GETTING TO ZERO COALITION

GLOBAL MARITIME FORUM

Mapping of Zero-Emission Pilots and Demonstration Projects

Fourth Edition | May 2023

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GLOBAL MARITIME FORUM

About the Getting to Zero Coalition

The Getting to Zero Coalition is an industry-led platform for collaboration that brings together leading stakeholders from across the maritime- and fuels value chains with the financial sector and others committed to making commercially viable zero-emission vessels a scalable reality by 2030, towards full decarbonisation by 2050. It is managed by the Global Maritime Forum, who initially founded the Coalition together with the World Economic Forum and Friends of Ocean Action.

The views expressed in this report are those of the authors alone and not the Getting to Zero Coalition or the Global Maritime Forum.

Summary of key takeaways

- The Mapping of Zero-Emission Pilots and Demonstration Projects now includes 373 registered projects, up from 203 registered projects in the third edition, with new trends emerging.
- More than one-third of registered projects have progressed to a new phase or reached an important development milestone since the third edition. This includes more than 30 Approvals in Principle for ship technology projects in 2022 and 2023.
- Pilots and demonstration projects continue to take a highly collaborative approach.
  - 87% of projects involve at least two parts of the value chain. The involvement of classification societies has increased, while demand-side actors and financial institutions remain comparatively under-represented.
  - 70% of projects involve project partners from at least two countries. The top five countries most frequently represented in projects with international industry collaboration are Norway, Germany, the United Kingdom, the United States, and Japan.
- Hydrogen-based fuels face continued innovation needs with ammonia and hydrogen as the top fuels in focus. More mature methanol technologies have begun to move beyond pilot and demonstration work to a commercialisation phase.
- Bunkering and infrastructure technologies see an increased focus on bunkering vessels.
- Around 40% of all projects are publicly funded, a majority of these by European funders.

What is the Mapping of Zero-Emission Pilots and Demonstration Projects?

This study includes zero-emission pilots and demonstration projects from the global maritime ecosystem focusing on ship technology, fuel production, and bunkering and infrastructure solutions that can help the maritime industry decarbonise by 2050. The term pilots and demonstration projects refer to projects or services in their early concept stages and exclude those that are now readily available to the mass market. The fourth edition of this study is based on updated projects from previous editions as well as new projects that have been discovered or announced since the **third edition** was published in March 2022.

To ensure continued relevance, the scope[1] of this study has been revised to reflect new trends and developments in the maritime industry. Collected projects have been categorised based on their project focus, project phase, fuel focus, technology type, involved value chain segments, geographical location, and other categorisations. New to this year's edition is the inclusion of the geographical representation of project partners to provide insights into the level of international collaboration among industry members.

Projects have been gathered via desk research and outreach to the wider global shipping community of the Getting to Zero Coalition and Global Maritime Forum. While the authors are hopeful that a majority of announced zero-emission pilots and demonstration projects have been captured, the findings of this study do not claim to be based on an exhaustive list of projects. Lastly, the fuel scope of this study is based on the Getting to Zero Coalition's definition of zero-carbon energy sources.[2] With this definition in mind, this study aims to objectively present some of the key trends and developments in zero-carbon fuels and technologies that the maritime industry is facing.

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1 **Methodology 'Mapping of Zero Emission Pilots and Demonstration Projects'**

2 **Getting to Zero Coalition 'Definition of zero carbon energy sources'**

Where are we today?

Increased industry activity

The past year has seen continued momentum and increased activity among industry members to innovate and find solutions to decarbonise shipping. This year's study includes 373 zero-emission pilots and demonstration projects, an 84% increase over last year's edition.

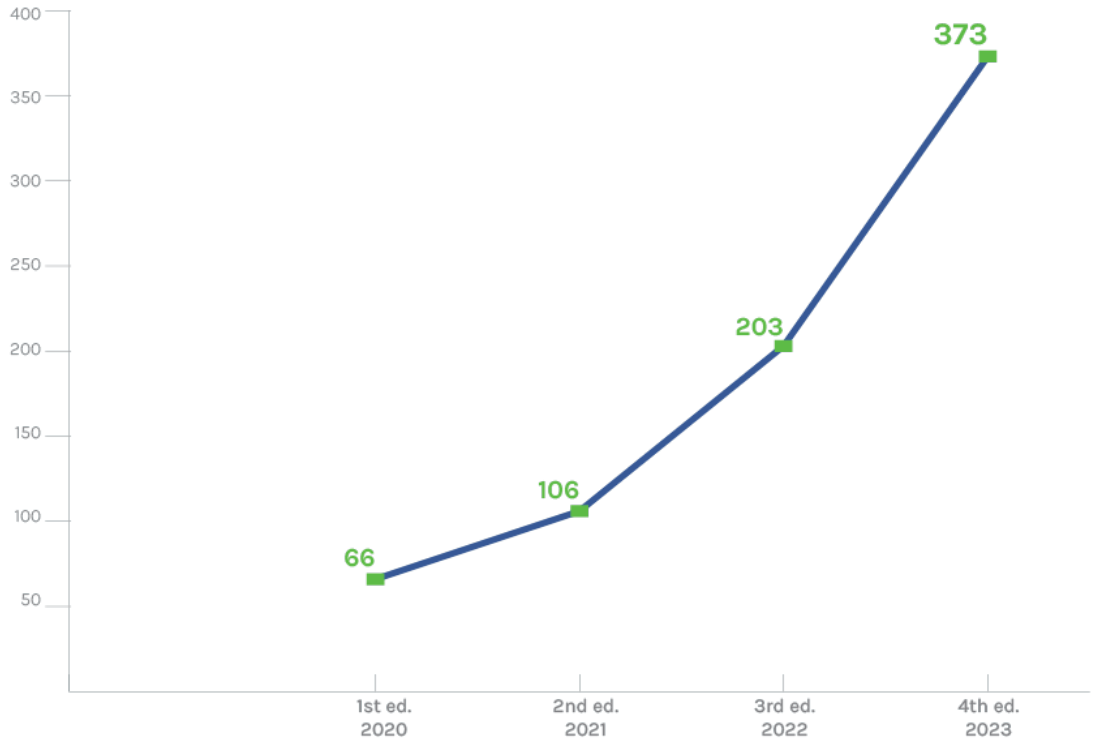

Figure 1: Cumulative number of projects collected from 1st to 4th edition

Projects continue to see global spread, with some regions having higher industry activity than others. The top three continents by number of project location are Europe (56%), Asia (33%) and North America (9%), with Norway, Japan, and Denmark as the most active countries. Since the third edition, zero-emission pilots and demonstration projects have also emerged in a number of countries previously not represented, including Thailand, Egypt, Malaysia and South Africa.[3]

