Second revised draft CCNR roadmap for reducing inland navigation emissions, as envisaged by the Mannheim Declaration

1. Initial situation

1.1 Climate change mitigation, general context

Addressing the issue of **climate change** is a political **priority** both nationally and internationally. The Paris Agreement, which aims to slow the pace of climate change (maximum 2 °C increase) by reducing greenhouse gases emissions is one of its key components.

In the Declaration signed in Mannheim on 17 October 2018, the inland navigation ministers of the Member States of the Central Commission for the Navigation of the Rhine (CCNR - Germany, Belgium, France, Netherlands, Switzerland) reasserted the objective of **largely eliminating greenhouse gases and other pollutants by 2050.**

In addition, to further improve the environmental sustainability of navigation on the Rhine and Inland waterways, the same Mannheim Declaration tasked the CCNR to develop a **roadmap** for:

- reducing greenhouse gas emissions by 35% compared with 2015 by 2035,
- reducing pollutant emissions by at least 35% compared with 2015 by 2035,
- largely eliminating greenhouse gases and other pollutants by 2050.

On 28 November 2018, the European Commission presented its strategic long-term vision for a prosperous, modern, competitive and climate-neutral economy by 2050 – A Clean Planet for All[1], asking for a European policy on the reduction of greenhouse gas emissions towards climate neutrality in 2050 for all transport modes including the inland navigation sector. In addition, the May 2018 Communication "A Europe that protects: Clean air for all" from the European Commission provides the policy framework for reduction of air pollutant emissions such as NOx and Particulate Matter, covering, amongst other sectors, the transport sector[2].

The European Commission's Green deal for Europe[3], of December 2019 and its "Smart and Sustainable Mobility Strategy" of December 2020, lay out priority policy areas, one such area being sustainable mobility, and actions to be realised to achieve climate neutrality by 2050. Among other things it promotes the prompt introduction of more ambitious policies aiming to reduce transport dependency on fossil fuels, in synergy with efforts to achieve the "zero pollution" target. In particular, it sets:

- a greenhouse gas reduction target of at least 50% and close to 55% by 2030 compared with 1990 (for all sectors);
- a greenhouse gas reduction target of 90% in the transport sector by 2050 (to achieve climate neutrality).

Finally, the Ministerial Declaration "Inland Navigation in a Global Setting" adopted in 2018 in Wroclaw under the auspices of the UNECE also stresses the importance of emissions reduction for the future of inland navigation[4].

In this context, there is no doubt that all modes of transport shall realise their transition towards zero-emission. Therefore, the inland waterway transport (IWT) sector needs to develop concrete measures to realise this transition, both for air pollutant emissions, and greenhouse gases.

1 https://ec.europa.eu/clima/policies/strategies/2050
2 http://ec.europa.eu/environment/air/index_en.htm
3 https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en#policy-areas
4 https://www.unece.org/fileadmin/DAM/Poland_Ministerial_declaration_e__002_.pdf

1.2 The inland navigation energy transition context

Today, the energy transition must be seen as an existential challenge for inland navigation. Only if inland navigation can effect the transition to climate neutral propulsion, will political support continue for the sector' continued development. The energy transition will be a very complex and long process. The strong interest by national governments, the CCNR and the EU in the energy transition will endure, but other important issues will come up over the years, as the latest Covid-19 pandemic showed, and the energy transition may in the long run be seen as less urgent. Despite the particularly difficult socio-economic and sanitary situation created by the Covid-19 pandemic, it must be ensured that the energy transition remains a priority topic. Such a crisis shows how interconnected our economies are and how severe global impacts can be if disaster strikes in one particular region. More than ever before, it is necessary despite current uncertainties to make an energetic and immediate start on designing an approach towards zero-emissions in inland navigation that can be sustained in the medium and long-term.

In addition, based on today's knowledge, while innovations to reduce emissions from existing and new vessels have increased in recent years, they tend to be limited to pilot projects, which however remain essential to gain knowledge of new technologies. This can be explained by various economic, financial, technical and regulatory reasons. In this context, identifying and considering the measures enabling an accelerated transition towards zero-emissions (innovation in zero-emissions technologies, financial support for the energy transition, more stringent environmental targets…), together with the development of pathways towards zero emissions, are also essential elements to be included when designing a realistic and future-proof roadmap.

Wherever possible, careful attention should be paid to developments in other modes of transport, such as road, rail and short-sea shipping. Indeed, there is much to be learned from the experience gained by other modes regarding the energy transition. Moreover, it is important to take the multimodal dimension of inland navigation into account. If inland navigation were to lag behind in its transition process, transport demand might shift to other modes like rail, road or short-sea.

In light of the above, largely eliminating both greenhouse gases and air pollutant emissions from inland navigation by 2050 is clearly no longer an option but a necessity if inland navigation wants to preserve and strengthen its position as a competitive, sustainable and environmentally friendly mode of transport.

2. Role of CCNR and purpose of the roadmap

Beyond its essential regulatory jurisdiction for the navigation of the Rhine, the CCNR is active in the technical, legal, economic, and environmental fields. In all its areas of action, its work is guided by the efficiency of inland waterway transport, safety, social and environmental considerations.

Many of the CCNR's activities now extend beyond the Rhine and are directly concerned with European navigable inland waterways more generally, even if the CCNR does not have all-encompassing jurisdiction, neither in terms of geography nor in terms of legal jurisdiction. In this context, the CCNR works closely with industry representatives, the European Commission, and other river commissions. As highlighted in the Mannheim declaration, the CCNR plays a leading and pioneering role as a centre of excellence for Rhine and European inland navigation.

This roadmap aims primarily to deliver on the mandate conferred by the Mannheim Declaration in 2018 and to help address the existential challenge of the energy transition for Rhine and European inland navigation.

Built on the recent studies carried out regarding the financing of the energy transition, this roadmap should be understood as the main CCNR public policy tool for climate change mitigation and for giving effect to the energy transition to reduce Rhine and inland navigation emissions by:

- setting transition pathways for the fleet (new and existing vessels),
- suggesting, planning, and implementing measures directly adopted or not by the CCNR,
- monitoring intermediate and final goals set by the Mannheim Declaration.

It goes without saying that many players will be involved in this energy transition, such as shipowners, operators, shippers, and shipbuilders as well as representatives of the sector, classification societies, equipment manufacturers, infrastructure operators, service and energy providers, universities or research institutes, European institutions, international organisations including river commissions, the CCNR, EU Member States, and other non-EU States with inland waterways. In addition, it will be necessary to coordinate and take part in the European Commission's NAIADES III Action programme as well as in ongoing projects relating to the energy transition, such as, the STEERER[5] project, coordinated by the Waterborne Technology Platform or the PLATINA3[6] project. Already today, as in recent years, major efforts have been, are being, and will continue to be made by such players, through coordinated actions, to gain knowledge, test and support the adoption of innovative solutions towards zero-emissions.

The CCNR hopes that this roadmap will help develop a shared vision of the energy transition and associated challenges within the inland navigation sector, while also generating support and acceptance for related policy measures. This roadmap could serve to coordinate decisions at the political level, namely decisions of the Member States but perhaps even more so of the EU. For this reason, it is of the utmost importance to design such a roadmap in full collaboration with as many involved players as possible, taking into account and creating synergies with existing initiatives.

5 The STEERER project (Structuring Towards Zero-Emission Waterborne Transport), financed by the European Commission in the context of the Horizon 2020 programme, and coordinated by the Waterborne Technology Platform, aims at setting emission targets towards 2050, developing a Strategic Research and Innovation Agenda, an implementation plan and a communication plan to reach the agreed targets. A Green Shipping expert group, to which the CCNR Secretariat will participate, is being set up to monitor and assess the implementation of the agreed strategy.

6 The PLATINA3 project aims to support the implementation of a future NAIADES programme, as the successor of previous projects PLATINA and PLATINA2. The energy transition will have a prominent place in this project.

3. Preliminary definitions, targets, and estimation of emissions

3.1 Basic definitions

The Mannheim Declaration states:

To further improve the ecological sustainability of inland navigation, we task the CCNR to develop a roadmap in order to

- *reduce greenhouse gas emissions by 35% compared with 2015 by 2035,*
- *reduce pollutant emissions by at least 35% compared with 2015 by 2035,*
- *largely eliminate greenhouse gases and other pollutants by 2050.*

To ensure a shared understanding, the CCNR considered necessary to clarify the scope of the roadmap by providing the following definitions. These definitions are deemed to be a first step and will be reviewed by the CCNR at regular intervals, in the light of scientific, technical and political developments.

1. “inland navigation”: means here the transport of goods and the carriage of passengers by inland waterway vessels on the Rhine. Recreational craft[7] and floating equipment[8] are not included.

By extension, for future revisions of this roadmap, it might apply to all European navigable waterways and the associated transport system as well as all other types of craft (floating equipment and recreational craft).

2. “emissions”: emissions of atmospheric pollutants and greenhouse gases arising from the operation of an inland navigation vessel’s propulsion and auxiliary systems[9].

A “tank-to-propeller” approach is adopted for estimating emissions. Application of this “tank-to-propeller” approach generates assumptions concerning the upstream chain (emissions produced and fuel availability) in accordance with the legal and scientific sources (such as the work of the intergovernmental panel on climate change (IPCC)). Although this simplification implies limitations and possible inaccuracies, it is considered as a first step and will be reviewed again by the CCNR at a later stage. The same approach is used for all technologies to ensure a technology-neutral approach. Consistent assumptions for all energy sources make for a balanced analysis of the different technological solutions, thereby avoiding excessively favouring or penalising one solution compared with another. These assumptions are also taken into account when developing fleet transition scenarios.

There are several explanations for choosing a simplified approach such as this. The well-to-propeller approach would require consideration of energy production sustainability. That would mean, for example, that electric navigation would not contribute to a reduction in emissions if the electric power were not produced sustainably. That would render the intermediate goals of the Mannheim Declaration virtually unachievable if in the short term all the electricity and all the hydrogen had to come from sustainable sources. Such an approach could therefore, for example, result in a slowdown in the development of sustainable technologies using hydrogen, or could impede the development of navigation using batteries to supply the necessary electricity for propulsion. This decision also aims to concentrate on the CCNR’s remit, namely inland navigation. The inland navigation sector has only a marginal influence on this external factor, namely the sustainable production of these energies, and their availability in sufficient quantity.

