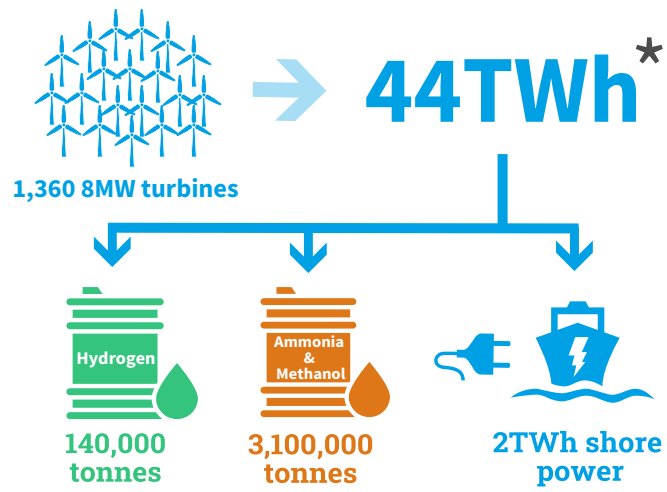
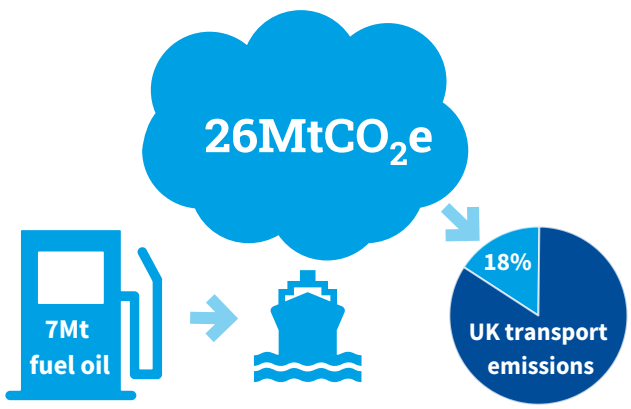
Implications of an e-fuel mandate for UK shipping

April 2023

In March 2023, the UK government published assumptions for how much low-carbon shipping fuel will be required in 2035 to stay within the carbon budgets. T&E calculate that meeting these assumptions with a combination of **zero emission renewable e-fuels** and **direct electrification** - the most cost-effective options - would require **44TWh renewable electricity,** to produce **140,000 tonnes hydrogen**, **3.1 million tonnes ammonia/methanol**, and nearly **2TWh shore power**. 44TWh would require an additional **1,360 8MW wind turbines**.



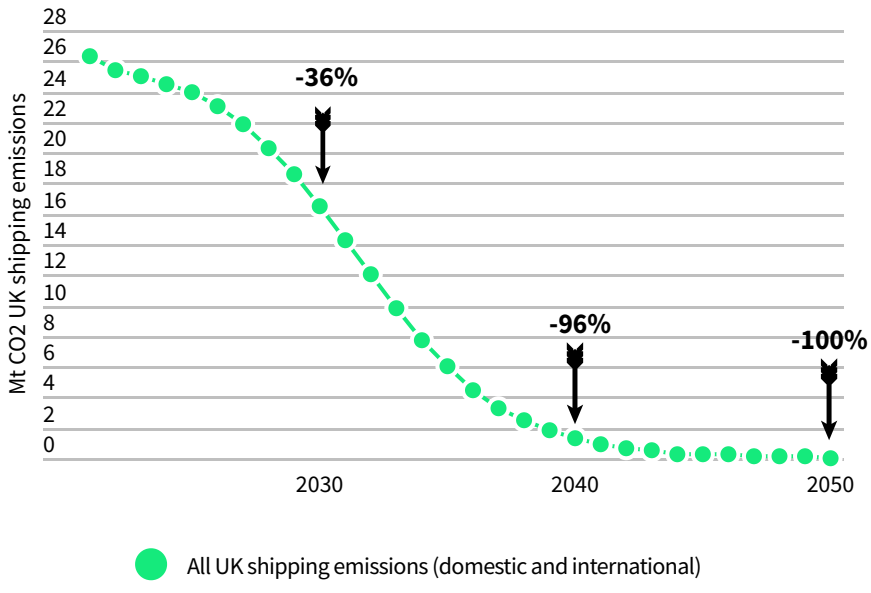
* Total UK wind generation in 2021 was **49TWh**



In 2021, UK shipping used over **7 million tonnes** of fossil marine fuel oils, producing more than **26 million tonnes of carbon dioxide equivalent** and accounting for **18%** of UK transport emissions.

