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MAGPIE: Towards the European Green port of the Future

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Abstract

The Horizon 2020 Green Deal project MAGPIE began in October 2021 with a living lab approach to demonstrate solutions for smart, green, and integrated multimodal transport. Solutions include green energy carriers, digital solutions, and non-technological solutions for truck, train, inland waterway vessels, and maritime transport to, from, and in ports. The demonstrations will take place in the port of Rotterdam region and be evaluated based on the roll-out potential to other ports. All developments in MAGPIE will culminate in a Master Plan with the roadmap towards smart and green ports. MAGPIE will work with key stakeholders in transport and logistics to evaluate the exploitation potential and to ensure market uptake of the project results. This paper discusses the project plans and preliminary developments, looks ahead to the results of the project.

Keywords: European Green deal, Green Ports, Decarbnoised mobility, Alternative Fuels, Supply Chain, Carbon Neutral and zero-emission vehicles, Electrification, Efficient and Innovative logistics;

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Nomenclature

EC	European Commission
EGD	European Green Deal
EU	European Union
GHG	Green House Gas
NOx	Nitrogen Oxides
TCO	Total Costs of Ownership
TEN-T	Trans-European Transport Network
ZES	Zero Emissions Services

1. Introduction

Urgent action is needed to flatten the curve of climate change. In 2019 the European Commission (EC) launched the European Green Deal strategy (European Commission (2019)) to overcome climate change challenges and provide growth for the European economy. Complementary to this the Sustainable and Smart Mobility Strategy (European Commission (2020)) was published in December 2020. Greening transport is one of the key objectives of the EGD. Transport accounts for 25% of the EU's greenhouse gas emissions (European Commission (2019)). The objective of the EGD is to reduce the GHG emissions of transport by 90% by 2050. Waterborne transport accounts for approximately 13% of the EU's transport GHG emissions, more than 3% of the total EU GHG emissions.

In this context, seaports will play a major role in boosting the use of cleaner technologies, green energy carriers and logistics concepts in maritime transport (sea), port operations (transhipment and storage) and hinterland transport (road, rail, barge, and pipeline) to reduce GHG emissions. The port of Rotterdam, the largest seaport in Europe with numerous connections for all modes of transport, is frontrunner in the energy transition ("Lighthouse port") and aims to be a zero-emission port by 2050. Together with the "Fellow Ports" HAROPA (Le Havre, Rouen, and Paris), Sines and DeltaPort, the port of Rotterdam Authority supports the EGD sustainability goals. These four ports, complemented by a consortium consisting of 9 research institutes and universities and 32 private companies, are working together in the MAGPIE project which was awarded under the Horizon 2020 Green Deal call in 2021. The MAGPIE ports want to use the demonstration results of the MAGPIE project to accelerate decarbonisation (smart and green). MAGPIE will further develop the vision and the Master Plan that leads to zero-emission green ports in 2050 and to share knowledge and expertise with other seaports and inland ports in Europe.

The MAGPIE consortium is a unique collaboration addressing the missing link between green energy supply and green energy use in port-related transport and the implementation of digitalisation, automation, and autonomy to increase transport efficiency. This project accelerates the introduction of green energy carriers in conjunction with logistical optimisation in ports through automation and autonomous operations. A living lab approach is applied in which technological and non-technological innovations are developed or demonstrated. All results feed into the Master Plan for the future European green port, which will aim for full decarbonisation by 2050. The solutions demonstrated during the project can be implemented immediately to make significant steps in decarbonisation already by 2030 and 2040. The MAGPIE project is widely supported by stakeholders.

This paper discusses the plans for the demonstrators, digital solutions, non-technological innovations, and the smart green port of the future. The MAGPIE project is work in progress and (preliminary) results will be shared when they are available.

2. Living lab demonstrators

MAGPIE consists of real-life demonstrators for road, rail, inland waterway, and maritime transport, which together constitute a living-lab environment. A living lab is a learning-by-doing approach for testing innovations in real life conditions with regular interactions between the demonstrators, non-technological solutions, impact assessment and the Master Plan. Where necessary, the demonstrators will have the flexibility to adapt to these internal and external changes to ensure that a result is relevant for the market and for the local environment, and that is contributes positively to the energy transition in transport. This flexibility is necessary to keep the results of a 60-month project relevant and to achieve the highest impact and exploitation levels.

