Roland Berger's view on Port Decarbonization

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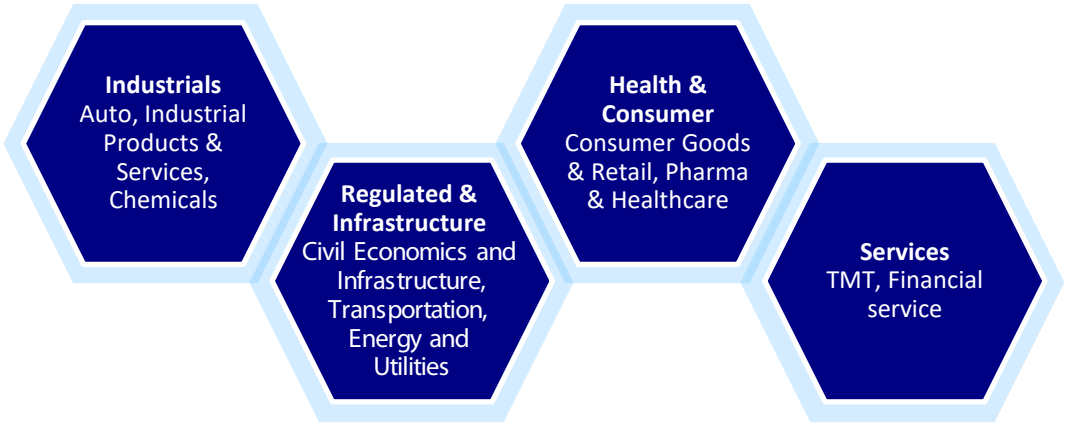
Roland Berger is a European-rooted, leading global consulting firm with a strong foothold in Asia and a trusted partner for clients

In-depth expertise in all industries

Full industry coverage along with **4** industrial expertise platforms, each with rich project experiences:

Full industry coverage



Our senior experts and advisor network with extensive experiences covering all **major economic regions** and **industry sectors**

Long-term trusted partner of industry leaders

We serve … … the largest international companies

30%
of the Global 1000

40%
of Europe's leading companies

75%
repeat clients

Client trust

Source: Roland Berger

Founded in Germany, Roland Berger has increasingly expanded into the Southeast Asian region with several offices in all major countries

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52 offices in 36 countries, with approx. 2,400 employees
Over 220 partners with specific expertise organized in 14 competence centers
Serving over 1,000 international clients

Clients

75% repeat clients

40% of top 1,000 global companies

50% of Europe's leading companies

Source: Roland Berger

Decarbonization in freight logistics industry: Freight logistics companies' net-zero transition exhibits a dual momentum - top-down policy "push" from government and bottom-up market "pull" from customer demand

Investors

- Enforcing standardized ESG and other **rating system**
- Establish a **net-zero centered investment strategy**
- **Actively support** the development of net-zero enterprises **by targeted beneficial policies**

Government/ Regulatory authorities

- Set up **laws and regulations**
- Establish **regulatory mechanism**
- **Oversee** the order of the carbon reduction **market**

Downstream customers/Shippers

- Publicly **promote net-zero commitment** and carbon reduction initiatives
- Establishing **green vendor partnerships** and implement **net-zero operations**

Global freight logistics operators

- Proactively conduct CFV and develop carbon reduction **action plans**
- **Implement carbon reduction** plans and participate in carbon trading
- Participate in the **carbon reduction alliance** and promote the industry development

Source: desktop research; Roland Berger

Among logistics value chain, the highly standardized maritime sector is expected to be one of the first areas to undergo a decarbonization transformation

Comparison analysis of the carbon reduction potential in major logistics segments

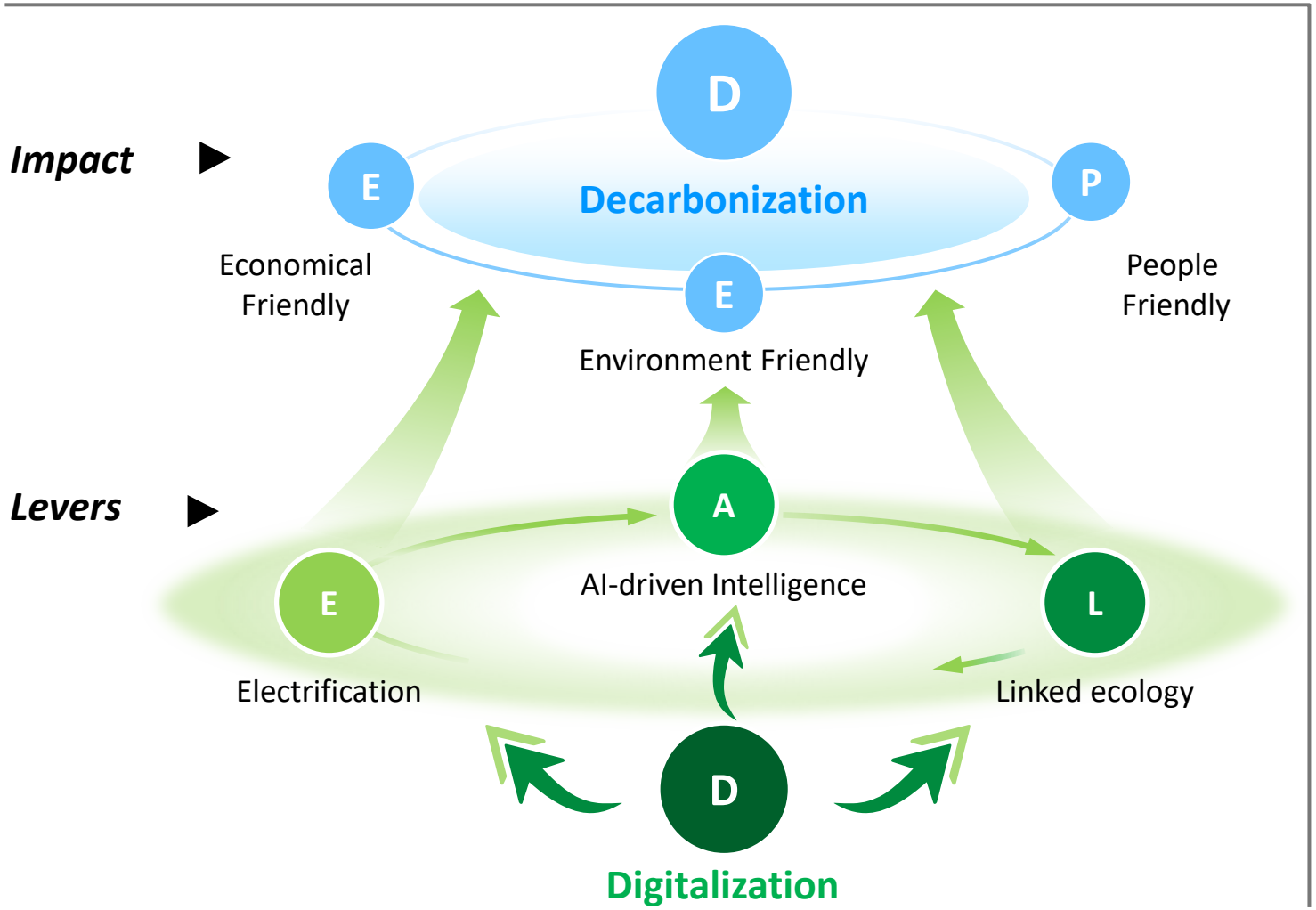
	Attractiveness			Feasibility		
	% of Carbon emissions [%, 2022]	% of Global freight turnover [%]	Comprehensive evaluation	Environmental complexity	Degree of standardization	Comprehensive evaluation
Maritime	14%	~85%		• Closed section with high operation repetition	• Mainly container transportation	
Aviation	14%	<1%				
Road	71%	8%		• Non-closed sections with interfering factors		
Railway	<1%	5%				
Others	<1%	<1%		• Short-distance logistics such as factories are applicable		

