Expert Survey Assessment of Emerging Maritime Decarbonization Challenges and Priorities

Rubal Dua, AHM Mehbub Anwar

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About KAPSARC

KAPSARC is an advisory think tank within global energy economics and sustainability providing advisory services to entities and authorities in the Saudi energy sector to advance Saudi Arabia’s energy sector and inform global policies through evidence-based advice and applied research.

*This publication is also available in Arabic.*

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The decarbonization of the maritime sector has emerged as a global concern due to the shipping sector’s 3% contribution to world’s total greenhouse gas (GHG) emissions. Notably, the latest developments involving the adoption of more ambitious GHG reduction targets by the International Maritime Organization (IMO) highlight the increasing urgency to address maritime decarbonization. The revised IMO strategy includes indicative checkpoints and intermediary targets, aiming at emission reductions of at least 20% by 2030 and at least 70% by 2040 and reaching net-zero emissions “by or around 2050 (Carbon Pulse 2023). As nations strive to meet such commitments, it becomes crucial to comprehend the latest challenges associated with decarbonizing the maritime sector. Using an expert survey, we seek to identify the key priorities for achieving effective and equitable decarbonization by engaging a diverse group of maritime fuel, policy, technology, and infrastructure experts to gain valuable insights into the industry’s most pressing challenges. Research on such priorities is anticipated to generate actionable recommendations for policymakers and industry stakeholders, facilitating informed decision making and fostering the development of targeted strategies to accelerate the global transition toward a carbon-neutral maritime sector.

This insight is structured as follows. We outline each of the overarching themes derived from summarizing and categorizing the wide-ranging scope of recent media investigations pertaining to maritime decarbonization. This approach includes a concise analysis of the relevant media articles, after which we proceed to delineating specific research challenges and priorities that require more thorough consideration. Furthermore, we integrate succinct statements from the media to offer the contextual backdrop that stimulated the formulation of these research challenges and priorities. Finally, we present the results obtained from the evaluation of the expert survey, followed by concise concluding remarks.
Such investigations highlight the importance of attaining consensus in terms of carbon pricing within the IMO, as well as the potential consequences of carbon pricing in promoting the transition to cleaner fuels and financing climate action. Additionally, there is a notable emphasis on the financial implications and challenges linked to the process of decarbonizing in the shipping industry, encompassing the necessity of a substantial carbon price and concerns regarding potential cost impacts.

**Potential Research Challenges and Priorities**

**Challenges and strategies for global cooperation on carbon pricing for shipping:** Context – Carbon pricing is not a new concept for the IMO, but previous attempts to progress it have failed. It is therefore an enormous step forward that there is now (some) consensus on this (Carbon Pulse 2022ak).

**Examining how carbon pricing revenue for shipping can be directed to support climate finance in developing economies:** Context – Carbon pricing could be one of the most impactful ways to achieve this, as it would incentivize the switch to clean fuels while also providing a fresh revenue stream to finance, for instance, enhanced climate action in developing countries (Carbon Pulse 2022at).

Carbon pricing revenue from maritime shipping should be used to facilitate an equitable transition to net-zero emissions (ITF 2022).

**Estimating carbon prices for shipping needed to meet the IMO’s 2050 emission reduction target and net-zero emissions goal for shipping by 2050:** Context – An average carbon price of almost $200 per tonne would be required to decarbonize the global shipping sector by 2050 (Carbon Pulse 2022aw).

**Assessing the socioeconomic and distributional impacts of carbon pricing for shipping in different countries:** Context – The China-led approach is also clear that the consortium of countries will not support an accelerated level of ambition, noting concerns over cost impacts. It also notes that any proposed measures associated with alternative low-/zero-carbon fuels ignore supply constraints and the significant costs of the associated infrastructure (Carbon Pulse 2022aq).