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[7] As defined in article 3.2) of Directive 2013/53/UE: ‘recreational craft’ means any watercraft of any type, excluding personal watercraft, intended for sports and leisure purposes of hull length from 2,5 m to 24 m, regardless of the means of propulsion;

[8] As defined in ES-TRIN, Article 1.01(1.23): “a floating installation carrying working gear such as cranes, dredging equipment, pile drivers or elevators;”

[9] The following emissions are not included: noise emissions within and outside the vessel, and underwater; leaks of water pollutants, such as lubricants, anti-fouling paints wastewater; cargo-related waste.

Finally, there is currently little quantitative data on emissions by the upstream chain (from the well to the tank). However, in 2021 the CCNR endeavoured to collect initial qualitative data on these emissions in order to evaluate at least qualitatively the emissions reduction potential of technologies applying a “well-to-propeller” approach. The CCNR took due account of this in the transition pathways proposed in this current roadmap. It will be possible to collect more reliable upstream chain emissions data for a future revision of this roadmap.

Similarly, at a later stage, particular attention needs to be paid to emissions associated with other aspects of a vessel’s life cycle, such as construction, maintenance, and scrapping. Emissions associated with the manufacture and disposal of propulsion systems (for example electric propulsion system accumulators) need to be estimated, as far as possible, to measure their environmental and climate impact.

3. “atmospheric pollutants”: gaseous pollutants, such as carbon monoxide (CO), all hydrocarbons (HC) and nitrous oxides (NOx), and solid particles such as particulate pollutants (measured in PM or PN), as referred to in Regulation (EU) 2016/1628[10].

4. “greenhouse gases”: carbon dioxide (CO_2) and methane (CH4)[11].

5. “largely eliminate”: a reduction of **at least 90%** of greenhouse gases and other pollutants by 2050 compared with 2015. This interpretation does not however preclude a reduction exceeding 90%. As with the approach adopted for estimating emissions, this reduction ambition may be upgraded in a future edition of the roadmap.

3.2 Targets for reduction of air pollutants and greenhouse gases

3.2.1. Compatibility of CCNR and EU inland navigation emissions reduction targets

As developed in part 1.1, the CCNR and EU have both set ambitious emissions reduction targets.

The CCNR and EU share the same long-term vision with “a zero greenhouse gas emissions inland navigation sector by 2015”. However, the emissions reduction targets differ in terms of their material scope (entire transport sector / inland navigation only) and benchmarks, and there are significant differences concerning medium-term targets (the EU’s reduction targets being approximately double those of the CCNR).

This observation is important, because it supports the conclusion that most of the measures envisaged in this roadmap, and the array of technologies envisaged in the transition pathways, remain relevant beyond the Rhine. However, the more ambitious the intermediate target, the more the intensity of the measures (including financial support) and the speed of technological change is likely to increase.

It should be noted that except for road transport, there is no EU objective for reducing atmospheric pollutants, notwithstanding the ambitions stated in the Mannheim Declaration.

[10] Regulation (EU) 2016/1628 of the European Parliament and of the Council of 14 September 2016 on requirements relating to gaseous and particulate pollutant emission limits and type-approval for internal combustion engines for non-road mobile machinery, amending Regulations (EU) No 1024/2012 and (EU) No 167/2013, and amending and repealing Directive 97/68/EC

[11] Kyoto Protocol names six different greenhouse gases of which the only two stated above are relevant for inland navigation.

3.2.2 Information on the emissions reduction targets of other modes of transport

To have a basis for comparison, it seems also useful to consider the targets set by other transport modes.

Regarding the EU Smart and Sustainable Mobility Strategy[12],road transport alone accounts for 20 percent of total EU GHG transport emissions. The EU targets for road transport are set at a 15 percent reduction from 2025 onwards and a 30 percent reduction from 2030 onwards compared to the EU average in the reference period (1 July 2019- 30 June 2020).[13] Road transport and inland waterway transport exhibit considerable differences in terms of the scope for modernisation or extensive renewal of their fleets. Whereas road vehicles can be adapted faster and are in a lower cost category, the length of the life cycle of inland vessels is considerably greater, as is evident from the average age of the Rhine fleet (50% of the fleet is more than 50 years old).

In the maritime arena, the International Maritime Organisation (IMO) adopted a greenhouse emissions reduction strategy[14] in April 2018. Its objective is to phase out international maritime transport greenhouse gas emissions as early as possible within this century. This strategy sets two intermediate objectives. The first is to reduce CO_2 emissions from transport activities by at least 40% by 2030, while continuing the drive to achieve a 70% reduction by 2050 compared with 2008. The second is to reduce the total volume of annual greenhouse gas emissions by at least 50% in 2050 compared with 2008. Adoption of a revised Strategy is anticipated in 2023.

3.3 Estimation of the emissions in 2015 as a baseline

The CCNR tasks its Inspection Regulations Working group to collect, evaluate and correct the data of emissions generated by inland navigation nationally in 2015. Improving the quality of data is fundamental if these data are to be used as a basis for policy action. To this end, there will be a simplified data sense check.

[12] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0789
[13] https://ec.europa.eu/clima/policies/transport/vehicles/heavy_en
[14] https://unfccc.int/sites/default/files/resource/250_IMO%20submission_Talanoa%20Dialogue_April%202018.pdf

The data provided by the Member States represent the emissions generated by inland navigation vessels (belonging to the national fleet or otherwise) on all the navigable waterways of the national territory of each CCNR Member State. The geographical data collection footprint encompasses all the CCNR Member States navigable waterways. It does not enable rigorous identification of Rhine navigation. These data should be further examined, for example, to avoid double counting of navigable waterways in border areas. In accordance with the definitions, the data of other European waterways is not taken into account.

Data collection follows the same guidelines established for the official inventory reports in the framework of the Climate Convention and of the Convention on Long-Range Transboundary Air Pollution, but the calculation methods differ from one Member State to another. At first glance, the national model developed by the relevant agencies cannot be harmonised.

However, the plausibility of emissions data (i.e. whether the data are reliable and consistent with other available data) is verified in several ways, such as comparing emissions data notified by Member States and with other inland navigation data (e.g. transport volumes per country and number of passengers transported). For example, since the fleets, engines and fuels are basically similar between countries, the ratios between the different emissions should also be similar for each country regarding the emissions from cargo vessels.

The following table summarises the data provided by, or obtained from, sources provided by Inspection Regulations Working group experts. These data represent the emissions generated by inland navigation nationally in 2015; they have however been collected using different methods.

Units: kt	**Total**
Carbon dioxide (CO2)	4149,2
Carbon monoxide (CO)	38,2
Methane (CH4)	0,2
Nitrogen oxides (NOx)	60,9
PM10 (Particulate matter)	2,0

Fig 1. Summary table of atmospheric pollutant and greenhouse gas emissions by the inland navigation sector in 2015

The above-mentioned data were compared to the results obtained from a different methodology based on fuel consumptions. The values below come from the study commissioned by Switzerland into the evaluation of technologies and published in October 2020. They confirm the plausibility of the data mentioned in the figure 1.

CO_2 (kt)	NOx (kt)	PM (kt)
4 281,7	47,4	2,4

Fig 2. Estimate of European level emissions (Rhine and EU waterways) in 2015 according to the study commissioned by Switzerland into the evaluation of technologies and published in October 2020.[15]

For each of the vessel families identified as part of the Horizon 2020 Prominent project, the consultant estimated the emissions factors and number of vessels concerned in 2015. The emissions values are based on CDNI and Prominent data, supplemented by consultations with the Danube Commission and Via Donau.

The data were also compared with previous activities on the evaluation of the carbon footprint that fall within the CCNR working group on infrastructure and environment. A first provisional estimate concluded that the carbon footprint of cargo vessels in Rhine basin countries (Switzerland, Germany, France, Netherlands, Belgium, and Luxembourg) was around **4 634 340 tonnes of CO_2 equivalent** in 2015. This estimate was calculated using a simple multiplicative model in which the two basic inputs are the emission factors and the aggregated inland cargo navigation transport performance data. This study also illustrates the advantages and limitations of the various methods for aggregating emissions data.

In summary, GHG emissions by the inland navigation sector in CCNR Member States can be estimated at between 4,1 and 4,6 kt in 2015. The figures are consistent, allowing for a 10%margin of error.

The comparisons with the data obtained by aggregating national data, by fuel consumption or by the afore-mentioned multiplicative model highlight the possible uncertainties to be considered when using this data, especially when they underpin a political initiative.

3.4 Representativeness of 2015

The CCNR also wanted to verify whether 2015 is representative of emissions generated by the inland navigation sector. The particular challenge is to ascertain whether volume of transport and transport performance was or was not affected by economic difficulties or by low-water periods. The CCNR's Market Observation (2019) confirms that 2015 may be deemed representative because no major variation in volume of transport (Mt) or transport performance (t.km) is to be observed during this period. In particular, the emission intensity (kt per tkm) was measured during this period to identify a possible increase in fuel consumption (and associated emissions) owing to the low water period.

[15]https://www.ccr-zkr.org/files/documents/EtudesTransEner/Deliverable_RQ_C_Edition_1_Oct2020.pdf

4. Transition pathway scenarios for inland navigation by 2035 and 2050

Today, several scenarios are being studied as there does not yet seem to be a “one-size-fits-all” solution for achieving the energy transition. Indeed, the choice of an appropriate emissions reduction technology depends for example not only on the sailing profile of the vessels and the market segment in which they operate but also on the related technical constraints. It is anticipated that different (modular) options for zero-emissions powertrains, using a mix of energy sources/fuels, will play a role in achieving this ambitious objective. Given the uncertainties surrounding the development of certain technologies, and the knowledge of new technological possibilities that might be gained from ongoing research projects, no technologies or solutions should be ruled out at this stage. The achievement of the inland navigation energy transition should be as technologically neutral as possible and regular evaluation of the possible transition pathways is therefore essential. In addition, safety aspects, including operational issues, to do with possible new technological developments, especially operational issues, are equally important and should also be subject to regular evaluation,

The purpose of the transition pathways is to describe the expected evolution over time of the entire fleet with a breakdown of the technologies used (energy carriers and converters) to achieve the intermediate and final objectives. It concerns the building of **new vessels as well as the retrofitting of existing vessels**. Both influence the composition of the inland navigation fleet and corresponding emissions. For this purpose, the CCNR conducted comprehensive studies looking in particular at the financing, technological and regulatory aspects governing the energy transition, which feed into this roadmap.