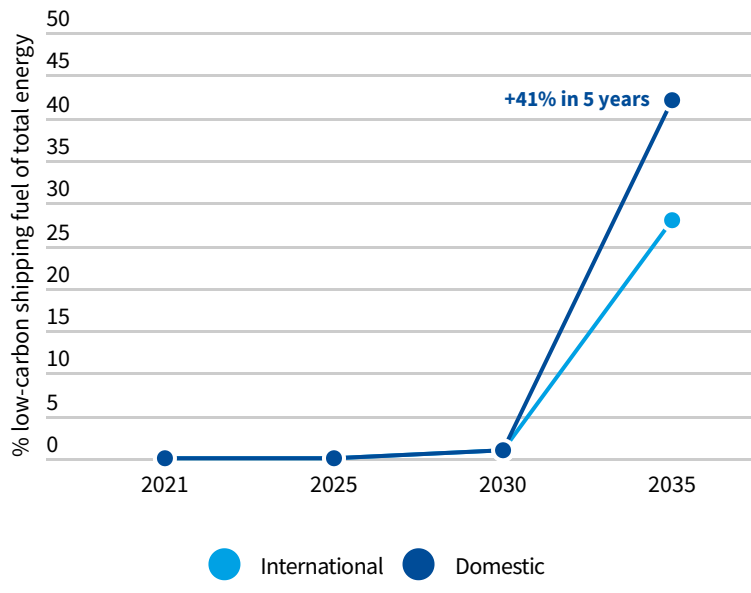
Net Zero requires these emissions to be eliminated by 2050, and significant reductions are required by 2030 and 2040 for the UK to remain compliant with the carbon budgets.

How UK shipping emissions must reduce to zero



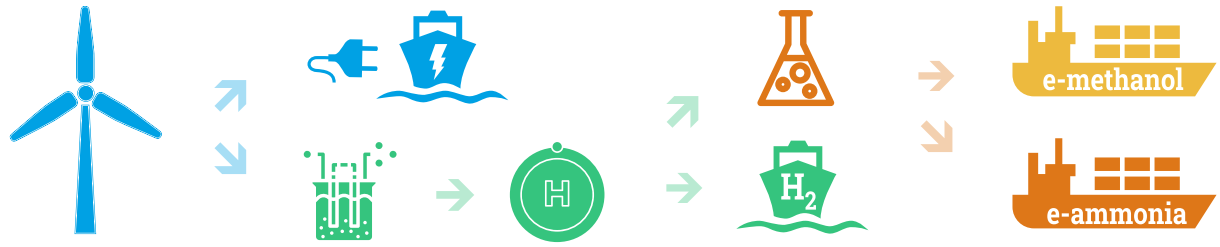
The UK government has endorsed the **Science Based Targets initiative (SBTi)** at the **International Maritime Organization (IMO)**, an emissions reduction pathway compatible with the climate goal of the Paris Agreement. SBTi requires emissions cuts of **36% by 2030** and **96% by 2040**. When applied to UK shipping, emissions need to decline as shown above.

Required uptake of zero-emission fuels



To stay within the carbon budgets, the UK government assumes **1% of all UK shipping fuels used in 2030** must be low-carbon, increasing to **28%** and **42% in 2035** for UK international and domestic shipping, respectively.

