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Can the EU Fishing Fleet Be Decarbonised Without Raising Capacity Ceilings?

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25 August 2026

About this report

This report has been commissioned by Seas At Risk. The report examines options for transitioning to low- and zero-carbon fuels in the EU fishing fleet and assesses whether the gross tonnage capacity ceilings set by EU regulation may limit opportunities for decarbonisation.

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Authorship

This report was researched and written by John Burant. Correct citation of this document:

John Burant, August 2026, *Can the EU Fishing Fleet Be Decarbonised Without Raising Capacity Ceilings?*, Amsterdam, The Netherlands: Profundo.

Front page cover photograph by Arno Senoner - Unsplash.

Acknowledgements

The author would like to thank Barbara Kuepper and Gerard Rijk for support and insight.

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Executive summary

The European Union (EU) fishing fleet is dependent on fossil-fuel propulsion, principally through the combustion of marine gas oil (MGO) diesel. At the same time, the EU and its Member States have committed to achieving climate neutrality by 2050. Elected officials, industry leaders and other stakeholders are actively examining ways to decarbonise the EU fishing fleet. One practical question that has arisen is whether the EU's current fishing-capacity rules present a barrier to decarbonisation.

Under the Common Fisheries Policy (CFP), each Member State has national ceilings for fleet capacity measured in gross tonnage (GT) and engine power. Gross tonnage is a (dimensionless) measure of vessel size based on volume, so fuels requiring more onboard storage space - which is the case for all current low- and zero-carbon fuels - can increase the GT of a redesigned or replacement vessel even where fishing capabilities or vessel space devoted to fishing activity does not increase. Capacity ceilings are a core safeguard of the Common Fisheries Policy, helping to prevent uncontrolled growth in fishing capacity and supporting the long-term balance between fleet capacity and available fishing opportunities; any changes to capacity ceilings risk undermining this goal.

Nevertheless, some industry representatives have claimed that current capacity ceilings limit the potential for decarbonisation and have argued for changing capacity limits or definitions but have not provided hard numbers to back up their claims. This study provides a grounded assessment of whether the EU GT capacity ceilings need to be increased to accommodate full decarbonisation of the EU fishing vessel fleet, using a quantitative analysis that incorporates representative vessel specifications for every active fleet segment across the entire European Union fishing fleet. It identifies the capacity increases needed to accommodate battery-electric, methanol, and fatty acid methyl ester (FAME) biodiesel options. To our knowledge, this is the first analysis of its kind at this scale.

The analysis shows that although alternative fuels do indeed require additional storage volume, current EU fleet capacity ceilings do not present a material barrier to decarbonisation. The current GT ceiling across the Member States was approximately 1.67 million GT at the end of 2024. In comparison, the active fleet amounts to less than 1.2 million GT, leaving substantial unused GT capacity even before considering any policy changes at the EU level. All Member States operate below their own GT capacity ceiling, but some are closer to the ceilings than others.

The most ambitious modelled scenario assigns each representative vessel specification to the lowest-carbon option that suits it: battery-electric propulsion where possible, methanol for remaining vessels where it is suitable, and FAME biodiesel as the fallback option. Under this scenario, total fleet GT increases by 16.7%, from approximately 1.16 million GT (the 2023 total) to approximately 1.30 million GT. This remains substantially below both the total current GT ceiling and the current ceiling less registered inactive fleet GT.

Less ambitious scenarios produce smaller EU-wide and Member State-level GT increases: 10.2% when battery-electric and methanol uptake are each modelled at 50% of their maximum share, 7.8% when battery-electric is used but methanol is excluded, and 3.7% when all vessels are modelled as FAME biodiesel vessels.

The only case in which a Member State is modelled to exceed its GT capacity ceiling is Poland, which represents less than 3% of the total EU fleet by GT. Under the two most ambitious scenarios modelled, its GT would reach approximately 5.8% and 1.2% above its current GT ceiling, respectively. For no other Member State is the GT capacity ceiling breached even under the most ambitious modelled scenario. A general downward trend in fleet sizes, the possibility that vessel owners may choose less-ambitious decarbonisation strategies, and the need to reduce overfishing may mean that for Poland, this GT capacity ceiling may never actually be reached in reality, and that in any case the time at which the capacity ceiling could become an issue is years away.

The vessel-level results show that the suitability of these fuel options is not evenly distributed across the fleet. Battery-electric propulsion is suitable for smaller vessels that make short trips and have lower daily energy requirements, but, notably, it appears feasible for more vessels than just those in the small-scale coastal fisheries (SSCF) fleet. Methanol is suitable across a broader range, including many of the largest vessels in the fleet, but tank accommodation constraints exclude some vessels from being candidates for methanol. FAME biodiesel is treated as technically available to all vessels because its energy density and storage requirements are close to those of MGO, but it is less desirable from overall environmental, emissions and food security standpoints.

This study fits within a larger context, as a transition to carbon-free fisheries must go beyond simply replacing fossil fuels with alternative energy sources. The larger goal requires a whole-system approach that addresses emissions across the fisheries value chain, including by reducing overall energy demand through changes in fishing practices, fleet operations and fisheries management. Fuel combustion, however, remains the dominant source of emissions for many fisheries, and the propulsion energy-source question considered in this paper is therefore a significant component of the full picture.

The central finding is that decarbonising EU fishing fleet propulsion has a real but manageable effect on GT requirements. Existing unused capacity is sufficient at the EU level to accommodate the modelled transition pathways, including the most ambitious scenario considered here. The results point to a practical policy conclusion: the capacity-ceiling framework can accommodate fleet decarbonisation in the modelled scenarios, with attention needed only to very limited, specific Member State situations. No general EU-wide increase in GT ceilings is needed. The energy transition should instead be supported through investment, innovation and effective fleet management rather than by weakening this essential safeguard.

Abbreviations

Abbreviation	Description
CFP	Common Fisheries Policy
CO_2	Carbon dioxide
DWF	Distant-water fleet
EEA	European Environment Agency
EMEP	European Monitoring and Evaluation Programme
EU	European Union
EUR	Euro
FAME	Fatty acid methyl ester
GJ	Gigajoule
GT	Gross tonnage
HVO	Hydrotreated vegetable oil
ICCT	International Council on Clean Transportation
IRENA	International Renewable Energy Agency
kW	Kilowatt
kWh	Kilowatt-hour
L	Litre(s)
LHV	Lower heating value
LNG	Liquefied natural gas
LSF	Large-scale fisheries
m	Metre(s)
MDO	Marine diesel oil
MGO	Marine gas oil
MJ	Megajoule
MS	Member State
RISE	Research Institutes of Sweden
SSCF	Small-scale coastal fisheries
SHI	Sustainable Harvest Indicator
STECF	Scientific, Technical and Economic Committee for Fisheries

1

Introduction: Must capacity ceilings be raised?

The European Union and its Member States have committed to achieve climate neutrality, or net-zero greenhouse gas emissions, by 2050 [1]. The EU fishing fleet, however, remains heavily dependent on fossil-fuel propulsion, principally through combustion of marine gas oil (MGO) diesel. The need to decarbonise the fleet has been the subject of significant discussion - though with little concrete progress to date - from EU institutions, industry groups and other stakeholders [2,3].

One area of focus has been identifying ways to improve the fuel efficiency of the existing fleet and of new MGO-fuelled vessels compared with the current generation of vessels. Although improving the energy efficiency of fishing vessels is laudable - and achieving net zero emissions in other aspects of the full fisheries value chain is important as well - the question of the primary fuel source cannot be sidestepped. Fishing vessels need significant propulsive power, and that energy must come from somewhere. Numerous possibilities have surfaced: hybrid and diesel-electric systems, renewable liquid fuels, methanol, hydrogen, ammonia and battery-electric propulsion have all been discussed [2,4]. The perceived suitability of these options varies substantially by vessel type and operating profile.

Many of these options, particularly methanol, hydrogen, ammonia and batteries, have lower effective energy density than MGO, meaning that they carry less usable energy per unit volume or weight. They therefore require more onboard space, weight, or both to provide comparable energy and range. Renewable drop-in fuels, such as some biodiesel and renewable diesel products, have a much smaller space penalty but do not resolve the longer-term question of how to replace fossil fuels at scale. Fishing vessels naturally have limited space on board, creating a tension between using space for fuel storage and propulsion on one hand and fishing, catch handling, processing, crew, and other commercial functions on the other [3,4].

At the same time, the EU's Common Fisheries Policy (CFP) requires that fishing and aquaculture activities be environmentally sustainable in the long term and seeks to ensure that the exploitation of marine biological resources restores and maintains stocks above levels capable of producing maximum sustainable yield [5]. The level of fishing effort (a combination of capacity and activity) and the resulting catch levels are monitored by Member States and at the EU level by, among others, the Scientific, Technical and Economic Committee for Fisheries (STECF), which aggregates Member State data to provide an ongoing picture of the situation of fisheries across the EU [6].

One of the major regulatory tools used by the EU and Member States is the direct regulation of the allowable capacity of each Member State's fishing fleet. Fishing capacity, in this sense, is defined as a vessel's gross tonnage[i] (GT) and its engine power in kilowatts (kW) [5]. Under the CFP, each

[i] Gross tonnage (GT) is a dimensionless vessel-capacity measure. For EU fishing vessels with overall length of 15 meters or more, it is derived from the volume of all enclosed spaces under the 1969 International Convention on Tonnage Measurement of Ships. For EU fishing vessels under this length, it is calculated using an EU proxy-volume formula based on length overall, breadth, and depth, with coefficients specified in Commission implementing rules.

Member State has a national ceiling for both GT and kW, set out in Annex II of the CFP, and must ensure that the capacity of its registered fleet does not exceed those ceilings.

Capacity ceilings are a core safeguard of the Common Fisheries Policy, helping to prevent uncontrolled growth in fishing capacity and supporting the long-term balance between fleet capacity and available fishing opportunities. By limiting the overall capacity that Member States can maintain, they reduce the risk of fleets becoming too large or powerful relative to the fish stocks and fishing opportunities available, which can drive overfishing, economic inefficiency and increased pressure for higher catch limits.

The entry-exit scheme of the CFP requires that the capacity of vessels added to the fleet be offset by the removal of vessels with equal or greater capacity, though there can be a (substantial) time lag between exit and entry, with "reserve" or "unused" capacity accumulating at the Member State level. In addition, the capacity of vessels removed from the registered fleet with the assistance of state aid is deducted from the Annex II levels. Member States may also enact other regulatory measures that affect the entry or replacement of vessels.

The question of whether the existing capacity ceilings, specifically the GT ceilings, are sufficient to allow equivalent fishing operations with vessels using alternative fuels is contested.

Some industry representatives have made blanket claims suggesting that "existing limits on gross tonnage are hampering the transition to new types of propulsion systems" [7]. In EU stakeholder forums, they have argued for changing capacity limits and definitions of capacity [8–10]. The issue has also surfaced in work of consultants advising the European Commission, with a recent report claiming that "[…] regulatory adjustments concerning tonnage and vessel length are required, as alternative-fuel storage demands more onboard space" [3].

