Development of Business Cases for Fuel Cells and Hydrogen Applications for Regions and Cities

FCH Port operations equip.

Brussels, Fall 2017

This compilation of application-specific information forms part of the study ***"Development of Business Cases for Fuel Cells and Hydrogen Applications for European Regions and Cities"*** commissioned by the Fuel Cells and Hydrogen 2 Joint Undertaking (FCH2 JU), N° FCH/OP/contract 180, Reference Number FCH JU 2017 D4259 .

The study aims to **support a coalition of currently more than 90 European regions and cities** in their assessment of fuel cells and hydrogen applications to support project development. Roland Berger GmbH coordinated the study work of the coalition and provided analytical support.

All information provided within this document **is based on publically available sources** and reflects the **state of knowledge as of August 2017**.

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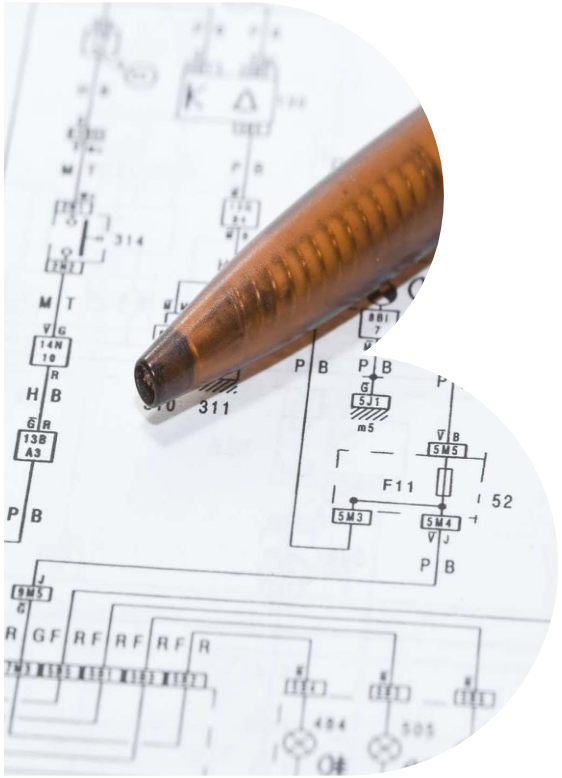

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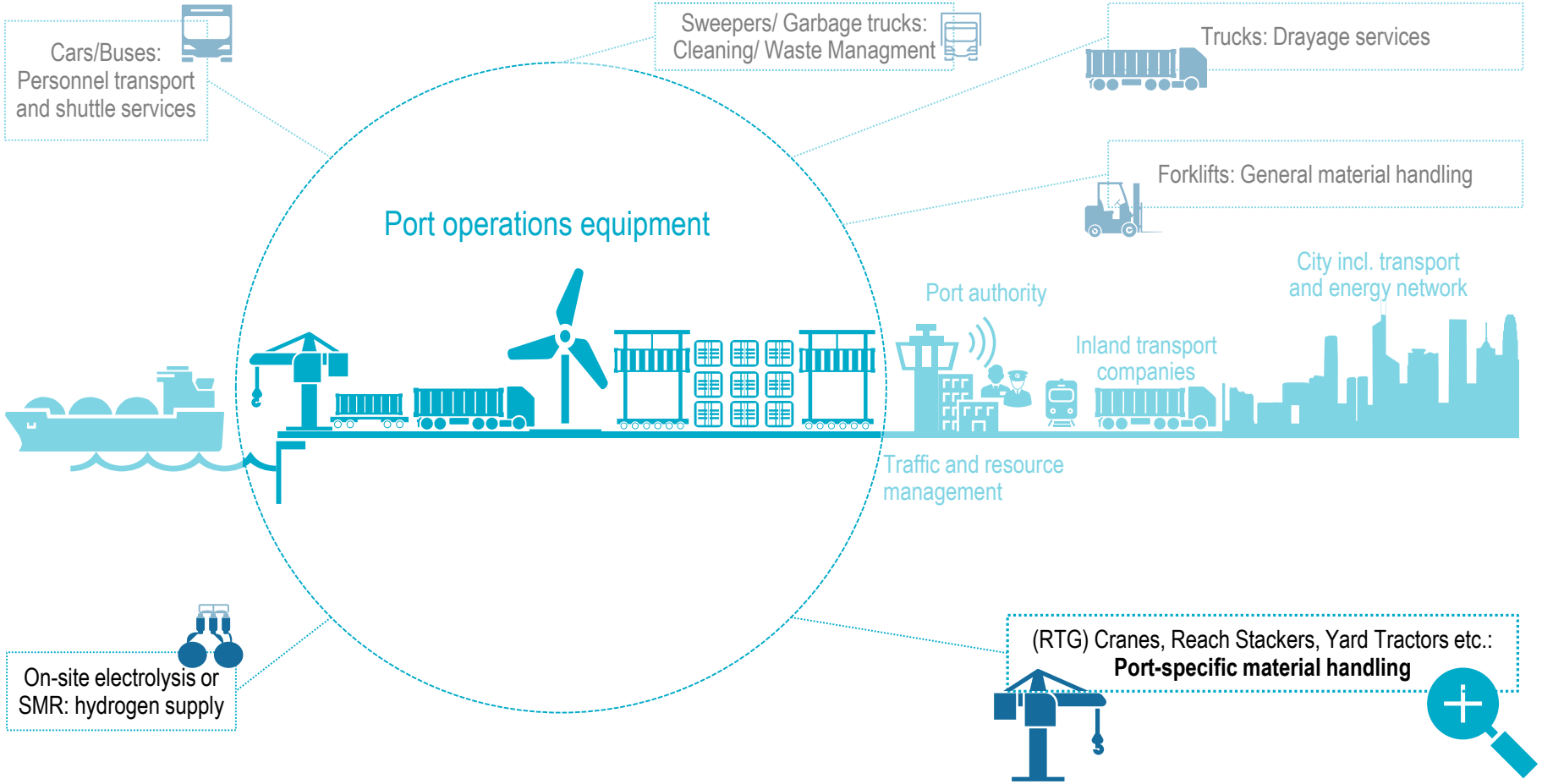
Port operations require numerous types of equipment – some applications have been already covered in other Working Groups