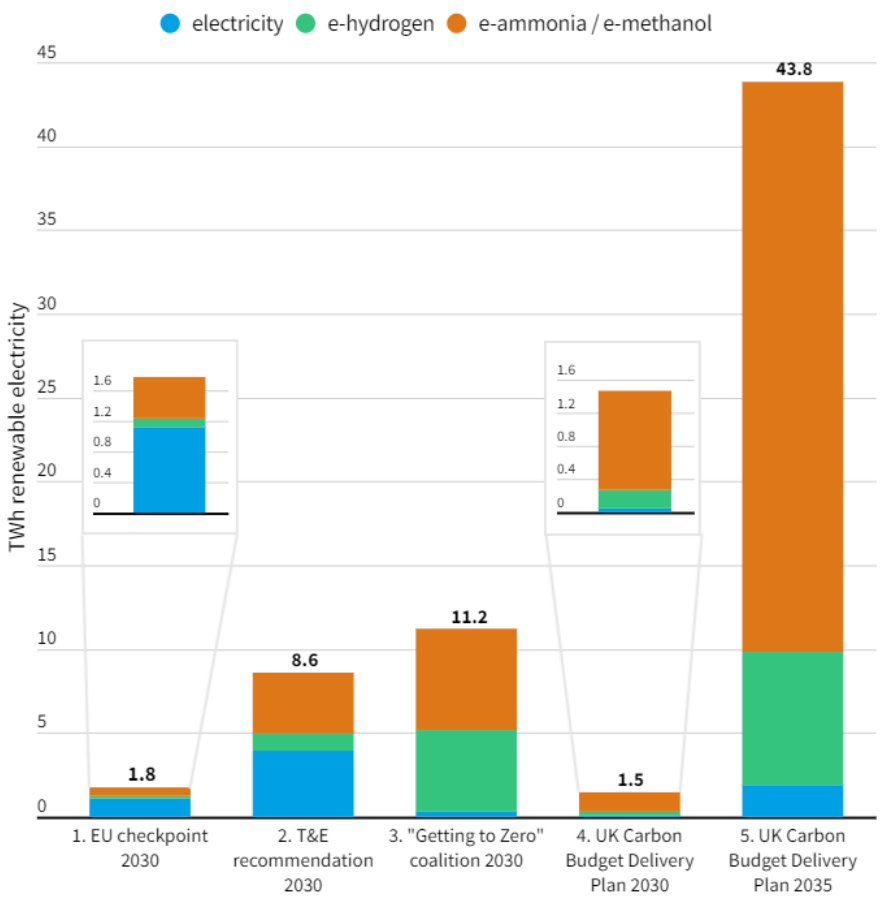
Zero-emission shipping fuels will be required to achieve these pathways. T&E analysis shows the least-cost, scalable technology options to be based on **renewable electricity**: directly for **battery electric charging** and **power requirements at berth**, and indirectly though **e-hydrogen** and **e-hydrogen-based e-fuels** such as **e-ammonia** and **e-methanol** for propulsion.



T&E recommends the use of fuel mandates to drive the uptake of such fuels. Mandates are effective instruments already in use by the UK government. Here, we show the energy requirements for the UK of implementing five different zero emission mandate scenarios. Each scenario assumes fulfilment with a combination of **direct electrification** and **green e-fuels**, using **100% renewable electricity**.

	Scenario	% zero emission fuel mandated in the UK (energy basis)	Year
1.	Recently agreed checkpoint under EU law	1%	2030
2.	T&E recommendations for UK / EU / global shipping	6%	2030
3.	Getting to Zero coalition	5% international, 30% domestic	2030
4.	UK Carbon Budget Delivery Plan	1%	2030
5.	UK Carbon Budget Delivery Plan	28% international, 42% domestic	2035

Electrical energy* required to meet mandates



* Includes electricity required for electrolysis, carbon or nitrogen capture and for e-fuel synthesis

Total electricity required

	TWh	Turbines
EU checkpoint 2030	1.8	55
T&E recommendation 2030	8.6	267
'Getting to Zero' coalition 2030	11.2	349
UK Carbon Budget Delivery Plan 2030	1.5	46
UK Carbon Budget Delivery Plan 2035	43.8	1359

= 50 x 8MW turbines

In 2021, UK shipping used almost 7 million tonnes (Mt) of fossil marine fuel oil, producing 26.3 Mt of carbon dioxide equivalent (CO_2e) and accounting for over 18% of UK transport emissions.[1]

The UK government is currently considering policies to decarbonise the UK shipping sector, for publication in the Clean Maritime Plan later in 2023. But at the time of writing, the Government has not published or committed to a decarbonisation pathway for UK shipping, or a policy framework to achieve it.

