Emission reduction roadmap for inland shipping on the Tidal Thames

PORT OF LONDON AUTHORITY

Introduction

This report sets out the conclusions of an emissions reduction roadmap exercise, completed to identify the technologies available and applicable to meet the environmental goals set out in the PLA's Air Quality Strategy for the Tidal Thames

The Thames is home to the UK's largest fleet of inland vessels. These vessels will require ultra-low or zero-emission technologies to minimise emissions as air quality targets tighten, they move towards the Net Zero target, and the use of the river for freight and passenger increases.

This roadmap for Thames inland vessels will benefit operators, the PLA and all other stakeholders by offering direction in reaching current and potential future emission targets. It also highlights the barriers to achieving these targets and serves as a tool to build upon as operators further define their own emission reduction strategies.

The work wsa led by E4tech, who have done similar work for the automotive, aviation and rail industries, as well as working for the Department for Transport on the development of the Clean Maritime Plan.

The Clean Air Strategy published by Department for Environment, Food & Rural Affairs in January 2019 has the aim to cut air pollution across all sectors to protect public health and the environment. As the environment route map of Maritime 2050 and to encompass the maritime commitments within the Clean Air Strategy, the Department for Transport published the Clean Maritime Plan to outline the pathway to zero emission shipping while securing growth opportunities in the UK. The 2050 greenhouse gases reduction target set out by the Climate Change Act 2008 was amended in 2019 to tackle and respond to climate change. The review of the PLA's Air Quality Strategy underway for publication in Summer 2020, will incorporate these ambitions set out for the British maritime sector.

Maritime Emission Regulations

MARPOL Annex VI

NOx emissions from diesel engines installed or constructed on or after 1st January 2021 in Baltic & North Sea NO_x Emission Control Areas, which includes London, are limited to Tier III standards. For perspective, the maximum amount of sulphur content of fuel (% mass) limited to 0.1% in Baltic & North Sea SO_x Emission Control Areas from 1st January 2015 to reduce SO_x emission.

EU Regulation

Under EU Non Road Mobile Machinery legislation inland vessels built after 2009 needed to meet Stage IIIA 2009. Further standards (Stage V) are required for engines above 19 kW that have a market placement data from 2019. In port requirements for sulphur content of fuel for inland vessels is already 0.001%.

Climate Change Act

In June 2019 the UK updated its commitment to reducing UK carbon account for all six Kyoto Greenhouse gases (CO_2, CH_4, N_2O, HFC, PFCs, SF_6) in the Climate Change Act 2008 (as amended). The commitment was to reduce by 80% for the year 2050, it is now at least 100% lower than the 1990 baseline and includes all sectors such as domestic shipping. The only exceptions are international shipping and aviation.

Clean Maritime Plan

It is expected that by 2025 all vessels operating in UK waters, are maximising the use of energy efficiency options, and zero emission commercial vessels are in operation. All new vessels being ordered for use in UK waters are being designed with zero emission propulsion capability. By 2030, low or zero emission marine fuel bunkering options are expected to be readily available across the UK.

Inland Fleet on the Tidal Thames

The tidal Thames is the UK's busiest inland waterway, carrying 60% of all goods lifted on the UK's inland waterway network. There is potential for further growth in freight and passenger traffic on the River Thames. Studies have shown the carbon impact of moving freight by water is better for the environment compared to road, reducing lorries on the road and moving emissions away from sensitive receptors such as schools.

Likely Technological Solutions

Just as the level of emissions needed to be established, the technology solutions available to meet the targets that the PLA had set at the time for the type of vessels, uses and constraints were unclear. For example, could a passenger vessel be electric and run safely in London and where would there be enough electricity for that vessel to charge as well as all the other vessels?

As an initial step the PLA published guidance on how the vessel and operators could make incremental changes like cleaning vessel hulls, introducing operational changes and retrofitting their vessels. This guidance was published in 2018 and is available in the website here. We are also partners in the Clean Air Thames Project which was awarded £500,000 by the Mayor of London's Air Quality Fund in 2019. The project objective is to retrofit up to eleven inland vessels with emission reducing technology and monitoring the effect over the next two years.

Inland shipping in the UK presents a relatively small market for the technology providers, especially with possible numerous mitigation solutions that could be adopted. Some of these innovative technologies are at a low maturity or have not been applied to inland vessel use, which makes investment decisions difficult and constitutes a significant operational and financial risk for the inland vessel operators.

Sharing Lessons

The PLA has also set up a group for annual discussions on air quality, under Chatham House Rule, with the fleet operators after the annual Thames Vision Environment Conference in January. We also host a web based portal for operators to share learnings with each other. In 2019 this was expanded to a one-off event, Greening Inland Shipping, as part of London's International Shipping Week. This created a forum for international technology providers, regulators and boat operators to come together, share knowledge and understanding of a rapidly evolving area. The event was such a success that we expect to run it again in a few years' time.

Contribution to Emissions

When the PLA first developed the Air Quality Strategy for the tidal Thames, published in 2018, little was known about the emissions of the vessels and how they might interact with the banks, piers and other vessels. Much of the research underpinning the strategy helped improve understanding (for example Figure 1), to provide a robust baseline as to the benefit and impact of the use of the river for cargo and passengers.

Inventory

The port wide inventory carried out alongside the publication of the Air Quality Strategy quantified the contribution for the various categories of inland vessels (Figure 2). The inventory was developed with Transport for London (TfL) to contribute to the data in London, while it extends the length of the port. The vessel activity data was collected from the PLA's Automatic Identification System; engine performance and fuel usage were shared by the operators themselves.