3 **See appendix A for project exemplification**

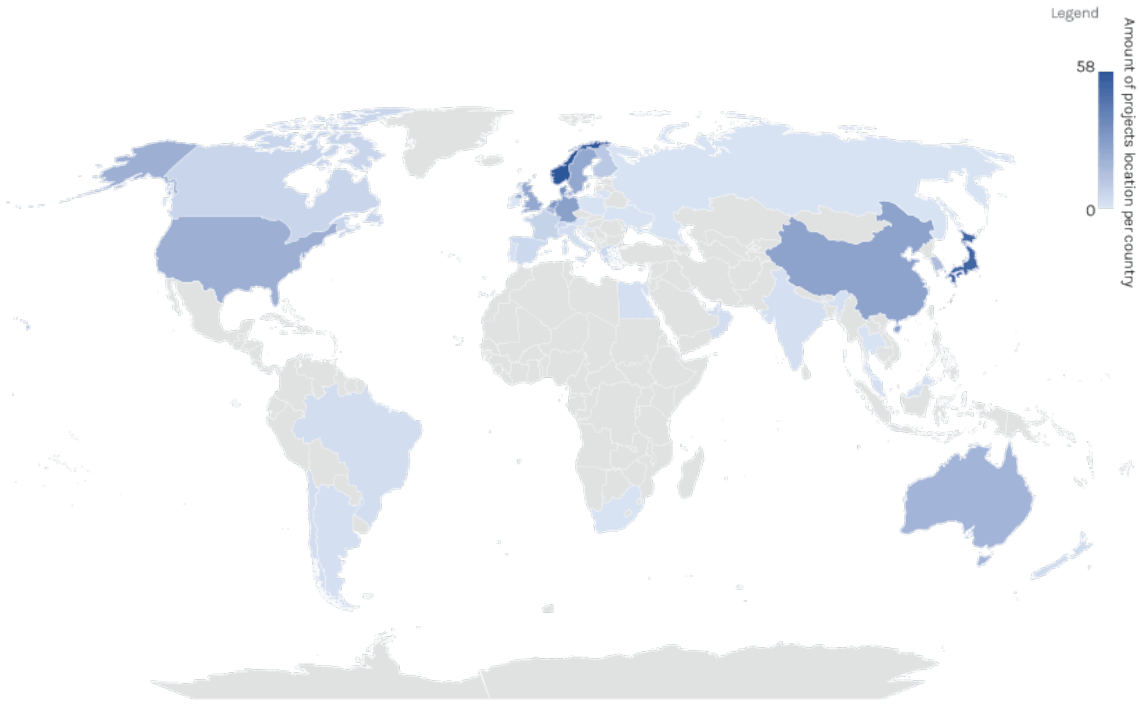

Figure 2: Project location of zero emission pilots and demonstration projects

The yearly development of zero-emission pilots and demonstration projects' locations according to continent can be seen in Figure 3.

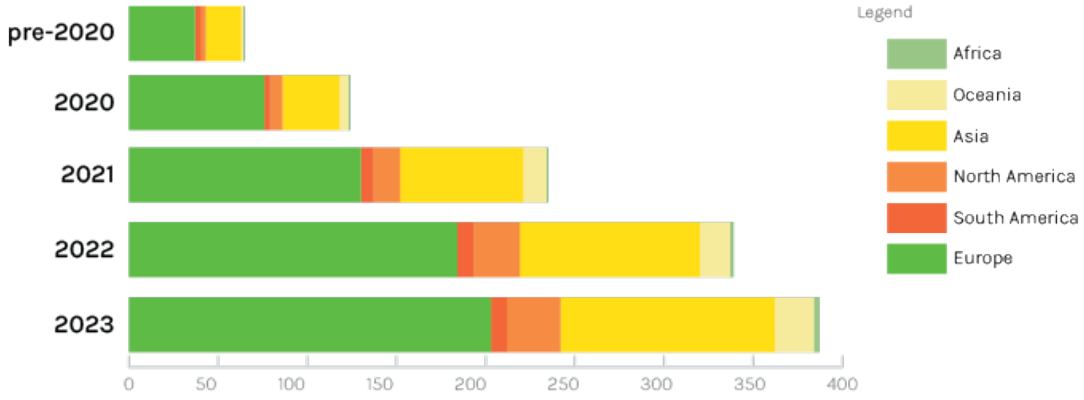

Figure 3: Cumulative number of projects according to start year and continent

One hundred and seventy projects have been added to this year's study, 121 of which have been announced since the publication of the previous edition.[4] With projects focusing on different building blocks of shipping's decarbonisation, the increased industry activity points towards continued knowledge formation and, hopefully, advancements in zero-emission fuels and technologies in the years to come.

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4 Remaining projects that started before the release of the previous edition have been added thanks to improved data collection

Project developments

In parallel to the increase in project announcements, 35% of projects have demonstrated progress since the third edition. This is an increase from the roughly 20% progress rate registered in the third edition, implying that a higher share of announced projects is moving forward. Progress has been determined by tracking project developments shared in the public domain, including parameters like signing new partnership agreements, receiving funding, getting a concept approved by classification societies, or moving from a feasibility stage to demonstrating technology in normal operations. A significant development includes the more than 30 Approvals in Principle (AiP)[5] for ship technology projects that have been registered in 2022 and 2023, compared to 7 in 2021. This demonstrates an increase in the number of innovative, initial zero-emission ship designs showing technical feasibility, bringing zero emission ships one step closer to reality.

Emerging trends

Collaboration

Considering the importance of collaboration in accelerating shipping's decarbonisation,[6] this year's edition has extended the category of collaboration to include both collaboration across value chain segments and across geographies.

Continued high presence of value chain collaboration

The number of projects involving a minimum of two value chain segments now constitutes 87% of all zero-emission pilots and demonstration projects. Among these projects, the most active value chain segments consist of shipbuilder, equipment and technology (23%), energy production (16%), shipowner and ship operator (16%), classification society (9%) and port and terminal (7%) (see Figure 4).

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5 Approval in Principle refers to the evaluation and approval of a concept in its initial design stages, confirming its technical feasibility and moving it into further development stages.

6 **Getting to Zero Coalition, 'The Next Wave: Green Corridors'**

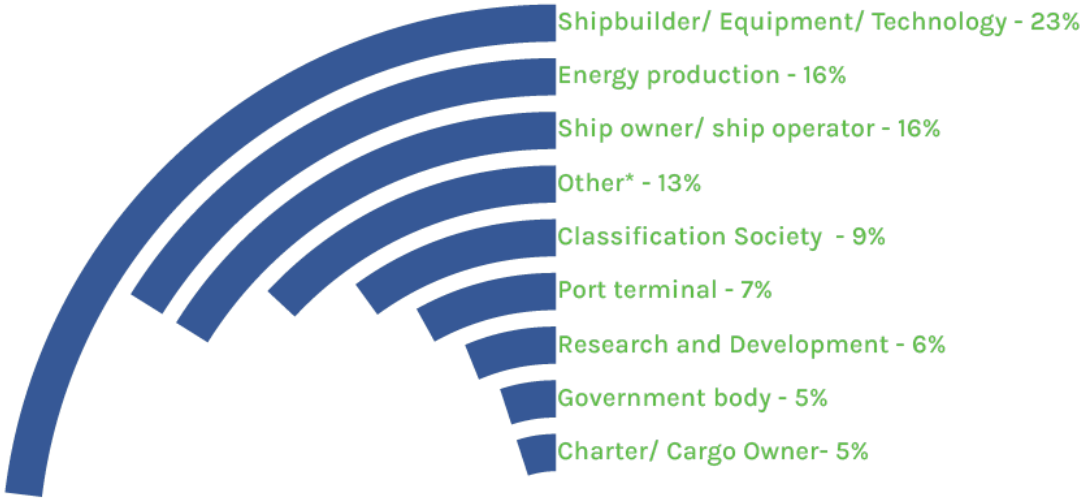


Figure 4: Post-2020 yearly average project participation across value chain segments

The participation of value chain segments[7] looks similar to last year's edition and continues to represent a lack of involvement from demand-side actors and financial institutions, both of which are important building blocks in securing the necessary offtake and funding to bring pilots and demonstrations to success.