At the level of the International Maritime Organization (IMO) however, the UK has endorsed and supports a goal-based maritime emissions reduction pathway called the Science Based Targets initiative (SBTi)[2]. SBTi is compatible with the climate objective of the Paris Agreement and requires emissions reductions of 36% on a 2020 baseline by 2030, and 96% by 2040. SBTi is intended to guide IMO, national and company-level emissions reduction pathways. It is therefore an appropriate trajectory for UK shipping, which we have used for this analysis.

To meet the SBTi pathway (and any Paris-compatible decarbonisation trajectory) will require large-scale use of zero-emission marine fuels and energy. Because there are no scalable drop-in zero-emission replacements for current fossil marine bunker fuels, non-fossil alternative technologies such as the renewable e-fuels and direct electrification featured in this report must be introduced and scaled far faster than typical rates of fleet turnover. Normal market conditions, even with carbon pricing under current proposals to include a small percentage of UK shipping in the UK Emissions Trading Scheme, will not precipitate the technological transition required. An incentive mechanism is needed.

Mandates are effective instruments to drive the uptake of near-zero- and zero-emission transport fuels. The UK already uses such a mandate (the development fuels sub-target) through the Renewable Transport Fuel Obligation (RTFO), whilst another for sustainable aviation fuel is being designed. A mandate either for zero- or near-zero-emission shipping (or specifically on shipping fuels) will certainly be necessary to create a market for both the supply and use of these fuels, and achieve the required emissions reductions for Net Zero and the UK carbon budgets.

In the maritime sector, policies and precedents for mandating zero emission shipping fuels already exist. These include EU regulation on renewable shipping fuels of non-biological origin (RFNBO), and the UK's own low-carbon fuel uptake assumptions set out in the Carbon Budget

Delivery Plan from March 2023. These could and should be used to inform and underpin how the UK configures maritime decarbonisation policy and sets binding targets.

To decarbonise the UK's maritime sector, T&E favours a combination of shore power and battery-electrification, and zero-emission e-fuels including e-hydrogen and e-ammonia. All technologies require 100% renewable electricity. T&E modelling[3] of the European shipping sector shows that the above e-fuels are likely to be the least-cost, zero-emission alternative fuels to conventional fossil marine fuels. At present, sector interest is growing in e-methanol which, although more expensive than e-hydrogen or e-ammonia on a total cost of operation (TCO) basis[4], has certain advantages over other e-fuels including lower toxicity and relative ease of handling. We include all three fuel options in this analysis.

T&E does not support the use of biofuels or biomass in shipping. As advised by the Climate Change Committee[5], biofuel in maritime applications is a non-optimal use of bioenergy even in the short-term, and will simply delay the introduction of zero-emission fuels and technologies.

Methodology

Using the UK's 2021 shipping emissions inventory described above, T&E has calculated the UK shipping sector's current energy requirement based on an average fuel emissions factor of 75.34 gCO_2/MJ[6]. From this we have determined quantities of renewable e-hydrogen, e-ammonia, e-methanol and electricity necessary to replace percentages of current fossil fuel use with zero-emission alternatives according to the amount specified in each scenario. We have also determined the quantity of renewable electricity necessary to produce these e-fuels using efficiencies from Concawe's 2022 assessment of European e-fuel production[7] for water electrolysis, the Haber-Bosch and methanol synthesis processes.

All estimates of energy requirements include the entirety of the production process, including supplying heat to the reaction and any necessary liquefaction or pressurisation. We have illustrated quantities of fuels in tonnes for the headline scenario and also the overall electricity requirement for all scenarios, including the number of wind turbines[8] necessary for each.