Decarbonizing Global Shipping: Challenges, Perspectives, and Collaborations Within and Beyond IMO

These inquiries scrutinize the efficacy and perception of IMO regulations designed to mitigate carbon emissions from maritime vessels, alongside the imperative for an equitable transition toward decarbonization that takes into account the requirements of developing and susceptible nations. Such an approach also delves into the ongoing discourse surrounding the adoption of green shipping corridors and the potential market disruptions that may arise as a result. The examination of this particular subject matter may yield valuable understandings regarding the endeavors, intricacies, and diverse viewpoints associated with the process of reducing carbon emissions in the worldwide maritime sector.

Potential Research Challenges and Priorities

Assessing existing the efficacy and enforcement challenges of IMO GHG regulations: Context – The IMO has introduced regulations that reduce carbon emissions from ships, taking effect as of 2023, but these regulations have proven to be unpopular thus far... (Carbon Pulse 2023i).

Exploring consensus building among governments with different priorities and abilities for a just transition to net-zero shipping emissions: Context – The session’s (MEPC78’s) chair attempted to surpass the common but differentiated responsibilities (CBDR) issue through language calling for a just transition to decarbonization, including through the recognition of the needs of developing and vulnerable countries so that they can take meaningful action (Carbon Pulse 2022ae).

Examining the potential of country-regional-level efforts versus global IMO agreements in achieving shipping decarbonization goals: Context – China, Europe (including the UK), and the US account for 38.4% of direct shipping emissions. However, some 84% of shipping traffic calls at ports in these three territories... (Carbon Pulse 2022j).

Could smaller green shipping collaborations, like green shipping corridors, support global IMO agreements?: Context – …Six “green shipping corridors,” corridors that connect two shipping ports using zero-emission technologies... However, at last month’s IMO talks, some parties said that the “unilateral” approach of green corridors “undermined shipping’s international nature and would likely cause market distortion,” while others said that they support only voluntary initiatives... (Carbon Pulse 2023n).
Alternative Fuels and Strategies for Decarbonizing the Maritime Industry

This theme includes reporting on the shipping sector’s willingness to adopt different fuels (methanol, hydrogen, ammonia, advanced hydrogen, and electricity) based on price considerations, the development of onboard carbon capture technology to reduce emissions, and the assessment of green shipping corridors. Additionally, there is an emphasis on the financial aspects of decarbonization, including the imperative for substantial capital allocation to the development of vessels utilizing clean fuels, as well as the expansion of infrastructure to facilitate the increased production and distribution of carbon-neutral fuels.

Potential Research Challenges and Priorities

Techno-economic analysis of alternative shipping fuels: Production costs, infrastructure needs, and economies of scale: Context – …The shipping sector is not yet willing to commit entirely to one fuel. Rather, it is exploring numerous different fuels with price underpinning most of its decisions (Carbon Pulse 2023f).

Economic feasibility of onboard carbon capture in the maritime sector: Context – Maritime energy players jointly develop “onboard” carbon capture technology to reduce shipping emissions (Carbon Pulse 2022 m).

Analyze stakeholders’ roles, responsibilities, incentives, and concerns in developing green shipping corridors to promote low-carbon shipping fuels: Context – A consortium including BHP, Rio Tinto and two shipping firms has agreed to assess the development of an iron-ore green shipping corridor between Australia and East Asia… (Carbon Pulse 2022as).

Estimating the annual investment needed to decarbonize the maritime sector by 2050: Context – The maritime industry will need additional annual investments of $8-28 billion in ships using clean fuels if it is to reach full decarbonization by 2050… Furthermore, between $28 and 90 billion per year will also be needed for investment in onshore infrastructure to scale up production, fuel distribution, and bunkering infrastructure to supply 100% carbon-neutral fuels for shipping by mid-century (Carbon Pulse 2022p).
Liquefied Natural Gas (LNG) as a Transitional Fuel in Shipping

The primary theme focuses on examining the prevalence of LNG-powered vessels among the ships currently being commissioned. This theme also explores the potential vulnerability of these vessels, as they may become stranded assets, considering the growing cost competitiveness of zero-emission fuels like green hydrogen and ammonia. Additionally, the discussion encompasses the shipping industry’s emphasis on various initiatives and collaborations dedicated to addressing methane emissions and developing measurement and mitigation strategies.