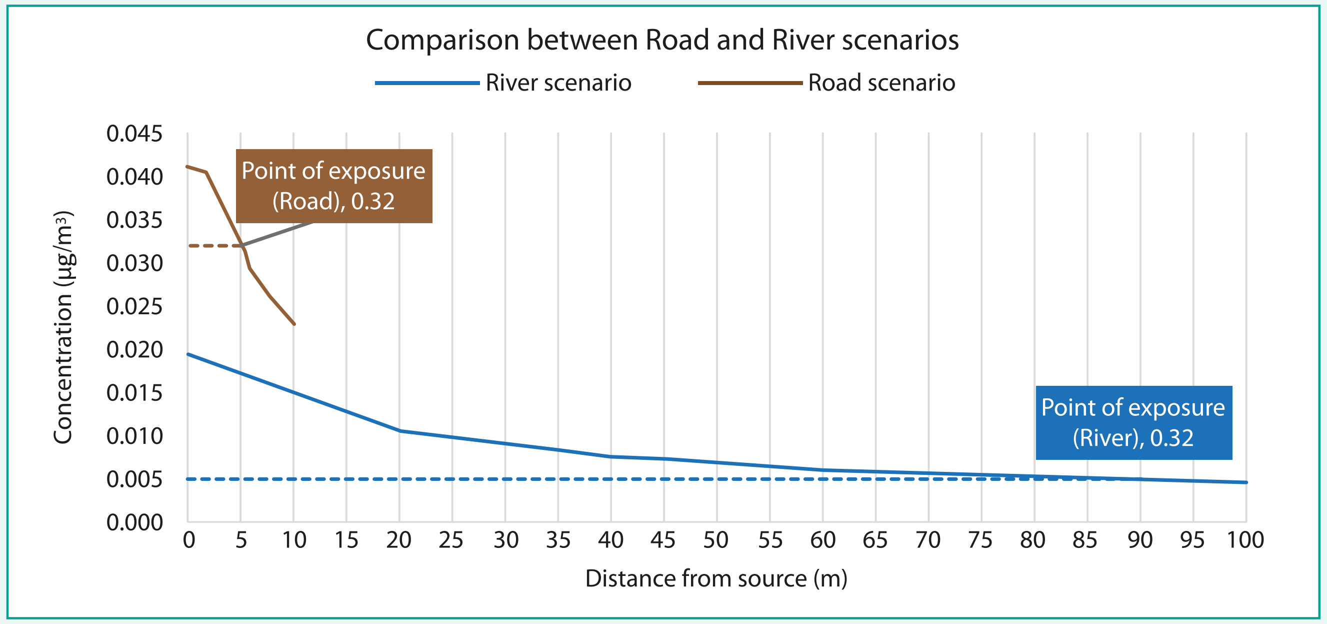


Figure 1: Modelling dispersion of annual NOx emissions from a vessel versus the same amount of cargo carried by lorries, in the relationship to a receptor

Monitoring Data

Recent analysis of data from air quality monitoring around Greenwich, aimed to access the impacts of cruise ship mooring, have highlighted a difference in the air quality on the river compared to the background, especially for the hourly averaged NO_2 concentration at the Greenwich Pier. Meanwhile, in collaboration with the City of London, a different set of monitoring had been carried out using NO_2 diffusion tubes to evaluate the annual NO_2 concentration on the river (on-pier), and from the riverbank to a kerbside of a main road in central London. The data indicates the river and road traffic causes localised hotspots of NO_2 at the pier and at the kerbside but no subsequent increase at the riverbank due to the fall-out in NO_2 emission way from both sources. Further work and data collection are required to establish both short- and long-term impacts of river traffic to air quality river-wide.

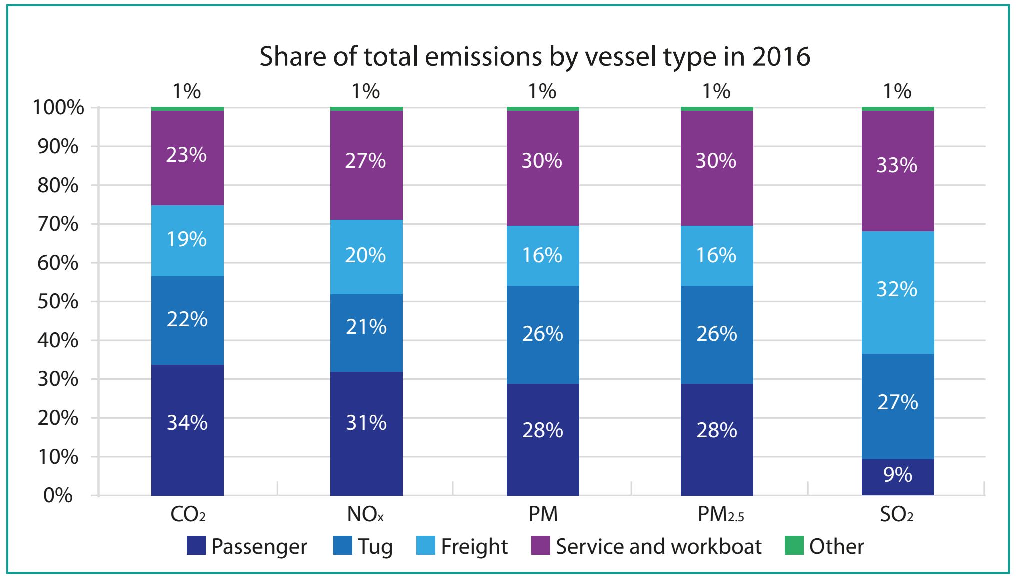


Figure 2: Contribution of inland vessels by type to the Port Wide Emission Inventory 2016

However, the PLA is already implementing actions to tackle reductions, taking the precautionary approach, to drive improvements while monitoring the benefits those measures, as evidence becomes available these actions can then be adapted.

Further details on the monitoring at Greenwich Ship Tier is available in the report on the PLA website.

Transitional Roadmap

Given the continued uncertainty of the ability of the Thames inland fleet to adopt decarbonised solutions and their need for infrastructure to be available, the PLA took a step further to fully identify the barriers to achieving those targets previously set in the AQS in 2018 and since by UK government. The PLA employed energy and sustainability strategy consultancy, E4tech, to work with inland operators on the tidal Thames to develop a roadmap, which offers direction in reaching current and potential future emission targets and identifies the associated costs.

The roadmap can also serve as a tool to build upon as operators define their own emission reduction strategies but is not operator or vessel specific and can only be indicative if used in this way.

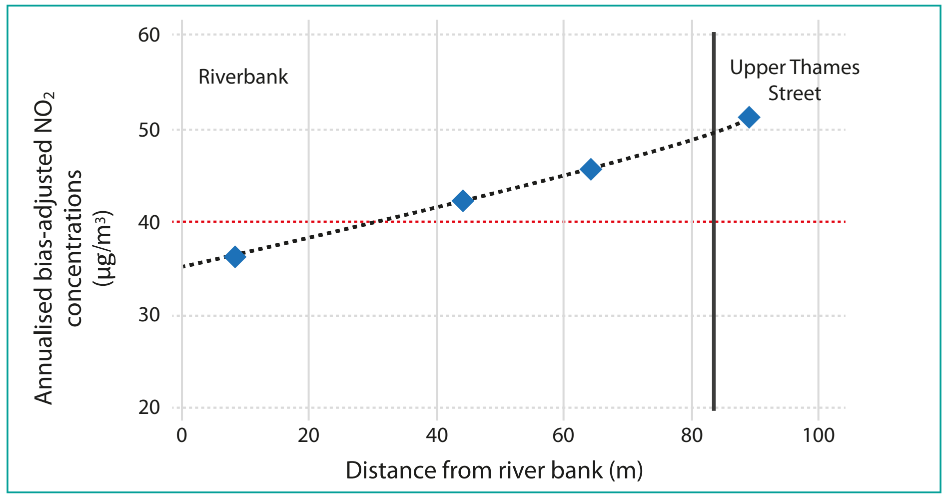


Figure 3: Annualised and bias-adjected NO_2 concentration from kerbside to the riverbank, with the riverbank at 0m

Figure 4: Categories of inland vessels on the tidal Thames considered in the roadmap

Methodology

A roadmap consists of two main components – Drivers and Related Technologies. The "Drivers" refers to the targets that will drive the development of technologies. "Set Drivers" are the legislations and regulations that applied to the industry and have specific quantitative goals, while the "Predicted Drivers" are the potential policy expected to be adopted over time. The "Related Technologies" groups the related technologies into sub-categories and outline the development time frame and the associated uncertainties.

