CCNR ROADMAP
for reducing inland navigation emissions

CCNR
CENTRAL COMMISSION
FOR THE NAVIGATION OF THE RHINE

CCNR roadmap

FOR REDUCING INLAND NAVIGATION EMISSIONS

CCNR
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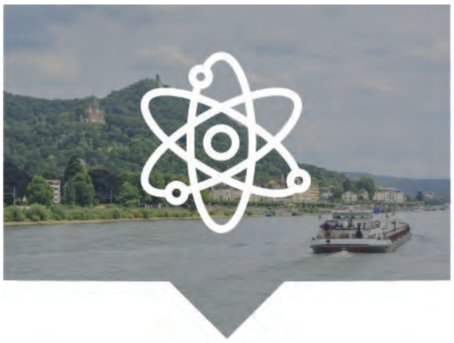
FOR THE NAVIGATION OF THE RHINE



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TRANSITION PATHWAYS FOR INLAND NAVIGATION BY 2035 AND 2050

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IMPLEMENTATION PLAN

6

NEXT STEPS

Executive summary

In accordance with the mandate given by the Ministerial Declaration of 17 October 2018 in Mannheim, the CCNR developed a roadmap aiming at largely eliminating greenhouse gas (GHG) emissions and air pollutants of the inland navigation sector by 2050, a long-term vision which is also shared by the European Union (EU). This energy transition must be seen as a crucial challenge for Rhine and European inland navigation. Based on today's knowledge, while innovations to reduce emissions from existing and new vessels have increased in recent years, they tend for time being to be limited to pilot projects, which are however of utmost importance in gaining knowledge of new technologies, and addressing economic, financial, technical and regulatory obstacles to the deployment of relevant technologies (see chapter 1 "Initial situation").

Despite current uncertainties concerning especially the development, the cost, the level of maturity and the availability of the technologies contributing to the transition towards a zero-emission inland navigation sector, it is necessary to make an immediate start on designing an approach towards this ambitious objective that can be sustained in the medium and long-term. In this context, identifying and considering the measures enabling an accelerated transition towards zero-emissions (such as regulatory measures, monitoring of the emissions, financial support for the energy transition, …), together with the development of technology transition pathways for the fleet, are essential elements to be included when designing a realistic and sound roadmap. This roadmap shall, in this respect, be understood as the primary CCNR instrument for mitigating climate change, fostering the energy transition and contributing to the European IWT policy. It notably builds on the final results on the CCNR study on the energy transition towards a zero-emissions inland navigation sector and close consultation with the relevant stakeholders. (see chapter 2 "Role of CCNR and purpose of the roadmap").

To ensure a common understanding between all the actors involved in the energy transition of inland navigation, it was essential to agree on a scope for this roadmap and on key definitions (see chapter 3 “Preliminary definitions, targets an estimation of emissions”). In particular, it was decided to:

» lay focus on inland navigation meaning the transport of goods and the carriage of passengers by inland waterway vessels. Recreational crafts, service vessels and floating equipment were not included at this stage;
» define emissions as atmospheric pollutants and greenhouse gases arising from the operation of an inland navigation vessel’s propulsion and auxiliary systems;
» adopt a “tank-to-wake” (TTW) approach, as an interim solution, until a “well-to-wake” (WTW) approach is available for the relevant energy carriers. Application of this approach however implies making assumptions concerning the upstream chains (emissions produced and fuel availability) which are idealised.

In particular, the roadmap aims to outline two transition pathways for the fleet (new and existing vessels). A more conservative transition pathway, based on technologies that are already mature, cost efficient in the short-term but with uncertainties on the availability on certain fuels, and a more innovative one, relying on technologies still in their infancy stage but providing more promising emission reduction potential on the long run. The transition pathways also address the role which the different technological solutions will play in the energy transition challenge, assess their suitability according to the different fleet families in Europe and the sailing profiles of the vessels. The two transition pathways are both sufficiently ambitious to achieve the objectives of the

Mannheim Declaration. A key conclusion points to the absence of a "one size fits all" technology solution adapted to all types of vessels and navigation profiles. A technologically neutral approach appears therefore relevant to achieve the energy transition. Considerations regarding the financial challenge and possible no-regret investments are also included. Indeed, the financial gap to be bridged to achieve the Mannheim Declaration emission reduction objectives varies significantly from one transition pathway to another but is expected to reach several billion euros in both (see chapter 4 "Transition pathway for inland navigation by 2035 and 2050").

Economic, technical, social and regulatory aspects need to be considered to tackle the challenge of the energy transition towards zero emissions. How to address them through concrete policy measures was a guiding question when developing the implementation plan proposed in the roadmap, which aims at suggesting, planning and implementing measures to be adopted directly or not by the CCNR, as well as monitoring the intermediate and final objectives laid down by the Mannheim Declaration (see chapter 5 "Implementation plan"). The CCNR will undertake, to report, by 2025, on the progress in the implementation as well as the need to update and, if necessary, revise the roadmap by 2030, the roadmap and the corresponding action plan (see chapter 6 "Next steps").

Eventually, the CCNR aspires to this roadmap being of assistance in developing a shared vision of the energy transition and the concomitant challenges within the inland navigation sector. It is desirable to deepen its cooperation with other energy transition actors, especially the EU, with a view to implement the proposed action plan jointly as well as to ensuring that measures are tailored to the inland navigation sector.

Initial situation

1

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 (GHG) 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 GHG 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 GHG emissions by 35% compared with 2015 by 2035,
- reducing pollutant emissions by at least 35% compared with 2015 by 2035,
- largely eliminating GHG and other pollutants by 2050.

Additionally, 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.[1]

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,[2] asking for a European policy on the reduction of GHG emissions towards climate neutrality in 2050 for all transport modes including the inland navigation sector.

[1] *https://www.unece.org/fileadmin/DAM/Poland_Ministerial_declaration_e__002_.pdf*
[2] *https://ec.europa.eu/clima/policies/strategies/2050*

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 NO_x and particulate matters, covering, amongst other sectors, the transport sector.[3]

The European Commission’s Green deal for Europe,[4] 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 GHG reduction target of at least 50% and close to 55% by 2030 compared with 1990 (for all sectors);
» a GHG reduction target of 90% in the transport sector by 2050 (to achieve climate neutrality).

On 14 July 2021, the European Commission published its “Fit for 55” legislative package,[5] consisting in a package of proposals to make the EU climate, energy, land use, transport and taxation policies fit for reducing net greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels.

Furthermore, the European Commission’s NAIADES III Action plan[6] was released in June 2021, with the core objective of shifting more cargo over Europe’s rivers and canals and facilitating the transition to zero-emission vessels by 2050. Some flagship measures relating for instance to the speeding up of the certification process for innovative and low emissions vessels, the development of multimodal alternative fuel supplying infrastructure hubs and the need to support the sector and Member States in the transition towards zero-emission, particularly regarding funding and financing, are key to meeting the energy transition challenges.

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

[3] *http://ec.europa.eu/environment/air/index_en.htm*
[4] *https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_fr#policy-areas*
[5] *https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/delivering-european-green-deal_en*
[6] *https://ec.europa.eu/transport/modes/inland/news/2021-06-24-naiades-iii-action-plan_en*

1.2

The inland navigation energy transition context

Today, the energy transition must be seen as a crucial challenge for inland navigation. Only if the IWT sector is ready to tackle the transition to climate neutral propulsion, will there be long-term political support 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 are however essential to gain knowledge of new technologies. This can be explained by various economic, financial, technical and regulatory reasons. More generally, these innovations also reach different levels of maturity.

Apart from the purely technical issues, legal uncertainties and long administrative procedures also pose considerable problems.

In this context, identifying and considering the measures enabling an accelerated transition towards zero-emissions (support to research and innovation in zero-emissions technologies, financial support for the energy transition, more stringent environmental targets …), together with the development of transition pathways towards zero emissions, are also essential elements to be included when designing a realistic and future-proof roadmap.

In today's circumstances, air pollutants can be reduced to a large extent with internal combustion engines (ICE) equipped with modern aftertreatment, while the reduction of GHG emissions is the most challenging part. Beyond the use of new energy carriers and converters as a means of reducing emissions, reduction of energy consumption by all possible means is an important lever to achieve the emission reduction objectives, GHG emissions in particular.[7] This includes for example a better use of vessels, an increased efficiency by means of modern propulsion systems, the improvement of the vessels' hydrodynamics, smart navigation with less waiting time at locks and an efficient integration of inland navigation into the logistic of seaports.

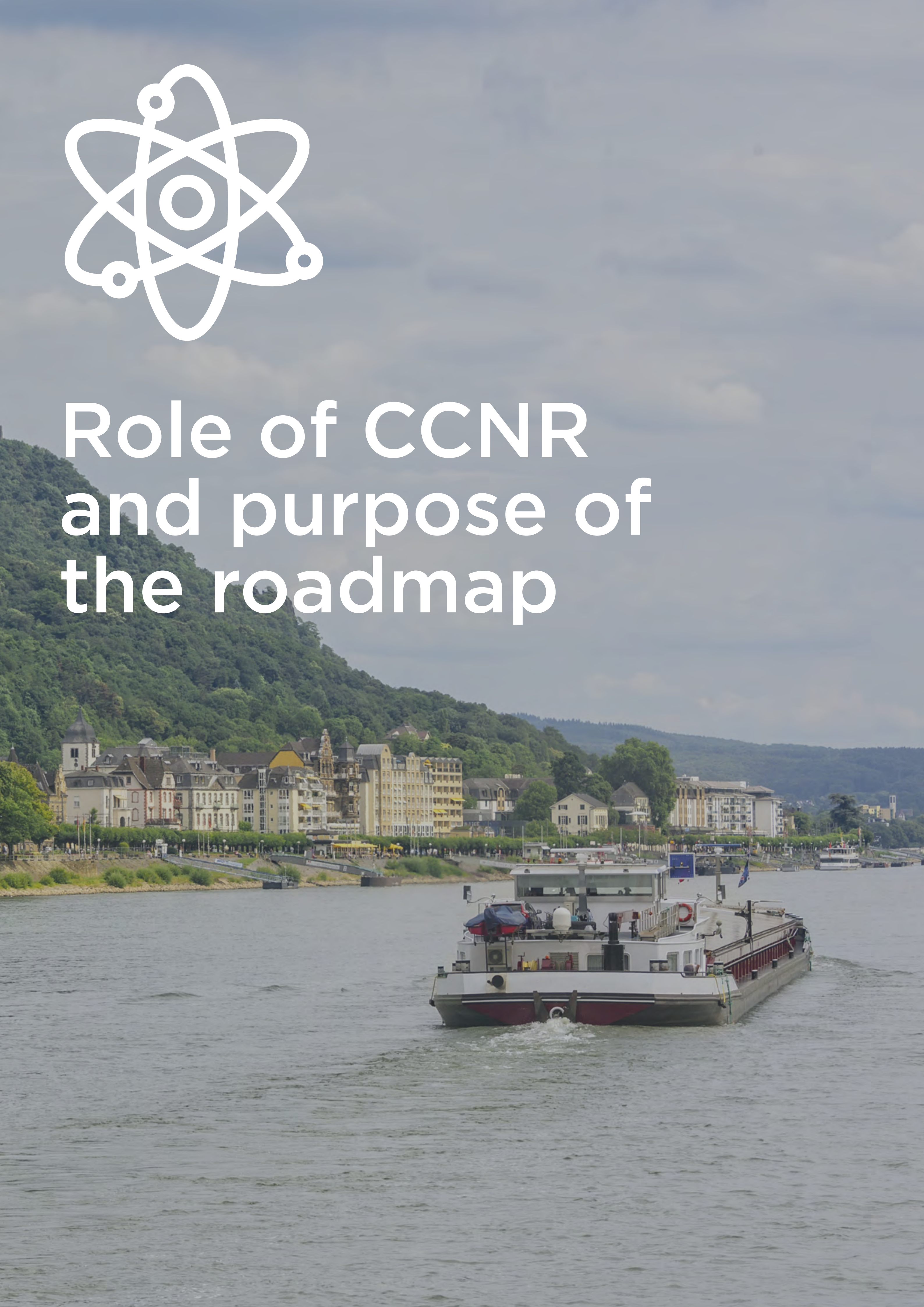
Wherever possible, careful attention should be paid to developments in other modes of transport, such as road, rail and short-sea shipping. Indeed, there is much to be learned from the experience gained by other modes regarding the energy transition. Moreover, it is important to take the multimodal context 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.

