ENERGY CONSUMPTION IN TERMINALS

BENCHMARKING AND TECHNOLOGICAL CHANGE

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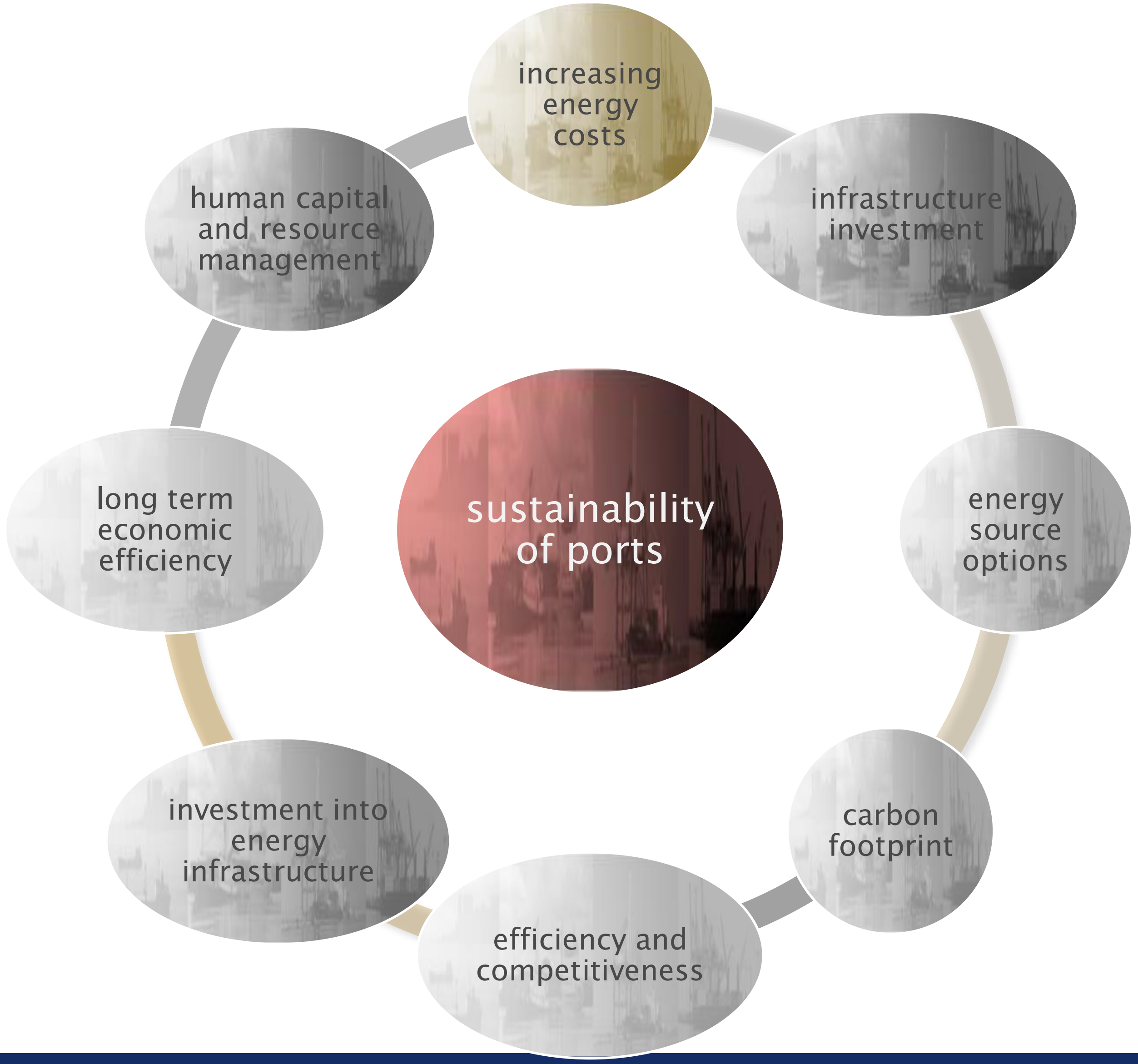
WHY SHOULD ENERGY ISSUES BE DISCUSSED IN THE CONTEXT OF PORTS?



ENERGY PERFORMANCE AND SERVICE QUALITY OF PORTS IN LOGISTICS CHAINS

RESEARCH QUESTIONS

Benchmarking

What is the energy consumption…

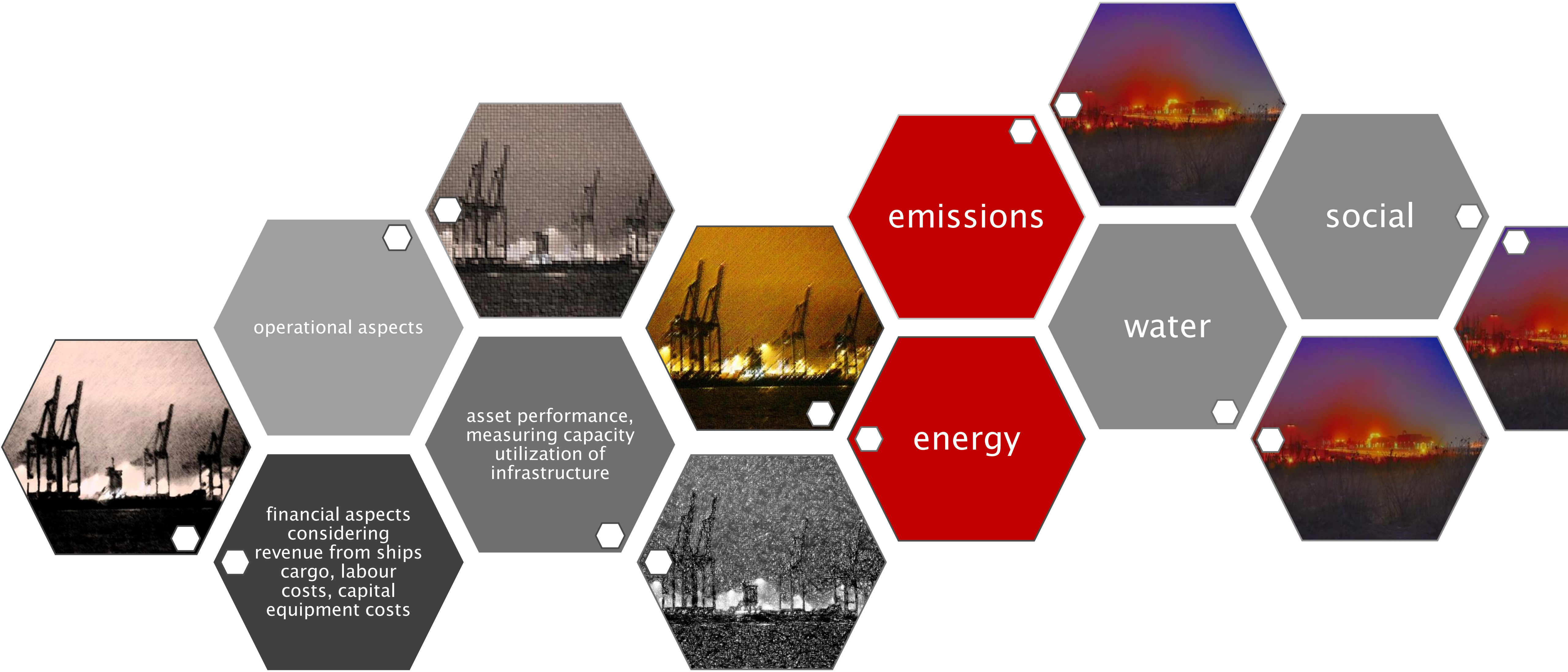
What are the energy expenses …

What are the emissions…

What are the possibilities and limitations of technlogical change in terminal operations …

…for handling a container in a terminal?

