



# Innovative Science and Technologies Toward Greater Sustainability

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U.S Committee on the Marine Transportation System  
7<sup>th</sup> Biennial Conference on the Marine Transportation System  
Summary of Recommendations

December 2023

*The views expressed in this document are those of the author(s) and are intended to help inform and stimulate discussion. The document is not a report of the National Academies of Sciences, Engineering, and Medicine and has not been subjected to its review procedures.*

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## Forward

This summary and recommendations do not represent the opinions of the CMTS Maritime Innovative Science and Technology Integrated Action Team (MIST IAT) or the member agencies of the CMTS, but rather of those of conference presenters. The MIST IAT has used and considered recommendations from previous innovative and science conferences to guide workplan initiatives.



## Conference Overview

The U.S. Committee on the Marine Transportation System (CMTS) in partnership with the Transportation Research Board (TRB) held the Seventh Biennial Conference on the Marine Transportation System, “Innovative Science and Technologies Towards Greater Sustainability,” in person on June 20-22, 2023. Over this three-day forum, over 50 experts from government, academia, and industry participated in 3 plenary sessions and 10 technical breakout sessions sharing their expertise and perspectives on environmental sustainability, vessel, and port decarbonization, alternative fuels usage and supply chains, green technologies, and regulatory and governance reform. Over 120 representatives from across the maritime sector participated in the event.

The conference concluded with an interactive closing summary session held on June 22, consisting of breakout session overviews, key takeaways, and discussion on leveraging information to inform CMTS strategy and improve overarching policy for the green transition of the marine transportation system (MTS). During the summary session, conference organizers presented five general framing questions to guide discussion and formulate a summary on challenges and opportunities for maritime sustainability and overall decarbonization. Recommendations within this report were gleaned from these framing questions, conference breakout sessions, plenaries, and keynote speeches, and give an overview of the highlights, synopses, and the major points discussed throughout the event. Also identified are specific gaps, opportunities, and needs that MTS stakeholders should consider informing future research and policy prioritization.

Full decarbonization both domestically and internationally comes with massive challenges. Shipping companies need to begin the process of transitioning ships to lower emission alternatives, however supply chains to provide that alternative energy are not fully formed. Ports need to implement more electric equipment, but this strain on the grid system in the surrounding areas needs to be managed strategically. Community engagement around ports has been lacking in the past, but with more significant communication between community leaders and ports, progress can lead to beneficial change. Cargo owners must be willing to pay premiums for environmentally sustainable shipping methods and work towards communicating these efforts to the consumer. Overall, to tackle these challenges the following general recommendations were provided:

- Full decarbonization of the maritime sector will be one of the biggest challenges the shipping industry has faced, and it needs to be tackled from all sides, including shipowners, cargo owners, government, and ports, with public support.

- More collaboration between all agencies, industry, and communities is needed, especially in the interagency space to decrease duplicated efforts, and effectively coordinate inter-agency projects.
- More research is needed on life cycle and safety assessment of fuels such as methanol, methane, biofuels, hydrogen, and ammonia, so that we fully understand the potential benefits and drawbacks of each.
- There may not be one fuel solution for marine transportation in the future, but various fuel and energy options based on the specific needs of that transportation mode.
- Community engagement is critical to sustainable and balanced port decarbonization and improvements. This outreach should be creative, substantial, and early within any port infrastructure project so that insightful community input can be integrated.
- The federal government's role should be in de-risking green fuels by funding pilot projects to develop off the shelf solutions and to develop policy frameworks that incentivize the industry's transition to green alternatives. This would include further work within the IMO Maritime Safety Committee developing a safety regulatory framework to support GHG emissions reduction using new technologies and alternative fuels in the maritime sector.
- Green Shipping Corridors provide a means to showcase decarbonized shipping solutions while testing how they will perform in the actual marine environment.
- Leverage the Ocean Climate Action Plan (OCAP) as a guide to direct funding and budget efforts from the IRA and BIL towards significant ocean-based climate mitigation and adaptation actions that progress the U.S. decarbonization goals.
- While the chicken and egg problem of alternative fuel-powered ships and fuel supply is challenging, port infrastructure is an essential starting point for electrified port equipment and alternative fuel bunkering technology.
- While the regulatory environment surrounding the docking of nuclear-powered ships at ports is challenging, these technologies should be considered and evaluated as an option.

## Conference Keynotes

### Keynote Address 1: Miriam Goldstein

Miriam Goldstein, the White House Council on Environmental Quality Director of Ocean Policy, provided insight on the Biden-Harris Administration's commitment to furthering ocean-based climate priorities. The United States joined the Paris Agreement, creating a National Climate Task Force and committing to reduce greenhouse gas emissions 50-52% below 2005 levels. The White House is committed to reaching a net zero emission economy by 2050, providing 40% of the benefits to disadvantaged communities through the Justice40 Initiative. Further commitments have been made to deploy 30 gigawatts (gW) of offshore energy and to conserve 30% of lands and waters by 2030. Executive Order 14008 established the White House Environmental Justice Council, and further efforts to expand interagency coordination were achieved with Executive Order 14096, which established the Office of Environmental Justice.