Last but not least, the relatively small size of the European inland waterway vessel market implies that technological solutions designed specifically for the inland navigation sector alone are not commercially viable. It is therefore unlikely that a technological solution will be developed for the inland waterway transport sector alone. From this perspective, synergies should be found with technologies developed for seagoing vessels and for non-marine applications whether in Europe or in other parts of the world.

[7] See in this regard the proposal for an EU Directive on energy efficiency (recast) in the context of the "Fit for 55" package aimed at further stimulating EU efforts to promote energy efficiency and achieve energy savings in the fight against climate change: https://ec.europa.eu/info/news/commission-proposes-new-energy-efficiency-directive-2021-jul-14_en

In light of the above, largely eliminating both GHG 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. In other words, the fleet modernisation and the energy transition are motivated by addressing climate change with reduction of GHG emissions, reducing health related risks by improving air quality but also reducing operational costs (OPEX) of the sector by increasing efficiency of the inland navigation.

Role of CCNR and purpose of the roadmap



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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.

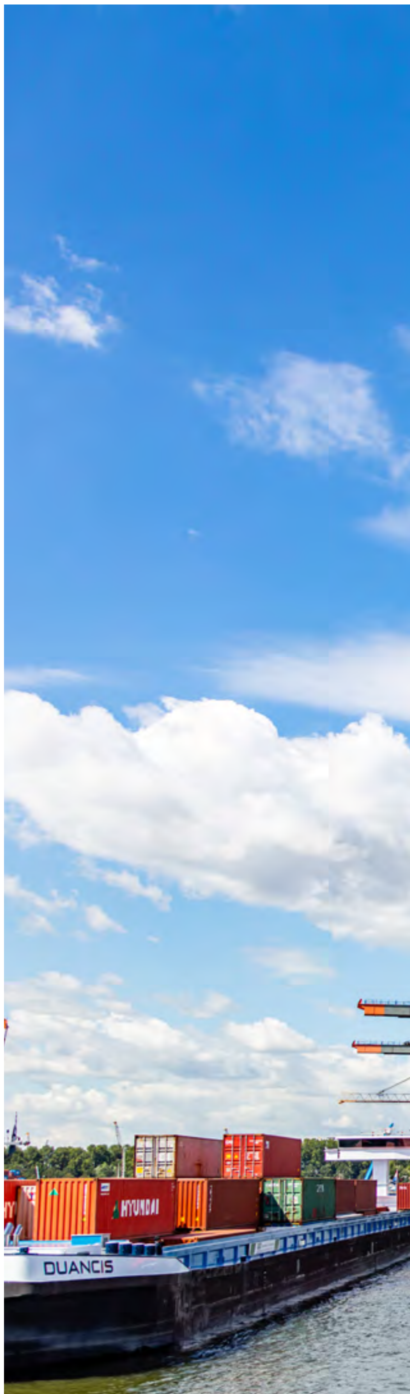
Many of the CCNR's activities now extend beyond the Rhine and are directly concerned with European navigable inland waterways more generally, even if the CCNR does not have all-encompassing jurisdiction, neither in terms of geography nor in terms of legal jurisdiction. In this context, the CCNR works closely with industry representatives, the river commissions and the EU. 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 crucial challenge of the energy transition for Rhine and European inland navigation.

Built on the CCNR study on the energy transition towards a zero-emissions inland navigation sector ("the CCNR study"), this roadmap should be understood as the primary CCNR instrument for climate change mitigation and for giving effect to the energy transition.

The objective is 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.

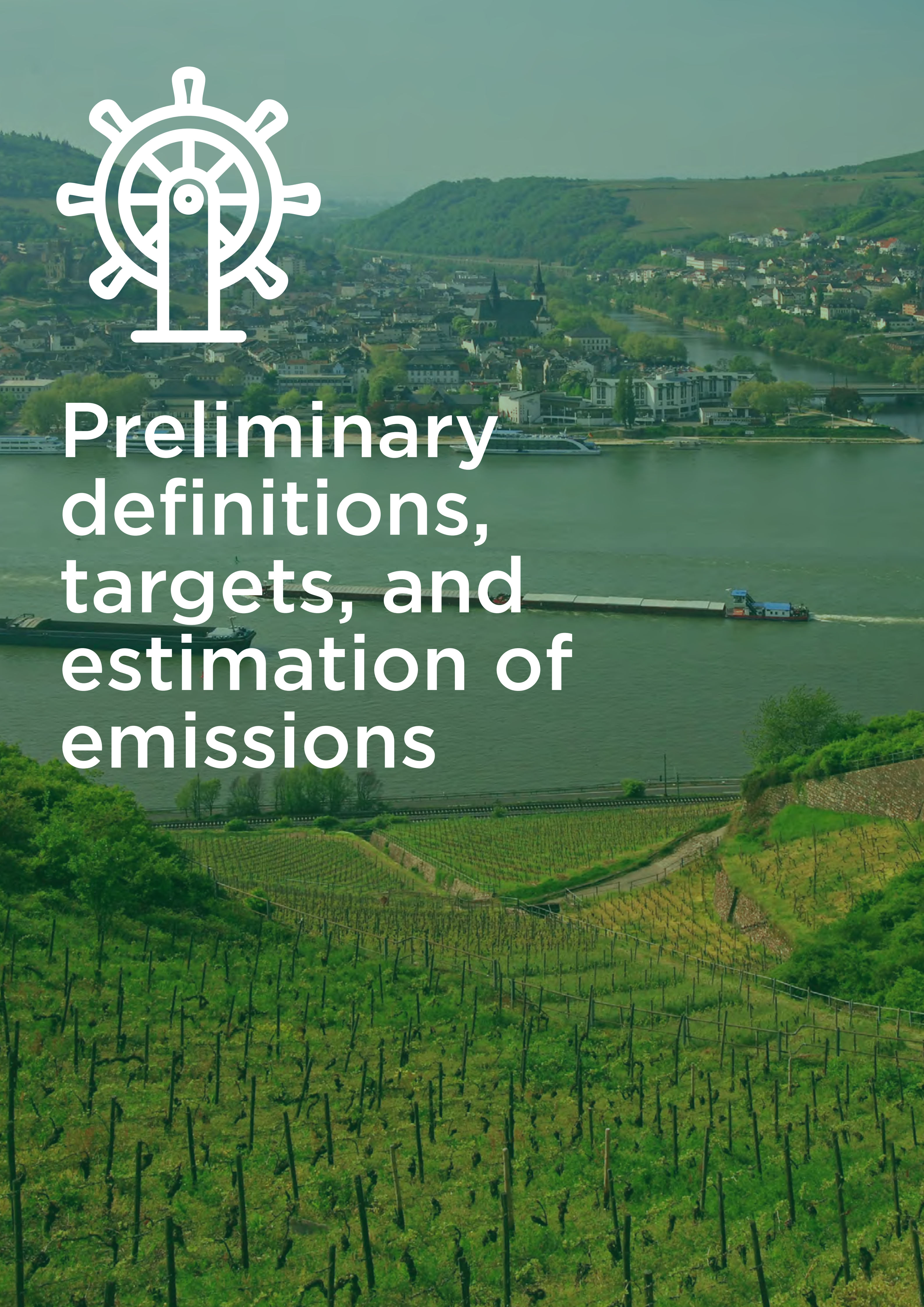


It goes without saying that many players will be involved in this energy transition, such as vessel owners, operators, shippers, and shipbuilders as well as representatives of the sector, classification societies, equipment manufacturers, infrastructure operators, service and energy providers, universities or research institutes, European institutions, international organisations including river commissions, the CCNR, EU Member States, and other European States with inland waterways. In addition, it will be necessary to coordinate and take part in the European Commission's NAIADES III Action plan[8] as well as in ongoing projects relating to the energy transition, such as, the STEERER[9] project, coordinated by the Waterborne Technology Platform or the PLATINA3[10] 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.

[8] *https://ec.europa.eu/transport/modes/inland/news/2021-06-24-naiades-iii-action-plan_en*
[9] *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.*
[10] *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.*

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.

Preliminary definitions, targets, and estimation of emissions



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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 GHG emissions by 35% compared with 2015 by 2035,*
- » *reduce pollutant emissions by at least 35% compared with 2015 by 2035,*
- » *largely eliminate GHG 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**: the transport of goods and the carriage of passengers by inland waterway vessels. Recreational craft,[11] service vessels (including for police authorities, port operation and waste collection) and floating equipment[12] are not included at this stage.

By extension, for future revisions of this roadmap, it might apply to other types of craft (floating equipment, service vessels and recreational craft).

2 **Emissions**: emissions of atmospheric pollutants and greenhouse gases (GHG) arising from the operation of an inland navigation vessel's propulsion and auxiliary systems.[13]

3 **Atmospheric pollutants**: gaseous pollutants, such as carbon monoxide (CO), all hydrocarbons (HC) and nitrous oxides (NO_x), and solid particles such as particulate pollutants, as referred to in Regulation (EU) 2016/1628.[14]

4 **Greenhouse gases (GHG)**: carbon dioxide (CO_2), and methane (CH_4).[15]

5 **"Largely eliminate"**: a reduction of at least 90% of greenhouse gases (GHG) and air 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 adjusted in a future edition of the roadmap.

[11] 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.
[12] 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;".
[13] 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.
[14] 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.
[15] Kyoto Protocol names six different greenhouse gases of which the only four stated above are relevant for inland navigation.

3.2

Tank-to-wake approach

In this roadmap and especially for the fleet transition pathways, a tank-to-wake (TTW) approach was used. In accordance with recognised scientific methodologies[16] as well as those used in regulatory frameworks,[17] this TTW approach allows to also consider the potential of carbon neutrality of certain fuels.

Application of this TTW approach implies making assumptions concerning the upstream chains. The estimation of emissions produced is therefore simplified and fuel availability idealised at this stage (for all technologies). It also requires that the origin of biofuels is traceable in accordance with internationally recognised methods.

There are several reasons for choosing a simplified approach. The same approach was used in the published CCNR study report relating to the economic and technical assessment of the technologies (Research question C Edition 2).[18] Moreover, this approach is consistent with the CCNR's wish to concentrate on its remit, namely inland navigation. Indeed, the well-to-wake (WTW) approach would require consideration of energy production sustainability and availability. With the current uncertainties regarding sustainable energy production, a too early use of the WTW approach could result in misconsidering the benefits of future sustainable technologies and in a slowdown in the development of sustainable technologies. It could also impede the development of navigation using these technologies.

The CCNR acknowledges that this TTW approach may be deemed a simplification and that it implies limitations and possible inaccuracies. However, the CCNR considers it as a first step and commits to reviewing this approach at a later stage. In order to adopt a WTW approach, it will be important to collect more reliable data regarding the upstream chain emissions and take into account the life cycle for all foreseen technologies. Similarly, particular attention needs to be paid to emissions associated with other aspects of the life cycle of the vessel and its propulsion system, such as construction, maintenance, and scrapping.

[16] Intergovernmental panel on climate change, 2006 Guidelines for National Greenhouse Gas Inventories, Volume 2, Chapter 3, https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_3_Ch3_Mobile_Combustion.pdf. The basis laid down in IPCC is also included in the Directive (EU) 2009/28/EC on the promotion of the use of energy from renewable sources.
[17] Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (recast), https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2001
[18] Research question C Edition 2 available here: https://www.ccr-zkr.org/files/documents/EtudesTransEner/Deliverable_RQ_C_Edition2.pdf. More information regarding the CCNR study on the energy transition towards a zero-emission inland navigation sector is available here: https://www.ccr-zkr.org/12080000-en.html.

3.3 Estimation of the emissions in 2015 as a baseline

The CCNR collected, checked plausibility and evaluated the data of emissions generated by inland navigation nationally in 2015.

The data provided by the Member States represent the emissions generated by inland navigation vessels on all the navigable waterways of the national territory of each CCNR Member State. This data 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 models 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).

Table 1 summarises the emissions generated by inland navigation in 2015 on all the CCNR Member States navigable waterways.

Table 1

SUMMARY TABLE OF ATMOSPHERIC POLLUTANT AND GHG EMISSIONS BY THE INLAND NAVIGATION SECTOR IN 2015

Emissions	Total (kt)
Carbon dioxide (CO_2)	4149.2
Carbon monoxide (CO)	38.2
Methane (CH_4)	0.2
Nitrogen oxides (NO_x)	60.9
PM_{10} (Particulate matters)	2.0

Source: CCNR

Notwithstanding the different methods used to collect the data in the Member States, the figures are comparable to the results obtained in a recent study using a different methodology based on fuel consumptions.[19]

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 t.km) was measured during this period to identify a possible increase in fuel consumption (and associated emissions) owing to the low water period.