Fuel cell powered port operations equipment (selection) 1/5



Source: Roland Berger

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Port operations equipment today is offered on a diesel, (battery) electric or hybrid basis - FCH appl. not yet commercially available

Fuel cell powered port operations equipment (selection) 2/5

	RTG Cranes A	Reach Stackers B	Yard Tractors C
			
Brief description	Rubber tyred gantry (RTG) cranes are mobile cranes which are used to ground or stack containers from yard tractors or drayage trucks and vice versa	Reach Stackers are used to handle containers and other cargo in ports; they are both able to shortly transport as well as to pile containers	Yard tractors are used to transport trailer and containers short distances from ships to distribution centres or container terminals and vice versa
OEMs	Liebherr, Kalmar, Konecranes, Sany	Liebherr, Kalmar, Konecranes, Sany, Hyster-Yale, Terex	Terberg, Kalmar, Orange EV
Engine	Diesel, electric (via a conductor bar for example), hybrid (diesel/electric)	Diesel, hybrid (diesel/electric)	Diesel, (battery) electric, hybrid (diesel/electric)

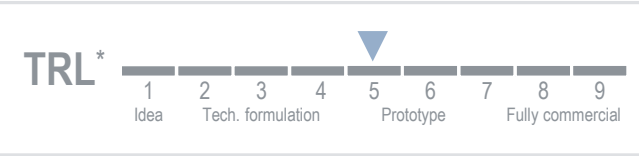
Source: Roland Berger

A

Various port operators tackle emission reduction goals via demos of FCH equipment – so far mainly with non-port-specific applications

Fuel cell powered port operations equipment 3/5

Overall technological readiness: Application overall at prototype or even still concept stage, to be demonstrated in relevant environment over the coming months and years; however some equipment (e.g. forklifts) more advanced than other



Demonstration projects / deployment examples (selection)

Project	Country	Start	Scope	Project volume
Project Portal		2017	Proof of concept with a Toyota heavy-duty truck for drayage operations at the Ports of Los Angeles and Long Beach. The truck fuel cell system, powered by two Mirai fuel cell stacks and a 12kWh battery, is capable of supporting port drayage operations. It will operate to support class 8 load operations, generating more than 670 horsepower and 1,800 Nm torque, with an estimated driving range of about 320 km per fill	n.a.
Surf ´n´ Turf		2016	Surplus generated by onshore wind on the Orkney Islands is converted into hydrogen by a 500 kW electrolyser and shipped to the port of Kirkwall where – among others – a fuel cell is used to supply electricity to ships while docked	n.a.
Demo2013		2011	Vuosaari Harbour at the Port of Helsinki demonstrates FC applications in a variety of port applications (stationary FCs as well as FCs for material handling equipment) e.g. Wärtsilä 50kW SOFC, Hydrocell portable FC, metal hydride storage for boats, H_2 refuelling station by Woikoski Oy. Project partners: Federation of Finnish Technology Industries and the Port of Helsinki	n.a.