While demand-side actors may become increasingly involved in projects at later stages of maturity, it is possible that more projects would benefit from their perspectives on some of the early decisions made for zero-emission pilots and demonstrations. Additionally, a majority of projects involving financial institutions are fuel production projects, which comes as no surprise given their large capital expenditure. However, large investment costs are also expected for bunkering and infrastructure projects, where the involvement of financial institutions has so far been much lower.

For projects initiated in 2022 and 2023, the average number of value chain segments involved per project is 2.58 and 3.16 respectively, which remain similar to the average number of value chain segments involved in 2021 (2.66) (see Figure 5).

7 The 13% representing other categories includes financial institutions (2%), associations or organizations (3%), other services or consultancies (3%), as well as non-specified actors (5%).

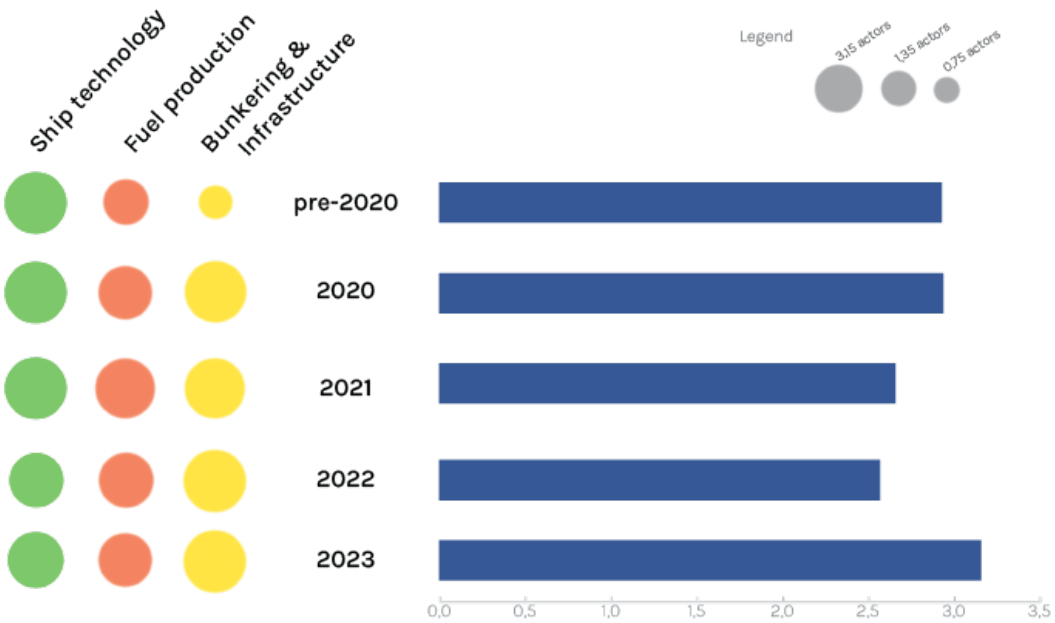


Figure 5: Average value chain segments represented by project start year (Left = according to their project focus; Right = average across all projects)

Among the three project categories of ship technology, fuel production and bunkering and infrastructure, projects within the latter category have been the most collaborative since 2020, amounting to 3.23 value chain segments represented per project. A notable development is the 12 feasibility studies for bunkering and infrastructure announced in 2022 and 2023, averaging 3.4 segments per project but with some featuring involvement of as many as eight value chain segments.

Fuel production projects have an average of 2.58 value chain segments involved per project. Here, demand-side actors in the form of off-takers see little involvement. Some may become involved at a later phase, while others may remain undisclosed.

Finally, for ship technology projects initiated post-2020, an average of 2.96 value chain segments are involved per project, with the three most common value chain segments being shipbuilder, equipment, and technology (29%), shipowner and ship operator (20%), and classification society (13%). A notable development is the higher involvement of classification societies compared to previous editions of the study, now present in more than 80 projects, reflecting the progress of zero-emission concepts towards approved ship designs.

Tracking of international industry collaboration

This year's edition seeks to provide insights into the level of international industry collaboration on zero-emission pilots and demonstration projects. The shipping industry is highly globalised, and it is important that zero-emission solutions are developed in a way that leverages opportunities to share expertise and resources across borders.

Among the 373 projects covered in the study, 70% involve project partners representing at least two countries. The top five countries most frequently represented in projects with international industry collaboration are Norway, Germany, the United Kingdom, the United States, and Japan. While acknowledging potential biases in the data collected,[8] this finding seems to reflect the activity emerging from these countries related to international shipping.

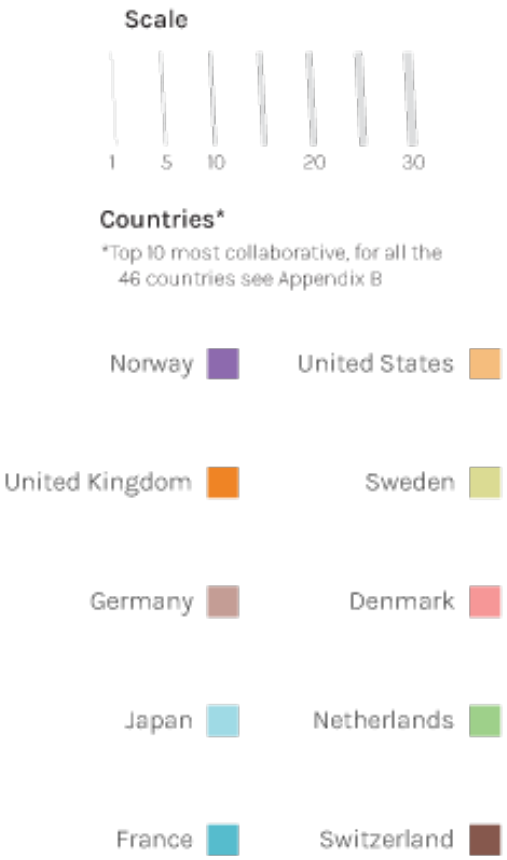
Looking at the flow of expertise and resource exchange happening across borders, Figure 6 shows the countries that are most frequently mentioned together on projects with international industry collaboration.

To exemplify one of these connections, industry representatives from Norway are collaborating on several projects with the United Kingdom, Germany, the United States, Sweden, Denmark, and Japan. Looking at their top collaborator, the United Kingdom, the two countries have domestic fleets where electrification of smaller ships or ferries is a shared strategy, implying a beneficial flow of expertise between them.

On average, bunkering and infrastructure projects include project partners representing three different countries, followed by fuel production (2.8) and ship technology (2.7). In general, ship technology projects' international industry collaboration is often seen between countries with geographical proximity, while bunkering and infrastructure projects see higher geographical spread among project partners. This is especially the case for bunkering feasibility studies by larger consortia

Figure 6: Top five most collaborative countries and their top collaborators

8 **Methodology 'Mapping of Zero Emission Pilots and Demonstration Projects'**



where companies from various geographies contribute their expertise and resources as well as benefit from the findings' applicability to their own operation [e.g., home port]. Lastly, it is worth noting a trend of Global North-South collaboration on fuel production projects.

