Sustainable, safe and economically feasible energy concepts and technologies for European Inland Shipping

D 6.8 Roll-out plan for innovative greening technologies and concepts

Public

Grant Agreement: 633929
(Sub)Work Package: 6.4
Deliverable No: D6.8
Author: STC-NESTRA
Version (date): April 27, 2018

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 633929

Document history

Document version (date)	Comments (changes compared to previous version)	Authorised by
0.1	Draft report	Harrie de Leijer (STC-NESTRA)
0.2	Draft report	Richard van Liere (STC-NESTRA)
1.0 (27th of April 2018)	Final report	Jaap Gebraad

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1. Introduction

a) About PROMINENT

The EU project PROMINENT - Promoting Innovation in the Inland Waterways Transport (IWT) Sector - which was launched in May 2015, was a multiannual research and innovation programme for inland navigation. The project brought together the economy, the environment and safety for inland navigation with a clear focus on reduction of air pollution emissions and greenhouse gas emissions and increased environmental friendliness of navigation as well as an increase of competitiveness of inland navigation in logistics networks.

With 18,000 vessels and 40,000 crew members, the inland navigation sector can make a large contribution to the sustainability of the transport chain and the reduction of traffic jams on European roads.

This project funded from the Horizon 2020 programme addresses the key needs for technological development, as well as the barriers to innovation and greening in the European inland navigation sector. PROMINENT thereby is fully in line with the objectives of the European action programme NAIADES-II, COM/2013/0623 final, and ultimately aiming at providing solutions which make inland navigation an ever more competitive alternative to road transport in terms of air pollutant emissions by 2020 and beyond. In parallel, PROMINENT aims at further decreasing the energy consumption and carbon footprint of inland waterway transport, an area where it already has a strong advantage compared to road transport.

b) Sense of urgency

Recent headings from the news highlight the growing concerns concerning the air quality, climate change as well as the shortage of personnel in the inland waterway transport sector.

While much has been done already by various governments to reduce air pollution by trucks, the air pollution levels of inland waterway transport are still quite high. More and more local governments are actively measuring the air quality levels (NOx and Particle Matter concentrations) in the urban environment. In road transport already significant steps have been made by means of installing environmental zones linked to the age or EURO norm of vehicles.

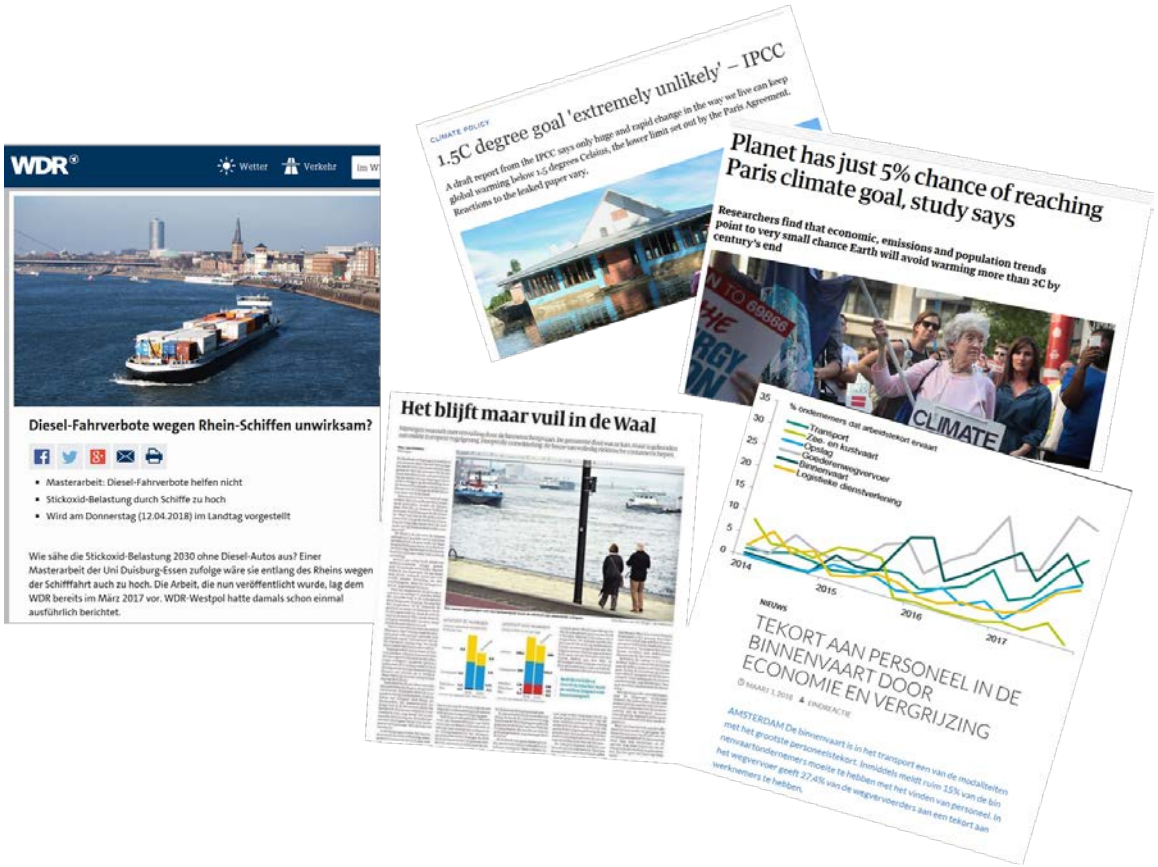

Figure 1: Selection of recent highlights from news websites, illustrating the relevance of topics addressed within PROMINENT

In inland waterway transport however, the emission standards are lagging behind, which is illustrated by the next figure.