Potential Research Challenges and Priorities

Cost–benefit analysis of LNG as a transitional fuel, weighing short-term economic benefits against the long-term costs of stranded assets and low-carbon alternatives: Context – …A recent report from classification society Det Norske Veritas (DNV) stated that LNG dominates the total tonnage of ships on order to be built that will use alternative fuels (Carbon Pulse 2022).

…raises the risk of LNG-fueled ships becoming stranded assets as zero-emission fuels such as green hydrogen and ammonia become more cost competitive… (Carbon Pulse 2022).

Techno-economic analysis of methane slip reduction from LNG-fueled ships: Context – A coalition of shipping industry players, including oil major player Shell and container firm Mediterranean Shipping Company (MSC), has launched an initiative to seek out solutions for the maritime industry to measure and mitigate methane emissions… (Carbon Pulse 2022r).
Shipping Companies’ Strategies for Achieving Net-Zero GHG Emissions

The discussion in relation to this particular theme revolves around the implementation of efficiency improvements and cleaner fuels as measures through which to reduce emissions, along with the deployment of carbon dioxide removal (CDR) initiatives to offset any remaining emissions. Notably, companies like Maersk have embraced accelerated net-zero emission targets, showcasing their dedication to pursuing ambitious sustainability objectives. Additionally, the formation of alliances between shipping companies and technology corporations highlights a collaborative endeavor taken to harness technological advancements, aiming to enhance operational efficiency and minimize environmental impact.

Potential Research Challenges and Priorities

Effectiveness of shipping companies’ net-zero GHG strategies including reduction, removal and offsetting and their potential implications for shipping costs: Context – To reach net-zero GHG emissions by 2050, Mitsui OSK Lines (MOL) envisages that approximately 70% of the emissions reductions will be achieved through the adoption of cleaner fuels..., while approximately 20% will be achieved with efficiency improvements… This leaves up to 10% of residual emissions that will be neutralized with the use of CDR projects, according to MOL (Carbon Pulse 2023d).

Danish shipping giant Maersk has accelerated its net-zero emission target by a decade, to 2040… (Carbon Pulse 2022ay). Maersk has placed an order for six mid-sized container vessels, all having dual-fuel engines able to operate on green1 methanol (Maersk 2023).

Techno-economic analysis of maritime sector strategies to optimize energy use, reduce emissions, and improve operational efficiency: Context – Commodities trading firm Vitol has entered into a strategic partnership with Danish tech company ZeroNorth, through which the partners will share access to maritime optimization and emission reduction services (Carbon Pulse 2023a).

Assessing carbon pricing mechanisms in shipper-shipping firm contracts: Motivations, risks, benefits, and broader economic-environmental impacts: Context – According to the agreed-upon mechanism, implemented in this year, Klaveness Combination Carriers Chartering (KCCC) will receive a higher amount of freight if actual emissions are below the baseline and a lower amount of freight in the event of underperformance relative to the baseline (Carbon Pulse 2023c).
The main focus of this theme involves evaluating the effectiveness and reliability of carbon-neutral shipping that incorporates carbon offsetting. Furthermore, this theme includes addressing concerns related to greenwashing, emissions data, and reporting protocols. Moreover, the discussion focuses on the implications of low-level evaluations of carbon offset initiatives related to ship energy efficiency by rating agencies, with an emphasis on their impact on regulations.

