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WISTAR

Waterways for Green Inland Sustainable Transport and Rural Businesses
WISTAR

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D1.1.1. Strategy for implementing green transportation concepts by using inland waterways

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List of Abbreviations

Acronym/ Term	Description
AFSCM	Agri-Food Supply Chain Management
ATP	Agreement on the Transport of Perishable Foodstuffs
BDDV	Federal Association of Independent Inland Shipping (Germany)
BWI	Ministry for Economics and Innovation (Germany)
CCNR	Central Commission for the Navigation of the Rhine
CEMT	European Conference of Ministers of Transport (Classification of Vessels)
CFT	Compagnie Fluviale de Transport (River Transport Company)
CO_2	Carbon Dioxide
DPD	Dynamic Parcel Distribution (Logistics Company)
ENO	Energy and Greenhouse Gas Optimization
EU	European Union
GFT	Vegetable, Fruit, and Garden Waste
GHG	Greenhouse Gas
GLS	General Logistics Systems (Logistics Company)
GTL	Gas-to-Liquids
GNC	Compressed Natural Gas
HAROPA	Ports of Le Havre, Rouen, and Paris
H2	Hydrogen
HVO100	Hydrotreated Vegetable Oil
IOK	Intermunicipal Association for Waste Management (Belgium)
IWT	Inland Waterway Transport
IWW	Inland Waterways
KOMODO	Cooperative Use of Micro Depots (Urban Logistics Project in Berlin)
LNG	Liquefied Natural Gas
MBO	Beerse Environmental Company (Belgium)
MBS	Mechanical-Biological Separation (Plant in Geel, Belgium)
MMO	Mol Environmental Company (Belgium)
NWE	North-West Europe
PPP	Public-Private Partnership
SCIC	Cooperative Society of Collective Interest
SCOP	Cooperative Society for Participative Ownership
SEMASER	SEM Seine Axis Renewable Energy
SRF	Solid Recovered Fuel
SSMS	Sustainable and Smart Mobility Strategy
STEF	Specialist in Temperature-Controlled Supply Chains
ST4W	Smart Tracking Data Network for Shipment by Inland Waterway
SWOT	Strengths, Weaknesses, Opportunities, and Threats (Analysis Framework)
SOW	Spree-Oder Waterway
TWh	Terawatt-hour
VNF	Waterways of France

1. Executive summary

The WISTAR project, *Waterways for Green Inland Sustainable Transport and Rural Businesses*, aims to develop sustainable urban logistics solutions in North-West Europe (NWE) by leveraging Inland Waterway Transport (IWT) to create an eco-friendly supply chain that aligns with both environmental and economic objectives. This report, titled "Implementable Concept Report," delves into the challenges, opportunities, and actionable strategies for integrating renewable energy solutions and optimizing transshipment points specifically designed for inland waterway logistics.

The report addresses three key objectives:

1. **Market Demand Analysis**: We assess the demand for IWT services across urban and rural areas in Germany, France, and Belgium. The study examines the role of inland waterways in sectors such as agrifood, last-mile urban deliveries, and intermodal logistics, focusing on how these services can meet business needs while reducing transportation costs and environmental impact.

2. **Transportation Infrastructure and Renewable Energy Concepts**: This section evaluates the current infrastructure supporting IWT in each region, highlighting renewable energy options such as bio-GNC, hydrogen, and electric energy for transport logistics. The report also examines the potential for adopting energy-efficient practices in line with local and national regulatory frameworks.

3. **Identification of Transshipment Points**: The report offers a mapping of potential transshipment points that can serve as strategic hubs for IWT operations. These points enable flexible and decentralized logistics solutions, reducing dependency on traditional ports and facilitating supply chain connections between rural and urban regions.

The findings highlight the potential for IWT to become a cornerstone of sustainable logistics in the NWE area. WISTAR's transnational approach underscores the need for collaborative efforts to harmonize policies, streamline regulations, and foster infrastructure development, ensuring that solutions are tailored to each country's unique characteristics.

In summary, the WISTAR project envisions a green, integrated supply chain model that reduces greenhouse gas emissions, supports energy efficiency, and promotes the economic growth of rural-urban logistics networks in North-West Europe. By developing region-specific recommendations and best practices, this report sets the foundation for a sustainable logistics framework capable of evolving to meet future challenges.

2. Introduction

The WISTAR project aims to address critical challenges in sustainable urban logistics in North-West Europe (NWE) by leveraging the potential of Inland Waterway Transport (IWT) to promote a green supply chain. This report, titled "Implementable Concept Report," seeks to outline the challenges and opportunities related to implementing logistics solutions that integrate renewable energy and suitable transshipment points for inland waterway transport.

The study, segmented by country (Germany, France, and Belgium), explores the optimization potential of logistics chains connecting rural and urban areas through sectoral analyses. By capitalizing on inland waterway transport to serve urban areas, WISTAR addresses issues of energy efficiency, greenhouse gas emissions reduction, and adaptability to local infrastructure, while meeting the specific needs of various sectors, including agrifood, last-mile delivery, and intermodal logistics.

This report is structured around the following focus areas: market demand analysis for IWT services in urban and rural environments, assessment of transport infrastructure and renewable energy concepts, and identification of potential transshipment points.

Each section examines practical cases and solutions tailored to local particularities, while aiming to meet stakeholders' requirements in terms of sustainability, reliability, and compliance with national and European regulations. This transnational approach, combined with feasibility studies and region-specific recommendations, aims to build a green and integrated supply chain model aligned with the environmental and economic objectives of the WISTAR project.

3. Market demand analysis

3.1. Overall approach: state of the art of IWT logistics chains in urban areas

To analyze the state of the art, more than reviewing academic publications, we conducted an in-depth screening of relevant EU projects. This approach enables us to identify and analyze the technologies currently being implemented across Europe on the project thematic of WISTAR. Moreover, it helps us, in the early stages of the project, to pinpoint potential interfaces between these emerging solutions and the products. Our research identified 5 EU projects related to inland waterway (IWW) navigation systems in Europe. The following fact sheets of these projects summarize the most relevant aspects.

Development of a concept for container distribution in North Rhine-Westphalia using small inland vessels and decentralized transshipment points- DeConTrans

Duration:	October 2018 – March 2022
Partner Countries:	Germany
Project´s Targets:	The DeConTrans venture's primary aim is to formulate decentralized, inventive goods transport systems along the West German canal system with an intention of reducing road congestion, reducing emissions and maximizing the use of inland waterways. It aims to include these systems into current global supply chains with a key focus on affordable and energy-efficient oversea mode alternatives.
Project description:	The project focuses on utilising container transport along the West German canal route by employing small, hybrid-electric powered automated ships for this purpose. During the project 105 probable transhipment sites were identified, special vessels for carrying goods in containers were concibed as well as integrates them within existing supply chains. It also looks into efficient handling and transloading processes at decentralized locations that make use of present or newly constructed infrastructures such as mobile cranes. A simulation enabled assessing different scenarios of transportation and determining their realizability in real logistics.
Web Page:	https://www.dst-org.de/decontrans/

Relevance for WISTAR:	High
Possibility for Interfaces:	• Both projects share a focus on sustainable logistics using waterways, and the use of small, energy-efficient ships in DeConTrans could complement WISTAR's efforts. • The integration of IT services, data management, and innovative transshipment methods in DeConTrans could serve as a model for WISTAR to optimize logistics in urban environments.

Table 1: DeConTrans concept

Innovation-driven Collaborative European Inland Waterways Transport Network– IW-NET

Duration:	1 May 2020- 30 april 2023
Partner Countries:	Belgium, Germany
Project´s Targets:	It aims at improving the efficiency, competitiveness, and reliability of European Inland Waterway Transport (IWT), addressing IWT operations in different regions all over Europe – in particular rivers Danube, Spree/Oder and Weser, and the regions of Brussels and Ghent.
Project description:	Thema addresses themes as the exploration of innovative vessel designs, the establishment of collaborative berth plans, sustainable infrastructure, automation and finally an advanced location accuracy through GALILEO services. IW-NET uses simulations and tests in examining navigability under changing water conditions, efficient use of shore power, automation, and therefore integrating IWTs into multimodal transport chains. The project aims at making IWTs more resilient and sustainable while minimizing greenhouse gas emissions from logistics processes.
Web Page:	https://www.iw-net.eu/
Relevance for WISTAR:	High
Possibility for Interfaces:	• Interfacing between WISTAR and IW-NET may be likely to happen in the range of vessel automation, digitalization of logistics, and also sustainable infrastructures.

	• IW-NET's innovations for optimizing waterway transport for urban areas and IT integration, that could serve WISTAR in urban logistics and real-time cargo tracking improvement.

Table 2: IW-NET concept

Emission-free autonomous towing system– Treideln

Duration:	1 May 2020- 30 april 2023
Partner Countries:	Germany
Project´s Targets:	The aim of this research topic is to prove a modern version of an old transport system, towing, taking into account modern drive and control technology. This is made possible by modern tractor systems, i.e. autonomously operating carriages or tractors on a guided-like rail system. The main advantage is the possibility of supplying these tractors with the necessary energy via the rail system. This is intended to make an important contribution to decarbonising.
Project description:	The autonomous towing framework is the focus of this particular project as it seeks to modernize freight transport along inland water bodies. This entails coming up with tractor systems that run on guided-like systems providing energy within the rail. The control and decision-making systems used in this project are highly advanced and logical respectively. Negative sides of towboat systems, hydrodynamic behavior, cornering and driving forces in constricted fairways are some of the key topics are investigated. CFD calculations and model tests are being carried out to test and validate the solutions that will lead to the creation of a reliable, efficient, climate-neutral system that brings together ship, shore infrastructure and towing technologies. Besides, an energy concept is being considered in order to temporarily detach from land power supply.
Web Page:	https://www.sva-potsdam.de/category/forschung/
Relevance for WISTAR:	moderate
Possibility for Interfaces:	• This project has a great likelihood of interfacing with Wistar in the field of autonomous navigation, energy independence, and modernizing waterways transportation systems.

	• Since both projects target decarbonisation and the deployment of automation, it is possible to work collaboratively which would also yield great benefits.

Table 3: Treideln concept

DigitalSOW – Digital test field for automated and autonomous operation on the Spree-Oder waterway
SVA: test vehicle for city logistics and autonomous driving– Treideln

DigitalSOW

Duration:	June 2021- December 2023
Partner Countries:	Germany
Project´s Targets:	The aim of the project is to show that autonomous inland shipping is possible and that autonomous vehicles make inland shipping economically viable, even with smaller units. The aim of the project is to provide a defined test field environment (sections of the Spree-Oder waterway (SOW)) for research into autonomous and networked watercraft, particularly with regard to a new type of city logistics based on autonomously operating and electrically powered watercraft.
Project description:	The DigitalSOW project is centered on developing an experimental environment for self-directed and mechanized vessels operating in inland waters. Two modular testing vehicles will be designed, built and delivered as platforms for further research into sensors, control systems and driving technologies crucial for automation. These vehicles which can operate as a pair or attach to other ships are meant to test logistic networks in cities while being eco-friendly and compatible with other similar projects. This area should serve as an adaptable research space aiming at promoting synergistic initiatives on autonomous shipping management especially within urban logistics.
Web Page:	https://www.sva-potsdam.de/category/forschung/ https://www.digitalsow.de/index.html.en
Relevance for WISTAR:	High

Possibility for Interfaces:	• The developement of sensor technology and logistics chain demonstrations for inland shipping. • The autonomous logistics systems and urban waterways are the common area for both propjects.