Fuels and technologies

Continued focus on hydrogen-based fuels

Hydrogen and ammonia are the top two fuel focuses across all three project categories, reflecting the ongoing development needs for these fuel pathways. As shown in Figure 7 the number of zero-emission pilots and demonstration projects focusing on ammonia as a fuel has seen a relative increase to other fuel focuses, while hydrogen has remained somewhat stable. Methanol and batteries, constituting the third and fourth biggest fuel focuses among zero emission pilots and demonstration projects, have instead seen a relative decrease among project announcements and have made up a smaller share of projects each of the last two years.

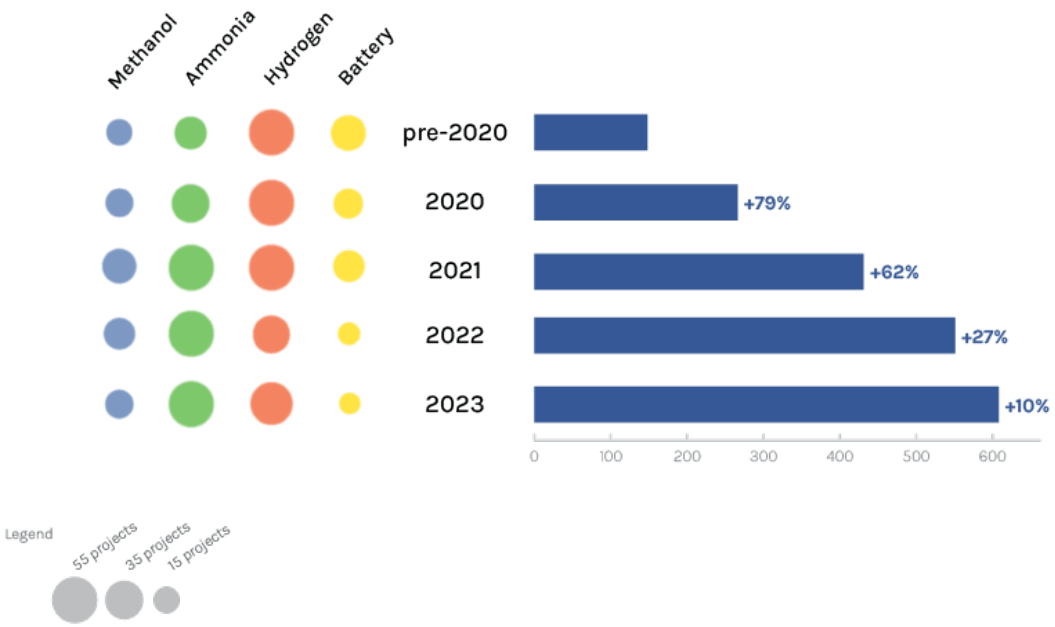


Figure 7: Yearly number of new projects by main fuel focus across all three project categories. One project can have more than one fuel focus
(Left = per fuel focus; Right = cumulative across all projects)

Ship technology projects, which represent over half of all projects in this study,[9] are split between ammonia, battery propulsion, and hydrogen fuel cells with methanol and hydrogen combustion engine projects at a slightly lower level (see Figure 8). Ammonia is the dominant fuel focus for larger ship types and has seen important progress since the third edition,[10] with most of the Approvals in Principle handed out in the past year being for ammonia-powered ship designs. For smaller ships, the leading technologies remain battery technology, hydrogen fuel cells, hydrogen internal combustion engines and methanol. Notable developments since last year's edition include the increase in ship technology projects focusing on onboard carbon capture and storage. Methanol fuel cells as propulsion technology for smaller ships are also new to the mapping.[11]

9 **See the % share of project focuses among all projects in Appendix C**

10 **See yearly development of top five ship technologies among announced projects in Appendix D**

11 **See full graph of ship technology projects in Appendix E**

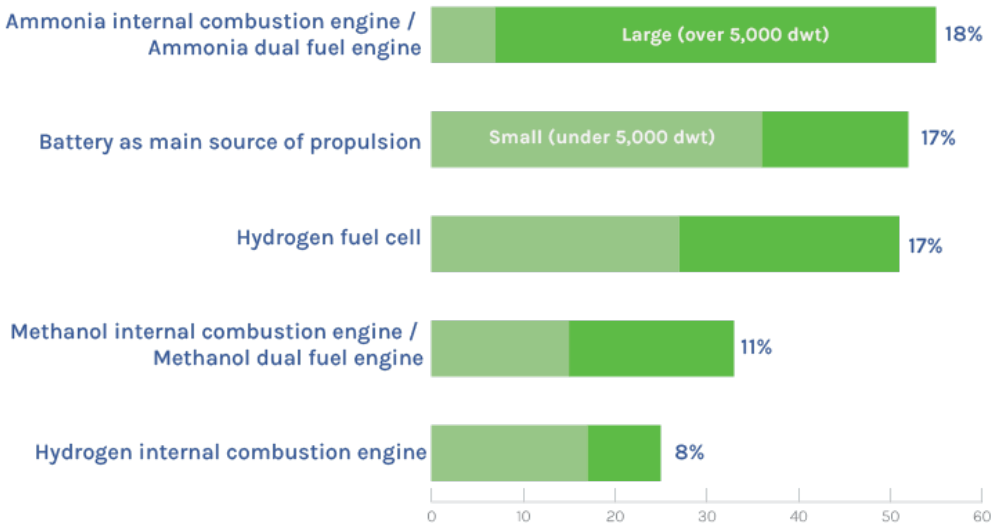


Figure 8: Top five ship technologies according to ship size. Percentages refers to the total amount of projects under each technology

Lastly, fuel production and bunkering and infrastructure projects see a similar trend to ship technology projects, being largely dominated by hydrogen-based fuels with hydrogen in the lead followed by ammonia, methanol and battery power (see Figure 9). What should be noted is that hydrogen and ammonia fuel production projects are often connected to each other, as some hydrogen projects may also be used to produce ammonia. For a yearly development of fuel production and bunkering and infrastructure projects' fuel focuses, see **Appendix F**.

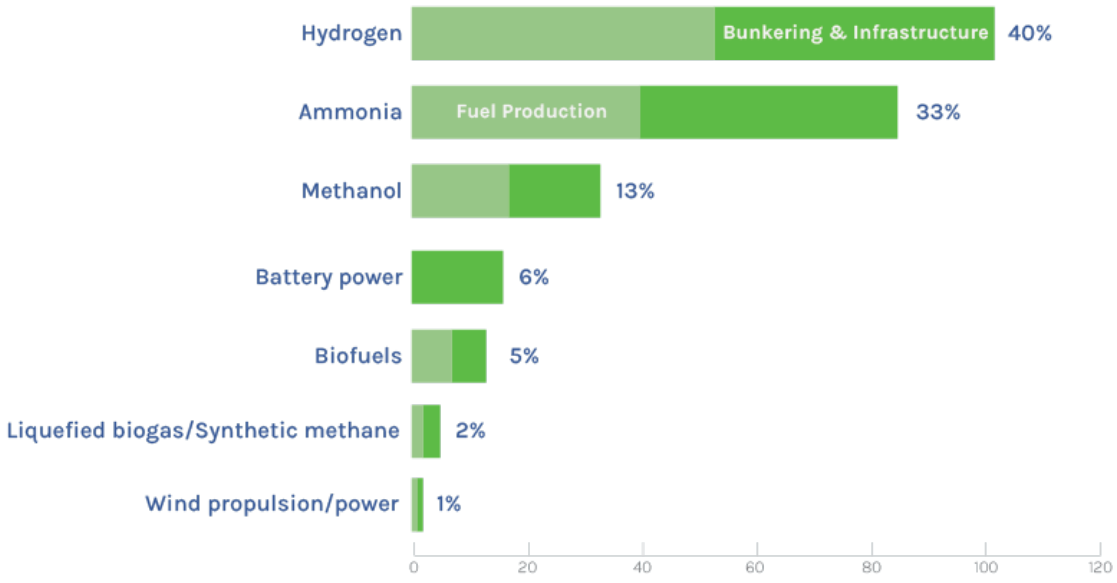


Figure 9: Fuel Production and Bunkering & Infrastructure projects according to their fuel focus. Percentage in reference to both project focuses combined, according to the fuel focus