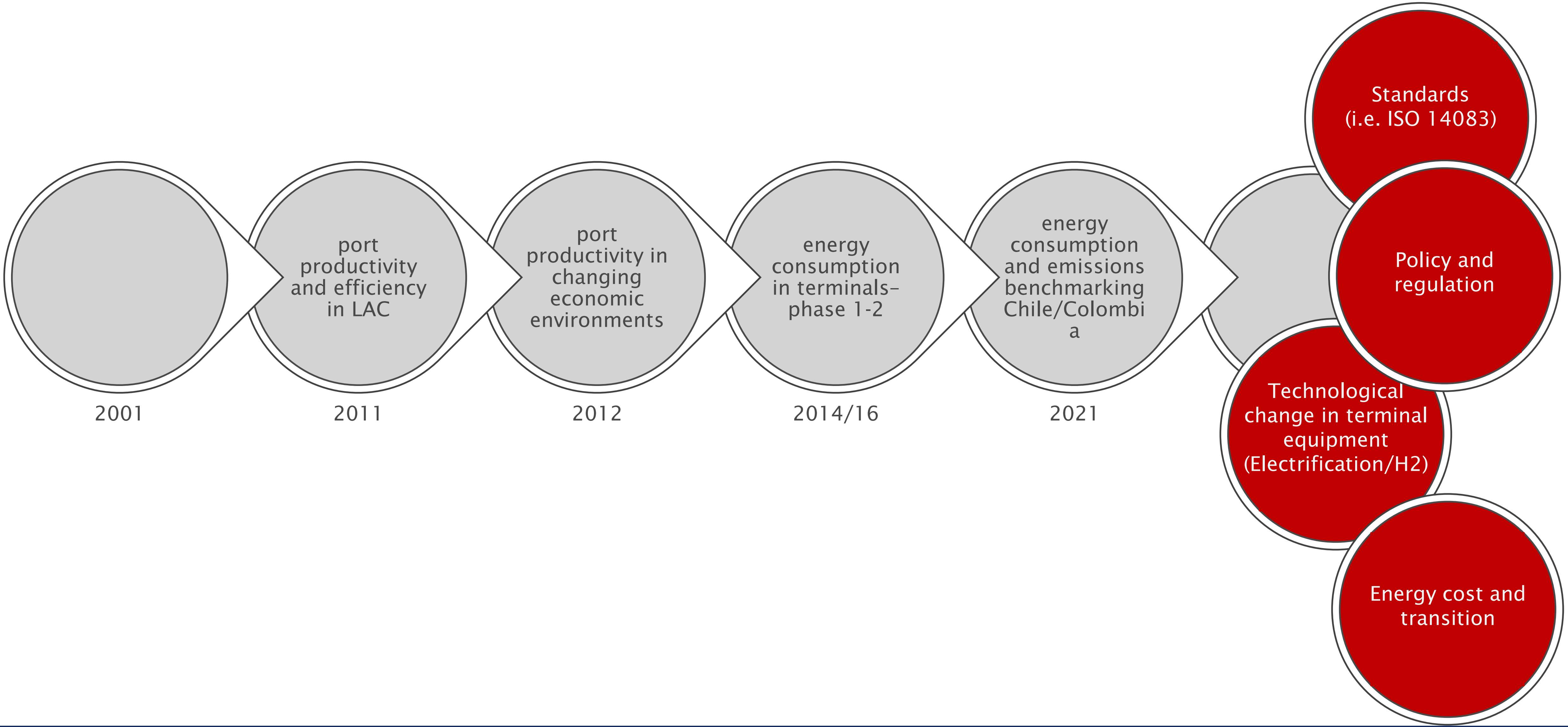
CONSTRUCTING A WIDER SET OF MEASURES OF PERFORMANCE



LITERATURE REVIEW

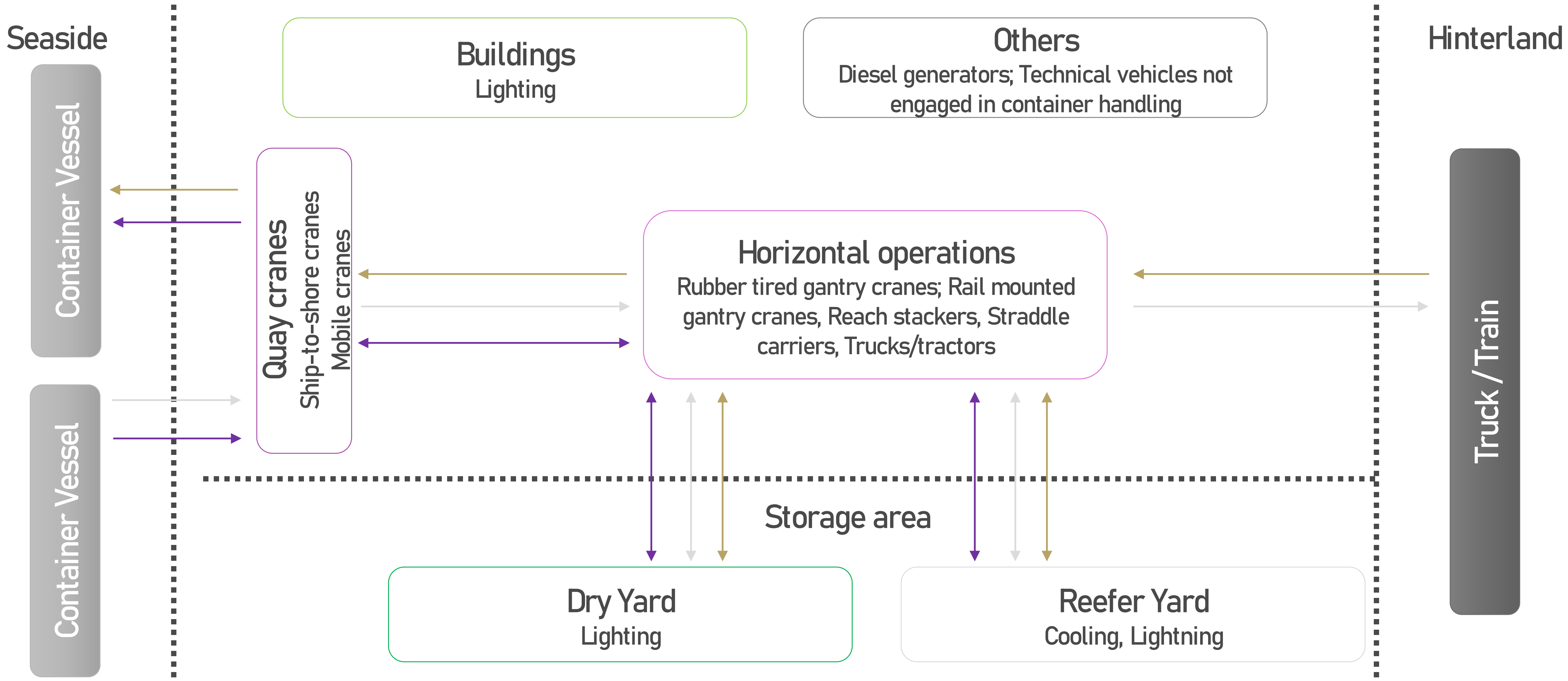
Activity-based cost approach						Quantitative analysis of the impact of terminal processes and the related CO_2-emissions		Integer problem	Pure technical, environmental efficiency (PTEE)	WPCI and IPCC Guidelines	Slack-based measure and Response-based procedure
ECLAC (2014)	Wilmsmeier et al. (2014)	ECLAC (2015)	Wilmsmeier & Spengler (2016)	Spengler & Wilmsmeier (2019)	Wilmsmeier, G. (2020)	Geerlings & van Duin (2011)	Martínez-Moya, et al. (2019)	Sha et al. (2016)	Na et al. (2017)	Atulya et al. (2017)	Quintano et al., (2020)
4 container terminals	13 container terminals	41 container terminals	35 container terminals	45 container terminals	23 multipurpose terminals	1 container terminal	1 container terminal	10 container terminals	8 container terminals	1 multipurpose terminal	24 container terminals
2014	2011-2012	2010-2013	2012 - 2015	2012-2016	2014 - 2017	2006 - 2011	2011	2007-2009	2005 - 2014	2014 - 2015	2005 - 2014
Chile	Southern cone countries	Latin America and the Caribbean	Latin America and the Caribbean	16 countries	Colombia	Europe	Spain	China	China	India	Europe