[19] *CCNR study commissioned by Switzerland: https://www.ccr-zkr.org/files/documents/EtudesTransEner/Deliverable_RQ_C_Edition1.pdf*

3.4

Targets for reduction of air pollutants and greenhouse gases

3.4.1 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 GHG emissions inland navigation sector by 2050”. However, the emissions reduction targets differ in terms of their material scope (entire transport sector/inland navigation only) and benchmarks. Moreover, there are significant differences concerning medium-term targets (the EU’s reduction targets, all sectors combined, being approximately double those of the CCNR for the inland navigation sector).

This observation is important, because it supports the conclusion that most of the measures envisaged in this roadmap remain relevant beyond the Rhine. The same applies for the array of technologies envisaged in the transition pathways.

However, the more ambitious the intermediate target, the more the intensity of the measures (including financial support) and the speed of technological and fuel change is likely to increase.

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

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

Regarding the EU Smart and Sustainable Mobility Strategy,[20] road transport alone accounts for 20% of total EU GHG transport emissions. The EU targets for road transport are set at a 15% reduction from 2025 onwards and a 30% reduction from 2030 onwards compared to the EU average in the reference period.[21] 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.[22] In addition, road transport benefits from a much larger scale of series production, which allows for more investment in research and development and lower costs for advanced technologies (economies of scale).

In the maritime arena, the International Maritime Organisation (IMO) adopted a greenhouse emissions reduction strategy[23] in April 2018. Its objective is to phase out international maritime transport GHG emissions as early as possible within this century. This strategy sets two intermediate objectives. The first is to reduce GHG 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 GHG emissions by at least 50% in 2050 compared with 2008. Adoption of a revised strategy is anticipated in 2023.

[20] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0789
[21] Reference period: 1 July 2019 – 30 June 2020, https://ec.europa.eu/clima/policies/transport/vehicles/heavy_en
[22] 50% of the fleet is more than 50 years old.
[23] https://unfccc.int/sites/default/files/resource/250_IMO%20submission_Talanoa%20Dialogue_April%202018.pdf

Transition pathways for inland navigation by 2035 and 2050

4

4.1

Purpose of transition pathways

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 mixes 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 and pollution risks in case of accidents to do with possible new technological developments, 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. The replacement of older and more polluting engines also helps to lower emissions.

Those factors influence the composition of the inland navigation fleet and corresponding emissions. For this purpose, the "CCNR study" feeds into this roadmap.

Given the final results of the "CCNR study" and other research work, the transition pathways reflect the anticipated evolution of the fleet in the years ahead, derived in particular from the following inputs: economic variables, market maturity and availability of technologies, rate of new construction/scrapping, vessel age and modernisation of existing vessels.

Such transition pathways could ease the dimensioning of policy measures, especially for

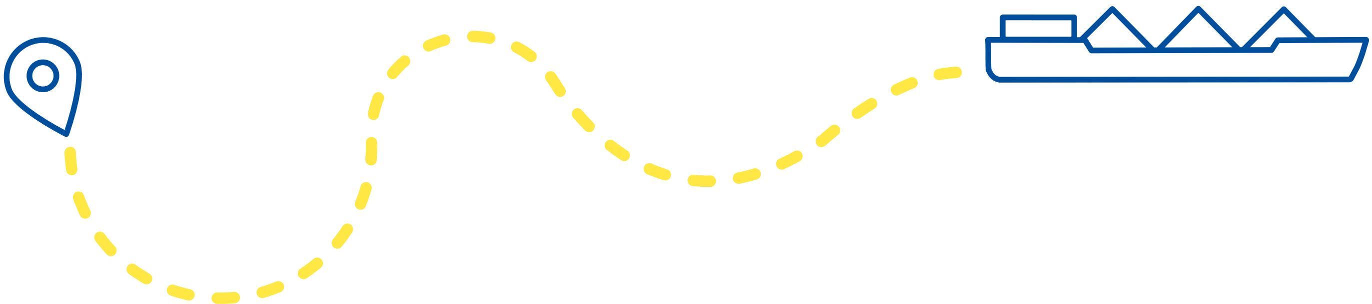
» financing measures (in which technology, for which type of fleet, and when to invest with a focus on no-regret investments),
» regulatory measures (such as the certification of new technologies or the banning of the most polluting technologies inconsistent with the 2050 long term emission reduction ambitions),
» 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 transition pathways, in the light of scientific, technical and political developments.

It cannot be stressed enough that there are quite substantial uncertainties surrounding the development of such transition pathways and the transformation process that the inland navigation sector will need to undergo to achieve the zero-emissions target by 2050. Such uncertainty relates in particular to prices, the availability of fuels, and technology development.

4.2 Technologies considered

For the purpose of this roadmap, the technologies chosen reflect the current state of knowledge. It was decided to focus on a set of technologies with a technology readiness level (TRL) of 5 and above. Some were not considered mature enough to be used, especially in light of current cost predictions. However, no technologies should be excluded at this juncture. For instance, other technological options like lithium-air batteries, LOHC (Liquid Organic Hydrogen Carrier), formic acid (hydrozine) or green ammonia in combination with fuel cells (FC) or internal conbustion engines (ICE) might play roles in later stages of the energy transition. Regarding ammonia for instance, it is a serious candidate as an energy carrier for seagoing vessels but still presents important safety issues to be investigated in inland navigation. Eventually, some other technologies which are not known today might be deployed in the next decades.



As explained in chapter 1 of the present roadmap, the small size of the inland waterway transport sector requires that account be taken of possible technologies from marine applications and other industrial sectors. This was also taken in account in the transition pathways considered here.

In light of the above, the following technologies were considered in the transition pathways:

Table 2
TECHNOLOGIES, TRL LEVELS AND EMISSION REDUCTION POTENTIAL

Technologies considered in the pathways	**Description**	**TRL** (1-9) **vessel application**	**TRL** (1-9) **fuel/energy production and supply**	**Emission reduction potential** (in an ideal upstream chain)		
				GHG/ CO_{2e}	**NO_x**	**Particulate matters**
CCNR 2 or below, Diesel	Fossil diesel in an internal combustion engine which complies with the emission limits CCNR 2 or older engine.	9	9	0%	0%	0%
CCNR 2 + SCR, Diesel	Fossil diesel in an internal combustion engine which complies with the emission limits CCNR 2 and equipped with an additional Selective Catalytic Reduction system.	9	9	0%	82%	54%
Stage V, Diesel	Fossil diesel in an internal combustion engine which complies with the emission limits EU Stage V.	9	9	0%	82%	92%
LNG	Liquefied Natural Gas in an internal combustion engine which complies with the emission limits EU Stage V.	9	9	10%	81%	97%
Stage V, HVO	HVO in an internal combustion engine which complies with the emission limits EU Stage V. HVO stands for hydrotreated vegetable oil itself (without blending with fossil fuels) and all comparable drop-in biofuels (including e-fuels) as well as synthetic diesel made with captured CO_2 and sustainable electric power.	9	9	100%	82%	92%
LBM	Liquefied Bio Methane (or bio-LNG) in an internal combustion engine which complies with the emission limits EU Stage V.	9	8	100%	81%	97%
Battery	Battery electric propulsion systems, with fixed or exchangeable battery systems.	8	7	100%	100%	100%
H_2, FC	Hydrogen stored in liquid or gaseous form and used in fuel cells.	7	7	100%	100%	100%
H_2, ICE	Hydrogen stored in liquid or gaseous form and used in internal combustion engines.	5	7	100%	82%	92%
MeOH, FC	Methanol used in fuel cells.	7	6	100%	100%	100%
MeOH, ICE	Methanol used in internal combustion engines.	5	6	100%	82%	92%

Source: CCNR

Observations regarding the table:

1

In accordance with the approach taken in part 3.2, all the technologies used in these transition pathways assume an ideal upstream chain.

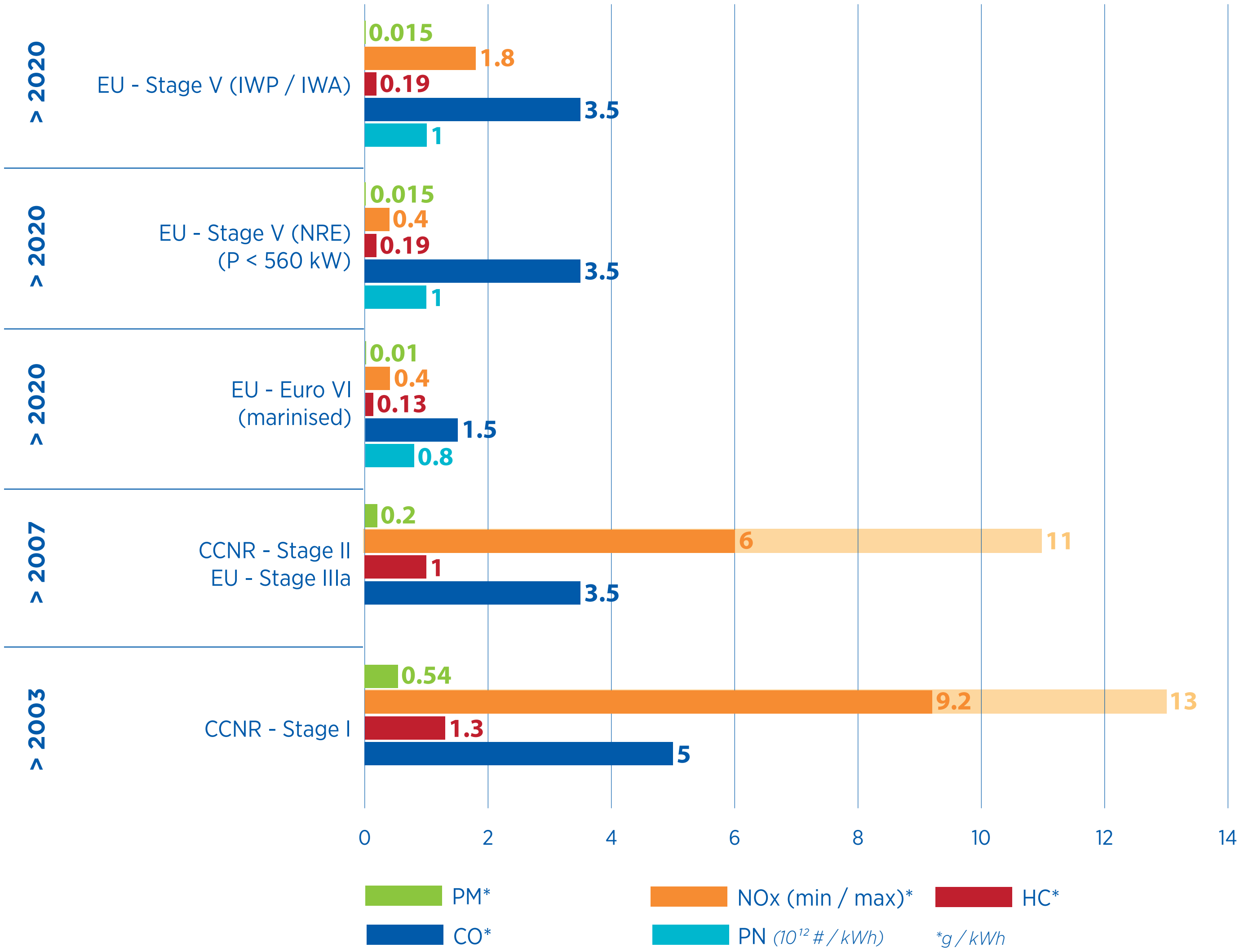
2

Regarding the energy converter, the mono-fuel engine is considered in the transition pathways for each fuel. In practice dual-fuel engines could also be applied, e.g. engines that run on LNG and gasoil but have significantly higher GHG emissions. This could also apply to the MeOH and H_2 engines' once these enter the market.

3

The stage CCNR 2 refers to the emission limits adopted by the resolution CCNR 2005-II-20. The EU Stage V refers to emission limits adopted by the Regulation (EU) 2016/1628 for non-road mobile machinery (categories IWP, IWA, NRE or EURO VI marinised truck engines). As a reminder, the mandatory limits of air pollutants emissions are summarised in figure 1.