Table 4: DigitalSOW concept

Autonomous electric shipping on waterways in metropolitan regions– A-SWARM

Duration:	
Partner Countries:	Germany
Project´s Targets:	The aim of the project is to research and develop technologies that enable autonomous operation of electrically powered watercraft on inland waterways. The requirements concern both real-time trajectory planning in the very limited space of rivers, canals and locks and the most precise possible execution of this trajectory under influences such as currents, shallows, wind and oncoming traffic, which pose particular challenges on inland waterways.
Project description:	The project’s focus is on the technical requirements of autonomous electric watercraft in urban areas, emphasizing safe navigation without significant infrastructure investments. It investigates if these ships’ up-to-date sensors can provide precise environmental understanding and navigation or if external data must be included (e.g., traffic control information). Ultimately, two test vehicles will be built as a demonstrator to verify and showcase this technique both in laboratory and real-life conditions. Thus allowing to unload freight traffic from roads to waters, especially concerning “last mile” urban logistics, while being eco-friendly.
Web Page:	https://www.sva-potsdam.de/category/forschung/
Relevance for WISTAR:	Moderate

Possibility for Interfaces:	• The autonomous navigation and sensing system being developed in the project can be beneficial to the WISTAR project. • Also, optimization of urban freight transport solutions using electric vessels

Table 5: A-SWARM concept

3.1.1. Germany : agrifood sector and intermodal interfaces with IW in the Ruhr-area

Before the characterization of the agrifood sector and its intermodal interfaces with IW in the Ruhr-area is done, an introduction about important concepts on agri-food supply chain management will be shared.

The Agri-food supply chain management (AFSCM) is a multifaceted system that requires the coordination of numerous stakeholders, including farmers, processors, distributors, retailers, and consumers. The AFSCM encompasses various functional areas, such as production, harvest, storage, and distribution, each of which involves critical decision-making processes (Leng et at. 2018).

Production decisions in AFSCM involve factors like land allocation and planting timing, while harvest decisions revolve around crop collection timing and machinery choices. Storage decisions encompass determining storage and sales volumes and optimizing inventory placement within the supply chain. Lastly, distribution decisions pertain to selecting transportation modes and distribution routes. Additionally, AFSCM faces challenges related to free trade policies, globalization, and the demand for safe, hygienic, and high-quality food.

There are different definitions of Agri-food supply chain management given by different authors.

One definition associates the concept with the points of production and consumption of agricultural items. In this position, AFSCM is defined as the management of the relationship between agricultural production raw material supply, production, processing, and product logistics and distribution (Luo et al. 2018).
In general, an AFSCM consists of a series of activities from "farm to fork," including farming (i.e., food growth and production), processing/producing, testing, packing, transportation, storage, distribution, and marketing. These operating stages are supported by

administrative, financial, and technological services, and they manage five kinds of flows: (i) tangible substance and product flows, (ii) financial flows, (iii) information flows, (iv) process flows, and (v) energy and natural resource flows (Iakovou et al 2012).

The agri-food supply chain has many distinguishing characteristics that set it apart from other kinds of supply chains. Among these, the following stand out (Ondeersteijn et al. 2006):

- Because most products have a short life span, they are unique.
- Product diversity is high.
- Harvesting and production activities are seasonal.
- Quality and quantity variations in agricultural inputs and processing yields.
- Transportation, storage conditions, quality, and substance recycling requirements, National/international legislation, regulations, and directives concerning food safety and public health, as well as environmental problems, must be followed. (e.g., Carbon and water footprints).
- Specialized characteristics, such as traceability and visibility, are required.
- Despite lengthy production times, there is a need for high efficiency and productivity of expensive technical equipment.
- Increased operational complexity, as well as the presence of substantial capacity constraints.

There two main type of Agri-food supply chain management according to (van der Vorst et al. 2007):

- Agri-food chains that deal with fresh produced (such fruits and vegetables) products from farms. These chains' several steps all preserve the commodities' original properties. They stand out due to factors including their short product lifetimes, the need for quick shipping, and their low use of energy, all of which happen more so during the process of delivery than the storage phase.
- Agri-food chains for processed foods (such canned goods, portioned meat, snacks, and juices). Agribusiness supply chains employ agricultural outputs as raw materials to produce consumer commodities with higher added values. In turn, this extends the items' shelf lives, slows down transportation, and uses a lot of energy, especially during stocking.

Many experts argue that nowadays the predominant traditional linear food system is not sustainable in the long term and that a more circular approach is needed to ensure that food production and consumption are both environmentally and socially responsible. A circular food system is one that aims to minimize waste, reuse resources, and regenerate natural systems. This approach involves designing food production and consumption systems that are sustainable and that work in harmony with the natural environment (Rahul et al. 2021).

Food produced for human consumption is lost by one third every year. A trillion dollars' worth of goods are produced annually, which amounts to roughly 1.3 billion tons. The total amount of food waste produced in the world is the third largest contributor of carbon dioxide to the environment. Most of these losses take place post-harvest and during the processing process. Because of climate change, food waste, water depletion, inequality, healthy living, and biodiversity loss, today's food system has a significant social and environmental footprint. The linear nature of food production results in 5.7 trillion dollars' worth of costs because finite resources are used, they are polluted, and they harm natural systems (TraceX 2022).

Air, soil, and water pollution are all caused by Green House Gas (GHG) emissions from the agrifood industry. Several factors threaten food security, including pollution, pesticides, overuse of fertilizers, antibiotic use in animals, untreated human waste, and antimicrobial resistance. These externalities can be minimized by adopting circular economies (TraceX 2022) and at the same time food systems that are healthy and fit for everyone can be achieved.

Circular economy

A circular economy is an economic system that aims to minimize waste, reuse resources, and regenerate natural systems. In a circular economy, resources are kept in use for as long as possible, and waste is designed out of the system. This approach involves designing products and production systems that are sustainable and that work in harmony with the natural environment.

AFSC can benefit greatly from the principles of a circular economy. For example, waste generated during processing and packaging can be used for various purposes, such as animal feed, compost, or biofuel. The peel and pulp of fruits or vegetables e.g. can also be used to extract essential oils or pectin, which are valuable ingredients for the food and beverage industry. In addition, agrifood growers can implement sustainable agricultural practices, such as regenerative farming, to improve soil health and reduce the use of chemical fertilizers and pesticides.

By adopting a circular economy approach, small rural businesses can reduce waste, increase resource efficiency, and promote environmental sustainability. This approach can also provide new opportunities for value creation and innovation, such as the development of new products and services.

The four main potentials for a circular economy in the food industry are low-impact ingredients, diversified ingredients, repurposed ingredients, and regenerative ingredients. To 2030, a circular economy can increase economic benefit by up to $4.5 trillion by eliminating waste and using natural resources more efficiently (TraceX 2022). Fig. 3.1. describes a graphical representation of an example for circular economy system in the agrifood sector for the case of potatoes.

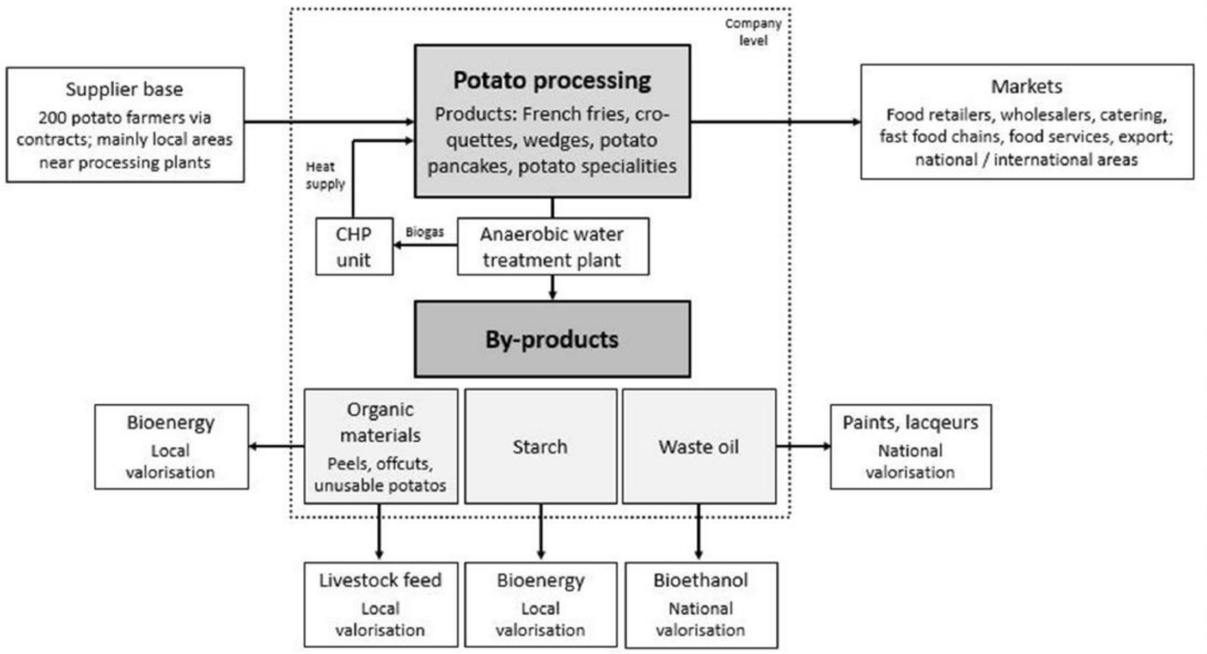

Fig. 3.1: Graphical representation of an example for circular economy system in the agrifood sector for potatoes

Further, food loss and waste recovery practices improve local economies while promoting sustainable food management.

Overall, the circular economy offers a promising framework for transforming AFSCM into a more sustainable and resilient system that benefits both industry and the environment. There are social, economic, and environmental problems affecting the present food and agriculture supply chain. By enhancing and optimizing production and consumption, the circular economy leads to the achievement of sustainability.

Collaborative logistics models in agri-food

The development of collaborative logistics models has enhanced efficiency across the supply chain. Notable examples include:

1. Shared warehousing facilities for multiple agri-food companies
2. Cooperative vessel chartering to optimise capacity utilisation
3. Joint last-mile delivery services in urban areas
4. Integrated information systems for better coordination among stakeholders

A study by Cruijssen et al. (2007) found that collaborative logistics models can lead to a 15% reduction in overall logistics costs and improved service levels for smaller producers.

Agri-food in the Ruhr-area

As one of Europe's most densely populated and industrialised regions, the Ruhr-Rhine area has a significant demand for agri-food products. According to Sys and Vanelslander (2021), the region's agri-food sector is characterised by a mix of local production and substantial import volumes, necessitating an efficient logistics network. The study highlights that the proximity to major seaports like Rotterdam and Antwerp is crucial in importing agri-food products distributed throughout the region via inland waterways.

Agri-food logistics in the Ruhr-Rhine area face unique challenges due to the perishable nature of many products. Wegmans and Konings (2017) emphasise the importance of temperature-controlled transport and storage facilities in maintaining the quality of fresh produce and dairy products. Their research indicates that the region has invested in specialised cold chain infrastructure along its inland waterways to meet these requirements.

The CCNR report (2019) provides insights into the region's utilisation of inland waterways for agri-food transport. It notes that bulk agricultural products such as grains and animal feed are among the most commonly transported goods on the Rhine and its tributaries. The report highlights that approximately 15% of all agri-food products in the region are transported via inland waterways, with growth potential.
Kuipers and Nijdam (2019) discuss the importance of multi-modal integration in agri-food logistics. Their study reveals that the Ruhr-Rhine area has developed sophisticated multi-modal hubs connecting inland waterways with road and rail networks. These hubs are crucial for efficient last-mile delivery of agri-food products to urban centers within the region.

Despite the advantages, the agri-food sector in the Ruhr-Rhine area faces several challenges in utilising inland waterways. Wiegmans and Konings (2017) point out that seasonal water level variations can affect transport reliability, particularly for time-sensitive agri-food products. However, they also note opportunities for improvement, such as developing more flexible vessel designs and better forecasting systems to mitigate these challenges.

The CCNR report (2019) suggests significant potential for increasing the share of agri-food products transported via inland waterways in the Ruhr-Rhine area. This growth is expected to be driven by increasing environmental concerns, advancements in logistics technology, and ongoing infrastructure improvements along the region's waterways.