FROM TERMINAL PRODUCTIVITY TO SUSTAINABLE PERFORMANCE



METHODOLOGY

AN ACTIVITY BASED APPROACH TO ALLOCATE ENERGY CONSUMPTION IN CONTAINER TERMINALS



Export Container   Import Container   Transshipment Container

Source: Authors based on Wilmsmeier & Spengler, (2016)

FORMULA ENERGY CONSUMPTION

$$TC_{ij} = \sum_{z=1}^{n} \left(QCC_{ij} + HOC_{ij} + CRC_{ij} + BC_{ij} + LC_{ij} + OC_{ij} + GEN_{ij} \right) + UC_{ij}$$

where:

z = type of energy

TC_{ij} = Total energy consumption in terminal i in period j

QCC_{ij} = Energy consumption within the process cluster of quay cranes

HOC_{ij} = Energy consumption within the process cluster of horizontal operations

CRC_{ij} = Energy consumption within the process cluster of reefer cooling

BC_{ij} = Energy consumption within the process cluster of buildings

LC_{ij} = Energy consumption within the process cluster of lighting

OC_{ij} =Energy consumption within the process cluster of others

GEN_{ij} = Energy consumption within the process cluster of generators

UC_{ij} = Undefined consumption

EXAMPLE: FORMULA QUAY CRANE AND HORIZONTAL ACTIVITY CLUSTER

$$QCC_{ij} = \sum_{z=1}^{n} (EC_{ijk}) + UC_{ijk}$$

where:

z = type of energy

K = type of equipment / model

EC_{ijk} = Total energy consumption in terminal i in period j

UC_{ijk} = Undefined consumption

$$HOC_{ij} = \sum_{z=1}^{n} RMGC_{ijk} + RTGC_{ijk} + RSC_{ijk} + SCC_{ijk} + TRC_{ijk} + UC_{ijk}$$

Where:

RMG_{ijk} = rail-mounted gantry cranes.

RTG_{ijk} = rubber-tired gantry cranes.

Rs_{ijk} = reach stacker

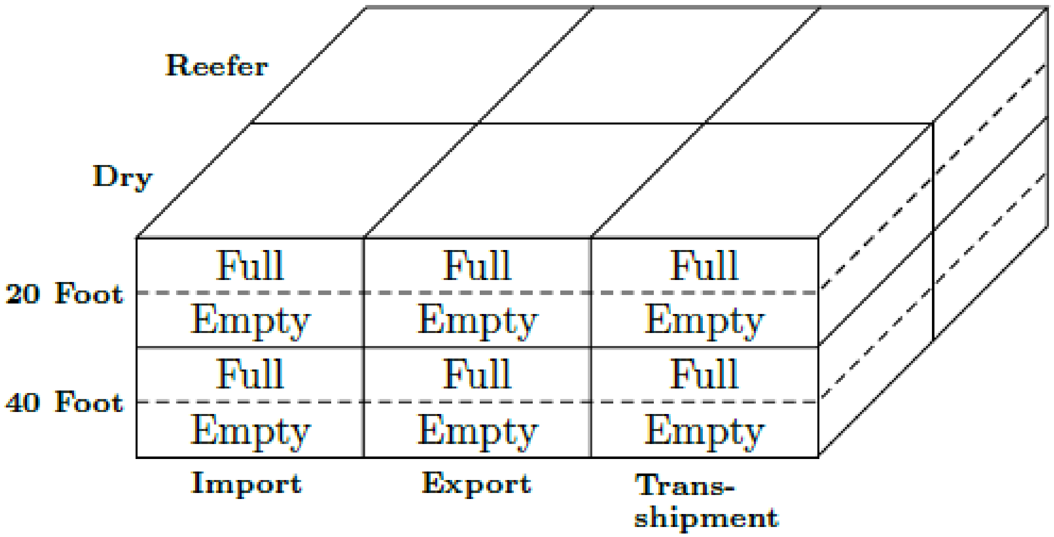
SC_{ijk} = straddle carrier

TRC_{ijk} = trucks

UC_{ijk} = undefined consumption

EXAMPLE: CONTAINER TERMINALS ARE MULTI PRODUCT OPERATIONS

- differentiation necessary between:
  - container types (i.e., dry, reefer)
  - transhipment and impo/expo cargo
  - full and empty



Thus, different “products” have different requirements and performance

RESEARCH PROCESS

Data collection

- Workshops
- Surveys
- Field visits
- Open databases
- Public reports

Data analysis

- Terminal level
- Port system level

Benchmark

- Comparison between Colombia and Chile data
- Comparable quantitative approach
- GLEC framework
- Public policy strategies

BENCHMARKING

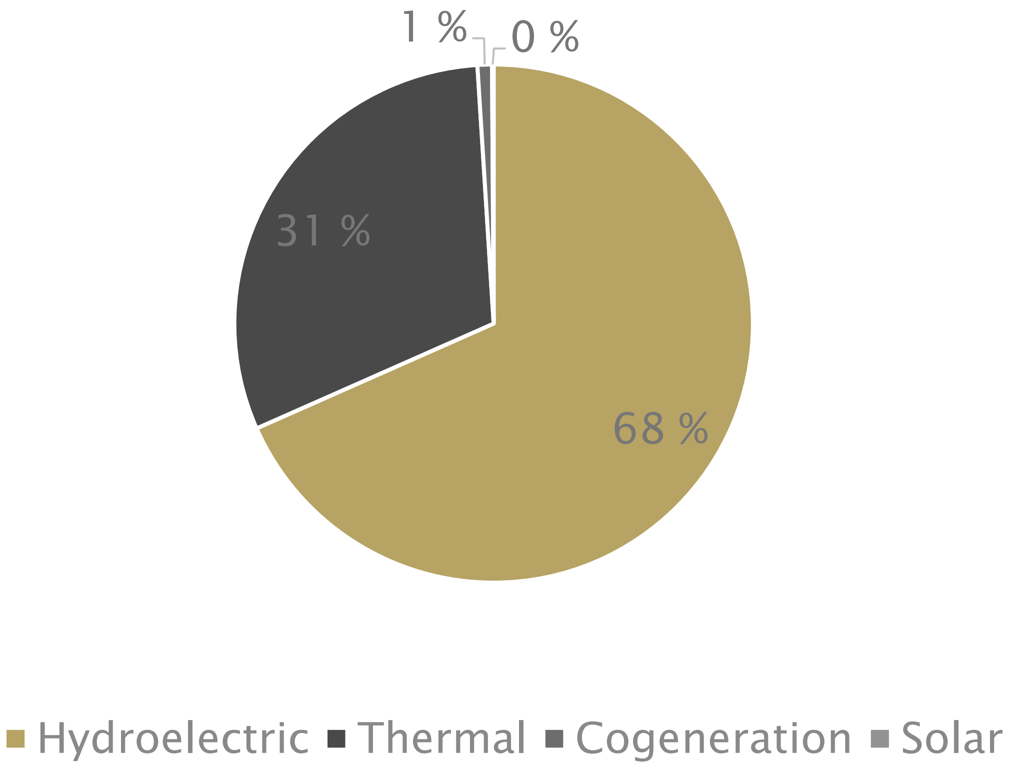
ECONOMIC INFORMATION

Economic indicators	Chile	Colombia
GDP per Capita (USD) (2017)	14,998.82	6,376.71
GDP per Capita (USD) (2020)	13,231.70	5,322.77
Diesel price per Liter (2017)	1.14	0.36
Diesel price per Liter (2020)	1.05	0.27
Emissions per Kwh (g de CO_2)	383.40	164.38