Additionally, the White House recognizes the importance of the Marine Transportation System (MTS) in reaching its climate goals. Through the Bipartisan Infrastructure Law (BIL), 17 billion dollars in funding is allocated to improve the safety and efficiency around ports and waterways and the Inflation Reduction Act (IRA) provides an additional 3 billion dollars to support reduction in air pollutants surrounding ports. To accelerate and coordinate further federal activities, the Ocean Policy Committee developed the Ocean Climate Action Plan (OCAP). OCAP is a whole of government approach to guide significant ocean-based climate mitigation and adaptation actions. It integrates environmental justice strategies, engages with stakeholders and tribal nations, and accelerates climate solutions. OCAP recognizes that the ocean is deeply affected by climate change and must be a part of the solution. The document itself tackles three major themes, the first being to create a carbon neutral future through offshore energy, green shipping, and carbon sequestration and removal. The second is to accelerate nature-based solutions. Finally, OCAP seeks to enhance community resilience and create well-paying jobs for disadvantaged communities.

OCAP will require support from other agencies and external partners and will serve as a guide for the implementation of funding and budget efforts, such as the IRA and BIL. Next steps for the administration include the development of a National Strategy for a Sustainable Ocean Economy and an Ocean Justice Strategy. These pieces will help ensure that coordinated federal ocean space activities are performed in an equitable way while recognizing that the harmful effects of climate change are not shared equally. The Biden Administration is committed to tackle climate change through continued federal efforts, using OCAP as a guide to future climate change actions.

### Keynote Address 2: Bo Cerup-Simonson

Bo Cerup-Simonson, CEO of Mærsk McKinney Møller Center for Zero Carbon Shipping, discussed the progress, challenges, and best practices regarding accelerating marine decarbonization. Shipping is a central part of all global supply chains, and it directly affects almost everything that we use or buy. If shipping goes wrong, it will disrupt these global supply chains, but due to the increasing

urgency of the climate crisis we do not have long before we need to start implementing zero carbon shipping. The AP Møller center started this process by giving a donation to support the whole private-public ecosystem and to establish visions and objectives for the future. One such vision is to decarbonize the maritime industry by 2050. Møller recognizes that no country or company can get this transition started alone, and that policy and regulation must be utilized together to create a scalable solution.

Individual companies are starting to explore fuels with low climate impacts, such as methane, ammonia, and methanol because of a growing market-driven push towards greening the supply chain. Electric vehicles are an obvious example, but production of both the vehicle and the electricity need to be addressed. The EU is trying to take leadership by establishing lifecycle requirements for electric vehicles. The current issue is that these solutions are not scaling fast enough.

The marine transportation system is one of the most efficient shipping regimes on the planet, but we must do more to reduce emissions as the shipping industry continues to grow. Pursuing more efficient practices alone would result in a 15% reduction in emissions. Therefore, we have a major opportunity to create a scalable and sustainable ecosystem that is net zero emissions. To reach this we need to be working across five critical levers that in tandem can drive the reduction of maritime emissions. National and international regulation is critical to driving both emissions and safety standards. Elevating energy efficiency can get us closer to our goals in the meantime while low emission fuels are still not at scale. Energy and fuel advancements, specifically in methanol, methane, ammonia, and bio-oils, that increase sustainability, scalability, and availability need to be enabled. Customer demand can be used to increase the pace of maritime decarbonization if more end-product buyers are willing to change their spending habits to support green shipping. Finally, finance sector mobilization is necessary as it is difficult to make these large-scale infrastructure projects bankable.

Møller has developed four work programs with strategic focus that will assist efforts moving forwards. The first is to enable sustainable and scalable alternative fuel pathways through technology and safety developments. The second is to elevate energy efficiency. The third is to transition to green shipping corridors by researching sustainable and scalable fuel solutions. The fourth is to establish business and regulatory frameworks, such the EU carbon pricing plan or book and claim strategies that decouple physical decarbonization with the selling of carbon. To decarbonize maritime, we must have both short- and long-term goals for technologies, fuels, regulations, and businesses. Future technologies have varying levels of maturity with regards to readiness in this decade and achieving change across the entire MTS will require engagement and collaboration across private and public sectors.

### Keynote Address 3: Ingrid Irigoyen

Ingrid Irigoyen, Director of the Aspen Institute Shipping Decarbonization Initiative, explored the role of demand in driving the transition to zero-emission shipping. Cargo owners are starting to recognize that they have an important part to play in decarbonizing the MTS due to pressure from



both outside and inside of their companies. They can no longer rely on sector offset, but they are also recognizing that investment in carbon-zero shipping will not be free. The vision is to develop a reliable and affordable solution that will also meet the Paris climate goals. The COVID 19 pandemic caused a series of supply chain issues, bringing the importance of the MTS to the attention of many companies.