Methanol moving into commercialisation

Pilot and demonstration activities related to methanol have not expanded significantly since the third edition. This development is in line with the industry's market trends over the past year, with a total of 82 methanol ships on order for delivery in 2028.[12] In March 2023, methanol represented 12% of the orderbook by capacity compared to less than 1% a year ago.[13] These developments suggest that methanol technology is moving into commercialisation with less research and innovation needed to establish its role as a zero-emission shipping fuel. Instead, methanol-focused pilots and demonstration projects registered in this study concern technology with a lower readiness level, such as methanol bunkering vessels or methanol fuel cells as propulsion technology.

Maritime-linked fuel production projects

Fuel production projects have seen a number of interesting developments over the past year, including new feasibility studies for green ammonia and hydrogen production, some of which include collaboration between developed and developing countries (e.g., Japan-Malaysia), a floating ammonia production unit, and a green methanol value chain collaboration feasibility study for a first-of-its kind pilot plant in Southeast Asia. The most common technology types in fuel production projects can be seen in Figure 10 below.

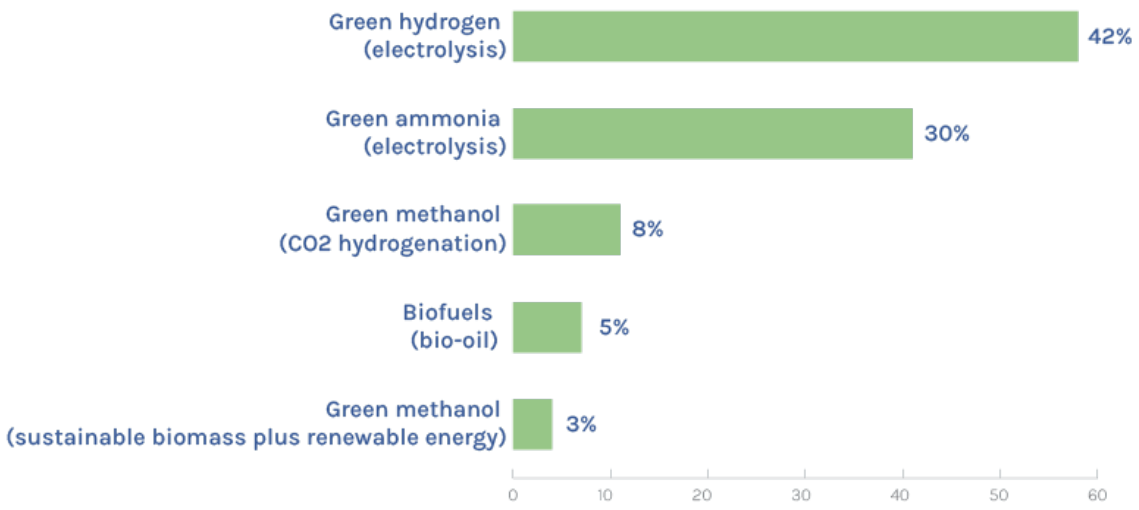


Figure 10: Top five most common fuel production technologies. Percentage in reference to total amount of fuel production projects

What should be noted is that fuel production projects have seen a relative decrease in project announcements compared to the total number of

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12 **Offshore Energy, 'A year in review for methanol as marine fuel: 82 ships by 2028'**

13 **Splash 24/7, 'Methanol boxship orders growing more rapidly than all other fuel types'**

announced pilots and demonstration projects registered in this study (down from 31% to 24% over the past year).[14] This is unlikely to reflect the overall technology development and growth in production of hydrogen and hydrogen-based fuels, which appears to be significant.[15] Many hydrogen-based fuel production projects have moved beyond the pilot and demonstration stages of development and are focused on commercial-scale project development. In addition, fuel production projects that do not indicate a connection to or intention to serve maritime off-takers have been excluded for the purposes of this study.[16]

Trends in bunkering and infrastructure technologies

Zero-emission pilots and demonstrations focusing on bunkering vessels became more common in 2022 and 2023 (see Figure 11). These now represent 19% of all bunkering and infrastructure projects in the study. Onshore bunkering technology constitutes the largest sub-category within bunkering, followed by shore-side storage, bunkering vessels, offshore bunkering technology and siting and spatial planning work.

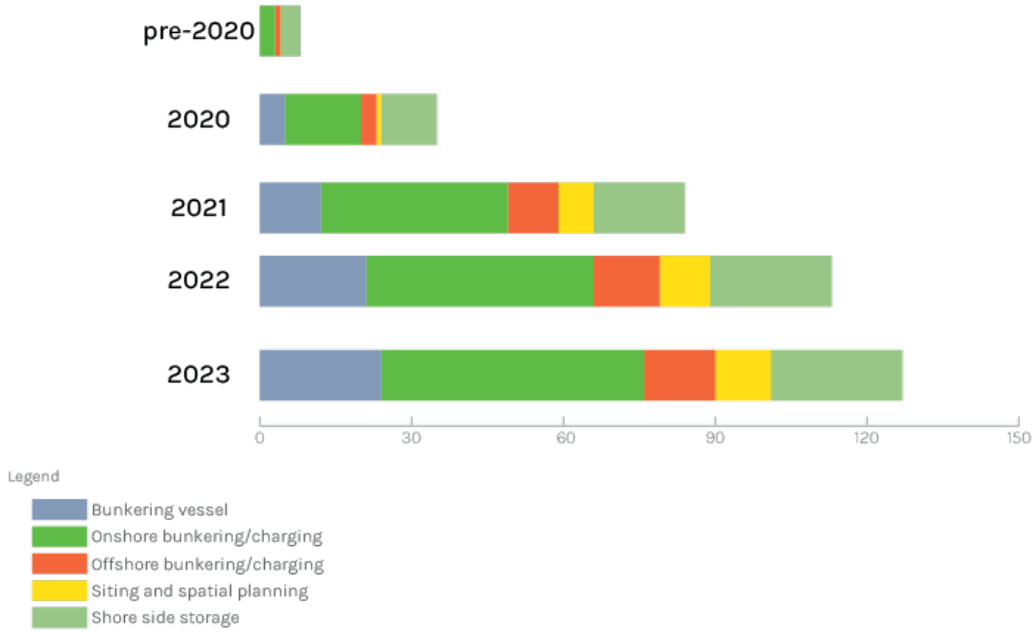

Figure 11: Number of bunkering and infrastructure projects by technology type

Among the new projects focusing on bunkering vessels announced in 2022 and 2023, seven focus on ammonia and four on methanol, and are located across Europe, Asia, and North America.