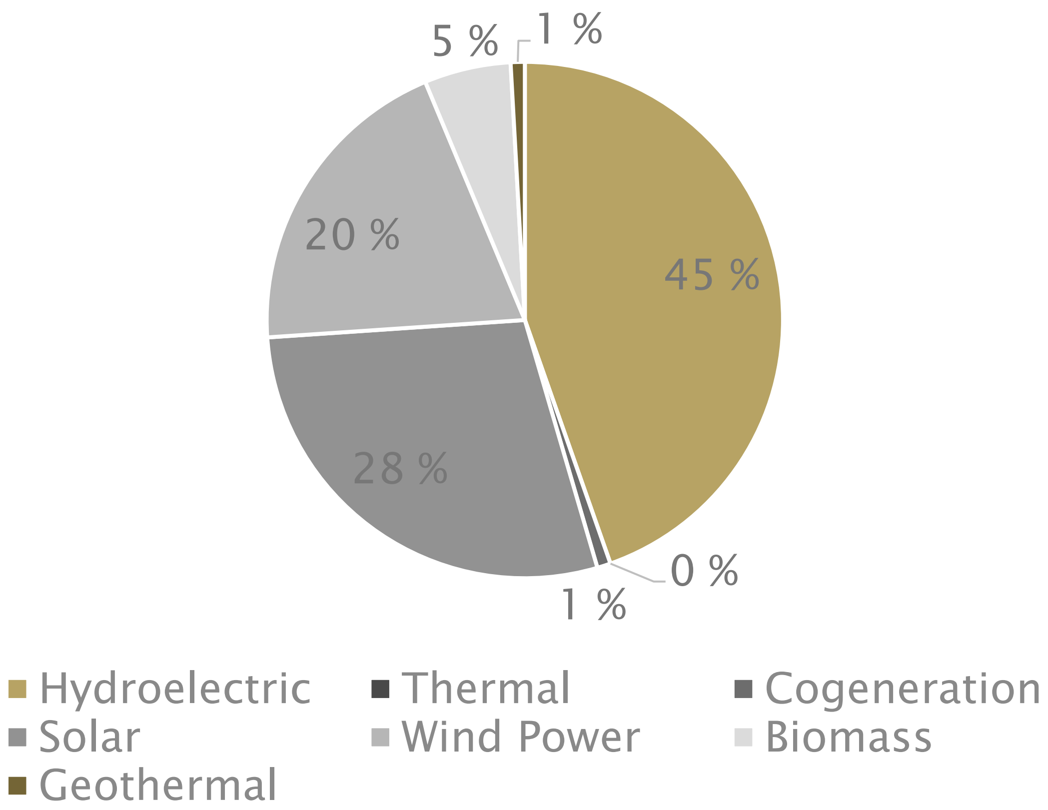
Source: Authors

ENERGY GENERATION

Colombia



Chile



Source: OLADE 2022

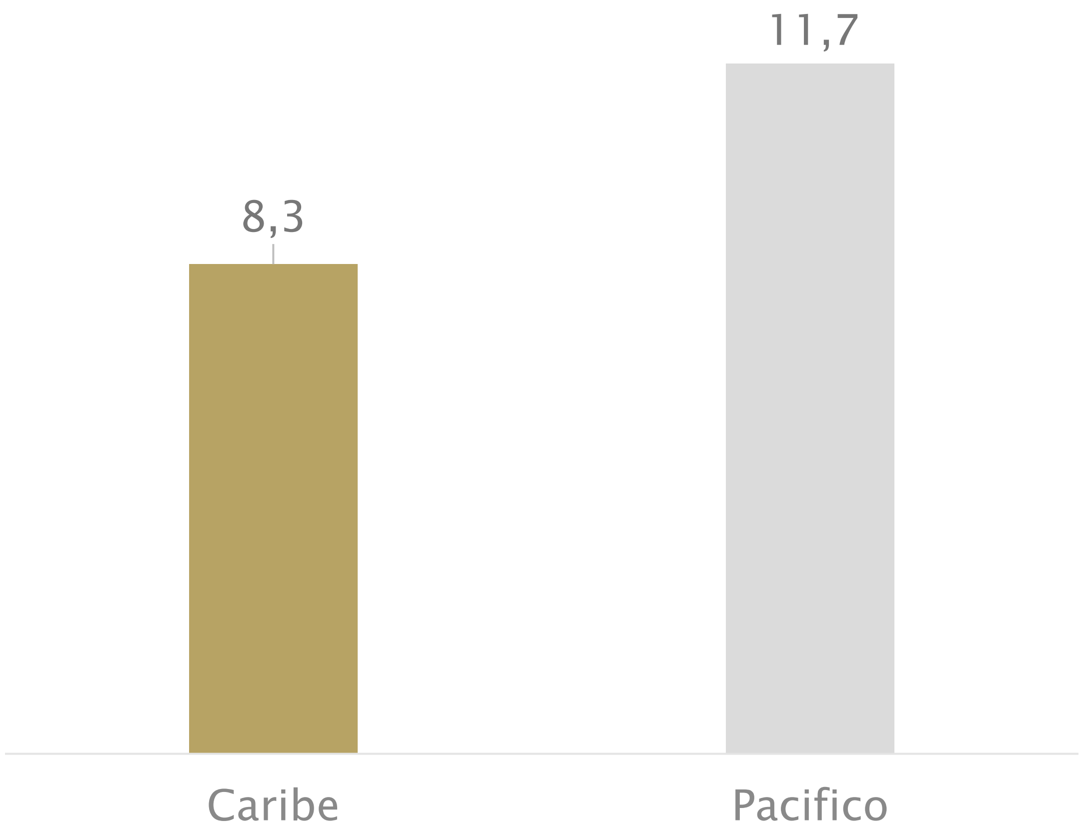
KEY ENERGY KPI PORT SECTOR

KPI	Chile 2014*	Colombia 2017**	Chile 2020 ***	Colombia 2020
Movements (millions of containers)	1.1	2.23	1.25	2.85
Diesel consumption (millions of liters)	9.9	17.56	11.25	21.27
Electricity consumption (GWh)	40.7	106.83	65.32	127.4
Energy consumption (GWhe)	108.5	339.9	202.42	360.46
Energy expenditures (USD millions)		15.87	12.85	30.7

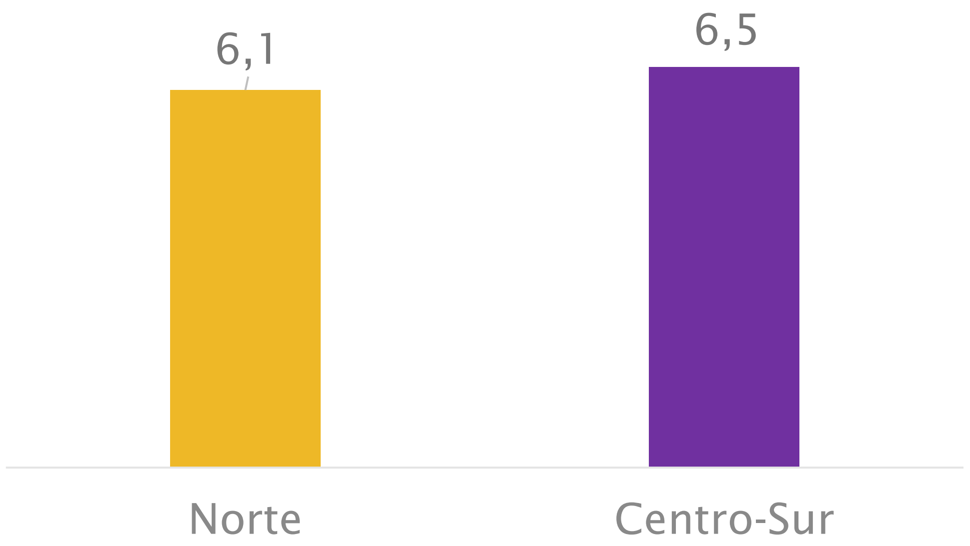
* ECLAC, 2015: ** Wilmsmeier, 2020, *** Ministerio de Transporte y Telecomunicacoines, Chile, 2022,