Potential Research Challenges and Priorities

Could recent partnerships among shipping companies, technology providers, and carbon market participants create a sustainable maritime carbon offsetting ecosystem?: Context – Dubai tanker firm Oilmar signs up for a new offsetting platform designed for marine players (Carbon Pulse 2022u)… Clarksons introduces a voluntary emission reduction (VER) platform for corporate shipping clients (Carbon Pulse 2022af)… A shipping firm signs up for a carbon credit scheme for vessel retrofits (Carbon Pulse 2022ao)… The firm UAE collaborates to set up an online carbon exchange in Africa using blockchain (Carbon Pulse 2022ar).

Effectiveness and reliability of carbon-neutral shipment strategies involving carbon offsetting: Addressing greenwashing, emissions data and reporting practices: Context – “I think that there is an element of companies stopping announcing [carbon-neutral deals], and I think part of the reason for that is a feeling that no matter what they do, somebody will pick up on that [and say] it was not the best offset or that they underestimated [the amount of emissions calculated].” Wood Mackenzie, head of gas and power consulting for Gavin Law (Carbon Pulse 2022aj).

Examining the implications of rating agencies’ low ratings of ship energy efficiency carbon offset projects for policy and carbon pricing: Context – “Our review indicates higher additionality risk than that previously assessed due to evidence that the project’s activities are common practice, the project’s financial attractiveness in the absence of carbon finance, and the introduction of efficiency guidelines to promote increased efficiency in the shipping industry,” BeZero said of GS2767 (Gold Standard ID for a project on the application of advanced hull coatings to reduce shipping fuel consumption) (Carbon Pulse 2023b).
The theme includes reports on legislation deliberations among the European Parliament, Council of member states, and Commission to include shipping in EU ETS. The reports delve into the potential consequences of this integration, examining concerns such as inflationary pressures and changes in trade patterns as ships attempt to avoid carbon costs by evading EU ports. The primary objective of this thematic analysis is to understand the economic and emission reduction implications of including shipping within the EU’s ETS.

Potential Research Challenges and Priorities

Investigating stakeholder negotiations regarding the inclusion of shipping in the EU’s ETS, including actors’ interests, power dynamics, positions, and consensus building: Context – Envoy from the European Parliament, Council of member states, and the Commission met to discuss the bill in another round of closed-door trilogue talks, with the maritime sector being the main topic of debate (Carbon Pulse 2022d).

Assessing shipowners’ EU ETS understanding and developing strategies to raise awareness: Context – Despite the upcoming shift, some shipowners are not aware of the policy, according to Nick Lurkin, a senior climate adviser at the Royal Association of Netherlands Shipowners (Carbon Pulse 2023h).

Exploring the potential impact of including shipping in the EU’s ETS on freight costs, trade flows, and overall inflation levels: Context – The EU’s plans to including shipping in its ETS will fuel further inflation and could change trade flows as vessels try to evade carbon costs (Carbon Pulse 2022v).

Investigating the effects of including shipping in the EU’s ETS on carbon credit market supply, demand, and prices: Context – Carbon analyst Emma Coker at BloombergNEF agreed that the entry of the shipping sector into the market would likely have a bullish effect on the ETS overall (Carbon Pulse 2022f).

Cost–benefit analysis of shipping sector’s EU ETS compliance and EU port evasion as a circumvention strategy: Context – …A cost–benefit analysis for five scenarios of potential port evasion, including adding an extra port from outside the EU to the trading route or sailing to a neighboring non-EU seaport instead of directly to an EU seaport (Carbon Pulse 2022au).
This subject matter relates to the FuelEU Maritime initiative, including its provisions, objectives, and efforts to promote the use of clean fuel in the maritime industry. This initiative includes reports on the interim agreement reached by negotiators from the European Parliament and Council, which establishes a fuel standard for maritime vessels in an effort to reduce the emission intensity of energy consumed onboard.