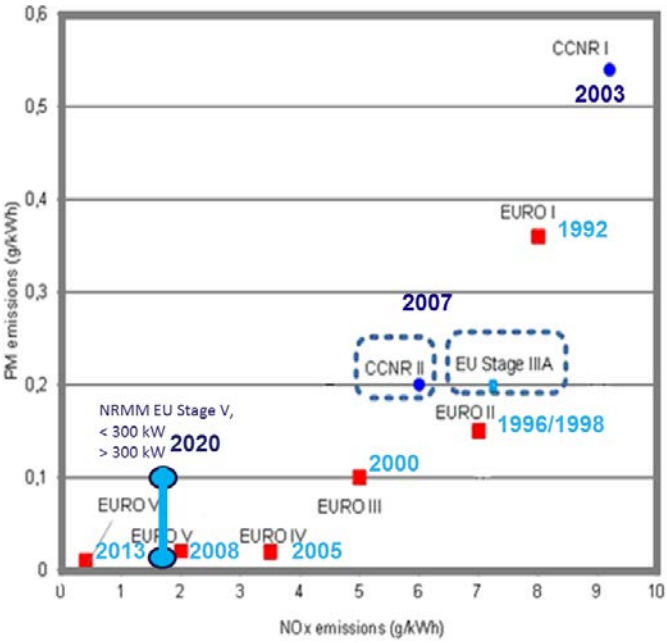

Figure 2: Emission limit comparison between trucks and engines applied in IWT.

While for trucks the Euro VI limit was introduced already in 2013, the current emission limit for IWT engines dates from 2007. The NOx emission levels in grams/kWh for a new engine in IWT are about 15 times higher compared to a new truck, while for particle matter the difference is a factor 20. Although the energy consumption of a vessels is much lower (60-80%), the air pollutant levels in terms of tonkilometer of a new truck versus a vessel with a new (CCNR2 engine) are much higher and IWT therefore is losing the competition in terms of environmental performance.

Moreover, also the new NRMM Stage V limit which will come into force in 2019/2020 is not at the same levels when compared to Euro VI trucks. For NOx the factor will be 4.5 to 5, while for small engines (<300 kW) the particle matter emission in grams/kWh is still 10 times higher (without a requirement on the particle number).

An advantage is however that IWT has a much lower CO2 emission level and also has sufficient capacity to accommodate growth. This is still a big strategic asset for Inland Navigation. However, there is a threat that the public perception and the support for IWT is decreasing due to the high air pollutant emissions.

Another major development is the COP21 agreement and the urgency to reduce the greenhouse gas (GHG) emissions. Actions are needed to reduce the consumption of fossil fuels and to bring emission levels of CO2 down. For example, The Netherlands has the goal for IWT to reduce GHG emissions in 2030 by around 60% and to develop towards zero-emission in 2050. This requires all measures possible, such as more energy-efficient navigation, increasing the logistic efficiency (payloads) and also introduction to and availability of alternative fuels and engine room solutions.

c) PROMINENT goals

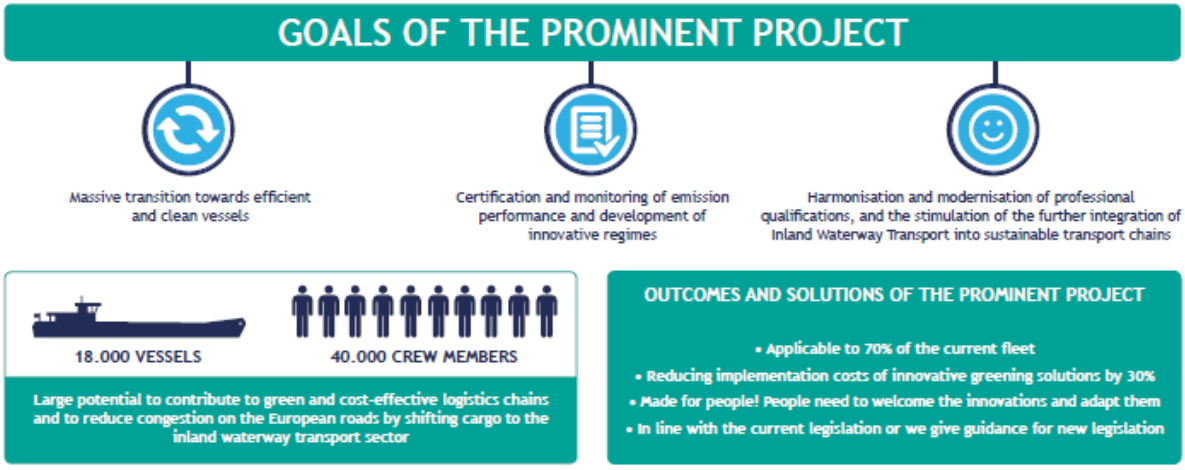

Figure 3: Goals of the Prominent Project

The PROMINENT project aimed for the target to ultimately provide technologies and concepts which make inland navigation as competitive as road transport in terms of air pollutant emissions by 2020 and beyond, while keeping inland waterway transport's (IWT) advantage regarding the 60-80% lower energy consumption and carbon footprint.

PROMINENT therefore took into account a series of technologies and concepts, which are grouped around several main themes:

- efficient and clean IWT, to be realized through engine room improvements and energy-efficient navigation leading to NRMM Stage V emission levels for NOx and PM and savings on fuel consumption and CO2 emissions;
- certification, monitoring and enforcement of stringent emission limits (NRMM Stage V);
- skilled workforce and quality jobs, through harmonisation and modernisation of professional qualifications and integration of IWT into transport chains.

The technologies and concepts developed in PROMINENT must provide cost effective solutions, which is defined as:

- applicable to 70 % of the fleet;
- lead to 30 % reduction of implementation costs;

which is to be realised through:

- 100% stakeholder involvement;
- actively addressing and removing implementation barriers.

It is important that stakeholders work together to roll-out the innovations. This is illustrated in the next figure.