This view is not universal. A ClientEarth/RISE study concludes that the relative GT effect is likely to be small and that existing national capacity margins can accommodate decarbonisation measures [11]. A recent academic study by Bastardie et al. concludes that the extent to which innovations require extra GT is "uncertain" and that lifting the GT ceiling should be considered only as a last resort [12]. In closing remarks at an Energy Transition Partnership conference, the leader of the EU's Directorate-General for Maritime Affairs and Fisheries stated that capacity ceilings are not, in practice, a real constraint because significant unused capacity exists below them [13].

What is common among all these competing claims, however, is that none of them has been accompanied by a rigorous, fleet-wide analysis of the potential GT increases required to accommodate decarbonisation across the EU fishing fleet. Backing evidence, where it is even presented, has generally been limited to qualitative statements, stylised examples of individual vessels, or analysis of limited technologies or vessel types.

This study examines whether the EU GT capacity ceiling needs to be increased to accommodate full decarbonisation of the EU fishing vessel fleet. It provides a quantitative analysis based on representative vessel specifications for each active fleet segment across the entire European Union fishing fleet, accounting for the additional volume required to accommodate battery-electric, methanol, and biodiesel options. To our knowledge, this is the first analysis of its kind at this scale.

2

Background on EU fisheries, vessels and capacity regulation

2.1 Fishing in the EU generally

The EU fishing fleet operates across 22 coastal Member States and covers a wide range of fisheries. Some vessels fish close to their home ports and return after a few hours or at the end of the day. Others operate offshore, in the Mediterranean and Black Sea, in the North Atlantic, in international waters, or from outermost regions and far outlying territories. The fleet targets and harvests several thousand distinct marine species each year. In 2023, Member State data reported through the 2025 European Commission data call and analysed by the STECF show approximately 1.56 billion litres of energy consumption (MGO), 3.39 million tonnes of landings and €6.14 billion in landing value across the EU fleet. The sector is therefore small compared with major EU industrial sectors, but it is economically and socially important in many coastal regions and remains highly dependent on marine diesel fuel [6,14].

2.2 The fishing vessel fleet

The EU fishing fleet is highly heterogeneous. It includes open vessels only a few metres long; small coastal vessels using passive gear; medium-sized vessels fishing with nets, hooks, pots, dredges, or trawls; and large vessels capable of making long voyages and carrying substantial gear, crew, fuel, and catch. Figure 1 illustrates key aspects of the fleet's diversity and its implications for work towards decarbonisation. Read from the bottom to top, this figure shows, for each of five vessel length categories, the relative share of vessels, days spent at sea, gross tonnage, and energy consumption (in litres of MGO). Although most of the vessels are small, their total GT and fuel consumption are – even in the aggregate – a small portion of the fleet's total GT and fuel consumption. Larger vessels account for the majority of GT and energy use. The consequence for decarbonisation is straightforward: Despite being far outnumbered by smaller vessels, the largest opportunity comes from the largest vessels.

Three broader fleet subcategories are commonly used in EU fleet policy matters. Small-scale coastal fisheries (SSCF) are defined as vessels under 12 metres that use passive or static gear. Large-scale fisheries (LSF) include vessels over 12 metres that use static gear and all vessels that use towed gear. The distant-water fleet (DWF) is a subset of the LSF comprising EU-registered vessels over 24 metres that operate in other fishing regions. These categories are useful shorthand, but there is still significant heterogeneity within each.

The finest level at which the fleet is regulated and at which data are commonly reported is the *fleet segment*. A fleet segment is a group of vessels registered in a single Member State with the same length class[ii] and predominant fishing technique used during a given calendar year [15]. In practice, Member States often also distinguish segments by the geographic area in which they operate and, in several cases, by more detail on the fishing gear used and the level of activity. Although the vessels within a given fleet segment are not identical, by definition they do share much in common,

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ii We group vessels categories of 0-12 m, 12-24 m, 24-40 m, and 40 m and above. Regulatory reporting for fleet-segment uses finer-grained groupings within the under-12 m category; subdivisions occur at 6 m, 8 m, or 10 m depending on the geographic area.

and individual representative specifications can be developed that describe a typical vessel in that segment fairly. Taking account of the relative number of vessels in each segment, these specifications provide a reasonable picture of the diversity and distribution of vessels in the fleet [3,4,7,14,16].

2.3 Capacity regulation

EU fishing capacity is defined using two vessel measures, GT and engine power measured in kW. Under the CFP, each Member State has national GT and kW capacity ceilings, and the Member States must ensure that the capacity of their registered fleets does not exceed these ceilings [5]. Capacity ceilings are a core safeguard of the Common Fisheries Policy, helping to prevent uncontrolled growth in fishing capacity and supporting the long-term balance between fleet capacity and available fishing opportunities. By limiting the overall capacity that Member States can maintain, they reduce the risk of fleets becoming too large or powerful relative to the fish stocks and fishing opportunities available, which can drive overfishing, economic inefficiency and increased pressure for higher catch limits.

The starting points for these ceilings are the levels set out in Annex II of the CFP. The Annex II levels, which relate to historical levels some years ago, are not the same as the current actual ceilings. When vessels are withdrawn *with public aid*, the corresponding GT and kW must be deducted from the Member State's capacity ceilings. This prevents that capacity from being reintroduced later. The Annex II GT levels and the actual GT ceiling levels adjusted for these removals are presented in Table 1.

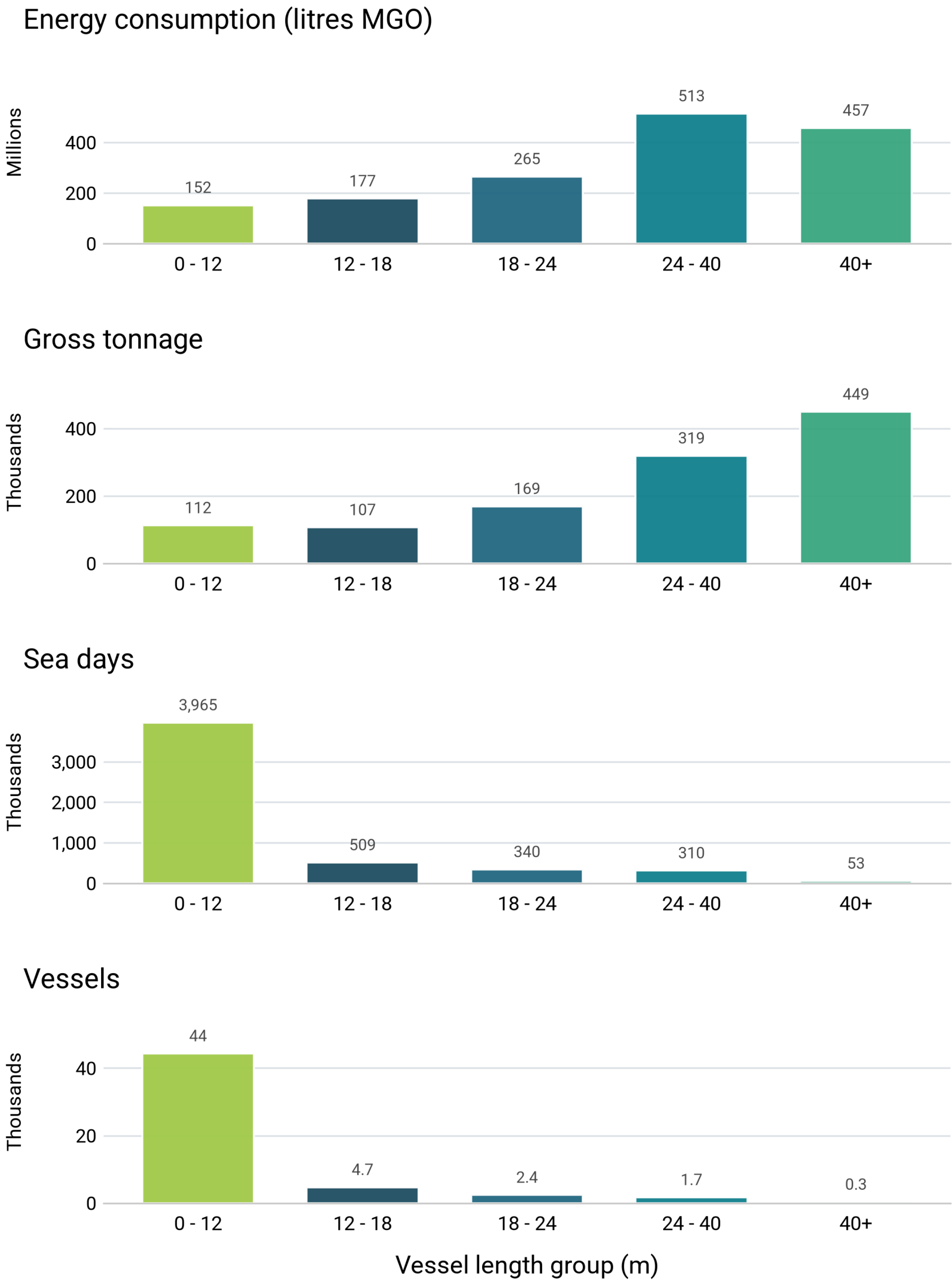
The CFP sets out an entry-exit system to ensure these ceilings are not exceeded: New fishing capacity entering a Member State fleet must be offset by the withdrawal of at least the same amount of capacity, but these do not need to be contemporaneous; a new vessel can be placed into service on the basis of capacity removed years before. But because many vessel withdrawals have been made over the years without any public aid, all Member States have built up “reserve” or “unused” capacity, i.e., a gap between the Member State’s GT ceiling and the GT of all the registered vessels.

Member States may further regulate the replacement of existing vessels or the entry of new vessels with their own capacity rules, which may require additional procedures for the use of this reserve capacity. For example, owners of retired vessels may retain the right to use or trade the capacity of the retired vessels for a period after they are removed from service, or Member States may limit entry into specific fleet segments. However, the EU does not impose any restrictions on this reserve capacity itself. Where these exist, they are matters of Member State policy.

The vessel capacity measured for compliance with ceiling levels includes all vessels on a Member State’s fishing vessel registry. This includes both active vessels – those that engaged in fishing activity in a given year – as well as inactive vessels. The total GT of active vessels in each Member State’s fleet for 2022, 2023 and 2024, and the total GT of inactive vessels for 2024, is reported in Table 1. Capacity accounted for by inactive vessels is not simply available for use by newly registered vessels. For inactive vessel capacity to be made available for new vessels, these vessels would need to be permanently removed from the registry so that they are no longer able to engage in fishing operations.

At EU level, the broad trend in fleet capacity over time has been downward: The number of vessels, total GT and total kW have all declined, and the EU fleet as a whole sits substantially below its combined capacity ceilings. Member States nevertheless differ in how close they are to their GT and kW ceilings. A consideration of fleet capacity ceilings needs to take into account not only whether the EU as a whole has unused capacity, but also the situation in the Member States [6,14].