Given the [intermediate] findings of these studies and other research work, the transition pathways reflect the anticipated evolution of the fleet in the years ahead, derived from the following inputs: economic variables, market maturity and availability of technologies, rate of new construction and modernisation of existing vessels. Such pathways could ease the dimensioning of policy measures, especially for

- financing measures (in which technology, for which type of fleet, and when to invest with a focus on no-regret investments)
- regulatory measures (such as the certification of new technologies or the banning of certain technologies)
- logistical and infrastructural measures (supply chain and bunkering facilities) and
- incentivisation measures based on the possible implementation of a label for environmental and climate protection.

The CCNR will regularly monitor the evolution and the emissions of the fleet and may adapt the pathways, in the light of scientific, technical and political developments.

[Preliminary] transition pathways

The proposed transition pathways presented below are based on the latest available results of the studies relating to the financing of the greening of the inland navigation fleet. These pathways will be updated as the discussions between the delegations and stakeholders progress[16]. It cannot be stressed enough that there are **uncertainties surrounding the development of such pathways** and the transformation process that the inland navigation sector will need to undergo to achieve the zero-emissions target by 2050. Indeed, this process will continuously develop over the coming years and decades, based on new technological developments, newly available energy sources and their corresponding costs. Hence, the need to regularly evaluate the pathways proposed below.

All abbreviations and types of vessel used are defined in detail in appendix 1.

In general, the types of fuels identified in the graphs below could be divided into three types from an emissions reduction perspective:

- fossil fuels, such as conventional diesel,
- advanced biofuels such as HVO (Hydrotreated Vegetable Oil) or LBM (Liquefied Bio Methane)
- zero emissions solutions/fuels such as: methanol fuel cells (if bio methanol is used), hydrogen fuel cells (if green hydrogen is used), batteries (if electricity comes from green sources).

[16] More information regarding the CCNR studies on the energy transition towards a zero-emission inland navigation sector is available here: https://www.ccr-zkr.org/12080000-en.html. In particular, the results from deliverable C on the greening techniques which fit into zero-emission development of inland navigation transport will be the most relevant to identify the relevant transition pathways.

4.1 Definition of the business-as-usual scenario (2015 / 2035 / 2050)

The graph below provides an overview of the development of technologies between 2020 and 2050 for the entire fleet, for a "business-as-usual" scenario. It estimates that by 2050, more than 95% of vessels would continue to operate using fossil fuels.

Fig. 1 Business-as-usual scenario- Development of technologies by 2050

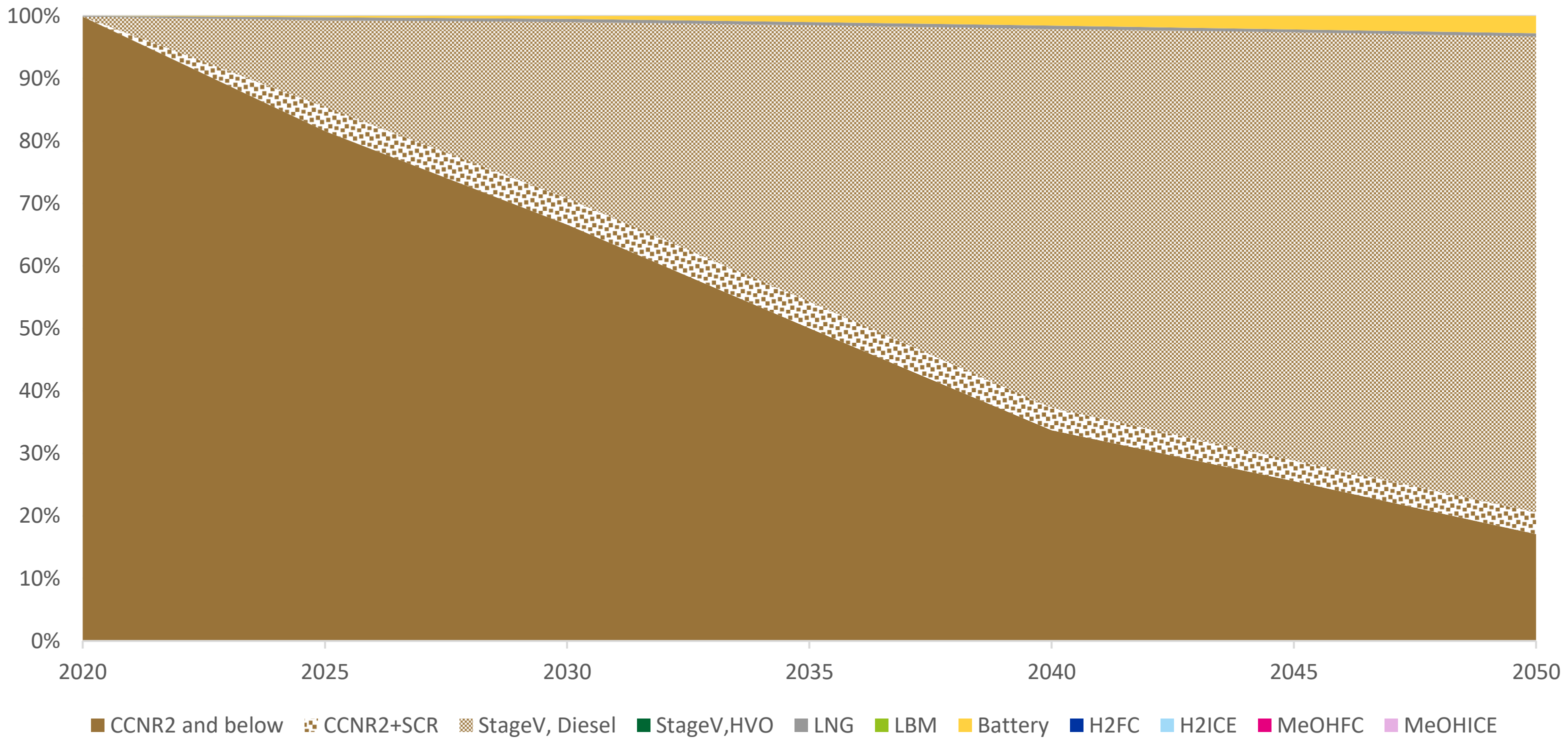
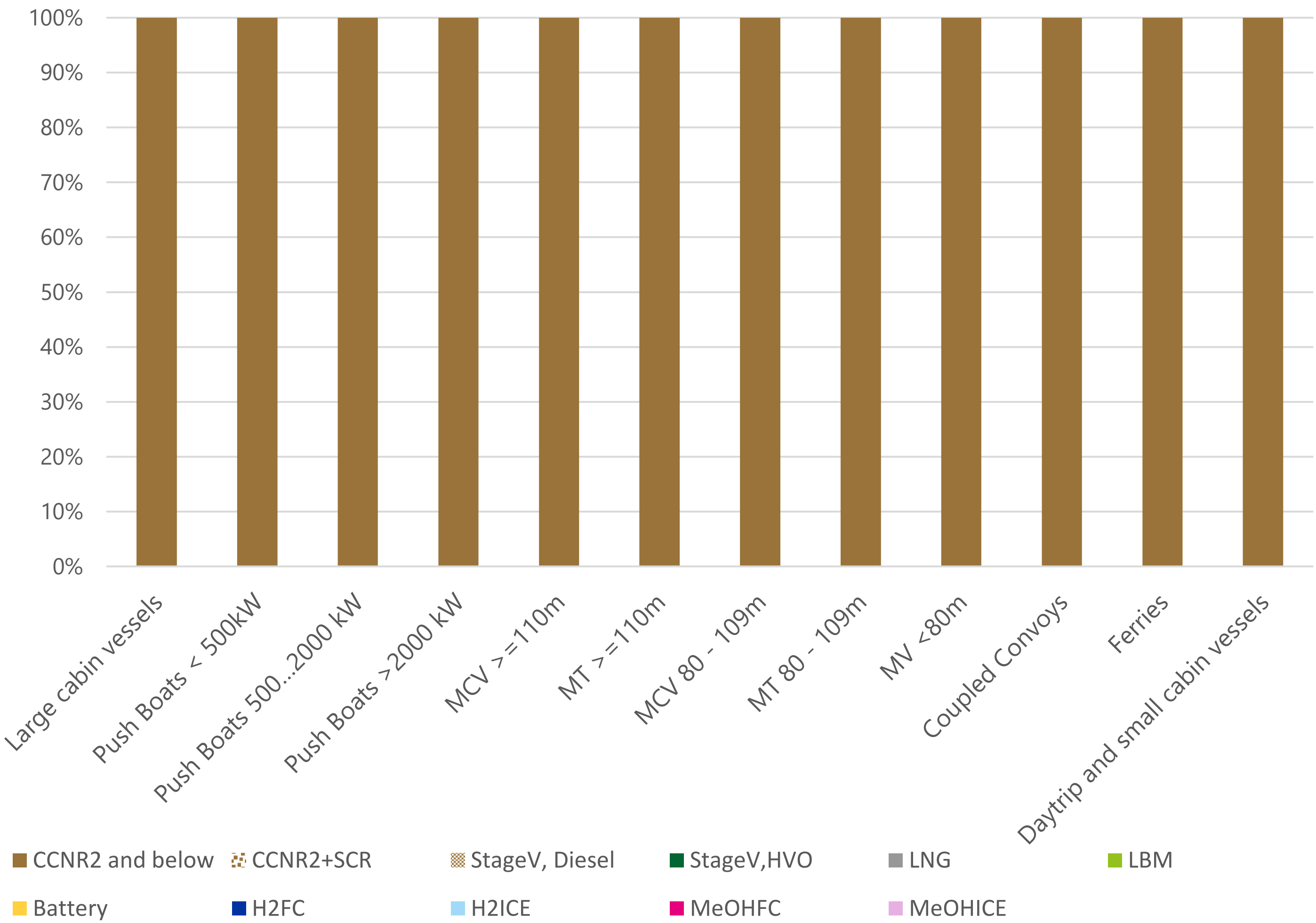
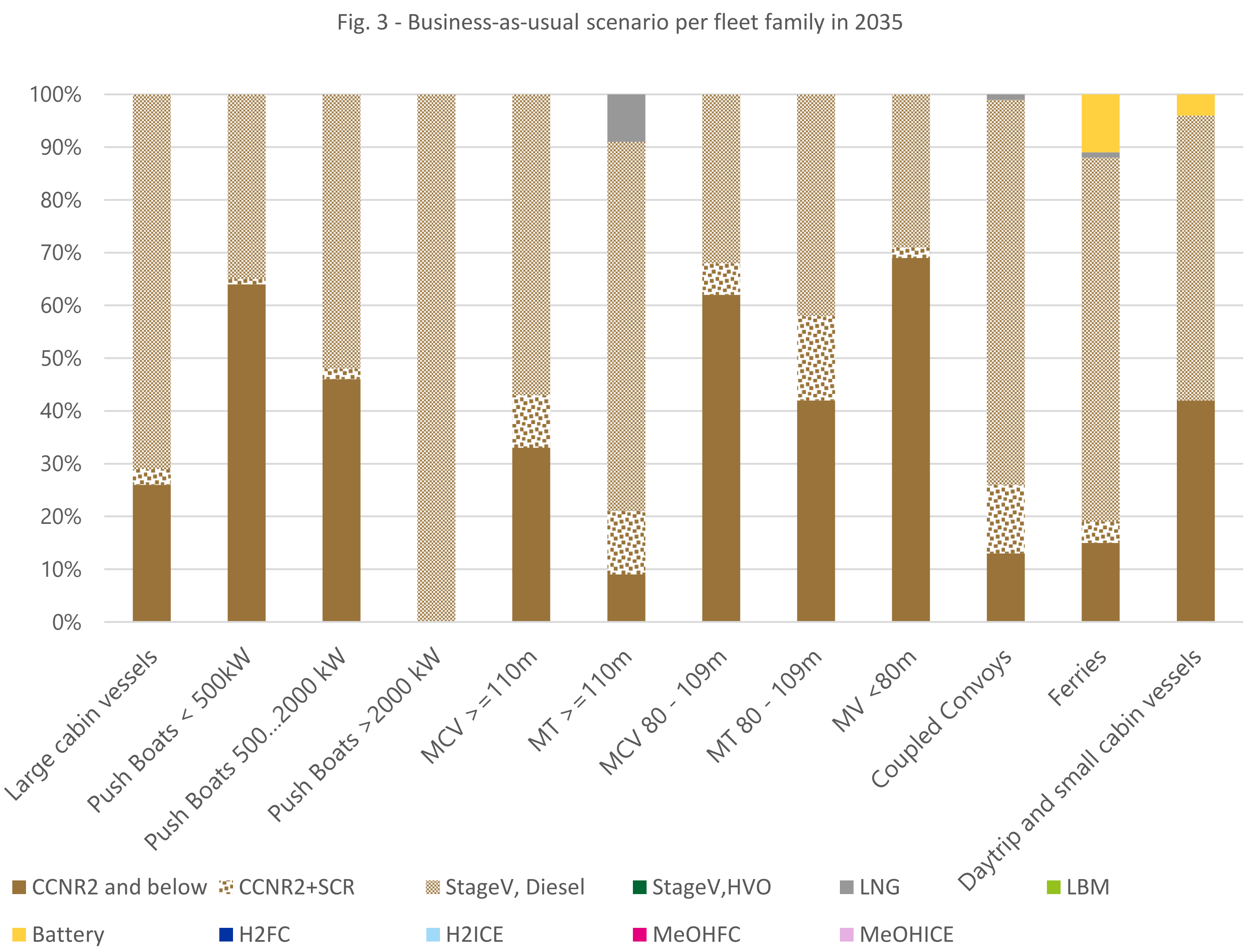