As the total emission impacts are dependent on the type of vessel and their operational needs, the inland fleet of the Thames is split into four main categories to reflect those used in the Port Wide Inventory. The four main categories are Passenger, Towage Tugs, Freight, and Service or workboat. These then split into to sub-categories to represent the differences in the fleet as accurately as possible. The roadmap is developed for each sub-category through a mixture of research, iterative stakeholder engagement, and cost modelling.

Roadmaps are best developed via a consensual approach and so E4tech hosted a specific workshop in November 2019 with the fleet operators in the categories mentioned above, alongside regulators and asset owners. The work was then presented at the annual convening of the fleet operators groups under the Air Quality Strategy, directly following the PLA's Thames Vision Environment Conference in January 2020.

The information in each category was based on data provided by operators to the PLA during the Port Wide Inventory in 2017. Any changes or adjustment in the data was done in consultation with the operators following the November 2019 workshop.

Technology Options

Technical options for low and zero emission include efficiency improvements, exhaust clean-up, and new fuels and powertrains. Each was considered for their applicability to reduce emissions, provide appropriate power and fit within the operational limitations. The cost effectiveness of the investment was also assessed, to indicate the impact on full adoption of zero emissions.

A roadmap is:

- Representation of a direction of change at a sector level
- Usually visually represented
- Created with the shared views of shareholders

A roadmap is not:

- A company-specific business plan
- A policy
- A perfect forecast

Ref: E4tech report

Emission savings

Options to increase efficiency help to reduce emissions but are unlikely to reach zero alone, e.g. hull coating, rudder bulbs, and renewable energy for auxiliary loads. Emission clean-up technologies can be used to reduce or eliminate emissions such as SOx and NOx that result from the combustion of fuels, e.g. Diesel Particulate Filters (DPF), Selective Catalytic Reduction (SCR), and Exhaust Gast Recirculation (EGR).

Fuel or powertrain technologies include options to change to a fuel with lower emission properties, e.g. Ammonia, Liquid biofuels, and LNG, or to a powertrain solution, e.g. Conventional diesel internal combustion engine (ICE), Dual-fuel internal combustion engine (DF-ICE), and electric motor.

The combination of diesel (or low carbon fuel) hybrid electric drive or diesel (or low carbon fuel) with advanced exhaust clean-up can only achieve low emissions (which may be possible to offset), but alternative fuels and powertrains can fully achieve zero emission. However, these technologies are not fully mature, many of the other options will be required in the interim.

Powertrain Options

Three propulsion methods – Battery Electric, Fuel Cell Electric, and Diesel-Electric, were investigated in further detail, which all have the potential for zero emissions or low emissions. These options are comparable to each other as there are small efficiency loses due to no direct drive from the diesel engine/gunset or connection straight from fuel cell-to-inverter-to-motor. As there is no direct drive from the diesel engine/genset or connection straight from fuel cell-to-inverter-to-motor that it is comparable across them. These three options can also use a charger, but in general, only apply to battery and diesel electric. Fuel cell is built independent of any charging facilities where possible and depending on delivered electricity price, operation and location of chargers, it may be favourable economically.

The powertrains are sized for the power and energy requirements of the operational profile, including a margin on each installed technology as emergency back-up. The margin also provided some flexibility and redundancy in the installed equipment.

Cost modelling

The technologies that could fulfil the targets by 2050 are selected for each sub-vessel category as viable options subject to being both technically and commercially suited. Modelling is required to determine the energy and cost required for each vessel type. The

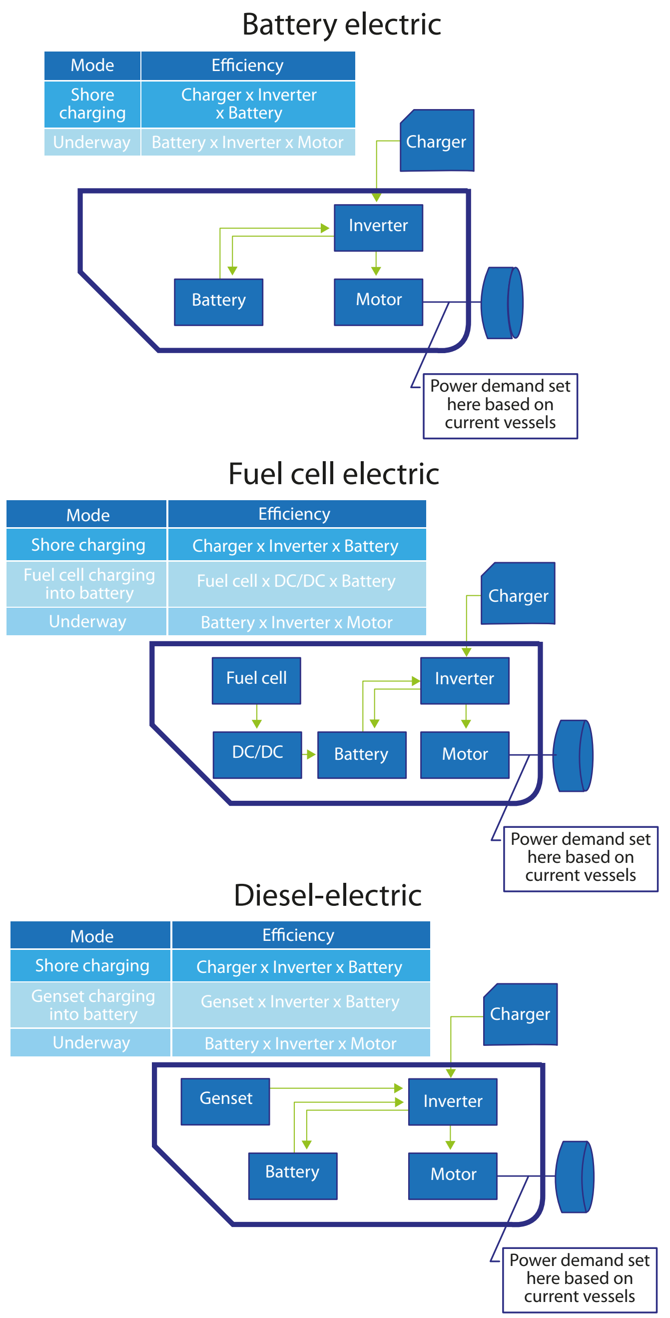


Figure 4: Three Propulsion Methods That Were Investigated in Detail, With the Potential For Zero Emissions (Battery And Fuel Cell) or Low Emissions (Diesel-Electric).

cost model assumes an average operational profile and estimates what would be needed from alternative powertrains based on the engine characteristics and energy requirements for each vessel type. Assumptions are also made on the future projection of the fuel/production cost and technology progression.