Figure 1 Distribution of vessels, sea days, GT, and energy consumption by vessel length class



Source: Profundo analysis EU STECF fishing fleet data (2025-07 Annex)

Table 1 Member state GT ceilings and fleet GT

Member State	GT Ceiling		Fleet GT				
	Annex II	Actual 2024	Active 2024	Active 2023	Active 2022	Registered Inactive 2024	Active as % Actual Ceiling 2024
Belgium (BEL)	18,962	18,741	12,752	13,668	13,698	961	68.0
Bulgaria (BGR)	7,250	6,917	4,793	4,571	4,778	1,049	69.3
Croatia (HRV)	53,452	45,656	28,246	30,097	31,439	14,016	61.9
Cyprus (CYP)	11,021	10,831	3,448	3,331	3,580	504	31.8
Denmark (DNK)	88,762	84,002	59,490	67,146	70,061	12,428	70.8
Estonia (EST)	21,677	20,890	11,862	12,060	15,296	4,311	56.8
Finland (FIN)	18,066	18,066	9,078	9,111	8,989	5,534	50.2
France (FRA)	214,282	214,282	134,087	160,977	168,174	4,505	62.6
Germany (DEU)	71,117	66,851	52,474	46,329	49,857	3,574	78.5
Greece (GRC)	84,123	76,741	60,130	54,493	55,111	0	78.4
Ireland (IRL)	77,568	77,568	55,371	60,190	62,624	4,385	71.4
Italy (ITA)	173,506	156,148	125,907	126,449	127,977	15,046	80.6
Latvia (LVA)	46,418	44,134	15,915	18,988	18,971	6,166	36.1
Lithuania (LTU)	73,489	73,489	32,979	31,795	34,461	753	44.9
Malta (MLT)	14,965	14,965	5,592	5,421	5,572	1,249	37.4
Netherlands (NLD)	166,859	145,129	79,232	84,554	94,046	3,469	54.6
Poland (POL)	38,270	35,751	33,385	34,473	34,378	1,256	93.4
Portugal (PRT)	114,549	111,809	70,121	63,941	67,943	16,608	62.7
Romania (ROU)	1,908	1,908	1,380	1,508	1,513	280	72.3
Slovenia (SVN)	675	675	359	376	369	309	53.2
Spain (ESP)	423,550	398,583	298,667	304,274	312,985	19,268	74.9
Sweden (SWE)	43,386	43,386	22,506	21,931	25,153	1,844	51.9
Total	**1,763,855**	**1,666,522**	**1,117,774**	**1,155,682**	**1,206,975**	**117,514**	**67.1**

Source: Profundo analysis of EU & Member State reporting

3

Overview of alternative fuel options

3.1 Fuels and their decarbonisation potential

Many fuels have been examined as alternatives to fossil fuels for marine vessels. These include battery-electric propulsion, biofuels, methanol, hydrogen, ammonia, and liquefied natural gas (LNG). Hybrid systems incorporating multiple energy sources (often combining electric and existing liquid-fuel sources) are also frequently discussed as an option. These fuels have varying characteristics, but the issues of availability, safety and handling requirements, and increased storage volume are relevant to all in some form. For fishing vessels, the main realistic candidates discussed are fewer battery-electric propulsion, methanol, biodiesel, and hybrid systems [2–4,7,8].[iii] In this study, battery-electric, methanol and biodiesel are considered.[iv]

These energy pathways differ in the extent to which they can reduce greenhouse-gas emissions. The true carbon emissions impact of a fuel depends upon its full lifecycle, from the production of the energy carrier to its delivery and its use on board a vessel. All carbon-containing fuels, such as the biodiesel and methanol options considered in this study, generate carbon dioxide when burned. Their potential climate benefit therefore depends on upstream factors: the net negative or positive emissions associated with the fuel's feedstock, the process of converting the feedstock into the desired fuel, and its transport to the location where it is consumed. This is where differences between biodiesels and methanol arise.

3.1.1 Biodiesel

Feedstocks for biofuels such as fatty acid methyl ester (FAME) biodiesel and hydro-treated vegetable oil (HVO) biodiesel, sometimes referred to a “renewable diesel”, include vegetable oils extracted directly from rapeseed, soy, palm, and other plants, as well as used cooking oil and animal fats. The reduction in atmospheric carbon comes as plants extract CO_2 from the air during their growth. The use of direct-from-harvest crop feedstocks, however, places these fuels in direct

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[iii] Hydrogen and ammonia require compressed and/or cryogenic storage. Hydrogen is extremely flammable and ammonia carries significant safety risks. These are additional barriers to deployment on fishing vessels. LNG is a fossil fuel and therefore does not reduce carbon emissions significantly.

[iv] Hybrid propulsion is widely discussed as a transition option for fishing vessels, but this encompasses a broad array of options. This term can include diesel-electric systems, in which a diesel generator produces electricity for an electric motor that is the only mechanism driving the propeller shaft, but which may or may not include batteries as an energy storage mechanism. Hybrid systems can also include parallel-hybrid systems, in which a diesel engine and an electric motor can each drive the same propeller shaft, separately or together, with the mixture of battery storage and diesel combustion variable. Where batteries contribute to propulsion, the resulting emissions reduction depends on the source of charging electricity, the share of propulsion supplied by batteries and diesel and the vessel’s usage patterns. It is therefore difficult to identify a single “hybrid” scenario for modelling, and this study does not do so. Depending on the configuration, the net GT impact of a hybrid system could lie between the base MGO configuration and the fully battery-electric replacement configuration modelled in this study. However, it could also exceed the battery-electric result. For example, a parallel-hybrid system may retain MGO tanks, a diesel engine, and mechanical equipment while adding batteries, an electric motor, power electronics, and associated cooling and safety systems. The resulting volume requirement depends on the configuration and the scale of each component. Furthermore, hybrid options are not necessarily preferable to a single-energy-source design. These may be viewed as near-term options because they can partially reduce MGO use while avoiding hard trade-offs. To the extent hybrid systems rely on combustion of (bio)diesel fuels, the extent of emissions reduction also may not match the best full battery-electric or alternative-fuel designs.

competition with food production and other agricultural land uses. Increasing the use of fuels from these feedstocks therefore requires additional cultivation, but that is not without carbon cost: Direct and indirect land-use change associated with additional cultivation increases net CO_2 emissions, thereby limiting the net decarbonisation impact of biofuels [17]. As such, biodiesel fuels are not generally expected to be truly zero-carbon. Moreover, competition with food cultivation presents risks to food security, and there is not enough sustainably available cropland to meet the world's food needs and potential biofuel demand. When these fuels are made from waste and residues, greater lifecycle savings can be achieved, but the supply of waste and residue feedstocks is limited [18].

3.1.2 Methanol

The promise of methanol is that renewable methanol, also known as e-methanol, can be produced by combining hydrogen made with low-carbon electricity and carbon dioxide captured directly from the atmosphere. [v] When all inputs are low-carbon, this can substantially reduce lifecycle emissions. At present, renewable methanol production remains limited compared with conventional methanol production (which is not considered low-carbon), but it can expand through investment in low-carbon electricity, electrolytic hydrogen generation, and suitable non-fossil carbon dioxide [19]. The International Renewable Energy Agency (IRENA) estimates that the potential e-methanol supply from renewable electricity and sustainable carbon dioxide could reach around 250 Mt per year by 2050, which is approximately 100 times the energy needs of the entire EU fishing vessel fleet, indicating a credible pathway for substantial scale-up [19].

3.1.3 Battery-electric

Battery-electric propulsion differs from combustion fuels because it produces no exhaust emissions during operation. Its fuel-cycle emissions depend primarily on the emissions of the electricity source used for charging.[vi] Electricity generation is the most advanced component of the EU energy transition: renewables supplied 47.5% of EU electricity consumption in 2024, up from 28.6% in 2014, with projections to reach a 68% renewable share of EU electricity generation by 2030 [20,21]. Battery-electric propulsion therefore already offers lower fuel-cycle emissions, with its performance improving as the grid continues to decarbonise. Over the period to 2050, it is assumed that electricity generation throughout the EU will become net-zero, so that vessels powered by battery-electric systems will have (near) net-zero carbon emissions.

From these facts, a natural triage emerges regarding the medium- to long-term decarbonisation potential of these three options for the fishing fleet: electrical propulsion will be the lowest-carbon option, followed by methanol, with biodiesel as the last choice.

3.2 Fuels and their suitability for fishing vessels

The EU fishing vessel fleet encompasses a wide range of vessel types, employs numerous distinct fishing techniques, and exhibits significantly varying usage patterns. These range from open vessels under 5 metres in length with simple outboard motors, which may fish in coastal waters for only a few hours a day or during limited times of the year, to vessels over 100 metres that make trips of several months' duration far from EU waters and remain active throughout the year [3,6]. As a result, the energy use patterns and fuel storage needs vary significantly within the fleet [4,16].

v Synthetic diesel, sometimes described as e-diesel or e-MGO, is also technically possible. It is not included as a separate pathway here because it shares the need for renewable electricity, hydrogen and a suitable carbon source, while current Commission analysis identifies e-MGO as relatively energy-intensive and among the most expensive e-fuels [4]. This is a question of current cost, efficiency and expected availability, not technical impossibility.

vi Carbon emissions embedded in generation infrastructure and battery production are also a factor for evaluating the full carbon footprint of battery-electric systems.

One common denominator among the vessels is nearly uniform reliance on MGO as the fuel source.[vii]

3.2.1 Battery-electric

Battery-electric propulsion is widely regarded as a promising option for much of the SSCF vessel fleet, where the operating profile allows charging between trips [7,22]. This reflects relatively low energy needs while at sea and a return to port at the end of each day. Although the fuel tank capacity of much of the SSCF fleet currently allows multiple days of sailing without refuelling, this is expected to be different for the battery-electric case: A one-for-one replacement of MGO with batteries carrying the same total energy content would not be feasible on the basis of volume considerations alone, but daily charging can allow vessels with suitable duty cycles to operate with much smaller onboard energy stores. Implementation depends on the development of charging infrastructure at ports, but this is deemed feasible for fishing-vessel ports [7].

Larger and longer-sailing vessels need to store substantially higher volumes of fuel. They are therefore generally not considered candidates for full battery-electric propulsion with current technology, because the required battery weight and volume would be prohibitive for long-range, high-energy operations [3,22].

Battery energy density has been steadily improving and is expected to continue to improve in the coming years. Over the last two decades, battery-pack energy density has increased more than eight-fold, and this is projected to improve further in the coming years, with reductions of more than 50% already being taken into account in planning for decarbonisation in maritime and other sectors [23–25]. The feasibility of battery-electric propulsion systems in fishing vessels is therefore likely to increase in the coming years relative to what can be assessed concretely in this study.

3.2.2 Methanol

The situation with respect to vessel size is the opposite for methanol. Methanol, which has slightly under one half the energy density of MGO - and therefore slightly more than two times the raw storage requirements on a like-for-like basis - is not generally considered an option for smaller vessels but is considered realistic for larger vessels. In addition to the larger fuel volume required for methanol relative to MGO, methanol installations require additional protective and safety arrangements, including cofferdams adjacent to the tank itself, as well as ventilation, gas detection and segregated piping systems [26–28].

On small vessels, such as most of the SSCF fleet, these arrangements can make the installed fuel assembly materially larger than necessary based on the fuel volume alone. Materials from an EU stakeholders' forum suggest that stakeholders currently see methanol as infeasible for small-scale vessels because of space constraints and cost [7]. Port bunkering for methanol also requires appropriate safety infrastructure and procedures and is currently limited in small fishing ports [29].