Figure 1
EMISSION LIMITS FOR IWT ENGINES (Power > 300 kW)



Source: CCNR
All abbreviations used are defined in detail in the annex (page 72).

4.3

Definition of the business-as-usual scenario

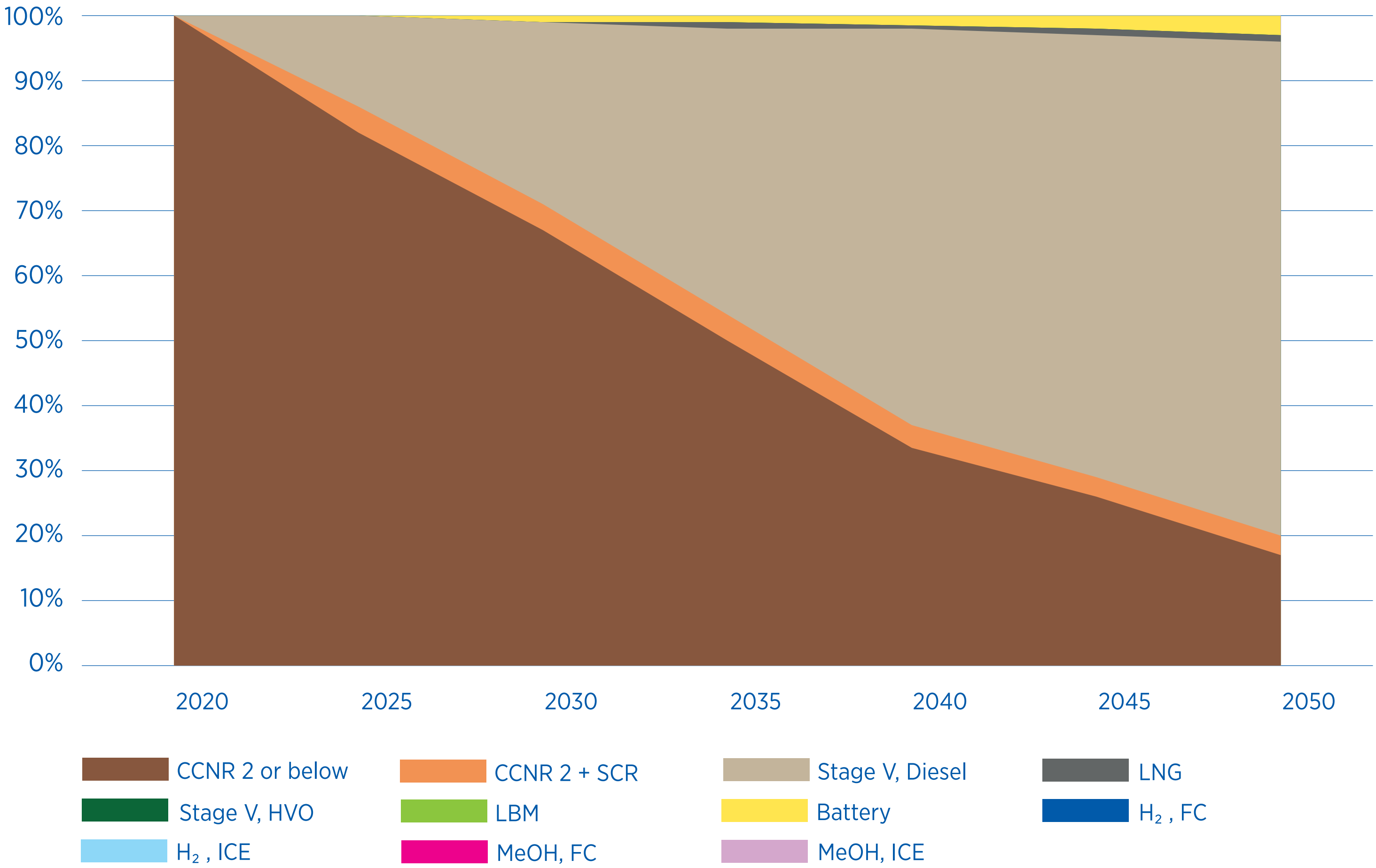
Figure 2 provides an overview of the development of technologies between 2020 and 2050 for the entire fleet, for a "BAU" scenario (business-as-usual, BAU). It estimates that by 2050, more than 95% of vessels would continue to operate using fossil fuels. This scenario also assumes a slight overall increase in the use of biofuel by the whole fleet as result of diesel blends consisting of biofuel and fossil diesel provided by the fuel suppliers. Starting with 0% in the year 2015, it is assumed that this share grows linearly to a maximum of 7% of overall diesel consumption in 2050. However, more optimistic assumptions point to higher shares. While limited today to 7% (FAME in non-road Diesel), the best estimates would be for bio and renewable fuels blending shares to rise to 10% by 2035 and 20% by 2050.[24]

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 BAU scenario.

[24] *According to the European Association of Internal Combustion Engine Manufacturers (EUROMOT)*

Figure 2

BAU SCENARIO - DEVELOPMENT OF TECHNOLOGIES BY 2050



Source: CCNR

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, 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 BAU scenario in respect of key milestones identified in the Mannheim Declaration: 2015, 2035 and 2050.[25] In this BAU scenario, in 2015, for all fleet families, the outstanding majority of the vessels is equipped with "CCNR 2 or below" engines. It is assumed that the vessels' engines are using conventional diesel (EN 590) as fuel.

All types of vessels used are defined in detail in the annex (page 73).

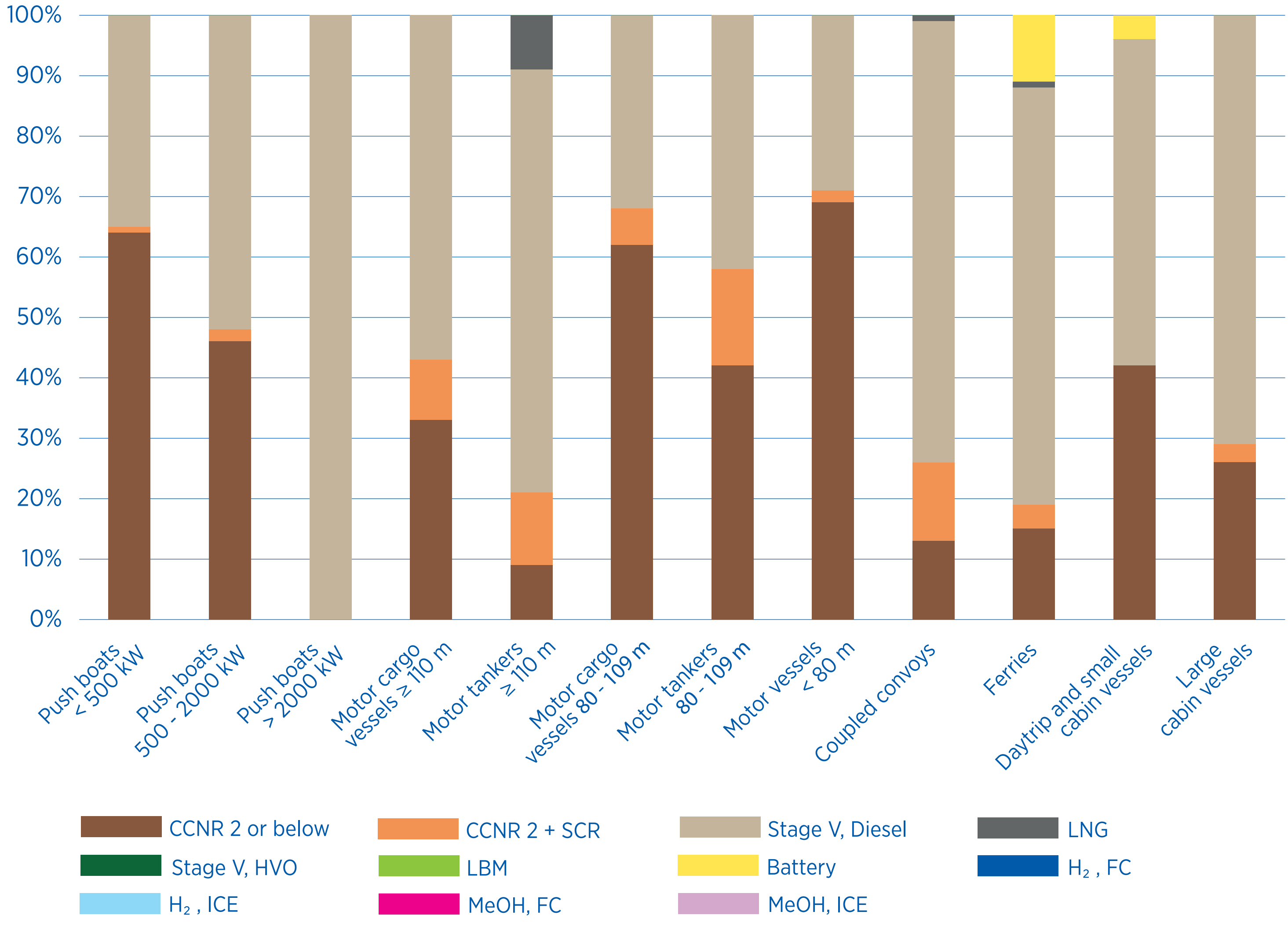
[25] *The parameters of this BAU scenario are defined in detail in the context of the CCNR study on the energy transition (Research question C in particular): https://www.ccr-zkr.org/12080000-en.html.*

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

GHG: -14%
NO_x: -57%
Particulate matters: -63%

In this BAU scenario, in 2035, unless stated otherwise in the figure 3, 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 (NO_x and particulate matters) in the Mannheim Declaration can be achieved. However, to achieve the GHG reduction target requires specific measures to be taken if the 35% reduction compared with 2015 is to be achieved.

Figure 3
BAU SCENARIO PER FLEET FAMILY IN 2035



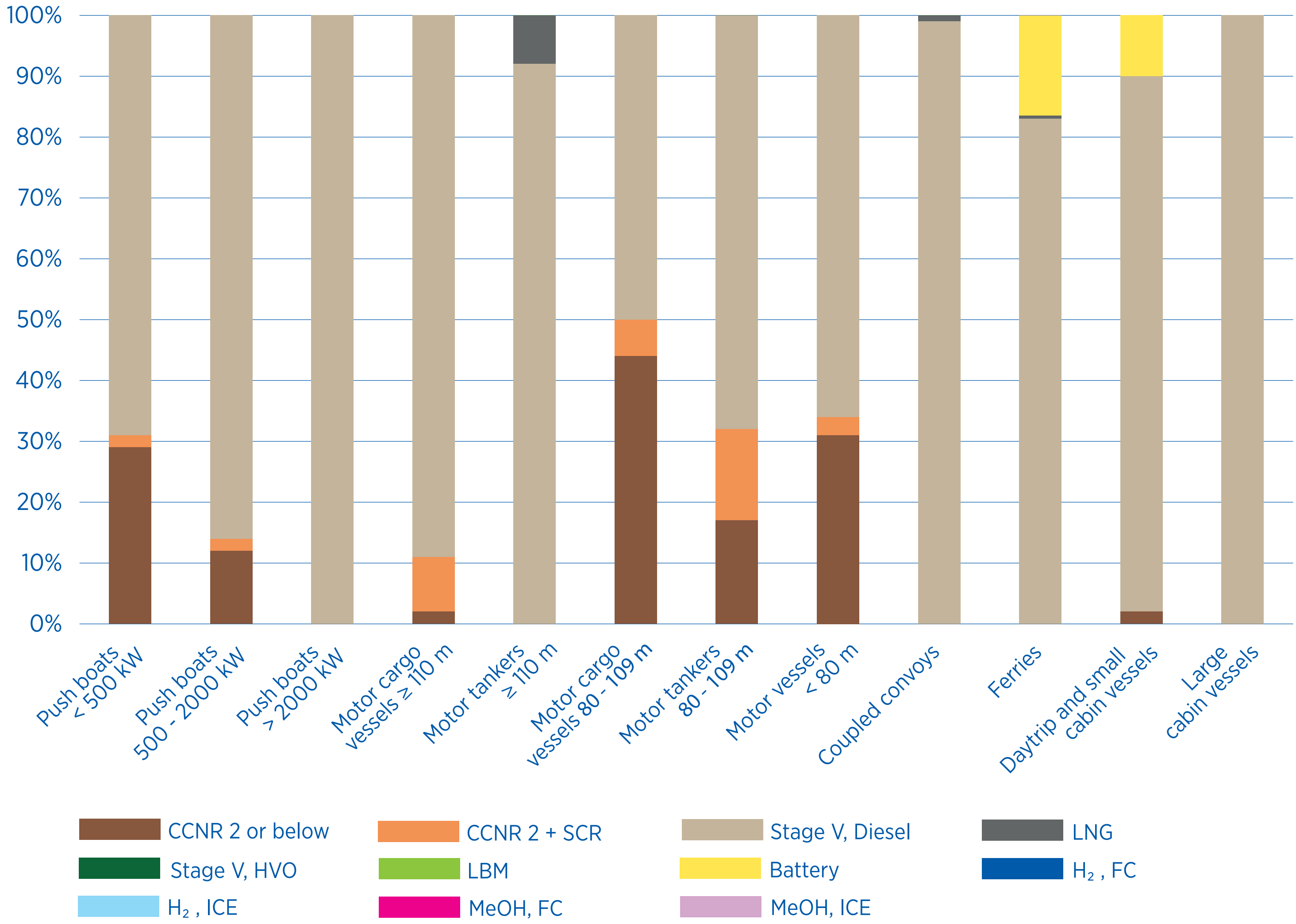
Source: CCNR

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

GHG: -22%
NO_x: -76%
Particulate matters: -83%

In this BAU scenario, in 2050, unless stated otherwise in the figure 4, 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 GHG 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.

