

## Literature Review: Green Corridors

### Introduction:

At the 2021 COP26 Conference, the Clydebank Declaration was signed by 25 states which pledged to participate in the creation of 6 'green corridors' by the end of 2025. Green corridors are zero-emissions maritime routes between 2 (or more) ports, the objective of which is to - in line with the Paris Agreement and the findings from the [Fourth IMO Greenhouse Gas Study 2020](#) - reduce the environmental impact of the shipping industry.

The Green Corridors approach was adopted in order to 'concentrate policy, investment, and infrastructure development in specific geographical locations where key actors are ready and willing to act'<sup>1</sup>— tackling the high infrastructural costs of introducing environmentally advanced technology throughout the world's ports, by breaking up investment into different, consciously chosen routes. One of such technological advances, and arguably the key factor for the creation of zero-emissions maritime passages, is the transition from oil-based fuels to hydrogen-based fuels. The infrastructure needed to store, transport, and supply these new types of energy accounts for the bulk of the cost of green corridors. My purpose in this literature review will be to draw similarities between the transition from oil to hydrogen with the transition from coal to oil at the turn of the 20<sup>th</sup> century, focusing my analysis on the infrastructural cost across transitions. The Aden Port case study will be brought in to illustrate the cost structure of the oil introduction. Ultimately, the political approach taken by colonial powers and that taken by modern international organisations like the United Nations will be compared in the context of fuel transitions.

This literature review examines the Lloyd's Register Foundation Archives, including Lloyd's Register (LR) Publication Articles, and resources from the Heritage & Education Centre (HEC). Other external sources have also been cited if relevant. It is structured in the following way: (1) sources on what green corridors are (2) hydrogen: its efficiency and challenges (3) the history of the transition from coal to oil (3) the Aden case study. Comments and abstracts have been added to some of the sources in order to display their contents and thus aid investigation

## Present-day fuel transitions: Green Corridors

### 1. Official presentations, declarations, and reports

*From Lloyd's Register Catalogue:*

- [LR and partners unveil 'Silk Alliance' green corridor project](#). Lloyd's Register 2022

*External Sources*

- [Clydebank Declaration](#), signed by 25 states at COP26 2021, Glasgow

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<sup>1</sup> Cozev. [Roadmap to 2040](#). Released at COP27 2022

- [Presentation of the Clydebank Declaration](#) at COP26 2021, Glasgow
  - Presentation on the methodology of choosing passages for green corridors, discussion panels with different stakeholders, and discussion of new green projects.
- [Ministerial Declaration on zero emission shipping routes between the Nordic countries](#), Oslo, 2022
  - Adoption of the Clydebank Declaration by the Nordic countries, with an emphasis on intra-Nordic zero-emission passages
- [Clear to proceed - green shipping corridors in the Nordic Region](#), 2022
  - Report on Nordic Ministerial Declaration
- [First-ever North Atlantic Green Shipping Corridor prioritized by Montreal and Antwerp ports](#), Julie Gedeon, April 2022, Chamber of Maritime Commerce
  - Policy report on the green corridor to be established between the Montreal and Antwerp ports.
- [Port of Los Angeles, Port of Shanghai, and C40 Cities announce partnership to create world's first transpacific green shipping corridor between ports in the United States and China](#), press release 2022
- [A big first step towards green shipping corridors](#), Prashanth Gururaja, February 2022, Climateworks Foundation
  - Article on the first transpacific green corridor between the Port of Los Angeles and the Port of Shanghai

## 2. The transition from oil to hydrogen:

### a) Effectiveness of hydrogen as a substitute for oil, and comparisons with LNG

#### From the HEC catalogue:

- Lloyd's Register Horizons supplement. *What is the future of shipping?* February 2012
  - Special reports on future fuels, engines designs and technologies.
- *Low carbon pathways 2050*. Lloyd's Register Horizons Magazine. Issue 47 April 2017
- *Decarbonisation*. Lloyd's Register Horizons Magazine. December 2019
- *Inside and LNG Tank*. Lloyd's Register Horizons Magazine. Issue 45. February 2016 p.14-20
- *LNG Fuelled Ferries*. Lloyd's Register Horizons Magazine. Issue 43. May 2015. P.34 – 36
- *Stena pioneers first methanol-powered ferry*. Lloyd's Register Horizons Magazine. Issue 42 January 2015
- *LNG Fuelled Shipping*. Lloyd's Register Horizons Magazine. Issue 41 September 2014. P.10
- *Future fuels 2030 study*. Lloyd's Register Horizons Magazine. Issue 40 June 2014
  - A farsighted report by Lloyd's Register and University College London looks at the future of fuels and the economic factors likely to affect shipowners and operators
- *Gateway to 2030*. Lloyd's Register Horizon Magazine. Issue 37 May 2013
  - A major report by Lloyd's Register and two stakeholders compares the major global influences today with 2030, with some focus on energy and fuels
- *The methanol story*. Lloyd's Register Horizons Magazine. Issue 37 May 2013
  - Trials of the alternative fuel could have significant implications for the global shipping industry