In larger vessels, the volume of the full fuel assembly is less of a concern for two reasons. As a general rule, the relative proportion of a vessel's overall volume devoted to fuel storage decreases as vessels get larger, particularly above 40 metres.[viii] Furthermore, the volume required for a fixed-width buffer around a tank scales with the tank edge dimension rather than with total fuel volume. Although for small tanks the buffer can dwarf the actual tank size, the required buffer volume

vii Some very small vessels are powered by gasoline. Transition options for gasoline-powered vehicles are not discussed separately, but these are expected to be suitable candidates for battery-electric systems.

viii Profundo analysis of approximately 60 manufacturer vessel specification sheets and other manufacturer documents sourced from Crowley/Jensen Maritime, Damen Shipyards Group, Karstensens Shipyard A/S and Macduff Ship Design Ltd.

grows more slowly than the inner tank volume as the total fuel volume increases, becoming much more manageable for the largest vessels.[ix]

3.2.3 Real-world battery-electric and methanol prototypes and redesign studies

A study prepared for the European Commission several years ago identified electric and hybrid vessels already active in the fleet [30]. These include a Catalan fishing vessel with a fully electric mode of up to 14 hours, supported by solar panels and wind generators, as well as multiple hybrid vessels designed for a significant electric share of propulsive power. Outside the EU, a lobster-potting vessel converted from diesel to battery-electric propulsion, operating on trips of 6–7 hours and 24 miles, and a 6.6 m fishing catamaran converted to pure electric propulsion for close-range lobster potting have been reported [31–33].

Furthermore, the feasibility of battery-electric and methanol-powered propulsion systems has already been demonstrated in a number of other challenging contexts. Methanol has been used in passenger and vehicle ferries, ocean-going tankers and methanol-enabled container feeder vessels; dual-fuel harbour and escort tug deployments have also been launched [34–37]. Battery-electric propulsion has been deployed in commercial use as car and passenger ferries and in a short-sea container operation [38]. The ferry examples include an 80-metre car ferry that makes a 6 km, 20-minute crossing 34 times daily and a 59.5-metre car ferry that can handle six 22-nautical-mile (approximately 40 km) return trips daily [38,39].[x]

A detailed examination of how existing fishing vessels can be redesigned (for rebuild, not retrofit) to accommodate battery-electric and methanol propulsion systems is available in the work of Scottish shipbuilder Macduff Ship Design Ltd. Macduff undertook redesigns of a 10-meter creel boat with both electric and methanol systems as well as methanol redesigns for a 15-meter Nephrops trawler and a 24-meter whitefish trawler. In all cases, these redesigns were deemed practical by the shipbuilder [28].

3.2.4 Biodiesel

Biodiesel is generally regarded as widely applicable across the fishing vessel fleet. HVO biodiesel is sufficiently chemically similar to MGO to be regarded as a drop-in replacement that can be used in many existing engines. FAME biodiesel is chemically different from MGO and has somewhat different handling needs and slightly lower energy density but is also regarded as a feasible fuel for new fishing vessels of all specifications, provided the vessels are equipped with suitable engines and other handling equipment [3,40–42].

[ix] For example, a cubic tank holding 5 m^3 (5,000 L) of methanol with 60 cm cofferdams on five sides would require 19.6 m^3 for a total tank assembly volume, or 3.9x the volume of methanol stored. A cubic tank holding 500 m^3 (500,000 L) of methanol with 60 cm cofferdams on five sides would require 712 m^3 for a total tank assembly volume, or 1.4x the volume of methanol stored.

[x] The second of these vessels receives a brief, partial recharge after each round-trip but relies on an overnight charge to fully power its batteries. This indicates that the actual range on a single charge is (possibly significantly) greater than the round-trip distance.

4

Analytical method and results

4.1 Summary of modelling approach

The modelling approach used in this study is two-stage. The first stage is a vessel-level analysis using more than 600 distinct vessel specifications derived from the EU fleet segment data. This stage assesses which vessels are candidates for each alternative fuel and estimates the additional storage volume and GT needed to accommodate an alternative fuel scenario. The second stage models adoption of the fuel options across the fleet to varying degrees.

4.1.1 Vessel-level modelling method

We have developed and applied a detailed model of how alternative propulsion technologies could affect the registered GT of vessels in the EU fishing fleet. This model takes individual vessel specifications as input and returns the GT increase necessary for the adoption of battery-electric, methanol and FAME biodiesel propulsion systems as output. An overview of the approach follows in the section, and a detailed methodology is available in Appendix 1.

For this work, a representative vessel specification is derived for each of the 602 active fleet segments reported by Member States and aggregated by STECF for the year 2023.[xi] The specification parameters are based on average size, activity, and fuel use (per day and per trip) for each fleet segment. Our individual vessel specification also includes an estimate of existing MGO fuel tank capacity, which is not reported in STECF or vessel registry data. The tank volume estimate is derived from reported energy consumption and sailing pattern data and is biased to *overestimate* fuel tank capacity relative to reported needs.

This model therefore captures differences among vessels of different sizes, using different fishing gear and techniques, operating in distinct geographic areas, and following distinct utilisation patterns. STECF data are not complete, but they include the key measures for fleet segments that represent more than 96% of all vessels and more than 86% of all vessel GT. Where key operating data are unavailable, the model imputes values using the median values of comparable fleet segments.

Suitability assessments of battery-electric, methanol, and FAME biodiesel-powered propulsion systems are developed separately for each representative vessel specification, as is the impact on GT needs. Battery-electric propulsion is considered for vessels that make single-day trips and have limited daily energy needs. Methanol is considered where an appropriately sized fuel-tank assembly, including the associated safety and fuel-handling space, are reasonable with respect to the current length of the vessel. In practice, this means that smaller vessels are generally not deemed candidates for methanol propulsion. FAME is considered for all vessel types because its energy density is close to that of MGO and it does not require the same additional safety-related volume requirements [41,42].

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xi The latest STECF-aggregated data includes the year 2024, but the 2024 data is not complete enough to do a full analysis for all EU member states and fleet segments. The 2023 data is sufficiently completely and was therefore used in this study. The impact of changes in the composition in the fishing fleet from year-to-year are expected to be immaterial for the conclusions of this study, and specific issues are addressed individually herein.

For each fuel alternative, the additional onboard storage volume required to provide a sufficient operating energy supply is estimated. For battery-electric propulsion, it is assumed that batteries can be recharged at every port return, so the required battery volume is based on a conservative multiple of daily energy requirements that account for differences in the efficiency of electric and diesel powertrains. For methanol and FAME, the full energy storage of the MGO case is replicated, accounting for the lower volumetric energy density of the fuels. The calculated change in vessel volume is then converted into GT using the applicable EU tonnage rules.

Through this modelling effort, each representative vessel specification is identified as a candidate for one or more of the three fuels.

This work does not entail a comprehensive redesign of each vessel specification for the candidate fuels. It is limited to estimating additional GT necessary to accommodate the alternative propulsion systems while leaving the rest of the vessel's volume use unchanged. The concept is intimately tied to fleet renewal: the assumption is that, over time, vessels will be replaced one by one, and our model demonstrates how much increase in GT is necessary to preserve the existing non-propulsion-related space on a vessel while accommodating the alternative propulsion system. The model does not directly consider retrofitting existing vessels, but it is reasonable to imagine that, in some cases with relatively low additional volume demands, existing vessels could be retrofitted within the estimated GT requirements.[xii]

Furthermore, this model does not account for the potential to improve the overall fuel efficiency of vessels, which is likely achievable in new builds. Such measures could materially bring down the estimated fuel requirements for replacement vessels, but modelling these possibilities was considered beyond the scope of this work [3,11].

4.1.2 Adoption scenario and fleet-level impact modelling method

The individual vessel-level modelling serves as input to fleet-level modelling reflecting any desired scenario of alternative fuel adoption levels. We apply four distinct scenarios to the fleet-segment representative vessel specifications, reflecting differential uptake of alternative fuels. All scenarios involve a full migration away from MGO but rely on battery-electric, methanol, and FAME biodiesel to varying degrees. The four scenarios, progressing from the most ambitious to the least ambitious, are as follows:[xiii]

Scenario One: This scenario applies the lowest-carbon option available to each vessel specification. Every vessel that is deemed a candidate for battery-electric propulsion is modelled as a battery-electric vessel. Every remaining vessel that is deemed a candidate for methanol propulsion is modelled as a methanol vessel. Remaining vessels are modelled as FAME biodiesel vessels.

Scenario Two: This scenario retains battery-electric and methanol as possible options but assumes that the uptake of each is only 50% of the value (by GT) as Scenario One. It is not based on further individual vessel modelling for assignment to either battery-electric or methanol options; rather, it assumes that, in the aggregate, there would be a 50% take-up of each option among the vessels in each category in Scenario One. The other 50% is assigned to the FAME biodiesel option.

Scenario Three: Like Scenario One, this scenario assumes that all battery-electric candidates become battery-electric vehicles. But this scenario excludes methanol and instead assumes that any methanol candidates that are not also battery-electric candidates become FAME biodiesel

[xii] This study does not consider changes in the composition of the fleet. It is possible that shifts towards lower-intensity fishing techniques may also reduce energy demand - and therefore reduce but not eliminate carbon emissions as well - even without changes to the energy sources.

[xiii] Due to the uncertainty in the carbon-intensity of the production of electricity, methanol and biodiesel in the future, it is not possible to quantify the reduction in carbon emissions from each of these scenarios at this time. The order of ambition is drawn from the expected carbon reduction potential of each of these fuels, as described in Section 3.1.

vessels. Vessels that are neither battery-electric nor methanol candidates are also modelled to become biodiesel vessels.

Scenario Four: This scenario models all vessels as FAME biodiesel vessels, fully excluding battery-electric and methanol as possibilities.

4.2 Modelling results

The following sections report the results of the two modelling stages described above.

4.2.1 Vessel fuel candidates and vessel-level GT impact results

Candidates

As described above, the vessel-level modelling assesses whether a given vessel specification is a reasonable candidate for each alternative fuel and the GT increase needed to accommodate that fuel.

The results of the individual vessel-level fuel candidate assessments are shown in Table 2. Of the 53,260 vessels represented in the fleet, 42,950 vessels were deemed potential battery-electric candidates. This amounts to 80.6% of all vessels in the fleet. But because these are primarily smaller vessels, they amount to only 24.3% of the fleet's total GT. Another 10,854 vessels were deemed potential methanol candidates, representing 20.4% of the fleet. But because these include larger vessels, they amount to 85.2% of the fleet's total GT. The overlap between the battery-electric and methanol candidates is 4,497 vessels, amounting to 8.4% of the fleet's total GT. Another 3,953 vessels, representing 7.4% of all vessels in the fleet and 7.7% of the fleet's total GT, were not deemed candidates for either battery-electric or methanol propulsion, but were deemed suitable for FAME biodiesel propulsion, as all vessels in this study are.