Ports play a large role in the supply of green energy to the transport sector. MAGPIE will study the supply chains of green hydrogen, green ammonia, electricity, and biofuels to maritime ships, inland waterway vessels, trucks, and trains. This process starts with the evaluation of the energy demands of these modalities based on the current knowledge of the energy transition. This evaluation will be repeated towards the end of the project based on the knowledge developed in the projects and the energy transition steps made by the modalities in the 5-year span of MAGPIE. Once the required quantities of each energy carrier are known, supply chains from the green source to the modalities will be studied.

This chapter will describe the demonstrators for road, rail, inland waterways, and maritime transport, as well as the monitoring and evaluation approach.

2.1. Road transport

Multiple energy carriers will be explored for green trucking depending on the distance to be travelled. Currently, for long distances the requirements for driving range and refuelling / recharging do not match the available sustainable vehicle technologies, and adaptions are required to logistics planning and operations. This presents a loss in assets and manpower and therefore an increase in costs and inefficiency at present. To overcome this, a network of refuelling / recharging areas needs to be implemented across the main TEN-T corridors and in the hinterland. Furthermore, solutions for cost-effective and optimal assets utilisation need to be in place. Smart energy management, together with integrated logistical planning and solutions for (autonomous) recharging / refuelling, needs to be developed and implemented. This will require not only truck technology and port infrastructure but also the distribution of the energy carriers to the hinterland. In this project, a demonstration of green connected trucking will focus on batteries and hydrogen for short to medium distances. The first MAGPIE demonstration of automated trucking will commence in the port of Rotterdam in late 2022.

Trucks are often needed for the last mile or for destinations for which other modalities have no options. The focus in this demonstration is on further implementing zero-emission trucking, the reduction of unnecessary transport, improving trucking operations by digitally connecting trucking, removing bottlenecks and congestion in ports, and preventing excessive numbers of trucks at the same place at the same time to reduce congestion and waiting time. Furthermore, additional efforts are needed to spread road traffic and therefore reduce congestion at peak times. A network of bundling hubs will therefore be developed. A pilot will be initiated in this project to demonstrate the impact on congestion of digital tools and bundling hubs on the spread of road traffic. By spreading the traffic more evenly, fewer start and stop movements will be made, enhancing environmental performance. In combination with the green connected trucking demonstration and the pilot project for spreading road traffic, the autonomous recharging of trucks at a decoupling point or bundling hub can further smoothen operations, integrating smart grid management, vehicle energy management, logistics management and traffic management.

2.2. Rail transport

In most ports, the last/first mile of rail tracks lack an overhead line to supply the electricity, due to the loading and unloading of cargo. Diesel locomotives are therefore used for first/last-mile operation, typically with very poor environmental performance due to the use of diesel, variable loads, and significant idle times. Part of the operation time of the shunting locomotives is on tracks with overhead line where decoupling takes place, and the cargo is handed over to a conventional electric locomotive, requiring additional operational planning and costs. Fully electric hybrid locomotives, which operate on the overhead line where possible and on batteries where needed, can replace the diesel locomotives and operate electrically both with and without overhead line. The integrated battery system was purposely designed for shunting operations. Two revolutionary hybrid shunting locomotives (Fig. 1) will be tested and demonstrated in the port of Rotterdam.

Fig. 1. Design of hybrid shunting locomotive

2.3. Inland waterways

Autonomy in modalities will increase the efficiency of the assets and reduce costs where barge crew costs typically account for 35 – 50% of overall costs. The introduction of unmanned vehicles and related methods will therefore allow for completely new operational modalities that would otherwise be prohibitively expensive. In this case, electrical inland barges that are operated flexibly for intra-port transhipment are demonstrated. In many ports, barges transport cargo between terminals and follow a fixed route. In a port as large as Rotterdam, multiple barges operate on this inter-terminal route (Fig. 2) at the same time. To achieve autonomy in the inter-terminal operating barges, autonomous docking and sailing technologies need to be applied. A demonstration in MAGPIE will show the increased efficiency of an autonomous e-barge in the port of Rotterdam. The impact on jobs of increased autonomy will be evaluated in MAGPIE.

Operations at many terminals are already largely automated with, for example, automated guided vehicles at the container terminals. A missing link in automation from the (autonomous) ship to the (autonomous) trucks or trains is transhipment. To complete the automated logistics chain, MAGPIE will also demonstrate autonomous transhipment. In Rotterdam, autonomous transhipment over water will often follow a significantly shorter route than autonomous transhipment by truck, reducing emissions further.