*) Technology Readiness Level ▼ ≤ 5 ▼ 6-7 ▼ 8-9

Source: Roland Berger

A

Significant decrease of emissions and very low noise pollution as major benefits – especially for inner-city harbours

Fuel cell powered port operations equipment

Use case characteristics

Stakeholders involved

> Municipality-owned and/or private port operaters and logistics companies
> Port authorities
> OEMs

Demand and user profile

> 24/7 operation requiring fast refuelling time
> Range, performance and refuelling service offerings ideally similar to conventional port operations equipment, in order that no operational changes are needed

Deployment requirements

> Hydrogen storage and refuelling infrastructure
> High safety standards for hydrogen storage and transportation

Key other aspects

> Possibility of coupling with on-site electrolysis from solar or wind

Benefit potential for regions and cities

Environmental

> Zero local emissions (CO_2, pollutants, fine dust particles)
> Depending on the production type of hydrogen, down to zero well-to-wheel emissions
> Significantly reduced noise level, therefore especially beneficial to inner-city harbours

Social

> Increased public acceptance of commercial harbours, especially in cities
> Ultimately thanks to low/zero emission footprint and low noise pollution: higher standard of living in areas near the harbour
> Improved working conditions for harbour workers

Economic

> Depending on the development of oil prices, CAPEX reduction and cost of hydrogen – lower TCO in the long run than diesel-fuelled port operations equipment
> As ports comprise an entire ecosystem, it is easier to generate a critical mass of hydrogen vehicles and applications for efficient and cost-effective hydrogen supply

Other

> Depending on the production type of hydrogen, reduction of dependency on fossil fuels or energy imports

Source: Roland Berger

A

Ports have to offer demo cases, industry has to define products and develop prototypes for port-specific FCH applications

Fuel cell powered port operations equipment

5/5

Hot topics / critical issues / key challenges:

> **Technological readiness and system/product definition** (until now, only proof of concepts and prototype demonstration projects in operation – and hardly any for port-specific applications e.g. in port-specific material handling; very specific operational requirements regarding the various potential use cases of fuel cells for port operation equipment)

> **Product cost** (capital expenditures expected to be significantly higher than for equipment powered by diesel; business case highly dependent on fuel prices with port operators requiring a positive return on investment)

> **Hydrogen infrastructure** (availability of distribution logistics, local storage and refuelling stations must be ensured; adequate location inside or outside the harbour must be found)

> **Environmental sustainability** (well-to-wheel emissions largely depend on resources used in hydrogen production)

> **Regulation** (unresolved regulatory issues such as certification of the equipment; emergency protocols; permitting of hydrogen use)

> **Training of workers** (usage as well as storage of hydrogen; behaviour in case of emergencies)

Further recommended reading:

> Fuel Cells 2000: Port of the Future
www.hfcarchive.org/fuelcells/uploads/Port-of-the-Future.pdf

> FCH2 JU 2017 Workshop on Maritime and port applications
http://www.fch.europa.eu/event/workshop-maritime-and-port-applications

Key contacts in the coalition:

Please refer to working group clustering in stakeholder list on the share folder

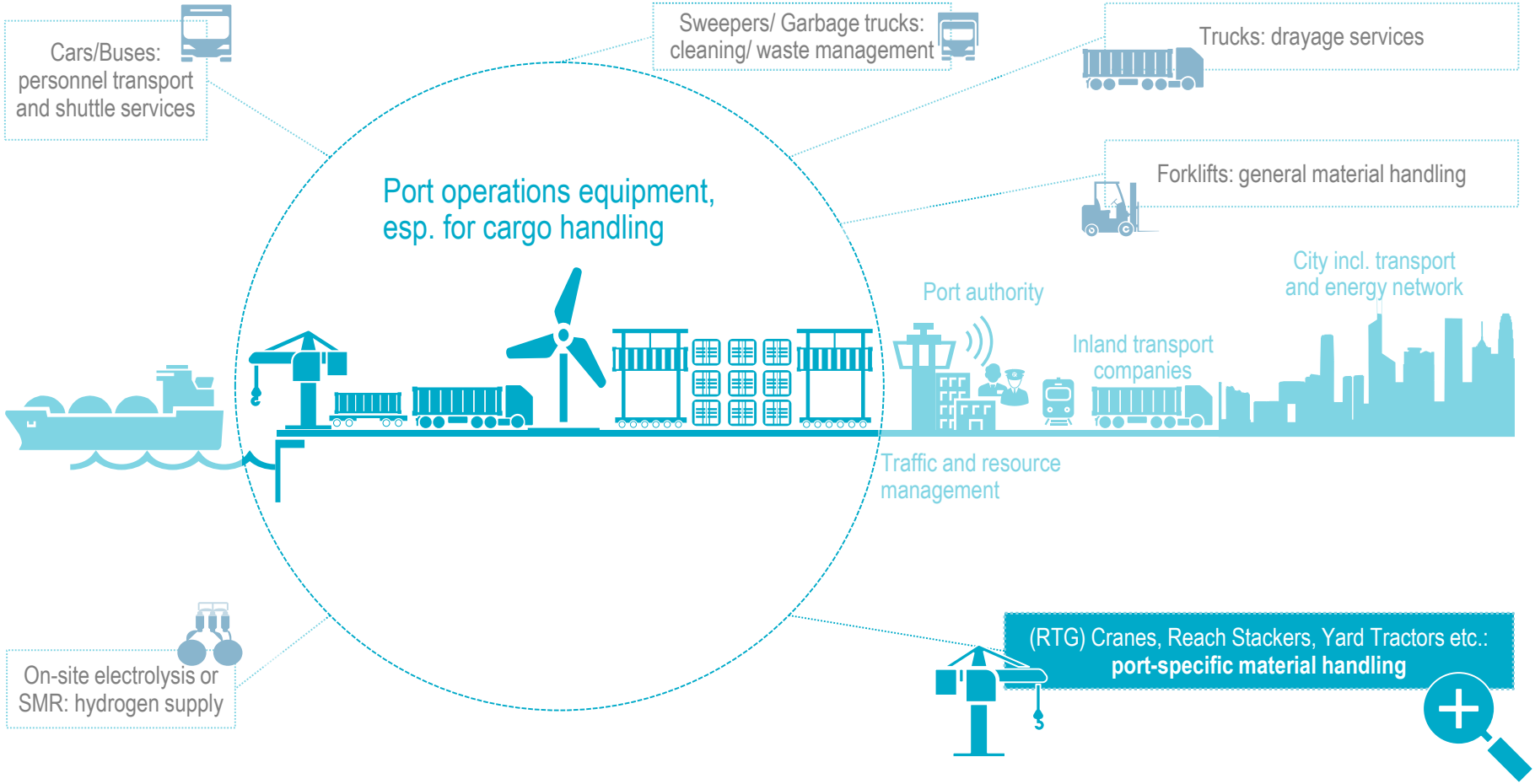
https://sharefolder.rolandberger.com/project/P005

Source: Roland Berger

B. Preliminary Business Case

Port operations are a complex ecosystem requiring multiple types of equipment – Manifold potential for FCH applications

Port operations ecosystem and FCH opportunities (selection)



Source: Roland Berger

RTG Cranes, Reach Stackers and Yard Tractors are the most important specific port operations equipment in this ecosystem

Port operations equipment (selection)