Table 2 Candidate fleet totals

	Number of vessels			Gross tonnage		
	Battery-electric	**Methanol**	**FAME only**	**Battery-electric**	**Methanol**	**FAME only**
Total	42,950	10,854	3,953	280,491	984,650	88,742
Percent of Total	80.6	20.4	7.4	24.3	85.2	7.7

Source: Profundo modelling of fuel alternatives for EU fishing vessel fleet

The distributions of vessel sizes for each of the candidate fuels are shown in Table 3. This table presents selected percentile measures of the distribution of vessel length and GT among the set of candidates for each fuel. For instance, this table shows that the 10^{th} percentile length among all battery-electric candidate vessels is 5.2 metres, that the median (50^{th} percentile) length among this candidate group is 9.6 metres, and that the 90^{th} percentile length is 19.0 metres. The other columns follow similarly. As expected, battery-electric candidates are primarily smaller vessels, extending down to the smallest vessels in the fleet and gradually tailing off beyond 20 metres. Methanol candidates are substantially larger, with the smallest starting around 10 metres and extending to the largest vessels in the fleet. The FAME-only candidates are spread throughout the fleet-size distribution but are more concentrated among smaller vessels.

Figure 2 provides a detailed, graphical representation for each set of candidates. The four facets each represent a distinct set of candidates (battery-electric, methanol, both battery-electric and methanol, and FAME only). Each dot in this figure represents a single fleet segment representative specification, positioned by its length overall in metres (x-axis) and its GT (y-axis). Note that the axes are logarithmic.[xiv] As expected, battery-electric candidates are primarily smaller vessels. By separating the fuels into distinct facets, the positioning and overlap of the candidate groups is easily observed. Light grey vertical lines at 12, 24 and 40 metres, representing fleet segment length boundaries, are also shown to help the reader assess the suitability of the different fuels across fleet segments.[xv]

Table 3 Candidate vessel size distributions

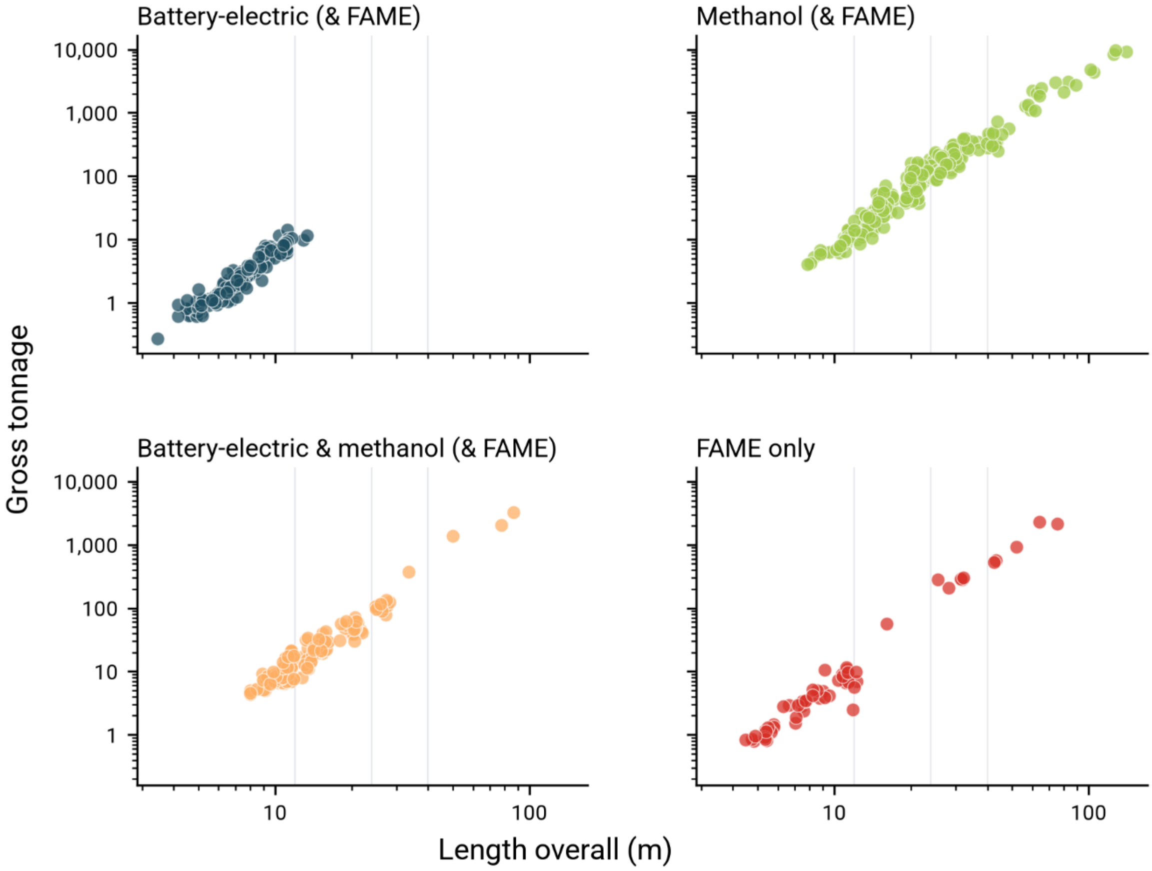
Percentile	Average length (m)			Average gross tonnage		
	Battery-electric	Methanol	FAME only	Battery-electric	Methanol	FAME only
10th	5.2	10.7	5.4	1.1	8.0	0.9
25th	7.2	12.7	6.6	2.3	14.3	1.8
50th	9.6	16.2	9.1	6.7	40.4	4.5
75th	11.9	24.0	11.9	14.4	123.3	10.1
90th	19.0	33.0	32.0	41.3	295.8	296.9

Source: Profundo modelling of fuel alternatives for EU fishing vessel fleet

xiv On a log-log graph, the labels on each axis increase by multiplying - such as 1, 10, 100, 1,000 - rather than by adding the same amount each time. The equal spacing between the labelled tick marks therefore represents a tenfold change, whether it is from 1 to 10 or from 100 to 1,000. This format is useful when the values range from very small to very large, because data across the full range fits clearly on the same graph rather than have most data points being bunched at one end of the range.

xv To reduce visual clutter, the fleet segment boundary at 18 metres is not shown.

Figure 2 Candidate fuels by vessel size

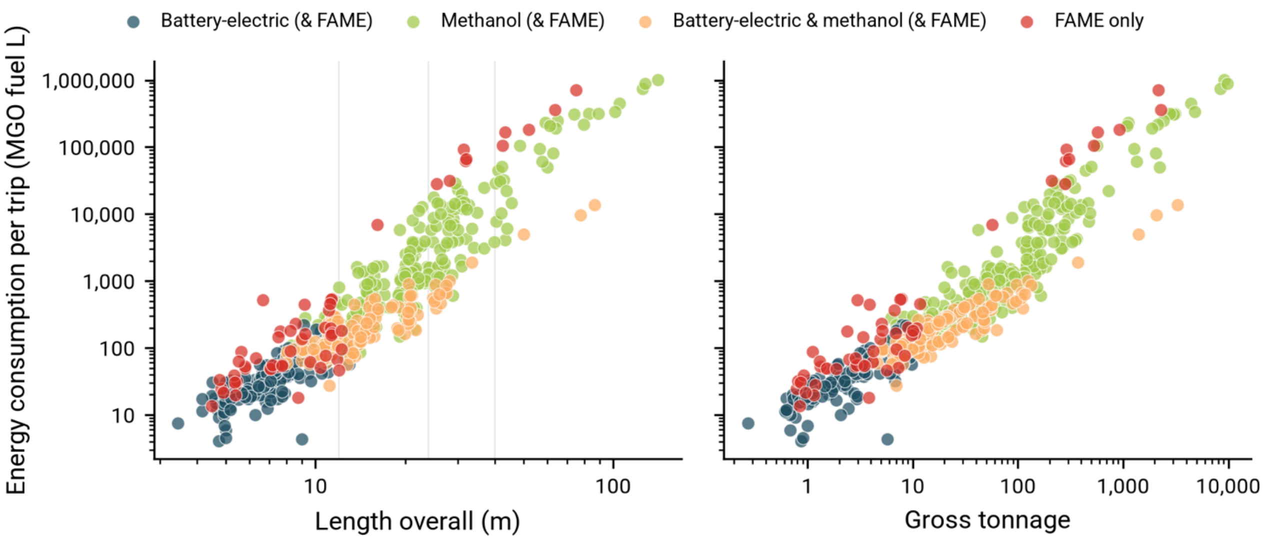


Source: Profundo modelling of fuel alternatives for the EU fishing vessel fleet

Figure 3 provides more clarity on why certain vessels are not candidates for the battery-electric or methanol options. Again, each dot in this figure represents a single fleet segment representative specification. This chart shows the length (left panel) and GT (right panel) of each representative vessel, plotted against energy consumption per trip, measured in litres of MGO fuel. Each dot represents a single vessel specification corresponding to a single fleet segment. Vessels with equivalent length or GT may have different energy needs, driven by varying daily fuel use and average trip durations. At each length or GT, vessels with lower per-trip energy needs tend to qualify as candidates for battery-electric or methanol propulsion, whereas vessels with higher per-trip energy needs are more likely to fall back on biodiesel because of its higher energy density. In these cases, the vessels do not meet the basic screening criteria in our model, and/or the increases in GT for the battery and/or methanol are simply beyond specified cutoffs.[xvi]

[xvi] As described more fully in the Methodology, no fuel that would require GT of a vessel to increase by more the 50% is deemed a suitable candidate fuel.

Figure 3 Candidate fuels by vessel size and energy use



Source: Profundo modelling of fuel alternatives for the EU fishing vessel fleet

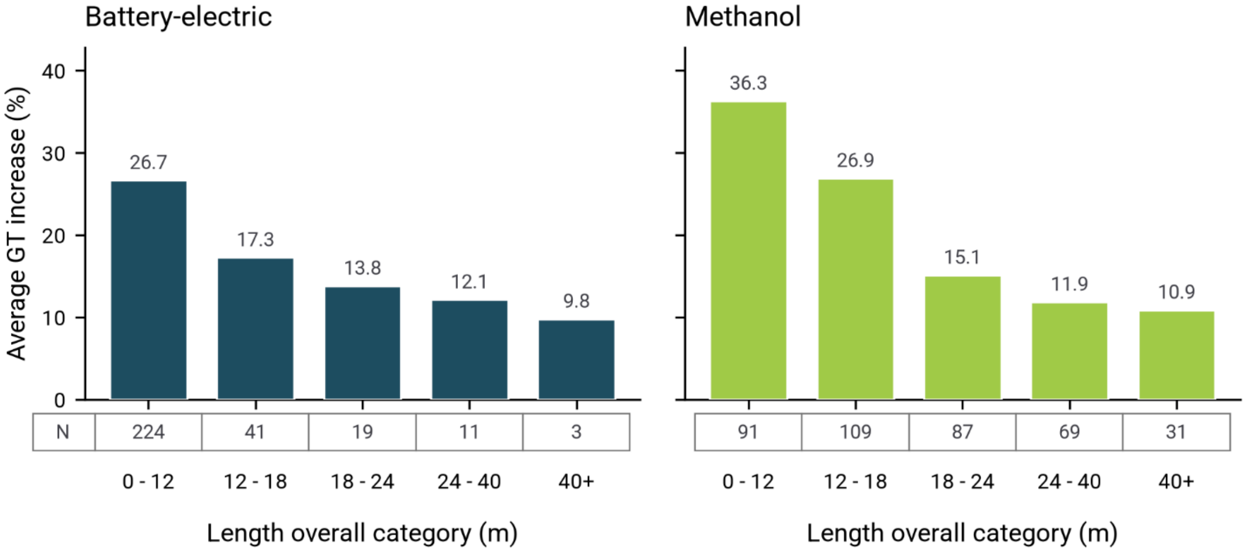
The vessels that qualify as both battery-electric and methanol candidates, shown as orange dots in Figure 2 and Figure 3, are notable because they include not only the expected smaller vessels but also some larger ones. Discussion within EU stakeholder groups and research on the EU fishing fleet has often focused on the viability of electric propulsion for the SSCF fleet, i.e., vessels under 12 metres in length [7,22]. Our analysis also identifies some longer vessels as battery-electric candidates. Although not part of the SSCF by definition, these vessels still have lower energy needs per trip than many other vessels of similar length and GT; lower energy use may be driven by shorter trip durations and the use of lower-energy fishing techniques. The existence of such electric candidates should not be surprising, as reported fleet-segment data show several fleet segments above the 12-metre classification with average trip durations of a single day. It is also consistent with operational evidence from the ferry examples discussed above. Although the needs of fixed-route ferries are not identical to those of fishing fleet vessels, they do demonstrate that battery-electric propulsion is viable on vessels substantially larger than those in the SSCF fleet.