The inland waterway (IW) agri-food logistics sector in the Ruhr-Rhine area involves diverse stakeholders, each playing a critical role in the supply chain. The primary stakeholders include:

1. Farmers and Producers: These stakeholders are essential as they supply the agri-food products that move through the logistics chain. Their efficiency and productivity directly impact the availability of goods for transport.
2. Logistics Companies: This group encompasses barge operators, freight forwarders, and multi-modal transport providers specialising in agri-food logistics. They are responsible for planning, executing, and managing the transport process.
3. Port Authorities manage inland ports and terminals, facilitating the transfer of goods between different modes of transport. Their role is crucial in ensuring smooth operations and efficient cargo handling.
4. Regulatory Bodies: National and EU-level agencies govern transport policies, environmental regulations, and food safety standards. Their regulations shape operational practices and compliance requirements for all stakeholders.
5. End Consumers: Although not directly involved in logistics operations, consumers' preferences and demands significantly influence production practices and logistics strategies.

Each stakeholder group has distinct interests and priorities that shape their involvement in IW agri-food logistics. According to Sys and Vanelslander (2021), farmers prioritise getting their products to market efficiently and cheaply. Logistics companies focus on maximising operational efficiency while meeting customer demands. Port authorities aim to increase throughput and attract business to their facilities, while regulatory bodies prioritise safety, environmental protection, and fair competition. End consumers demand fresh, high-quality products at reasonable prices.

However, various challenges affect these stakeholders. The CCNR report (2019) highlights infrastructure limitations during low water periods, regulatory complexities across jurisdictions, technological adaptation issues, and balancing economic interests with environmental sustainability. Despite these challenges, there is significant potential for collaboration among stakeholders. Kuipers and Nijdam (2019) emphasise that partnerships between logistics companies and port authorities can lead to more efficient multi-modal transport solutions.

To effectively manage stakeholder relationships, a Power-Interest Grid can be employed to visualise the influence and interest of various stakeholders in IW agri-food logistics. Based on Mendelow's Stakeholder Matrix (Mendelow, 1991), this analysis categorises stakeholders into four quadrants:

1. High Power, High Interest: Regulatory bodies and large logistics companies fall into this category as they significantly influence operations and are deeply invested in outcomes.
2. High Power, Low Interest: End consumers have power through purchasing decisions but typically have lower direct involvement in logistics operations.
3. Low Power, High Interest: Farmers and smaller logistics companies are keen on improving their conditions but often lack the power to effect change independently.
4. Low Power, Low Interest: The general public may have limited interest or influence over specific logistics operations but can impact broader public policy discussions.

In conclusion, effective stakeholder analysis reveals a complex interplay of interests within the IW agri-food logistics sector in the Ruhr-Rhine area. Collaborative efforts among these diverse stakeholders are vital for developing sustainable and efficient logistics solutions that meet economic goals and environmental standards.
Based on a comparative analysis, we can construct a SWOT analysis for the Ruhr-Rhine IW logistics system:

Strengths:

1. Extensive network of waterways
2. Strategic location in Europe's industrial heartland
3. The strong existing industrial base

Weaknesses:

1. Ageing infrastructure in some areas
2. Fragmented governance across different jurisdictions
3. Underutilisation of IW transport compared to road transport

Opportunities:

1. Growing emphasis on sustainable transport modes
2. Potential for increased multi-modal integration
3. Technological advancements in vessel design and logistics management

Threats:

1. Climate change impacts on water levels
2. Competition from improved road and rail networks
3. Regulatory challenges at the EU and national levels

This comparative analysis reveals that while the Ruhr-Rhine region has significant strengths in its IW logistics system, it can also learn from other regions, such as the extensive network and strategic location. The extensive network and strategic location provide a strong foundation, but issues such as infrastructure modernisation and multi-modal integration present opportunities for improvement. The Ruhr-Rhine region can enhance its position as a key player in European IW logistics by addressing these areas and capitalising on emerging opportunities.

In most cities, road transport is still the main method for delivery while inland navigation is usually meant for long hauls. However, research and pilot programs carried out in some European cities show that inland navigation can be a valid option for city freight movement. Including inland waterways into intermodal transport chains can improve economic efficiency whilst providing the following:

- Mitigation of increased road traffic,
- Reduction on harmful gas discharge from combustion engines,
- Minimization of risks related with hazardous or oversized cargoes,
- Improvement of the whole traffic flow system.

By including inland water routes in their plans, cities could meet growing demands of urban freight transport in much more sustainable and efficient ways.

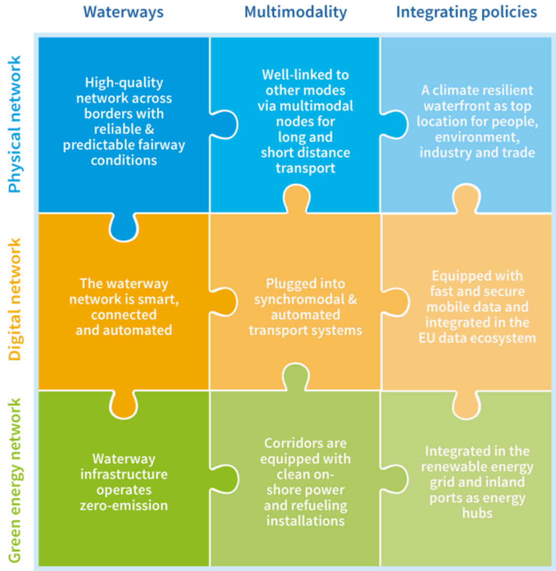

Fig 3.2: Fit for Future: Integrating Waterways, Multimodality, and Sustainable Policies for a Resilient and Digital Transport Network

In the image each square represents a different aspect of a future, sustainable waterway transport system. The grid is divided into three categories, Waterways, Multimodality, integrating policies, and these are further divided by the type of network: Physical network, Digital network, green energy network. Each square has a text describing the benefits of a multi-modal approach to maritime transport.

The Waterways column focuses on the physical network and describes a high-quality network across borders with reliable and predictable fairway conditions, a smart and automated waterway network, and waterway infrastructure that operates zero-emission.

The Multimodality column focuses on the digital network and describes a well-linked network to other modes via multimodal nodes for long and short distance transport, a network that is plugged into synchro modal & automated transport systems, and corridors that are equipped with clean onshore power and refueling installations.
The Integrating Policies column focuses on the green energy network and describes a climate resilient waterfront as a top location for people, environment, industry and trade, a network equipped with fast and secure mobile data and integrated in the EU data ecosystem, and an integrated renewable energy grid and inland ports as energy hubs.

3.1.2. France: IWT use for last mile delivery on river Seine Axis

Urban logistics is an essential pillar for the functioning of our cities. Faced with the effects of climate change, this sector is at the heart of environmental preservation issues. Support the ecological transition of goods transport in the city, through the development and signing of a partnership charter for sustainable urban logistics.

Within the global supply chain, urban logistics is the last link that finalizes the delivery of goods to their recipients in the city. It refers to all operations aimed at organizing, planning and managing the movement of these goods in urban areas. Different parties are involved in this process, such as carriers, institutional or private sector actors (commercial, industrial or tertiary activities). Citizens, who benefit from logistics activities, are also involved. They can indeed be impacted by these activities (noise pollution linked to transport, air quality, etc.).

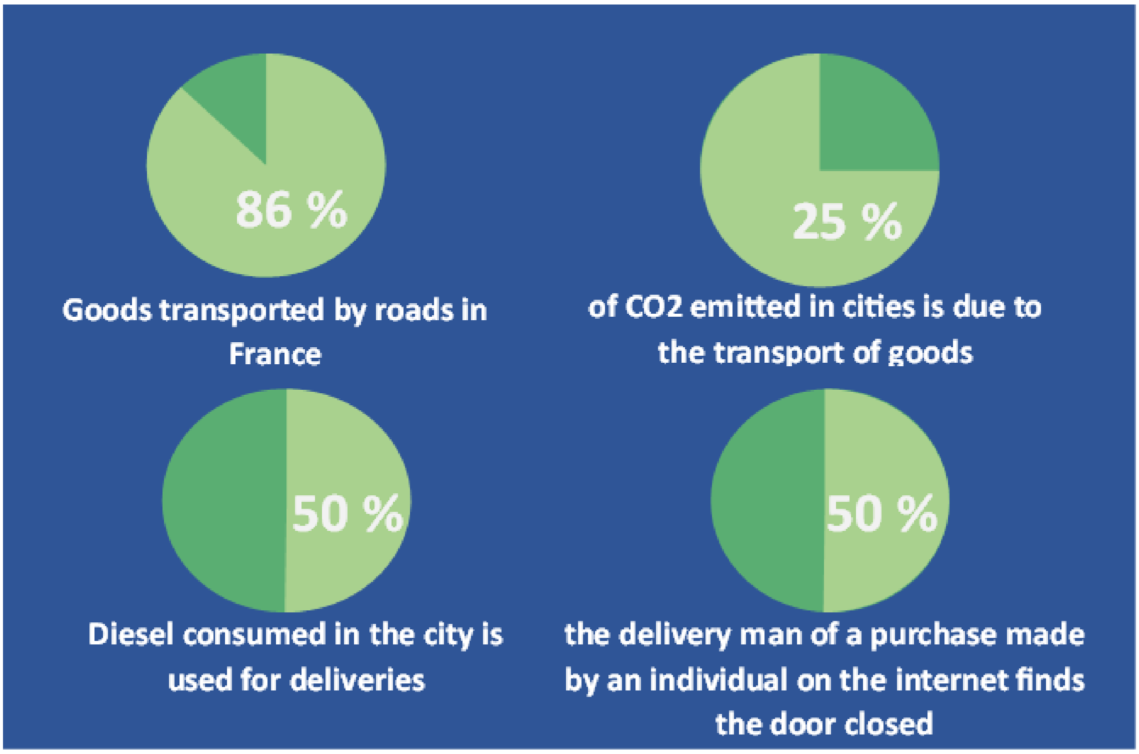

Fig 3.3: Ecological impact of freight transport on cities

In France, transport generates most greenhouse gas emissions, particularly road transport of goods in urban areas. However, its challenges are fundamental for the ecological transition, whether it is to contribute to improving the quality of life in the city or to promoting more eco-responsible consumption patterns. It is therefore essential to adopt a sustainable urban logistics approach, which goes beyond the simple reorganization of the sector.

Urban freight transport is a major source of air pollutant emissions **(40% of NOx emissions and 50% of fine particles)** and up to **20% of greenhouse gas emissions**. Urban logistics also raises social issues (working conditions of delivery drivers, road safety and sharing of roads, congestion, noise pollution) and urban planning issues (land use and use of space).

The transport of goods represents flows that are estimated at **between 15% and 20% 1 of the vehicle kilometers of a city**. They are divided between flows linked to household purchases, to the management of the city (construction sites, public services, hospitals), to economic activities in all sectors combined.

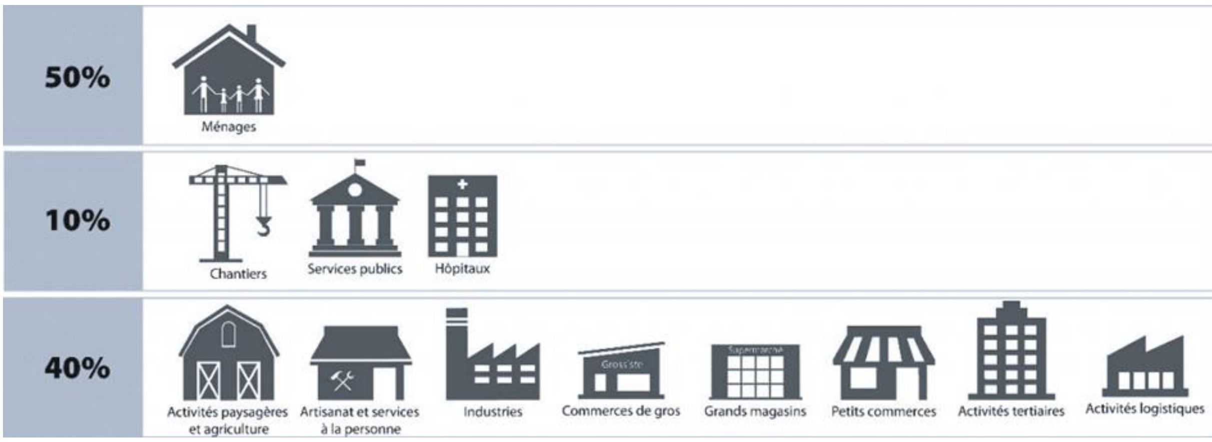

Figure 3.4: Flows (in vehicle-km UVP) of goods transport in the city

Limiting the carbon footprint and relieving congestion in the city: the Parisian urban logistics strategy

Consumption patterns are changing as technologies progress, and urban logistics are following the trend. Due to significantly boosted e-commerce and home deliveries, parking and delivery spaces are under increasing pressure, and traffic is congested, while public authorities are redoubling their efforts to limit urban flows, sources of air pollution.