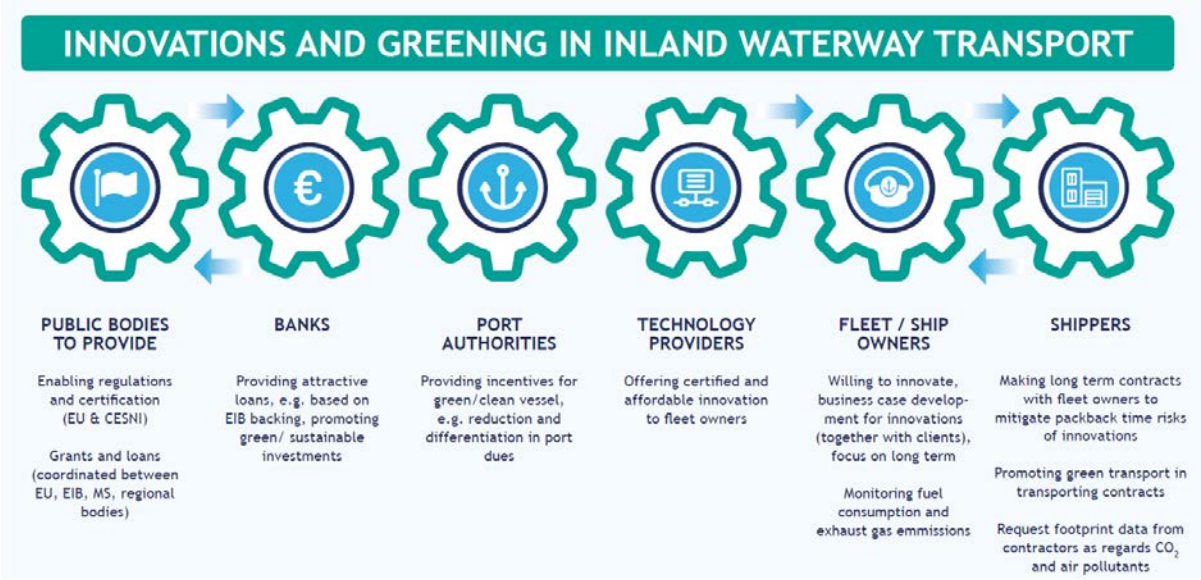

Figure 4: Stakeholder action required for Roll-Out

2. Key results from the studies and pilots

The PROMINENT project resulted in a huge set of deliverables containing detailed studies on new technologies, new concepts, simulations, real life tests and pilots, simulations, impact studies, training programmes, awareness actions and stakeholder consultations, dialogues and involvement.

The main conclusion in the field of emission control and energy savings is that, from a technical viewpoint, substantial improvements can be realised. A saving of around 915 million euro can be reached by means of a combination of:

- 10% fuel saving by means of application of energy-efficient navigation and right sizing new Stage V engines, meaning a saving of fuel costs of 65 million euro per year;
- 78% reduction of external costs for emissions by reaching Stage V emission levels, meaning 848 million euro savings per year.

What also can be seen is that NOx has by far the highest external costs. Currently the NOx emissions have an external costs of 825 million euro per year. The following table presents the figures.

	NOx [mln EUR]	PM [mln EUR]	CO2 [mln EUR]	TOTAL [mln EUR]
External costs per year in current situation	825	140	126	1092
Savings Stage V	-686	-135	-3,2	-821
10% fuel saving energy efficient navigation	-83	-14	-12,6	-109
Remaining external costs Stage V	139	5	123	271
Relative reduction Stage V	83%	96%	3%	75%
Reduction Stage V and 10% fuel cost saving	700	135	15	848
Remaining external costs Stage V + efficient navigation	125	5	111	244
Relative reduction Stage V and 10% fuel cost saving	85%	96%	12%	78%

Table 1: External cost for current situation, the situation after Stage V reached for all cargo and passenger vessels and situation with 10% fuel savings for the whole fleet.

Costs for implementing the Stage V levels sum up to around 1 billion euro. It can therefore be concluded that from a socio-economic viewpoint, these costs will be earned back within 14 months. As a result, it can be concluded that the cost-benefit ratio for providing support measures (e.g. by means of grants) is very high.

Furthermore, the developed and validated greening technologies contribute and fit into the long-term ambition to reach zero emission transport and decarbonisation. At present, several techniques have reached a high Technical Readiness Level (TRL), meaning that they are market ready. Some other techniques require further development first before they are ready for commercial applications. They are promising, but are still in the initial stages of development, and deployment is a number of years away. Pilots show that LNG and retrofit after-treatment systems (SCR-DPF) reaching Stage V emission levels are ready for the market. Furthermore, the required monitoring and certification systems are also in sight and can be rolled out in the short term.

Low emission and low carbon vessels are generally more expensive than diesel run vessels, although costs will come down with an increased uptake of these new technologies. It is concluded that implementation of a number of the solutions studied leads to increasing of cost, without generating sufficient operational advantages to reach any break-even point for the ship-owner/operator. The potential benefits for society are however very high. In other cases, there is a cost advantage on medium term for the ship-owner/operator, but this only applies to specific type of operations and/or specific vessel types. Solutions leading to lower energy use of course do relate to cost advantages, but may have operational disadvantages, such as a longer sailing time which might not be acceptable for the client. If waiting times at locks and terminals are reduced, the overall trip time can remain the same while bringing down the energy used.

Although cargo owners appreciate the attempts of the inland navigation industry to take measures in emission reduction, there is no general financial compensation in terms of higher freight rates. Only a few frontrunners (e.g. Heineken, Akzo) are investing in low emission transport. This is done by means of offering long term contracts and sometimes by means of discussing and accepting open calculations with the involved transport operators. However, the vast majority of the cargo owners make the transport choice based on the lowest transport price and the majority of cargo is traded on the spot-market, often on single trip basis via multiple brokers.

All in all, the conclusion is justified that operators investing in clean solutions are not rewarded for making such investments. This can be classified as a market failure, as market forces are not driving greener inland navigation and external costs of air pollution and greenhouse gas emissions are not internalised.

There is a number of failures and reasons for the slow uptake of greening technologies:

- investments in greening technologies and measures do not generate cost reductions, while reduced external costs are not internalised to create a business case and there is a lack of incentives and willingness to pay by shippers/forwarders;
- financers like commercial banks are hesitating to invest in new technologies, which are yet to prove its value (risk avoiding behaviour);
- the regulatory framework and EU IWT policy does not include stringent emission targets/regulation and timeline for existing vessels and their engines to accelerate greening of existing vessels.

3. Prominent Roll-out Strategy

In order to reach the original PROMINENT targets, a balanced package of measures is required in different areas:

- regulations on EU level;
- incentives;
- a financial support scheme;
- further R&D in the technical field;
- expansion of pilot systems to other areas.

The Roll Out Strategy for PROMINENT does focus at:

- speeding up the solutions which have a positive impact on society and at the same time have a positive business case;
- giving support to the solutions which have a positive impact on society but miss the positive business case.

This support strategy can contain measures in the field of giving incentives and subsidies, but could also relate to tax measures for systems which contribute in a negative way to society but are positive on business level (e.g. pollution causing negative impact for society could be taxed, while zero emission transport which has a negative impact on business level should be supported). The next figure illustrates the policy strategies for the different situations.