GT Increases

Beyond simply identifying potential fuel candidates for each vessel specification, our model estimates the GT necessary to accommodate that fuel. The GT estimate is a component of determining whether a given fuel is a reasonable candidate, but it is also an interesting output on its own: it is crucial for assessing whether decarbonisation using these fuels requires GT increases that would conflict with fleet capacity ceilings.

The average increase in GT for vessels for battery-electric and methanol systems within each standard vessel-length class is shown in Figure 4. This figure shows the average increase needed for vessels falling into the standard vessel length categories of 0-12, 12-18, 18-24, 24-40, and 40+ metres. The left panel shows the results for the battery-electric candidates, and the right panel shows the results for the methanol candidates. For battery-electric propulsion, the average GT increase is 26.7% in the smallest length class (0–12 metres) and decreases to 9.8% for the largest battery-electric candidates. The trends for methanol are similar, with methanol-candidate vessels in the smallest length class showing a 36.3% increase in required GT and the largest vessels showing a 10.9% increase in GT. The number of candidate vessel specifications for each fuel and length class is shown in the row of boxes just below the x-axes in this figure. As observed earlier, battery-electric candidates are concentrated among smaller vessels, with a thin tail extending into the largest length class. Methanol candidates include some vessels at the high end of the shortest length class but are concentrated in the larger length classes. The value shown is an average across the length category and therefore does not reflect the full heterogeneity within each fleet class - some vessels will require more additional GT, and some will require less - but is useful as a general estimate. The overall trends are as expected.

Figure 4 Vessel GT increase by fuel and length class



Source: Profundo modelling of fuel alternatives for the EU fishing vessel fleet

The modelled changes are broadly consistent with the relatively limited available literature on fishing vessel design for these fuels. The Macduff Stage 2 report developed alternative-fuel concept designs for a 10-metre creel boat, a 15-metre Nephrops trawler, and a 24-metre whitefish trawler [28]. Its battery-electric 10-metre creel-boat design is notable in that it required *no* increase in GT, but it used batteries sized for two four-hour operations, with the intent that they would be recharged after each operation. Our model is designed to accommodate a higher (more-than-full-day) energy requirement and therefore treats an increase in GT as appropriate for battery-electric vessels. Another redesign effort for battery-electric propulsion, in this case a 9.8-metre vessel by a group of Korean naval architects, also shows agreement with our modelled changes [43]. That exercise focused on ensuring an equivalent capacity for a vessel that could undertake five consecutive days of single-day sailings without recharging, but a reworking of their approach to reflect our model's requirement of daily sailing with daily recharging (and accounting for our model's additional 50% safety margin as described in Appendix 1) yields a total increase in GT of 29.9%, similar to what we see at that length range in our modelling.

For its methanol designs, Macduff reports a 53.8% GT increase for the 10-metre creel boat, a 27.4% increase for the 15-metre Nephrops trawler, and a 19.4% increase for the 24-metre whitefish trawler. These are somewhat larger than, but still broadly comparable with, the modelled increases shown by our work. Macduff's designs lengthen the vessels not only to fit the larger methanol tank and cofferdams, but this also results in the creation of additional usable space: the 15-metre design shows an additional cabin that could support processing or an ice machine, while the 24-metre design includes a larger galley/mess and an additional metre of processing space. Our framework includes only propulsion-related changes in energy storage and explicitly excludes additional space for fishing, processing, accommodation, or other onboard functions. The two approaches therefore address the same underlying tankage and safety-space constraint, but

Macduff's headline GT increases also encompass design choices that can improve the vessel's wider fishing or onboard working arrangements beyond the intent of our model [28].

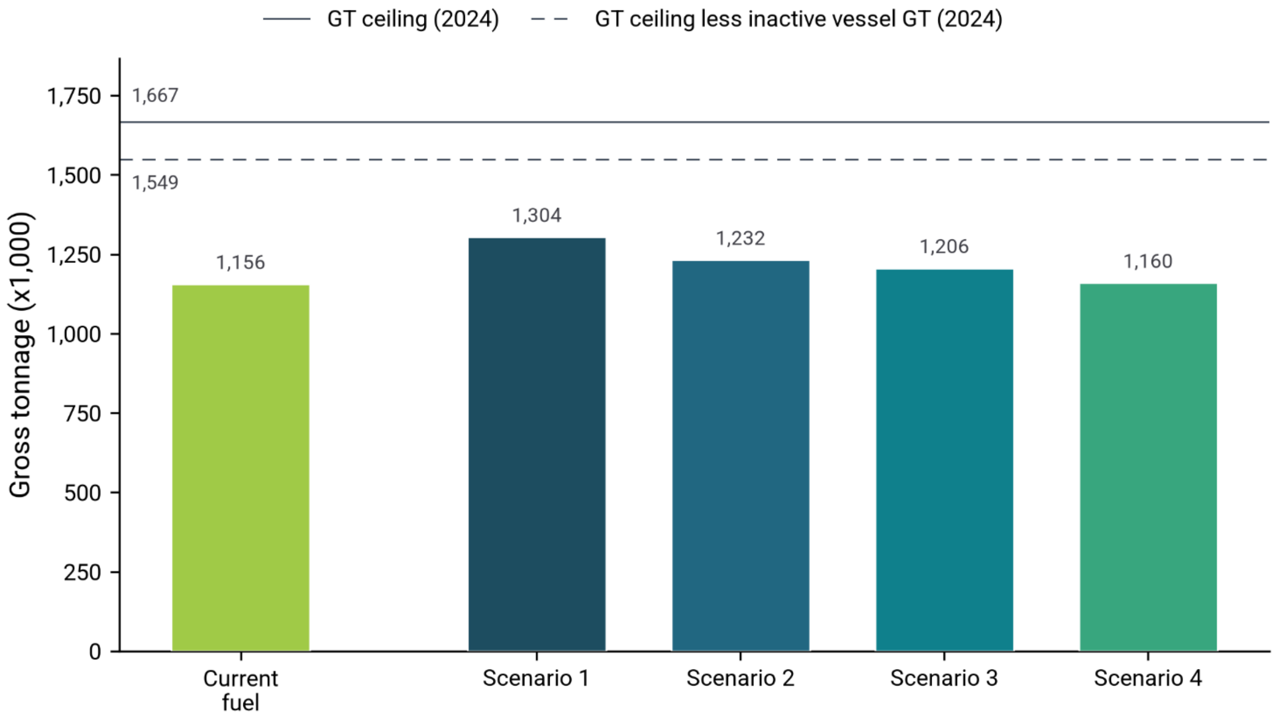
It is likely that increases in GT (and thus volume) to accommodate these alternative fuels could, in some or many cases, require increases in vessel length as well. Our model does not provide an estimate of the increase in length that would be necessary to accommodate the alternative fuels.[xvii] For the methanol cases, the space needed along the longitudinal axis of a vessel for a below-deck tank assembly is estimated as an internal parameter and is one of the criteria used to determine whether a vessel can be considered a methanol candidate. But because our model does not encompass a full vessel redesign, it does not estimate the net impact on vessel length, which could be more or less than the amount associated with the tank assembly itself. For battery-electric candidates, we do not use any internal length parameter and expect that battery storage positioning would be more flexible than that for a methanol tank with its cofferdams and other requirements, and so would likely have less impact on vessel length than methanol. More detail on the model's internal handling of methanol tank length is available in Appendix 1.

4.2.2 Scenario modelling and fleet impact results

The impact on the overall EU fleet GT under the four scenarios modelled is shown in Figure 5. This figure shows that Scenario One results in an increase in overall vessel GT of 16.7%, from 1,156,000 GT to 1,304,000 GT. Each of the subsequent scenarios has lower impact on GT: Scenario Two, 10.2%; Scenario Three, 7.9%; and Scenario Four, 3.7% In all cases, the EU total remains *substantially* below the aggregate Member State capacity ceiling of 1,667,000 GT (shown by the solid lines) as well as the aggregate capacity ceiling less the GT held by registered but inactive vessels (shown by the dashed line), which is a total of 1,549,000 GT. At the EU level, none of these scenarios comes close to breaching the GT capacity ceiling.

[xvii] The EU has, and Member States may have, regulatory measures that treat vessels differently according to their length. These may include the required use of tracking devices, availability of subsidies or other funding, electronic reporting of catch, or other matters. To the extent that decarbonisation via fleet renewal results in a smaller vessel being replaced by a larger vessel that crosses a regulatory threshold, different requirements may have to be met by the vessel operator. These are separate matters from those of the capacity ceilings, however, and are therefore not discussed in this study.