A baseline powertrain is established using data on engine characteristics and the calculated power requirements of the vessel from the operational profile. Emissions from the baseline are also calculated from the engine specifications and fuel consumption to estimate the potential emissions reduction. While the operational cycles could be changed to reduce emissions or to support the move to lower emission powertrains or fuel, this has not been considered in this initial analysis.

Production of a Roadmap

The most appropriate technology for each vessel category is highly dependent on specific vessel operating characteristics. By combining several vessel sub-categories with similar properties, such as energy usage, and charging frequent stops, the roadmap can be summarised into retrofitting existing vessels and seven new vessel archetypes. The summarised pathways to achieve emissions reduction by 2050 and the related energy infrastructures timeline are shown in Figure 5 and Figure 6.

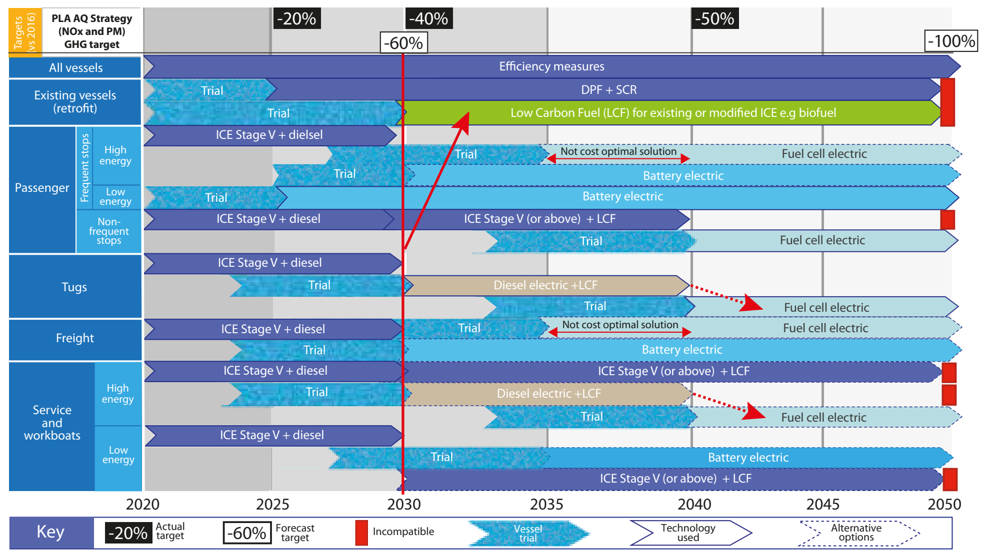


Figure 5: Emission Reduction Roadmap Summarised by Matching of Vessel Operation with Candidate Technologies

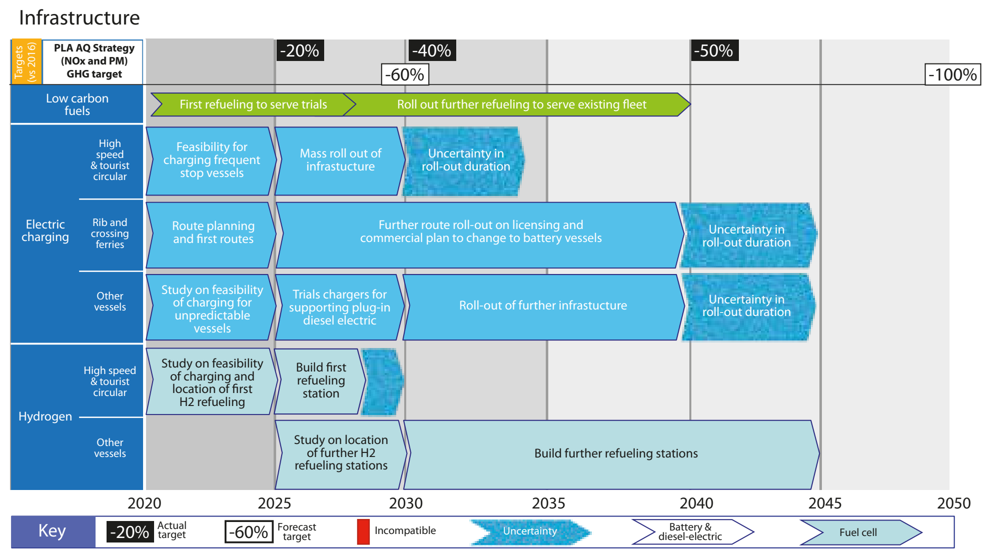


Figure 6: Energy Infrastructure Timeline to Match with The Needs of The Candidate Technologies

Case Study

To demonstrate how a roadmap is developed, here is an example based on the operational profile (Table 1) and vessel characteristics (Table 2) of one the PLA's workboats – *SV MAPLIN.*

Purpose	Heading into estuary and carry out survey
Harbour	8 minutes
Transit	1 – 1.5 hours
Survey	3.5 hours
Transit 2	1.5 hours
Operational days per year	300

Table 1: Operational Profile of PLA Workboat – SV MAPLIN

Top speed	25 knots
Engine power	1400 hp (1050 kW)
Load	3 kW (Hotel load), 8 kW (on survey)
Fuel consumption	735 litres

Table 2: Baseline Vessel Characteristics

Operational profile

The workboat category needs the ability to do long distance and significant speed. It has a very varied operational cycle day-to-day but needs to retain the ability to do longest fastest distance. The alternative powertrain properties and corresponding infrastructures required to match the operational needs are listed in Table 3. The comparisons between estimated cost, weight and volume required for installing the three different powertrains on the workboat is shown in Figure 1.