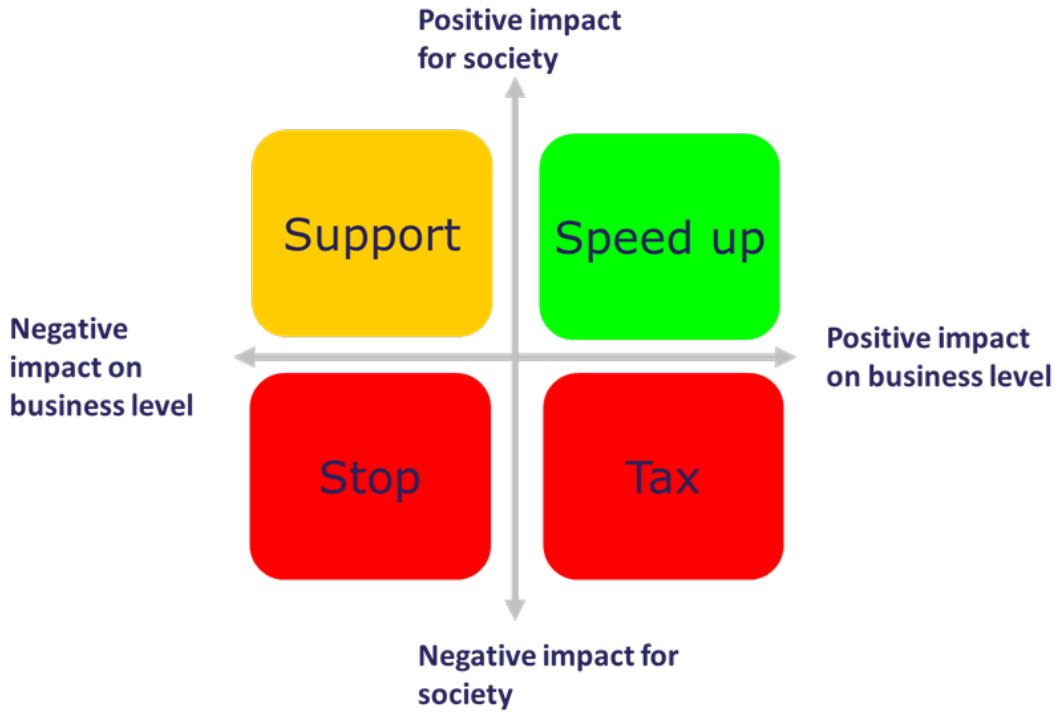

Figure 5: Policy strategies for different situations

Although there is a great variety in Technical Readiness Levels, barriers identified, challenges to address and actions needed for roll-out and implementation of the solutions, there is a lot of synergy between the four PROMINENT areas:

- Certification, Monitoring and Enforcement;
- Engine Room;
- Energy Efficient Navigation;
- Skilled Workforce and Quality Jobs.

The challenge is to prepare a strategy with follow-up actions which leads to the realisation of the PROMINENT targets. This means that the synergies between the four PROMINENT areas are determined and to be translated into the overall roll-out strategy and detailed actions, actors, budgets and support programmes.

In defining the roll out strategy, three main variables are of importance:

1. The broader societal impact of solutions, technologies, instruments:
    - in terms of energy savings, emission reduction, and market volume that will benefit.

2. The barriers that have to be addressed for further uptake and roll-out:
    - technical (barriers caused by immaturity of technology or operational requirements);
    - legal (barriers caused by regulations and laws, or a lack of this);
    - financial (barriers caused by access to capital or business case);
    - knowledge (barriers caused by a lack of expertise or skills);
    - market (barriers caused by market conditions, infrastructure, and the supply chain);
    - cultural (barriers caused by behavioural routines).

3. The business case for the actor who needs to decide on the investments (usually the ship-owner/operator).

A package of actions is recommended to stimulate specific positive developments (e.g. uptake of LNG, applying slower sailing speeds), to carry out more R&D in specific areas (e.g. ENAT, zero-emission technologies).

Next to providing support programmes through incentives, it may also be needed to take certain actions against polluting systems and polluters, so as to discourage unwanted developments from a socio-economic viewpoint. This is especially the case when operators carry on using old diesel engines, do not invest or pay for after-treatment or other measures, and find a good business case in such continuation. For these operations and operators, no improvements are expected on a voluntary basis. Measures and actions could come from other stakeholders such as port authorities, municipalities, and a few pioneering cargo owners, but will also need regulatory reforms to enforce the change that is necessary and to internalise greening of the fleet in market mechanisms.

One of the keys to unlock the greening door is of course creating financial benefits. One of the conclusions of the cost and benefit analyses and the I-STEER App/IWT greening tool developed in PROMINENT is that most of the greening technologies also result in increased costs, due to higher

investment or operating costs or even both. In the latter two, there is no return on investment and in the first one (higher investment costs only), only in some cases a positive business case is found. This complicates the financing of emission reducing technologies and causes a major bottleneck for the Roll-Out of these technologies.

There are several examples in which suppliers are actively involved in seeking external finance for the customer, mostly in grants or utilising tax discount benefits. While there are possibilities for innovative financing solutions by the system supplier, it is more likely that the financing will rely on traditional financing from banks combined with subsidies. Establishing a greening fund is one of the recommendations from the system suppliers. An easier to implement measure is their wish for implementation of further incentives for emission-reducing technologies, such as lower port dues and tax discount benefits.

At the same time, it was found that the supply in financing solutions is minimal compared to the actual demand, which shows figures between 1 and 2 billion euro to bring the fleet to Stage V emission levels.

An additional difficulty is that loans often do not suffice for innovative technologies that have greatest positive impacts for society, for the simple reason that the Return on Investment (ROI) is too low and risks are considered to be high. So, despite the theoretically legitimate ground to support green technologies in IWT, current instruments are mostly insufficient.

The inland navigation industry is requesting certainty about the desirable pathway for a lower carbon footprint and emission. Investment in new technologies will be done quicker, once it is clear where the industry will head to, and when existing vessels and engines will have to meet higher requirements. The inland vessel industry is in this field often compared with the sea going ships and marine industry, which is a misperception. Inland shipping is competing with trucks and rail, and the truck industry resembles much more the inland transport systems and technologies. Moreover, the lifetime of inland vessels and their engines is much longer compared to trucks, which calls for a stable medium/long policy for greening the fleet.