Attractiveness Low → High

Feasibility Low → High

Source: Roland Berger

Seaport decarbonization methodology: "LEAD" the green wave, bring the "DEEP" impact



Key Measures

Phase I: Electrification

- Switch to e-power equipment and facilities
- Energy facilities (incl. charging, battery swap, storage)

Phase II: AI-driven intelligence

- Smart vehicles
- Intelligent management system (vehicle, equipment)
- Energy management system

Phase III: Linked ecology

- AI-enabled TOS
- Circular economy
- On-site green power supply

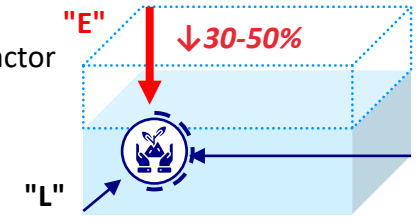
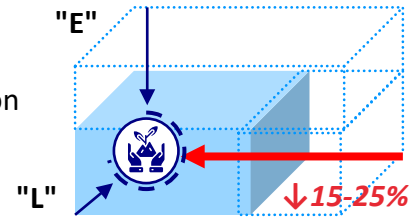
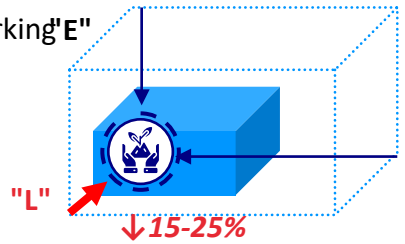
Fundamental: Digitalization

- Quantify operational activities in Carbon footprint verification
- Standardize operator behaviors

Source: Roland Berger

“LEAD” benefit seaport with carbon emission reduction and other value-added impact

"DEEP" impact

	D Decarbonization	E Economical friendly	E Environment friendly	P People friendly
Phase I	Change emission factor 	• Scale-up brings equipment cost savings • Lower electricity prices • Battery technology brings unit battery cost cut		
Phase II	Reduce unit energy consumption 	• Battery size reduction through dispatch and charging systems • Reducing energy consumption and maintenance costs through digital operations optimization		• Improve site safety • Protect crew from hazard & extreme weather
Phase III	Shorten working distance 	• Further cost optimization with TOS system • Reduce operational instability due to labor shortages through automated systems	• Improve overall seaport operation efficiency • Reduce resource waste • Set up on-site green energy station	• Shorten operation time by intelligent scheduling • Minimize idle time

Carbon emission volume

Note: *carbon reduction level compares to original level where most of equipment are diesel driven

Source: Roland Berger

Phase I – "E" Electrification

Transforming the energy utilization method of equipment from diesel-driven to electric-driven