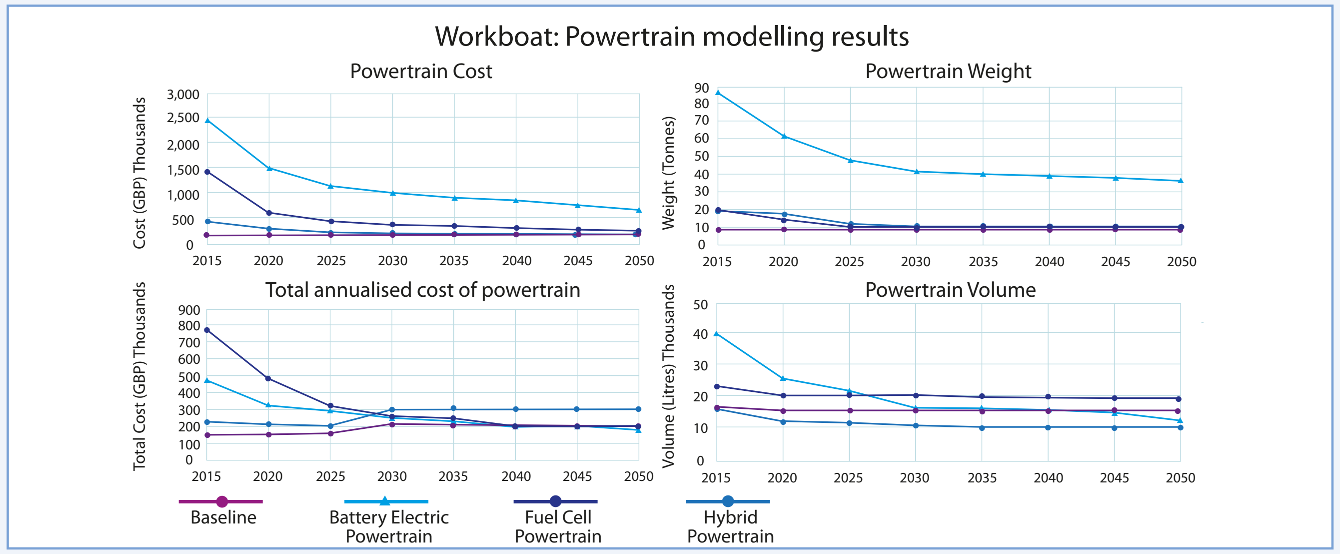


Figure 8: Powertrain Modelling Results to Estimate the Cost, Weight, and Volume Required for Installing Battery Electric, Fuel Cell, and Hybrid Powertrain on a Workboat

Options

Due to its large energy or power demand and the unpredictability of operational route or stops, the size of battery needed, is not achievable with the weight of the vessel and therefore, not suited to battery electric. A diesel electric powertrain is also not suited for a workboat, as the vessel would consume more diesel than in the baseline scenario. Hybrid diesel genset option is ruled out for workboat as the limited opportunity to recharge.

Battery Electric	Diesel Electric	Fuel cell Electric
Alternative powertrain properties		
9600 kWh battery (includes 20% emergency margin) 1,432 kW motor	560 kWe diesel genset (450 kW used) 1200 kWh battery 1,100 litre diesel tank (879 consumed) 1,432 kW motor	530 kWe diesel genset (425kW used) 1,200 kWh battery 240 kg H2 storage (350 bar) 1,432 kW motor
Infrastucture requirements		
Charger at overnight berth 350 kW charger for 15+ hours	Charger at overnight berth 100 kW charger for 15 hours Biofuel availability may be needed	Charger at overnight berth 100 kW charger for 15 hours Can also charge using fuel cell but more expensive and would need to refill hydrogen Hydrogen refuelling infrastructure needed

Table 3: Alternative Powertrain Requirements and Specifications

Fuel cell could be a feasible option despite an increase in the weight and volume compared to the baseline. The model predicts that fuel cell electric will become competitive with the baseline by 2040 with the costs intersecting by 2045, which makes it the most cost-effective option at that time.

Alternatively, a viable temporary and more immediate option would be continue using internal combustion engine with a low carbon fuel, e.g. biofuel, as well as post-combustion technology to reduce emissions as low as practicable. Alone this is not zero carbon and is not fully compatible with decarbonisation.

Infrastructure requirements increase with the switch to lower carbon solutions, especially when charging is required. In the workboat example it is likely to only require charging overnight, assuming it only works no more than 50% of the 24hour period. This could be challenging depending on the grid availability to any pier that might be used as a base for the work boat, a more innovative approach to provide charging will be required for those vessels that do not moor near a pier with grid power or alongside the bank of the river.

An indicative category roadmap

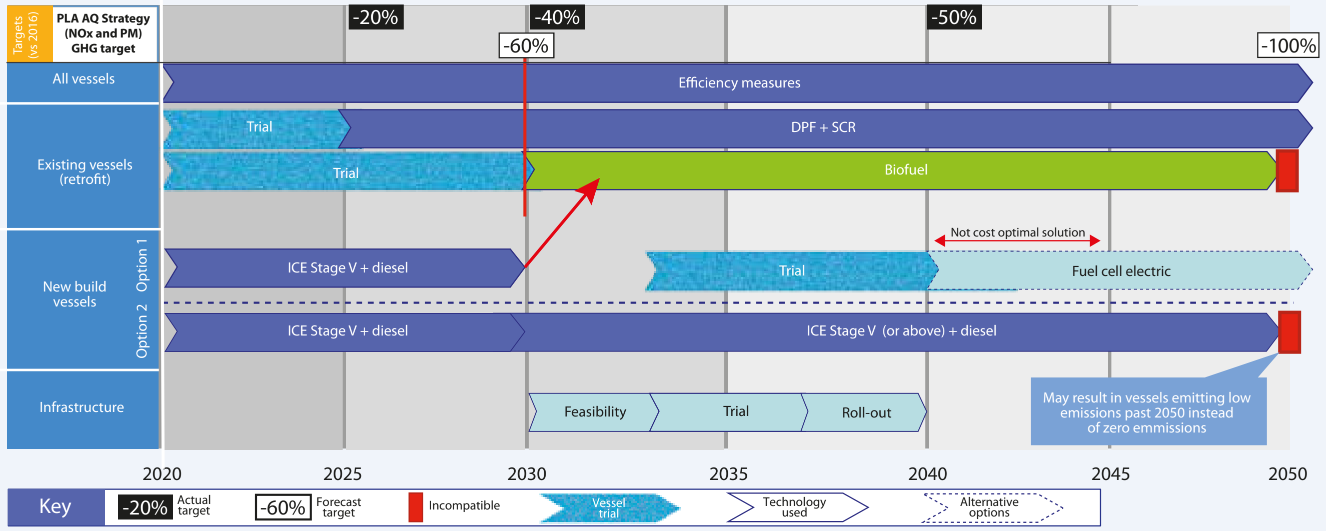


Figure 9: Decarbonisation roadmap for a workboat

Conclusion

The completed Inland fleet roadmap for the Thames recommended the best technologies to meet current and potential emission targets through techno-economic analysis on the basis of current available technology and research. For existing vessels, ultra-low emissions can be achieved by retrofitting vessels with advanced exhaust clean-up and through the use of low carbon fuel for existing or modified ICE. For new build vessels, the candidate technologies that could achieve ultra-low emissions are diesel (or low carbon fuel) hybrid electric drive or diesel (or low carbon fuel) drive with advanced exhaust cleanup. For zero emissions the candidates are battery electric drive or hydrogen fuel cell drive.

