Decarbonisation pathways for the shipping sector

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IRENA at a glance

» Intergovernmental Organization (IGO)

» Established in 2011

» HQ in Abu Dhabi, UAE

» IRENA Innovation and Technology Centre – Bonn, Germany

» Permanent Observer to the United Nations

» Director-General – Francesco La Camera

Membership

161 members + 22 in accession
Important considerations in the context of shipping

• **Similarities with power sector**
  • Long-lived assets, high upfront capital costs
  • Could likely benefit from technology-specific support mechanisms to reduce costs

• **Differences with power sector**
  • Shipping sector competes internationally
  • Shipping is outside national climate policy regimes
  • Different techno-economic challenges
    • RE: capital costs, variability
    • Shipping: fuel costs and availability
Let’s start with the problem

On average, the shipping sector is responsible for 3% of annual global green-house gas emissions on a CO2-equivalent basis.

Annual CO2 emissions associated with international shipping

Source: JRC-EDGAR (2018)
What are the options?

» Alternative marine fuels / propulsion
  » Biofuels
    » Biodiesel substitutes
    » Bio-alcohols
    » Gaseous biofuels
  » E-fuels
    » Hydrogen
    » Ammonia
    » Methanol
    » Methane
    » Other liquid fuels (gasoline, diesel)

» Electric engines / Batteries

» Efficiency improvements
  » Incl. solar and wind applications

» Other technologies (carbon capture)
Not all fuels are made the same

Total life cycle GHG emissions per kWh of engine output for different fuels

Source: Balcombe et al. (2019)
Biofuels

- GHG, NOx and SOx emission reductions
- Some are compatible as drop-in fuels
- Safer in case of spills due to biodegradability
- Low storage, bunkering, infrastructure and logistics costs (diesel substitutes)

- Can reduce engine lifespan (carbon build-ups, SVO; water contamination, FAME)
- Sustainability concerns
- Availability concerns
- High production costs (mainly due to feedstock)
- High adaptation costs (bio-alcohols and gaseous biofuels)

Source: Biofuel cost projections (IRENA, 2016); fossil fuel cost range (Lloyd’s Register, 2019; Ship & Bunker, 2019)
Power-to-X / E-fuels

- Renewable electricity
  - Physical energy storage, e.g., pumped hydro
  - Chemical energy storage, e.g., battery
    - Hydrogen production through electrolysis
      - Direct use
        - Ammonia
          - Methanol
          - Synthetic methane
            - Synthetic liquids, gasoline, diesel, kerosene
Renewables are getting cheaper

Cost reduction (2010 - 2018)

Solar PV 77%

Onshore Wind 30%

Onshore wind

Solar photovoltaic
Hydrogen

+ Zero carbon if produced from RES
+ No SOx and negligible NOx emissions

- Not at commercial scale
- Very low volumetric energy density
- Difficult to store, requires cryogenic temperatures or very high pressure
- Considerable changes to infrastructure and logistics
- High costs
- High flammability

Source: Hydrogen cost projections (IRENA, 2019); fuel cost projections (Lloyd’s Register, 2019; Ship & Bunker, 2019)
Ammonia

- Zero carbon, SOx, and negligible NOx if used in fuel cells (can produce NOx if combusted, might need SCR)
- Higher volumetric energy density than H₂
- Easier to store than H₂
- Widely used commodity

- No active commercial applications
- Bunkering and storage need modification due to refrigeration needs
- High costs
- Toxic

Source: Hydrogen cost projections (IRENA, 2019); fuel cost projections (Lloyd’s Register, 2019; Ship & Bunker, 2019)
Overview and Outlook

- To achieve the 2050 carbon reduction targets, the shipping sector will need to shift to carbon-free propulsion alternatives such as advanced biofuels, electric propulsion, renewable hydrogen and other hydrogen-based fuels such as ammonia.

- Given that bunker costs can account for 24 - 41% of total vessel operation costs, fuel prices and its availability will play a critical role in selecting one or another clean fuel option.

- Other key, decisive factors will include the infrastructural adaptation costs of ships and ports, technological maturity and sustainability issues (e.g. food security in the case of biofuels).

- As the adoption of clean technologies grows across sectors, technology improves, renewable fuel costs fall and regulation becomes more favourable, carbon-neutral options are expected to become more competitive in the medium to long-term.

- Decarbonising the shipping sector will require a global effort where the close cooperation between private and public stakeholders will be highly important.
IRENA’s work on Hydrogen and Shipping

> **Key Findings - Hydrogen**
> - Important synergies with RE – Storage and flexibility
> - Electrolysers are scaling up from MW to GW
> - Electrolyser costs to halve by 2050 (850 USD/kW today)

> **Key Findings - Shipping**
> - Need for global effort and cooperation of public and private sectors
> - Fuel price and availability will be decisive
> - Cost reductions in technology and RE will make alternative fuels competitive in the medium to long term
> - Life cycle emissions will have to be considered

Thank you

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Hydrogen production costs - Currently accelerating investments in electrolysers worldwide

**Key assumptions**
- Electrolyser load factor: 4200 hours (48%), conversion efficiency 75%

- Energy content 8 kg hydrogen = 1 GJ natural gas. Natural gas wholesale price today USD 2/GJ (US) – USD 8/GJ
- Replacing gas with hydrogen - saving 0.056 t CO2/GJ – translates into 100-200 USD/t CO2
- This would apply to ammonia, synthetic methanol from H2/CO2

Hydrogen from renewables is close to competitiveness at best solar and wind sites

**2020-2030**
- LCOH (USD/kg H2): 3.53
- Capex 840 USD/kW

**2040-2050**
- LCOH (USD/kg H2): 2.51
- Capex 200 USD/kW

Cost of producing hydrogen with fossil fuels technologies with CCS, considering a fuel cost from 1.9 to 5.7 USD/GJ

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**IRENA Innovation and Technology Center**

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Modern bioenergy deployment should be over four times larger than the current level.

Data based on the Global Energy Transformation: A Roadmap to 2050 (IRENA 2019)