E Electrification

Carbon emission reduction parameters

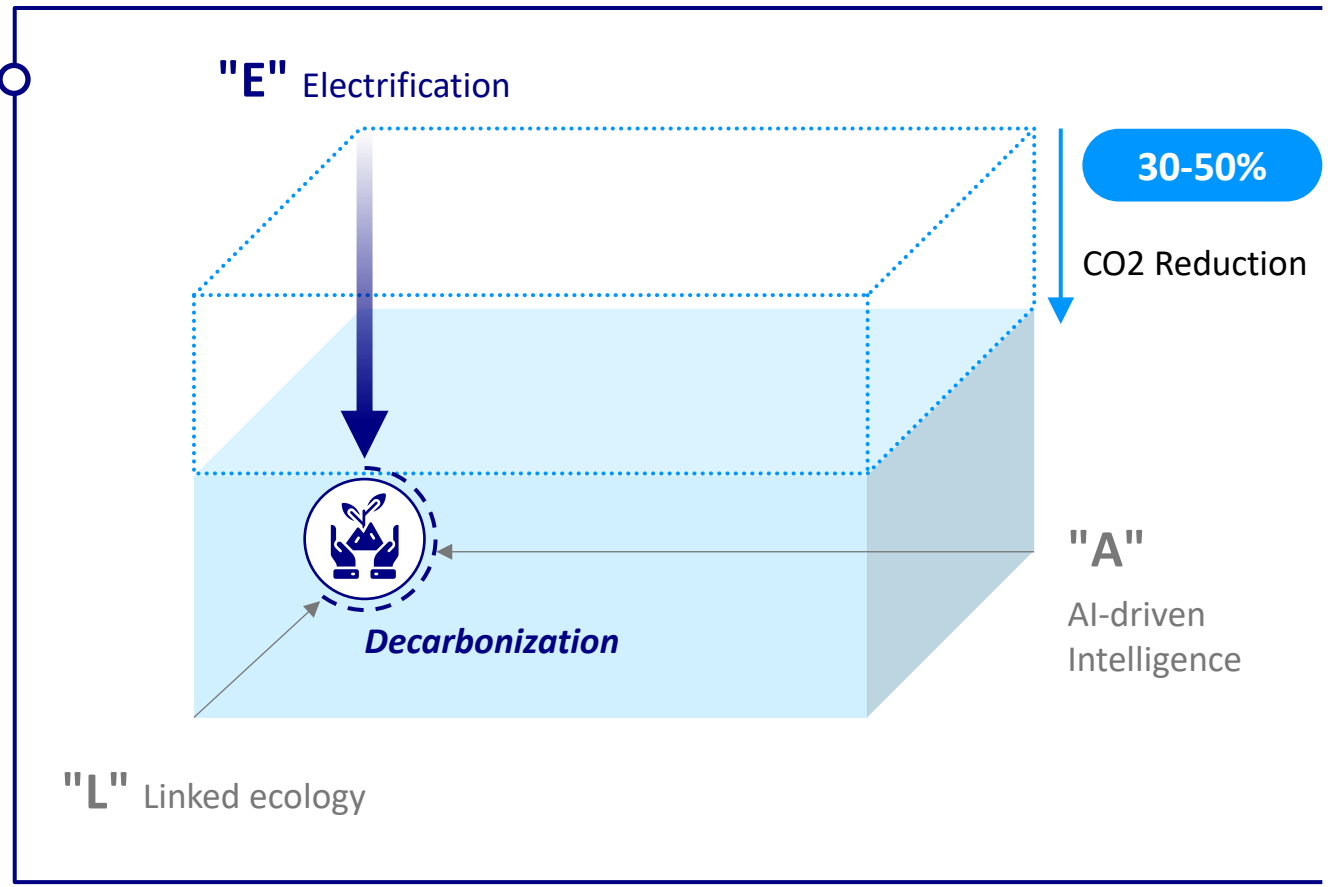
Total CE = Emission factor × Energy consumption × Distance

Key measures

- Energy facilities (incl. charging, battery swap, storage)
- Switch to e-power equipment and facilities

Value creation

- Economical friendly
- Environment friendly
- People friendly



Source: Roland Berger

Case Study: Seaport of Hamburg

Embraced sustainability as a core part of its strategy, introducing electric working equipment, aiming carbon neutral by 2040

Key points

- High carbon emissions
- One of the largest ports in Europe

Port throughput

~630

KTEU/month

Electrification initiatives

Electrification Of Working Equipment

- Shift to electric fleet: **CTA's AGV fleet is 90% electrified**, with a complete shift to lithium-ion batteries anticipated by 2023. Most of the port's container and rail **gantry cranes are powered by green electricity**
- Transition to electrify its fleet of Elbe ferries, which currently run on diesel. the Cöllni, an electric-powered workboat, is the first of its kind in the port of Hamburg

Installation Of Onshore Power Supply

- **First-mover of OPS installation:** The port of Hamburg has installed onshore power supply (OPS) facilities at its container terminals and cruise ship terminals since 2018
- **Launch 11 berths in 2025 :** the port plans to have a total of 11 OPS-equipped berths by 2025, including 7 connection points for container ships and OPS facilities at the Steinwerder and HafenCity cruise terminals

Introduction Of Hydrogen-powered Trucks

- **Plan in Hydorgen replacement and refuelling station:** The port is in the process of replacing diesel-fueled cargo trucks with hydrogen-powered trucks and plans to install 5 hydrogen refueling stations and 2 mobile refueling facilities, as well as an electrolyzer facility
- **acquire financial support on hydrogen transformation:** The port is receiving €15 million in German federal funding for the hydrogen truck project through the HyPerformer II scheme

Value creation

D Decarbonization

- The seaport's shore power facilities are estimated to reduce CO2 emissions by **30,000** tons per year

Source: Port of hamburg press, Torqeedo press; Roland Berger

Case Study: The Seaport of Long Beach, CA, US

Announced the famous 'Clean Truck Program' to reduce total truck emissions by over 80% within 5 years

Key points

- High carbon emissions

Port throughput

668

kTEU/mon

Aims to become the world's first zero-emissions seaport

Announce several port decarbonization plans from 2017 (incl. <Clean Air Action Plan>) to achieve zero-emission target, incl.