Fig. 2. Barge shuttle routes in the port of Rotterdam

Hydrogen is expected to play a large role in the energy mix of the future. Not only will there be demand from transport for this energy carrier, there will also be industry and residential use. Expected demand for green hydrogen exceeds the production capacity in Europe. Hydrogen imports will therefore be needed to meet growing demand. Several projects such as the H2SINES initiative are already covering the supply of green hydrogen (with imports). The form in which hydrogen will be required (e.g., liquid/gas, pressurised, combined with other atoms (ammonia or methanol)) by the transport sector is still unclear, requiring flexibility in the supply infrastructure. The ZES battery container concept is currently being implemented in inland shipping. A ZES battery pack placed on a vessel can be replaced once the energy in the battery has been used, providing energy as a service. As an alternative, the shipping container can carry hydrogen and a fuel cell. MAGPIE will demonstrate both options for inland shipping including container logistics and charging infrastructure. In this way, ready-to-use energy containers will be available when and where an inland vessel needs it.

2.4. Maritime transport

Ammonia is a hydrogen carrier with high potential for use in maritime transport. Ammonia can either power a fuel cell or be used in a full ammonia combustion engine. Ammonia is widely available throughout the world but the missing links in the chain are storage in the port for refuelling vessels and the safe refuelling of the vessels given the toxicity of the energy carrier. MAGPIE will demonstrate ammonia bunkering with a bunkering barge and for the roll-out design of an ammonia terminal with an ammonia cracker (to produce hydrogen).

For many individual ships, the existing electricity grid can deliver the required electricity for in port operations. However, if large numbers of ships need electricity in a large port and if there are individual ships with large in-port loads, such as passenger ships, crane vessels with large cranes operating in port, or vessels with reefer containers, load demand will exceed the capacity of the standard electricity grid. Either expensive heavier cables will need to be laid or a parallel energy source for the peak load will be required. The demonstration for shaving the shore-power load peak will show how locally stored energy can be used in parallel with the grid to achieve peak shaving. This project will be at the Heerema location in the port of Rotterdam. At this where large crane vessels are moored which operate the cranes also in port, thus requiring large loads during short periods of time.

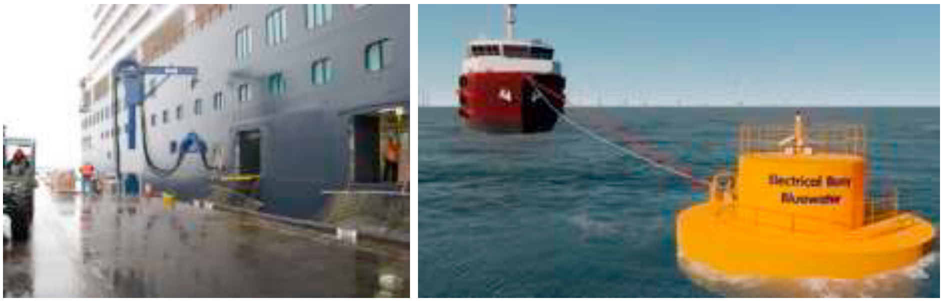

Fig. 3.Shore power installation (left) and offshore charging buoy concept (right)

Vessels moored in a port can use shore power and therefore shut down their own generators. However, vessels moored in the waiting areas offshore need to keep their generators on for on-board electricity. This results not only in GHG emissions and high fuel costs, but also has adverse effects on air quality in cities. Installing mooring buoys in the waiting areas that supply electricity, allows vessels in a waiting area to connect to a green electric source. This concept will be tested in MAGPIE by demonstrating an offshore charging buoy for a crew transfer vessel at an offshore windfarm to charge its batteries while the crew is performing maintenance activities on the windfarm.

2.5. Monitoring and evaluation

The MAGPIE demonstrators are highly diverse which makes it challenging to compare the outcomes and impacts and to evaluate the roll-out potential. To address this challenge, a measurement and evaluation framework will be deployed for the quantitative assessment of environmental, operational, and socio-economic indicators. This framework will be initiated with the baseline values for benchmark demonstrators and project results. During the project the indicators will be measured for the port, as well as for the city environment and for the entire logistics origin-destination chains. The harmonisation of the approach between different demonstrators is needed to compare the results and bring them together in a coherent way. MAGPIE will result in the overall evaluation of demonstrators, including the efficiency of the solutions and the related GHG abatement costs.