Despite the differences, much can be learned by looking at the way how the trucking sector evolved from polluting trucks to the present green truck fleet, enforced by stringent emission limits (e.g. Euro VI) in combination with an extensive emission test procedure, supported by incentives (e.g. subsidies for purchasing cleaner trucks) and implementing emission zones where old and polluting trucks are not allowed anymore. This could not have happened without the technical innovations in the sector, but was heavily supported by a clear regulatory regime and funding from public bodies.

A regulatory system for the existing fleet on EU level, in combination with admission limitations by countries, municipalities, and ports (sector regulation), requirements from cargo owners and traders to lower carbon footprints, and the creation of a support fund, will lead to realisation of the PROMINENT targets. Like said, a clear guidance is of the utmost importance for the inland navigation industry to accelerate the change towards clean and greener inland shipping.

The PROMINENT Roll Out Strategy and Implementation Plan consists of a number of proposed activities, to be implemented in parallel:

a) Legal and policy actions

1. Update the EU greening the fleet policy and set clear and ambitious targets in the field of emission limits which are to include the existing fleet and engines:
   - set medium/long term policy, pathways and targets for addressing CO2 reduction towards zero-emission (biofuels with clean combustion engines, fuel cells/battery and electric propulsion);
   - provide the legal basis and budgets in the Connecting Europe Facility for providing funds by the European Commission for the Greening Fund supporting voluntary investments by ship-owners in air pollutant and greenhouse gas emission reduction technologies, linked to the policy targets and required investments.

2. Introduce targets to be enforced by the legal regime and monitoring systems:
   - legislation and regulations in this field to be developed, air pollutant emission test procedures and limits for the existing fleet;
   - including On Board Monitoring to ensure emission control systems are working properly.

3. Incorporate in the legal framework of River Information Services (RIS) and the TEN-T guidelines/Good Navigation Status the obligation for providing detailed data on waterway conditions and waiting times to enable more energy-efficient navigation.

4. Provide the legal support for digitisation of the service record book and logbook (e-SRB, e-logbook) in the framework of the Digital Inland Navigation Area (DINA).

5. Provide the legal support for minimum requirements and certification of Vessel Handling Inland Navigation Simulators.

b) Financing for reaching Stage V and zero-emission

6. Development of an EU-wide Greening Fund to finance a large-scale uptake of proven solutions, dedicated to reducing air pollutant emissions and greenhouse gas emission:
   - the fund can be filled in several ways, through stakeholder contributions supporting green initiatives:
     - Grants from EU, Member States and regional governments;
     - Sector contribution by means of revenues provided by a differentiated environmental surcharge on IWT fuel and the Reserve Fund.
   - that is technology neutral and creates a level playing field;
   - revenues from the environmental surcharge are earmarked to the Greening Fund, with a strong governance by the sector;
   - integrating further supporting incentives from shippers and port authorities.

c) Research and Development and Innovation deployment

7. Programme Research and Development calls (H2020, FP9) as well as supporting actions for deployment (CEF) related to the promising solutions focused at:
   - widening the geographical scope of PROMINENT energy-efficiency tools (ENAT), by: equipping more vessels, setting-up central database(s) for processing the data from the vessels, executing ship borne measurements of waterway conditions and combine data with those provided by the waterway administrations;
   - digital tools / DINA: e-SRB and e-Logbook;
   - monitoring data for more vessel types, operation schemes etc.;
   - further technological research to promising greening engine room techniques with low TRL such as full electric (battery) sailing, hydrogen (fuel cells) and biofuels.

d) Support for promotion, training and education

8. Providing support for purchasing of Vessel Handling Inland Navigation Simulators across Europe.

9. Providing support for promotion activities aiming at knowledge collection and dissemination on greening technologies and innovations to the entrepreneurs in the sector, through continuation and expansion of the platforms (e.g. EIBIP) and training/education institutes hosting and further developing the I-Steer App/IWT Greening Tool as well as energy-efficient navigation, including awareness campaigns on energy consumption and emissions.

More details about the above mentioned clustered actions are provided in the following chapter.

4. Detailed actions for each area in PROMINENT

This section presents the main results of the studies and pilots for each of the specific area that was distinguished in PROMINENT:

- Certification, Monitoring and Enforcement (CME);
- Engine Room (ER);
- Energy Efficient Navigation (EEN);
- Skilled Workforce and Quality Jobs (SKQJ).

It presents a concise description of the main barriers and measures and actions needed for support and speeding up of promising solutions.

a) Certification, monitoring and enforcement

The first PROMINENT area deals with certification, monitoring and enforcement of air pollution emission performance of vessels, notably NOx and PM. It addresses the options for introducing additional regulatory emission schemes for the existing fleet and their engines, on top of the laboratory-based type approval of the engine. A regulatory framework shall support reaching NRMM Stage V equivalent emission levels for existing vessels equipped with greening technologies such as SCR-DPF.

Study and pilot results show that the practical Type Approval procedure for Retrofit Emission Control devices (REC) developed in PROMINENT can support the greening of the inland vessel fleet, and that On Board Monitoring (OBM) can fulfil an important role in securing and demonstration of the environmental performance of a vessel. RECs are after-treatment systems consisting of SCR catalyst and Diesel Particulate Filter (SCR-DPF).

A number of barriers prevent a quick and easy deployment of the devices and tools. Concerning REC, currently there are no legal requirements. There is no formal certification procedure yet either for REC for operators who are willing to (voluntary) invest in after treatment systems (e.g. SCR-DPF). Moreover, there are no clear financial benefits for the ship-owner/operator if engines comply with stringent limits (NRMM Stage V) due to installed REC, and the market has limited financial means to invest in REC systems.

For OBM, there is no legal requirement for continuous OBM, while the installation and operating costs for OBM are significant. Looking at the positive societal benefits, and in line with the strategy types mentioned in the introduction, a series of actions and measures are needed for the market uptake. This is a balanced combination of different types of measures.

For REC a certification procedure is required: PROMINENT proposes to implement the ‘Retrofit’ type Approval procedure as CESNI ES-TRIN standard (e.g. a new Article 9.10). The REC type approval procedure is to be based on a scaled engine test, for which detailed procedures will need to be compiled. This would also require a special technical working group to make a number of specific choices and to review the detailed procedure.