Fig. 2 Business-as-usual scenario per fleet family in 2015



In order to develop transition pathways towards 2035 and 2050, it is necessary to determine how much emissions reduction can already be expected in a "business-as-usual" (BAU) scenario. In the context of this roadmap, the BAU scenario follows the current legal framework and includes confirmed legislation and intervention measures. It therefore excludes any intervention measures which are pending, uncertain or as yet undecided. The BAU scenario is established on the basis of factors used in determining the emissions levels. This concerns factors such as transport demand for IWT services, the development of the inland navigation fleet, changes in a vessel's energy consumption, changes in transport / logistic efficiency as well as changes in a vessel's emissions profile., Assumptions were made for each factor, to identify a business-as-usual scenario in respect of key milestones identified in the Mannheim Declaration: 2015, 2035 and 2050[17]. In this BAU scenario, in 2015, unless stated otherwise in the graph, it is assumed that the vessels' engines are using conventional diesel (EN 590) as fuel.

[17] The parameters of this business-as-usual scenario are defined in detail in the context of the CCNR studies on the energy transition (Research question C in particular).



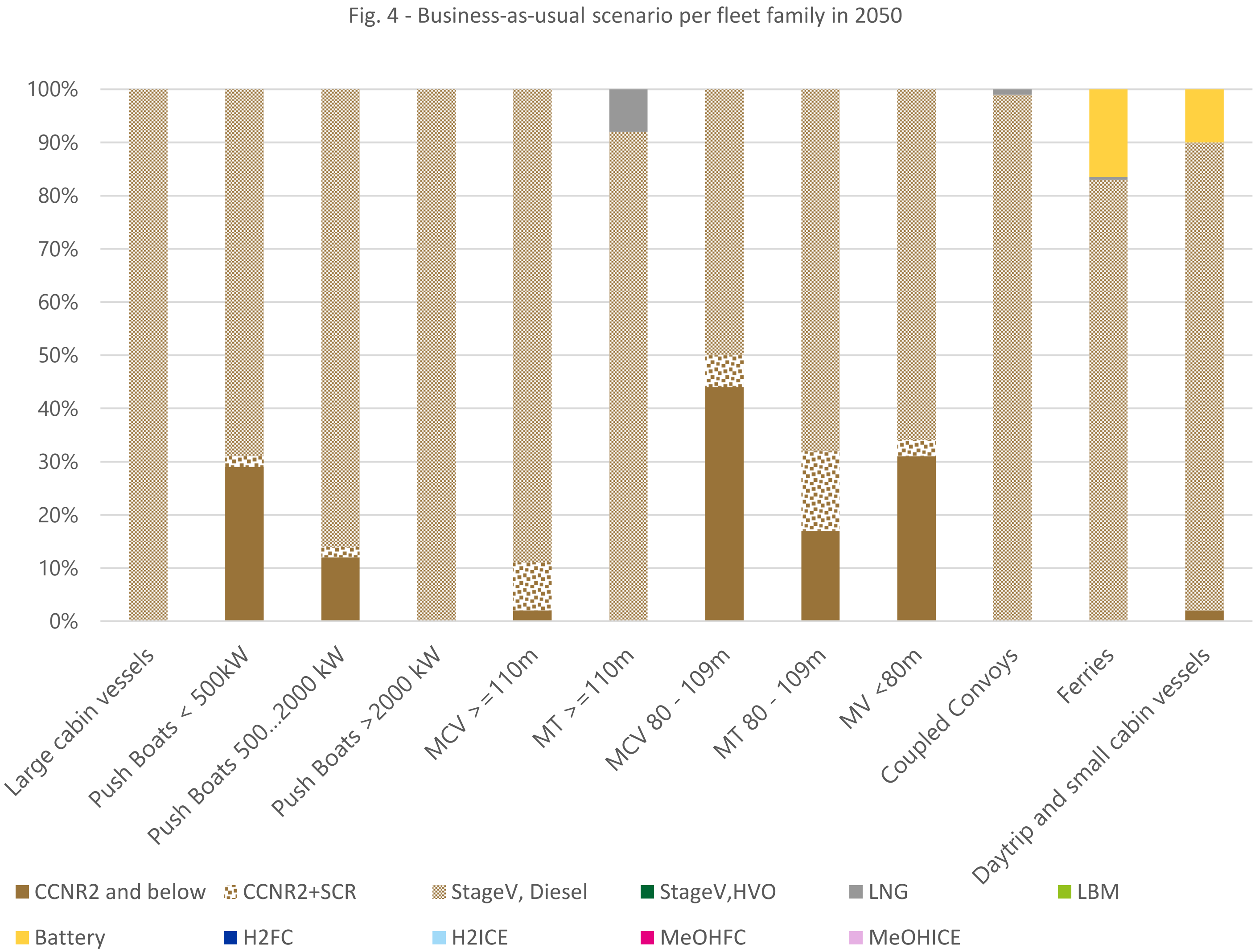
In 2035, the BAU scenario will have enabled the following emissions reduction potential to be achieved compared with 2015:

CO_2: -14%

NOx:-57%

PM: -63%

In this BAU scenario, in 2035, unless stated otherwise in the graph, it is assumed that the vessels' engines are using a fuel blend composed of conventional diesel and 4% biofuel. The outcome of this BAU scenario is that the 2035 air pollutant targets (NOx and PM) in the Mannheim Declaration can be achieved. However, to achieve the CO2 reduction target requires specific measures to be taken if the 35% reduction compared with 2015 is to be achieved.



In 2050, the BAU scenario will have enabled the following emissions reduction potential to have been achieved compared with 2015:

CO_2: -22%

NOx: -76%

PM: -83%

In this BAU scenario, in 2050, unless stated otherwise in the graph, it is assumed that the vessels' engines are using a fuel blend composed of conventional diesel and 7% biofuel. The outcome of this BAU scenario is that the air pollutant and greenhouse gases emissions targets to be achieved in 2050 as provided for in the Mannheim Declaration cannot be achieved. Specific measures must be taken to achieve these objectives.

4.2 Transition pathways towards 2050

To achieve the air pollutant and greenhouse gases emissions targets in 2035 and in 2050 provided for in the Mannheim Declaration, two transition pathways have been developed for each milestone. A conservative pathway and an innovative one.

The conservative pathway refers to a pathway in which the alternative fuels and techniques considered are relatively easy to implement and cost efficient in the short-term. Such alternatives consist, for instance, in advanced biodiesel that can be used in existing diesel engines or liquefied bio methane (LBM) that can be used in gas engines. These are fuels and techniques which have a relatively higher Technology Readiness Level (TRL) and are already available on the market.

The innovative pathway encompasses a more innovative approach, in which the fuels and techniques considered are currently still in their infancy (low TRL) and significantly more expensive as compared with advanced biodiesel and LBM. This concerns alternatives like battery-electric and hydrogen powered propulsion systems.

The decision to present two transition pathways primarily derives from the many uncertainties surrounding their development. These uncertainties concern several aspects such as technological developments, the price of these technologies, their level of maturity, and their availability by 2050. Likewise, the energy source itself (hydrogen, electricity, bio-fuels) is also subject to uncertainties, especially as concerns their availability in sufficient quantity and at an affordable price for inland navigation.