Fuel efficiency is no longer a viable long-term solution because it will not get us to carbon zero. Instead, we have to invest in other fuels that will also be more expensive. Businesses recognize this and that they can no longer be passive beneficiaries of carrier efforts. Ship owner and operator costs will increase with changes in infrastructure and fuel. This cost is risky for vessel owners, making it difficult to incentivize the switch. The best incentivization for vessel owners comes from their customers, which is why companies that utilize vessels must make known their demand for a switch to green shipping.

Even the largest companies cannot make this switch alone, which is why we will need to develop policy frameworks. Companies are already engaging in preexisting frameworks through the EU, the IMO, and other policy forums. Further action is occurring with the development of green shipping corridors, but more support is needed from cargo owners. Miami Beach has served as an example for catalytic work in zero emissions shipping, fuel research, and scaling technologies to support a greener MTS. The U.S. government can get involved and has made steps in the right direction with the OCAP. The IRA and BIL are funding opportunities that can be leveraged and more effectively harnessed in the maritime space. Permitting has also slowed down efforts to decarbonize. In the end, a mixture of market forces, research, and policy within the shipping industry can put us on the path to achieving the reliable and affordable clean energy of the future.

## Conference Plenaries

### Plenary Session 1: Federal Perspectives on Decarbonization and Sustainability in the Marine Transportation System

In this plenary, representatives from USACE, BSEE, NOAA, EPA, MARAD, USCG, and DOE shared their current goals and efforts in decarbonizing the MTS. USACE is focused on updating waterways and ports to increase resiliency, strengthen the supply chain, and reduce pollution in disadvantaged areas. BSEE is working to ensure safety and environmental enforcement in offshore energy by engaging with stakeholders to promote knowledge sharing and cooperation. NOAA is focusing on decarbonizing their fleet of vessels to further green shipping and is working through budgetary and market power issues. The EPA's goal is to increase awareness of IRA funding for ports and highlights the importance of communicating successes and failures as we work to decarbonize our waters. MARAD is working on streamlining communications, programs, and funding to ensure that agencies can work together on challenges to hit 2050 carbon-zero goals. USCG is prioritizing looking at the ocean as a climate-change solution by investing in technologies and systems that can increase harmonization and resilience within the MTS system. The DOE is focused on the scalability of alternative fuel options and how these fuels can operate within the existing infrastructure.

Across the board it was acknowledged that information-sharing and communication would be key factors in the effort to decarbonize. There are a number of emerging alternative fuels and technologies, each coming with their own challenges. By sharing the successes and failures of each fuel the federal government can work together to find cost-efficient solutions that maintain the reliability of the MTS. The panelists agreed that collaboration with funds and information can also help de-risk decarbonization efforts. Given the limited resources that each agency has, it is also important to work outside of the government with researchers and industries. Agencies further agreed many factors, including existing infrastructure and resources, will have to be considered when making the switch to alternative fuels. The panel concluded with an agreement that more collaboration is necessary in the future while potential solutions are explored.

### Plenary Session 2: Decarbonization and Sustainability: Maritime Industry Perspectives

Representatives from Blue Sky Maritime Coalition, Port Authority of New York and New Jersey, Cruise Lines International Association, Amazon, and MSC Shipping Group discussed decarbonization efforts from an industry perspective. Blue Sky Maritime Coalition began the conversation by explaining the company's efforts to bring stakeholders together to collaborate and communicate about climate change. The Port Authority of NY and NJ has been using the results of emissions studies to develop programs that incentivize lessees to switch to more sustainable technologies. Cruise Lines International Association is working to increase sustainability in the cruise line sector by partnering with ports, investing in onboard technologies, and switching to low-carbon fuels. Amazon is actively investing in sustainable new technologies and working to achieve net-zero carbon emissions by 2050. MSC Shipping Group is pushing for sustainable, scalable fuels at every

level of the value chain. Together, the company representatives discussed the efforts made and challenges faced by industries in the move to reduce carbon emissions.

Some ships have 30–50-year lifespans, which has made the switch to LNG or other renewable fuels daunting for companies. We have no way of knowing if the best alternative fuel right now is going to be the best option in ten years, so retrofitting or ordering new fleets is a risky investment. Despite this, industry does not have time to wait for other companies to lead the charge. Smaller companies may need assistance with finding funding programs or sourcing affordable alternative fuels, and even larger companies still need to ensure that they have a stable supply chain. The panelists recognized that alternative fuels come with green premiums, and that these premiums are a greater barrier to smaller businesses. At the end of the day, it was agreed that industry has to work together to address these challenges and large companies will need to set the example and signal that there is a demand for green fuels.