Figure 5 GT impact and ceilings – EU totals

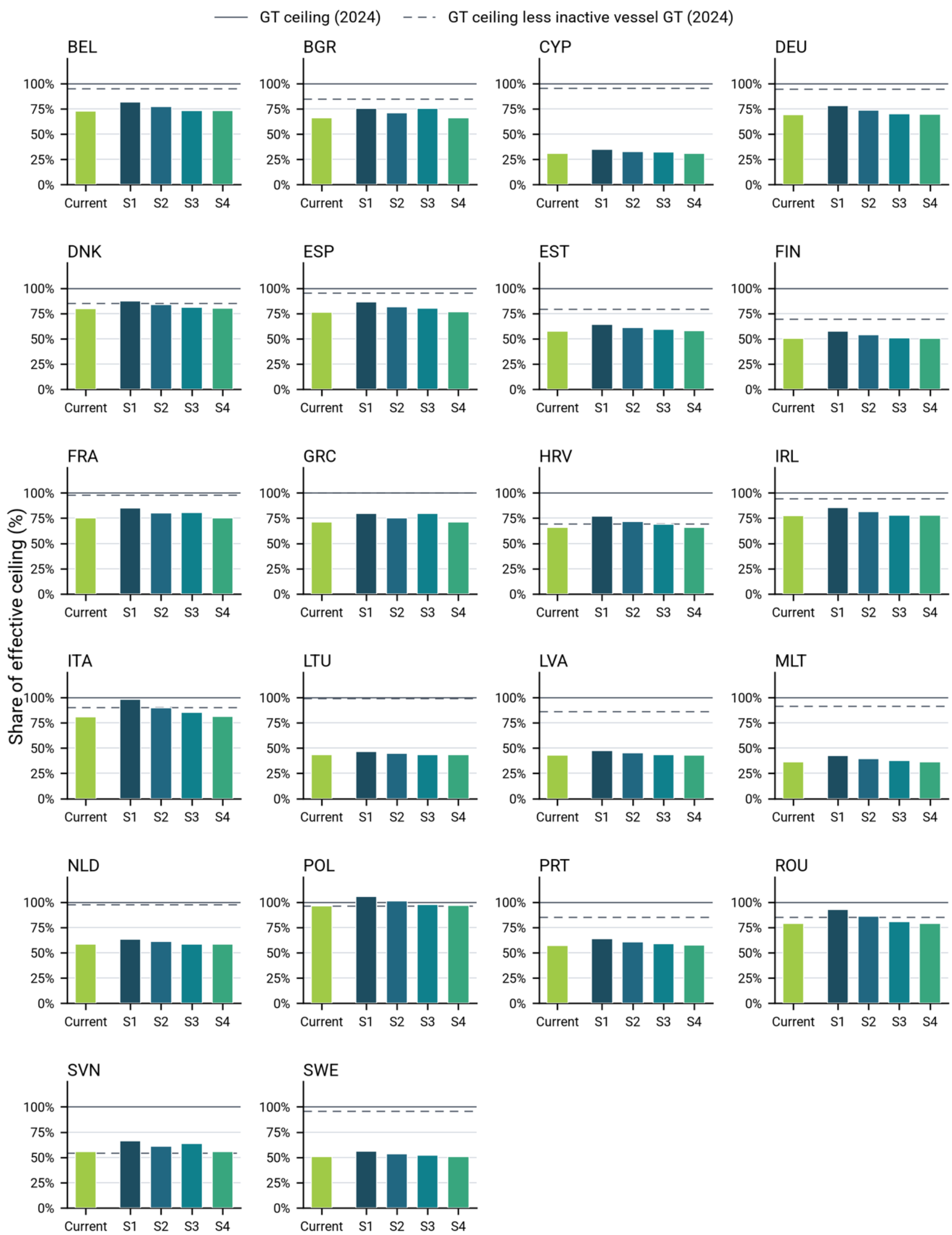


Source: Profundo modelling of fuel alternatives for the EU fishing vessel fleet

The impact of these scenarios on each Member State’s total GT and its relationship with the Member State’s capacity ceilings is shown in Figure 6. The presentation in this chart is identical to that in Figure 5, except that it presents a separate facet for each Member State and, instead of using the absolute GT measure, presents each Member State's GT totals under the scenarios as a percentage of that Member State's current GT ceiling level.

In our modelling, only one Member State's GT ceiling was breached. This occurred for Poland, which represents less than 3% of the EU’s total fleet GT, under Scenarios One and Two, which registered as 5.8% and 1.2% above the current GT ceiling, respectively. Notably, Italy comes close to - but still remains 2% under - its GT ceiling in Scenario One. In six cases, the modelled GT increases result in a Member State's GT total remaining below its ceiling level but exceeding the level of their GT capacity ceiling *minus* the amount of GT held by registered but inactive vessels. This includes Denmark (Scenario One), Croatia (Scenarios One and Two), Italy (Scenario One), Poland (Scenarios Three and Four), Romania (Scenario One), and Slovenia (all Scenarios). Although the level of the capacity ceilings minus the GT of inactive vessels has no legal relevance at the EU level, it may raise issues at the Member State level regarding vessel retirement and the exchange of capacity rights, as discussed further in Section 5.

Figure 6 GT impact and ceilings – member state detail



Source: Profundo modelling of fuel alternatives for the EU fishing vessel fleet

5

Discussion and conclusions

Discussion

The results of our modelling clearly demonstrate that the EU GT capacity ceiling regulation does not pose a material barrier to the decarbonisation of the fishing fleet. At an overall EU level, the increased GT needed to accommodate decarbonisation does not come close to the EU aggregate ceiling levels under any modelled scenario. Our findings at the Member State level also show that capacity ceiling regulations should not ultimately be a barrier to decarbonisation, but slightly more nuance is needed in interpreting the Member State results.

First, we present and discuss several general points that are relevant to interpreting and applying the results of our study. After that, we discuss these points in the context of Poland.

Data limitations & fluctuations in active fleet size

Due to data limitations, our model was applied to fleet segment data from 2023 while comparing against the latest available capacity ceiling levels. At the EU level, there has been a general, continuing downward trend in the size of the active fleet, as shown in Table 1 and in STECF's reporting on economics, balance and capacity [6,14]. As such, the use of two different years does not *ipso facto* represent a concern. In fact, this downward trend is likely to widen the gap between fleet capacity ceilings and the actual actively deployed capacity.

Although no general upward trend is observed in any Member State, the capacities of the active fleets do fluctuate modestly from year to year at the Member State level. Table 1 shows that eight Member States (Bulgaria, Cyprus, Germany, Greece, Lithuania, Malta, Portugal and Sweden) had higher active fleet capacity GT in 2024 than in 2023. If the same vessel-level analysis could be run on complete 2024 fleet-segment data – which would mean starting from a higher baseline for those Member States - the room between active fleet GT and capacity ceilings would therefore be somewhat narrower for those Member States. However, in none of those cases would the increase in GT required for decarbonisation exceed the Member State's ceiling, as is clear from a simple visual inspection of Figure 6. Understanding this issue is worthwhile, but it does not change the fundamental conclusion.

Timing of decarbonisation and fleet renewal

Our model calculation rests upon a 1-for-1 substitution of current vessels with low(er)-carbon vessels. It does not involve modelling over any time horizon or phase-in; the figures presented in this report represent an instantaneous transition. This is worthwhile for determining the magnitude of the GT impact, but it does not represent the reality of the timeline over which decarbonisation might occur. Phase-in will be slower, with vessels gradually leaving the fleet and being replaced by low(er)-carbon replacements.

The gradual nature of fleet renewal has two important implications for the interpretation of our results. First, there has been a well-established, gradual downward trend in the size of the EU fishing fleet, with vessels leaving the fleet both with and without state aid. As such, the GT capacities used in the model – which were those for 2023 - will likely decrease further. This, in turn, will further increase the gap between Member States' capacity ceilings and their registered capacity. As a result, Member States will likely have more GT available in the future for the purposes of decarbonisation than is shown in Figure 6. Any issues of "running into" capacity ceilings may therefore be reduced or eliminated by this process alone.

Second, the timing of a transition is uncertain; there are questions related to technological readiness and shipyard capacity, among others. A baseline case could be considered linear fleet renewal, meaning the same amount of capacity is replaced every year between now and 2050. A recent report prepared for the European Commission considered such a baseline, as well as several other timing options. Those analysts argued that a slower early ramp-up and stronger decarbonisation actions after 2040 would be more likely and more preferable due to the readiness and capacity issues [4]. If this were the case, the timeline for any concern about capacity ceilings would be pushed off even further into the future.

Fuel choices

The Scenarios chosen for modelling represent a range of ambitions. Our Scenario One is the most ambitious possible under the framework we have chosen, and it also has the largest impact on the fleet's GT. It may well be, however, that the decarbonisation pathways pursued by the industry will align more closely with some of our less ambitious scenarios, in which case less additional GT would be needed. Therefore, any cases in which Member States are modelled to exceed either the GT ceiling levels or their GT ceiling level minus the amount of GT represented by registered but inactive vessels might be rendered moot by vessel operators' decisions not to pursue the most ambitious decarbonisation routes possible. In this context, it is worthwhile to point out that some industry-oriented work openly advocates for biodiesel, which has the lowest GT impact, as the preferred - or at least easiest - decarbonisation pathway [3,32,40].[xviii]

Inactive vessel capacity management

The handling of the capacity of inactive vessels merits some attention at the Member State level. Registered inactive vessels count against a Member State's capacity ceiling even though they are not part of the active fleet modelled in this paper. Because of this, our analysis compared the increased GT needs associated with our scenarios not just with the Member State GT ceiling levels, but also with the lower level calculated as the Member State GT ceiling level minus the GT capacity held by registered, inactive vessels. Although the aggregate EU levels on this measure are not breached in any scenario, in six Member States (Denmark, Croatia, Italy, Poland, Romania and Slovenia), at least one modelled scenario projects the decarbonised fleet to exceed this more conservative measure. This means that, in those Member States, some of the GT increase needed for decarbonisation would have to be reallocated from the capacity now held by registered but inactive vessels. This could occur through withdrawal, transfer, reallocation or other national capacity-management mechanisms and may have implications for the use of state aid to assist in vessel decommissioning in certain instances. For most Member States, however, the capacity associated with inactive vessels could still be removed from the register and from the current capacity ceiling without undermining the modelled decarbonisation pathways. The inactive-vessel issue is therefore not a general argument for higher EU capacity ceilings, but rather a practical issue that a few Member States may have to address as a matter of national fleet management.

[xviii] It is interesting to note that the industry - though it should be acknowledged to be heterogeneous and not necessarily speaking with one voice - is saying two contradictory things: That the lowest GT impact pathway, which has no interference from capacity ceilings, is preferred, but simultaneously, that capacity ceilings should be raised anyway.

Fishing techniques and fisheries balance

EU fisheries continue to show substantial imbalance between fleet capacity and fishing opportunities in a significant number of fleet segments. The latest STECF assessment found that 35 of 125 North Atlantic segments and 46 of 81 Mediterranean and Black Sea segments for which the Sustainable Harvest Indicator (SHI) could be meaningfully assessed were biologically out of balance. Other biological, economic, and technical indicators also identify imbalance in substantial parts of the fleet [6]. The CFP requires Member States to adjust fleet capacity to fishing opportunities and to establish action plans where structural overcapacity is identified [5]. Reductions in fleet capacity made for reasons of fisheries balance would reduce the baseline fleet size, and thus the GT impact of alternative fuel adoption as well, relative to the modelled scenarios.

Furthermore, some energy-intensive fishing techniques have important environmental effects separate from their carbon emissions. Bottom trawling, including beam and demersal trawling, is associated with high fuel consumption and can cause significant environmental damage via seabed abrasion and disturbance [3,44]. Replacing these techniques with less-damaging techniques is therefore important for reasons beyond just decarbonisation, but would also reduce total energy requirements - and thus fuel storage needs – even without changes in overall GT. But a future fleet with fewer vessels engaged in energy-intensive operations could result in less additional GT for alternative-fuel adoption than estimated in our model, which assumes a status quo mix of fishing techniques.

Implications for Poland

Taken together, the points in the foregoing discussion give good reason to expect that even for the case of Poland – which represents just 3% of the EU's total fishing fleet GT capacity and is the only Member State that would exceed its GT capacity ceiling in any of our modelled scenarios – the capacity ceilings may not end up being a problem in reality.

First, the GT of Poland's active fleet declined from 2023, the year that we used as input to our model, to 2024. The reduction amounted to 3.2% of the 2023 GT capacity figure. Our Scenario One showed Poland exceeding capacity by 5.8%; starting from a 3.2% lower capacity would reduce this projected overage for Scenario One significantly and eliminate the overage for Scenario Two.