Clean trucks program

- Replace 16,000 heavily polluted old trucks with **clean energy trucks** such as electric and nitrogen oxide vehicles

Clean container handling equipment program

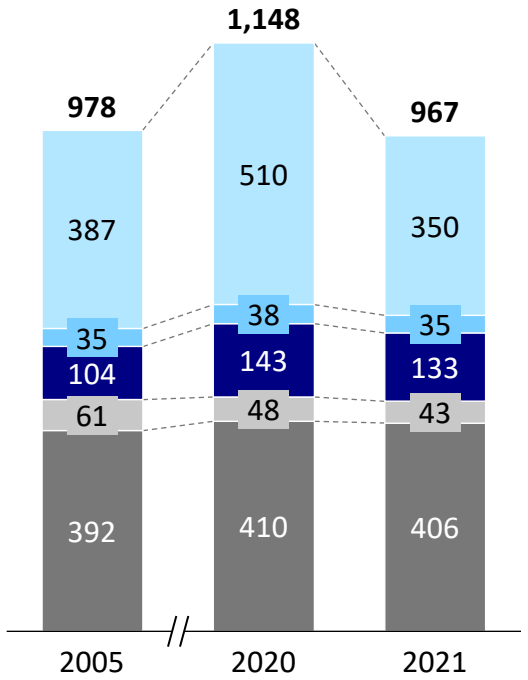
- The existing diesel-powered gantry crane has been modified to operate on electricity, initiate the largest port **machinery zero-emission** pilot project in US

Green energy project "Pier wind"

- Build a 400-acre terminal for manufacturing, sectioning, assembly, and possible maintenance of **offshore wind turbines**

CO2 Emission by source category

[bn Ton, '05-'21]



Value creation

D Decarbonization

- A dramatic reduction in diesel particulate matter by **91%** , nitrogen oxide levels by **63%**, and sulfur oxides by a staggering **97%** since the year 2005

*"As the world's first **fully electric, zero-emission mega port**, LBCT sets industry standards for sustainable transportation of goods, **maintaining port competitiveness**."— Long Beach Port Executive Director Mario Cordero*

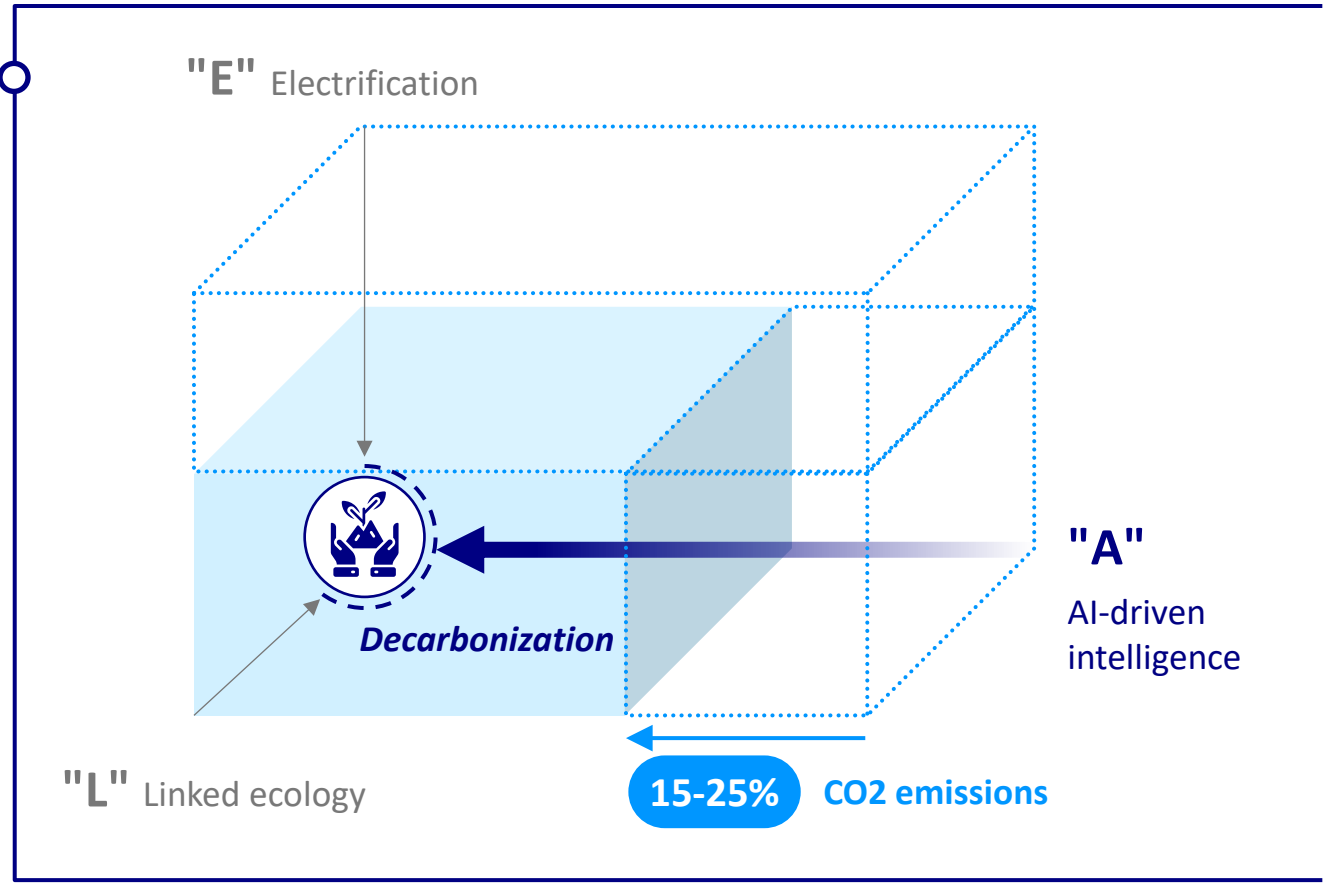
Source: Port of long beach 2022 Air Emissions Inventory; Roland Berger

Phase II – "A" AI-driven intelligence

Further reduce carbon emission and improve working environment based on intelligence technology