Scenarios

We have adapted the five mandate scenarios set out below to illustrate how much renewable electricity would be required to replace current use of fossil fuels with the selected zero-emission alternative technologies at the percentages given. The different scenarios specify the use of RFNBO, zero-emission fuels and low-carbon fuels, respectively. The definitions of these fuels (where given) vary. However, as the technologies selected for this analysis represent

the least-cost options to achieve zero-emission shipping, we have limited the analysis to these technologies only.

Scenario	UK target
Fuel EU Maritime (recently-agreed checkpoint under EU law)	1% RFNBO[9] by 2031, all commercial cargo and passenger vessels above 5000GT excluding fishing vessels. 100% energy used within a port of call[10] and on voyages between UK ports; 50% energy used on voyages between UK and non-UK ports
T&E's recommendations (for the UK, EU and global shipping)	6% RFNBO by 2030, all vessels above 400GT. 100% energy used within a port of call and on voyages between UK ports; 50% energy used on voyages between UK and non-UK ports
Global Maritime Forum's "Getting to Zero" coalition (endorsed by the UK at the IMO)	30% domestic and 5% international shipping powered by zero emission fuel[11] in 2030
UK Carbon Budget Delivery Plan 2030	1% domestic and international shipping using low-carbon fuels[12] [13]
UK Carbon Budget Delivery Plan 2035	42% domestic and 28% international shipping using low-carbon fuels

We estimate the following allocation of fuel and energy use[14] for all scenarios:

Emissions source	**Abatement technology assumed**
At-berth domestic and international vessels	Shore power
Domestic ferries	Battery-electric
International ferries	Liquefied e-hydrogen internal combustion
Other domestic vessels	Liquefied e-hydrogen internal combustion
Other international vessels	E-ammonia / e-methanol internal combustion

Further work

In addition to fulfilment of any UK zero-emission shipping mandate, further abatement will be necessary for compliance with the SBTi pathway. This is because, even if the Carbon Budget Delivery Plan assumptions for low-carbon marine fuel uptake for UK domestic and international

shipping correlate directly to emissions reductions, a maximum of 30.5%[15] abatement would be achieved in 2035, compared to the SBTi target of 77% reduction by the same date.

Additional consideration must therefore be given not only to the low-carbon fuel uptake assumptions, but also to targets and even mandates for energy efficiency technologies (to maximise their use by 2025 as envisioned in the Clean Maritime Plan[16]) and speed reduction. However, as this is beyond the scope of this analysis we include these as policy recommendations only, consistent with our response to the Course to Zero consultation[17].

