Pathways and barriers to zero emission shipping

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Navigating Towards a Zero-Carbon Future
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THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

Presentation overview

- Introduction and background
- 2019 Technical Workshop on Zero Emission Vessel Technology
- Upcoming research

Pathways and barriers to zero emission shipping

Introduction and background

International Council on Clean Transportation

- Goal of the ICCT is to dramatically reduce conventional pollutant and greenhouse gas emissions from all transportation sources in order to improve air quality and human health, and mitigate climate change.
- Promotes best practices and comprehensive solutions to:
  - Improve vehicle emissions and efficiency
  - Increase fuel quality and sustainability of alternative fuels
  - Reduce pollution from the in-use fleet, and
  - Curtail emissions from international goods movement.
- The Council is made up of leading regulators and experts from around the world.

www.theicct.org

Climate damage and protests are accelerating around the world

IMO's Initial GHG Strategy

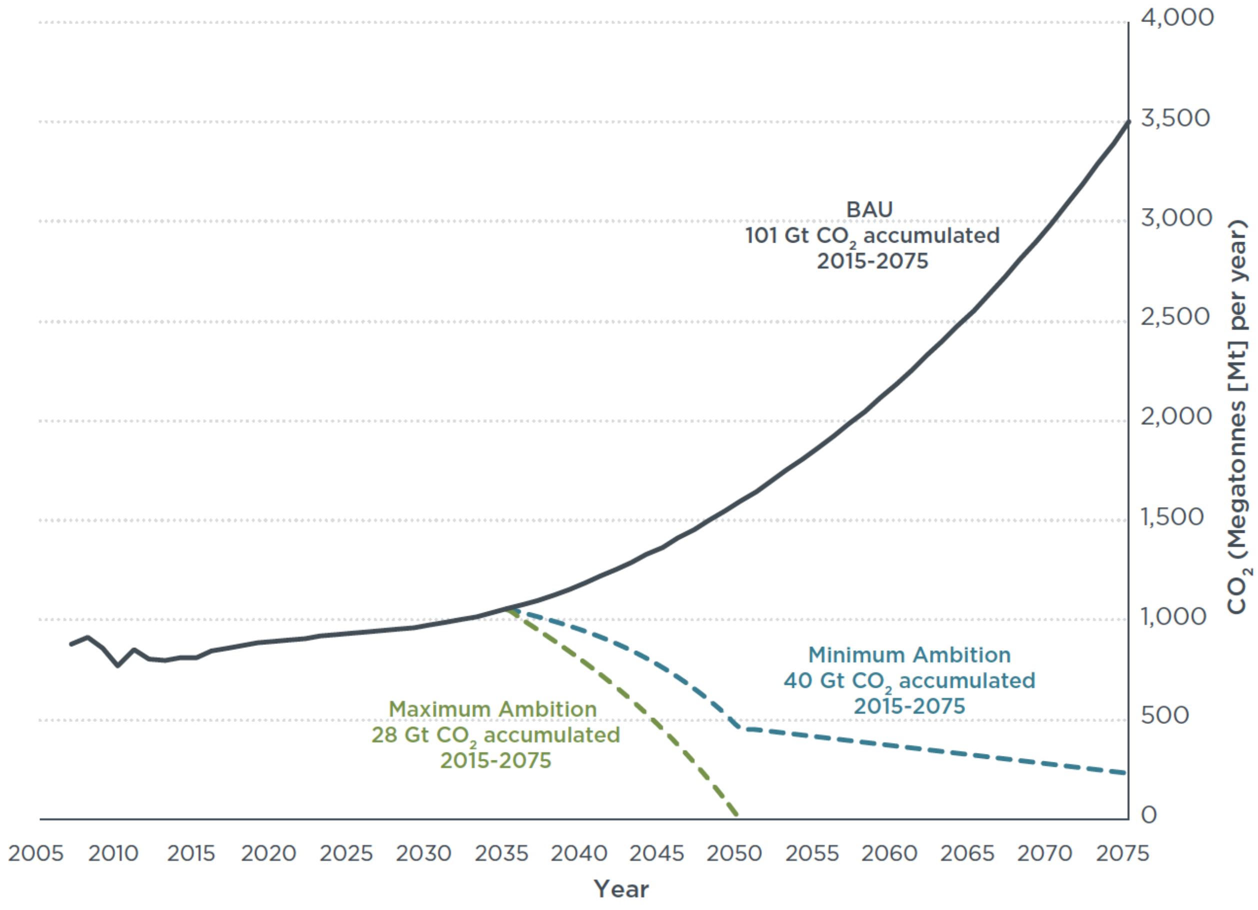

Figure 1: CO_2 emissions from international shipping under IMO's initial GHG strategy (blue and green) vs. BAU (black), with cumulative emissions 2015 through 2075.