The roadmap has identified that achieving Net Zero is unlikely in the current circumstances by 2050, and in light of growth in river use, the reductions required are unlikely without intervention by regulation, incentives and funding. Some barriers identified were regulatory, i.e. having clear goals and targets to meet but also in the practical implementation. The art of the possible particularly resonated around the licensing of the operational vessels with clean technologies and provision of the clean fuel in London safety.

The lack of availability or application of technology within similar types of vessels, operating in similar environments was also noted as a barrier to investment confidence.

Next Steps

The summer 2020 revision of the Air Quality Strategy for the tidal Thames will include a number of actions to drive forward the decarbonisation agenda by tackling several of the challenges:

- Targets for reduction will reflect those in UK & International regulation and relevant policies.
- An inland environmental scheme is being developed to encourage actions towards Net Zero emission and improve environmental performance with other authorities and regulators, which will help London to have a green recovery from Covid-19.
- The PLA is planning to develop a demonstrator project to accelerate the trial of new technologies and de-risk the investment by the inland operators. We welcome interested parties to come forward and contact the PLA if interested in getting involved.
- The PLA is also investigating infrastructure solutions and hoping to link this to the demonstrator project above.

The PLA will be continuing the fleet operators' group and other events as ongoing actions within the strategy, as well as publication of material such as this report. The PLA is also supplementing the Air Quality commitments with work to get the activity in the port to Net Zero. This commitment was launched at the January Environment Conference, which focused on Net Zero.

In particular, as part of its commitment to Net Zero, the PLA is actively exploring options for cleaner berth operations when vessels are in port. We are seeking technical, operational and investments business partners to enable us to establish the first cleaner berth as soon as possible.

Notes

The final Tidal Thames Inland Roadmap image is available as a jpeg and we encourage use of the image in sharing with the sector and technology providers beyond the Thames. Reference should be made to both E4tech and the PLA.

If you have a technology that you would like to implement on the river in the transition to zero emissions, please get in touch with the PLA environment team.

Glossary

CO_2	Carbon dioxide	NO_X	Nitrogen oxides
ICE	Conventional diesel internal combustion engine	N_2O	Nitrous oxide
		PFCs	Perfluorinated compound
DPF	Diesel Particulate Filters	PM	Particulate matter
EGR	Exhaust Gast Recirculation	PLA AQ Strategy	Air Quality Strategy published by PLA in 2018
GHG	Greenhouse gases		
HFC	Hydrofluorocarbon	SCR	Selective Catalytic Reduction
LCF	Low Carbon Fuels	SF_6	Sulphur hexafluoride
CH_4	Methane	SO_X	Sulphur oxides

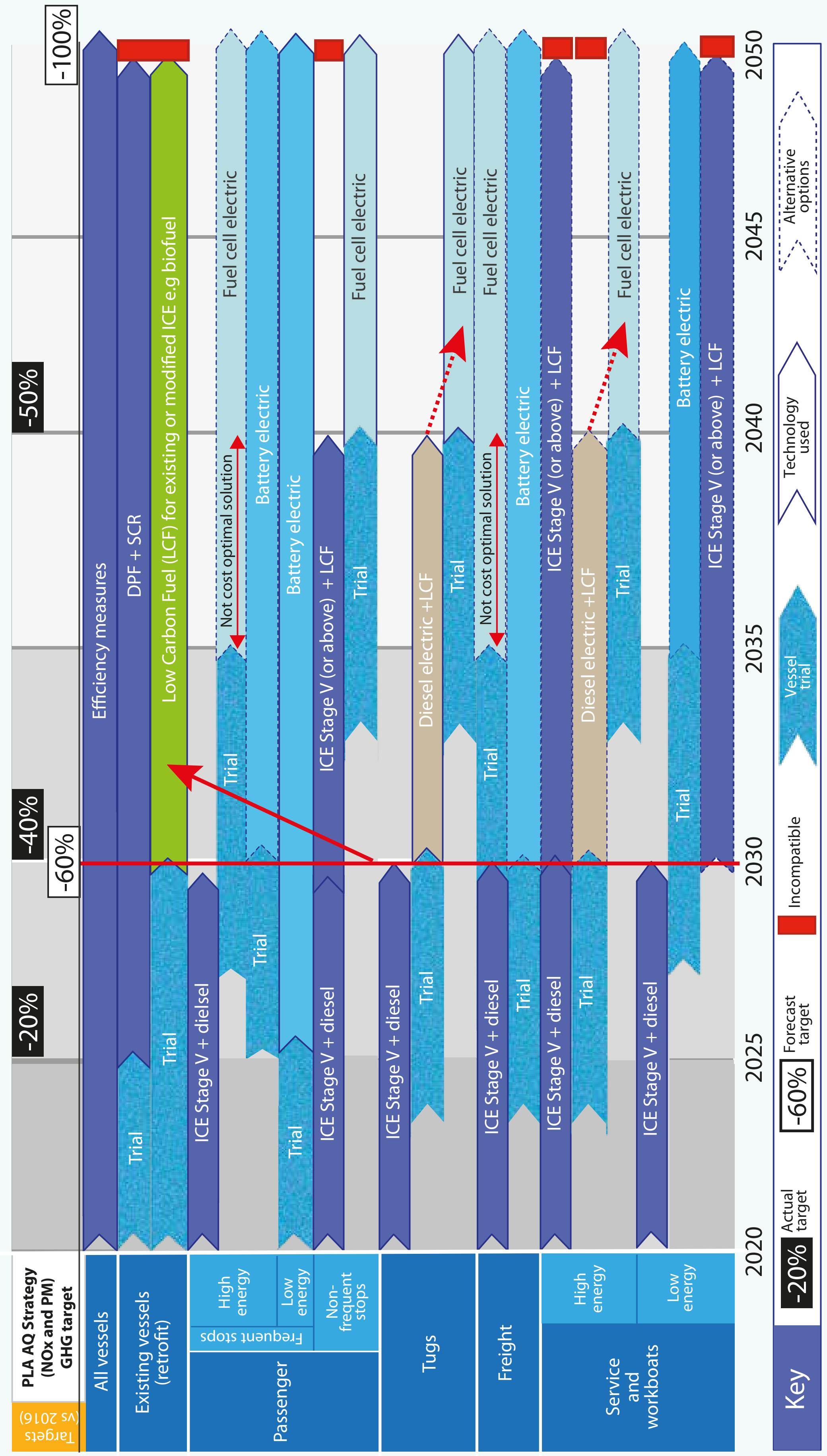
About E4tech

E4tech has over 20 years of working in the low carbon transport sector, helping businesses, government bodies and investors understand uncertainty that comes with transition to sustainable energy.