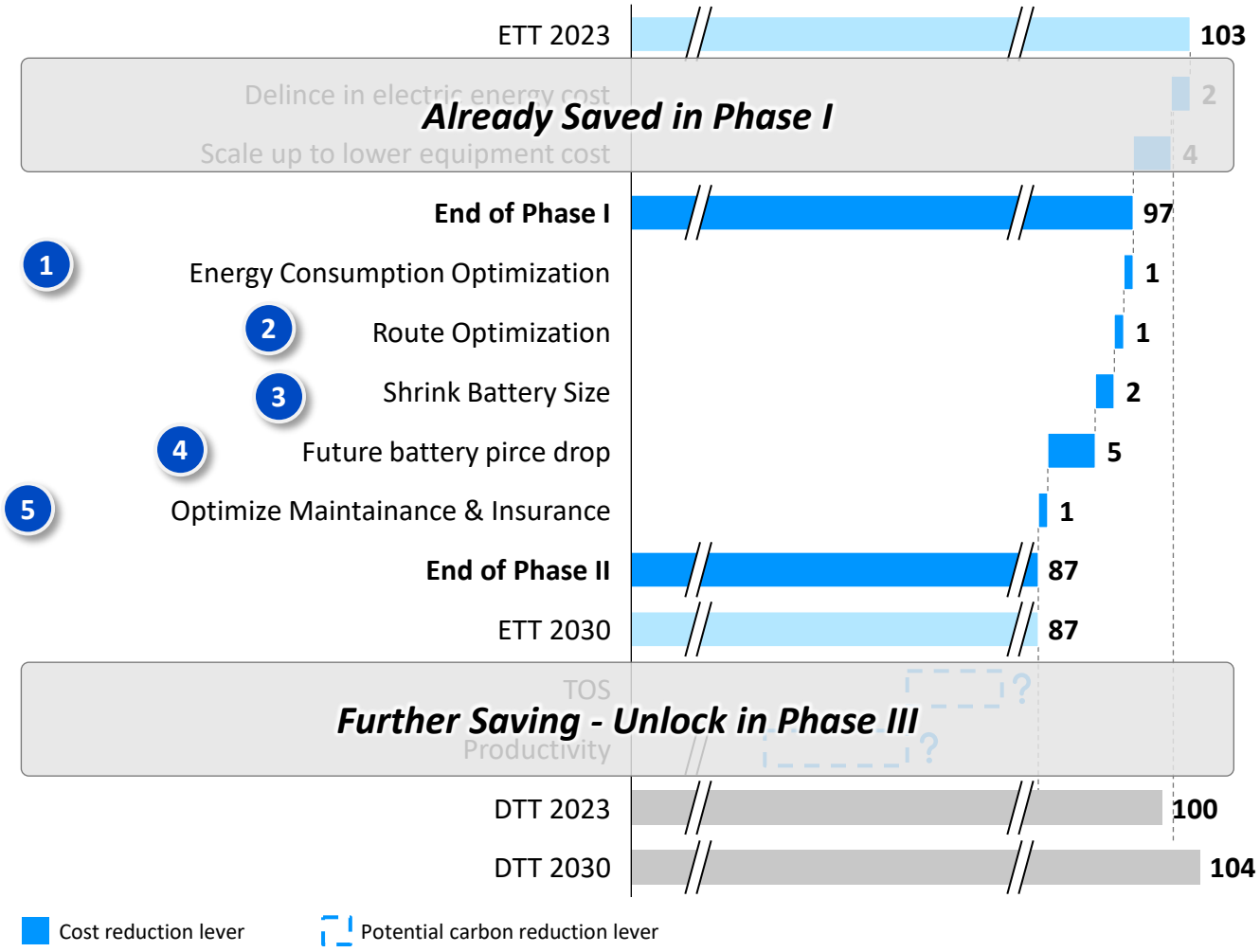
A **AI-driven intelligence**

Carbon emission reduction parameters	Total CE =	Emission factor × Energy consumption × Distance
Key measures		Smart vehicles Intelligent management system (vehicle, equipment) Energy management system
Value creation		Economical friendly Environment friendly People friendly



Source: Roland Berger

Economical value add in Phase II: Multiple combined factors drive cost reductions, including energy consumption optimization and others



1) ETT is electric powered vehicle, DTT is diesel powered vehicle

Key Saving Contributors

1 Energy Consumption Optimization

- With driving assistance, high energy-consuming behaviors like sudden braking can be reduced, thereby lowering the energy consumption rate of electric vehicles

2 Route Optimization

- FMS can reorganize and shorten working routes with algorithms, minimizing empty runs and circuitous routes

3 Smaller Battery Size

- Through collaborative design of battery sizes and charging facilities, smaller batteries can meet the same operational requirements

4 Battery Price Drop

- Advancements in battery technology will lead to a decline in unit battery costs, while optimized battery usage habits will allow for procurement of cost-effective batteries

5 Optimized Maintenance and Insurance

- Operational and driving optimization strategies will help minimize wear and tear and accident rates, thereby reducing routine maintenance and insurance expenses

Source: Roland Berger

Case study - Seaport of Laem Chabang, Thailand

Mixed operation of electric vehicles and diesel vehicles, helping save energy costs and optimizing driver driving experience

Key points

- Difficulties in recruiting drivers
- Safety hazards exist
- High carbon emissions