Already good progress on small ZEVs

Shore Power and Cargo Handling Equip. (Today in CA; China, Rotterdam, others)

Hybrid and Battery Tugs (Today in Baltimore, etc.)

Small Ferries (Today, especially in Norway)

Short-distance Bulk Cargo Ships (1 in China; more coming)

Small Autonomous Barges and Container Ships (20-120 TEU, 2018/2019 Europe, more coming)

Need dedicated resources to scale up for larger ships.

Small H_2-powered ships already exist

Larger H_2-powered ships are largely concepts

Pathways and barriers to zero emission shipping

2019 Technical Workshop on Zero Emission Vessel Technology

THE INTERNATIONAL COUNCIL ON
Clean Transportation

Technical Workshop on Zero Emission Vessel Technology

Goal: Discuss technology pathways and barriers to zero-emission international shipping to help identify related research, development, and demonstration needs.

Workshop participants

https://theicct.org/events/zero-emission-vessel-workshop-SF-2019

Day 1 Agenda (1/2)

Time	Activity
9:00-9:30	**Registration, coffee/tea and a light breakfast**
9:30-9:45	**Review of agenda and workshop goals** (Dan Rutherford, ICCT)
9:45-10:00	**Setting the stage: A proposal to establish a Board to accelerate RDD&D of ZEVs for international shipping** (Bryan Wood-Thomas, WSC)
10:00-11:00	**Hydrogen, fuel cells, and batteries** • Hydrogen co-combustion in ICE (Roy Campe, CMB) • Electric and H_2 fuel cell ships in China (Guiyang Ling, Commission Office of Shanghai Port)
11:00-11:15	**Coffee/Tea Break**
11:15-11:45	**Wind-assist: opportunities for existing and new ships** • Wind-assist technologies (Jay Gardner, Wind+Wing)
11:45-12:00	**Group photo**
12:00-1:00	**Lunch (provided)**

Day 1 Agenda (2/2)

Time	Activity
1:00-2:00	**ZEV concepts** • Zero fuel ship concept (Madadh MacLaine, ZESTAs) • The Zero-V: Feasibility of an LH_2 research vessel (Lennie Klebanoff, Sandia)
2:00-3:00	**Longer-term low/zero emission energy sources for the shipping sector** • Green ammonia (Tim Scarbrough, Ricardo) • Utilization of H_2 and ammonia as marine fuel (Yoichi Niki, NMRI)
3:00-3:20	**Coffee/tea break**
3:20-4:30	**Potential ZEV pathways for international shipping** • Scaling batteries and fuel cells to larger ships (Joe Pratt, Golden Gate ZEM) • ZEV Roadmap to 2050 (Shinichi Hanayama, Class NK)
4:30-5:00	**Day 1 Closing remarks** (Dan Rutherford, ICCT)
5:00	**Adjourn for the day**
6:00	**Group Dinner** (complimentary) Top of the Mark (19^{th} floor)

Final technology list

Table 1. Technologies discussed at the workshop

Propulsion Technology	Fuel or Energy Carrier	Other
Fuel cells	Ammonia	Advanced hull design
ICE (Diesel + Otto) & gas turbine	Bio and synthetic LNG	Advanced systems integration
Nuclear	Biofuel	Energy recovery
Pure batteries + electric motor	DME	Hybrid electronics/systems
Wind power/Assist	Electricity/batteries	On-board carbon capture + storage
	Hydrogen, including LH_2	Reforming
	Methanol, including e-MeOH	Solar
	Nuclear	
	Synthetic MGO	

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Day 1 takeaways (1)

