The Role of Hydrogen in Decarbonising Ports

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FEnEx CRC Theme - Data Driven Modelling: Development & Validation.
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Introduction

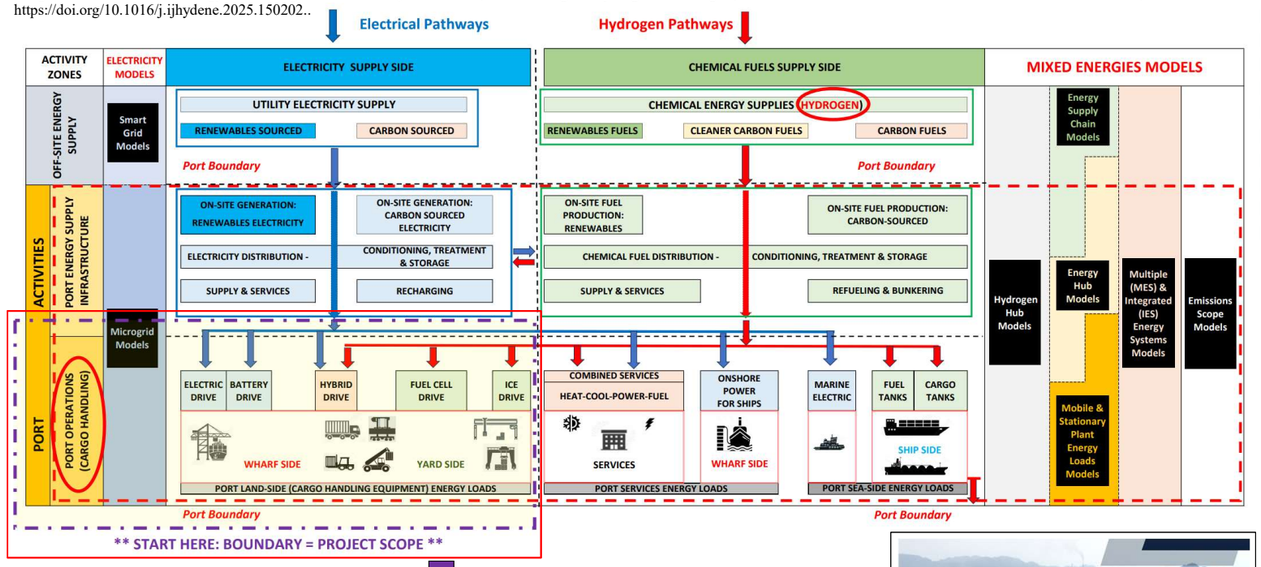
- Ports sector a significant emitter of diesel-based carbon emissions.
- Emissions studies highlight significant diesel usage by port vehicles.
- Emissions predicted from average diesel factors and are not measured.
- In-port emissions measurement profiles for vehicles tasks required.
- Task profiles provide basis for assessing hydrogen technology applications.

Literature Review

1) Maritime Global Impact ≈ 1,056 million Tonnes CO2e/yr (≈ 2.89% of global emissions).

2) Port Energy Map Showing Energy Models Coverage

Image modified from: Port energy models alignment with real port activities, their coverage of hydrogen technologies, and as tools for decarbonisation. David M. Holder and Ali Yavari, https://doi.org/10.1016/j.ijhydene.2025.150202..



3) Diesel fuelled Cargo Handling Equipment: up to 80 % of Port Carbon Emissions


Quay Cranes (Electric: 10%)


Terminal Tractors (Diesel: 23%)


Reach Stackers (Diesel: 2%)


Yard Gantry Cranes (Diesel: 45%)

Pictures: Cargo Handling Equipment at Ports, Argonne National Laboratory, March 2022
Emissions Percentage Data (Rounded): Port of Valencia, 2011, https://doi.org/10.1016/j.enpol.2019.04.044


Port Trials: Senari Port, Kuching, Malaysia
Kuching Port Authority
https://www.kpa.gov.my/web/subpage/webpage_view/113

4) Diesel & Hydrogen fuelled Cargo Handling Equipment model characteristics to reduce Port Carbon Emissions

Legend	
Typical Efficiency Curves: Present Best Technology **	
Hydrogen Fuel Cell	———
Hydrogen Internal Combustion Engine (H2ICE)	———
Diesel Internal Combustion Engine (ICE)	- - -
** *Excludes vehicle drive-train efficiency*	
Vehicles average yearly load factor (ALF)	———
Engine ALF = Yearly Average Power / Maximum Power	

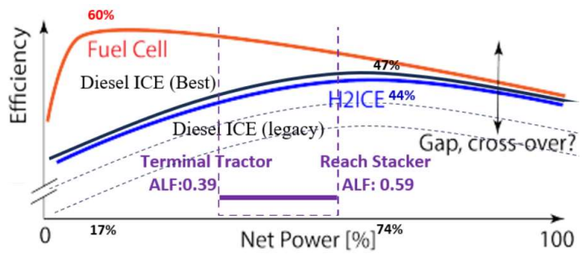


Figure above adapted from, with shown data sourced from: https://www.energy.gov/eere/fuelcells/february-h2iq-hour-overview-hydrogen-internal-combustion-engine-h2ice-technologies, 2023.
Cargo Handling Equipment vehicle average yearly load factors data from: https://doi.org/10.1016/j.marpol.2023.105480.