### **Plenary Session 3: Sustainability, Environmental Justice, and Social Equality in Maritime**

In this plenary session, panelists from the EPA, Duwamish Valley Port Community Action Team, Friends of the Earth U.S., and NOAA Fisheries SEFSC discussed ways in which they are working to connect communities with sustainability and environmental justice efforts. The EPA is working to provide funding and technical assistance to ports to help improve air quality, community engagement, and public health. The Duwamish Valley Port Community Action Team is working to develop community involvement with the Duwamish Valley Port to improve the health, economy, and future of the port community. Friends of the Earth U.S. is assisting with port funding applications, environmental justice advocacy, and connecting local leaders to port authorities in the Delaware community. NOAA Fisheries are engaging with Miami, Florida's MAST Academy to connect Miami youth to maritime careers through partnerships with NOAA research laboratories. The panelists each recognize the need for community involvement in port actions, particularly those impacting public health.

The impacts of port-related air and water pollutants are primarily distributed among historically disadvantaged communities. The panel agreed that in order to promote environmental justice and social equality, a connection has to be built between ports and local communities. Engagement has to occur on many levels, from inviting community comment to establishing outreach and education programs on port activities. Furthermore, ports need technical assistance so that they can access the funding opportunities available to them. Even with the existing funding, it will not be enough to support every port community. The panel ended by switching focus to the individuals that make up the port community. Providing training and educational opportunities to these individuals can help them turn their jobs into careers.

# Takeaways From Technical Breakout Sessions

## Session 1 A: Alternative Fuel Distribution and Networks

The Department of Energy (DOE) is launching the Hydrogen Hub (H2 Hub) initiative to address the maritime industry's need for hydrogen support on a national scale. Recognizing that the maritime sector holds a competitive advantage in supporting most of these hubs and may not require significant new infrastructure, the initiative outlines four key areas of focus. First, it emphasizes regionally focused asset analyses to understand the specific timelines and adoption pathways for commercial vessels, leveraging digital twins to identify risks. Second, it aims to conduct hydrogen demand analysis up to 2050 to determine where and how scaling should occur. Third, it highlights the importance of addressing policy needs related to ports, pipelines, and vessels, with a focus on safety and risk management and filling regulatory gaps. Lastly, the initiative underscores the critical role of stakeholder development capacity, particularly engaging ports, and their local communities to support hub growth.

The drivers behind the construction and design of offshore hydrogen production facilities are foremost climate change and decarbonization, with hydrogen seen as a solution to fill gaps in electrification when produced sustainably. Political pressures, such as tax credits and subsidies, can further support construction, along with expanding business opportunities in the clean energy marketplace as green hydrogen prices decrease. Advancements in technology, especially the increased availability of renewable energy and electrolyzer improvements, are driving the feasibility of hydrogen production. However, the success of this hypothetical production project relies on factors like suitable facility locations, financial backing, governmental support, storage and export strategies, contractor availability, and early engagement with off-takers and consumers.

The distribution of alternative fuels across future fleets is influenced by the diverse characteristics of the global maritime fleet. While fishing vessels make up the majority in numbers, bulk carriers and oil and chemical tankers dominate fleet tonnage. The most efficient engines currently in use are slow-speed diesel engines with direct drives, while ships that require higher speeds rely on gas turbines. To accommodate alternative fuels effectively, the focus should be on dual-fuel, hybrid, or electric vessel options, considering that 80% of vessel operating time occurs at just 20% engine output. Importantly, the choice of operational speed has a more significant impact on engine size than the ship's physical size. The alternative fuels under consideration include biodiesel, which is advocated by the aviation sector as a drop-in fuel; natural gas, which is widely available but has cryogenic and low flashpoint characteristics; alcohols, with low flashpoints and toxicity issues for certain metals; ammonia, known for its toxicity, corrosiveness, and extreme cold; and hydrogen, which, if compressed, may be useful but presents challenges due to high liquification costs and its cryogenic, low flashpoint nature.

## Session 1B: Electrification of Vessels, Ports, and Associated Infrastructure

Current and projected funding for port infrastructure is experiencing historically robust support, with an overall increase of 71% and a remarkable 423% increase specifically allocated for ports. The Clean Ports Program is recognized as the leading initiative for electrification, with a focus on enhancing energy resilience, implementing shore power solutions, adopting alternative fuels, and facilitating offshore wind projects. Key policy considerations in this context encompass charging standards, permitting processes, net-metering regulations, grant timelines, and the principles of building and buying American to bolster domestic infrastructure and manufacturing.

Over the past decade, the practice of cold ironing has been in place, but it has seen a significant increase in costs during this time. Shore power plugs now demand 2 MW of power, equivalent to the energy consumption of approximately 1600 homes. However, as vessels are expected to grow in size to accommodate increased shipping capacity, their power requirements could exceed 3 MW, solely for the vessels themselves, not accounting for other equipment like cranes. Notably, at the Port of Oakland there have been completed zero-emission projects involving first-generation electric battery trucks, and looking ahead, plans include the deployment of mobile shore power outlets and infrastructure upgrades to further advance sustainable maritime practices.