- *Lloyd's Register's LNG Bunkering Study*. Lloyd's Register Horizons Magazine. Issue 35 September 2012
- *Europe's first hybrid tug*. Lloyd's Register Horizons Magazine. Issue 35 September 2012 p.17
- *The Great Fuel Debate*. Lloyd's Register Horizons Magazine. Issue 34 May 2012.
- *World greets first new LNG-fuelled tanker*. Lloyd's Register Horizons Magazine. Issue 33 January 2012
- *The LNG debate*. Lloyd's Register Horizons Magazine. Issue 32 September 2011
- *Is LNG the fuel of the future?* Lloyd's Register Horizons Magazine Issue 31. May 2011
- *Gas Focus*. Lloyd's Register Horizons Magazine. Issue 28 February 2010
- *The Potential For Energy*. Lloyd's Register Horizons Magazine. Issue 27 June 2009
- *Going Green Class*. Lloyd's Register Horizons Magazine. Issue 25 December 2008
- *Getting into Gas*. Lloyd's Register Horizons Magazine. Issue 24 June 2008
- *Fuelling the Future*. Lloyd's Register Horizons Magazine. Issue 18 December 2006
- *The Arctic LNG Carrier*. Lloyd's Register Horizons Magazine. Issue 12 June 2005
- *Assuring LNG quality in Japan*. Lloyd's Register Horizons Magazine. Issue 11 March 2005 p. 12
- Lloyd's Register Magazine Horizons. Issue 10 December 2004
  - Special feature on LNG
- *LNG sloshing study*. Lloyd's Register Horizons Magazine. Issue 5 September 2003
- *LNG developments and fuel cell technology*. Lloyd's Register Horizons Magazine. Issue 2 November 2002
- *Fuel Cells*. Lloyd's Register Horizons Magazine. Issue 9 September 2004
- Veldhuis, Richardson, Stone. *A hydrogen fuelled gas turbine powered high-speed container ship: a technical and economic investigation of the ship and associated port infrastructure*. 2005
  - The properties of hydrogen offer the potential for increased payload particularly in long-haul operation which in turn improves economics. Studies associated port and terminal facilities as well.
- Zhang, *Development and application of fuel cell*, 2006
  - The fuel cell is extremely efficient and safe and a clean and convenient form of energy. The main type of fuel cell is examined.
- Tayyab M. *Performance comparison of diesel with hydrogen at different speeds*. 2004
- Roemendael L P, *Return to ammonia or practical experience with ammonia as a refrigerant in modern reefers*, IMarE Conferences and Symposia, 1995
- MER, *A clean green engine*, 1993
  - Advantages of methanol engines include - reduction of NOx and SOx emissions to about half that of conventional engines a reduction of deposits and consequently cleaner combustion chambers and cleaner lubricating oil. Drawbacks include methanol's low flash point and its poisonous properties.

External Sources:

- [The Future of Hydrogen: Seizing Today's Opportunities](#). 2019
  - Report prepared by the IEA for the G20 in Japan
- Fayaz et al. An overview of hydrogen as a vehicle fuel. Renewable and Sustainable Energies Reviews. Volume 16 Issue 8. October 2012, Pages 5511-5528

- Armaroli et al. *The Hydrogen Issue. Energy for a Sustainable World. From the Oil Age to a Sun-Powered Future*, Wiley-VCH, Weinheim, 2011.