In order to initiate changes and respond to these developments, a new urban logistics strategy 2022-2026 has been adopted by the City of Paris. This strategy was developed in partnership with private and public stakeholders who work in the field of freight transport on a daily basis. Here are the outlines.

The commitments of the City of Paris

The Parisian administration, through its public procurement, is a major player in urban logistics. Structuring an internal logistics chain, reducing the carbon footprint and implementing responsible public procurement are all essential levers for the transformation of Parisian urban logistics.

- Promoting local purchases in public procurement
- Implement blind spot prevention devices on heavy goods vehicles
- Reduction in road traffic caused by construction sites commissioned by the City of Paris
- Transition of the City of Paris fleet to a fleet of electric and hydrogen vehicles, which emit less greenhouse gases
- Reduce road traffic on its construction sites
- Decarbonize your vehicle fleet by favoring electric and hydrogen.

Parisian urban logistics in figures

- 500,000 parcels delivered every day in Paris.
- 4.4 million deliveries/collections every week in Île-de-France.
- 51% of operations in Île-de-France are carried out by carriers, the remaining 49% on own account.
- 9,000 Parisian delivery places.
- ¼ of goods movements in Île-de-France take place in Paris, which only hosts around 1% of real estate areas dedicated to logistics.
- 30% of tonnages of materials and construction waste are transported by river.
- 25% of CO_2 emissions come from the transport of goods in Paris.
- River freight means 60% fewer greenhouse gas emissions compared to road transport. If river transport is coupled with rail, this can reach up to 90%.

The Seine is attracting more and more economic players. The potential is enormous: it is estimated that the river could accommodate up to 4 times more goods traffic than currently. River freight also has ecological virtues: it consumes 5 times less fuel than road transport and emits 2.5 times less CO_2 per tons transported.

Urban river logistics is part of a more sustainable logistics, yet it is still struggling to find its place in the entire logistics system serving metropolises and agglomerations. In in addition to relevant public actors such as Voies navigables de France and the port authorities, local authorities have a major role to play in promoting the modal shift from road to inland waterway transport.

Fig 3.5: The Swedish company Ikea uses the Fludis transport services to connect its depot situated at the Port of Gennevilliers, and the Paris centre where it has many customers.

The Ikea company delivers its Parisian customers to their homes by boat and electric vehicles. An innovation supported by the City of Paris, which has adopted an urban logistics strategy and encourages the waterway. With multiple objectives: relieve congestion in the city center, limit the carbon footprint, promote local trade and simplify the consumer's life.

Ikea's Parisian customers are delivered via the Seine: prepared at the distribution center in the port of Gennevilliers (Hauts-de-Seine), orders are transported in containers by boat to the port of Bercy (12th) and are then loaded onto electric vehicles to cover the "last mile" to their recipients.

This mode of transport, supported by the City of Paris and Haropa Port de Paris, should reduce the environmental impact of home deliveries. Transport by river between Gennevilliers and Paris should save the approximately 300,000 kilometers traveled each year by trucks.

The Swedish company will open a new distribution centre on the Seine in 2026, at the port of Limay in Yvelines.

Currently, 85% of cargoes arriving in Le Havre by sea are transported by road towards Rouen and Paris. With new environmental challenges, inland waterway transport appears as an alternative for urban transportation and last mile delivery. Inland navigation is perceived as economically advantageous, with the massification of goods; a typical barge navigating on the Seine can transport 5000 tons of cargoes, replacing 250 trucks. Moreover, inland waterway transport emits 2,5 less tons of CO_2 than road transport by ton transported. **(1)**

To pursue the decarbonation of IWT, new infrastructure projects need to be implemented in order to welcome alternative fuel barges.

The Fludis project (2) : Fludis is a company specialised in last-mile urban delivery. (or Fludis is a cyclo-logistics company specializes in last-mile urban freight delivery for professional clients and home customers is aiming to make the Seine and its canals a major axis for urban distribution, particularly for small parcels and pallets. Fludis offer low-carbon urban logistics solutions, which include both original land solutions on uncongested routes, mainly waterways, and last-mile deliveries using cargo bikes.)

The company has introduced a new innovation in this sector: an electric boat and a fleet of cargo bikes, used to deliver office supplies mainly in Paris.

From Monday to Friday, the ship makes each day two stopovers: at “le port du Gros Caillou” (7th arrondissement), near the Alexandre III bridge and at Solférino port in the 7th arrondissement as well.

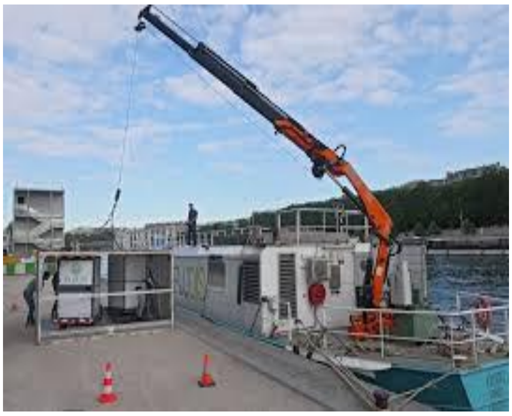

Fig 3.6: The boat delivers to its professional customers from Monday to Friday

Once the electric ship is docked, the electric cargo bikes take over, and deliver up to 1500 cargoes each day. One bike can transport between 180 and 250 kilos for each voyage, and one person can deliver up to1 ton of cargoes per day. In the western centre of Paris, deliveries are made with electric bikes and ship, while they are made only with cargo bikes in other sectors.

The warehouses located 15 km from Paris. Crossing Paris by boat from the Quai d'Austerlitz takes only 30 minutes and avoids numerous truck trips in the capital.

The ship also serves as a logistics space. The goods are sorted by district on the two lower levels of the ship. Each delivery person can fill his bike there during the crossing with the packages that will then be delivered in the center of the capital.

Fig 3.7: The boat is used by delivery people to prepare their orders.

The ship's batteries are recharged at night, at the Austerlitz quay, equipped of adapter charging infrastructures. From there, it takes only 30 minutes for the barge to cross Paris, compared to a truck which will be taking much more time due to road congestion in the capital.

Fig 3.8: The ship is electrically powered and recharges at night, at the quayside.

The mains clients of the Fludis agency are Ikea France, Lyreco France, Paprec D3E, Relais Colis and Colissimo (part of the La Poste group).

- joint partnership construction with the client LYRECO France (office supplies of the "small parcel" type, unbundling, tour preparation, delivery and return to the end customer); Lyreco delivers its parcels to its B2B customers
- co-construction partnership with the client PAPREC D3E (small recyclable waste; collection of groupage containers at the client).

Fig 3.9: Fludis cargo bike leaves for B2B delivery / Last-mile delivery parcels with Relais Colis

The bikes dedicated for last mile delivery parcels with Relais Colis are equipped with a two-m³ trunk that can hold 80 parcels.

As a carbon-free solution, Fludis intends to take up the ecological challenge, in parallel with the expansion of urban areas with low pollutant emissions. In addition, delivering parcels by bike reduces noise pollution and improves social relations at relay points.

Fig 3.10: On the Saint-Denis canal, Fludis has installed a barge that serves as a floating warehouse for La Poste Colissimo packages. Once sorted, they delivered by cargo bike across the city.

An innovative service consists of using a barge designed as a floating warehouse with electrical propulsion, mooring it at the Port Croizat, on the Saint-Denis canal, then delivery to Seine-Saint-Denis and Ile-Saint-Denis. This practice shown that it was supplied once a day by a Colissimo heavy goods vehicle coming directly from the Thillay platform (Val-d'Oise), which sorts on average more than 350,000 packages per 24 hours for five departments as well as the northern part of Paris. After some reorganisation, the service will restart the delivery, on average 2,000 parcels per day and will be carried out using Cyclofret-type cargo bikes.

The Seine Axis agreement (3): this project is an intercommunal initiative[8], aiming at mutualising the different expertise, engineering and knowledge of the territory to build a strategy to deploy a cleaner transport for urban deliveries.

A call for expressions of interest had been launched by the members of the agreement in April 2022, aiming at promoting inland navigation as an alternative to road transport, as well as supporting innovative solutions for decarbonised last mile delivery. Some winners

will be personally accompanied by the members of the agreement and call for proposals have been launched for other sites.
Concerning the promotion of renewable energies, members of the agreement have created a dedicated semi-public company, the SEM Seine Axis Renewable Energy (SEMASER), with the Territorial Bank and the association Energie Partagée. Its objective is to support the development of massive production of renewable energies. It will intervene in the development, the management, the storage and the delivery of renewable energies, as well as enabling the funding of projects of which the complexity and the profitability rate is an obstacle to their development by private actors.

Urban Logistic Solutions (4) : the company has won the two calls for proposals launched by HAROPA, Paris City, Rouen Normandy Metropole, Le Havre Seine Metropole and the "Grand Paris" Metropole. Urban Logistic Solutions is a start-up created in 2019, deploying its innovative solutions for unban waterway logistic in Strasbourg and Lyon for now.

The objective of the company is to massify cargo flows towards city centres thanks to inland waterway transport and cargo bikes used for last mile delivery. With the implementation of low emission zone in city centres, forbidding trucks of more than 3.5 tons of circulating, new solutions need to be found for last mile delivery, by prioritising inland navigation and electric bikes.

Urban Logistic Solution will participate to the implementation of two projects, one in Paris and one in Rouen. In Paris, a supply base will be installed at Charenton, from which barges will leave to dessert two ports in Paris: Javel Bas port (15th arrondissement) and Gros Caillou port (7th arrondissement), with last mile delivery by cargo bikes.

The same principle will be applied to Rouen: a supply base will be installed upstream of the city to the dessert the city centre, at Guillaume le Conquérant port, and the last mile delivery will be done with cargo bikes.

In total, the company has delivered 10 000 parcels for the Geodis group (drinks, flour…). On their way back, cargo bikes transport waste, in order to optimise their movements.

Distri-Seine: Distri-Seine is a project of urban distribution implemented in 2015 by HAROPA and its partner Waterway Transport Company (CFT). After observing road congestion in Paris, both partners decided to use a barge to reach the centre of Paris by the Seine, avoiding the traffic, and then deploying a fleet of electric trucks to take care of last mile delivery. The ship is hybrid, equipped of batteries to reduce the pollution in the river.

3.1.3. Belgium: benchmark of logistics schemes involving IWT in supply chains taking place between rural and urban areas

The analysis of existing logistics schemes in Belgium involving inland waterway transport in supply chains taking place between rural and urban areas resulted in the identification of use cases in 3 categories: food, waste and construction.