The monitoring plan specifies what to monitor and how, and how to deal with the data gaps. It specifies a baseline scenario as a benchmark for the demonstration and project results. MAGPIE will involve a continuous monitoring process and ensure that there are cross-demonstration synergies and feed the collected or computed data to the other parts of the project where primary (real-world) data is needed for useful experimentation and successful development. The monitoring of demonstrations is crucial to follow the impact and effects of the various demonstrations and projects.

Evaluation of the monitoring data will include an assessment of the effectivity of the demonstrated solutions and technologies in the Fellow Ports. The boundary conditions at those ports will vary, and this factor will affect the effectiveness of a solution or technology. A study will be produced of these boundary conditions and serve as the basis for the roll-out plans and as input for the Master Plan.

3. Digital and non-technological solutions

3.1. Digital technologies

The aim of integrated and multimodal transport to smooth the process between modalities and select the most efficient modality considering GHG emissions, air quality, congestion, and speed. MAGPIE focuses on digital infrastructure and tools, digitalisation for autonomous transhipment and creating a sustainable, autonomous ecosystem.

Integrated multimodal transport requires a platform where modalities are connected with each other and with the infrastructure. A digital twin of the port will serve this purpose, connecting the digital infrastructure, port vehicles, trains, ships, barges, and trucks. Digital twins of ports will also be able to connect to each other, supplying more information on the vessels en route between ports. A standard port digital twin will be developed for and demonstrated in the MAGPIE Fellow Ports. The digital twin is the central framework which will connect to the port infrastructure, port vehicles and cranes that are available for ships, barges, trucks, and trains. When modalities are connected to the digital twin, the data exchanged should include the type of energy carrier and the volume / quantity required at a certain time. The energy supply chains, which will also be connected to the digital twin, will then be able to prepare the required energy supplies. This may be a charged replacement battery, a bunkering barge, or a reservation on the electricity grid for a certain power demand. Matching energy demand and supply will provide a picture of the required quantities and can be used for the longer term to upscale the supply chains. This will optimise the production and supply of energy to the vessel.

A major step towards the operational selection of the most environmentally friendly combination of modalities, transport assets and routing will involve making the GHG emissions visible for the entire logistics chain and implementing environmental criteria in the optimisation algorithms of multimodal control systems. Currently tools are being developed to calculate the GHG emissions for the logistics chains mostly using default emission factors or aggregated ex-post data. In MAGPIE, GHG tooling will be built using operational data from the digital twin, which includes all the relevant greenhouse gases, air quality and the green energy carriers of the future. MAGPIE will demonstrate GHG emission reduction in day-to-day operations and on the strategic level against the background of trends and autonomous developments.

3.2. Non-technological solutions

Non-technological innovations and digital solutions to support and accelerate the transition of the transport sector will be instrumental in supporting the technical solutions to achieve smart, green, and integrated multimodal transport. The introduction and scaling-up of new forms of energy, smart data-driven energy-saving solutions and modal shift will, in most cases, involve issues like initial investment risks, initial price/cost gaps between existing and new solutions, competition risks and trust related behavioural issues. This requires the right conditions to be established, examples being the introduction of new market mechanisms, new financial arrangements, new organisational structures and/or new regulatory and legislative frameworks. The impacts of the innovations on port-city governance and relations will also be evaluated. Implementing innovations of this kind must benefit first movers but also facilitate general and result in the intended upscaling of the new innovations in the market. As a starting point, MAGPIE will consider and build on the following non-technological solutions:

- Zero-emission oriented price differentiation schemes for maritime and inland shipping.
- Blockchain-based end-customer-oriented services for accelerating the use of green energy carriers.
- New governance structures and business models for energy-saving solutions like digital twins.
- New market structures for sustainable last-mile transport.
- New governance arrangements for battery use in inland shipping.

In addition, regulatory incentives, new legislation and innovative financing are measures that will also be assessed and developed.