In Europe, the surge in the drive to electrify seaports is evident, with many projects focusing on Zero Emissions Port Stays (ZEPS). This effort aligns with European legal initiatives like the Green Deal and Fit for 55. However, the electrification challenge isn't one-size-fits-all, as each port has unique considerations, leading to the notion that "when you've seen one port, you've seen one port." In Europe, the central concern revolves around balancing global and local issues, highlighting concepts like "sock on stack" and the integration of electric boilers. The region is witnessing numerous similar efforts to transition towards greener and more sustainable port operations. While in the short-term electrification will have a negative impact, in the long term the impact will certainly be positive as costs decrease and efficient power use strategies are developed.

## Session 1C: Regulatory Environment Influencing Decarbonization Strategies

For marine operators it is imperative to coordinate policy developments, educate policymakers, and share opportunities within the maritime sector. There are several opportunities for decarbonization, such as improving operational efficiencies and exploring innovative designs, technologies, and systems for new vessels. However, various challenges remain, including safety concerns when switching energy sources or chemicals on board, cost considerations, limited space on tugboats, and disparities in port infrastructure and fuel availability across different ports. The key to success in decarbonizing the industry lies in collaborative efforts between marine operators, industry stakeholders, and government partners.

Blue Sky Maritime Coalition developed a National Blueprint for Transportation which emphasizes the importance of transparent communication and collaboration involving all stakeholders across the transportation chain. Challenges, including risk assessment, effective communication, and addressing knowledge gaps, are noted. The strategy advocates for an approach that involves thinking

big, starting with small-scale actions, and rapidly scaling them up for efficiency gains. It also underscores the need to create a space conducive to change, encouraging partnerships, expanding the workforce base, and ensuring open communication with all involved parties to drive progress.

MARPOL Annex VI and the International Maritime Organization's (IMO) strategy for decarbonizing global shipping are in development. The initial IMO GHG strategy aims to urgently reduce greenhouse gas (GHG) emissions from international shipping and targets a 50% reduction in total GHG emissions by 2050 compared to 2008 levels. A potential revision, currently under consideration, may seek even more ambitious goals. These initiatives focus on ships with a tonnage of 400 GT and above that operate internationally and concentrate on reducing both the 'technical carbon intensity' (measured by EEDI/EEXI) and 'operational carbon intensity' (CII) of international shipping. Provisions are outlined for an enhanced Ship Energy Efficiency Management Plan (SEEMP). Additionally, future work within the Maritime Safety Committee includes developing a safety regulatory framework to support GHG emissions reduction through the use of new technologies and alternative fuels in the maritime sector. Right now, the regulatory structure has focused on criteria pollutants, but more is needed to encourage decarbonization.

## Session 2A: Alternative Fuels: Pathways to Decarbonization

Oak Ridge National Labs have been conducting research on the feasibility of biofuels in maritime applications. Biofuels are an attractive renewable option for the maritime sector, given their compatibility with existing fuel and bunkering infrastructure. Biofuels are identified as a crucial pathway toward reducing greenhouse gas (GHG) emissions in maritime operations. Despite an increase in nitrogen oxide (NO<sub>x</sub>) emissions, biodiesel results in improved emissions profiles, with lower levels of particulate matter, carbon dioxide (CO<sub>2</sub>), and sulfur oxides (SO<sub>x</sub>). However, the stability of biodiesel blends is highly sensitive to fuel chemistry. However, there is a need for greater stakeholder input and engagement, as some companies claimed to use biodiesel but had not provided data to contribute to the assessment.

Carbon capture is deemed necessary for achieving carbon neutrality by 2070 within the maritime industry. The challenges and considerations involved include achieving high capture rates, potentially up to 90%, but facing limitations in onboard space for captured carbon. Energy consumption is another concern, as ships have limited energy capacity, potentially necessitating additional generators. Integrating carbon capture into ship design must prioritize safety within the marine environment. There are also challenges regarding onboard storage and a lack of infrastructure for permanent storage or utilization of captured carbon. However, opportunities arise as captured CO<sub>2</sub> can serve as a feedstock for other industries or be solidified with specific minerals for storage, injected into oil reservoirs for pressure enhancement, or permanently stored in depleted oil/gas reservoirs or deep saline aquifers. Achieving 100% carbon capture to yield chemical byproducts from existing plants and technologies remains uncertain.

In ferry operation, efficiency is a crucial intermediate step on the path to decarbonization. Several examples highlight its importance, such as operating vessels at their hull design speeds, reducing general energy consumption through practices like ensuring doors are closed during passenger

loading, and optimizing engine usage by running fewer engines at full capacity. Additional measures include installing fuel gauges for operators to actively monitor fuel efficiency impacts. Long-term solutions involve electrifying the fleet through retrofitting and new builds, as well as considering biofuels as an interim option. However, challenges encompass the availability and pricing of biofuels, the need for extensive collaboration with utilities and shoreside infrastructure for power supply, the absence of off-the-shelf solutions for cutting-edge technology, and the rapid pace of technological advancements outpacing design and construction processes in the maritime sector.