The conservative pathway thus reflects a somewhat pessimistic technological development in which there will be only a limited uptake of the most innovative technologies in the inland navigation sector (primarily because their adoption by the sector was never commercially practicable). The innovative pathway is predicated on a more optimistic technological development in which the innovative technologies have established themselves in the market (primarily because the limited availability and steep increase in the price of bio-fuels make these innovative technologies more competitive). This approach based on two complementary transition pathways reduces these uncertainties in an attempt to anticipate the development of the fleet between now and 2050. In practice, the actual development of the fleet will probably be somewhere between these two pathways, each presenting its own pros and cons.

Although the two transition pathways enable the objectives set by the Mannheim Declaration to be achieved (based on the “tank-to-propeller” approach), initial estimates show that the costs associated with the innovative transition pathway are almost double or even treble those of the conservative transition pathway. This difference has major implications for the associated level of public and private investment. This is primarily attributable to the significantly lower (medium-term) operating costs for the conservative pathway given the estimated prices of the different types of energy.

However, there are major uncertainties surrounding the availability of bio-fuels, especially given limited production capacity (for example the availability of the raw material for producing HVO is a limiting factor). In addition to these production uncertainties, one also needs to take account of competition with other modes of transport and other industrial sectors for priority in terms of the distribution and use of these bio-fuels. For example, it is possible that most bio-fuels will ultimately be earmarked for the aviation or maritime sector if no other technology proved to be appropriate for this sector’s energy transition.

In such a scenario, the cost of bio-fuels could increase significantly, thereby considerably reducing the economic interest of the conservative pathway.

Moreover, although bio-fuels are deemed to be neutral if the entire production chain is taken into account, burning bio-fuels for vessel propulsion purposes emits greenhouse gases and atmospheric pollutants, at least locally. If therefore local regulations were to impose low emissions zones, as is envisaged for example in European cities, vessels running on bio-fuels could no longer operate there. Here too, the conservative pathway would become less attractive.

Moreover, the anticipated progress with innovative technologies should generate benefits in terms of the propulsion systems' energy efficiency (compared with conventional diesel engines) and lower maintenance costs. This affords the prospect of lower operating costs after 2035 for the innovative pathway and demonstrates the long-term interest of such investments.

Finally, if these emissions reduction targets were to exceed 90% by 2050, the main technologies factored into the innovative pathway would have a greater prospect of achieving this additional reduction.

These explanations illustrate the value and need to imagine several transition pathways rather than just one, such is the magnitude of the uncertainties.

4.2.1 Conservative transition pathway towards 2050 (mature technologies)

The graph below provides an overview of the possible development of technologies between 2020 and 2050, for the entire fleet, and of their relative shares in the event of a conservative pathway.

Fig. 5 Conservative pathway: development of technologies by 2050

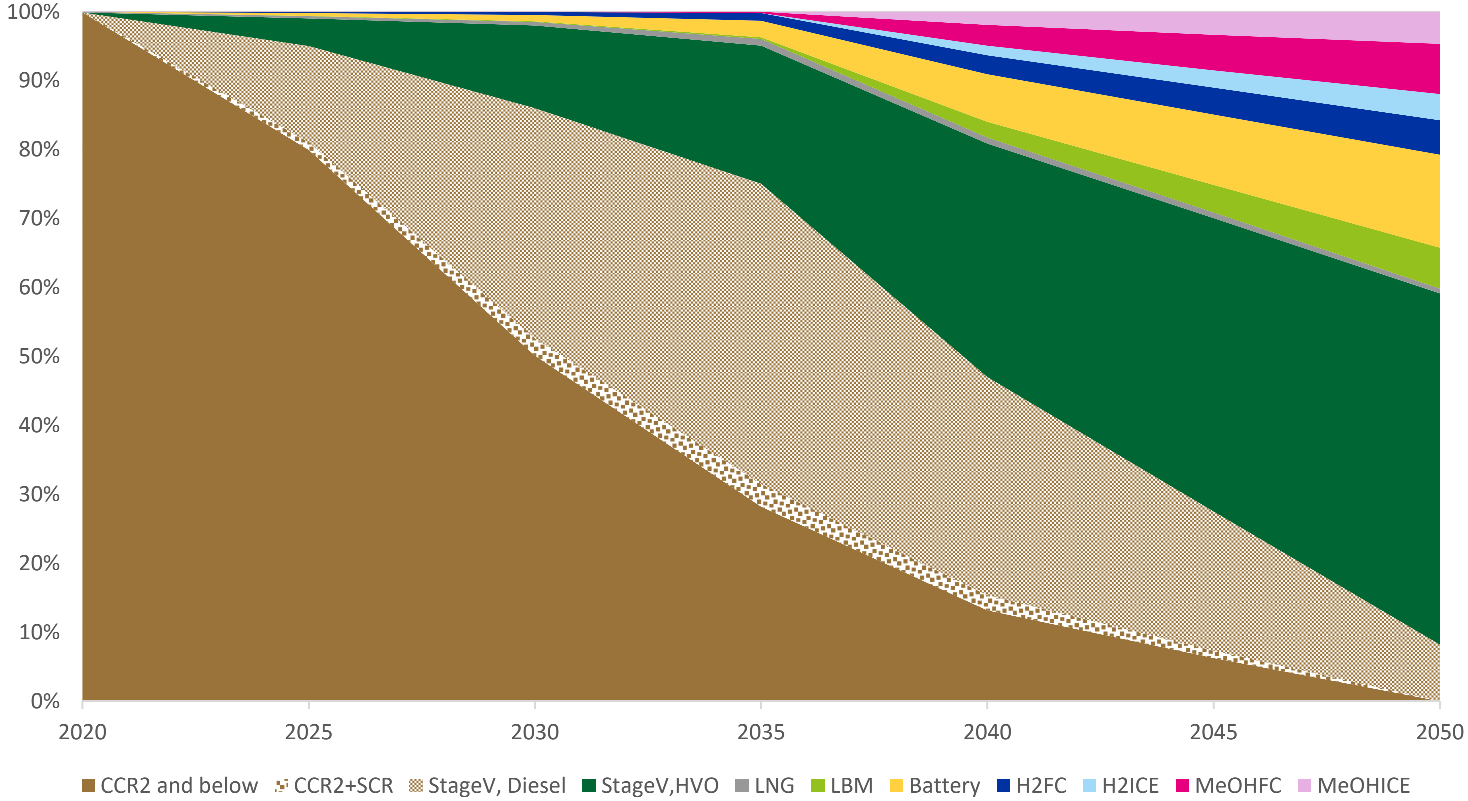
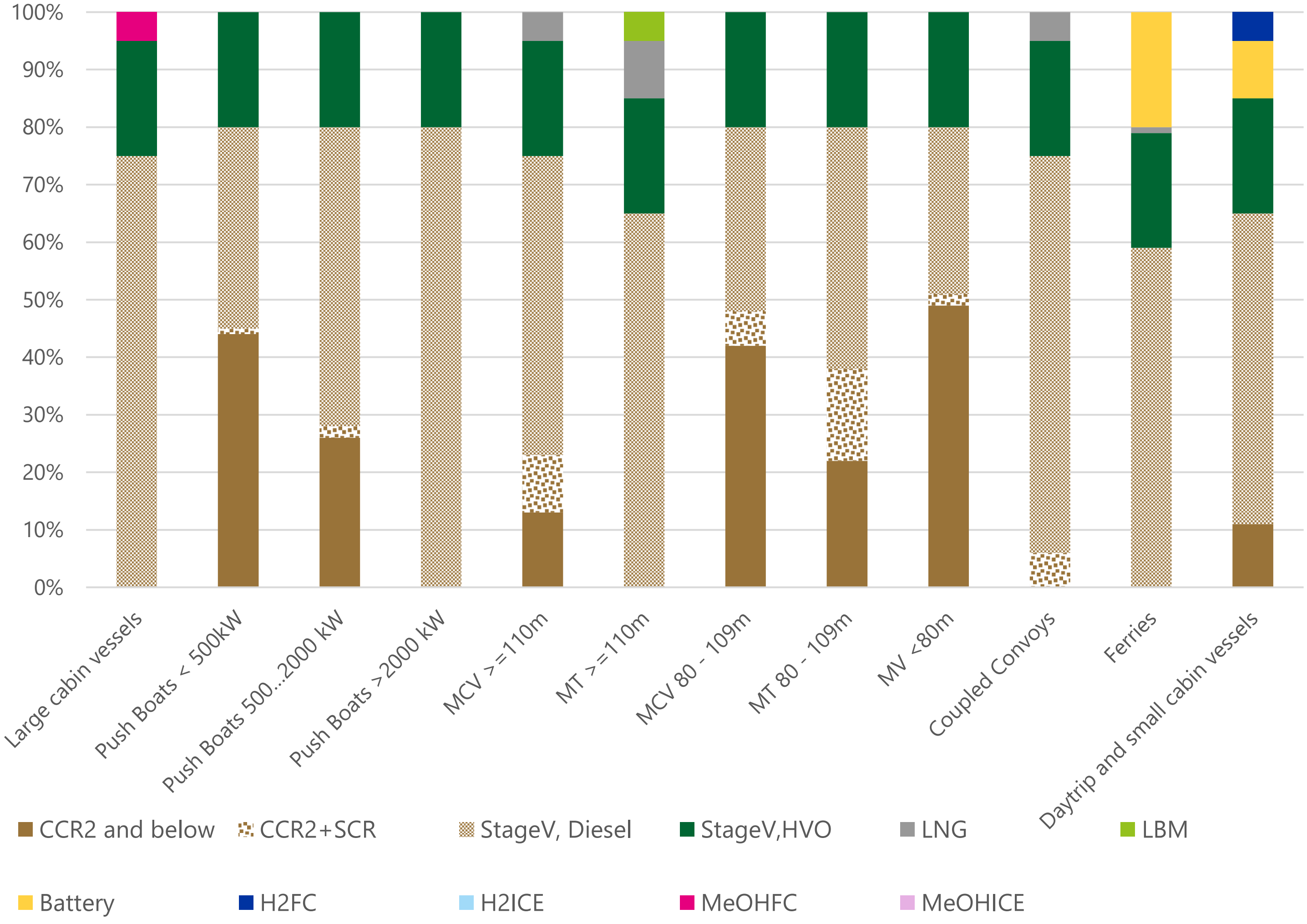