Further information

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Endnotes

1. Emissions calculated using 2021 AIS data and based on full geographical scope United Kingdom Monitoring, Reporting and Verification (UK MRV) regulations (which includes domestic and international) plus sub-5000 gross tonnage (GT) and other non-MRV commercial vessels. All inbound, outbound, intra-UK voyages and at-berth emissions from these vessels are included. Reflecting the Science-Based Targets initiative (SBTi) which the UK has endorsed at the International Maritime Organization, emissions are expressed as well-to-wake (WTW), carbon dioxide equivalent (CO_2e). Conversion factors taken from FuelEUMaritime proposal. The UK government does not count emissions from UK international aviation and shipping bunkers towards the UK greenhouse gas emissions totals as reported to the UNFCCC. However, the methodology used for this briefing uses the full geographical scope of the UK MRV regulations and therefore includes both domestic and international emissions. For completeness, we also include the UK's share of international aviation emissions in the total. UK transport emissions calculated for 2021 as 109.5MtCO_2e from government 2021 data tables, replacing 5.3Mt domestic shipping emissions with T&E's calculated 26.3Mt of domestic and international shipping emissions and including 13.3Mt UK international aviation emissions. Total 2021 UK transport emissions 143.8Mt CO_2e. Fuel quantity back-calculated from emissions using an average emissions factor (75.34gCO_2e/MJ, tank-to-wake) for all voyages reported under the European Union MRV regulations in 2020. This is a reasonable proxy for an average UK emissions factor in the absence of published UK MRV data.
2. The Science Based Targets initiative (SBTi) (IMO reference code *ISWG-GHG 14/2/9, 3 February 2023, Refining the levels of ambition in the Revised IMO Strategy on reduction of GHG emissions from ships (by Canada, United Kingdom and United States)*) was presented to the IMO in October 2022 and is aligned to the 1.5 degree temperature goal of the 2015 Paris Agreement (IMO reference code *ISWG-GHG 13/INF.2, 21 October 2022, Science-based target setting for the maritime transport sector*). The "S" curve depicted in this report accommodates a slower initial rate of abatement whilst zero-emission technologies are scaled up. The cumulative emissions are approximately the same as for a linear pathway. 2021 is used as the baseline year as it is the first year following the UK's exit from the European Union.
3. Shipping Technological Roadmap to Decarbonisation (April 2021), T&E. Accessed at https://www.transportenvironment.org/wp-content/uploads/2021/07/202104_Shipping_Technological_Roadmap_to_Decarbonization.pdf
4. Techno-economic assessment of zero-carbon fuels, Lloyds Register and UMAS, March 2020. Accessed at https://www.lr.org/en/insights/global-marine-trends-2030/techno-economic-assessment-of-zero-carbon-fuels/
5. The Sixth Carbon Budget, Shipping, Climate Change Committee. Accessed at https://www.theccc.org.uk/wp-content/uploads/2020/12/Sector-summary-Shipping.pdf
6. See footnote 1
7. E-fuels: A techno-economic assessment of European production and imports towards 2050, Concawe, November 2022. Accessed at https://www.concawe.eu/wp-content/uploads/Rpt_22-17.pdf
8. Assuming an average capacity of 8MW and capacity factor of 46%, consistent with the current best-performing UK offshore sites.
9. RFNBOs = Renewable Fuels of Non Biological Origin, as defined by the first EU Delegated Act to the revised Renewable Energy Directive (EU) 2018/2001, accessible at https://energy.ec.europa.eu/publications/delegated-regulation-union-methodology-rfnbos_en. RFNBOs are typically produced from renewable hydrogen. Relevant RFNBOs for shipping include e-hydrogen, e-ammonia, e-methanol, e-diesel, e-LNG.
10. The FuelEUMaritime regulation requires use of shore power by vessels in scope, but does not specify that this electricity needs to be 100% renewable. For the purposes of this analysis however, we assume that all shore power used in the first two scenarios is renewable, as per T&E's recommendation.
11. Five percent zero emission fuels by 2030 needed for Paris-aligned shipping decarbonization, Global Maritime Forum. Accessed at https://www.globalmaritimeforum.org/news/five-percent-zero-emission-fuels-by-2030-needed-for-paris-aligned-shipping-decarbonization
12. The Carbon Budget Delivery Plan (CBDP) defines low-carbon fuels as electricity, biofuels, solid biomass, hydrogen, ammonia and methanol. Accessed at

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1147369/carbon-budget-delivery-plan.pdf

13. The CBDP does not make explicit reference to shore power. However, T&E analysis shows 2021 UK port shipping emissions were 2Mt CO2 or around 10% of total UK shipping emissions. This is a significant proportion of energy use that must be decarbonised. We have therefore included percentages of renewable shore power corresponding to each CBDP scenario.
14. We have not undertaken analysis of precise configuration of fuels and technologies across different vessel types. The above are estimates only.
15. The 26.3Mt emissions inventory is split 82% / 18% international / domestic. Applying the CBDP low-carbon fuel uptake assumptions to those totals in 2035 for combined UK domestic and international shipping as percentages of emissions abated gives a maximum abatement potential of 8.03Mt CO2e, or 30.5%.
16. Clean Maritime Plan, July 2019, page 6. Accessed at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/815664/clean-maritime-plan.pdf
17. Consultation Response to Plotting the Course to Zero, T&E, October 2022. Accessed at https://www.transportenvironment.org/wp-content/uploads/2022/09/Copy-of-Course-to-Zero-Consultation-Response-05.10.22.pdf