## Session: 2B Sustainable Routing and Navigation

To reach global decarbonization goals, short term innovations in routing and navigation are critical in the maritime realm and can result in reduction of emissions by up to 15%. Natural wind and wave patterns can be harnessed to increase route efficiency and contribute to right-on-time arrivals, but more data is needed to utilize these patterns. Automated observations would allow for accurate reporting, but only 2% of vessels are fitted with these systems. Industry will need to fill in the gaps left by national programs. Existing vessel-based AIS can be used to automatically report weather conditions, which can be used to ensure safety, and vessels can use these systems to share weather information ship-to-ship across 80km distances. The same technology can be used to report shore-to-ship at further distances and integrate satellite collected data and communication technology to use the most up to date information.

Precision marine navigation is necessary to ensure safety at sea, calculate accurate arrival times, and better track GHG emissions. As the amount of goods being shipped and vessel sizes increase, the need for precision navigation is also increasing. By integrating NOAA navigation data from multiple locations and projects, the system can send notifications about hazards, bridge clearances, or weather-related updates. Panelists also addressed the usage of an ocean sensor network as a way to optimize vessel routing. Fuel can be reduced via trip optimization, but as weather changes daily, optimal routes must be updated and shifted as data becomes available. While this data is still difficult to collect, Sofar has 550 buoys that can provide wind and ocean current data that is useful in generating optimized routes. The panelists concluded that awareness, costs, cultural changes, and habits, as well as differences in international standards are all issues that we face in advancing sustainable routing and navigation.

## Session: 2C Green Shipping Corridors

The purpose of green shipping corridors (GSCs) is to enable accelerated progress of decarbonized shipping by showcasing available decarbonized technologies and building demand partnerships. These corridors can range in complexity from a single commodity between two ports to multiple commodities between multiple ports. Tracking the impact of these corridors remains vital to spring boarding the technology used to broader industry uptake. Through the use of simulations, GSC developers can plug and play different technologies, loads, and locations to assist with visualizing the impacts of a corridor. Green shipping corridors must also be connected to other initiatives such as

port electrification and hydrogen hubs, but none of these are fully standardized or developed yet. The entire lifecycle of fuels must also be taken into account in order to identify the lifecycle emission parameters for fuels and integrate a green shipping corridor abatement cost. The current front-runners in alternative fuels in this space are green bio-methanol, green ammonia, and wind-based green LH2.

The UK has a decarbonization strategy that is broken into three parts. The first is to work towards creating zero emission ports and hubs, conduct feasibility studies, and establishing green corridors domestically through domestic policy and regulation. The second part is to maintain UK leadership in the IMO through international policy and regulation, and the third is to invest in domestic research and development. The panelists generally agreed that LCAs should be more widely used, and that green shipping corridors will all be unique. While each corridor will be different, the terminology will need to be standardized.

### Session: 3A Alternative Fuel Diversification

Reaching net zero is no small task. It is estimated that alternative fuels will comprise 70% of emissions reductions, but fuels are not one-size-fits-all. We need to invest in multiple alternative fuel and energy sources by leveraging current technologies. For dual-fuel engines, alcohol-based solutions offer a potential pathway to decreasing NOx and Soot emissions. Additionally, innovative energy sources beyond alternative fuels must be considered. If we mount propellers in certain configurations on wing-sails, we can increase lift forces and decrease the necessary amount of fuel on sailing vessels.

The panelists identified nuclear power as another option that should be considered. While there are economic and regulatory issues to overcome, nuclear is a potential option for the marine industry to meet current IMO decarbonization goals. As we consider alternative fuels and energy sources, such as nuclear power, we cannot lose focus of the safety implications. Ammonia release within a vessel engine room can be modeled to inform optimization of ventilation and configuration of gas detection sensors to decrease toxicity and fire risks. Similar safety measures should be researched and invested in. Collaboration among the stakeholders and support from Federal agencies will be necessary as we move forward.

### Session: 3B Alternative Fuel Distributions and Networks

The panelists identified several important advancements and challenges to developing alternative fuel distributions and networks, including that there is a drive in the MTS to develop new technologies and uses for existing technologies. The current process of innovation is outpacing our ability to regulate, but the challenge is to ensure safety while not restricting innovation. That is why there is no uniform acceptable level of risk, and instead things should be handled on a case-by-case basis. The IMO developed IGF codes, but they only include guidance for LNG fuels. Amendments are being drafted to develop ongoing interim guidelines for other low flashpoint fuels.



Panelists pointed out that bulk carriage presents significant challenges for many emerging fuels. Hydrogen in bulk must be liquefied for transport, but this comes with added risks. It is much colder than LNG, has a larger flammability range, and can have an invisible flame. It will take special materials, welding, and insulation to ensure safe transportation. Methanol is also now considered a toxic material and has additional control requirements, showcasing a need for the EPA to update their ruling on many of these alternative fuels. The bottom line is that a lot of work remains to be done to ensure safety while working toward greater sustainability.