Fig. 6 Conservative pathway: technology share for each fleet family in 2035

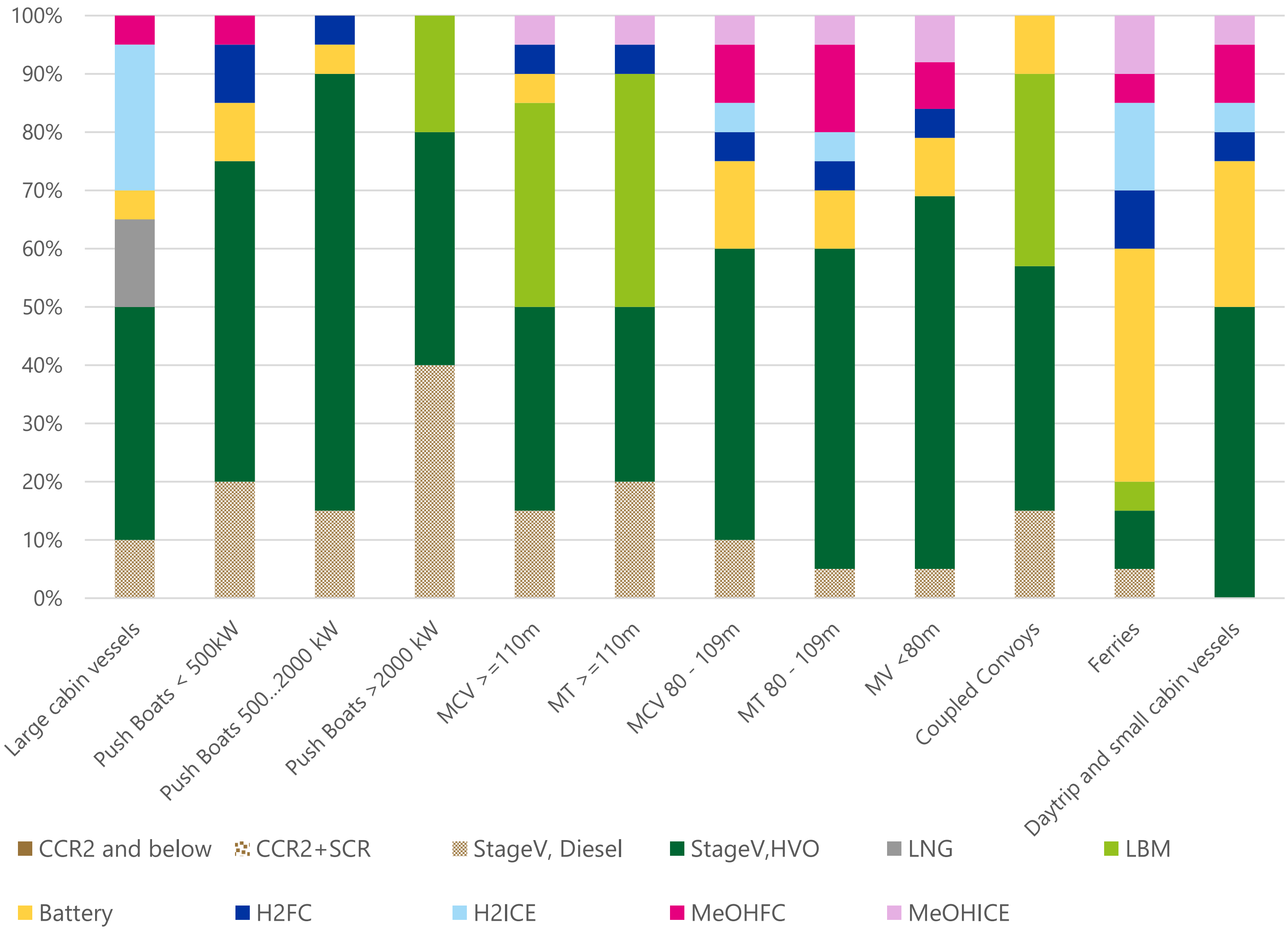


Technology share for each fleet family in 2035

By taking the conservative pathway to achieve the 35% reduction by 2035, much of the fleet will still be using the combustion engine.

However, in addition to conventional diesel, a higher proportion of HVO is assumed in the calculations. This proportion of HVO will be sufficient such that in the conservative scenario, the Mannheim Declaration targets can be achieved with a comparatively small proportion of advanced technologies such as fuel cells and batteries.

Fig. 7 Conservative pathway: technology share for each fleet family in 2050



Technology share for each fleet family in 2050

In 2050, the conservative pathway will enable the following emissions reduction potential to be achieved compared with 2015:

CO_2: -91%

NOx: -90%

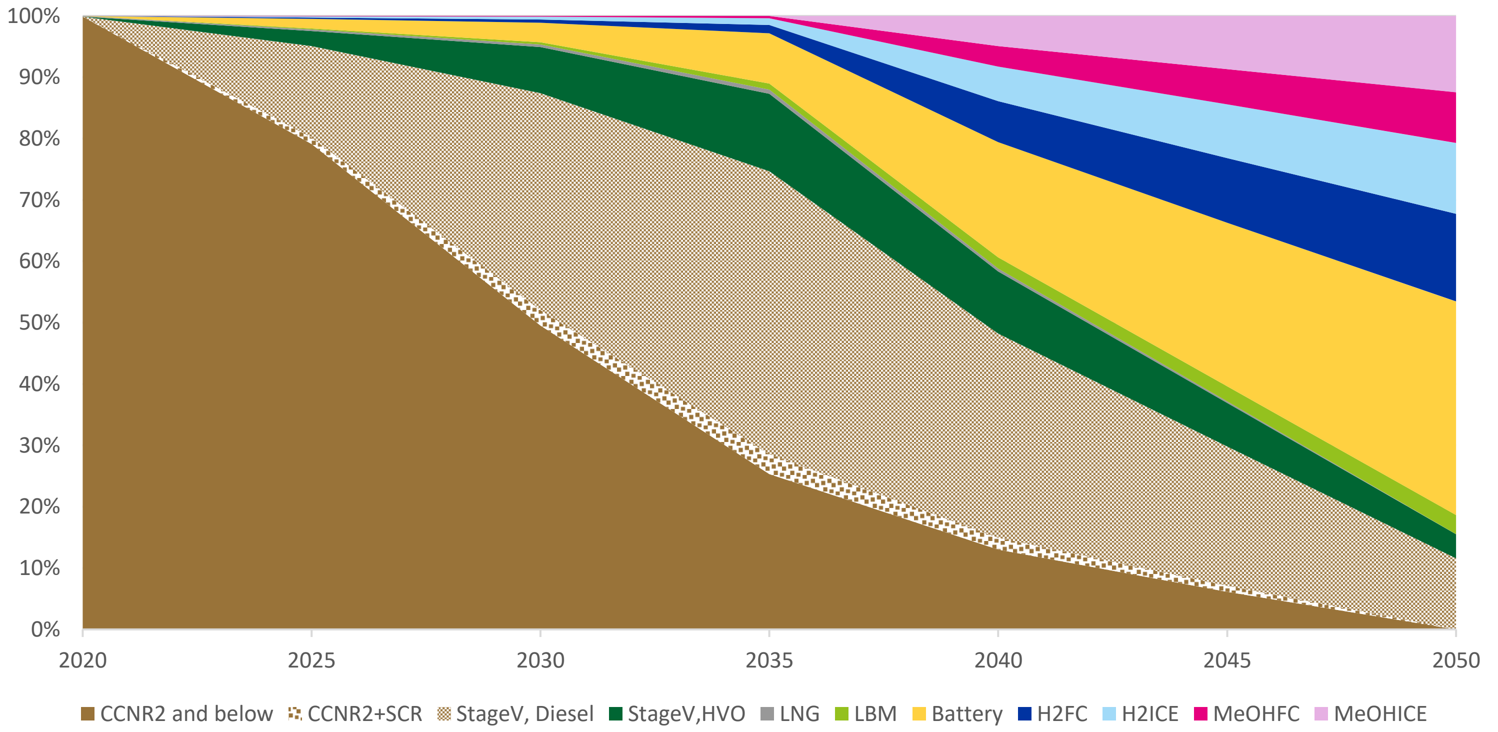
PM: -96%

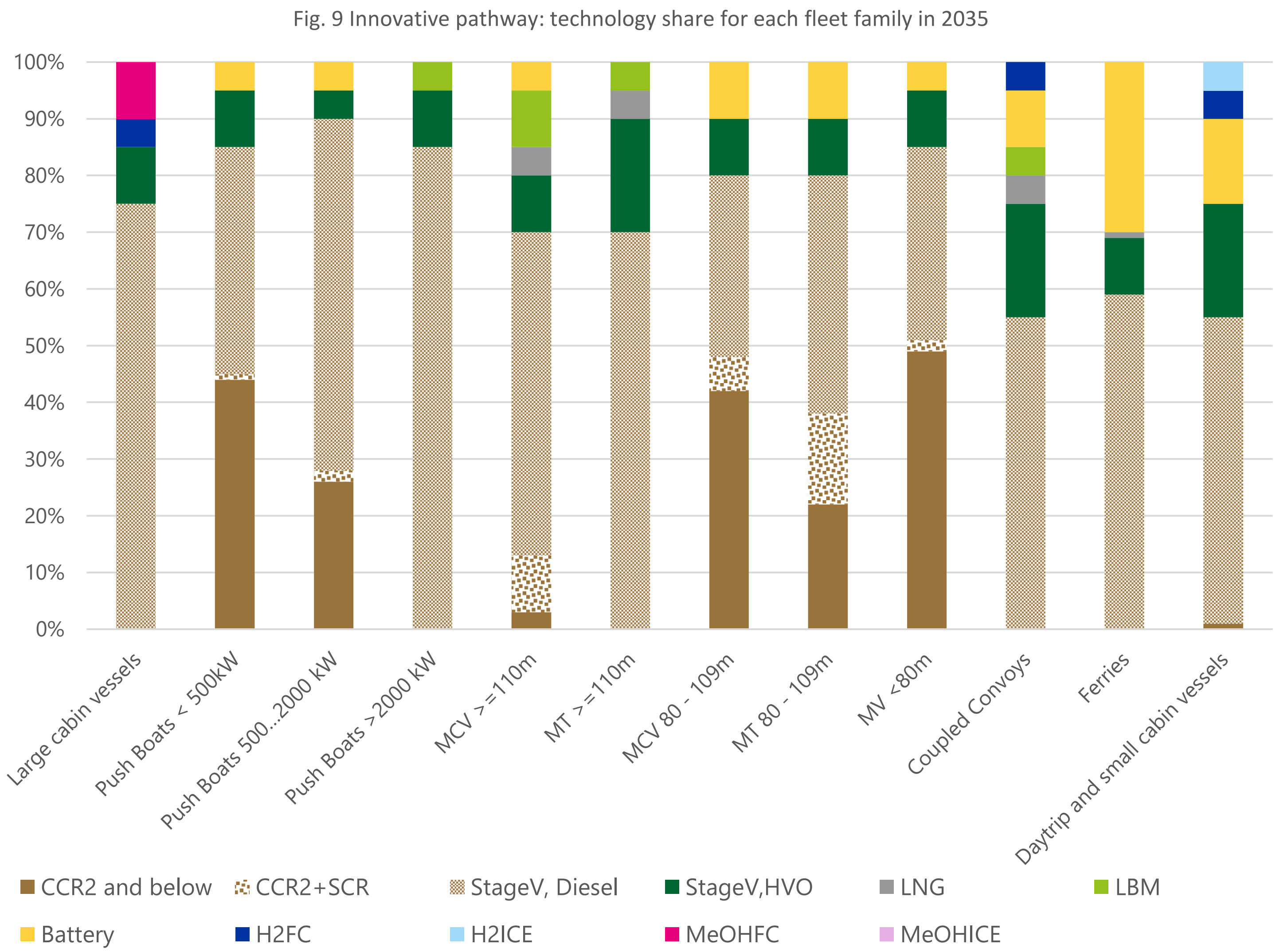
The “drop-in” fuels HVO and LBM account for a relatively large share, especially in the fleet families with a relatively high installed power. Vessels in those fleet families will be relatively less suitable for alternatives such as batteries.