## **b) Infrastructural costs of renewable fuels**

### From the HEC catalogue:

- *The Fourth Propulsion Revolution*. Lloyd's Register Horizons Magazine Issue 53, March 2020 p.5
- *Recent LNG Projects – new ships on the waters*. Lloyd's Register Horizons Magazine Issue 46, June 2016
- *LNG Bunkering Study*. Lloyd's Register Horizons Magazine Issue 40 June 2014.
- *LNG ship design and construction*. Lloyd's Register Horizons Magazine. Issue 1 June 2002
- Wursig G, *Shipping Liquid Hydrogen*. 1991.
  - Liquid hydrogen transport requires large-scale carriers and tanks with highly efficient insulation for low boil-off. No commercial LH carrier yet exists. The problems of vaporisation and boil-off insulation the benefits of mobile tanks and safety aspects are discussed.
- Jones, Bolton, *Hydrogen storage in future warships*, 2004
  - Storage of hydrogen poses difficulties in terms of mass and volume footprint and in dormancy for cryogenic storage. Generation of hydrogen at sea from logistic fuels poses challenges in terms of system complexity cost and heat signature.
- Dams, Hayter, Moore. *Progress in the commercialisation of fuel cell systems - an update*. 2002
  - Explores the major technical problems remain inhibiting the widespread use of fuel cell systems, and their use in commerce and defence
- Badan, Affolter. *Danger of damages in electric fuel cell boats due to a lightning stroke*. 2005
- Greig, *Fuel cells and issues for their use in warships*, IMarEST, 2003

### External sources:

- Verhelst S. *Hydrogen-fueled internal combustion engines*. Volume 35 Issue 6. December 2009, Pages 490-527
- Crabtree and Desselhaus. *The Hydrogen Fuel Alternative*. MRS Bulletin, Volume 33 , Issue 4: Harnessing Materials for Energy , April 2008 , pp. 421 – 428
- Berry G D. *Hydrogen as a transportation fuel: Costs and benefits*. United States: N. p., 1996. Web. doi:10.2172/230382.
- Sun et al. *Societal lifetime cost of hydrogen fuel cell vehicles*. International Journal of Hydrogen Energy Volume 35 Issue 21. November 2010, Pages 11932-11946
  - This paper employs societal lifetime cost for evaluating hydrogen fuel cell vehicles (FCVs) from a societal welfare perspective as compared to conventional gasoline vehicles.

## **Fuel transitions in the past**

### **1. The transition from coal to oil**

#### From the HEC Catalogue:

- Watson, Nigel. [\*Maritime Science and Technology: Changing Our World\*](#). Chapter 8. Lloyd's Register Foundation, Heritage & Education Centre, 2017. Barbara Jones.
  - A discussion of the transition between coal and oil, from technological to safety, infrastructural and port developments.
- Right S D. *Experiences with high pressure steam installations in the Royal Navy*. 1932
  - Changes in steaming conditions are reviewed with reference to the move from coal to oil-firing
- *Recent Developments in Oil Ship Construction* Thompson 1920
  - Technical account on oil ship construction, followed by a discussion by Lloyd's Register Association
- *The Practical Construction of Oil Tankers* Macdonald 1931
  - Technical account on oil ship construction, followed by a discussion by Lloyd's Register Association, and a response from the author
- *The Storage and Transfer of Liquid Fuel in Ships* 1921
- *Kingdom of Allah and Oil* 100A1 April 1983
  - Report on Saudi Arabia
- *Guardian of the Oil* 100A1 April 1983
  - Oman and the Straits of Hormuz
- *LR in the Lochs: Building for oil* Society February 1977
- *LR inspects Brazil's first oil production platforms* LR No 17
  - Inspection of 5 steel jacket fixed platforms in Brazil for Petrobras
- *Products Carriers: Ready for a Come-back?* 100A1 March 1975 p. 10-14
  - As more refineries are operating in countries where oil is produced, will there be an increased need for products carriers rather than crude carriers

External sources:

- Khalili L. *Sinews of War and Trade: Shipping and Capitalism in the Arabian Peninsula*. Chapter 2: Harbour Making. 2020
  - An account of the origin of the shipping oil supply chain, through the development of ports and the influence of colonial powers.
- Goldrick, J. *Coal and the Advent of the First World War at Sea*. War in History Volume 21, Issue 3. 2014
  - This article assesses the issues of coal through analysis of the problems related to ship operations which were encountered with manpower, ship design, and coal supply, in the context of its replacement with oil.
- Jones, G. *Oil: a novel energy source*. Futures Volume 15, Issue 3, Pages 224-225. 1983
  - Short historical account of the introduction of oil fuels.
- Brown, M. *The Royal Navy's Fuel Supplies, 1898-1939; the transition from coal to oil*. PhD Dissertation, King's College London, 2003
- Fletcher, M E. *From coal to oil in British shipping*. The Journal of Transport History. 1975

**2. Aden Port Case Study: infrastructural transitions**

**a) Historical context:**

External Sources:

- Margariti R E, *Aden and the Indian Ocean Trade: 150 Years in the Life of a Medieval Arabian Port*. pp. xiii, 343. Chapel Hill, University of North Carolina Press, 2007
- Pankhurst R, *The Trade of the Gulf of Aden Ports of Africa in the Nineteenth and Early Twentieth Centuries*, Journal of Ethiopian Studies Vol. 3, No. 1 (JANUARY 1965), pp. 36-81.