Potential Research Challenges and Priorities

Evaluating the FuelEU Maritime initiative’s provisions and targets for promoting clean fuels in the maritime sector: Context—Negotiators of the European Parliament and Council reached a provisional deal early Thursday morning (March 23, 2023) on the FuelEU Maritime initiative... sets up a fuel standard for ships to cut the emission intensity of energy used onboard vessels by 2% as of 2025, 6% as of 2030, 14.5% as of 2035, 31% as of 2040, 62% as of 2045, and 80% as of 2050 (Carbon Pulse 2023).
The points discussed in these articles are related to the theme of expanding the LCFS to encompass aviation and marine fuels in different geographical areas, such as British Columbia, Canada. The main purpose of this expansion is to include these industries in the overall efforts to reduce carbon emissions and promote the adoption of low-carbon fuels. Furthermore, the articles also highlight the incorporation of direct air capture initiatives as a means of earning credits, showcasing the regions’ commitment to innovative strategies for further carbon emissions reduction. By examining this subject matter, valuable insights are gained into the initiatives undertaken by regional regulatory bodies to address carbon emissions in the aviation and marine sectors, as well as their endeavors to promote the use of low-carbon fuels.

Potential Research Challenges and Priorities

Cost assessment for making marine fuels comply with the carbon-intensity targets of low-carbon fuel standards: Context – The Canadian province of British Columbia will broaden the scope of its LCFS to include aviation and marine fuels, as well as allow direct air capture projects to earn credits, the government announced Monday (May 10, 2022) (Carbon Pulse 2022an).
These inquiries pertain to the role of ports in reducing carbon emissions in shipping as well as the climate impact of the shipping industry. These inquiries evaluate the capacity of ports to facilitate the industry’s transition toward sustainability by providing clean shipping infrastructure, such as hydrogen-based refueling systems and shore-side electrification options. In addition, these inquiries highlight the costs of climate-change-related impacts on the industry, which are projected to increase significantly by 2050. In addition, these inquiries investigate port-related strategies for reducing shipping CO₂ emissions, such as optimizing ship speed for just-in-time port arrival.

**Potential Research Challenges and Priorities**

**Cost–benefit analysis of port initiatives - onshore power supply and alternative fuel infrastructure - for decarbonizing the maritime sector:** Context – …Ports have a crucial role to play in the industry’s green transition, given their role as bunkering facilities for the ships importing and exporting goods… “Ports can have a direct impact in greening our planet by providing clean shipping infrastructure. This means installing hydrogen-based refueling infrastructure and shore-side electrification that would allow ships to turn off their engines and plug in at port,” as stated by Jacob Armstrong, T&E’s analyst for sustainable shipping, in a recent report (Carbon Pulse 2022av).

**Estimating potential climate-change-induced economic losses for ports, shippers, and carriers:** Context – By 2050, the cost of climate impacts to the industry could rise to as much as $10 bln annually, as stated in the report, which is higher than the current estimated annual costs from storm damage of around $3 bln (Carbon Pulse 2022av).

**Exploring the emission reduction potential of vessel-terminal-port collaboration, such as just-in-time port arrivals:** Context – Container ships can cut CO₂ emissions by an average of 14% if they optimize their speed to arrive ‘just in time’ at ports… They can also cut 5.9% if they regulate speed in the last 24 hours of a voyage to arrive when there is no need to wait around for the berth, fairway and other nautical services to become available… Optimizing speed in the last 12 hours of a voyage for just-in-time arrival cuts fuel consumption and CO₂ emissions by 4.23% (Carbon Pulse 2022ac).
This line of inquiry focuses specifically on the theme of GHG accounting and verification in the maritime industry, exploring the precise collection of GHG emissions data, with a focus on methane and carbon dioxide emissions. In addition, the articles highlight the importance of precise measurements and comprehensive reporting in this context.

Potential Research Challenges and Priorities

Investigation into the methods, protocols, and challenges of the accurate measurement and calculation of shipping GHG emissions:

*Context –* ...The first ever “onboard” study of methane and CO₂ emissions generated from an LNG carrier has reported higher levels of methane emitted during the voyage compared with previous assessments, highlighting the importance of accuracy in collecting GHG data... (Carbon Pulse 2022z).
Liquefied CO$_2$ (LCO$_2$) Shipping

The primary theme of this line of inquiry pertains to the establishment of secure and dependable transportation solutions for LCO$_2$, widely regarded as a pivotal measure in the progression of carbon capture, utilization, and storage (CCUS) technologies on a significant scale. This theme includes reports on partnerships between companies from the energy industry and shipping and logistics sector to evaluate the viability of shipping LCO$_2$.