The roadmap for REC and OBM is summarised in a number of specific actions:
For REC:

- CME - Action 1: Development of test procedure (approved on CCNR or EU level) for retrofit Stage V (equivalence to OEM Stage V) and obtain support from stakeholders such as shipping organisations ESO, EBU and award organisations like the Dutch Green award;
- CME - Action 2: Implement Stage V emission requirements for existing ships at some point in the future.

For OBM:

- CME - Action 3: Create support to accept OBM in combination with independent emissions test, as alternative to type approval for Stage V emission requirements;
- REC - Action 4: Implement OBM as formal additional requirement for Retrofit and OEM Stage V (2020-2025);
- CME - Action 5: Develop emissions control centre for OBM with algorithms for pass/fail based on simple parameters, to be operated by a public body;
- CME - Action 6: To integrate OBM standard in REC control systems or in OEM engine management control systems.

The REC and OBM implementation is highly depending on the overall scheme to introduce incentives, funds and a business case for the ship-owner/operator to invest in retrofit technologies on existing vessels to reaching Stage V emission levels. This concerns installation of incentives from shippers if ships comply with Stage V requirements such as 'condition to tender', 'slightly better price', 'longer contract period', etc. Notably if the vessel is continuously monitored (CO2 and NOx emission) an additional incentive can be provided by the shipper. Also, a green fund and further incentives are crucial to create a business case to invest in greening technologies. These Actions are addressed in the section 'Engine Room'.

Concerning REC and OBM, these are at a high level of technical development although some R&D is still necessary, the regulatory framework is required and a market push and acceptance from industry is needed.

b) Engine Room

The topic Engine Room addresses the engine, drivetrain and the fuels in relation to the emission performance. PROMINENT focusses particularly on the air pollutant emissions, NOx and PM. However, also fuel consumption and choice on the type of fuel are relevant in view of the global challenge to reduce greenhouse gas emissions (CO2 reduction).

The studies and pilots carried out in PROMINENT show that SCR-DPF and LNG from a technological viewpoint are able and mature to reach Stage V emission levels. Due to the modular design, the SCR-DPF systems are quite well transferable to other vessels if the engine is a medium or high-speed type. The certification is however an issue to be addressed in this roadmap (as discussed in the above section on REC) and also the legal arrangements. Last but not least, the business case for the ship-owner/operator proves to be negative based on the PROMINENT research.

LNG has a positive case only for the operators that consume a high volume of fuel. The Cost Benefit Analysis shows a severe dependency of the economic feasibility in relation to the fuel prices for gasoil and LNG. The uncertainty of the price developments and the rather low gasoil prices seen over the past couple of years make the ship-owners/operators reluctant to invest in LNG drive

trains. First certified NRMM Stage V approved LNG engines are expected to be available in 2019. The pilot tests with the LNG designs validate that emission limits for Stage V will be reached.

Moreover, variety of alternative fuels are currently being discussed (e.g. biofuels, full-electric/battery, fuel-cell hydrogen, methanol, ethanol), given also the need to reduce the CO2 footprint. In addition, application of marinized Euro VI truck engines is one of the additional options which seem suitable for smaller vessels and engine power. This may bring emission levels further down, notably NOx emissions. However, it is yet too early to make solid conclusions on the EU-wide application of this option for the PROMINENT fleet families. Further R&D will be needed on these technologies and alternative fuel/power sources. This will help to get a view on pathways towards a zero-emission performance of inland waterway transport with intermediate targets and realistic ambitions.

The right sizing of engines (in case of engine replacement) is an economically viable way to reduce fuel consumption and therefore also the emissions to air. The application of right sizing shall be promoted. However, it requires changing the engine and from 2019/2020 this implicates a Stage V engine which may be more expensive for an existing vessel compared to overhauling the existing engine. Calculations will need to be made for the specific vessel and operational profile to see if changing the engine has a business case and if the investment for doing so has a reasonable payback time. Tools like the I-Steer App/IWT Greening Tool are therefore important instruments to facilitate these assessments.

For the IWT fleet there is a small but growing group of electrical hybrid and diesel electric vessels appearing on the market, although energy savings are still uncertain. Electrification of vessels gives additional options to the dimensioning and operational use of the combustion engines. Despite the disappointing results from the cost-benefit study, electric propulsion is for the long term a promising technology contributing to zero-emission sailing. More effective, and more costly technologies such as batteries and fuel cells are suggested. Their capability to bring green energy on board is expected to overcome the disadvantages of diesel electric vessels compared to conventional vessels. However, the roadmap for implementation of fuel cells and full electric vessels is yet unknown and uncertain, since there are still many questions on the costs and applicability of these technologies. Investments in these technologies is out of reach for the dominant group of conventional ship-owners which usually operate on the spot market.

It can be concluded from the study, models and pilots that a transition using clean combustion engines with bio-fuels (e.g. biodiesel/HVO or bio-LNG) will be the preferred route to follow for the short term for many of the ship-owner/operators, depending on the operational profile and vessel type.

As discussed, there is no push from European or national legislations to green the existing engines, which is a major barrier for development. This in combination with the fact that there is no commercial added value in application of exhaust gas after-treatment systems (SCR-DPF) or to replace or modify the engine to use LNG or other clean fuels.

The analysis summarised above, leads to the conclusion that despite the very positive results for society in terms of energy use and emissions, a number of barriers are a hindrance for market uptake. These are:

- in the policy and regulatory field: lack of a medium and long-term EU policy towards zero-emission inland waterway transport, and missing legislation for existing engines/vessels to comply with low air pollutant emission levels and to enforce low Real Sailing Emissions for both Retrofit solutions and OEM engines, for example by On Board Monitoring;
- in the economic and financial field: in general, there is no business case for greening the fleet on business economic level for the ship-owner/operator as well as difficult access to finance (loans) and lack of long-term contract and willingness to pay from shippers/forwarders for green vessels;
- in the technical field: no mature zero-emission technology is available and commercially viable for 70% of the market, and it is unclear how the market position can be of these zero-emission technologies and, moreover, what the time-frame will be for the market implementation;
- the missing know-how and capacity of most (small) companies (80% of the EU fleet owners) to investigate the greening technologies/fuels for their specific business situation (vessel characteristics and sailing profile).