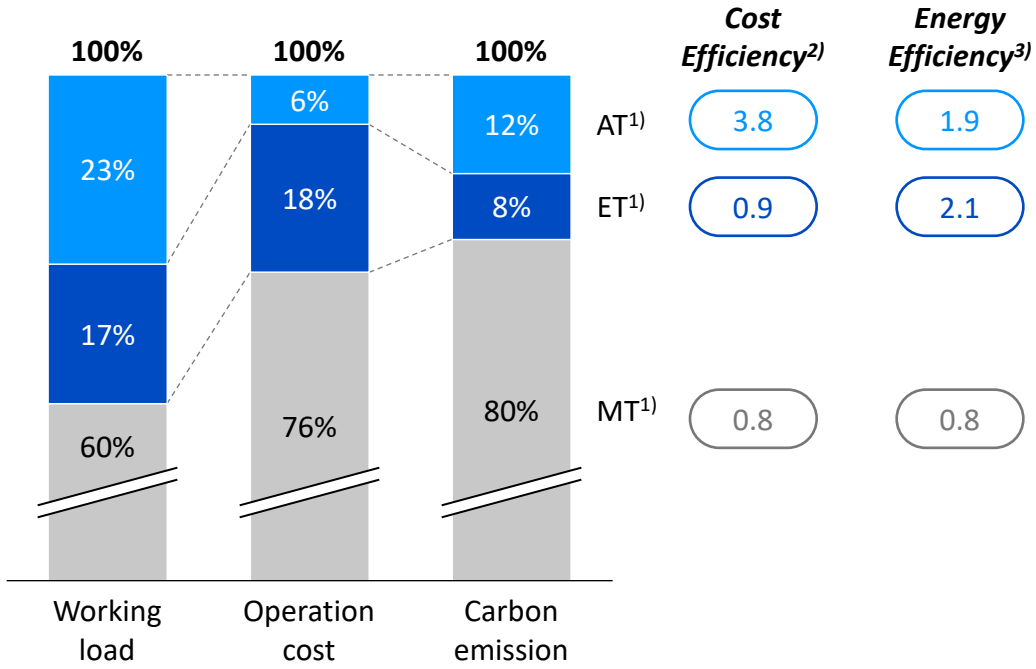
Port throughput

130

kTEU/mon

Performance comparison - MT vs. New energy truck

Introduce **24 new energy trucks** (15 AT, 9 ET) to achieve **100% non-isolated mixed operation** with 32 fuel trucks



Value creation

D **Decarbonization**

Potential to reduce carbon emission **~45** tons/truck*year with 100% green electricity

E **Economical friendly**

Reduce energy cost **111**4) k EURO/year

P **People friendly**

Zero CO2 emissions in working environment

*"E-Truck **has high driving comfort**, it is quieter, more smooth to drive"*

— Port truck drivers

1) MT = Diesel truck with drivers, ET= Electric truck with drivers, AT= Autonomous electric truck without drivers; 2) Cost efficiency = workload / operation cost; 3) workload / CO2 emission; 4) Euro to RMB exchange rate = 7.66 (2023 averaged rate) ;

Source: Roland Berger

Case study - Seaport of Felixstowe, United Kingdom

Achieve CO2 emission reduction based on integrated intelligent management system for truck, fleets, and energy

Key points

- The largest and busiest seaport in UK, with high requirements for operational efficiency and stability

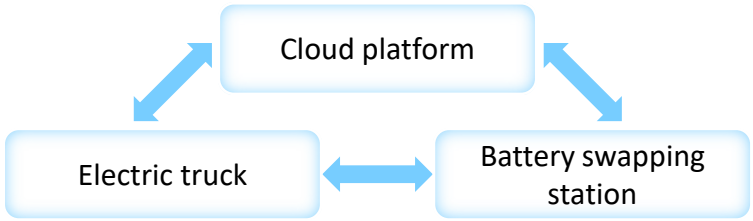
Port throughput

~320

kTEU/mon

Energy management system

PowerOnair battery swapping ecosystem



- Improve **energy efficiency** through energy management center
- Achieve **lifecycle carbon footprint** management by big data analysis

Extreme Precise Position system

New Generation Fusion Perception Architecture

Sensor

- AI camera
- Lidar

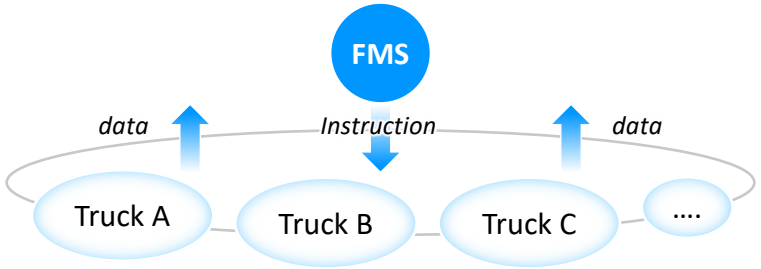
Q-truck

Algorithm

- Whole stack system

- Precise **centimeter-level** positioning of vehicles
- High-precision control with a **0.5-degree** steering deviation

Fleet management system



- Effectively manage fleets, perform one-to-one **task matching**, and **reduce vehicle idle rate**
- Advanced TOS **realize real-time interaction** between system and equipment

Value creation

D Decarbonization

Reduce CO2 emission **50**[1)] tons/ truck*year

P People friendly

Around 5 mins to Complete battery swapping

As **a supplement** to labor shortage to ensure working stability

"The new trucks help improve the efficiency of container handling at port and the stability of operations"

— Port executive director

1) based on scenario with 100% green electricity supply

Source: Desktop research; Roland Berger

Phase III – "L" Linked ecology

Constructing an interconnected ecosystem for enhanced efficiency and sustainability by integrating dispersed systems, devices, energy, information, and materials within the terminal