- Key barriers to ZEV technologies
  - Cost competitiveness
  - Reliability/availability
  - Energy storage volumes for larger transoceanic vessels
  - Hands on experience (including end user acceptability)
- Policy
  - Shipping is not currently receiving enough investment to get to a zero carbon future.
  - Regional demonstration/deployment projects will be needed in addition to IMO policies
  - Air quality, fuel costs, and potentially carbon pricing could be ZEV drivers
  - AQ and efficiency targets imply their own 2030 technology solutions that may impact ZEV roadmaps
- Co-benefits
  - Instant torque, no noise, no vibration, no exhaust emissions, no spills, lower fuel weight, maintenance savings on transmissions, etc.
  - Renewable fuel production as a new business opportunity for emerging economies
  - Pop up market/instant scaling of LH_2 production through shipping applications

Day 1 takeaways (2)

- Propulsion
  - Determinants for appropriate technologies include engine power, energy demand, range, duty cycle ("small and fast") and retrofit capabilities
  - A systems approach with broad expertise is valuable to combine innovations into a viable prototype
  - ICE (H_2 or green ammonia), starting as dual fuel and maybe A/E, as a potential platform to scale up synthetics and address the chicken-and-egg problem
- Fuels
  - Electric propulsion may be an important application for certain ship types
  - E-fuels plus hydrogen as the "last fuel standing" for transoceanic shipping. Carrier could be H_2, ammonia, methanol, DME, even bio or syn-LNG but each have tradeoffs.
  - Ammonia as a chemical already traded, generated, widely exported, more easily stored than H_2. N_2O emissions may require aftertreatment.
  - How to produce fuels does matter for GHGs
- Other partial zero emission technologies
  - Wind assist as supportive technology: useful to facilitate secondary renewables with higher cost/lower energy density, futureproof vessels
  - Advanced ship design may be important for newbuild ships: anti-drag, anti-friction hulls; air cavity friction reduction, etc.

Day 2 Agenda (1/2)

Time	Activity
9:00-9:30	**Coffee/tea and a light breakfast**
9:30-10:00	**Recap of Day 1 and brainstorming session on any technologies we haven't discussed** (Dan Rutherford, ICCT)
10:00-11:00	**Panel Discussion**: What are key barriers to deploying low/zero emissions fuels and technologies in international shipping? (B. Wood-Thomas, WSC; F. Abbasov T&E; J. Bradshaw, ICS; K. Iwaki, MLIT; J. Motlow, GGZEM; Madadh MacLaine, ZESTAs; Bryan Comer, ICCT, moderator)
11:00-12:00	**Breakout group discussion, part 1** Taking into account the key barriers, what advances are needed to deploy each 1) fuel and 2) propulsion technology (e.g., engines/fuel cells) in international shipping by 2030?
12:00-1:00	**Lunch** (provided)

Day 2 Agenda (2/2)

Time	Activity
1:00-2:30	**Breakout group discussion, part 2** What research, development, and demonstration activities could support these advances for 1) fuels and 2) propulsion technologies (e.g., engines/fuel cells)?
2:30-2:50	**Coffee/tea break** (facilitators collate breakout group responses)
2:50-3:45	**Review of collated breakout group discussions and additional comments from the full group** (Bryan Comer and Dan Rutherford, ICCT, Facilitators)
3:45-4:00	**Closing Remarks** (Dan Rutherford, ICCT)
4:00	**Adjourn**
5:00	**Happy Hour** Top of the Mark (19^{th} floor)

Fuel breakout conclusions (1)

- Advances needed in
  1. On-board reformation
  2. Advanced hydrogen carriers such as Liquid Organic Hydrogen Carriers (LOHC)
  3. Materials for H_2 storage, focus on reducing embrittlement and permeability and improving insulation
  4. On-board carbon capture for synthetic fuels that do emit CO_2
- Priority demonstration projects
  - Ensuring that fuels are suitable for all engine types/sizes, including transoceanic
  - Systems integration and architecture (fuel supply, modular design, distributed propulsion)
  - Large scale fuel storage onboard vessels
  - Fuel system designs for novel fuels
  - New bunkering procedures for novel fuels
  - Partial demonstrations to reduce investment risk

Fuel breakout conclusions (2)