E4tech has expertise in low emission technologies and fuels, working across the value chain in batteries, hydrogen, fuel cells, low carbon fuels (eg: biofuels or electrofuels). The expertise in technology allows us to advise on policy, regulation and economics associated with these technologies and fuels.

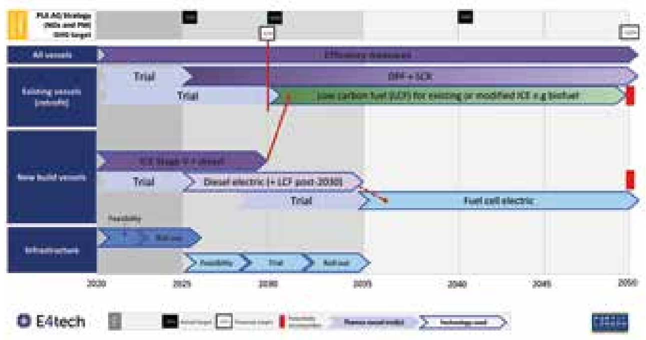
This expertise is complemented by extensive experience in supporting the transport sector to understand the possible technology directions and identifying the barriers that need to be overcome to continue on these pathways.

Annex I : Tidal Thames Roadmap

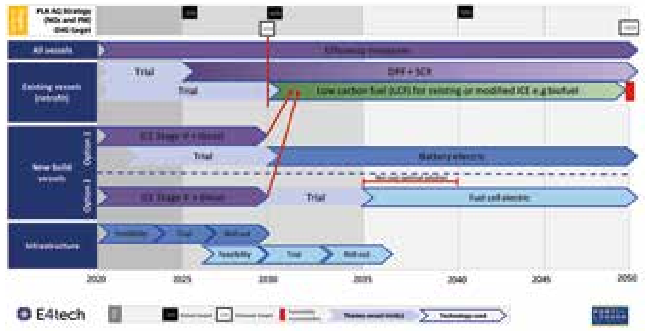


Annex 2: Indicative Roadmaps for inland categories

Towage Tugs

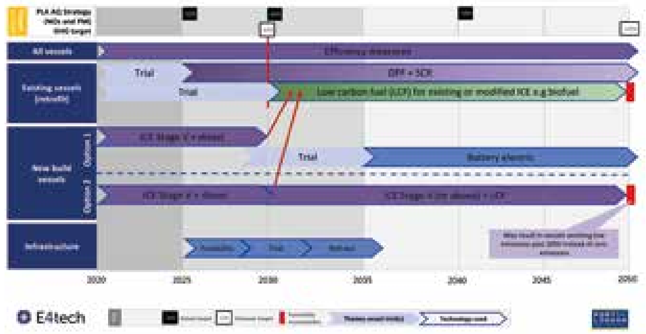


Freight

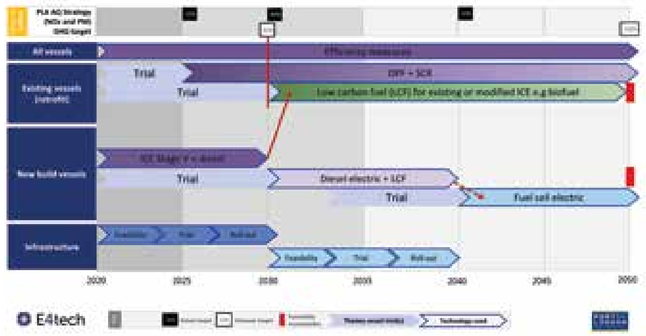


Service Boats

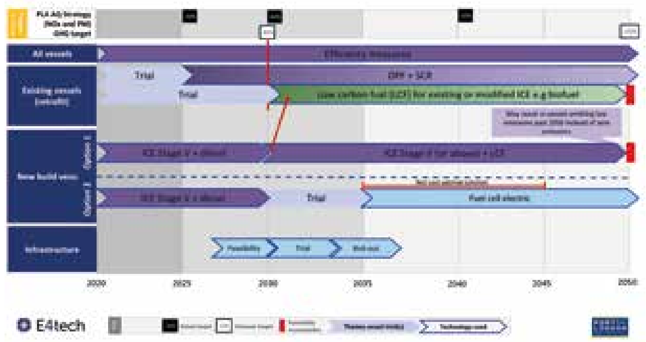
Service vessel



Harbour vessels

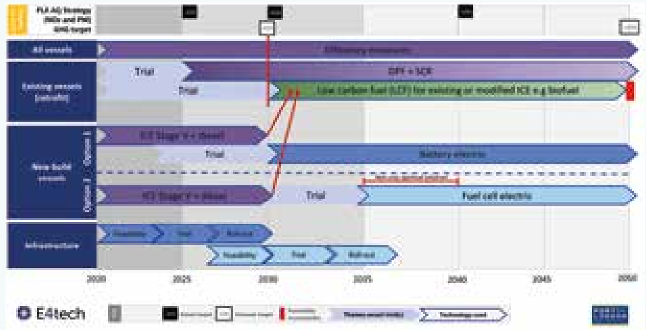