	RTG Cranes A	Reach Stackers B	Yard Tractors C
			
Brief description	Rubber Tyred Gantry (RTG) Cranes are mobile cranes which are used to ground or stack containers from yard tractors or drayage trucks and vice versa	Reach Stackers are used to handle containers and other cargo in ports; they are both able to shortly transport as well as to pile containers	Yard Tractors are used to transport trailer and containers short distances from ships to distribution centres or container terminals and vice versa
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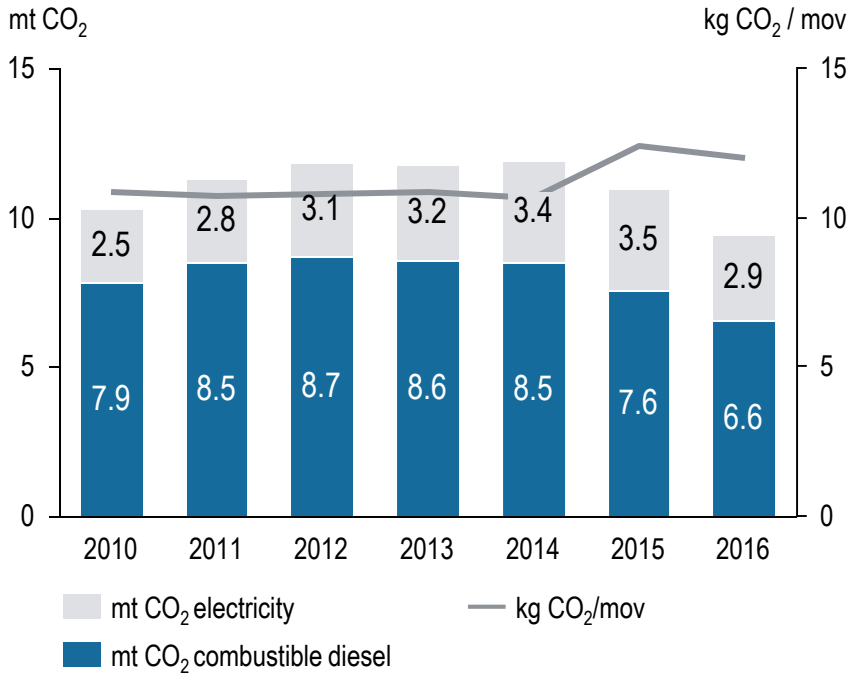
Engine / fuels	Diesel, electric (i.e. via a conductor bar), hybrid (diesel/battery-electric), LNG, CNG, biofuels	Diesel, hybrid (diesel/battery-electric), LNG, CNG, biofuels	Diesel, (battery-) electric, hybrid (diesel/battery-electric), LNG, CNG, biofuels

Source: Roland Berger

Collectively, they cause high CO_2 and noise emissions – the majority of emissions can be attributed to diesel-powered RTGs

Context and use case of a typical port operations terminal – EXEMPLARY

On-shore port operations are an important source of CO_2 emissions for port cities



> **CO_2 emissions of ports** can be attributed to electric and fuel powered applications[1]
  - **Fuel-powered yard machinery** (i.e. mainly diesel): RTGs (~60%), yard tractors (~35%), reach stackers and empty forklifts (~5%)
  - **Electric consumption:** Container reefers (~40%), STS cranes (~40%), yard lighting (~15%) and offices (~5%)
> In a **360,000 m² port terminal** with ca. 780,000 ship moves and 1.2 m TEUs, the collective energy demand causes **9.5 mt of CO_2** emissions per year, the equivalent of approx. 4,500 compact cars in 1 year
> Additionally, the **24/7 nonstop operating system** of ports negatively affects local residents due to **noise and pollutant emissions** like NO_X

1) Percentages based on 2012 data provided by 'Port of Valencia'

Source: MSC Terminal Valencia, Port of Valencia, Roland Berger

Alternative energy supply technologies are available – Electric solutions and alternative fuels have great potential

Benchmarking of non-diesel options for port op's equipment – SELECTION

	1 Battery electric	2 Electric conductor bar	3 LNG	4 FCH
				
Emissions				
- Well-to-Wheel	- Dependent on electricity source	- Dependent on electricity source	- Moderate, lower than diesel	- Zero, if green hydrogen is used
- Local	- Zero	- Zero	- Low-moderate	- Zero
Technological readiness	Only diesel/battery hybrids commercially viable	Demonstration stage	Commercially available, early deployments ongoing	Development stage
In-port fuel availability	Available - Sufficient power supply might be problematic	Available – Sufficient power supply might be problematic	Increasingly available – LNG will likely be increasingly used to fuel ship engines in the future	Limited availability of hydrogen so far, regulatory requirements *TBD*
Infrastructure requirements	Multiple charging stations with associated space, grid and supply requirements	Expensive conductor bar network, grid and supply infrastructure	Refuelling stations attachable to the LNG ship refuelling system	Refuelling station and hydrogen supply solutions (pipelines/storage)
Fit with operational requirements	Long charging times are potentially challenging 24h (i.e. 24/7) port operations	Due to limited operational flexibility of conductor bar, hybrid vehicles with additional diesel engines might be necessary	Short refuelling times, 24h availability and flexibility provide a fit with operational requirements – albeit stick with emissions	Short refuelling times, long ranges, 24h availability and flexibility provide a good general fit with operational requirements