AVERAGE ENERGY EXPENSE PER CONTAINER, CURRENT USD/BOX, 2020

Colombia



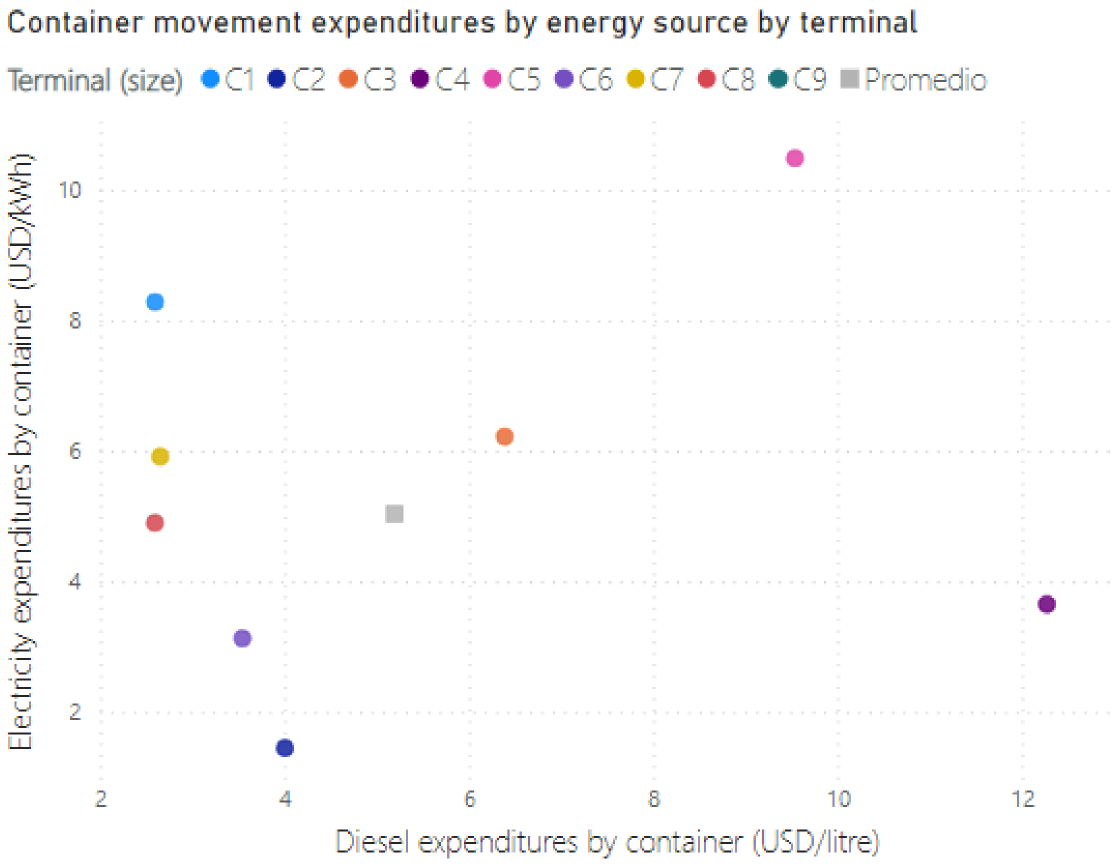
Chile



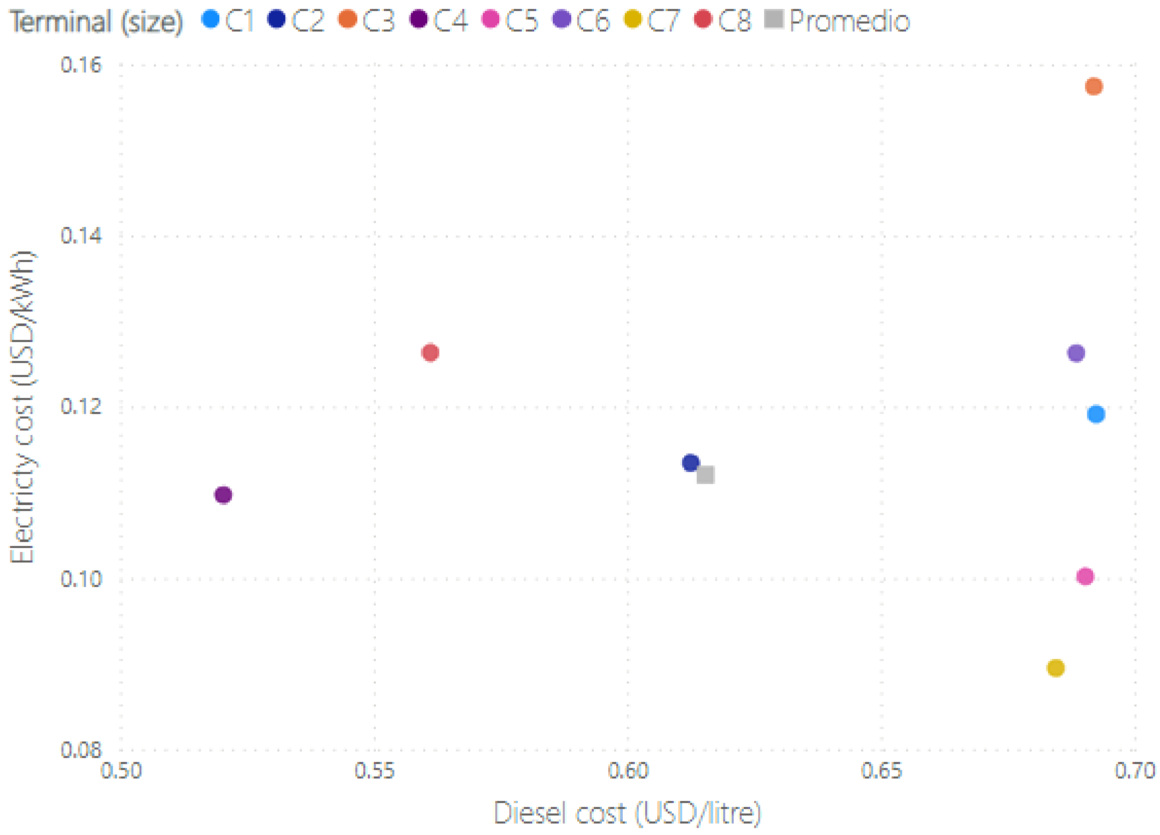
Source: Authors

COLOMBIA, DISPERSION OF ENERGY EXPENSES, 2020

By movement

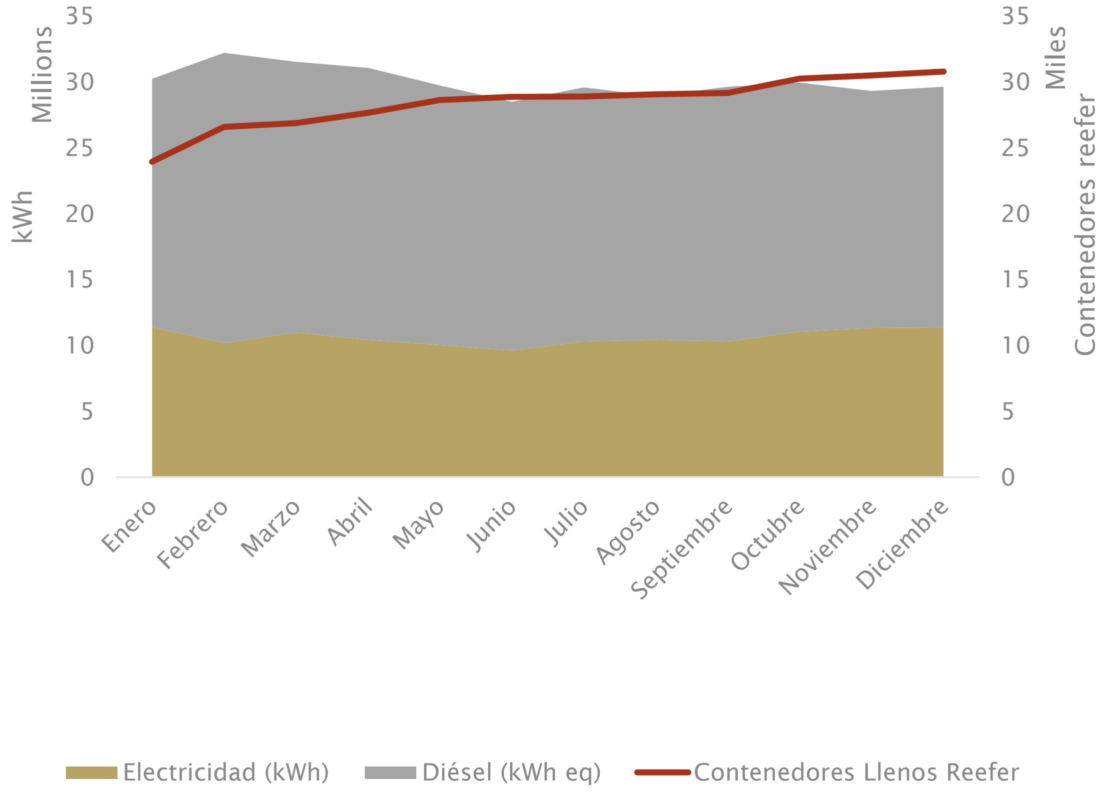


By energy unit

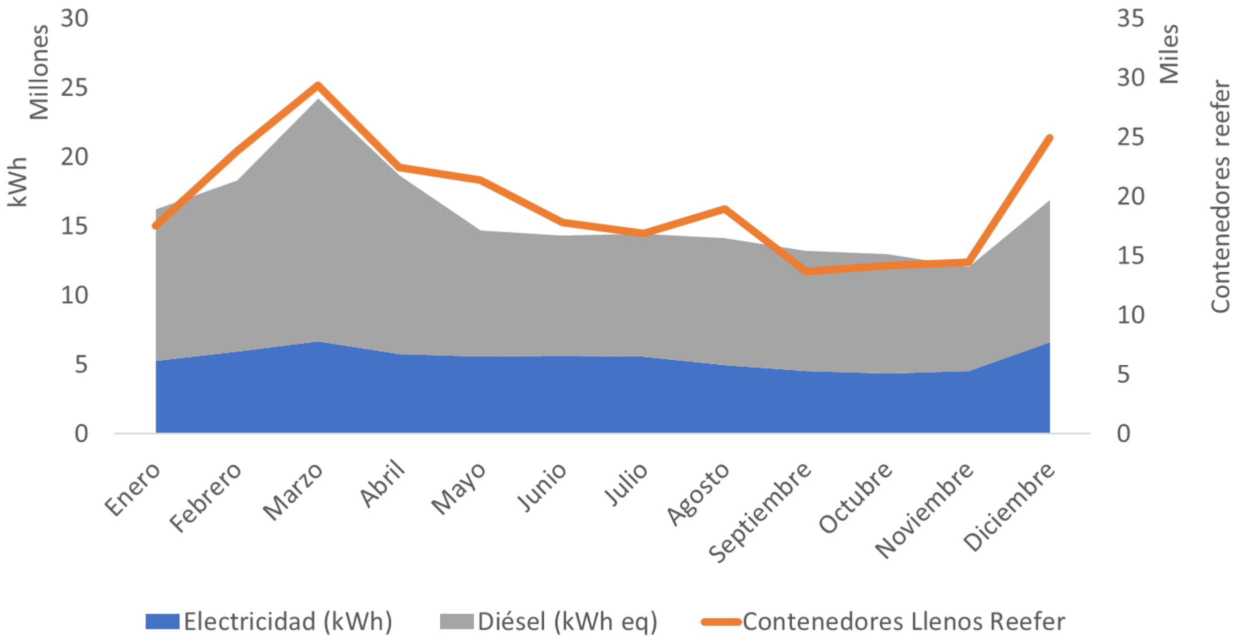


ENERGY CONSUMPTION AND REEFER CONTAINER MOVEMENTS PER MONTH

Colombia



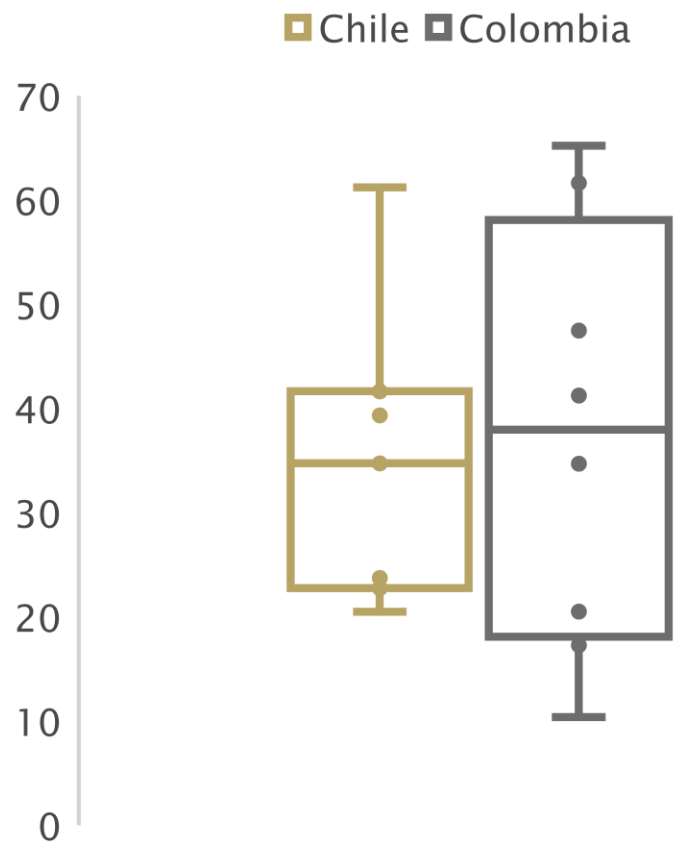
Chile



Source: Authors

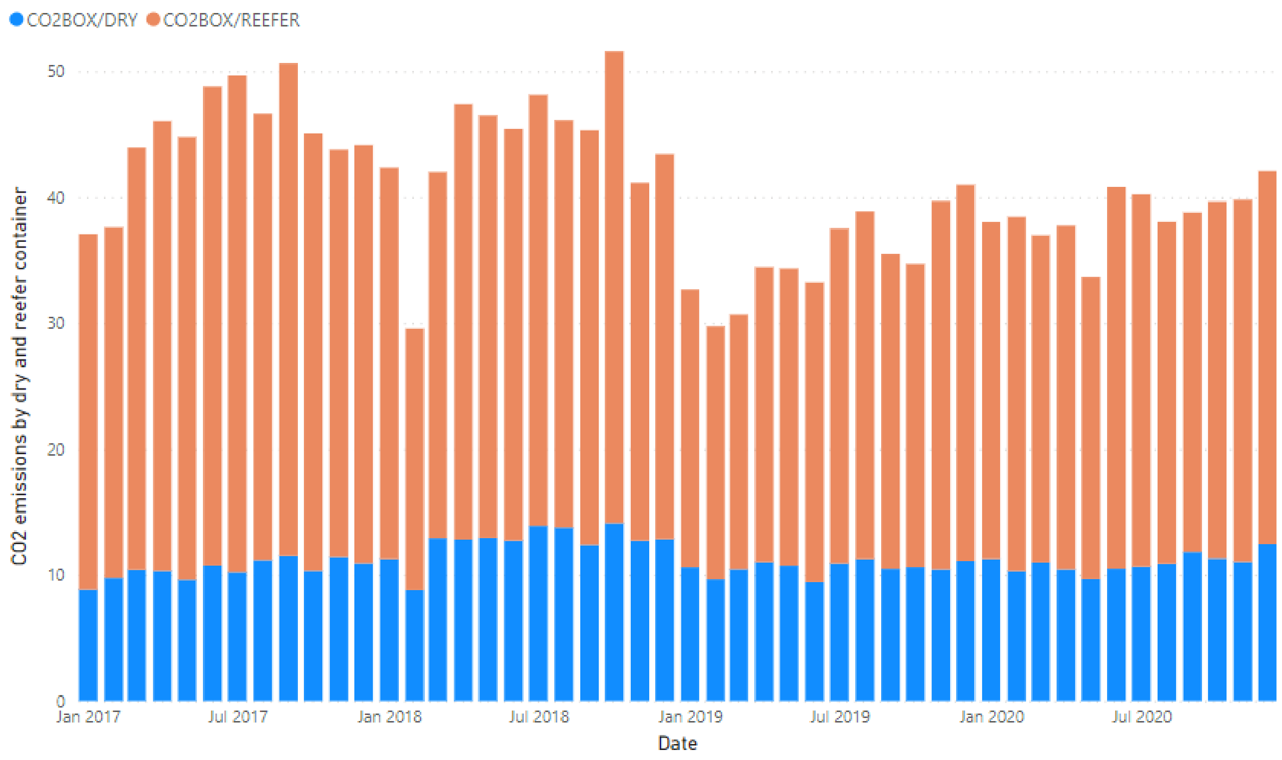
EMISSIONS PER CONTAINER, 2020

The general "normal" view

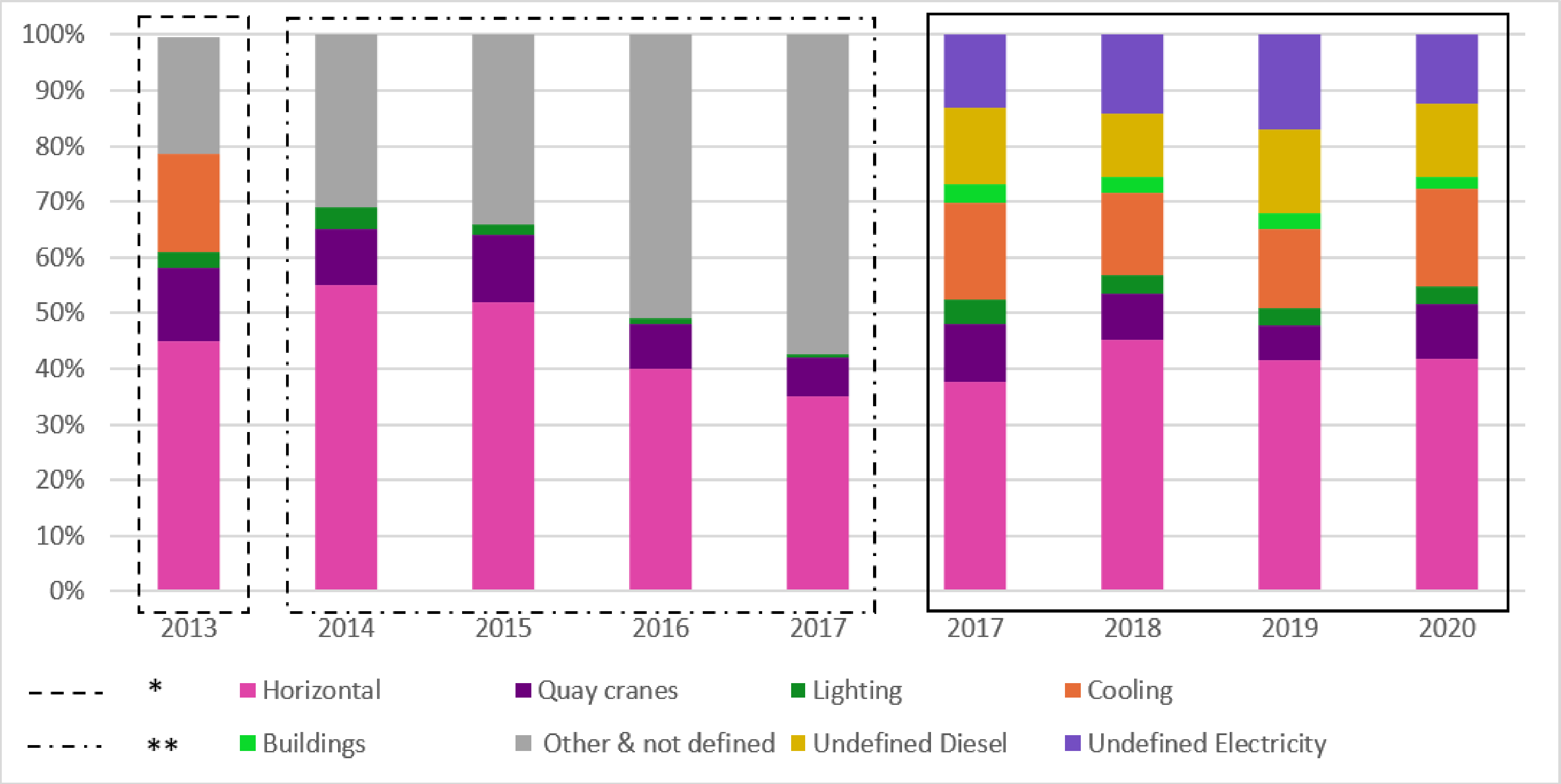


Source: Authors

A differentiated view



CLUSTERS OF ENERGY CONSUMPTION, COLOMBIA, 2013 – 2020



TECHNOLOGICAL CHANGE IN HORIZONTAL OPERATIONS

HYDROGEN EQUIPMENT

A FEW KEY MESSAGES

Transition from fossil fuels to potentially renewable fuels in port terminal operations

What do we know?

- Public interest is given
- H_2 is part of sustainability efforts, also in Germany
- Horizontal transport is defined as the biggest share of energy consumption and energy costs on a terminal and can yield the most potential of CO_2 savings