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14 **See Appendix C for projects distribution by Project Focus**

15 **IEA, 'Clean Energy Demonstration Projects Database'; Hydrogen Council, 'Hydrogen Insights 2022'**

16 **Methodology 'Mapping of Zero Emission Pilots and Demonstration Projects'**

Like previous editions, onshore bunkering technologies remains the largest category, representing over 40% of all bunkering and infrastructure projects. An interesting development is the increased number of bunkering feasibility studies, many of which take a broad value chain perspective that includes production, storage, transport, and bunkering.[17] Within the area of offshore bunkering technologies, zero-emission multifuel stations, offshore charging demonstrator, and ammonia floating storage and regasification barges (A-FSRB) are examples of technologies that have emerged since the third edition of this study.

Public funding

Almost 40% of registered zero-emission pilots and demonstration projects state that they have received public funding. Of these, almost 80% are found in Europe. Since the first edition of the study, Europe has continuously supported research and innovation for zero-emission shipping through regional and national funding programmes and direct government aide (see Figure 12). The region now represents 110 publicly-funded projects registered in the study, nearly double the 58 that were registered in 2020.

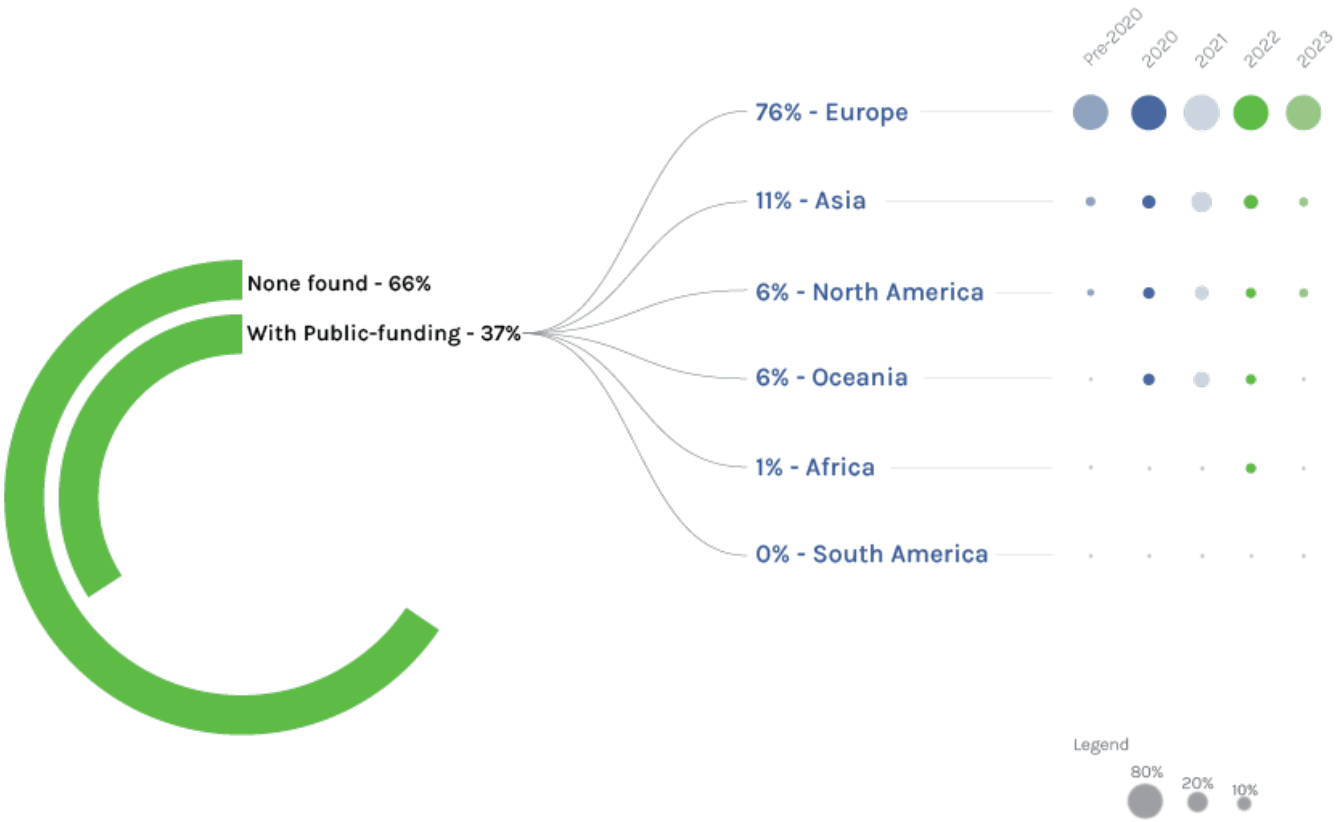


Figure 12: Public funding of projects (Left = overall number of projects by funding type; right = public funding evolution by continents)

17 **See Appendix G for project exemplification**

It is important to note that the above data only includes direct awards of public funding that have been publicly announced. This excludes cases of indirect funding, such as project partner contributions where the partner is a public entity. This may especially impact data for regions with higher state involvement in ownership structures. Transparency on public funding, which may vary between regions, are likely to impact these conclusions as well.

Finally, public funding can send an important signal that a country's government and public entities support the development of shipping's decarbonisation and can help support industrial leadership in the maritime space.

Where are we headed next?

This study focuses on zero-emission projects at the pilot and demonstration phase that can help pave the way for shipping's decarbonisation. The context for this analysis is changing, as some fuels and technologies are moving into commercialisation and the focus of research and development efforts moves to those solutions that require more innovation before coming to market.

This year's study has been updated to include new indicators to ensure that the methodology reflects the objectives of the report. The goal remains to document global industry action related to emerging technologies in shipping decarbonisation, and as such it should be seen as complementary to other resources that look at progress from other perspectives, such as **Climate Action in Shipping: Progress towards Shipping's 2030 Breakthrough**, the **Annual Progress Report on Green Shipping Corridors**, and the International Energy Agency's **Hydrogen Projects Database**.

A point of emphasis in this year's report has been the level of collaboration seen in recent pilot and demonstration projects. In the early phases of shipping's transition, a collaborative environment can help ensure a flow of expertise and resources across value chain segments and geographical borders, furthering alignment around new concepts.

However, another development featured in this report has been the movement of some of these concepts towards commercialisation, a trend that is likely to continue. A larger share of future innovation projects will focus on developing more affordable and robust variations of the decarbonisation solutions being tested today, rather than on proving general viability of new concepts. This shift towards focusing on competitiveness—some years away for most of these technologies—is healthy and inevitable. For now, though, innovation in shipping decarbonisation will continue to have its greatest impact when both resources and learnings can be shared.