Source: Roland Berger, worldcargonews.com, portstrategy.com, lngworldnews.com, nuvera.com

FCH solutions can in principle satisfy a port operator's key needs – FCH prototypes and demonstration projects necessary

Key considerations for port operators in their technology choice – SELECTION

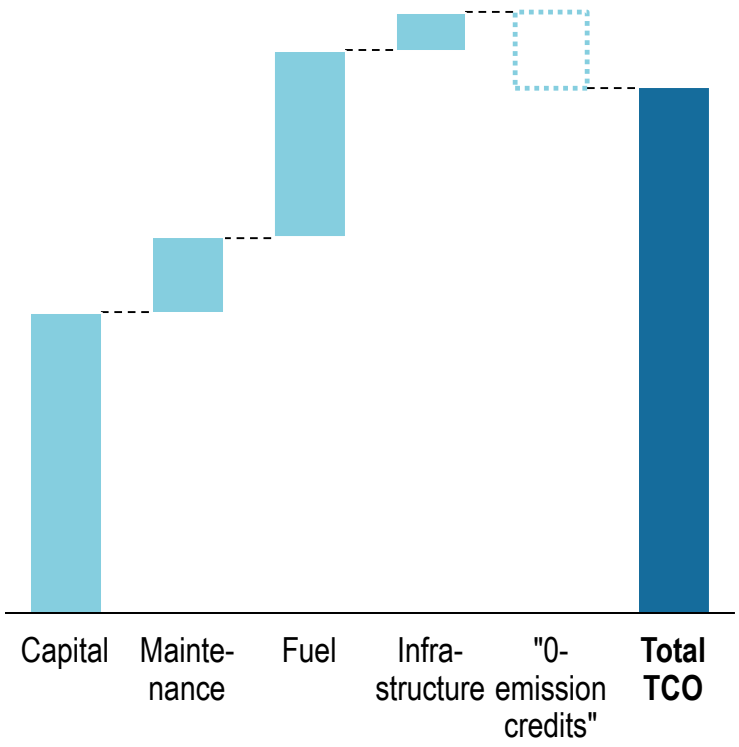
	High availability	High flexibility	Low / Zero emissions
Brief description	> **Tight scheduling** and **expensive delays** require high availability rates > **24/7 operating times** of ports minimize opportunities to counterbalance maintenance and downtimes	> **Complex container movement** and **storage strategies** (incl. efficient use of space and resulting constraints to manoeuvre) require port operating equipment with high operational flexibility	> Port cities are increasingly **challenged by emissions**, i.e. **CO_2 and noise** > 24/7 port operations can hence **significantly reduce life quality of local residents** within earshot
	Strict concern for Total Cost of Ownership (TCO)		**Regulation most relevant**
Opportunities & challenges of FCH applications	> **Short refuelling times** and **long ranges** fit port operator's requirements > **Lower availabilities** during **prototyping/ pre-commercial phases** can be covered by backup vehicles	> FC–powered equipment can **move flexible across the port terminal for several hours** (long range), before refuelling is necessary	> FCs **eliminate local emissions** such as CO_2, NO_X and **noise** entirely > **Green hydrogen supply** can reduce the carbon **footprint** to **zero**

Source: Roland Berger

Total Cost of Ownership for FC port operations have common drivers but will heavily depend on the individual ecosystem

Schematic outline of TCO for FC port operations and their drivers – SIMPLIFIED

Total Cost of Ownership (TCO)
(e.g. in EUR per TEU)



Capital cost

> FC technology (i.e. LT PEM FC 1,900 – 2,300 €/kW)
> Power range
> Fuel (& reforming), bunkering
> Durability / lifetime
> System integration

Maintenance cost

> Spare parts
> Labour and training
> Maintenance routine

Fuel cost – Cost of H2 vs. electricity, diesel, etc.

> Type of fuel and key input: electricity, natural gas
> Production and supply
> System efficiency (up to 60%$_{el}$, >90%$_{comb.}$)
> Fuel supply volumes and price

Refuelling infrastructure network costs

> Allocation of additional investments to cover costs associated with hydrogen supply

"0-emission credits"

> Potential future policy measures to promote zero-emissions for privately-operated ports

Source: Roland Berger, Shell

Please do not hesitate to get in touch with us

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Source: FCH2 JU, Roland Berger