- Policy issues
  - New codes and standards, including the IGF code
  - Guidance for LCA and certification of fuels to avoid problems like double-counting
  - Reducing infrastructure barriers through zoning or re-zoning
  - Integrating international alternative fuel goals with national programs
- Cross cutting issues
  - Enabling technologies to reduce overall ZEVs power demand
  - Scaling up supply and availability of cheap renewable energy
  - Reducing zero carbon fuels costs globally to ensure consistent supply
  - Analyzing pros/cons of distributed renewable fuel production/bunkering
  - Avoiding stranded assets and carbon lock-in while derisking ZEV investments

Propulsion breakout conclusions (1)

- Advances needed in
  - Scaleability to meet very large energy demands of ships
  - Range – improved energy density, better storage, and reducing overall energy demand of a ship
  - Retrofitting – means to reduce drydock time and associated costs
  - Transparency and information sharing to accelerate learning and reduce costs
- Activities to support
  - Biggest emitters and largest ship types that require ZEV technologies
  - Pilot projects to scale up to 10 MW+ applications while improving performance and reliability
  - Optimization – design studies pairing particular technologies with ship type/application to identify innovation gaps

Propulsion breakout conclusions (2)

- Activities to support
  - Operational and safety assessments to anticipate challenges → feed findings back into IMO
  - Enabling ZEV retrofits for legacy fleet after 2030
  - Emissions aftertreatment/carbon capture
- Policy issues
  - Accelerated ship retirement plus responsible ship recycling to pull ZEVs into the market faster
  - Port or regional-scale zero emission zones could provide local air quality benefits plus learning by doing

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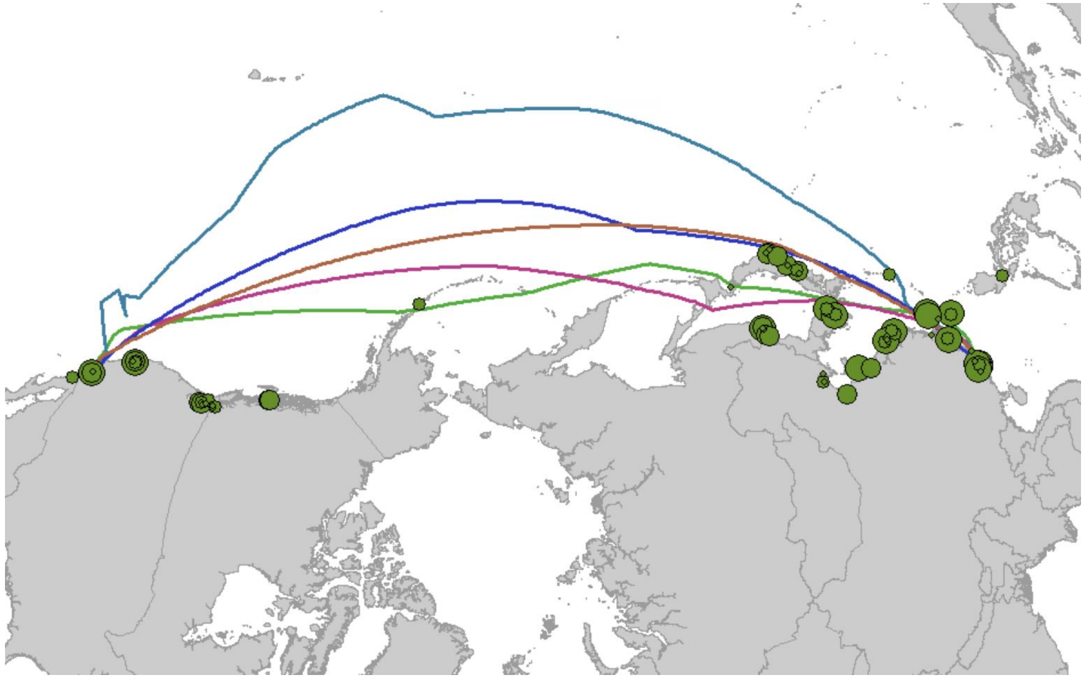
Upcoming research

Upcoming ICCT research

- Assessment of potential bridge fuels
  - LNG
  - Drop-in biofuels
- Transpacific (US and China) ZEV corridor analysis
  - Identify existing cargo routes, energy use, and associated emissions
  - Survey the range of suitable zero-emissions technologies
  - Describe the space, cost, and safety tradeoffs compared to fossil-fueled operations.
  - Identify priority ports to develop bunkering infrastructure.



Thank you!

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