Additional information on Zero-Emission Pilots and Demonstration Projects

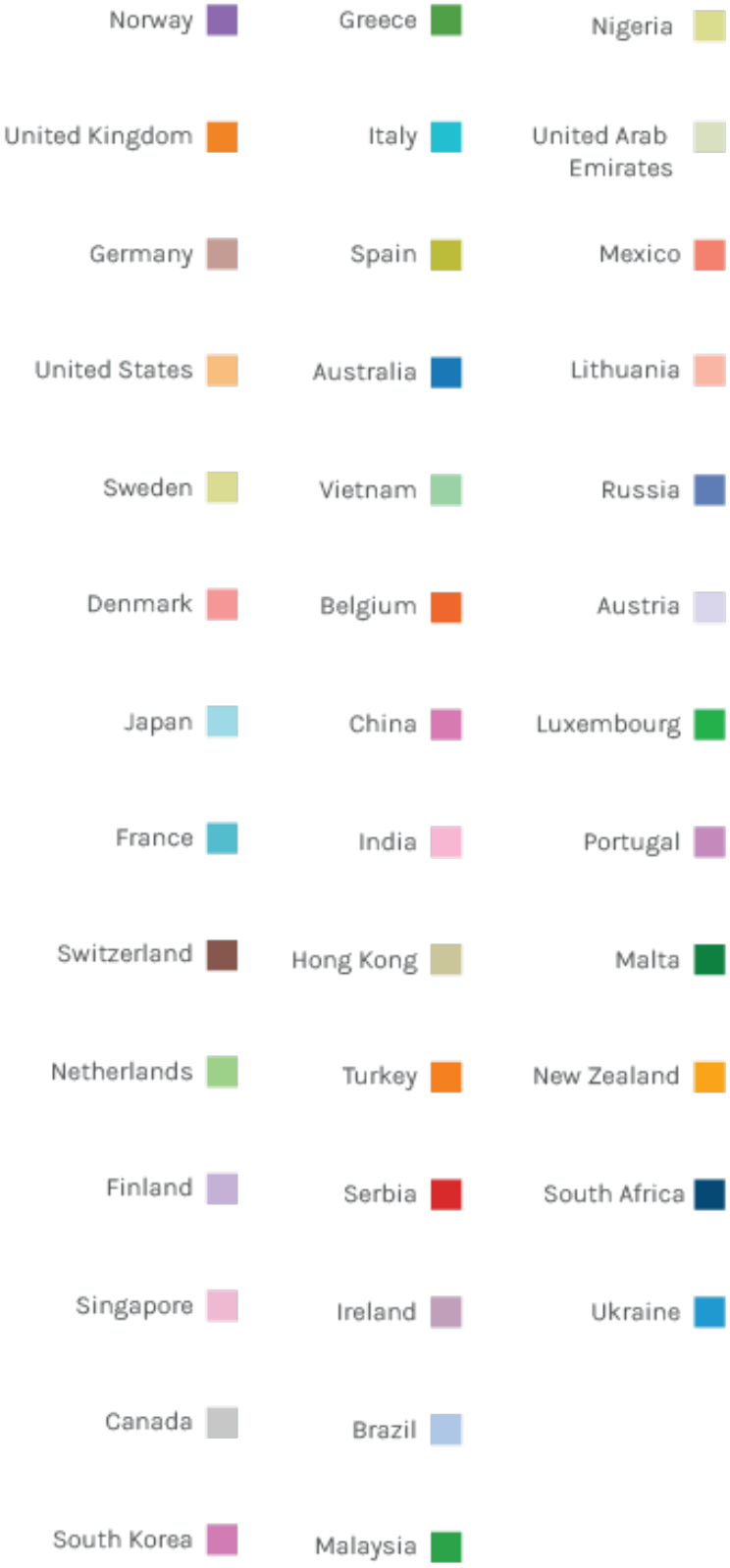
Appendix A

Industry activity in Thailand, Egypt, Malaysia, and South Africa

- Thailand: **Establishing an ammonia and hydrogen value chain in Thailand**
- Egypt: **Green hydrogen and green ammonia mega-project, Suez Canal**
- Malaysia: **Feasibility of green ammonia production and sales in Malaysia**
- South Africa: **Supply chain for green ammonia as marine fuel, South Africa**

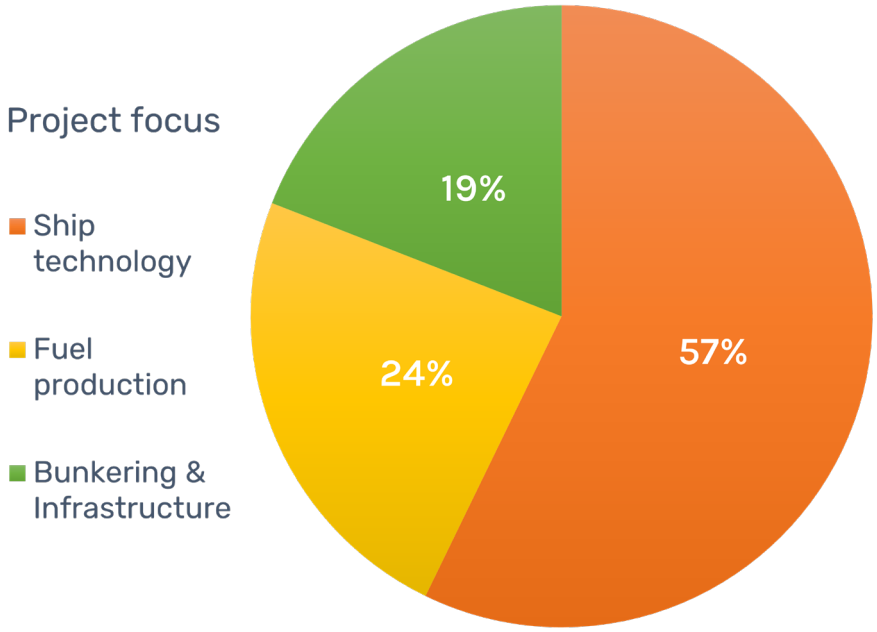
Appendix B

Legend Figure 5



Appendix C

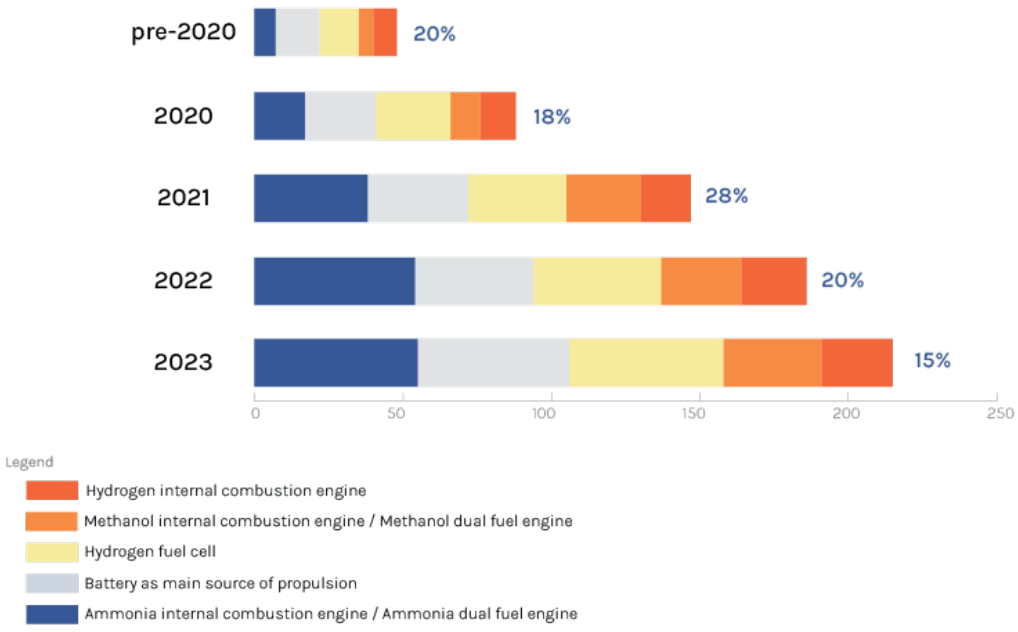
Project focus among total zero-emission pilots and demonstration projects.