Food

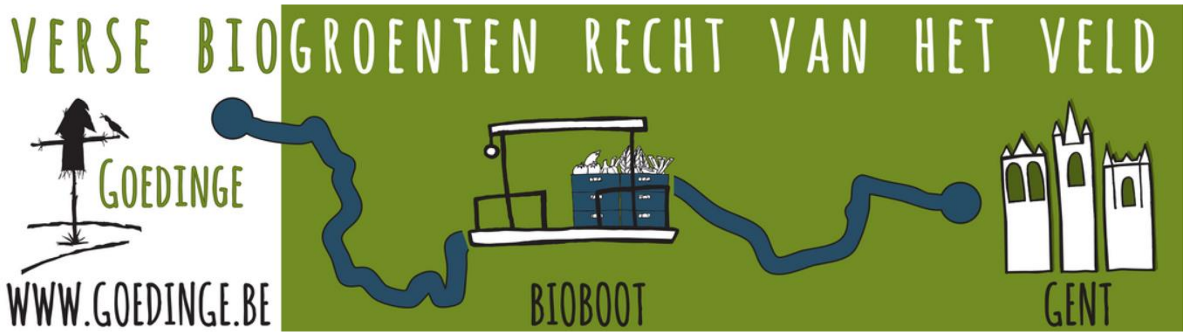

Fig 3.11: Goedinge

Goedinge is an organic farm from Afsnee (approximately 8 km from Ghent), close to the banks of river Leie. Its farmers started to operate a small electric ship, the Bioboat (Bioboot) **(5)**, as an alternative to use a van to deliver both citizens and restaurants in Ghent. The ship was built in partnership with Vlot Gent. **(6)** The project received a subsidy in 2020, and the service is still in operation. The ship is a catamaran in aluminum, has a load capacity of 1,5 tons and is equipped with solar panels on the roof. Its dimensions are 6m x 2,7m and it can sail up to 8 km/h.

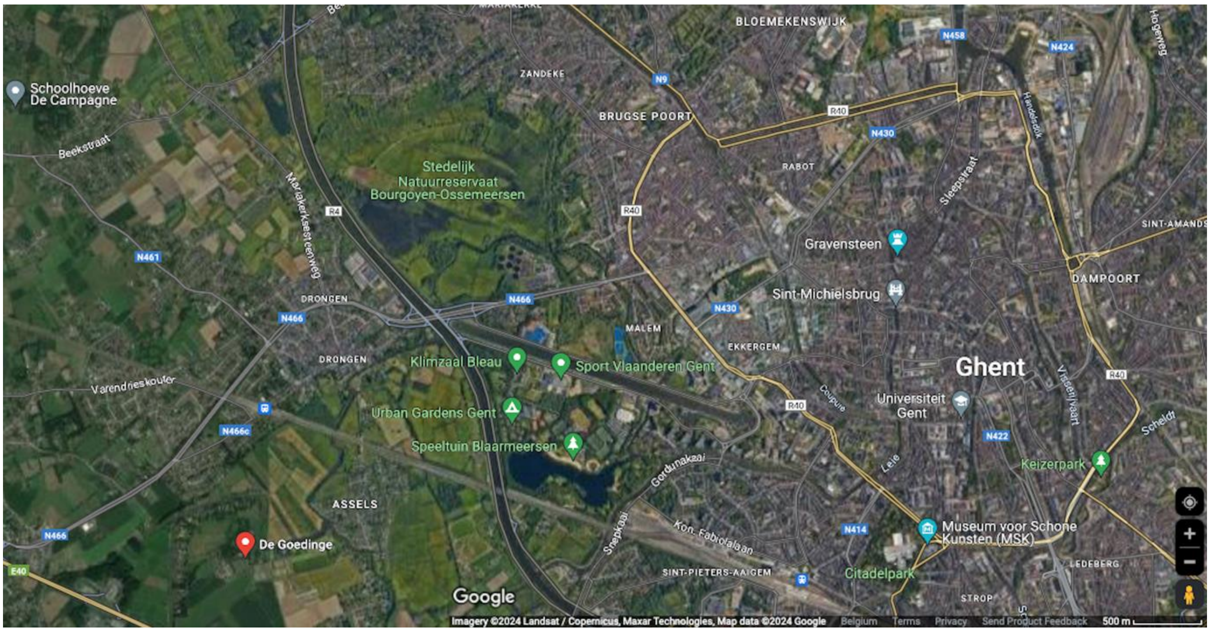

Fig 3.12: Ghent map

Fig 3.13: Stad Gent

Fig 3.14: Bioboerderij Goedinge (FB)

The project operates on a community-supported agriculture (CSA) model, where consumers subscribe for a full season by purchasing an annual share of the harvest. Fresh vegetables are harvested daily and available for weekly collection by consumers from designated vegetable boxes. These boxes can be picked up either at the farm itself or at various pick-up points. For those living in central Ghent, the Bioboat delivers the vegetables directly to the city center. Subscribers are offered three different vegetable packages, differing in the variety and quantity of vegetables. The program also encourages active participation from its members, offering opportunities to engage directly with the farm. Members can participate in harvesting activities or assist on designated work days, particularly during the potato and onion harvest, where they receive a portion of the yield. Any excess produce is distributed as additional portions to members. The season of the packages runs approximately 40 weeks from early April until the Christmas period, followed by a winter break of about 12 weeks, which may vary based on weather conditions.

Subscription fees

- Small (5 vegetable portions): €496/year
- Medium (5 large vegetable portions): €750/year
- Large (7 vegetable portions): €981/year

Fig 3.15: Smartship-eu (7)

Fig 3.16: Bioboerderij Goedinge (FB) (8)

Vegetables can be picked up at the berth, or last mile delivery to the customers is made with electric bicycles that can carry 300 kilograms and are charged by solar panels on the farmers' field. The boat sails once a week with the vegetables. **(9) (10)**

Fig 3.17: PZC, Jill Dhondt (11)

Waste

IOK is the intercommunal association for 29 member municipalities located at the west of the Antwerp Province and that includes 15 rural municipalities, 13 urbanised municipalities and 1 city centre. **(12)**

Fig 3.18: Scope of IOK Waste Management

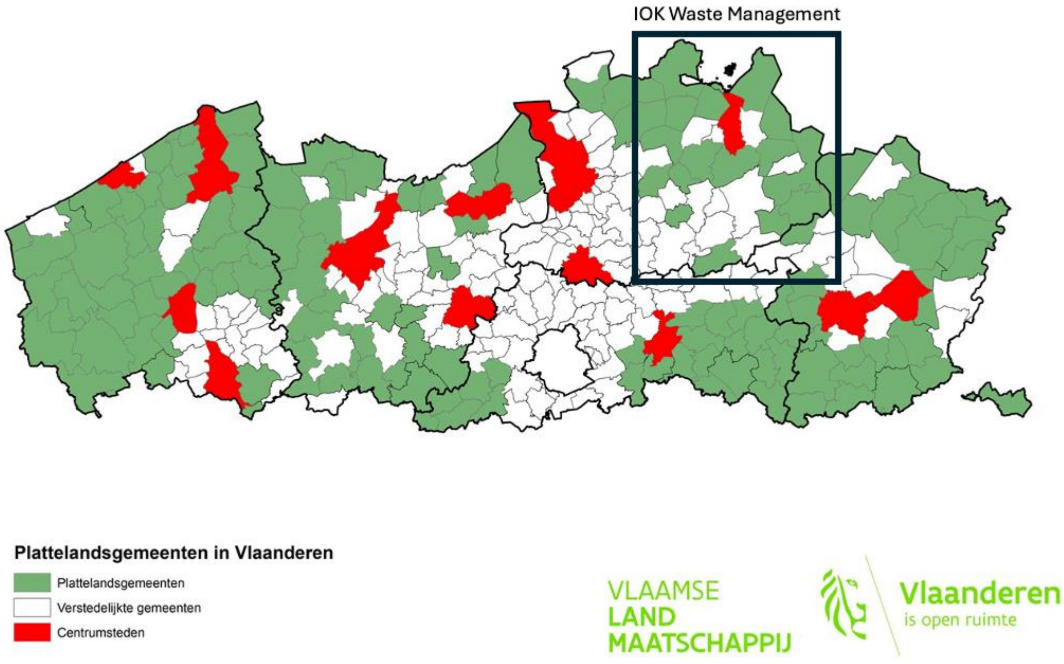

Fig 3.19: Identification of rural areas (green colour) in Flanders

The association is responsible for activities such as industrial land policy, social land policy and a whole range of support services in the context of extended local government. IOK Waste Management provides integrated waste management for a population of more than half a million. The focus has been on waste prevention and sustainable materials management for more than 25 years. This waste policy, with a thorough selective collection and much attention to communication, is bearing fruit. The municipalities have the lowest residual waste figures and the highest recycling rates in Flanders.

IOK Waste Management is a pioneer in selective collection, starting in 1990 with the separate collection of organic waste, very quickly followed by paper and packaging waste. Through the efforts of volunteer compost masters, the percentage of home composters is also high in the region, some 40% of households compost their vegetable, fruit and garden waste themselves.

After inhabitants deposit their waste at their door or take it to the recycling park, a complex logistics process follows to get it to the processors. The trend of circularity leads to the emergence of new processors as more and more waste is given a second life. IOK handles currently 30 partial waste streams. This complexity has led IOK to look at possibilities to achieve logistics optimisation in the sector.

The two most bulky waste streams go to IOK in-house sites. Organic waste, including GFT (Groente-, fruit- en tuinafval: vegetable, fruit and garden waste), is collected in Beerse (MBM) and Mol, while residual waste ends up in the Mechanical Biological Separation Plant (MBS) in Geel. The in-house composting plant with pre-fermentation produces compost and green natural gas.

Fig 3.20: Location of the IOK plants along the inland waterways

Because the IOK sites connect to waterways, the option of inland navigation for transport of waste to the processing sites was investigated to make logistics more efficient and reduce the ecological footprint.

Fig 3.21: Geel's Mechanical Biological Separation (MBS) Plant

Geel's site is connected to the Albert Canal **(13)**, Mol's site is connected to the Dessel-Kwaadmechelen Canal, and Beerse's site is connected to the Dessel–Turnhout–Schoten Canal. While large ships can sail on the Albert Canal (CEMT VIb) and the Dessel-Kwaadmechelen Canal (CEMT Va), the Dessel–Turnhout–Schoten Canal is limited to CEMT II (400-650 tonnes). Due to the narrowness of the Dessel-Turnhout-Schoten Canal, widenings and switch points have been constructed to facilitate shipping. These designated areas allow one ship to pause and wait for another to pass. The canal's speed limit is capped at 7 km/h to prevent excessive wave action, particularly as the water level is just about ten centimeters below the dike's crest at certain points, where strong waves could cause significant damage.

IOK Waste Management transports 60% of organic and residual waste by water. Only the transport of waste from the municipalities surrounding the processing sites is still by road. IOK manages to transport higher tonnages by water year after year. Adding up all the routes in the different directions, it accumulates to several thousand tonnes since 2016. Since the addition of the water transport of GFT waste from Mol to Beerse in 2019, the volumes peaked. In 2022, residual waste was transported to Geel in 651 containers via inland waterways and 478 containers of GFT to Beerse in 52 trips. Overall result was 45.000 tonnes in 2022, which amounts to around 6.000 avoided truck trips on public roads. In 2023, residual waste was transported in 507 containers to Geel via inland waterway and 449 containers GFT to Beerse.

Fig 3.22: Blue Line Logistics (14)

The inland waterway operator is Blue Line Logistics, a subsidiary of Sogestran, which use the Zulu02 (diesel engine, with a size of 50m by 6,6m and a capacity of 300 tonnes) to load 13 containers. Larger ships can load more containers, but these do not fit in the narrower Dessel- Turnhout-Schoten Canal.

The logistics scheme uses two types of containers, both having a capacity of 27m3 (approx. 10 tonnes): 48 compactors where waste is pressed in from the front, and 86 containers with a hydraulic roof.

The choice of transhipment method is crucial as the cost affects profitability. Loading and unloading via reach stacker is common but expensive. The height of the quay enables to take full advantage of the Zulu by loading and unloading using a container hook truck.

Fig 3.23: Transportmedia (15)

Creation of quay infrastructure was a significant investment but can also be used by others. The quays were built thanks to a public-private partnership (PPP), in which IOK funded 20% and Vlaamse Waterweg for the remaining 80%.