Figure 4
BAU SCENARIO PER FLEET FAMILY IN 2050



Source: CCNR

4.4

Transition pathways towards 2050

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

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, biofuels) is also subject to uncertainties, especially as concerns their availability in sufficient quantity and at an affordable price for inland navigation.

The conservative transition 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 transition pathway is predicated on a more optimistic development in which the innovative technologies have established themselves in the market (primarily because the limited availability and steep increase in the price of biofuels make these innovative technologies more competitive). This approach based on two complementary transition pathways limits 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 transition pathways, each presenting its own pros and cons.

4.4.1 Conservative transition pathway towards 2050

The conservative transition pathway refers to a transition pathway in which the alternative fuels and technologies 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 LBM that can be used in gas engines. These are fuels and techniques which have a relatively higher TRL and are already available on the market.

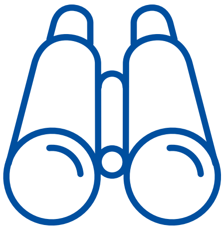
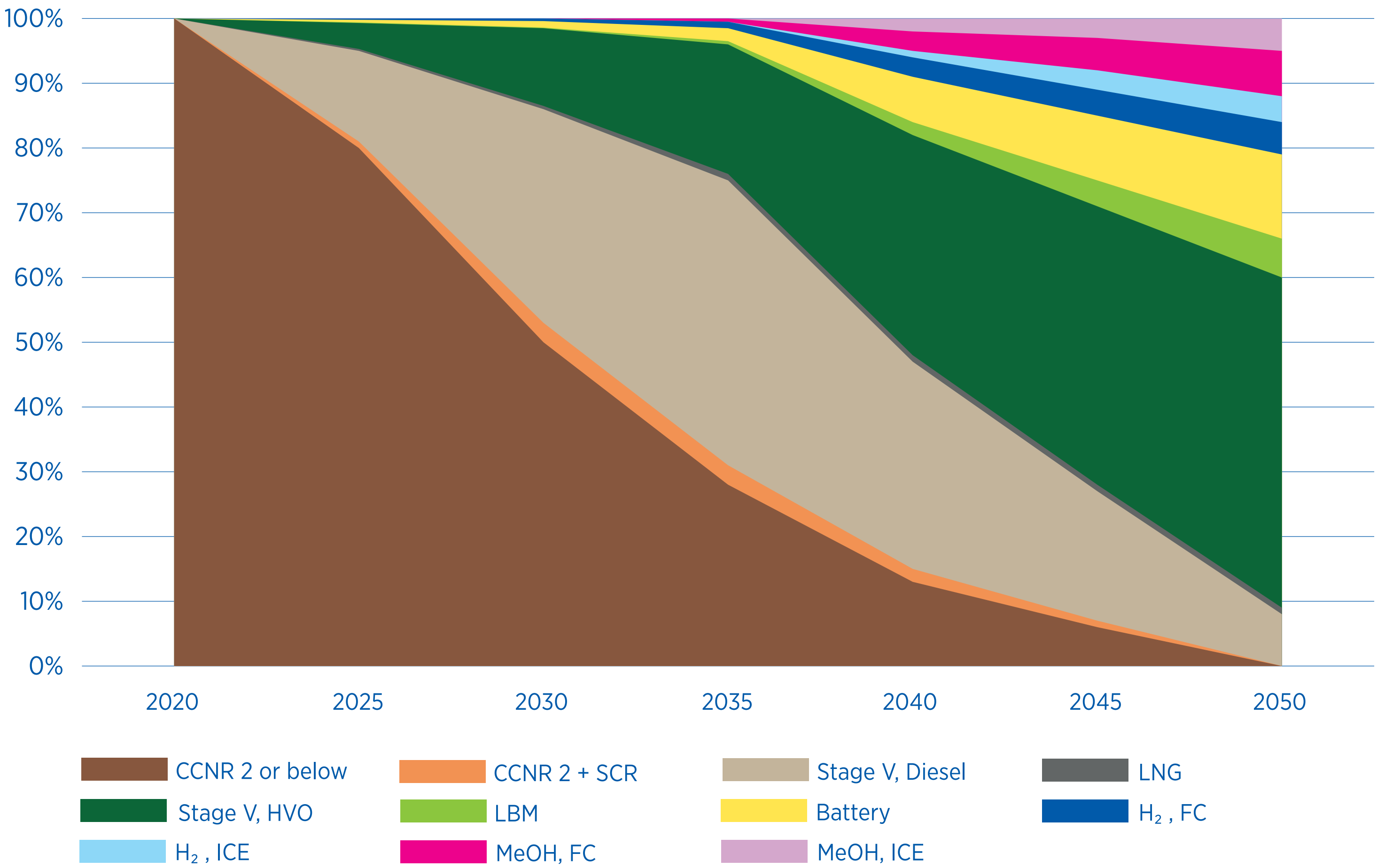


Figure 5 provides an overview of the possible development of technologies between 2020 and 2050, for the entire fleet, and of their relative shares in the event of a conservative transition pathway.

Figure 5
CONSERVATIVE TRANSITION PATHWAY: DEVELOPMENT OF TECHNOLOGIES BY 2050



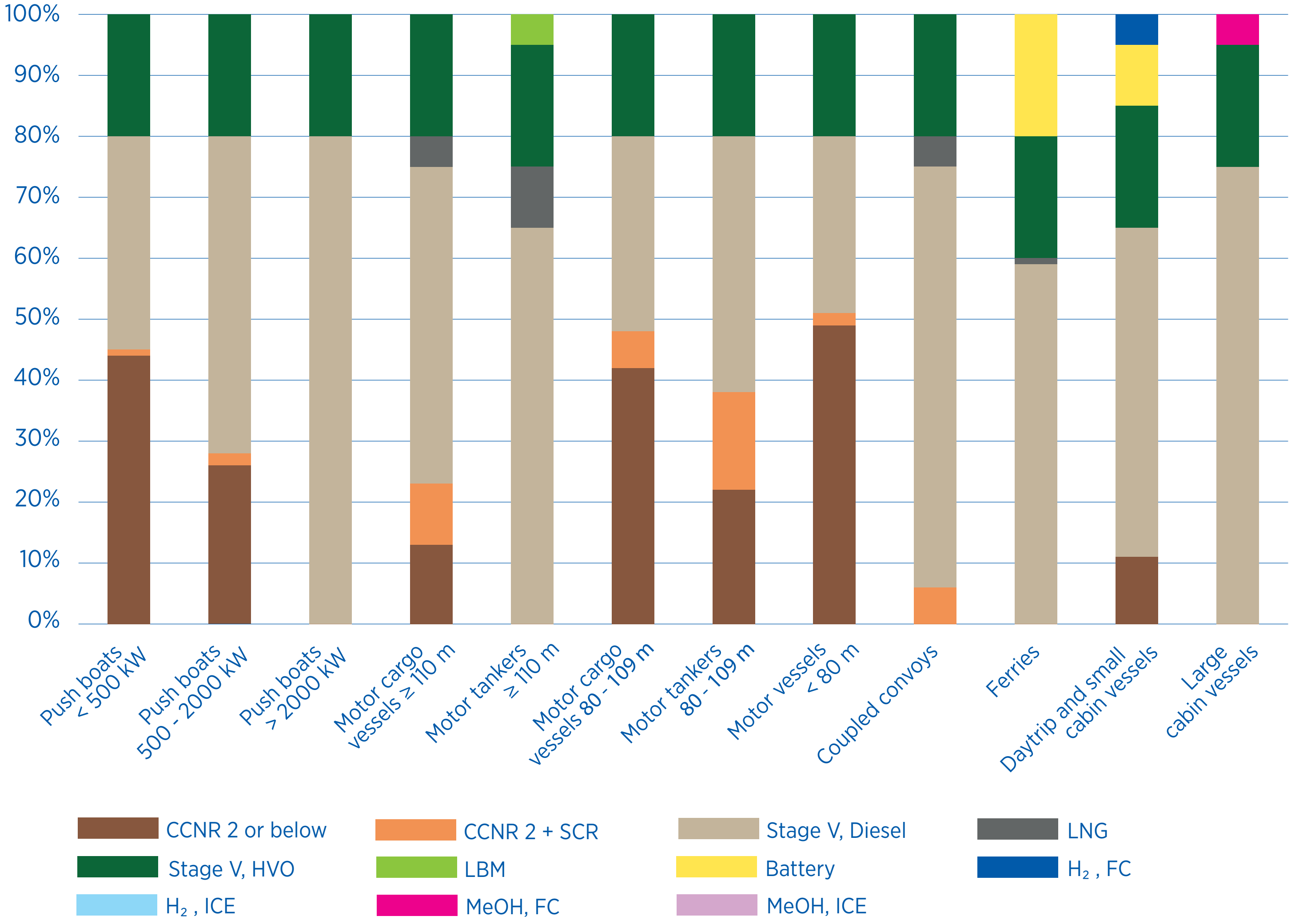
Source: CCNR

Technology share for each fleet family in 2035

By taking the conservative transition pathway to achieve the 35% reduction by **2035**, much of the fleet will still be using the internal conbustion engines (ICE) as shown in figure 6.

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 transition pathway, the Mannheim Declaration targets can be achieved with a comparatively small proportion of advanced technologies such as FC and batteries.