4.2.2 Innovative transition pathway towards 2050 (innovative technologies)

The graph below provides an overview of the possible development of technologies between 2020 and 2050, for the entire fleet, and of their relative shares in the event of an innovative pathway.

Fig. 8 Innovative pathway: development of technologies by 2050

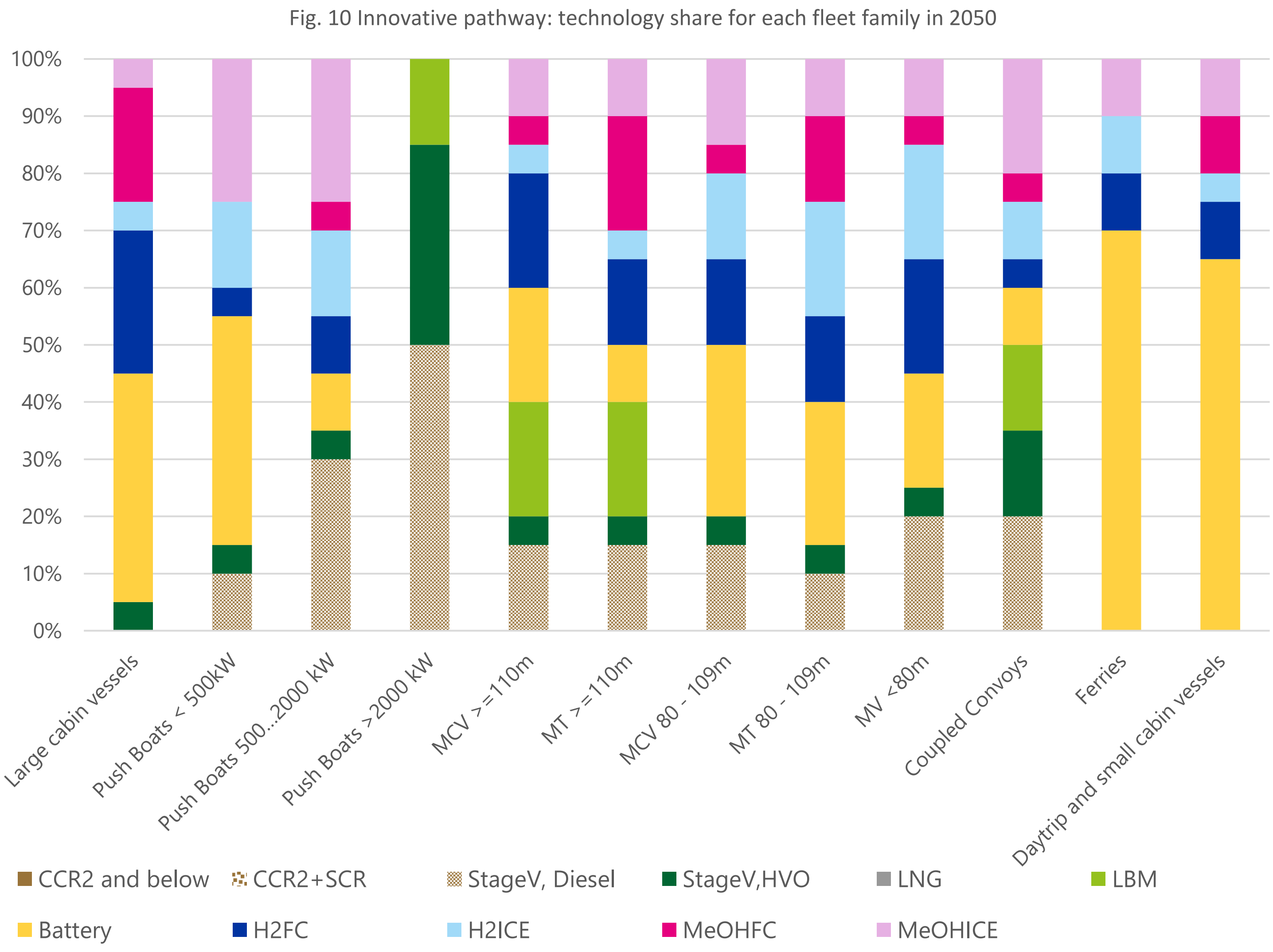




Technology share for each fleet family in 2035

For the innovative pathway, a variety of different technologies will be used for all parts of the fleet as early as 2035, battery electric propulsion as well as hydrogen or methanol fuel cell propulsion being the most relevant. The proportion of HVO compared with the conservative pathway is correspondingly smaller.

However, such a pathway would require a lot of grants to be provided to make it commercially viable for the inland navigation industry and energy suppliers, and shore-side infrastructure operators.



Technology share for each fleet family in 2050

In 2050, the innovative pathway will enable the following emissions reduction potential compared with the year 2015 to be achieved:

CO_2: -91%

NOx: -94%

PM: -98%

It can be seen from the figure that the share of technologies has shifted both towards battery-electric propulsion and hydrogen and methanol. All these technologies exhibit a relatively lower TRL level than HVO and LBM.

An exception is the fleet family for the largest pusher boats (>2000 kW). These vessels are characterised by high installed power, their high fuel consumption (highest in the sector on average), and their potentially limited suitability for alternative technologies/fuels. For example, owing to their volume and weight, batteries might be less suitable because of their potentially severe impact on the vessel.

A detailed transition pathway is envisaged for each fleet family.

[The CCNR Secretariat proposes supplementing this roadmap with information on the required investment to achieve the energy transition (including how much to invest, when, and for which technology) and to identify the timetable for these key investments. However, to do this, it is necessary to await publication of the outcome of the CCNR study on the financing of the energy transition anticipated in June 2021. This part will therefore be integrated into the third draft roadmap.]

5. Implementation plan

Economic, technical, social and regulatory aspects need to be considered if the inland waterway transport sector's energy transition towards zero emissions is to be achieved. When developing the implementation plan, attention could be given to these identified barriers and how to address them through concrete policy measures.

Economic barriers
For the time being, there is no positive business case to justify the investment decisions by shipowners/operators in technologies contributing to zero emissions. The knock-on effect of the costs involved in reducing emissions on transport costs also requires acceptance on the part of shippers and the entire transport chain.

Moreover, given the long lifetime of vessels and their propulsion systems, as well as the small size of the market, there is scant interest from engine and technology suppliers in developing and offering new propulsion and energy solutions specifically for inland navigation vessels, resulting in relatively higher costs for such solutions. The potential higher total cost of ownership (investment and operational costs combined) for greening technologies also constitute risk factors for shipowners.
Finally, the shipowners' investment capacity, depending on the sector concerned (liquid/dry/container/passenger), can be quite limited. The market structure of the IWT sector, consisting in a high share of small and medium enterprises, may be one explanation. The fragmented nature of the sector also becomes a barrier when considering ways of strengthening the shipowners' investment capacity, such as joint financing of greening technologies.

Technical barriers
Pending the availability of transition solutions, most zero-emissions technologies are still at an experimental stage and thus not yet sufficiently developed to enable large-scale use. There are multiple challenges to be considered, i.e. (1) more R&D to accelerate innovation in green technologies and alternative fuels, (2) more significant investments in bringing existing technologies to maturity and/or in improving them so that they too can be used in combating climate change and (3) the integration onboard ships of new innovative or mature technologies and fuels.
Pilot applications of zero-emissions technologies in inland vessels remain essential first steps in identifying and addressing the technical barriers to the deployment of technologies. At the same, such applications should clarify the capital/operational costs and demonstrate a viable business case.
This should also be accompanied by the development of appropriate alternative fuels bunkering infrastructure (investment in new infrastructure and in repurposing existing infrastructure).

Human/social barriers
Transition towards zero emissions also needs acceptance among the inland navigation work force. Education and training (initial and continuous) can create such acceptance while actively supporting the deployment of zero emissions technologies on board inland navigation vessels. In more general terms, the deployment of new technologies must ensure a high degree of safety and reliability if it is to be accepted by society and to maintain the associated confidence.

Regulatory barriers
At this stage, the current regulatory framework for inland navigation does not provide the necessary legal certainty to ensure investment, encourage players to take the plunge and more generally create sufficient incentives for zero-emission technologies. Improvements of the regulatory framework should allow the normal use of alternative fuels and batteries on board inland navigation vessels. This mainly concerns vessels, crew, police requirements and the transport of dangerous goods.

The implementation plan below is a list of possible implementation measures. It distinguishes between four types of measures: regulatory, voluntary, economic/financial support and monitoring.