The operations take place between 3 locations:

- MBS – Mechanische Biologische Scheidingsinstallatie – Eindhoutseheide 29, 2440 Geel
- MBO – Milieubedrijf Beerse Oost – Steenbakkersdam 42, 2340 Beerse
- MMO - Milieubedrijf Mol -Voortbeemden 10, 2440 Mol

The logistics scheme is the following:

- Trip 1: ship with 13 compacter containers with pressed residual waste from MBO (Beerse) to Mechanical Biological Separation Plant MBS (Geel) (trip time: 8 hours).
- Unloading of containers for processing at plant.
- Loading of (different) empty containers.
- Trip 2: 13 empty hydraulic roof containers on ship for trip from MBS (Geel) to MMO (Mol).
- Unloading 13 empty hydraulic roof containers in Mol and loading them with organic waste, including GFT, and loading them back onto the ship.
- Trip 3: ship with 13 containers with organic waste from MMO (Mol) to composting plant at MBO (Beerse).
- Unloading containers with organic waste and loading containers with residual waste at MBO (Beerse).
- Additional roundtrip required to transport empty compactor containers from MBS (Geel) to MBO (Beerse) and empty hydraulic roof containers back from MBO (Beerse) to MMO (Mol).

Three reasons motivated IOK to switch to inland shipping:
1. Innovation in ship design: The advent of new ships with a flat loading floor means to easily tranship containers with hook trucks, eliminating the need for expensive cranes.
2. Financial incentives: There is a discount on the Flemish environmental tax for residual waste, making water transport more attractive.
3. Economic and time considerations: Road transport is becoming more and more expensive, and congestion levels keep on increasing.

A second focus of IOK was on the transportation of Solid Recovered Fuel - or SRF, a substitute fuel produced from household residual waste at the IOK Mechanical-Biological Separation Plant (MBS) in Geel. Every year, some 35.000 tonnes of SRF goes to paper manufacturer Stora Enso in Langerbrugge (Ghent) where the material is processed and converted into electricity and steam.

Stora Enso is perfectly accessible via the Ghent-Terneuzen Canal and the Ring Canal. Hence, together with the team from Multimodaal.Vlaanderen and De Vlaamse Waterweg, IOK has worked on a research project to determine the feasibility of inland shipping for those routes. The biggest stumbling block in the business case was that it is only interesting if there is also a return cargo. In June 2023, IOK Waste Management and IVAREM launched a test run of SRF to Stora Enso on the route between Geel and Langerbrugge (Ghent). The following picture illustrates the loading of a barge (Shipit's Maasdam) with SRF compressed in bales at the quay of IOK Waste Management in Geel.

Fig 3.24: Flows

This modal shift came about through a strong collaboration between IOK Afvalbeheer/IVAREM, Stora Enso Langerbrugge, Multimodaal.Vlaanderen, De Vlaamse Waterweg and Shipit Multimodal Logistics and was facilitated by OVAM's increase in the environmental tax rebate.

Per shipment, 1.600 bales representing about 1.350 tonnes can be loaded. The ambition is to ship 35.000 tonnes of baled waste annually to Stora Enso's CHP (combined heat and power) plant which would avoid some 2.000 truck trips annually on the congestion-sensitive Geel-Antwerp-Ghent route and reduce CO2 emissions by 58%. **(16)**

Construction

The inland waterway transport of paletised construction materials take place in different logistics schemes throughout Wallonia, the Brussels Capital Region and Flanders. The Interreg NWE project ST4W highlighted two important use cases taking place between Walloon rural areas and the Brussels Capital Region. **(17)**

The first one concerns Blue Line Logistics that loads pallets from Roosens Bétons located in Seneffe and transports these towards the north using the Canal du Centre and the Brussels-Charleroi Canal. ST4W enabled to test a tool that tracks the logistics status along a multi-stop journey including Gobert Matériaux (Tubize and Anderlecht) and MPRO (Anderlecht). The Zulu can transport about 220 pallets.

Fig 3.25: Blue Line Logistics Interreg ST4W

The second one concerns Shipit that loads pallets (plaster bags) from Knauf located in Engis and transports these via the Albert Canal to the Brussels Construction Consolidation Centre (BCCC) from where the pallets are transported in smaller quantities by truck to construction sites in the Brussels area. Every trip allows for the transport of about 1.200 pallets, saving about 50 trucks.

Fig 3.26: Shipit Interreg ST4W

3.2. Specific approach: Market assessment per region

3.2.1. Germany: Concepts for green urban logistics (agrifood products)

Germany had won valuable experiences with the prove of concept of micro depots on urban areas. Due to the growing interest in greener mobility and logistics, micro depots have recently become a key solution to urban logistics challenges in the last-mile delivery of goods. These are small-scale and local distribution centers that enable the switching of goods from large freight vehicles to greener, smaller ones, such as cargo bikes or electric vans. The immediate benefit of the micro depot is a reduction in congestion and emission, raising the efficiency of deliveries in highly populated urban centers. As city growth continues, adding to the growth of e-commerce, the pressure on last-mile logistics has intensified. Traditional models of delivery are highly inefficient and a burden to both the environment and logistics, with large trucks making their way through narrow, congested streets. The micro depot concept, set conveniently in or around the middle of city centers, decentralizes delivery sustainably through an extension of operational efficiency, contributing to an overall low carbon footprint.

Case Studies on Micro Depots

UPS Micro Depot Project in Hamburg (2012)

UPS initiated a micro depot pilot project in Hamburg, Germany, way back in 2012. The central idea of the initiative was to reduce growing urban congestion and emissions. A centrally located micro depot was used as a transshipment hub where products were supplied through larger vehicles and further distributed using cargo bikes. The cargo E-bikes pass through narrow city streets, avoiding traffic and, therefore, ensuring faster delivery times during peak hours. This project was a very interesting use case, even for large urban areas, showing how micro depots could streamline logistics by completing deliveries using smaller, non-motorized vehicles. A related significant positive outcome of the project was the reduction in fuel consumption and, consequently, in CO2 emissions-a result well aligned with broader environmental objectives set by Hamburg. Moreover, the result of this project has encouraged UPS to execute the same strategies in other European cities.

"Green Logistics" mit GLS und DPD in Nürnberg (2016)

The "Green Logistics" project realized in Nürnberg in 2016 involved two logistic companies: GLS and DPD. Unlike the UPS project described above, which focused on the logistics of one company, it assumed a shared micro depot model in which both companies would share one hub. Goods consolidated at the micro depot are then distributed to customers through electric vehicles and cargo bikes. It was a rather unique project because of its collaborative nature, showing how many companies can work together to cut down their operational costs and environmental impacts. Sharing resources made the system more efficient, and fewer vehicles were needed to bring goods into the city center. The micro depot in Nürnberg also showed how cities can optimize their own existing infrastructure-for example, void lots or underutilized former warehouses-to service sustainable logistics. This shared infrastructure model also illustrates scalability possibilities for other cities facing similar challenges.

KoMoDo Project, Berlin, 2018:

Probably one of the most interesting current examples is the KoMoDo (Kooperative Nutzung von Mikro-Depots) project launched in Berlin in 2018, which in English translates to Cooperative use of micro-depots. While these earlier attempts were, in essence, one- or two-man shows, KoMoDo brought together five large freight companies-DHL, DPD, GLS, Hermes, and UPS-under one micro depot system. The micro depot in Berlin Centre allowed these companies to stock and sort merchandise for delivery by cargo bikes. With such a joint effort from KoMoDo, the inner city of Berlin saw a drastic reduction in delivery trucks, thereby keeping congestion and emission levels at their lowest. This project had very strong support from local authorities and was seen as integral to the urban sustainability plan of Berlin. Again, the clear environmental benefits and some of the challenges, such as coordination issues between the companies regarding shared space and resources, needed to be carefully planned and continuously revised so that such activities were satisfactorily completed without denting their operational efficiency.

Application of Micro Depot Strategies to the WISTAR Project

The key conclusions of these above micro depot projects would be useful in the WISTAR project, considering that the latter focused on inland waterways and developing a green supply chain in the Ruhr area. By including micro depots within this inland waterway network, the WISTAR project will be able to realize a multimodal logistics system in practice by making use of waterways in combination with urban, sustainable delivery methods. That is, the goods can be transported by inland waterways to transshipment points, or micro depots, from which they are distributed using low-emission vehicles, such as electric vans or cargo bikes.

The model of UPS in Hamburg gives a small glimpse into how WISTAR might make use of micro depots in a range of central locations close to the waterways to make an optimization of last-mile delivery. By placing micro depots near nodal points related to waterway transport, WISTAR will be able to shorten the distance cargo bikes or electric vehicles would have to travel. Also, the sharing model used in the "Green Logistics" project may be replicated for Nürnberg to encourage WISTAR to work with different logistic carriers that can share infrastructures and save on costs. Finally, the fact that the KoMoDo project was a collaborative affair between several different companies further reinforces the idea that co-operation is an ideal way to expend resources more efficiently while having further benefit to the environment.

Implementation Strategies for WISTAR

Various strategic approaches might be contemplated in the full realization of the potential of micro depots within the WISTAR initiative.

Intermodal transport integration: Inland waterways are, by themselves, an environmentally friendly mode of transport. By building micro-depots along the riverbanks or canals, cargo could be seamlessly transferred from huge vessels into smaller delivery vehicles for last-mile distribution. Aside from this, it gets rid of the dependency on large trucks and will lower the carbon footprint in both long-haul transportation and last-mile delivery.

Public-Private Partnerships: The key advantages for WISTAR would be to spark partnerships of logistics companies with local governments and environmental agencies, possibly leading to a mutual investment in the micro depot infrastructure-as witnessed in the KoMoDo project-minimizing the financial burden on companies but ensuring maximum environmental impact.

Dynamic Depot Location: Instead of relying on just fixed micro depot locations, WISTAR can try using mobile depots. These can be deployed based on real-time data about traffic congestion, weather conditions, and delivery demand. This flexibility would grant the project the capability to adapt to variable urban dynamics and optimize efficiency.

Technology and Automation: For WISTAR, intelligent technologies in logistics would be employed to trace goods, followed by optimizing delivery routes and counting environmental impact. The automation of sorting and consolidation at micro-depots would further reduce the time and labor required to process shipments.

Incentives for Green Transport: WISTAR could work with local governments to provide incentives for logistics companies to shift toward cargo bikes and electric vehicles for last-mile deliveries. The incentives could include access to priority lanes, reduced taxation for green methods of delivery.

Provided that the micro depot concept could follow these strategies and adapt to the success of previously implemented projects, WISTAR will be able to develop a truly innovative and sustainable logistics network using inland waterways for long-distance transportation and making the last-mile delivery efficient and eco-friendly. This would ensure a reduction in the environmental impact of logistics within the Ruhr area, besides being among the pioneers in this direction of supply chain management.

3.2.2. France: Green urban logistics for last mile deliveries (scallops, CAEN),

Call for proposals: the city of Caen is searching for actors offering innovative solutions for last mile delivery.(**18**) As a new regulation making the city centre a low emission zone by 2025 will be established, Caen needs to find projects promoting alternative transport modes for last mile transport.

Toutenvelo (19) : it is an initiative started in 2017, aiming at assuring the last mile delivery using cargo bikes. Toutenvelo is collaborating with national and international actors in the logistic sector, with daily parcel delivery rounds. In 2023, the company has delivered 41 000 parcels.

Toutenvelo provides several services: waste collection, food delivery, parcel delivery and cargo storage. Their aim is to participate to the decarbonation of the logistics sector, by assuring delivering in city centres.

The organisation is present in more than 10 cities, and those independent structures are ensuring the coordination and the development of the network, as well as the production of cargo bikes. Indeed, Toutenvelo builds its own cargo bikes, accompanied of standard or tailor-made trailers. They have temperature-controlled boxes which are ideal for transporting fresh seafood over short distances.

Tout en vélo is an urban cycle logistics specialist, network of cooperatives specialising in cargo bike transport (SCOP) :

– territorial Scops dedicated to cycle logistics, called 'freechises'

– a SCIC for the coordination of the network and the manufacture/marketing of cargo bikes

Spread over more than 10 cities in France, the Tout en Vélo Scops offer various services: removals, parcels, waste collection, shopping, training...