#### **b) The transition to oil and the construction of the refinery in 1954**

##### From the HEC catalogue:

- *Aden - Visit of Mr F H McD. Wilson*. LR News Letter Sept 1953 p.2
  - Report on arrival
- *Aden - Mr J.F. James (Kch.)* LR News Letter Sept 1953 p.9
  - Opened new exclusive office - now succeeded by Mr W.P. Watson (S.& E.) from Singapore.
- *Aden - Anglo Iranian Oil Co.* LR News Letter Jan 1953 p.2
  - To build new Oil Refinery
- *Anglo Iranian Oil Co.* LR News Letter Jan 1953 p.2
  - New Oil Refineries at Perth (Australia) and Aden. Plant, equipment and materials to be inspected at Makers' Works at home and abroad.
- *Aden Refinery* LR News Letter March 1955 p.7
  - BP to cover the operation of the plant in service
- *Non-marine work (oil tanks and pipelines)* Annual Report 1953
  - One of the society's surveyors has recently returned from an extended tour on behalf of the Motherwell Bridge Contracting and Trading Co., undertaken with the object of advising on the welding work - oil storage tanks and pipelines - on their construction sites in Syria, Lebanon, Iraq, Kuwait, Qatar, Aden, India and Pakistan.
- *100A1 July 1982*
  - Photo input heater desalination plant Aden refinery
- *Cover 100A1 July 1982*

##### External Sources:

- [Aden's Refinery Company Background Statement](#), 2020

#### **c) Colonial power in Aden**

##### External Sources:

- Sills C. *Colonial capitalism, boundary demarcation and imperial placemaking in South Arabia*. Third World Quarterly Volume 42, 2021 – Issue 7
  - Analyses the means through which indigenous stakeholders and British imperialists competed for influence in the shaping of Aden's built environment, thus complementing a robust body of literature highlighting the importance of the port city within the framework of the world capitalist system
- Smith S, *Rulers and residents: British relations with the Aden protectorate, 1937–59*, Middle Eastern Studies, Vol. 31 Issue 3, 1995
- Khalili L. *Sinews of War and Trade: Shipping and Capitalism in the Arabian Peninsula. Chapter 2: Harbour Making*. 202

- Watt D C. *Labor Relations and Trades Unionism in Aden, 1952-1960*. Middle East Journal Vol. 16, No. 4 (Autumn, 1962), pp. 443-456
- Robbins R. *The Legal Status of Aden Colony and the Aden Protectorate*. American Journal of International Law , Volume 33 , Issue 4 , October 1939 , pp. 700 – 715
- Willis J. *Colonial Policing in Aden, 1937-1967*. The Arab Studies Journal Vol. 5, No. 1 (Spring 1997), pp. 57-91
- Ingrams H. *The progress towards independence of Aden and the Aden protectorate*. Journal of the Royal Society of Arts Vol. 111, No. 5085 (AUGUST 1963), pp. 756-769

#### **d) Aden in current discussion**

##### External Sources:

- Alghaithi et al, *The Comparative Advantage of Aden Port from the Perspective of the Belt and Road Initiative*, Open Journal of Social Sciences, Vol.10 No.2 February 2022
- Chaziza M. *The Belt and Road Initiative: New Driving Force for Sino-Yemen Relationship*. Institute of Chinese Studies, Dheli. Volume 57 Issue 2.
  - Yemen can become the bridge between Asia and Africa, and between the Indian Ocean and the Mediterranean, and a vital component of China's Silk Road Strategy. The Belt and Road Initiative (BRI) could be used as a new driving force for the Sino-Yemen relationship, especially the integration between the state's post-war reconstruction and the realization of the initiative.
- Ho W. *One belt, one road' and the Middle East in China: Yemeni community in a transregional circuit*. Discussion Paper. Durham University, HH Sheikh Nasser Al-Sabah Programme, Durham