Figure 6
CONSERVATIVE TRANSITION PATHWAY: TECHNOLOGY SHARE FOR EACH FLEET FAMILY IN 2035



Source: CCNR

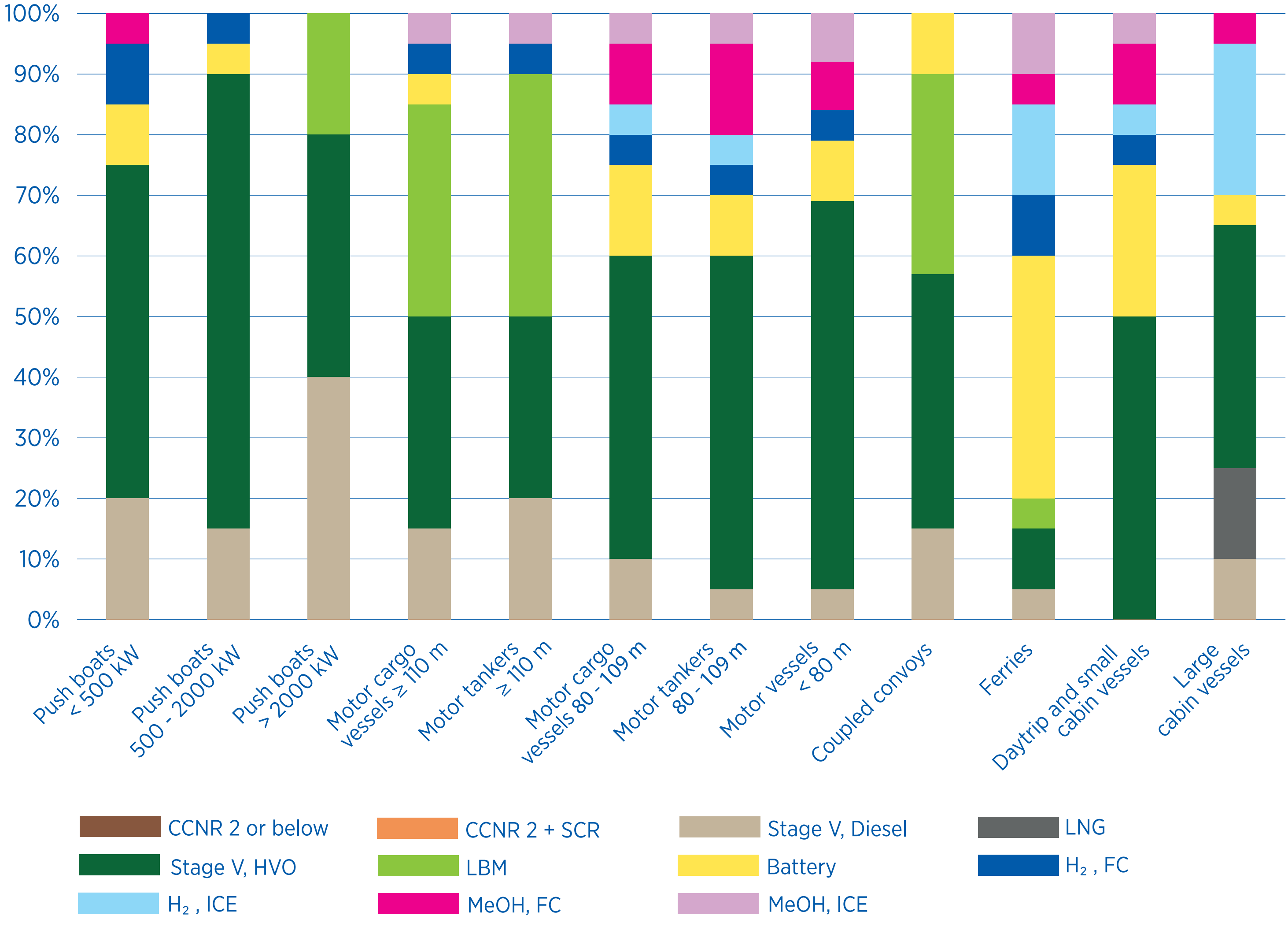
Technology share for each fleet family in 2050

In **2050**, the conservative transition pathway described in figure 7 will enable the following emissions reduction potential to be achieved compared with 2015:

GHG: -91%
NO_x: -90%
Particulate matters: -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.

Figure 7
CONSERVATIVE TRANSITION PATHWAY: TECHNOLOGY SHARE FOR EACH FLEET FAMILY IN 2050



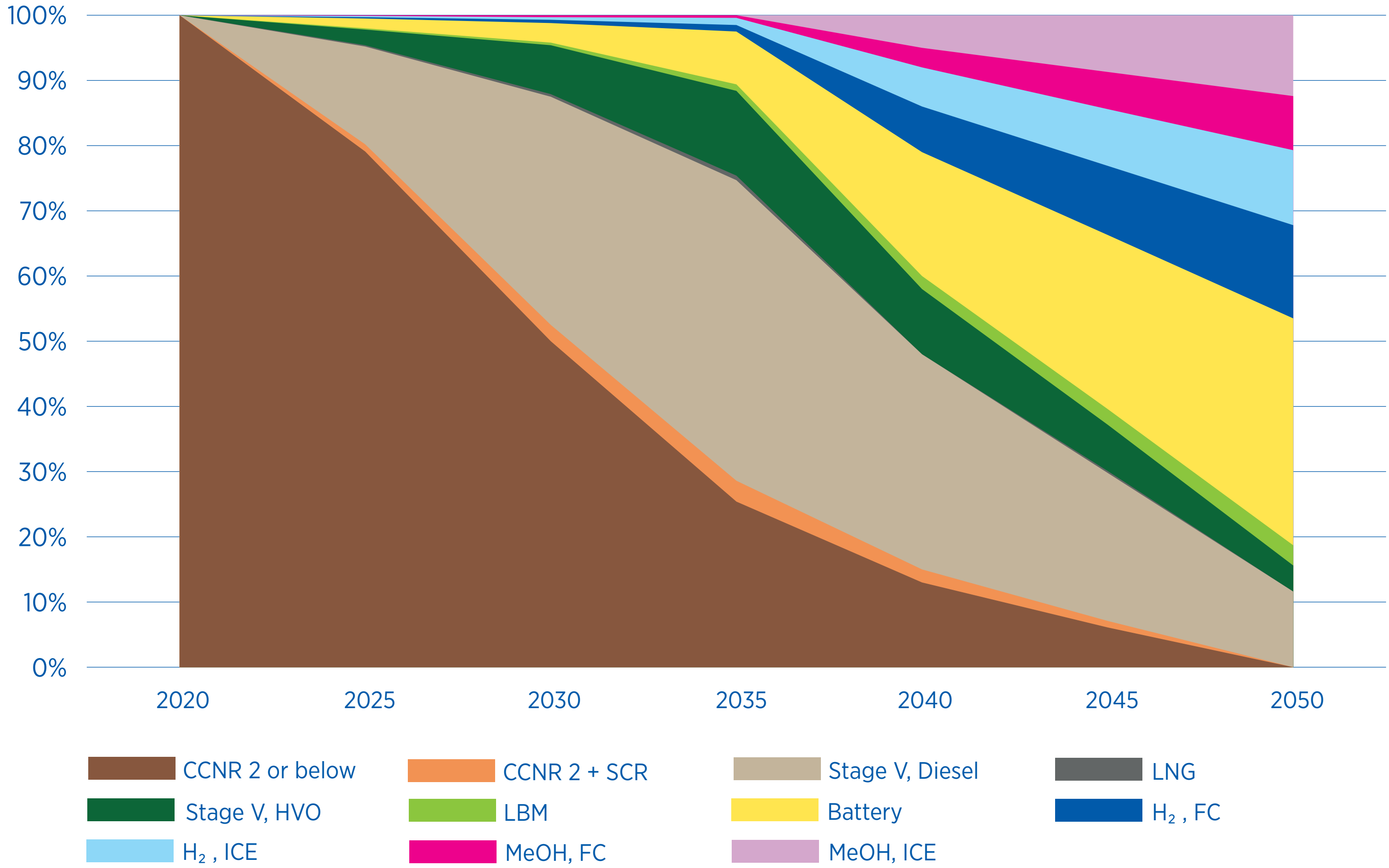
Source: CCNR

4.4.2 Innovative transition pathway towards 2050

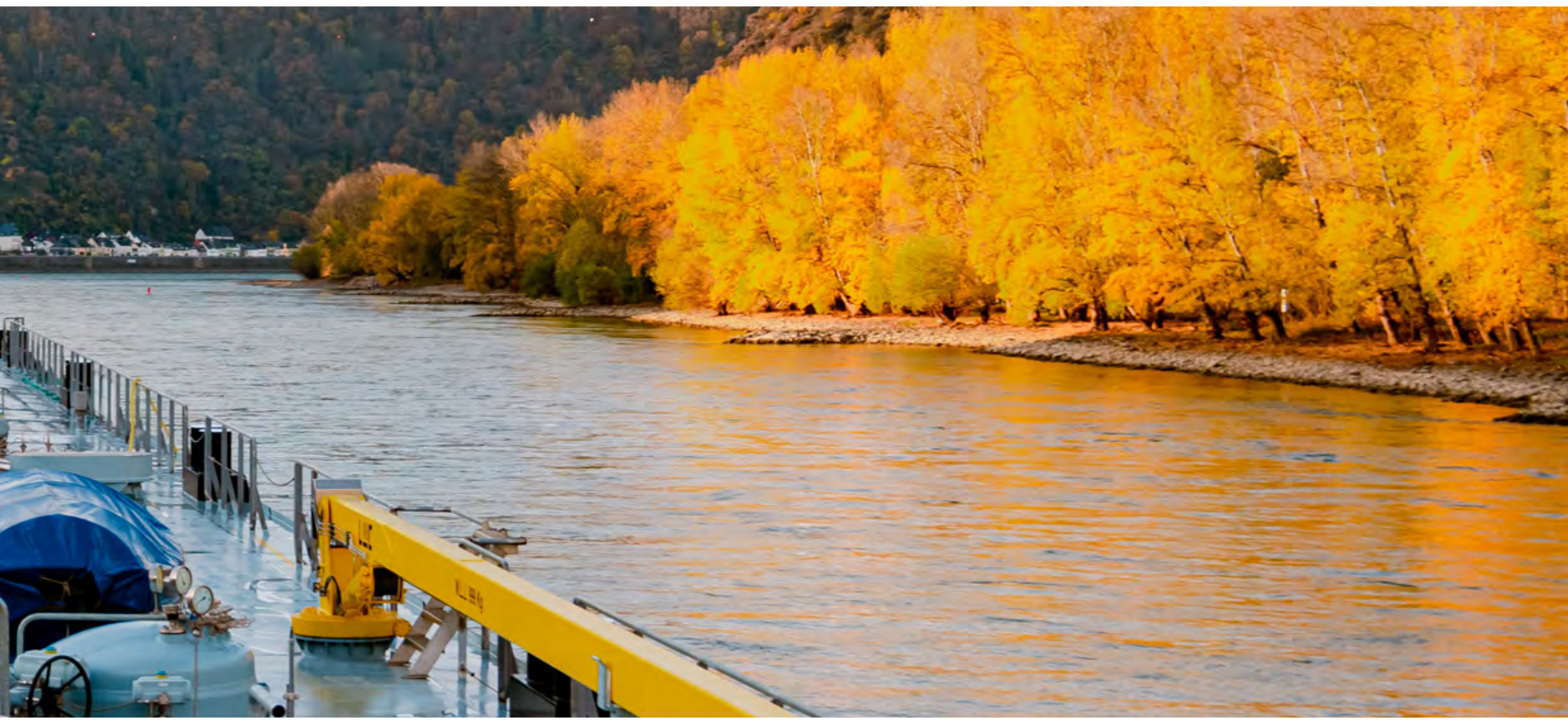
The innovative transition pathway encompasses a more innovative approach, in which the fuels and technologies considered are currently still in their infancy stage (low TRL) and significantly more expensive as compared with advanced biodiesel and LBM. This concerns alternatives like battery-electric and hydrogen-powered propulsion systems, which are zero emission locally. They are expected to become more mature in the years to come.

Figure 8 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 transition pathway.