Since the launch with two partners in October 2017 in a 15m2 garage, SCOP now has ten employees including 5 members.

Since August 2022, Scop de Caen has been making deliveries from the Caen wholesale market (MGAC) for Normandie Fruits, a fruit and vegetable wholesaler. These fruits and vegetables are sent to restaurants, school canteens, grocery stores, etc.

"Since April 2023, we have also been making deliveries for the STEF Group of products under controlled temperatures (0°C to 4°C). We deliver on average 3.5 tons monthly." explains François, co-manager of Toutenvélo Caen. "We use Toutenvélo dropside trailers with Cold&Co XL9 coolers."

Side containing:

XL9 with a 9 which recalls the 900 liters of useful volume and the 9 crocodile boxes 60x40x30cm that can be loaded.

Fig 3.27: Refrigerated trailer

Chassis side:

The container is integrated on a tray base with a payload of 150 or 300 kg.

Raised floor and specific fixing elements in addition. The container remains removable to use the tray for other purposes.

This is how to better plan and make your expense rounds profitable.

Benefiting from ATP certification, to assure the customer that the cold chain is respected.

TYPE OF TRAILERS:

1. Dropsied trailer :

The dropside trailer is the most popular product, very solid, ultra versatile, with many layout possibilities.

Fig 3.28: Dropside trailer

Caracteristics :

- Lengths: from 120 to 180 cm
- Chassis widths: 60, 70, 80 cm
- Curb weight: 40 to 45 kg (depending on size)
- Structure aluminium
- Payload: 150 to 300 kg
- Overall width from 85 to 115 cm

Dimensions

	Dimensions utiles L x l x h (en cm)	Dimensions hors-tout L x l x h (en cm)	Volume transporté (en m3 - Caisse + Galerie)
Caisson 120	120 x 75 x 70	173 x 93 x 92	0.6 + 0.3
Caisson 150	150 x 75 x 70	203 x 93 x 92	0.8 + 0.4
Caisson 150+	150 x 86 x 70	203 x 104 x 92	0.9 + 0.4

2. **Flatbed trailer:**

Trays are scalable and customizable models.

Benefits 9 chassis sizes, 2 payloads available, a leading product to transport everything or to think about a layout:

- bulky transport
- Relocation/move
- Waste collection

Fig 3.29: Flatbed trailer

- Lengths: 120, 150 or 180 cm
- Usable width: 60, 70, 80 cm
- Light trailer (from 20 kg)
- Structure aluminium
- Payload: 150 to 300 kg
- Overall width from 85 to 115 cm

<u>Dimensions :</u>

Dimensions plateaux 150kg de charge	Dimensions utiles	Dimensions hors-tout
120 x 76 cm	114 x 70	173 x 94
150 x 76 cm	144 x 70	203 x 94
180 x 76 cm	174 x 70	233 x 94
150 x 86 cm	144 x 80	203 x 104
180 x 86 cm	174 x 80	233 x 104

3. Boxes

Fig 3.30 : Boxes

- Useful lengths: 120, 150 cmMaterials: aluminium, aluminium dibond
- Widths: 60, 70, 80 cm
- Curb weight: from 45 kg
- Heights: 60, 70 cm
- Payload: 150 kg

Dimensions

	Dimensions utiles L x l x h (en cm)	Dimensions hors-tout L x l x h (en cm)	Volume transporté (en m3 - Caisse + Galerie)
Caisson 120	120 x 75 x 70	173 x 93 x 92	0.6 + 0.3
Caisson 150	150 x 75 x 70	203 x 93 x 92	0.8 + 0.4
Caisson 150+	150 x 86 x 70	203 x 104 x 92	0.9 + 0.4

TYPES OF GOODS

1. Parcels (DHL, Chronopost). The goods come by electric DHL or Chronopost truck to Tout en Vélo logistic plateform. Using velo cargo, this original and ecological mode of transport offers easy access to city centres and allows deliveries to be made as quickly as possible thanks to its small size.

Fig 3.31: Delivery parcels Chronopost

Fig 3.32: Delivery parcels DHL

2. STEF

STEF is a specialist in temperature-controlled food supply chains, take care of products, whatever their temperature from -25°C to +18°C. The morning fresh rounds for Normandie Fruits and the STEF which start from 6:30 am.

Fig 3.33: STEF

3. Fruit and vegetable wholesaler in the city centre

Fig 3.34: Fruits and vegetables delivery in the city centre

4. The Biocoop Passage Démogé The organic food store (bio) in the centre of Caen, offers a home delivery service. This home delivery service is offered "to people living less than 2 km from the store. The amount of the orders must be greater than or equal to €50, as the store covers the delivery costs of partner Toutenvelo.

"We continue to offer our home delivery service provided by bike by Toutenvélo, between 5 p.m. and 7 p.m., within a 2 km radius of the store. The customer can choose to come and shop in the store before 3 p.m. and then have it delivered or send us his shopping list by email. Shopping placed by email can also be picked up in the store between 2 p.m. and 6 p.m."

Fig 3.35: Biocoop

Delivery with cargo bike of regional Normandy drink "Meuh Cola" in the hyper centre

Fig 3.36: Meuh cola

Delivery of electric scooters with cargo bike from Caen to the Ouistreham city

Fig 3.37: Tout en vélo electric scooters flow

<u>LOCATION</u>

The model is more common, it is to drop off the goods in the storage place (logistic platform) at Tout en Vélo. The location of the premises is outside the city centre, not far away. Access to logistic platform is fast and efficient by the ring road to avoid traffic jams and city centre, especially for people who make the supplying of goods.

Fig 3.38: Storage tout en vélo

Toutenvélo's an urban logistics platform, a buffer zone where goods are received before being delivered by bike.

4. Transportation infrastructure evaluation, Concept for use of renewable energies for IWT (per region)

4.1 Germany

4.1.1. Germany: temperature control transportation aids (boxes, containers, etc.) powered by renewable energies

Food supply chains are often more intricate and difficult to manage than those for other products due to the perishable nature and limited shelf life of food items. A cold chain, or temperature-controlled supply chain, includes the facilities and methods necessary to ensure the quality and safety of perishable foods from harvesting and preparation through to packaging, transportation, and handling. Given that food is highly sensitive to time and temperature, effective management of these factors is essential. Temperature is the key factor in extending the shelf life of perishables, with refrigeration being the most common method used to inhibit bacterial growth and prevent food spoilage.

Refrigerated food can generally be classified by storage temperature: frozen at −18 °C or lower, cold-chilled at 0 °C to 1 °C, medium-chilled at 5 °C, and exotic-chilled at 10 °C to 15 °C. These temperature ranges are optimally suited for different agricultural products, such as frozen meats, dairy products, fresh fruits, and vegetables that are central to the WISTAR project.

Above all, the WISTAR project develops a strategy focusing on sustainability for its concept of renewable energy-powered transportation. Some key technologies in this line are solar-powered refrigeration units integrated into electric ships, hybrid cooling systems powered with renewable energy at transshipment points, and energy-efficient thermal storage units to be used along the canal network. Such innovations have their potential for creating an environmentally friendly and cost-effective cold supply chain, enabling the Ruhr area to achieve effective transportation of agri-food products.

By focusing on these renewable energy-powered temperature-controlled solutions, governments aim to create a more sustainable and cost-efficient cold supply chain while mitigating the environmental impact.

In solar-powered system, photovoltaic arrays generate electricity to drive refrigeration units, replacing traditional diesel generators. These photovoltaic modules, or specially manufactured laminates, are installed on the roof of the trailer to produce DC electricity.

A standout feature of the ROXBOX 101 is its solar-powered system, which leverages high-efficiency solar panels to operate independently of traditional electricity sources. This capability is especially beneficial in remote areas or regions with limited power access. The box's advanced thermal insulation technology minimizes heat transfer, ensuring consistent internal temperatures essential for preserving the integrity of sensitive goods during transport. Additionally, integrated sensors provide real-time monitoring of internal conditions, allowing users to track temperatures through a mobile app or dashboard, ensuring compliance with required temperature ranges throughout the supply chain.

Fig 4.1: Solar powered container (ROXBOX 101)

eTRUs utilize electricity-powered fans and temperature control mechanisms to cool the cargo as low as -25°C. Up until now, their performances have been promising and without any indication of inability to scale. While we have yet to see if their lifespan and reliability match those of diesel-powered TRUs, early indications are positive. Based on what we do know from similar electric engine technologies, it might be sound to reason that the eTRU could last longer and require less maintenance, hence be cheaper in the end. But in practical implementation, this novelty needs a very efficient electrical engine that can use possibly very low electricity and allow the inside to have good cooling and highly reliable with little possibility of malfunction. The investment cost should be low: the lesser the investments for structure and low maintenance cost afterwards, the greater will be the incentives to retrench widespread use in transportation industries.

4.1.2 Germany: Concepts for adoption of reliable renewable energy for freight distribution

Environmental Protection is one of the biggest topics and problems of recent years. The temperatures on this planet a constantly changing all around the world. An increase in climate catastrophes like floodings, the melting of ice caps at the north pole and the change of climate that makes it seem like the seasons are shifting are just a few signs that tell us that something needs to change. Most industries use processes that have high emissions, be it while producing goods or even energy. The use of fossil energies for the transportation of goods causes high emissions as well. One of the biggest potentials to reduce high emissions during the transport of goods lies within the use of green renewable energies and the use of barges and shallow-water vessels for transportation. Even the increased use of shallow-water vessels while they still use fossil energies for transport would already lower emissions if the usage of trucks could be decreased by it. But to reach low-emissions or even zero emissions with inland waterway transportations (IWT), green renewable energies must be used by barges and shallow-water vessels. For that, not only do new barges and shallow-water vessels need to be built or old ones get retrofitted to be able to use those energies, but also the infrastructure of ports need to be changed to support the usage of green renewable energies. The federal government in Germany developed a national port strategy for sea and inland ports on how the infrastructures of ports need to change to be able to make use of renewable energies and reach the goal of low-emission or zero emission ports and ships by 2045.

According to the federal government in Germany, in year 2030 a demand of 130 TWh (terawatt hours) hydrogen is to be expected nationwide. This kind of demand cannot be satisfied without importing hydrogen. About 50 to 70 percent of the demand needs to be imported. To reach low-emissions or zero emissions only green hydrogen and not fossil hydrogen should be imported. The import of such amounts of hydrogen can only be made possible with a change of the infrastructure for renewable energies at ports. With those changes, the ports in Germany can be turned into hubs for renewable energies like hydrogen (cf. Federal Ministry for Digital and Transport (BMDV) 2024: 18-19).

Ports will end up being transshipment points for renewable energies as well as for parts that are being used to build facilities renewable energies and power networks. One of a port's most important roles is being the supply point for renewable energies for ships and barges. Energy supply systems for battery powered and hydrogen powered ships and barges need to be at the ports as well as for other vehicles that are being used at ports like trucks and trains. Only if all vehicles, ships, barges and the usage of all machinery, buildings etc. make use of renewable energies at a port, only then can a low-emission or zero emission port be achieved (cf. Federal Ministry for Digital and Transport (BMDV) 2024: 19-20).

To take things further, the delivery of goods to the ports by trains and trucks as well as last mile delivery from ports to companies are part of the national port strategy plan. The goal for 2030 is to reach at least a modal-split of 25% for railways and 12% for inland waterway transport. For that, the infrastructure of ports and apron infrastructure needs to be changed and expanded to allow easier access to ports and airports via railways. But a change in the infrastructure of ports is easier said than done. Because of that the legal framework needs to be changed and modernized to allow the usage of green renewable energies, production of renewable energies and the easier access to permissions of buildings needed for green renewable energies like charging stations, bunkers and power plants for the production of hydrogen (cf. Federal Ministry for Digital and Transport (BMDV) 2024: 20-22).