Potential Research Challenges and Priorities

Techno-economic analysis of large-scale LCO$_2$ shipping and LCO$_2$ carriers’ role in the CCUS value chain: Context – Developing safe and reliable CO$_2$ transportation services is a crucial step in developing large-scale CCUS solutions (Carbon Pulse 2022k).

Research on energy and shipping companies’ collaboration to enable CCUS and LCO$_2$ shipping, including knowledge sharing and technology transfer: Context – Chevron has signed a joint study agreement with Japanese shipping company MOL to assess the feasibility of transporting LCO$_2$ from Singapore to permanent storage locations in Australia... (Carbon Pulse 2022k).
Expert Survey

A survey was carried out during an international maritime workshop held in Riyadh, Saudi Arabia, in May 2023. The workshop attracted participants from a range of settings, including think-tanks, academia, industry and policy. Participants were asked to evaluate the different research challenges and opportunities identified in this study using a Likert-type scale, assessing their importance, novelty, and feasibility. Furthermore, data were gathered pertaining to professionals’ affiliations with either nonprofit or for-profit entities, their educational credentials, their years of experience in the maritime sector, and their level of familiarity with the research subjects under examination.

Expert Survey Assessment

Among the 14 participants, 12 represented for-profit organizations, while the remaining respondents were affiliated with for-profit entities. Of the total sample, 8 individuals possessed a doctoral degree, 5 individuals held a master’s degree, and 1 individual possessed a bachelor’s degree or lower. Regarding the duration of expertise possessed by professionals in the maritime sector, over 50% of participants reported having accumulated 15 years of experience. On a scale ranging from 1 (very low familiarity) to 5 (very high familiarity), experts rated their familiarity with the research challenges examined in this survey as 3.86 on average. When asked to select all maritime-related areas from their current and past work, 11 experts chose policy, 5 chose technology, 6 chose fuels, and 6 chose infrastructure.

Considering three different types of weightings, the average expert ratings for the importance, novelty, and feasibility of the research challenges mostly fell within the range of 3 to 4 or above (see Figure 1). In essence, experts’ consensus indicates that the perceived levels of significance, originality, and practicality of the various research challenges identified in the survey range from moderate to highs. The themes “Global IMO Discussions on Carbon Pricing for Shipping,” “Shipping Companies’ Strategies for Achieving Net-Zero GHGs Emissions,” and “LNG as a Transitional Fuel in Shipping,” on average, received the highest ratings in terms of their importance, novelty and feasibility, respectively.

Figure 1d illustrates the range of Analytic Hierarchy Process (AHP)-Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS) scores for the different proposed research challenges, considering the various weighting schemes to account for sensitivity. The themes “Global IMO Discussions on Carbon Pricing for Shipping,” “Alternative Fuels and Strategies for Decarbonizing the Maritime Industry,” and “Carbon Offsetting: For Decarbonizing Shipping and Generating Offsets through Shipping Projects” were among the top-scoring themes, while “LNG as a Transitional Fuel in Shipping” received the lowest score. Table 1 displays the corresponding rankings for the

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1 Additional details pertaining to the identification of research challenges and priorities, as well as the development of the survey, will be elaborated in a forthcoming KAPSARC publication. Briefly, the research themes were formulated by applying an energy economics lens to recent maritime decarbonization developments reported since 2022 in Carbon Pulse, an internationally renowned climate-policy-focused investigative journalism outlet.

2 For more details on AHP-TOPSIS, a hybrid class of multicriteria decision making (MCDM) models, refer to (Zavadskas et al. 2016).