Linked ecology

Carbon emission reduction parameters

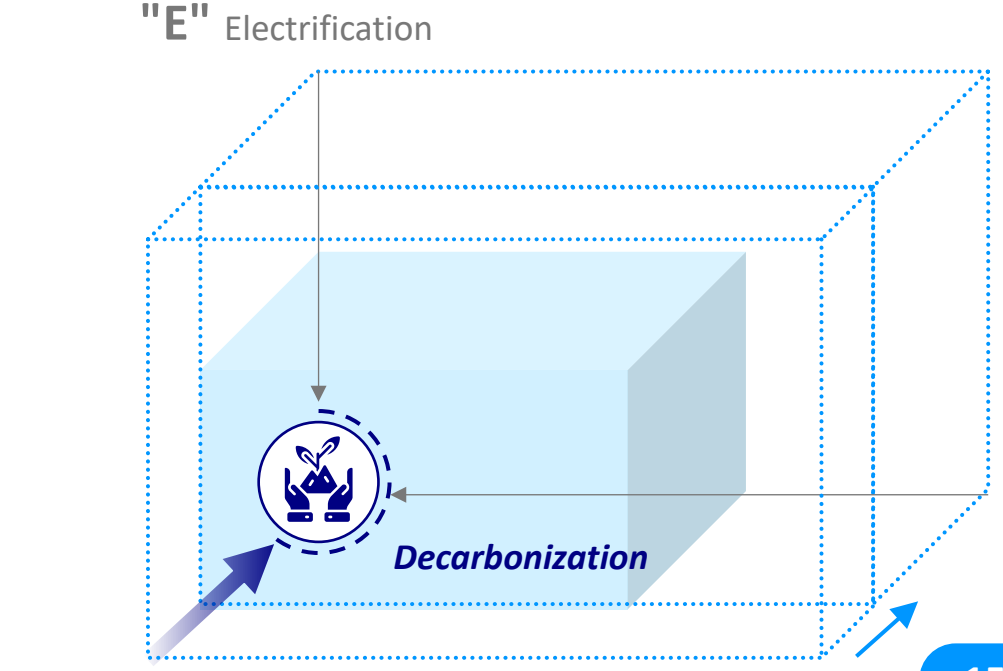
Total CE = Emission factor × Energy consumption × Distance

Key measures

- AI-enabled TOS
- Circular economy
- On-site green power supply

Value creation

- Economical friendly
- Environment friendly
- People friendly



Source: Roland Berger

Advanced TOS: Through intelligent algorithms and supporting equipment, TOS enables real-time data transmission to further optimize seaport operations

Original Version

TOS

Commend input

Standardized Interface

ECS

FMS BMS QCMS

Commend input

Single-unit control systems

Illustration of seaport equipment

Advanced Version

TOS – All-in-one solution

AI algorithm capability layer

data governance & service layer

Real time interaction *Real time interaction*

Standardized Interface

DPS (Dynamic Planning Scheduling)

FMS BMS QCMS

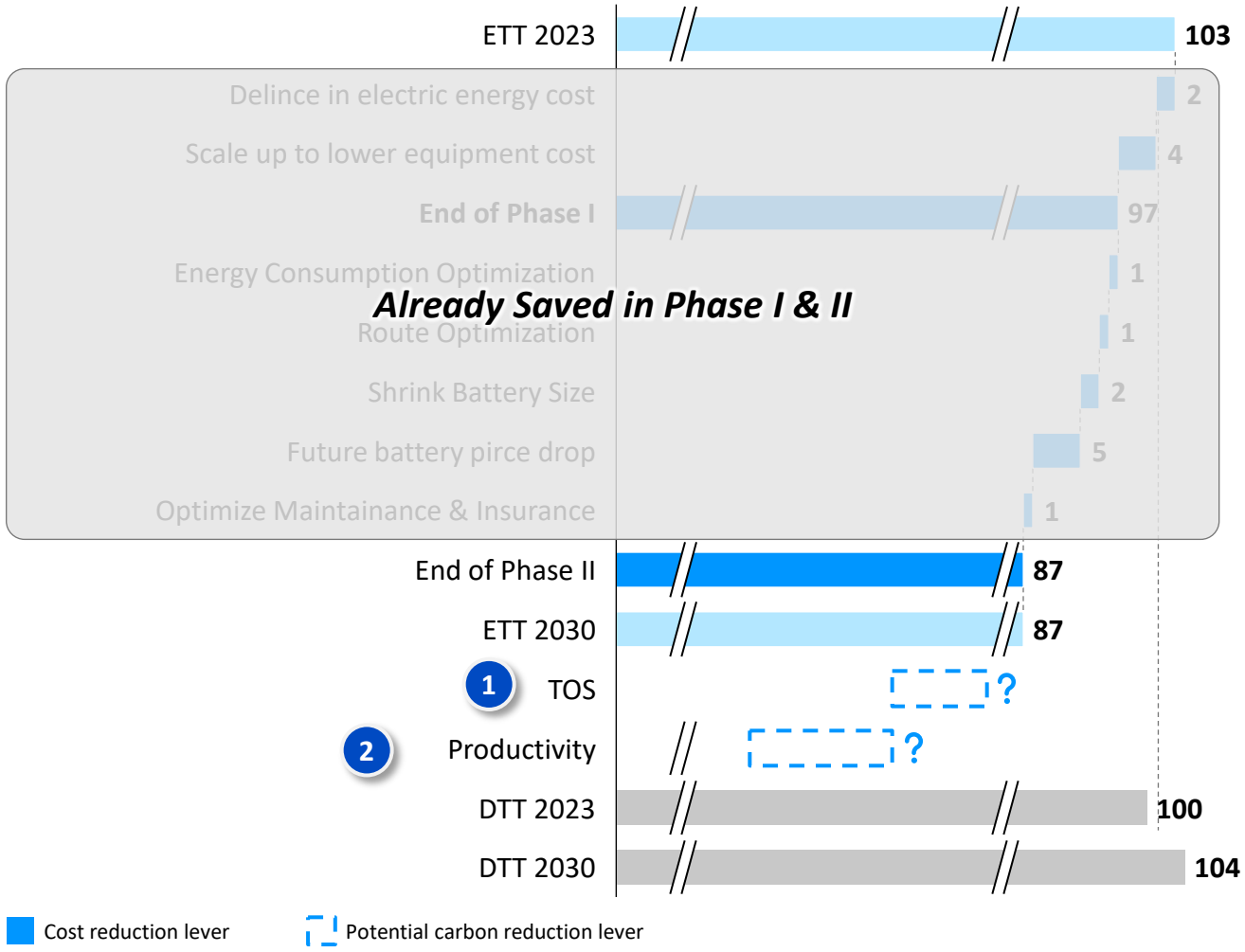
Real time interaction *Real time interaction* *Real time interaction*