### Session: 3C Decarbonizing Inland Water Systems and Underwater Noise

The panelists started by identifying challenges and opportunities in the inland marine sector regarding decarbonizing maritime shipping. Inland waterways pose unique challenges such as modernizing infrastructure of canals and dam structures. It is also difficult to convince industry to charter retrofitted vessels due to vessel age, and market growth is unlikely to increase investment. Furthermore, equipment onboard these vessels must be balanced so that they can work in rivers and shallow waters. Operational needs of the vessels have to be considered when electrification or alternative fuels are proposed, while estimating emissions for inland waterways is another issue entirely.

Current efforts are being made by USACE to transport sand from the upper Mississippi River to support coastal beach nourishment. The goal is to reuse dredged material, but it can be difficult to transport due to a lack of barges in inland waterways. Material reuse is also limited by federal standards and regulations but working with other agencies to identify different restoration projects may help get around these limits. Right now, the goal is to find new routes to transport dredged sands to beach restoration projects around the country. The cheapest option will likely be railway transportation, but it will vary by project.

The panelists also addressed the latest underwater noise reduction efforts at the IMO and in the Puget Sound. Underwater radiated noise (URN) is low frequency noise radiated from vessels that can cause harm to marine species. IMO is attempting to set guidelines to reduce URN through intersessional correspondence groups and the GloNoise Partnership. Partners are needed from academia, private corporations, and government in order to get the dialogue going. Efforts are ongoing to advance design and to better understand how noise is impacting species. Current studies are exploring how energy efficiency and slower vessel speeds might help with URN.

## Call to Action

On the final day of the conference, all attendees were invited to participate in an open forum final discussion. The moderators from each technical breakout session reviewed the takeaways from each session. Additionally, the conference organizers presented five questions to help guide discussion and develop a summary of the challenges and opportunities for sustainability and decarbonization within the marine transportation system:

- What gaps in research and development do agencies need to be focused on in order to achieve decarbonization goals by 2050? How do we balance potential IMO regulations with where the US and other countries are?
- With a move towards sustainability in the MTS, what changes to port infrastructure do we need and expect to see in the next 5-10 years? What are the biggest challenges in making the needed changes to port infrastructure?
- What opportunities do we have to educate and engage mariners, port communities, and other groups in the changes resulting from decarbonization, and how do we ensure neighboring communities benefit and are not negatively impacted?
- What steps can we take in the next few years to encourage and strengthen communication and collaboration in the maritime sector? What has worked thus far?
- We heard our keynote speaker Bo Cerup-Simonsen state that we “need to create an energy system that is both sustainable and scalable” - and a lot of the opportunities discussed are not both sustainable and scalable. How can government and the private sector co-produce this?

## R&D Gaps and Potential IMO regulations

Many panelists and attendees agreed that full spectrum decarbonization will be the biggest challenge that the maritime industry has faced, but that with proper technological development and regulation it is possible. This challenge needs to be tackled from all sides and include ship operators, cargo owners, government, and local communities. There was widespread agreement that this transition will take time, but in the short term we can focus on solutions that already have. Maximizing efficiency can lead to 15-20% reduction in emissions. This can be accomplished through scheduling and routing improvements, and implementation of better earth system prediction. In the longer term, focusing on fuel development and distribution will be critical. The government should be de-risking these fuels and aiding in the funding pilot projects for off the shelf solutions for industry to use. However, the practical application of these fuels in a marine environment isn't well known so further research in this area is needed. Additionally, we should be looking for co-benefits of these technologies, such as reduction in underwater noise. Oversight, assessment, and regulation from the federal government and the IMO may need to be evaluated so that the green energy transition can be promoted rather than hindered. This also includes providing strategies such as book and claim

for cargo owners to begin using the green technologies that are currently available and leveraging the power of consumer demand to push forward.

***Key Takeaways:***

- Ships, grids, infrastructure, interagency, state, and local regulators, and local communities must be involved in this transition
- Efficiency is a key short-term goal for emission reduction
- Federal government should be de-risking alternative fuels
- Cross cutting issues and must be managed from an interagency perspective to safely manage change
- The entire range of potential for each fuel is necessary to understand when and where to use different fuels
- Life cycle analyses of these fuels can aid in these efforts
- Many of these fuels are cryogenic, toxic, corrosive, or all three and therefore safety and training will be critical

## Port Infrastructure Changes

The two main challenges facing port infrastructure development for a green transition are electrification and alternative fuel supply. As we electrify port equipment and promote cold ironing of vessels while docked, there will be critical bottleneck in how we manage the grid system. This increase in electricity consumption will be a major draw on the grid and utilities and commissions will need to be included in all infrastructure plans to ensure they are prepared to handle the increased load. This increase in electrification will also need to come with changes in data infrastructure. Ports must be able to communicate optimal schedule and arrival plans and weather forecasting to ensure a consistent and reliable supply chain. Interoperability between these data systems will be crucial. This changing digital landscape needs an equal increase in cyber security awareness and protocol to keep critical supply chains secure.