Figure 8
INNOVATIVE TRANSITION PATHWAY: DEVELOPMENT OF TECHNOLOGIES BY 2050



Source: CCNR

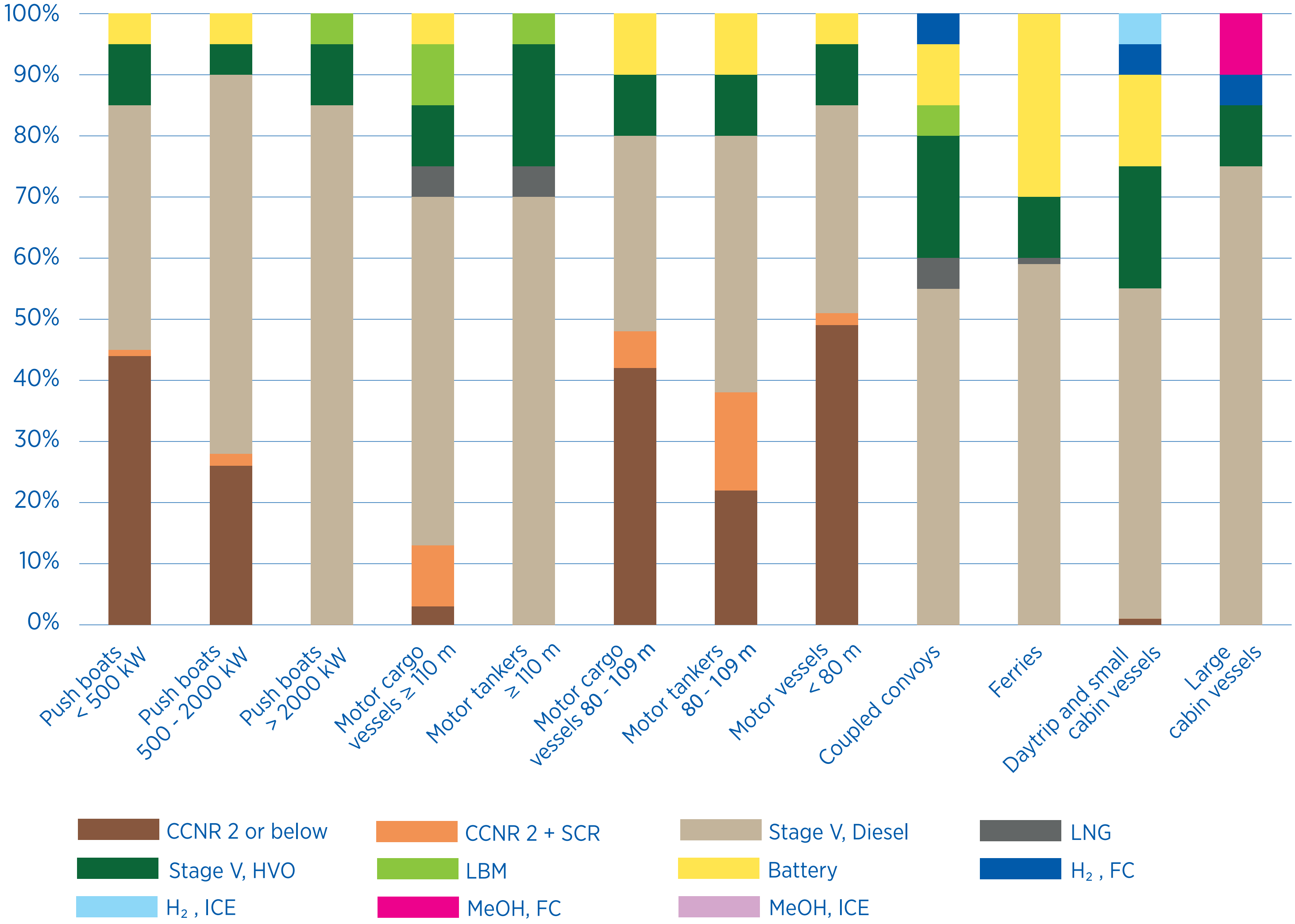


Technology share for each fleet family in 2035

For the innovative transition pathway, as shown in figure 9, 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 MeOH FC propulsion being the most relevant. The proportion of HVO compared with the conservative transition pathway is correspondingly smaller.

Figure 9

INNOVATIVE TRANSITION PATHWAY: TECHNOLOGY SHARE FOR EACH FLEET FAMILY IN 2035



Source: CCNR

Technology share for each fleet family in 2050

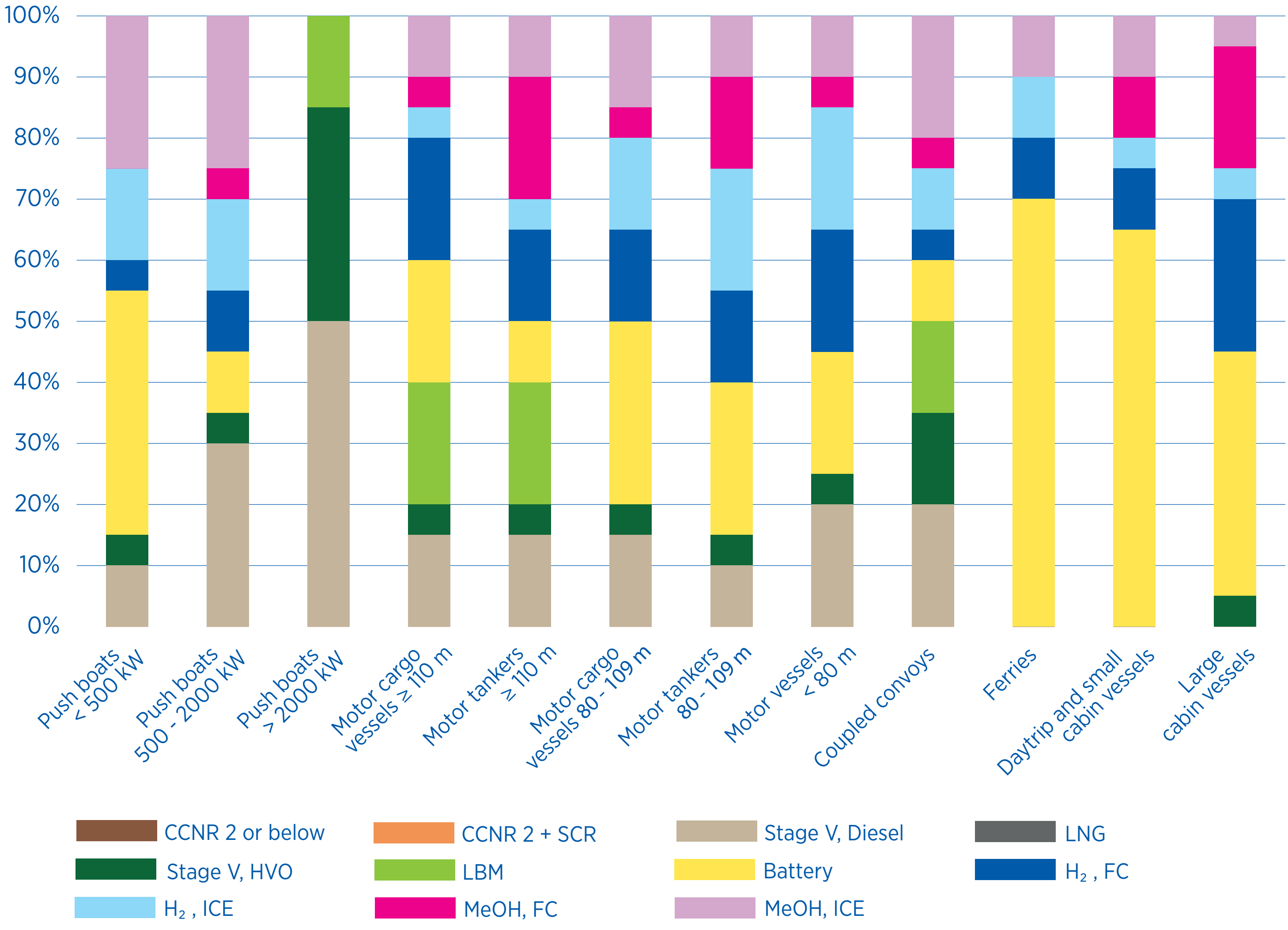
In **2050**, the innovative transition pathway will enable the following emissions reduction potential compared with the year 2015 to be achieved:

GHG: -91%
NO_x: -94%
Particulate matters: -98%

It can be seen from the figure 10 that the share of technologies has shifted both towards battery-electric propulsion and hydrogen and MeOH. All these technologies exhibit a relatively lower TRL level than HVO and LBM.

An exception is the fleet family for the largest pusher boats (>2,000 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.

Figure 10
INNOVATIVE TRANSITION PATHWAY: TECHNOLOGY SHARE FOR EACH FLEET FAMILY IN 2050



Source: CCNR

4.4.3 Further reflections on the transition pathways

Although the two transition pathways enable the objectives set by the Mannheim Declaration to be achieved (based on the "tank-to-wake" approach as explained in section 3.2), initial estimates show that the financial gap to be bridged[26] in the innovative transition pathway is, depending on the price scenario considered, a factor of 1.6 to 2.9 higher than in the conservative transition pathway (see section 4.3 for detailed information). This difference has major implications for the associated level of public and private financial support needed to achieve the energy transition as well as the related costs to be borne by the sector (both in terms of investment costs (CAPEX) and operational costs (OPEX)). These cost differences are primarily attributable to the less important share of more expensive technologies such as H_2, FCs, and batteries in the conservative transition pathway compared to the innovative transition pathway. Indeed, this generates significantly lower CAPEX and OPEX (given the estimated prices of the different types of energy and the lower maintenance costs) for the conservative transition pathway. However, in the long run, OPEX reduces for both transition pathways, in particular for the innovative transition pathway.

However, there are major uncertainties surrounding biofuels:

- One can speculate about the proportion of biofuels (up to 100%) that can be incorporated in a blend (indeed the higher the remaining share of fossil diesel/gas is, the higher the emissions).
- The availability of biofuels from sustainable production is also a concern, especially given limited production capacity (for example the availability of the raw material for producing HVO is a limiting factor). It is worth noting that such uncertainties surrounding availability are also true for other alternative fuels relying on renewable electricity, such as hydrogen produced by electrolysis.
- One also needs to take account of competition with other modes of transport and other industrial sectors, in terms of the distribution and use of these biofuels. For example, most biofuels may ultimately be earmarked for the aviation or maritime sectors if no other technology is proved to be appropriate for these sectors' energy transition.
  In such a situation, the cost of biofuels could increase significantly. Therefore, the economic interest of the conservative transition would be considerably reduced.

[26] Refers to the total accumulated Total Cost of Ownership (TCO) (total of 30 years between 2020 and 2050). In a minimum price scenario, the financial gap in the innovative transition pathway is 2 times higher than the conservative transition pathway in a minimum price scenario, 3 times higher in an average price scenario and 1.5 times higher in a maximum price scenario.

Moreover, although biofuels are deemed to be carbon neutral if the entire production chain is taken into account, burning biofuels for vessel propulsion purposes emits GHG and atmospheric pollutants, at least locally. If therefore applicable regulations were to impose zero emissions zones, as is envisaged for example in European cities, vessels running on biofuels might no longer be allowed to operate there. Here too, the conservative transition pathway would become less attractive. The origin of biofuels must also be traceable (see 3.2).

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, in particular regarding electric propulsion. This affords the prospect of lower OPEX after 2035 for the innovative transition 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 in the innovative transition pathway would have a greater prospect of achieving this additional reduction.

4.5

The financial challenge and related investments[27]

4.5.1 Considerable costs associated with the energy transition

The financial challenge of achieving the zero-emission objective by 2050 is considerable. Depending on the transition pathway, the financial gap to be bridged to achieve the Mannheim Declaration emission reduction objectives varies significantly but is several billions in any scenario.

The "CCNR study" concluded that the energy transition-related costs will exceed the navigation profession's financial resources, the profession therefore being able to bear only a part of the costs required to achieve this transition. As an example, currently, only very few vessel owners can finance "just" the first step towards investing in electric drivetrains.

Significant grants are needed to close this gap, and to make the transition pathways economically viable for the inland navigation industry, energy suppliers, and shore-side infrastructure operators. Strong public support (European and national) is therefore necessary. Greening investments for both newbuilt and existing fleet (retrofit) should be supported, in addition to pilot projects.

The financial gap was estimated by calculating the difference between the Total Cost of Ownership (TCO) (CAPEX+ OPEX) of the BAU scenario and the TCO of the two transition pathways (see 4.4).

[27] This part was largely derived from the CCNR study on the energy transition available at: https://www.ccr-zkr.org/12080000-en.html.

The total financial gap in the conservative transition pathway, covering the period 2020-2050 is approximately:

» €2.43 bn in the minimum price scenario
» €2.65 bn in the average price scenario
» €6.38 bn in the maximum price scenario

The total financial gap in the innovative transition pathway, covering the period 2020-2050 is approximately:

» €5.26 bn in the minimum price scenario
» €7.80 bn in the average price scenario
» €10.19 bn in the maximum price scenario

The financial gap between the BAU scenario and the two transition pathways can be explained mainly by the higher capital costs in the two transition pathways owing to the higher CAPEX required for the most innovative technologies (FC and batteries in particular). It is also important to note that OPEX are expected to decrease in both transition pathways in the long run, to reach the same or even a lower level than the OPEX identified in the BAU scenario. This can be explained mainly by the assumptions made in determining the costs of the two transition pathways, i.e. 30% energy saving assumed between 2020-2050 in the transition pathways versus a 15% energy saving assumed between 2020-2050 in the BAU scenario. In addition, it is important to note that OPEX can also be reduced through improved technology maturity (i.e. lower maintenance costs, particularly for batteries, which are currently higher for the most innovative technologies, particularly for batteries, or benefits in terms of propulsion system energy efficiency).

However, no situation was found whereby OPEX savings can cover the additional capital costs associated with investments in new technologies. Consequently, in general, there is no return on investment for (near) zero-emission technologies to be expected for the vessel owner/operator compared to BAU.