What do we want to know?

- Which types of vehicles can be powered by H_2?
- Which kind of terminals should consider H_2?
- What are important KPI's?

How can ports use H_2 in terminal vehicles?

EXAMPLES OF H_2 PROJECTS IN PORTS

Location/Company	Project	Source
Port of Valencia, Spain	Pilot - H_2 Reach Stacker	H_2PORTS (n.d.-b)
	Pilot - H_2 Yard Tractor	H_2PORTS (n.d.-c)
	Pilot – mobile H_2 refueling Station	H_2PORTS (n.d.-a)
Port of Auckland, New Zealand	Renewable diesel fuel and H_2 powered container equipment	World Port Sustainability Program (WPSP, 2018)
Ports of Long Beach and Los Angeles, USA	Multiple zero-emission cargo handling vehicles, including H_2 FC yard trucks	WPSP (2019a, 2019b)
Mitsui O.S.L Lines & Mitsui E&S Machinery	Joint initiative to introduce H_2 powered port cargo handling machineries, including rubber-tired gantry yard crane	Mol O.S.K Lines (2021)
Port of Antwerp, Belgium	H_2 powered truck initiative in Belgium	Port Technology (2021)
Port of Rotterdam, The Netherlands	H_2 production plant in Maasvlakte area, H_2 usage as transport fuel, H_2 transport to other industries	Port of Rotterdam (n.d.)

INTRODUCING H_2 AND THE TECHNICAL SIDE

H_2 is an energy carrier not an energy source!

Production

- H_2 production from any primary energy source
- H_2s CO_2 emissions are vastly dependent on the chosen production method

Usage as a fuel

- Usage either in traditional Internal Combustion Engines or in fuel cell technologies
- Fuel cells produce electricity to power the vehicle, with external tanks providing the H_2 in a controlled flow

LET'S COMPARE FUEL CELLS TO BEVS AND TRADITIONAL ICES

	Fuel Cell Technology	BEV	ICE
Strengths	• High driving ranges • Low refueling times • Low GHG emissions (no scope 1 emissions)	• Simple functionality • Low GHG emissions (no scope 1 emissions)	• Low vehicle costs/ infrastructure investments • High driving ranges • Low refueling times
Weaknesses	• Immature • Uncertain in terms of costs • Needs pure H_2	• Needs a heavy battery to offer comparable driving ranges • Recharging times	• High GHG emissions (scope 1) • Reliant on fossil resources

Vehicles with a frequent need for acceleration, long uptimes, and short refueling times are considered most attractive for FC technology.