When preparing ports to be hubs for multiple different fuels, adequate planning for the connection of these different systems must be done for both personnel and environmental safety. Training for port workers and mariners, safe bunkering technology, and smart coordination will be needed. These fuel systems and supply chains must also be resilient to severe weather hazards and other disruptions that are projected to increase. Many participants mentioned difficulties involved with the permitting and approval process for these infrastructure changes, and that streamlining these processes while upholding environmental and worker safety would be helpful for industries and ports wanted to make these changes. One participant also brought up the need for better understanding of regulations surrounding nuclear energy as a possible means for green shipping.

### ***Key Takeaways:***

- The grid needs to be prepared for the large electricity draw ports will have
- Digitalization and cyber security are critical to having a more efficient routing and scheduling scheme
- Permitting and approval processes can bog down alternative fuel infrastructure projects
- Safety and training must be at the forefront of this process
- Changing the current fueling scheme will also change the current business structure

### **Education Opportunities and Community Benefits**

During many different panels and sessions, the need for more and better outreach to port communities was stressed. This engagement must begin early in any large port development process, and it is important to be creative so that ports and governments meet communities where they are. Many members of these communities cannot attend meetings during work hours, so it can be helpful to meet at times when the most engagement can happen. Providing childcare or meals at any meetings can also increase involvement. Many participants mentioned that it is important to not use overly technical jargon and to truly listen to the input these communities provide, not just tell them what they think. There has been a lot of success with community involvement with the Port of Seattle. Using the lessons learned from projects like this can be beneficial to other ports wanting to do community engagement, while acknowledging that every port is different and has its own unique challenges. There are opportunities to use BIL/IRA funding for this kind of capacity building and community outreach strategies.

### ***Key Takeaways:***

- Port communities suffer increased health problems from living in close proximity to the port and the majority of the time these are communities of color
- Meet communities where they are
- Be creative in planning community outreach
- Aim to build transformative not transactional relationships
- Promote growth in place and avoid unintended consequences such as gentrification

### **Communication and Collaboration**

A running theme of the conference was that more communication and collaboration between and within all MTS stakeholders will be vital to navigating the green energy transition. From the federal side, a better understanding of projects and funding from each agency would be helpful. This kind

of coordination can help industry by reducing any duplicated work and making sure that all areas support needed are being tackled. One participant noted that it is important to publish all results and data from any studies so that everyone can benefit from lessons learned. Trust needs to be built between government, industry, NGOs, and communities and more spaces where that trust can be built would be very beneficial. On the industry and private side, innovative approaches such as the Blue-Sky Maritime Coalition can be very powerful in building collective demand for green shipping solutions, and the federal government should look for ways to support those types of structures.

***Key Takeaways:***

- More and efficient communication and collaboration in this sector is necessary
- Funding programs to ports can include criteria for community engagement and communication
- Forums for collaboration, such as the CMTS, can be helpful in communicating agency progress and identifying areas for collaboration
- Publishing results can help with lessons learned
- Cargo owner collectives show promise in consolidating demand and pushing the industry towards reducing emissions

## **Achieving Sustainable and Scalable Energy System**

The maritime industry is facing a chicken and egg problem with regards to green shipping. Shipping companies do not want to build ships that run on renewable energy when the infrastructure is not in place to support them and creating an entire renewable energy supply chain is difficult when there are no ships to receive that energy. This is a major barrier in scaling up green energy in this sector as the lead time for ship building and large infrastructure projects can be many years and there is hesitation from both government and industry in betting on the wrong fuels or the wrong solutions. While many noted that the federal government's role should be in de-risking these fuels, this is not incompatible with taking risks. It is better for us to learn the downsides of certain fuels quickly so that we can incorporate those lessons throughout the energy transition. It was also discussed that there may not be one winning fuel of the future. Factors such as trip time, load size, and opportunity for refueling can all influence which fuel is right for a certain ship. It is very possible that instead of one green fuel there will be a suite of different fuels for different scenarios. Having a better understanding of the flaws and benefits of these alternatives will guide when and where to direct resources. Green shipping corridors can begin the process of showcasing how these fuels will work in the actual environment and more work needs to be done to develop and implement them. Again, leveraging the demand signals from cargo owners and the public was brought up as a major force that if harnessed correctly can aid the green transition.

***Key Takeaways:***

- It's important to look at the green transition as a whole, not just from electrification or alternative fuels but the entire propulsion system
- If a fuel is going to be deemed unusable in the maritime space, we need to learn that quickly to disseminate lessons learned. Fail and Fail Fast
- Look for incentives to use and build demand signals
- The future may be multiple fuels used for different transportation needs
- Green shipping corridors are good avenues for learning and building up fuel supply chains

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