To kick off these developments in MAGPIE Bergsma and van Son (2022) reported on a study of the potential barriers to greening transport in the various transport modalities. The barriers that resulted from the consultation with project partners are:

- Two strong barriers to innovation were identified for road transport that hamper the adoption of zero emission trucks in the port context, both of which are economic in nature. First and foremost, interviewees identified a high Total Cost of Ownership (TCO) of new, relatively untested, zero-emission trucks. Secondly, interviewees noted a lack of demand for zero-emission trucks. The latter economic barrier is a culmination of infrastructural, knowledge and regulatory barriers that erode confidence among the prospective buyers and users of zero-emission trucks.
- Barriers identified in the interviews for rail transport were predominantly economic, infrastructural, and interaction-based. The core element in innovation barriers boil down to the high capital costs that contribute to a high TCO. The purchase of state-of-the-art e-locomotives is prohibitively expensive, and this represents a serious limitation and investment risk for rail operators.
- For inland shipping, the barriers were predominantly economic, and interaction- and directionality-based. in the economic area, the matching between supply and demand in a mutually sustainable business case to develop and operate solutions is challenging. As for the interaction, the principal barrier is the complexity involved in organising, informing and aligning all stakeholders in order to establish an informed perspective. However, due to the lack of harmonisation of policies for inland shipping (such as NOx regulations in the Netherlands, as opposed to the EU), the clarity of the direction, and the expected regulatory boundaries results in uncertainty.
- The innovation barriers identified for seagoing shipping were predominantly economic and interaction based, with interaction considerations being closely linked to the process of shaping standards and policy. The principal barrier is the lack of feasibility of a sustainable business case beyond niche operators.

Non-technological innovations that will be developed by MAGPIE will focus on overcoming these barriers for the modalities and accelerating the uptake of green energy carriers.

4. Green port of the future

Evaluations of the impact of the demonstrated technologies will feed into the Master Plan for the future Green European Port to be developed in MAGPIE, both for seaport and inland ports. This Master Plan will consider wider developments in and around ports, link up to other developments in and around ports and in the transport sector, and paint a picture of the future European port for 2030, 2040 and 2050 using input from the work packages, other projects, and existing research. It is the aim of the Master Plan to identify the necessary steps to establish a decarbonised transport and develop the future role of ports in that area.

This Master Plan will set out a bold vision for the future European green port and provide a roadmap to decarbonisation by 2050. Between now and 2030, energy supply chains will need to be flexible since the transition is still taking shape and searching for the best techno-economic solutions. Between 2030 and 2040, the energy supply chains will need to acquire a more structural form with less uncertainty about future energy requirements and volumes. The final stretch to decarbonised transport between 2040 and 2050 is about optimising the supply chains for green energy carriers.

The Master Plan will develop milestones, evaluate potential barriers, and identify the stakeholders needed to overcome those barriers. A clear timeline will be given with objectives and results to be achieved along the way. Demonstrators will feed into the Master Plan with the help of the impact evaluations to provide a handbook for rolling out the concepts in light of the port-specific boundary conditions. MAGPIE will further determine the cost efficiency of developed solutions relating to the GHG-abatement costs and show their potential in a European and world-wide context.

Most solutions and technologies are not one-size-fits-all and they will have to be adapted to the specificities and boundary conditions of each port. Currently, MAGPIE is drawing up an overview of the characteristics of the ports and of the boundary conditions which may affect the success of technologies, and regulations relating to smart, green, and integrated multimodal transport. This will serve as the basis to study the roll-out potential of the developments. MAGPIE will work with its sister project PIONEERS, which is being coordinated by the port of Antwerp, to compare results and learn from each other's developments.

5. Concluding remarks and future work

The MAGPIE consortium consisting of 4 ports, 9 research institutes and universities and 32 private companies has set out to demonstrate smart, green, and integrated multimodal transport to, from and in ports. Real-life demonstrators for road, rail, inland waterway, and maritime transport are complemented by the development of digital and non-technological solutions, all for improving transport.

MAGPIE began in October 2021 and the demonstrators will run for five years. At time of writing this paper, all the demonstrators were in the preparation phase, designs were being made, and simulations or scaled tests will commence soon. The consortium intends to publish (intermediate) demonstration results in future editions of TRA.

The experience of the demonstrators and developments will culminate in the Master Plan for the future European green port. This will include the roll out potential of the developments in other ports in the light of their boundary conditions and the differences with the boundary conditions of the port of Rotterdam, which is where all the demonstrators will take place. MAGPIE will interact with stakeholders outside the consortium to get their input and to encourage their active involvement in the living-lab environment. These stakeholders are also needed for market uptake and the exploitation of the concepts and technologies developed in the project.

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