No.	Measure	Nature of Measure	Required actions	Players	Methodology, tools and the CCNR's possible contribution
			(What)	(Who)	(How)
R1a	Appropriate regulatory framework for the use of alternative fuels and batteries (vessel construction)	Legal requirement	Develop standards and requirements applicable to the construction of inland navigation vessels to allow the normal use of alternative fuels and batteries on board these vessels.	CESNI, Member States of the CCNR, River Commissions[18], UNECE, EU, CEN	Standards and regulations developed based on experience gained with pilot projects as well as existing standards from other industrial sectors
R1b	Appropriate regulatory framework for the use of alternative fuels and batteries (crew)	Legal requirement	Develop crew-related standards and requirements for allowing the normal use of alternative fuels and batteries on board inland vessels.	CESNI, Member States of the CCNR, River Commissions, UNECE, EU	
R1c	Appropriate regulatory framework for the use of alternative fuels and batteries (vessel operation)	Legal requirement	Develop standards and requirements for operating vessels (navigation authority regulation)for allowing the normal use of alternative fuels and batteries on board inland vessels.	Member States of the CCNR, River Commissions, UNECE	
R1d	Appropriate regulatory framework for the use of alternative fuels and batteries (transport of dangerous goods)	Legal requirement	Develop standards and requirements for allowing the carriage of alternative fuels	UNECE	
R2	Possible out phasing of specific, polluting technologies	Legal requirement	Setting up a regulatory framework enabling the possible phasing out of internal combustion engines with fossil fuels, targeting existing vessels, addressing both greenhouse gases and pollutant emissions.	CCNR, EU	Sector dialogue, study, reports, regulations Label (see V1) could be used as criteria. Over-powering when retrofitting existing vessels should be prevented to ensure effective improvement of energy efficiency (taking into account the optimum power output defined by the shipbuilder)

18 "River commissions" means Central Commission for the Navigation of the Rhine, Danube Commission, International Sava River Basin Commission and Mosel Commission.

No.	Measure	Nature of Measure	Required actions	Players	Methodology, tools and the CCNR's possible contribution
			(What)	(Who)	(How)
R3	Infrastructure requirements for alternative fuel and electricity for propulsion	Legal requirement	Ensure that the revised directive AFID fits with the needs of the IWT sector in terms of alternative fuel infrastructure and ensure interoperability with all types of inland vessels.	CCNR, EU	Directive, report, interoperability standards
R4	Examination of the polluter pays principle as the basis of financial decision-making	Legal requirement	Examination of tax privileges for the navigation of the Rhine and for inland navigation from a legal, economic and political perspective prior to a discussion on internalising external costs in the inland navigation sector	CCNR	Examination of the compatibility of the polluter pays principle, especially with the Mannheim Act; consideration of the environmental repercussions of other modes of transport and of the modal split
R5	Scrutiny and where appropriate amendment of safety and statutory requirements for bunkering of alternative fuels in inland waterway transport	Legal requirement	It must be ensured that neither safety or statutory regulations nor other provisions relating to bunkering infrastructure prevent the bunkering of alternative fuels.	CCNR	Report Identify relevant legislation and requirements as well as gaps in the legislation together with national competent authorities for bunkering infrastructure
V1	Label for environmental and climate protection	Voluntary	Develop of an environmental and climate protection label	CESNI, CCNR, EC	Study, technical standards, guideline on the calculation and measurement methodology
V2	Offsetting measures (carbon offset)	Voluntary	Evaluate the possibilities and public acceptance of offsetting measures as a stop gap solution until 2035 for greenhouse gases reduction. A carbon offset is a reduction made somewhere to compensate for emissions made elsewhere.	CCNR, EU, IPCC	Guidelines on applicability of existing offsetting of emissions measures to inland navigation (and possibly new proposals)
V3	Pilot vessel trials	Voluntary	Follow, authorise, and support trials on pilot vessels and publish important results	CCNR, CESNI, EC	RV 2020-VI-1
V4	Innovative vessels	Voluntary	Setting up of a database on innovative vessels	CESNI, research institutes	Regular updates at least once a year

No.	Measure	Nature of Measure	Required actions	Players	Methodology, tools and the CCNR's possible contribution
			(What)	(Who)	(How)
V5	Innovation award	Voluntary	Award for special innovations for the transformation of the inland navigation energy system	River Commissions	Every two years
F1	Examination of European funding and financing instrument to support the inland navigation energy transition	Financial Support	Design, evaluate and implement a European funding and financing instrument	EU, European Investment Bank (EIB), CCNR, national banks, EBU, ESO	CCNR study on the energy transition of the IWT sector, PLATINA3
F2	EU Taxonomy – establishment of an EU classification system for sustainable activities	Financial Support	Take better account of inland navigation and its specific characteristics in the taxonomy regulations and related delegated acts	EU	Contribution and proposal in the context of the taxonomy regulation
F3	Stimulate research and innovation projects	Financial support	Support to pilot projects contributing to improving knowledge and experience as to zero-emission technologies in the inland navigation sector	EU, River Commissions, EBU, ESO, research institutes	Contribution and participation in key R&D forums and initiatives relevant to the IWT sector
M1	Energy price and demand monitoring	Economic	Monitor fuel prices and energy demand	CCNR	Annual report as part of the market observation (CCNR/EC)
M2	Situation reports	Voluntary	Regularly analyse emissions reduction status and the effectiveness of measures. It includes data collection, evaluation and correction (i.e. sense checks)	CCNR	Status report every 5 years, (see CCNR work programme RV 2020-VI-3 and 5) Regular conferences

6. Communication and involvement of the stakeholders once the roadmap has been adopted

As a reminder, the preparation of the roadmap included several exchanges with the CCNR approved organisations, as well as with international organisations.

This part of the roadmap aims to:

- ensure the involvement in and commitment of all the key players to implementation of the roadmap, over its entire duration.
- enable the broadest possible acceptance of the roadmap’s content.

It is already worth noting at this stage that synergies are expected with several projects, including STEERER and PLATINA3.

After adoption of the second revised roadmap either in the plenary in 2021, the CCNR Secretariat proposes following a step-by-step approach to ensure that the roadmap is widely disseminated and accepted. It is essential to present the roadmap’s content and to use this blueprint for policies to be implemented by the Member States and relevant players within the sector to achieve the objectives set by the Mannheim Declaration and the European Green Deal.

- The CCNR will share the adopted roadmap with international or national authorities which are competent to take the policy measures (by means of a letter or dedicated meetings).
- The CCNR will organise regular workshops with the approved organisations to intensify further the dialogue with the industry and to analyse the policy measures taken.
- The CCNR will regularly revise the roadmap to take account of emissions reduction status, the analysis of policy measures, and the knowledge gained in the use of new technologies, especially with pilot vessels or European projects such as PLATINA3.

Given that this roadmap could also inspire European public policies, a communication aimed at presenting this roadmap could be made to stakeholders in the European Commission, the European Council (Shipping working party) and the European Parliament (Committee on Transport and Tourism).

Appendix 1: List of abbreviations
[to be finalised once the roadmap is in a more finalised stage]

BAU	Business-as-Usual
CAPEX	Investment Costs
FC	Fuel Cell
GHG	Greenhouse Gas
GTL	Gas-to-Liquid
HVO	Hydrotreated Vegetable Oil
H_2	Hydrogen
ICE	Internal Combustion Engine
IWT	Inland Waterway Transport
IPCC	Intergovernmental Panel on Climate Change
LBM	Liquefied Bio Methane (CH_4)
LNG	Liquefied Natural Gas
MeOH	Methanol (or CH_3OH)
OPEX	Operational Costs
PEM FC	Proton Exchange Membrane Fuel Cell
PM	Particulate Matters
SCR	Selective Catalytic Reduction
TCO	Total Cost of Ownership
TRL	Technology Readiness Level is a scale used as a means for measuring or indicating the maturity of a given technology, ranging from 1 (Basic principles observed) to 9 (actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space). In general, many products go through the various stages of the TRL scale in their life cycle.

Definitions of vessel types used for the transition pathways

- Motor vessels dry cargo ≥ 110 m: a vessel equal to or longer than 110 m, intended for the carriage of dry goods and containers and built to navigate independently under its own motive power;
- Motor vessels liquid ≥ 110 m: a vessel equal to a or longer than 110 m, intended for the carriage of goods in fixed tanks and built to navigate independently under its own motive power;
- Motor vessels dry cargo 80-109 m: a vessel with length between 80 and 109 m, intended for the carriage of dry goods and built to navigate independently under its own motive power;
- Motor vessels liquid cargo 80-109 m: a vessel with length between 80 and 109 m, intended for the carriage of goods in fixed tanks and built to navigate independently under its own motive power;
- Motor vessels < 80 m: a vessel shorter than 80 m, intended for the carriage of all type of goods and built to navigate independently under its own motive power;
- Pushers with P[19]< 500 kW: a vessel specially built to propel a pushed convoy and equipped with a total propulsion power of less than 500 kW;
- Pushers with 500 < P < 2000 kW: a vessel specially built to propel a pushed convoy and equipped with a total propulsion power of more than 500 kW but less than 2000 kW;
- Pushers with P > 2000 kW: a vessel specially built to propel a pushed convoy and equipped with a total propulsion power of more than 2000 kW;

[19] P = Total Power installed

- Coupled convoys: a motor vessel (generally longer than 95 m) intended to be operated with one or several lighters;
- Ferries: a passenger vessel providing a service crossing the waterway;
- Hotel vessels: a passenger vessel longer than 86 m and with overnight passenger cabins;
- Passenger vessels (day-trip and small hotel vessels): a passenger vessel for day-trip operation as well as a passenger vessel with overnight passenger cabins but shorter than 86 m.

[Comment by the Secretariat: the terminology and consistency of the transition pathways' legends will require checking once the studies have been published.]

Remarks:

The fleet families were chosen based on the findings of the Horizon 2020 project "PROMINENT" - D1.1 List of operational profiles and fleet families (2016); IVR database; ES-TRIN 2021/1; DST study "Assessment of technologies in view of zero-emission IWT" (2020) and supplemented by the fleet families for passenger vessels.

For the cargo vessels, the classification was made by size and cargo (dry or liquid). The sizes for the fleet families are below 80 m, between 80 and 110 m and above 110 m. There is also an extra fleet family that includes vessels that can sail as a coupled convoy, since these vessels have a significantly higher installed power to be able to push one or more additional barges.

The fleet family "Day trip and small cabin vessels" was created by extracting the fleet family "Large cabin vessels" from the PROMINENT fleet family "Passenger vessels (cabin/cruise vessels)" which comprised all kinds of passenger vessels (except ferries). This categorisation was proposed to take account of the significant differences regarding age, installed power and energy demand between the smaller vessels and the larger vessels of the type passenger vessel.

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