Emergency

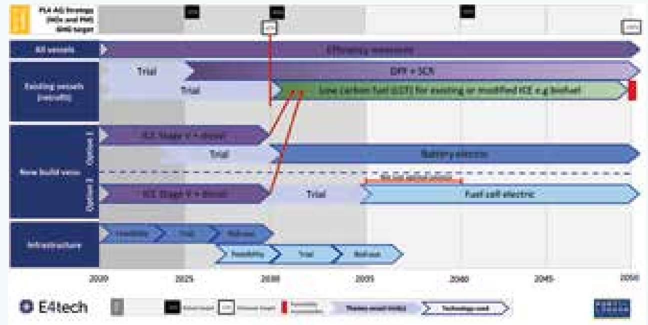


Passenger

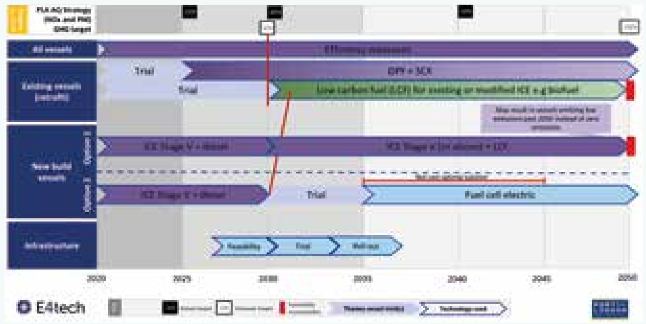
High-speed



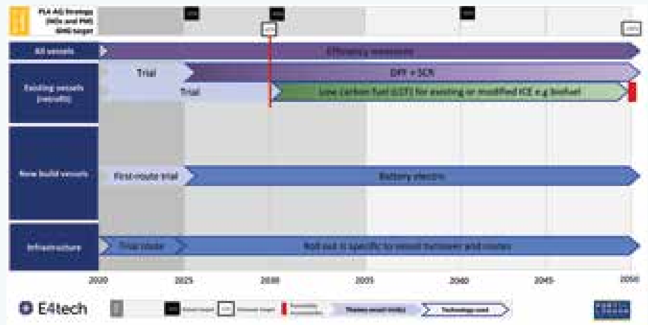
Tourist circular



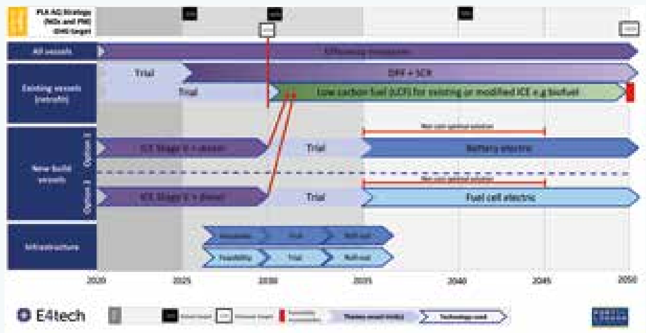
Charter boat



Crossing ferry



Small charter (max 12 pax)



Small RIB

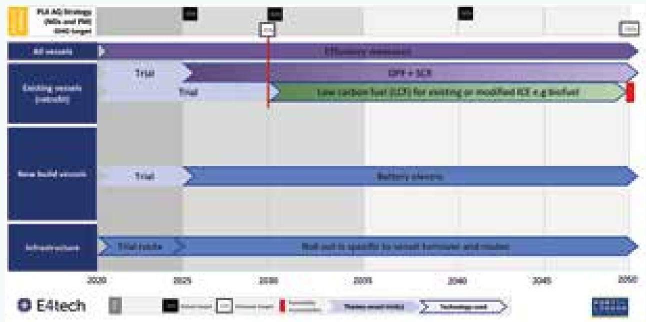
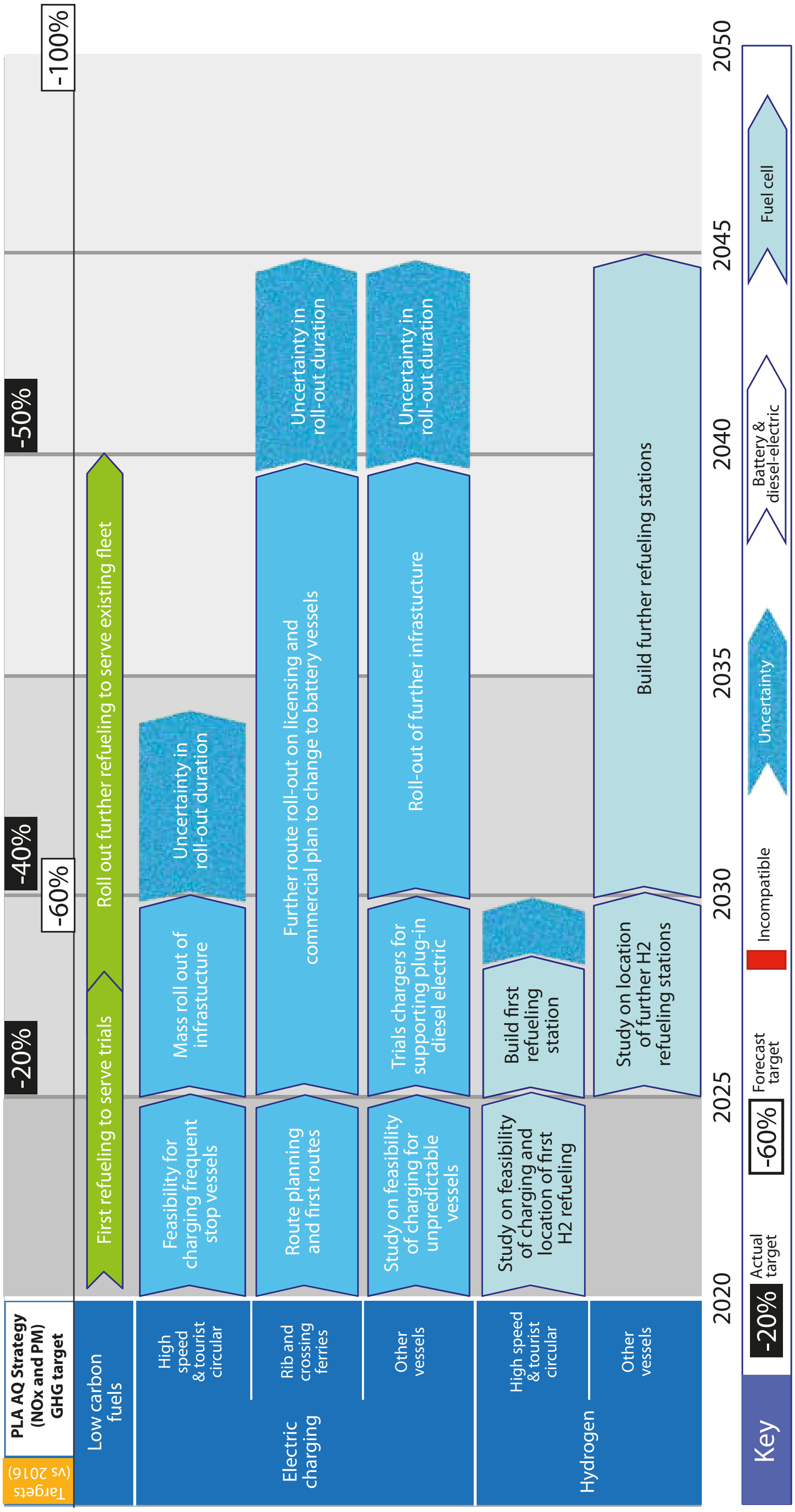


Figure 7: Energy Infrastructure Timeline to Match with The Needs of The Candidate Technologies



SUSTAINABLE DEVELOPMENT GOALS

The PLA's work in this area contributes to the following UN Sustainable Development Goals:

8 DECENT WORK AND ECONOMIC GROWTH

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

11 SUSTAINABLE CITIES AND COMMUNITIES

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

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CUSTODIANS OF THE TIDAL THAMES

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