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Modelling Methodology

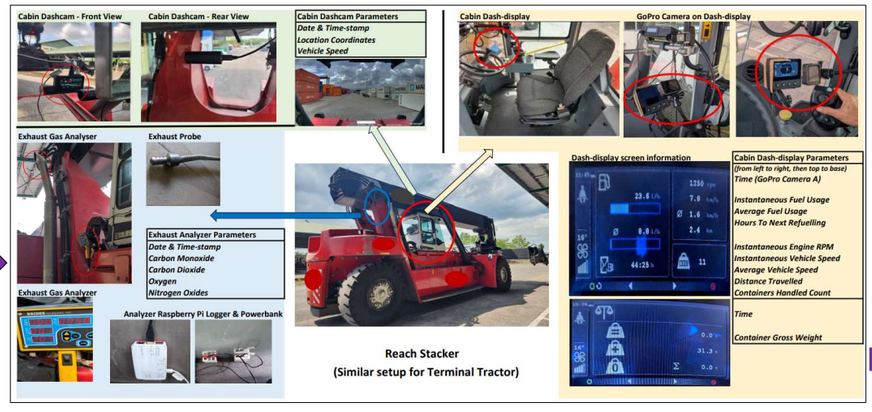
SWINBURNE UNIVERSITY OF TECHNOLOGY
VICTORIAN HYDROGEN HUB

5) Energy Modelling Options:

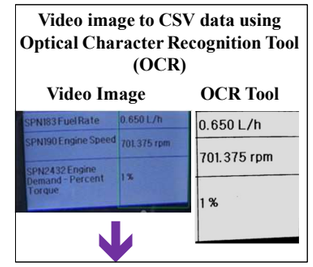
Port Energy Model Approaches	Nos. Reviewed Papers May 2017 to March 2024	Model Solving & Prediction Approach	Port Model Application Issues	Hydrogen Technologies	Research Opportunity
Conceptual-Driven *(White Box)*	25	Nodel Framework with Component Representation + Iterative Solving Algorithms, for Low Abstraction Model	Simplification Assumptions, 1 hour Time Resolution, Accuracy & Verification, Equipment Representative Energy Profiles	✓	(-)
START HERE → Data-Driven *(Black Box)*	8	Input Dataset + Machine Learning Algorithms, for High Abstraction Model	Obtaining Operational Data at High Temporal & Spatial Resolution, Quantity & Quality of Data for Energy Profiles	X	★
Hybrid-Driven *(Grey Box)*	(5) Overlapp	Conceptual + Data Driven *Combination* Approaches	Mitigate Above Model Issues but Complex	X	★

6) Data-Driven Energy Model – Port Measurements for Input Data:

- Model input data measured from real Cargo Handling Equipment (CHE) task-time profiles.
- Design, pilot test (in Australia) & then deploy portable energy & emissions measuring system (in Malaysia).
- Measure exhaust emissions & video capture information on diesel usage, engine rpm, speed, every 0.5 secs.



Video image to CSV data using Optical Character Recognition Tool (OCR)



Data Output

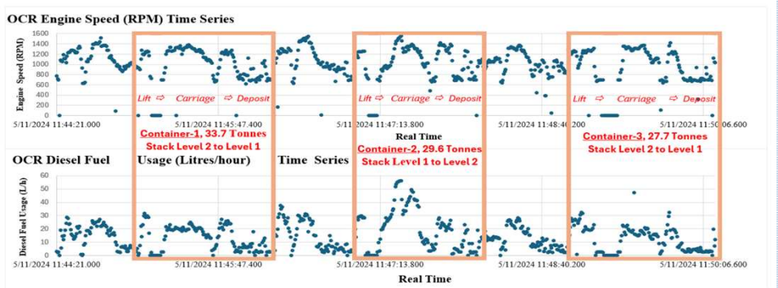
Engine Management System CSV data		
Video Frame	Fuel Rate (L/h)	Engine (RPM)
frame_0.jpg	0.65	697.3
frame_145.jpg	0.65	701.4
frame_290.jpg	0.50	102.6
frame_435.jpg	0.65	700.1
frame_580.jpg	0.65	699.1
frame_725.jpg	0.50	698.9
frame_870.jpg	0.65	701.1

7) Data-Driven Model Input Data (Initial) Results:


Reach Stacker

Reach Stacker 5-mins sample of measured task-time profile at 0.5 secs increment

Container Stack Level



8) Energy Modelling – Analysis - Conclusions: Next Steps 2025

- Improved model representation of diesel Cargo Handling Equipment task-time profiles.
- Match diesel CHE task-time profiles against Hydrogen technologies using Data-Driven algorithms.
- Technologies selection depends on CHE task-time profiles, yard layout, operations, & ownership costs.
- Identify hydrogen technologies potential for decarbonising ports diesel Cargo Handling Equipment (CHE).