The main actions for the Roadmap addressing the drive trains, engine room and fuels are aimed at providing the proper framework conditions to create the business case for greening the fleet. This shall be done by implementation of a stick & carrot scheme with clear overall targets and timelines for greening the fleet with respect to both air pollutant emissions and climate change emissions towards the year 2050. The development of a supportive greening fund is a useful and practical instrument in this respect. Shippers, forwarders, port authorities, regional and national authorities as well as the sector itself are recommended to align with the defined targets for supporting instruments. And a regulation should be implemented that prescribes the maximum emission limits to be reached within a certain timeframe.

Specific actions in this field concern:

- ER - Action 1: Development of an EU policy taking into account realistic technology and energy transition pathways and derived targets on reduction on greenhouse gas emissions and air pollutants for IWT specifically (CO2, NOx and PM), including existing vessels.
- ER - Action 2: Development of European wide financial support scheme and a funding regime based on a differentiated environmental surcharge on fuel to provide the business case and funding for supporting the large-scale deployment of greening technologies and alternative fuels, aiming at Stage V emission levels and further development towards zero-emission IWT. Such a scheme shall be technology neutral and supported by possible incorporation of grants and public loans from regional authorities, Member States, European Commission and EIB.
- ER - Action 3: Initiating Research and Development projects dedicated to IWT for promising zero-emission technologies to be applied in IWT in the period 2020 onwards such as application of biofuels (e.g. 100% or blends), hydrogen/fuel cells, biofuels and full electric, e.g. new R&D and pilot projects funded by the European Commission (H2020, FP9).

- ER - Action 4: Supporting platforms such as EIBIP and development of tools, pilots and dissemination work to bring more awareness and sharing information on the various technical options and alternative fuels, taking into account promising zero-emission technologies. Also, right sizing and diesel-electric and hybrid solutions need more support due to the enormous diversity (vessel types and sailing routes) of the inland navigation fleet. For diesel-electric and hybrids propulsion more data is needed to proof the advantages for certain market segments.

c) Energy-efficient navigation

The effect of energy-efficient navigation was included in several study parts, pilots and simulations in PROMINENT. Both different sailing strategies as well as implementation of new technologies and ship modifications have an impact on fuel consumption and CO2 emissions. Advanced simulations revealed that sailing with constant rate of revolutions or delivered power, results in a fuel consumption rather close to the minimum for a prescribed sailing duration. However, the most significant savings in fuel consumption can be achieved by sailing slower, which depends on the permitted duration of the trip (the time of arrival at the client for offloading the cargo or passengers). Reducing overall speed is of most importance. It shall be noted though that boatmasters often do not have much degree of freedom to choose the sailing duration and respective required speed. Therefore, also shippers (clients of IWT) shall be made aware of the relation between the journey time/arrival time and the fuel consumption.

Obviously, the greatest impact of energy-efficient navigation will be obtained by vessels with high fuel consumption, e.g. pushed convoys, or vessels with steep power-speed relations sailing with high brake power (tankers, container vessels). Most effective is therefore raising the awareness of the impact of different sailing strategies, provision of real-time information on energy-efficient ship operation and navigation conditions, as well as improvement and better utilisation of the waterway infrastructure through better knowledge on the conditions for these fleet families and operational profiles. The investigations carried out show that savings in CO2 up to 25 % may be achieved without additional large investment costs. However, the results differ greatly. They depend on the ship sizes, the characteristics and mode of operation of the vessel and the sailing area. In general, it was stated that a 10% saving of CO2 is certainly feasible on medium term as result of more efficient navigation.

Figure 6: Effect of energy efficient navigation

The simulations carried out reveal that for a typical Rhine vessel, a time increase by 1 % derived by slower sailing can result in a reduction of fuel consumption by 3 %; for a Danube vessel in single operation, a time increase by 1 % may result even in 4 % reduction of fuel consumption. For

modified lock operations between Rotterdam and Maastricht, allowing for slower sailing between the locks on the route, the fuel consumption of a large motor cargo vessel may be reduced by 13% according to results derived from the energy efficient navigation tool (ENAT).

The slower speed of the vessel leads to a longer sailing time, and thus could lead to a lower earning capacity of the vessel. In the current round-trip time of an inland navigation vessel, there is usually however a lot of slack (e.g. waiting time at bridges or locks or at terminals). Improved alignment in the supply chain and interaction with terminal and waterway managers (e.g. specific slots for loading/unloading and passing locks) will enable more energy efficient sailing. This links to concepts addressed in DINA (Digital Inland Navigation Area).

It can be concluded that a number of barriers exist to apply energy efficient navigation:

- the lack of availability of suitable information on navigation conditions (water depth, flow velocities);
- the difficulty to include locks and waiting time at terminals in voyage planning;
- the lack of availability of information on ship performance of a sufficiently great amount of vessels in order to cover the EU fleet (at least in the Rhine-Danube corridor);
- the poor capability to consider modified designs and new technologies;
- stakeholders in the supply chain are not yet informed on the benefits of more efficient navigation.

Further R&D, innovation deployment, measurement projects, data collection and awareness campaigns are therefore needed and recommended by PROMINENT.

The ENAT tool, developed in PROMINENT, can be a great support to more energy-efficient navigation, but, in line with the barriers mentioned before, better data on navigation conditions in different areas is required for validation of the tool, allowing a wider use and its integration in commercial route planners.

In the field of energy-efficient navigation, a number of actions are required to address the identified barriers, relating partly also to the better use of simulators, the actions needed for simulators specifically are described in the previous paragraph. The following actions shall be taken:

- EEN - Action 1: Further development of the simulation environment to increase the number of vessels to be considered for simulation (e.g. DST tank tests and modelling), their speed/power profile and resistance in different water conditions to further develop the models to calculate interaction between waterway information and the vessel. The results shall feed the further development and applications of tools such as ENAT (see next Action).
- EEN - Action 2: Further development of the tool for energy-efficient navigation (ENAT) to make infrastructure operating times and locations (locks, terminals at harbours) available as input and use real time information on the current availability of infrastructure (terminals and locks) for real time advise on the most efficient sailing speed and on the preferential ETA. This requires investments in data exchange between stakeholders (e.g. through RIS applications as developed within the framework of RIS COMEX at the moment) and improved logistics data analytics. It is advised to make this an important part of the digital

infrastructure, DINA. This can lead to substantial energy savings without increase of overall sailing time. Once the tool has reached a TRL such that it can be put in commercial operation, organisational and financial actions are to be elaborated and initiated in order to guarantee a continuous availability of the services the tool is going to provide.