Second, the timing of fleet renewal means that the date at which the fleet GT capacity ceiling could become relevant is some years off. Starting with the figure in our model, if an equal amount of the Polish fleet's GT capacity were renewed each year from 2027 until 2050, the capacity ceiling would not be reached until 2035. But as discussed, the long-term trend is that fleet capacity is shrinking and a fleet renewal process that begins slowly and accelerates closer to 2050 means that the year in which the capacity ceiling might potentially come into play could be (significantly) later than 2035.

Third, our Scenario One is the most ambitious scenario with the largest GT impact. If Polish vessel owners chose to adopt a less ambitious scenario, e.g., with a higher mix of biodiesel, the total additional GT needed would be reduced relative to our Scenario One.

Fourth, the level of imbalance in Poland is significant. According to STECF's most recent report, four out of the seven fleet segments for which the SHI could be assessed were out of balance [6]. According to STECF, these four segments represented nearly 72% of the reported value of Poland's catch. Our own analysis shows that these fleet segments represent 76.5% of the GT of Poland's fleet in segments for which the SHI indicator was available, the third highest of all EU Member States, and that more than 95% of this GT was in trawler fleet segments. This suggests that Poland may be among the most exposed Member States to reductions in fleet capacity due to balance considerations.[xix] If such reductions were to occur, this would also likely reduce the additional GT needed for decarbonisation relative to the scenarios we modelled.

Conclusion

Some industry representatives have claimed that current capacity ceilings limit the potential for decarbonisation and have argued for changing capacity limits or definitions, but those claims do not withstand the scrutiny of the analysis presented here. This study directly examines whether the EU GT capacity ceilings need to be increased to accommodate full decarbonisation of the EU fishing vessel fleet, using quantitative modelling with representative vessel specifications for every active fleet segment across the entire EU fleet to identify the capacity increases needed for battery-electric, methanol, and FAME biodiesel options. To our knowledge, this is the first analysis of its kind at this scale. The central finding is that the GT effect of decarbonising the EU fishing fleet is real but manageable. Existing unused capacity is sufficient at the EU level to accommodate the modelled transition pathways, including the most ambitious scenario considered here, and Member State-level concerns are limited and specific rather than systemic. Current EU fleet capacity ceilings therefore do not present a material barrier to decarbonisation, and the results provide no basis for a general or systemic increase in GT capacity ceilings.

[xix] Poland reported 14 active fleet segments. The seven fleet segments for which an SHI could be assessed is therefore only half of all fleet segments and less than half of Poland's total fleet GT.

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Appendix 1 Detailed methodology

The model Profundo applies in this paper identifies the additional volume, and thus GT, required to adopt alternative, lower-energy-density fuels on fishing vessels while keeping the other space use on the vessels unchanged. We term the input to the model a *vessel specification*, as explained more fully below. Each specification represents a single actual or hypothetical vessel. The model's output is a revised GT value.

For this paper, the model uses fleet specifications derived from Member State-reported and STECF-aggregated fleet-segment data. Although STECF's latest reports pertain to 2024, the 2024 data in those sources is not sufficiently complete to permit the necessary analysis. Therefore, we rely on 2023 fleet segment data. For 2023, STECF reports data on 602 active fleet segments. Vessel segments corresponding to inactive vessels are excluded. We develop a single specification for each of these 602 fleet segments. In this context, a fleet segment is defined as "a group of vessels with the same length class and predominant fishing gear during a given calendar year" [15]. In practice, most EU Member States also further differentiate fleet segments using geographical indicators and, occasionally, fishing gear and activity levels.[xx] Although there is some heterogeneity within each fleet segment, vessels within the same segment are by definition similar in many respects, and therefore average measures drawn from the fleet segment data provide reasonable modelling inputs.

Certain data points, including the main fishing technique, average length, and aggregate GT of vessels within a segment, are available for all 602 segments. EU data-collection rules, however, permit Member States to aggregate certain data elements across multiple fleet segments for the purpose of maintaining data confidentiality or to design a statistically sound sampling plan. These are referred to as "clustered" fleet segments. As such, not all data elements are available for all 602 segments.

The model relies on the following reported data points for each fleet segment: number of vessels, mean length overall, total GT, fishing technique, geographical indicator(s), total days at sea, number of fishing trips, total energy consumption (measured in litres of MGO), and GT-days at sea, as well as MGO tank volume estimated from the other data points in the specification.

Data is present in the 2023 data for all fleet segments for the first five variables listed. For the three key data points total days at sea, number of fishing trips, and total energy consumption, data is available for fleet segments comprising 51,237 (96.2%) vessels accounting for 86.7% of total GT. Data for GT-days at sea are available for segments comprising fewer than half of the vessels (but 56% of total vessel GT), but this value can be estimated from the product of average GT per vessel and total days at sea, or imputed as explained below.

For cases where the key operational data are missing, data can be imputed from similar fleet segments (matched on vessel length group and active/passive fishing technique). The data elements directly imputed in this work, when needed, are energy consumed per sea day and days at sea per trip. The ratio of reported energy consumption to GT-days at sea is set to the median observed value for non-clustered segments in the same vessel-length class and active/passive gear category when it cannot be computed from directly reported data. Days at sea per trip are set to the median of that measure for the same group when it cannot be computed from directly reported data.

These inputs, whether reported or imputed, are then used to calculate fuel consumption per trip and per day for each fleet segment. For cases where multiple fleet segments are clustered together, imputed values are always used for the finest-grained fleet segments within a cluster

[xx] For some Member States, all fishing vessels operate in a single geography (e.g., the North Atlantic). For other Member States, fishing activities can be spread across multiple geographies, including the North Atlantic, the Mediterranean and Black Sea region, international waters, and outlying areas such as Pacific Island territories.

because we deem them more accurate than measures derived from combinations of multiple distinct length classes.

Because no reported data directly indicate actual tank capacity in the fleet, the model estimates a needed MGO tank capacity for each representative vessel specification. Because estimated fuel volume needs, and thus our output GT increase, are derived from this quantity, we choose to err on the side of *overestimating* the size of the tanks needed, such that our model would err on the side of *overestimating* the GT increase needed. The calculation proceeds in three steps as follows: First, for non-clustered fleet segments, 75th-percentile fuel consumption per day is estimated using a vessel-count-weighted percentile regression of fuel consumption per day against mean vessel length overall. A 75th-percentile trip duration (in days) is assigned within per-vessel GT groups of 0-10, 10-100, 100-200, 200-400, and 400+ GT. A fuel consumption per trip that we deem to be towards the high end of the distribution is then taken to be the product of the two 75th-percentile measures.[xxi] Second, a *minimum* MGO tank capacity for each vessel segment specification is then taken to be the larger of the resulting estimated fuel consumption per trip or five times the estimated fuel consumption per day, with the implied five-day refuelling cycle deemed reasonable for vessels that return to port more often than that. Finally, the final tank capacity assigned to a fleet segment's representative specification is then taken to be the larger of that minimum or 150% of the fleet segment's average fuel consumption per trip calculated from directly reported data. The value of 150% is taken to reflect likely variation of trip duration above the average, as well as to reflect a margin of safety for unpredictable fuel usage. This approach allows us to err on the side of larger fuel capacity needs both for long-distance/long-sailing fleet segments (e.g., vessels going to sea for a month or more) that will refuel at every port visit, as well as to make reasonable estimates for the actual tank capacities of smaller vessels that may return to port each night but only need to refuel after multiple sailings. This MGO tank capacity provides the baseline fuel-storage volume for the alternative-fuel cases.

We then determine which vessel specifications are candidates for battery-electric and methanol systems.

Battery-electric candidates are vessels with trips whose use pattern is limited to one-day sailings (we used a cutoff of 1.05 to account for potentially noisy data) and that have a daily MGO use with total volume below 1% of the estimated vessel volume. For eligible vessels, the battery-electric energy storage requirement is estimated as 150% of the specification's actual or imputed MGO-equivalent daily energy use. The model uses an MGO energy density of 36.6 GJ/m^3, an MGO drivetrain efficiency of 35%, and an electric drivetrain efficiency of 90%. It therefore converts each litre of MGO-equivalent daily use into 3.95 kWh of required battery-output energy (10.17 kWh/litre × 0.35 ÷ 0.90), before applying the 150% capacity multiplier. The required battery volume is then calculated using an assumed installed battery energy density of 80 kWh/m^3.

The 35% diesel-engine efficiency assumption was used as a conservative representative value for the existing EU fishing fleet. This is below some reported efficiencies, e.g., the 41% efficiency implied by the EMEP/EEA Guidebook default specific fuel consumption for high-speed MDO/MGO marine diesel engines at cruise (205 g/kWh, using 42.7 MJ/kg LHV), but above the roughly 28–32% implied by lower-load operating conditions; it therefore provides a cautious fleet-average simplification for an older, heterogeneous fishing fleet rather than a best-in-class engine value [45,46]. The 90% electric-system assumption is conservative relative to what some manufacturers report (e.g., an approximately 95% motor efficiency reported by ABB Ltd). The 80 kWh/m^3 installed-density assumption is close to the 72 kWh/m^3 average recorded for marine battery systems in an ICCT assessment but below that used in some estimates [43,47–49].

[xxi] We examined using a high (e.g., 90th) percentile value of the fuel per trip as directly reported, but after sorting vessels into the appropriate number of categories, the statistical power at the high end of the distributions was not sufficient to permit this. We therefore used the product of the 75th-percentile measures derived from the two distributions as described, which we deem likely to exceed the 75th percentile of the pairwise direct product distribution itself.

The methanol candidate assessment begins with the total energy content of MGO fuel that can be held by the estimated MGO tank capacity. The required methanol volume is calculated using MGO and methanol liquid energy densities of 36.6 GJ/m^3 and 15.8 GJ/m^3, respectively. This produces a conversion factor of 2.32 litres of methanol per litre of MGO capacity [29]. The storage is modelled as a below-the-main-deck tank assembly with cofferdams and associated fuel-preparation equipment, in accordance with the design considerations in the Macduff Stage 2 report [28]. We determine maximum whole fuel-tank-assemblage width and height constraints for each representative vessel specification's length based on our own analysis of more than 60 fishing-vessel specification documents (as referenced earlier in this paper). A vessel is not treated as a methanol candidate if the longitudinal length of the tank assembly, including cofferdams and associated equipment, would exceed 25% of the current vessel's length.

The FAME case applies the same approach as the methanol case for determining the energy required from the baseline MGO tank capacity, but no additional cofferdams or other buffers are necessary for the FAME case. The model uses an FAME energy density of 33.0 GJ/m^3, resulting in a conversion factor of 1.11 litres of FAME per litre of MGO capacity. Because the FAME energy density is very close to that of MGO fuel, every vessel specification is deemed a candidate for FAME biodiesel.

For each alternative-fuel case, the model converts the representative specification's GT to volume in cubic meters, adds the applicable alternative-fuel storage volume estimated, and then subtracts (a portion of) the estimated existing MGO tank volume. This volume is then converted back to its GT equivalent. The GT/volume conversions are in accordance with the method in Regulation (EU) 2017/1130 and the 1969 International Convention on Tonnage Measurement of Ships [50,51]. In the battery-electric case, no more than half of the MGO tank volume is considered available for battery installation.

Vessels are not considered to be candidates for a particular alternative fuel if the increase in GT required to accommodate that fuel relative to the base vessel specification is more than 50%. This naturally leads to the exclusion of battery-electric as an option for many larger vessels and of methanol for many smaller vessels.

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