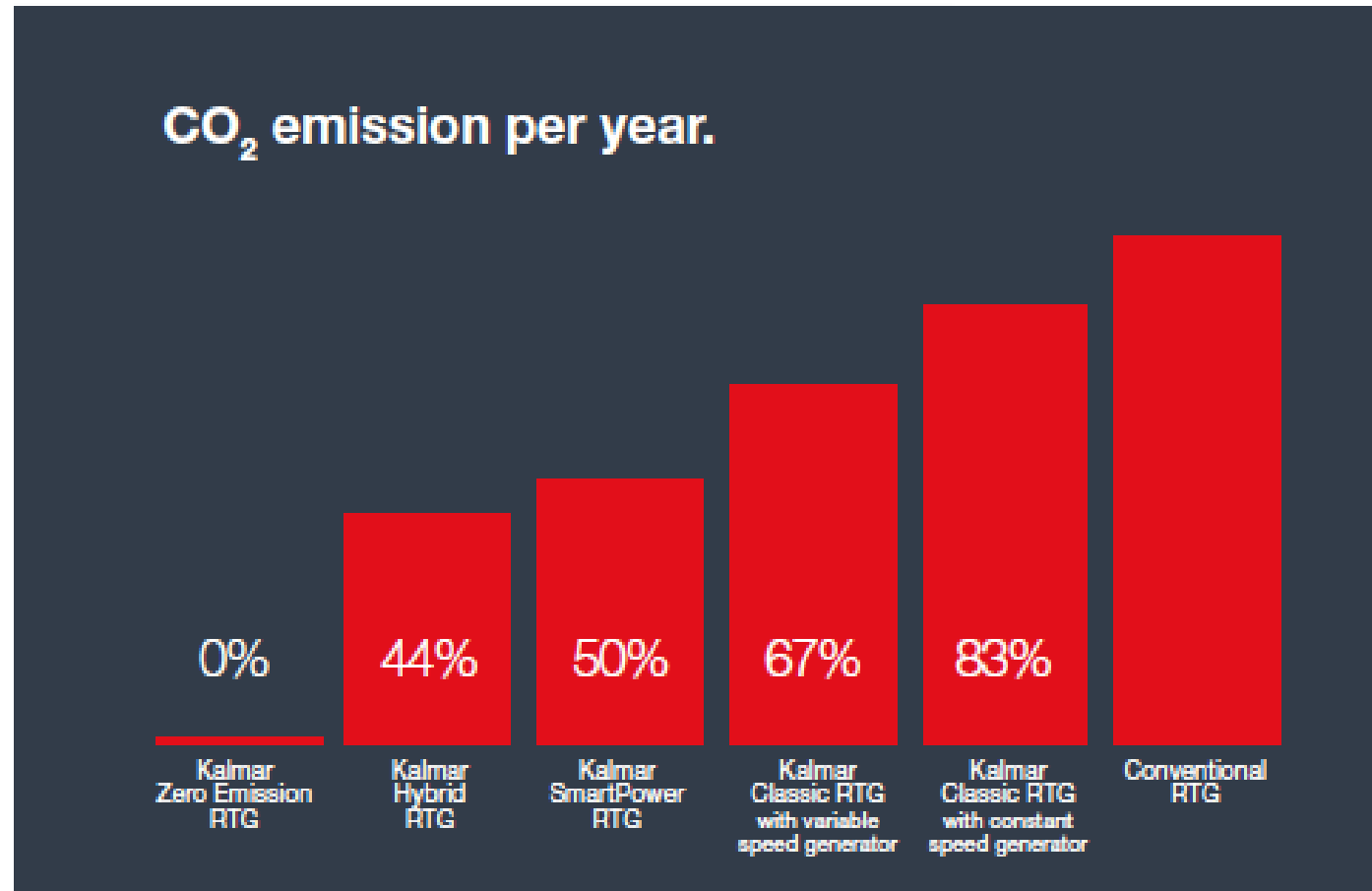
- ▶ STS cranes, Mobile Harbor Cranes, RTGs, RMGs, and ASCs
 - No significant cost increase associated with electrification
 - Retrofitting diesel equipment for electrification is feasible
- ▶ AGVs
 - Mature battery powered technology
- ▶ UTR, Shuttle Carriers, Top Picks
 - Currently at prototype level
 - Battery unit pricing is significantly higher than diesel units

Cost of Energy

- ▶ Electricity from Utility Service
 - Relatively stable cost
 - Lower maintenance costs for electric CHE
 - May required electrical infrastructure upsizing

- ▶ Diesel Energy
 - Price fluctuates with cost of crude
 - Higher maintenance costs for diesel CHE
 - Diesel supply is well established in marine terminals
 - Diesel CHE energy efficiency has seen significant improvement

Diesel Energy Improvements



Cost Comparison Case Study

General Input Data	
Annual operating hours [h]	4000
Diesel [\$/l]	\$.78
Electricity [\$/kWh]	\$.13
eRTG purchase price (electric)	\$1,800,000
RTG purchase price (diesel)	\$1,800,000
Diesel consumption [l/operating hour]	21
Electricity consumption [kW/operating hour]	50
RTG Design life (yrs)	20
Terminal Tractor purchase price (diesel)	\$120,000.00
Terminal Tractor purchase price (electric)	\$340,000.00
Diesel consumption [l/operating hour]	8
Electricity consumption [kW/operating hour]	15
Terminal Tractor Design life (yrs)	10

Cost Comparison Case Study

RTG	Diesel (USD)	Electric (USD)
Capital Expenditure	1,800,000	1,800,000
Energy cost 20 years	1,316,210	520,000
Investment and energy cost over lifetime	3,116,210	2,320,000
Terminal Tractor	Diesel (USD)	Electric (USD)
Capital Expenditure	120,000	340,000
Energy cost 10 years	250,707	41,600
Investment and energy cost over lifetime	370,707	381,600

Conclusions

- ▶ Terminal operations using ZE/NZE equipment are a long-term vision to reduce emissions.
- ▶ Electric versions of Larger CHE, (STS cranes, RTGs, RMGs, and ASCs) are currently available
- ▶ Electric versions of free range CHE is at early product stage
- ▶ New operational procedures and strategies are required to implement ZE/NZE technologies.
- ▶ Battery and charging technologies are evolving to provide a larger set of solutions
- ▶ Motivation to invest in ZE/NZE technologies include potential energy cost savings
- ▶ Significant cost differences of some CHE would not justify replacement investment unless ZE/NZE is a regulatory mandate and strict requirement
- ▶ Future ZE/NZE technology development is necessary to meet operational requirements.

THANK YOU

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