4.5.2 Can "no-regret investments" be identified in the inland waterway transport sector's energy transition?[28]

While it is difficult to predict with certainty which investments could be considered as "no-regret" for the entire fleet in light of the many interrogations surrounding the energy transition of the inland navigation, some reliable indications can already be made for some fleet families.

Whichever transition pathway is chosen, ferries and daytrip vessels are expected to often use batteries. In general, vessels operating locally (especially in densely populated areas) with a limited energy demand and a fixed route may benefit from low energy costs for electricity from the grid used.

Large push boats can be considered as the other extreme with their high energy demand, 24/7 operation and high engine utilisation. They are expected to continue relying on internal conbustion engines (ICE) for several decades. In this case, investment in clean and efficient internal conbustion engines (ICE) (according to the latest standards) could be considered future-proof. This is especially relevant for the navigation on the Danube, given that on the Lower and Middle Danube almost 60% of inland waterway traffic is accounted for by high-capacity push boats (up to 15,000 tonnes). For such vessels, optimising energy efficiency will also be a key component of the energy transition. The carbon footprint can be reduced by gradually increasing the use of compatible drop-in fuels (i.e. HVO or LBM), considering these fuels fulfil the requirements introduced under section 3.2.

Subject to the pertinent operating profile, electric drivetrains (generator with internal conbustion engines (ICE) and electric motor) can also be considered as a "no-regret investment", both for new or retrofitted vessels. Such investments allow for a modular system approach by replacing at one stage the energy source on board, given that the integration of batteries or FC systems requires a vessel to be equipped with an electric drivetrain.

[28] *Source: CCNR study, research question C, Edition 2*

4.5.3 How to financially support the energy transition?

In order to support the energy transition of the inland waterway transport sector, the CCNR considers it opportune to pursue the idea of a European financial support instrument for the energy transition of the inland waterway transport sector, based on mixed sources (public and private), including a sector contribution.

In order to ensure a level playing field, such a European funding and financing instrument should be open to EU countries as well as Rhine and Danube riparian states which are not members of the EU (Switzerland, Serbia, Moldavia and Ukraine in particular). Easy access to such an instrument is paramount, as is administrative simplicity.

However, several economic, technical, legal and practical feasibility questions remain to be addressed by competent organisations before such an instrument can be implemented. This is also reflected in the next section (Implementation plan) and in the CCNR resolution 2021-I-6 prescribing the publication of the final study results,[29] adopted on 2nd June 2021.

[29] *https://www.ccr-zkr.org/files/documents/resolutions/ccr2021-Ifr.pdf*

Implementation plan

5

Regulatory measures

Voluntary measures

Financial measures

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 has been given to these identified barriers and how to address them through concrete policy measures.

€

Economic barriers

For the time being, there is in general no positive business case to justify the investment decisions by vessel owners/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 TCO for greening technologies also constitutes risk factors for vessel owners.

Finally, the vessel owners' investment capacity, depending on the sector concerned (liquid/dry/container/passenger), can be quite limited due to the current IWT market.

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 and
3. the integration onboard ships of new innovative or mature technologies and fuels.

Pilot applications 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 CAPEX and OPEX as well as 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. 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 regular 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 is a list of possible implementation measures. It distinguishes between regulatory, voluntary and financial measures.

Regulatory measures

<table>
<tr><th>No.</th><th>Measures</th><th>Required actions
(What)</th><th>Players
(Who)</th><th>Methodology, tools and the CCNR's possible contribution and calendar (when available)
(How and when)</th></tr>
<tr><td>R1a</td><td>Appropriate regulatory framework for the use of alternative fuels and batteries (vessel construction)</td><td>Develop standards and requirements applicable to the construction of inland navigation vessels to allow the use of alternative fuels and batteries on board these vessels</td><td>CESNI,[30] Member States of the CCNR, River Commissions,[31] UNECE,[32] EU, CEN, GERC[33]</td><td rowspan="5">Standards and regulations developed based on experience gained with pilot projects as well as existing standards from maritime as well as other industrial sectors.

Timeline CESNI: CESNI work programme 2022-2024 includes several tasks regarding alternative fuels.

The vessel technical requirements for fuel cells and methanol should be adopted by end 2022. Those for the storage of hydrogen would follow shortly thereafter.

The development of competence standards for the use of relevant alternative fuels, batteries and electric propulsion systems will start in 2022-2023.

CCNR work program 2022-2023 includes to start the work on regulatory framework for vessel operation.</td></tr>
<tr><td>R1b</td><td>Appropriate regulatory framework for the use of alternative fuels and batteries (crew)</td><td>Develop crew-related standards and requirements for allowing the use of alternative fuels and batteries on board inland vessels</td><td>CESNI, Member States of the CCNR, River Commissions, UNECE, EU</td></tr>
<tr><td>R1c</td><td>Appropriate regulatory framework for the use of alternative fuels and batteries (vessel operation)</td><td>Develop standards and requirements for operating vessels (navigation authority regulation) for allowing the use of alternative fuels and batteries on board inland vessels</td><td>Member States of the CCNR, River Commissions, UNECE</td></tr>
<tr><td>R1d</td><td>Appropriate regulatory framework for the use of alternative fuels and batteries (transport of dangerous goods)</td><td>Develop standards and requirements for allowing the carriage of alternative fuels</td><td>UNECE, CCNR</td></tr>
<tr><td>R1e</td><td>Appropriate regulatory framework for the use of alternative fuels (definition, fuel characteristics, blending and supply)</td><td>Develop standards and requirements to ease the use of alternative fuels (definition, fuel characteristics, blending and supply), notably biofuels

Coordination on implementation of instruments such as EU Renewable Energy Directive</td><td>Member States of the CCNR, EU</td></tr>
</table>

[30] *CESNI: European committee for drawing up standards in the field of inland navigation*
[31] *"River commissions" means Central Commission for the Navigation of the Rhine, Danube Commission, International Sava River Basin Commission and Mosel Commission.*
[32] *UNECE: United Nations Economic Commission for Europe*
[33] *GERC: Group of European Recognized Classification societies for inland navigation*

Regulatory measures

No.	Measures	**Required actions** (What)	**Players** (Who)	**Methodology, tools and the CCNR's possible contribution and calendar (when available)** (How and when)
R1f	Scrutiny and where appropriate amendment of safety and statutory requirements for bunkering of alternative fuels in inland waterway transport	It must be ensured that neither safety nor other provisions relating to bunkering infrastructure prevent the bunkering of alternative fuels.	CCNR, EU	Report Identify relevant legislation and requirements as well as gaps in the legislation together with national competent authorities for bunkering infrastructure CCNR work program 2022-2023 plans to tackle this issue.
R2	Possible out phasing of the most harmful technologies which appear inconsistent with the CCNR's and EU's long-term emission reduction ambition	Setting up a regulatory framework enabling the possible phasing out of the most polluting technologies failing to achieve the CCNR and EU long term emission reduction ambition, targeting existing vessels, addressing both GHG 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).
R3	Infrastructure requirements for alternative fuel and electricity for propulsion	Ensure that the needs of the inland waterway transport sector in terms of alternative fuel infrastructure are taken into account, notably in the revision of the Directive on the deployment of alternative fuels infrastructure, and ensure interoperability with all types of inland vessels.	CCNR, EU	Directive, report, interoperability standards
R4	Examination of the possibility of a sector contribution in the framework of a European funding and financing instrument	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	Beyond the preparatory work done in the context of the "CCNR study" (research questions G and H), examination of the compatibility of a sector contribution, especially with the Mannheim Act; consideration of the environmental repercussions of other modes of transport and of the modal split Timeline CCNR: 2022-2023

Voluntary measures

No.	Measures	Required actions (What)	Players (Who)	Methodology, tools and the CCNR's possible contribution and calendar (when available) (How and when)
V1	Label for environmental and climate protection	Development of an environmental and climate protection label	CESNI, CCNR, EU	Study, technical standards, guideline on the calculation and measurement methodology Cooperation with EU in the framework of PLATINA3, especially for the measurement methodology Timeline PLATINA3: proposal for a methodology in 2022 Timeline CCNR: assessment of opportunity and development of labelling system by 2023
V2	Carbon offsetting measures (carbon compensation)	Evaluate the possibilities and public acceptance of carbon offsetting measures as a stop gap solution until 2035 for GHG reduction[34]	CCNR, EU, IPCC	Guidelines on applicability of existing offsetting of carbon emissions measures to inland navigation (and possibly new proposals)
V3	Pilot vessel trials (all vessel types)	Follow, authorise, and support trials on pilot vessels and publish important results	CCNR, CESNI, EU, GERC	Cooperation CCNR and EU to implement flagship 3 of NAIADES III which addresses the issue of speeding up certification of pilot vessels. Timeline CCNR: 4 meetings per year of the Inspection regulations Working group to examine the request of derogations for pilot vessels.
V4	Innovative vessels	Setting up of a database on innovative vessels	CESNI, research institutes	Regular updates at least once a year
V5	Innovation award	Award for special innovations for the transformation of the inland navigation energy system	River Commissions	Every two years Timeline CCNR: First edition in 2025
V6	Situation reports	Regularly analyse emissions reduction status and the effectiveness of measures. It includes data collection, plausibility check and evaluation .	CCNR	Timeline CCNR: status report every 5 years (2025, 2030, 2035, 2040, 2045, 2050)

[34] A carbon offset can be described as a way to compensate for emissions made somewhere by funding or undertaking an equivalent carbon dioxide saving elsewhere.

Financial measures

No.	Measures	Required actions (What)	Players (Who)	Methodology, tools and the CCNR's possible contribution and calendar (when available) (How and when)
F1	Examination of European funding and financing instrument to support the inland navigation energy transition	Design, evaluate and implement a European funding and financing instrument	EU, European Investment Bank (EIB), CCNR, national banks, EBU, ESO	CCNR study published in 2021 Cooperation CCNR and EU to implement flagship 8 of NAIADES III, to be developed within PLATINA3 Timeline PLATINA3: report in 2022 The CCNR work programme 2022-2023 includes the evaluation and implementation of the proposals identified by the above-mentioned study (task ECO-22-3).
F2	EU Taxonomy – establishment of an EU classification system for sustainable activities	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	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 inland waterway transport sector

Next steps

6

The CCNR undertakes to

» report by **2025** on the progress in the implementation as well as the need to update the roadmap,

» at the latest in **2025** evaluate whether it is opportune to revise the “CCNR’s study”, especially on the economic and technical evaluation of the technologies,

» review the TTW approach in a forthcoming revision of its roadmap,

» evaluate by **2025** whether it is opportune to extend the scope of the roadmap, for example to other greenhouse gases such as N_2O or to emissions associated with other aspects of the vessel’s life-cycle, to the manufacturing and disposal of propulsion systems, to other types of vessel, or even to the technologies’ safety,

» revise, if necessary, by **2030** the roadmap and the corresponding action plan.

Annex
List of abbreviations and vessels types

BAU	Business-as-usual
CAPEX	Investment Costs
FAME	Fatty acid methyl ester
FC	Fuel Cell
GHG	Greenhouse Gas
H_2	Hydrogen
HVO	Hydrotreated Vegetable Oil
ICE	Internal Combustion Engine
IPCC	Intergovernmental Panel on Climate Change
IWT	Inland Waterway Transport
LBM	Liquefied Bio Methane (CH_4)
LNG	Liquefied Natural Gas
MeOH	Methanol (or CH_3OH)
OPEX	Operational Costs
PM/PN	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.
TTW	Tank-to-wake
WTW	Well-to-wake

Definitions of vessel types used for the transition pathways

- Motor vessel 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 tanker cargo ≥ 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 vessel 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 tanker 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 cargo vessel < 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;
- Push boat with P[35] < 500 kW: a vessel specially built to propel a pushed convoy and equipped with a total propulsion power of less than 500 kW;
- Push boat 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;
- Push boat 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;
- Coupled convoy: a motor vessel (generally longer than 95 m) intended to be operated with one or several lighters;
- Ferry: a passenger vessel providing a service crossing the waterway;
- Large cabin vessel: a passenger vessel longer than 86 m and with overnight passenger cabins;
- Day-trip and small cabin vessel: a passenger vessel for day-trip operation as well as a passenger vessel with overnight passenger cabins but shorter than 86 m.

[35] *P = Total power installed*

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; CCNR Study, research question C edition 1 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, amongst other thing, age, installed power and energy demand between the smaller and the larger vessels passenger vessels. These differences have a major impact on the suitability of the technologies under consideration.

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