Single-unit control systems

Illustration of seaport equipment

Source: Roland Berger

Economical value add in Phase III: Through TOS deployment and productivity enhancements, there exists significant potential for reducing TCO in the future



1) ETT is electric powered vehicle, DTT is diesel powered vehicle

Key Saving Contributors

1 TOS Deployment: Operational Excellence through Integrated Systems

- Implemented comprehensive Terminal Operating System (TOS) to optimize seaport operations
- Integrated TOS with other critical systems for end-to-end efficiency

2 Productivity Boost: Mitigating Labor Shortage Impacts

- Leveraged intelligent and workforce management strategies to minimize productivity loss
- Stable operation and productivity supported by on-site green energy power station

Source: Roland Berger

Case study – Seaport of Tianjin, China

Intelligent interconnected all elements in seaport to achieve "DEEP" impact

Tianjin

Key points

- Difficulties in coordinating various elements
- High CO2 emissions with huge workload

Port throughput

~1,800

kTEU/mon

"Intelligent Interconnection of Everything in the Port"

Workers

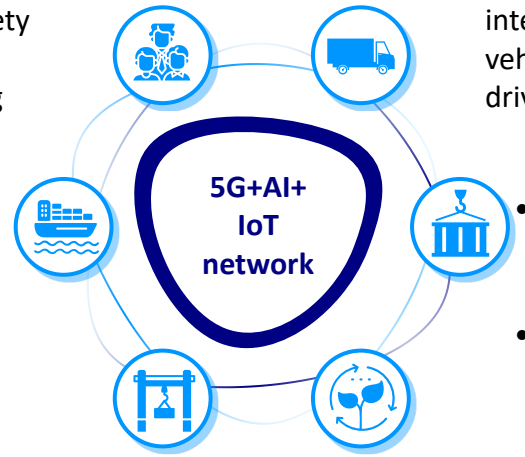
- Monitor & track work behaviors, reducing safety incidents & optimizing scheduling

Ship

- Accurate prediction of ship arrival time, and planning of loading and unloading time

Crane

- Remote precise control of cargo loading and unloading



Truck

- Autonomous trucks, intelligent cross-transport vehicles, and FMS to assist drivers

Container

- Container ground intelligent unlocking station
- 3 sec to identify container locks

Green energy supply

- Wind & PV power station
- ~60 million kwh/yr

TOS

Realize AI-powered dispatching, unlocking planning function soon

Value creation

D – Decarbonization

Reduce **20%** energy consumption per TEU

E – Economical friendly

Reduce **10%** operation cost ('22 vs. '21)

E – Ecosystem friendly

The world's **first 100% IoT** connected seaport

P – People friendly

Workers reside in the **cozy monitor house**

Source: desktop research; Roland Berger

Case study – Seaport of Rotterdam, Netherland

Leading the advancement of the seaport's circular economy by effectively closing the material loop

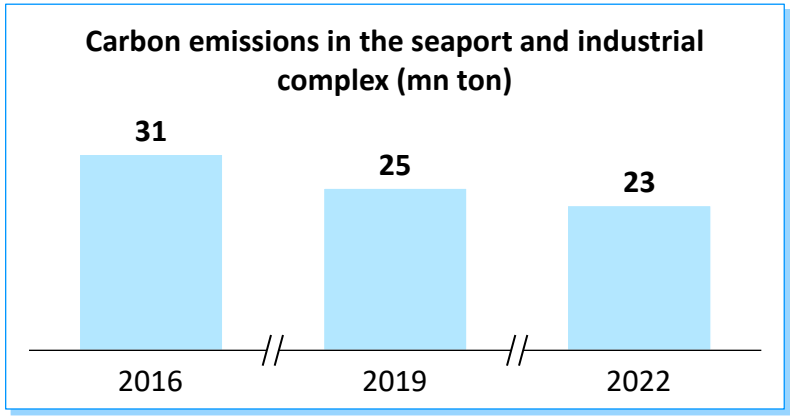
2023 Quick Glance

Heavily Loaded Business

- Container throughput: 13.4 mn TEU
- Revenue: 841.5 mn Euro

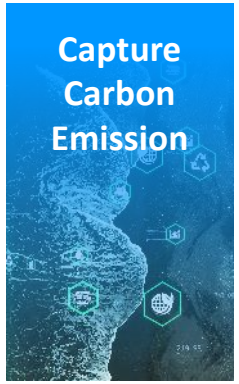
Highly Committed Decarbonization

- By 2030, aims to reduce carbon emissions by 90% compared to 2019 levels
- 2050 Carbon Neutral



Circular Seaport pillar

- Establish On-site plastic recycle plant, annually convert 20,000 tons of non-mechanically recyclable plastic into renewable raw material



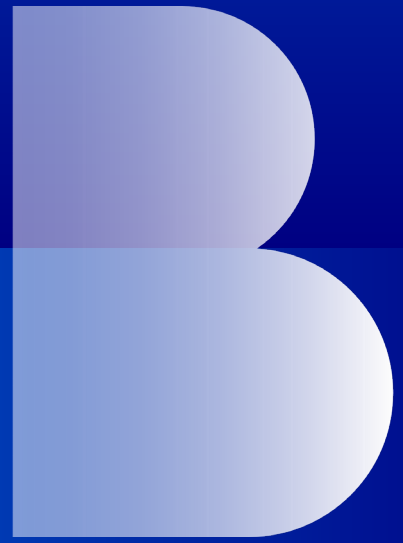
- Launch carbon capture program, which is the first CO2 storage project in the Netherlands, to further lower the carbon emission in seaport area

Value creation

- Reduces materials consumption
- Increase employment

- Accelerate carbon neutral process

Source: Annual Report 2023 - Port of Rotterdam Authority; Roland Berger



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