Appendix D

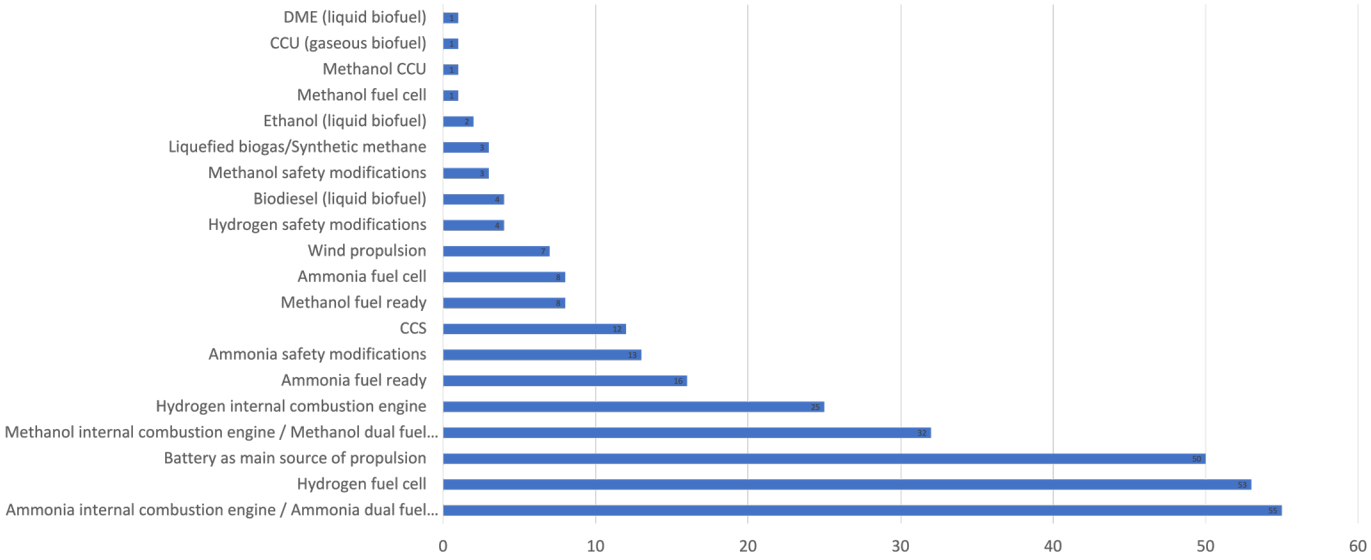
Yearly development of top five ship technologies among announced projects.

Percentages in reference to the yearly distribution of projects according to start year.



Appendix E

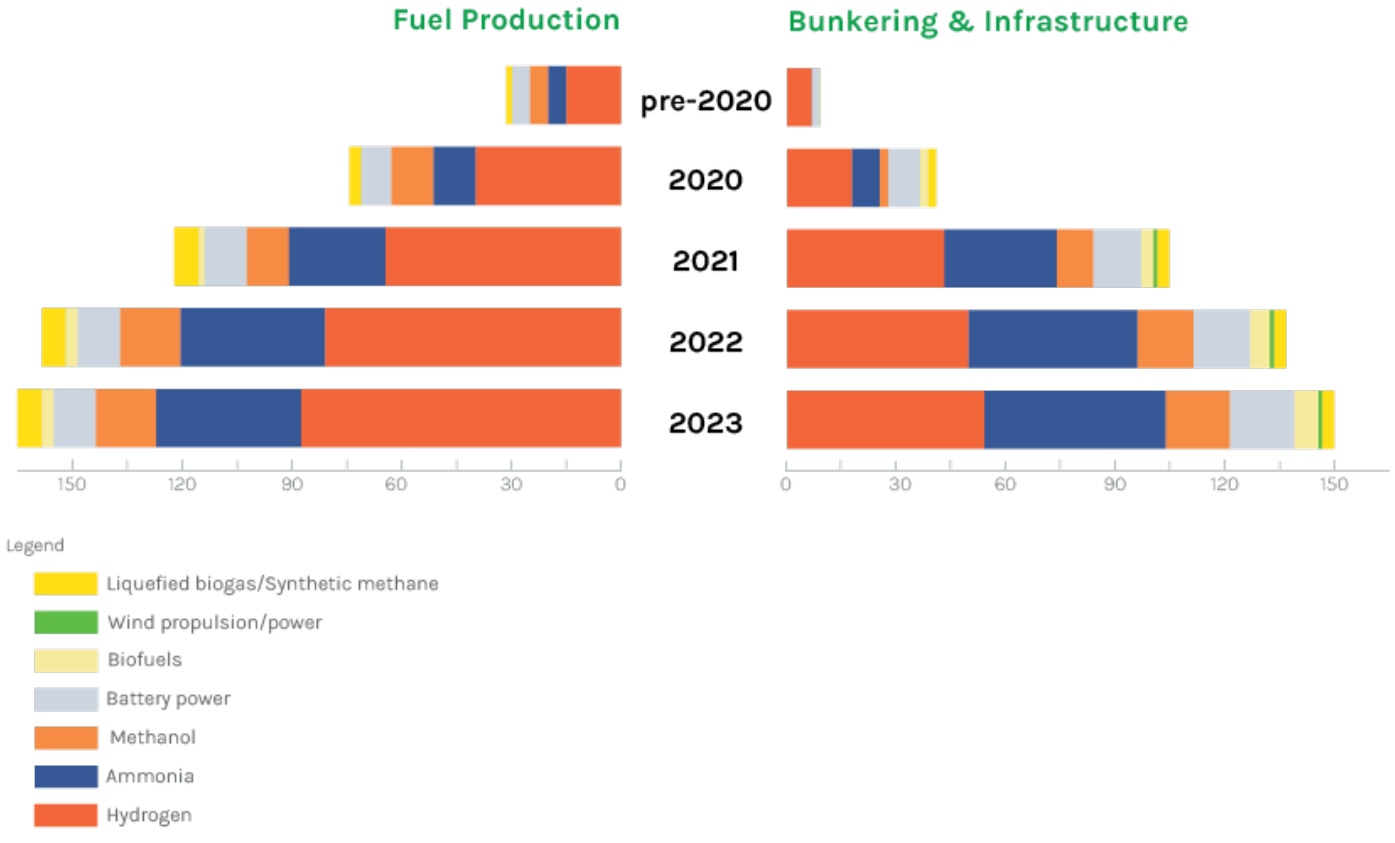
Ship technology focuses among ship technology projects.



Appendix F

Yearly development of fuel production and bunkering and infrastructure projects' fuel focuses among announced projects.

Cumulative number of fuel production and bunkering and infrastructure projects according to their starting year, referencing the fuel focuses in each year.



Appendix G

Examples of bunkering feasibility studies

- **Ammonia bunkering hub in the Oslo Fjord, Norway**
- **The Global Center for Maritime Decarbonisation Consortium's Biofuels Study**
- **The Pilbara Ports Authority and Yara Clean Ammonia's study of the uptake of clean ammonia as a marine fuel**
- **The Green Methanol Bunkering Hub in Australia between A.P. Moller Maersk and ANL**

About the Getting to Zero Coalition

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