3 Three different schemes were used to calculate the weighted average of the ratings given by the experts including (i) equal weighting, (ii) experience-based weighting, and (iii) familiarity-based weighting.
different themes, along with their sensitivities to the chosen weighting scheme. The themes “Ports’ Role in Shipping Decarbonization and Climate Impacts,” “Shipping Companies’ Strategies for Achieving Net-Zero GHG Emissions,” “Shipping GHG Emission Accounting and Verification,” and “Carbon Offsetting: For Decarbonizing Shipping and Generating Offsets through Shipping Projects” demonstrated the greatest variation in their scores when considering the sensitivity analysis conducted using three distinct weighting schemes. The above four themes demonstrate a maximum rank change of 5, 4, 4 and 3, respectively, whereas the remaining themes display a maximum rank change of up to 2.

Table 1. Ranking of potential research challenges based on expert ratings, considering three distinct cases.

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<th>Maximum change in rank</th>
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<td>Decarbonizing global shipping: challenges, perspectives, and collaborations within and beyond IMO</td>
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Cases: (i) equal weighting, (ii) experience-based weighting, and (iii) familiarity-based weighting. Rankings were obtained by employing the combined AHP-TOPSIS approach.
**Figure 1.** Variation considering three cases: (i) equal weighting, (ii) experience-based weighting, and (iii) familiarity-based weighting.

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n expert survey was conducted on the challenges and priorities of global maritime decarbonization to gain insights into the key areas requiring attention and action. The identified research challenges include global cooperation on carbon pricing for shipping, alternative fuels and strategies, LNG as a transitional fuel, shipping companies’ net-zero strategies, carbon offsetting, the inclusion of shipping in ETSs, clean fuel promotion, low-carbon fuel standards, ports’ role in decarbonization, GHG emission accounting, LCO₂ shipping, and other challenges.

The results of the expert survey indicated that these research challenges are regarded as important, novel, and feasible by respondents, indicating a consensus regarding their significance. The themes of global IMO discussions on carbon pricing for shipping, shipping companies’ strategies for achieving net-zero (GHG emissions, and alternative fuels and strategies for decarbonizing

the maritime industry received particularly high scores considering the AHP-TOPSIS framework used.

It is evident from the survey results that addressing these challenges and prioritizing actions in these areas are essential for achieving the efficient and equitable decarbonization of the maritime sector. In addition, ongoing research and analysis in these priority areas are essential for refining strategies, determining the economic viability of various options, and assessing the environmental and social impacts of decarbonization efforts. The measurement, reporting, and verification of GHG emissions are also essential for monitoring progress and ensuring accountability.

In conclusion, the findings of this expert survey provide a solid basis on which to identify the research challenges associated with the decarbonization of the global maritime sector.
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About the Authors

Rubal Dua

Rubal is a research fellow at KAPSARC working on vehicle regulatory policy and shared mobility research from the consumer perspective. He holds a Ph.D. from KAUST, Saudi Arabia, an M.Sc. from the University of Pennsylvania, and a B.Tech. from the Indian Institute of Technology, Roorkee.

AHM Mehbub Anwar

Mehbub is a Research Lead at KAPSARC. He currently leads the Maritime project, in collaboration with the Kingdom’s energy ecosystem. This project investigates future port activity and fuel forecasting. He also works on the KAPSARC Spatial Urban Energy System (KSUES) project. Prior to joining KAPSARC, he worked in Transport for New South Wales (TfNSW), a state government organisation, as a transport planner, and at the University of Wollongong (UOW) in Australia as a researcher. He led the update on the state of transport in the TfNSW regions as part of the strategic planning for its Future Transport 2056. He has also worked as a lecturer at Khulna University of Bangladesh and was later promoted to a professor in urban transport planning. He holds a Ph.D. with an examiners’ commendation for an outstanding thesis from the UOW. His thesis focused on modeling travellers’ preference heterogeneity.