- EEN - Action 3: water conditions and shipborne measurements on the Rhine and Danube are needed to improve the availability of detailed waterway information (water depths, currents, riverbed composition and riverbed shape) through measurements from waterway managers, notably water depth information on the Danube river is crucial. Another element is providing support for the continuation of the operation of the PROMINENT vessels equipped providing information on the waterway and expansion of fleet measuring the water conditions to provided data to ENAT. It is needed as well to establish further cooperation activities with ship-owners, including the set-up of an agreement with respect to sharing the data collected as well as the establishment of legal and organisational solutions for continuous running of the system and involvement of new ship-owners.
- EEN - Action 4: carry out comprehensive promotion activities. For an efficient roll-out of the toolset, awareness campaigns are required, both aimed at ship operators and at other stakeholders in the logistics chain, such as cargo owners, freight forwarders, terminal operators and infrastructure managers. This action shall be combined with Action 9 of the Engine Room (promotion and dissemination platforms such as EIBIP) and has also close links to feeding education programmes for students and crew working on vessels (e.g. full bridge simulator training facilities).

d) Skilled workforce and quality jobs

The PROMINENT work in this field considers three areas:

- the use of simulators and digital tools for the crew of vessels;
- the European electronic service record book and logbook;
- the integration of inland navigation in general logistics education through a Community of Practice.

The full bridge simulators for crew training can contribute to an increased safety level, and to an energy-efficient navigation. A major challenge is to make the profession of working in IWT more attractive and accessible for interested people. It therefore shall reduce the shortage of qualified nautical personnel.

Specifically, in CO2 savings, the effect of the use of simulators very much depends on the application, the awareness of impact of different sailing strategies (5 %), new technologies and ship modifications. In terms of improvements of efficient navigation, the full bridge simulators can play a significant role in raising awareness and knowledge about fuel consumption in relation to speed and manoeuvring the vessel. This combination with application of tools such as ENAT and advanced route planners in the operation of a vessel shall support more energy-efficient navigation.

With the introduction of the electronic service record book (e-SRB) and the e-logbook considerable benefits are to be gained, for example through the reduction of the administrative burden for stakeholders, and less time loss for inspections. In the field of e-SRB and e-logbook there are some issues to be solved and the legal base has to be settled. This is a bottleneck for implementation and

roll-out. It requires an Impact Assessment procedure by EC (DGMOVE) in order to address this issue and to prepare a legal intervention to support implementation of e-SRB and e-logbook.

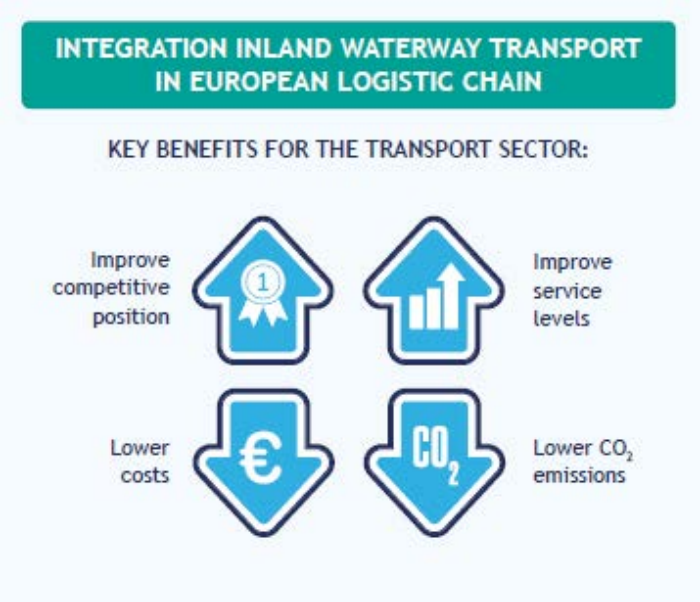

Figure 7: Key benefits for the transport sector of integrating IWT in supply chains

A more top-down approach to realise sustainable transport (less external costs) is to increase the modal share of IWT and to shift freight carried by trucks to the inland waterways. This requires however logistic decision makers to be aware of the performance and services that can be offered by inland waterway transport. The integration of knowledge about IWT services and performance in wider logistics education is therefore a major element. PROMINENT therefore addressed the integration of inland navigation in general logistics education by means of developing and testing an online web-based Community of Practice (CoP) to provide free up-to-date learning materials on the topic of IWT for general logistics education at an international basis. The CoP provides various types of learning materials, covering the aforementioned important topics of inland navigation which are currently underrepresented in general logistics education. The long-term goal is that the web-based CoP is used as a source for learning materials on the topic of inland waterway transport which can be integrated in logistics education. In addition, it should be used for all sorts of issues and discussions on the topic of inland waterway transport by different stakeholders from industry, research and education.

In the field of simulators, a wider application, in scope and scale, is possible and desired, but a number of barriers still prevent this. Notably a legal base is needed and standards for requirements for Vessel Handling Inland Navigation Simulators (as being developed by CESNI/QP) need to be adopted and applied. In addition, funding will be needed for roll-out of these simulators across the education and training institutions in Europe.

The barriers to better integrate inland navigation in general logistics education are limited, the main issue here is to overcome administrative barriers to include the developed learning materials and the capstone course.

One of the actions is to carry out promotion activities for energy-efficient navigation, however this action is already addressed in the previous section (Action 12: carry out comprehensive promotion activities).

The remaining specific actions recommended by PROMINENT are therefore the following:

- SKQJ 1 - Action 1: Establishing the legal basis for minimum requirements and certification of Vessel Handling Inland Navigation Simulators as well as supporting funding schemes for roll-out;
- SKQJ 1 - Action 2: carry out an Impact Assessment study leading to regulations for implementation of e-SRB and e-logbook within the wider framework of DINA. E-SRB and e-logbook shall be implemented together with a short transition period (an in-depth investigation of the investment costs needed has to be done related to this). Harmonisation of the format/procedure and exchange of information related to e-SRBs and e-Logbooks shall be settled in this way at EU level, creating a level playing field;
- SKQJ 1 - Action 3: Integration IWT in logistics by adapting the logistics curricula, to be stimulated by using the web-based CoP as a source for learning materials and for discussions on the topic of inland waterway transport. Funding is needed for training the teaching staff following the adaptations of the curricula.