HOW CAN PORTS EVALUATE THE SUCCESSFUL TRANSITION TOWARDS H_2 POWERED VEHICLES?

KPI	Description
Out of Service Times/Waiting Costs	The sum of times a vehicle is fueling or not in operation, and the corresponding waiting costs
Fuelling H_2/H_2 Costs	How much H_2 is needed for operation? Represents fuel costs
Emitted CO_2-equivalent/CO_2 costs	Depending on the source of H_2 and a possible carbon tax/ETS in place

These KPI's can determine whether H_2 can be considered an alternative energy carrier for a port terminal.

MODEL PARAMETERS

Focus on the usage of H_2 in terminal vehicles – How can ports use H_2 there?

Technical and operational parameters

- Tank capacity,
- Consumption/h,
- Refueling rate/h,
- Time to reach the refueling station.

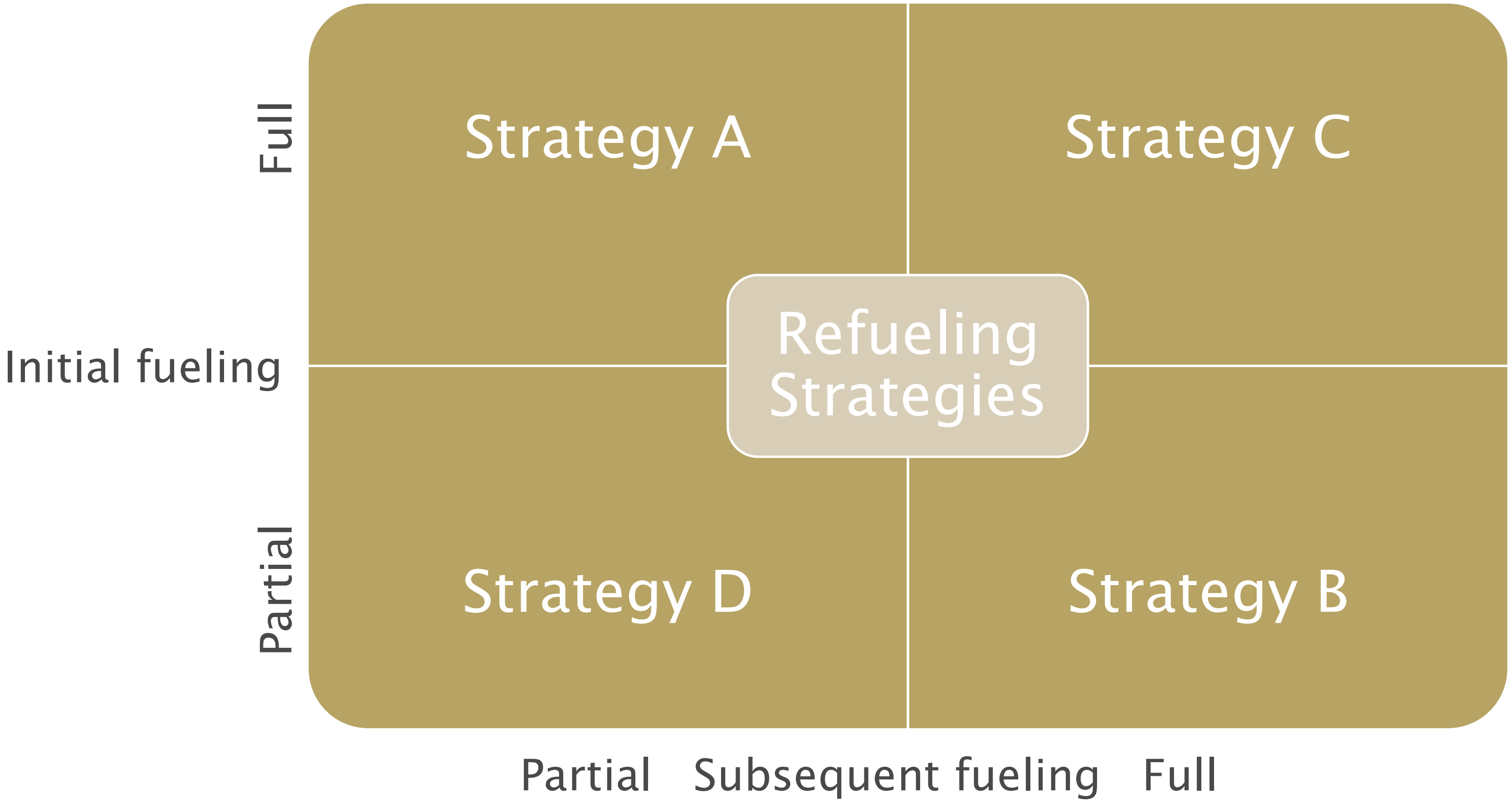
Determines how often the vehicle needs to refuel, and how much time is lost in a refueling operation.

Economical parameters

- Cost of hydrogen,
- Cost of emissions,
- Waiting costs.

Determines the economic impact of operating H_2 powered vehicles based on the refueling cycle.

FOUR ALTERNATIVE FUELING STRATEGIES



CONCLUSIONS

CONCLUSIONS

- This research investigates the correlation between energy consumption, terminal throughput, and overall energy expenses for Colombian container terminals.
- Energy consumption patterns within the port activity clusters were identified by analyzing's monthly data from 2017 to 2020.
- Horizontal movements are the most energy-intensive activities. Also, a significant part of the terminals' total energy consumption remains undefined.
- Recognizing and decreasing undefined energy with adequate measurement methods is essential for increasing energy efficiency measures and adapting emission reduction strategies.
- The need for complete and trustworthy data is crucial for monitoring and controlling energy consumption in container terminals.
- Analysis shows existing potential to reap the benefits for technological change (electrification, H2)

CONCLUSIONS

- There is a public interest in improving energy efficiency but no clear path to advance towards that goal in the port industry.
- There is lack of strategies or programs to measure energy consumption by source and their overall energy efficiency.
- This lack of data impacted the ability of regulators to draft and implement public policies for climate change mitigation.
- Measuring, monitoring, and sharing the results and best practices will be the key to maintaining this effort.
- A benchmarking culture must be stimulated between terminal management companies to improve individual and collective performance in GHG reduction and energy efficiency increase.

SPECIFIC CONCLUSIONS HORIZONTAL OPERATIONS

Total Costs are vastly dependent on the price of H_2. H_2 accounts for the largest portion of costs.

Source of H_2 determines both costs and potential CO_2 savings.

For the transition towards H_2 costs for CO_2 must match the impact of waiting costs to be profitable (at a competitive H_2 price)

H_2 is best applicable for smaller semi-automated terminals.

Large amount of technological uncertainty towards operating H_2 powered vehicles

FURTHER RESEARCH

- All of the insights gained by researching this topic may be combined with implementing new technologies to produce a positive feedback loop that results in more innovation and knowledge.

- Present sustainable practices as competitive so that the transition out of fossil fuels, for instance, does not depend exclusively on the goodwill of corporations.

- Fully understanding the potential economic benefits of increasing energy efficiency requires more research on public policies, port economics, and regulations.

- The relationship between the academy and private companies still has room to improve.

- A joint effort to improve key performance indicators, equipment analysis, and decision-making processes may produce yet-to-be-seen sustainability strategies for container terminals.

- Evolving this study based on realistic consumption data in different times of the day and implementing opportunity costs
- Further agent-based modelling on different cases to evaluate contextual conditions and boundary conditions

- Further evaluate the options of green hydrogen and its CO_2 implications

QUESTIONS?

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