Part of the success in reducing emissions in and around ports is also the further digitalization of ports. The data exchange within a multi-modal transport chain between ships, trucks, trains and other vehicles as well as the port and terminals themselves will help with the communication between people and possibly reduce emission due better plannings and adjusted speeds to reduce energy use during transports. Automation will play a big part in optimizing processes in the future. The automation of barges and shallow-water vessels as well as automation of transshipment activities are planned to further decrease emissions. Laws still need to be adjusted to make this kind of automation possible, especially the automated use of barges and shallow-water vessels without a crew (cf. Federal Ministry for Digital and Transport (BMDV) 2024: 50-53).

Changing laws, building ships and new building as well as changing the infrastructures of ports to enable the use of green renewable energies will need a lot of resources, be it time, materials or money. If the changes can be made until 2030 or 2045 and the goals of the Federal Government of Germany achieved will be seen in the future. There is one important port in Germany who already published their plans and strategy until the year 2040 to reach the goal of a low-emission or zero emission port, the port of Hamburg.

There are several changes the port of Hamburg wants to implement by the year 2040. Changes for the digitization, infrastructure and environmental protection are parts of their plans. The digitization of processes will help the port of Hamburg to make their processes more efficient and climate friendly. Not only will the much-needed modernization of digital processes optimize processes and reduce their costs, increase the communication and information between participants but also lower the emissions by reducing energy use thanks to optimized transport routes. The automation of processes, like automated harbor ships or transport vehicles, is also one important point the port of Hamburg wants to implement to reduce emissions and energy use (cf. Ministry for Economics and Innovation (BWI) 2023a: 54-57).

Until the year 2040 the port of Hamburg wants to be CO2-neutral. One of the first steps for them that needs to be taken is the use of shore power systems for ships, barges and shallow-water vessels. While the barges and shallow-water vessels are at the berth they usually use their diesel motors or generators to produce electricity, which not only uses a lot of fuel but also causes a lot of emissions. The goal is to reduce those emissions by using shore power systems, that mainly provide green electricity if possible. Cranes and transport vehicles within the ports will also make use of the shore power systems as soon as they are able to get powered by electricity. Fuel cells, hydrogen and batteries are other options that will be used shunters, trucks and other transport vehicles being used at the port. This will be especially important for the last mile deliveries for shipments provided by barges and shallow-water vessels that use green energies to reach the goal of zero emission transport (cf. Ministry of Economics and Innovation (BWI) 2023a: 65).

Hydrogen plays a big role for the port of Hamburg to reach its goals. There are plans to use parts of a coal power plant to produce green hydrogen with the help of an electrolyzer. Wind energy from the North Sea will be used as an energy source to produce green hydrogen. The amount that can be produced will not cover the need for the port or the need for all of Germany. This is also the reason why the port wants to build up an import infrastructure for the import of hydrogen and other derivatives like ammonia. The connection to a pipeline-network is one of the plans for their import strategy (cf. Ministry of Economics and Innovation (BWI) 2023a: 67-69).

One of the first connections to a pipeline-network is planned to be established in 2026. The pipeline HyPerLink I will be used to import hydrogen from all over Europe. An additional pipeline HyPerLink III is already planned. This pipeline will be connected straight to Denmark to make use of their huge hydrogen resources (cf. Ministry of Economics and Innovation (BWI) 2023b: 37).

For the last mile delivery and arrivals at the port, the port wants to further expand their railways system even if they already are the biggest railway port in Europe. This will give the port bigger capacities to provide an environmental means of transportation of goods (cf. Ministry of Economics and Innovation (BWI) 2023a: 77-78).

The port of Hamburg wants to provide various options of green renewable energy to its customers. Some ships already can be refueled with Liquefied Natural Gas (LNG) at the port. But other options such as ammonia, methanol and hydrogen will be available soon. The bunkers that can store those green renewable energies still need to be built for the infrastructure. The legal framework needs still to be adjusted for that and permission for the use of those energies at port being provided. Refueling stations as well as charging stations for renewable energies for ships, barges, trucks and trains still need to be built as well. To promote the use of hydrogen powered ships, the fleet of Hamburg will themselves build or retrofit up to two ships for the usage of hydrogen. Alternative drive systems for shunters will also be supported for their market launch (cf. Ministry of Economics and Innovation (BWI) 2023b: 30-31).

To summarize, a lot of things are necessary to use green renewable energies at ports for ships, barges and other vehicles for last mile deliveries. Especially if very low-emissions or zero emission are the goal for the entire port. To make the use of green renewable energies possible for IWT and last miles deliveries, following measures need to be taken first:

- Ports need to build bunkers and other necessary storage options for green renewable energies if not available already
- Recharging stations and refueling stations need to be established for ships/barges, trains, trucks and other vehicles that are used at the port or for last mile delivery
- Use of shore power systems that provide green energy for ships and barges at the berths are needed to avoid electricity generation through diesel motors
- Cranes and other vehicles at the port to move goods and containers to be powered by green renewable energies
- Technology for green renewable energy powered shunters needs to be further developed and used for last mile deliveries
- Railway system needs to be expanded if necessary
- Connection to a pipeline system or other supply system (refueling ships for example) are needed to provide the port with green renewable energies like hydrogen
- Import infrastructure for green renewable energies needs to be built because the demand for green renewable energies cannot be satisfied without imports
- The legal framework needs to be adjusted for the usage of green renewable energies at ports and ports need to apply for permits.
- Small hydro systems can be installed to harness the natural flow of canal or river water into electricity. This will be an environmentally friendly and efficient source of energy.
- Identify existing small ports or points that are non-operational and renovate them at low cost, focusing on the minimum required upgrade with sustainable practice to make them functional.

- Ther is an imperative need to adapt inland waterways systems and renewable energy corridors for sustainable handling of small freight, especially as part of decentralized energy systems that increases regions energy supply chain resilience.

Not necessary but nice to have:

- Further digitalization of processes to optimize loading and unloading processes by automation as well as communications between participants to reduce energy usage
- An own power plant / facility for the port that can produce green renewable energies like hydrogen
- Usage of green renewable energies and electricity for all other processes at the port.

To establish a wide use of green renewable energies for the use of IWT and last mile delivery a huge part of the infrastructure at a port needs to be changed and expanded first. If the necessary building and functions are not available first, building barges or retrofitting barges for the use of those energies is not of any use. Especially the use of hydrogen powered barges and vehicles cannot be accomplished without an import infrastructure. Also, a pipeline-network between the ports in Germany needs to be build first to guarantee the supply of hydrogen from hubs to smaller ports if refueling ships or barges are not being considered. Otherwise, the hydrogen would need to be delivered by trucks which would only further increase the use of fossil energies and increase the modal-split for road transports. Only if the goal is already in sight and possible to reach, the building or retrofitting of barges should be even considered in a larger scope. Funding support will most likely be necessary for the building of new barges or retrofitting of old barges, especially when those barges were just acquired by a private person or company.

How the infrastructure of a port could look like can be seen in "Fig 4.2". This picture shows the infrastructure of a port that uses, produces and bunkers hydrogen.

Fig 4.2: Infrastructure of a port that bunkers, produces and uses hydrogen

As can be seen on the picture, in an optimal situation, for a port that is able to bunker hydrogen, the port would not only be able to refuel barges, but also trucks, shunters and possible other vehicles that are being used. Electricity is being produced by wind energy and solar energy which is then being used for barges and vehicles that are being powered by electricity or need electricity for other necessaries. The green electricity made of wind and solar energy would also be used to produce hydrogen with an electrolyzer by the port's own facility.

The combined work of building up an entire infrastructure for renewable energies at most ports, changing the legal framework, establishing an entire pipeline-network inside of Germany and other countries and equipping barges with the necessary drive systems until 2040 will be a huge amount of work. 16 years is not a lot of time to reach the goal of zero emissions for the IWT and last mile deliveries with other vehicles. Will it be possible to reduce emissions by 2040? Most likely. But will it be possible to reduce emissions to zero? Only time will show it.

4.2 France

4.2.1 State of the art of using bioGNC, Hydrogen, Electric Energy

The AviCAFE project (**20**) : this project brings together VNF, HAROPA, GRTgaz and "La Banque des Territoires", with the aim of promoting the ecological transition of river transport on the Seine axis and the use of alternative fuels by helping to deploy a supply of these fuels. (**21**)

This project has two main objectives:

- To offer decision-making tools to players wishing to implement alternative fuel solutions for the various modes of transport near the Seine axis (river, road, rail transport).
- Accelerate the energy transition by providing visibility and coherence to economic players wishing to develop their activity around alternative fuels.

The first stage of the project consisted of an analysis of the current situation of fuel distribution on the Seine axis.

The study shows that in 2020 (current practices), about 35,000 tons of fuel were distributed in the basin via 3 modes:

- bunkering vessels (50%),
- dock stations (25%),
- trucks (25%).

USER VISION: the "practicality" of different refuelling methods

1. **Provisioning by boat**: Users will find a very complete service offer including the recovery of used oils, and the supply of drinking water.
2. **Provisioning at a fixed station**: Some stations are very well located geographically (in the city center), which allows boatmen to optimise the route for shopping, for example. The resorts also have shops, where boatmen can find a variety of products for their river activity.
3. **Truck refuelling**: Economic gain. A minority of boatmen believe that this type of provisioning saves them time, provided that it is a "large truck", because "small trucks" take much longer to refuel.

35% of respondents prefer road bunkering due to competitive prices in 96% of cases.

Respondents who prefer river bunkering (47%) cite practicality and the availability of all necessary services as their choice criteria. 23% of respondents have no preference for bunkering mode or supplier and make their choice "on the way."

However, 100% of the companies surveyed said they were ready to invest in greener fuel solutions, either because of customer demand (50%) or for brand image reasons. The most cited alternative fuels:

- GTL (Gas-to-Liquids)
- Natural Gas
- Hydrogen
- Biofuel
- HVO100 (Hydrotreated Vegetable Oil)
- No idea

GTL is also mentioned as a transitional fuel and not a fuel of the future.

The main OBSTACLES identified are:

1. ECONOMIC: Necessary investment (client and supplier).
2. TECHNOLOGICAL: Constraints related to adaptation and safety.
3. LOGISTICAL: Space and fleet management.
4. REGULATORY: Burdensome and sometimes counterproductive regulations.
5. PSYCHOLOGICAL: Fear and safety concerns regarding new technologies.

The project then identified the most likely trajectory for the use of alternative fuels. It concluded that electric propulsion would be most advantageous for small vessels, while hybrid propulsion would be suitable for larger vessels, initially with a battery powered by a generator running on synthetic diesel, then on biomethane or hydrogen.

The final stage of the study involves assessing the quantities of fuel needed compared with the quantities available. For the time being, biogas appears to be the most advantageous energy source.

This project has made it possible to establish refuelling projections based on the ships' itineraries. HAROPA has already begun planning refuelling stations in several ports, including Limay, Bruyère-sur-Oise, Gennevilliers, Bonneuil-sur-Marne and Montereau-Fault-Yonne, as shown in the figure above.

The Elementa barge: (**22**)

The port of Rouen should welcome by the end of 2026 or 2027 a barge equipped of a hydrogen fuel cell. The company HDF Energy should conceive the fuel cell. The goal of the barge is to replace auxiliary motors on oil-fuelled ships, supplying the heating, air-conditioning and electricity while the vessel is docked. The use of Elementa will allow a reduction of greenhouse gas emissions by 85% for docked ships.

The barge is fuelled by green hydrogen, which unlike grey hydrogen made with natural gas, is produced with a renewable or low-carbon energy. However, green hydrogen is expensive in comparison with fossil energies, explaining why it is used marginally in ports today; only 11 MW per year is used, when the barge Elementa would produce up to 1,5 MW.

Fig 4.3: Elementa H2 Barge

Elementa appears as a flexible and practical solution. It is an alternative to fixed charging stations, which takes more time to install. Moreover, as the barge is mobile, it can go everywhere, even in zones usually difficult of access in the port or with moored ships that cannot berth.

The Borne&Eau project: (23) HAROPA port and VNF (Voies Navigables de France) are working on a project to install 78 recharging points along the Seine over the next few years.

The aim is to promote the energy transition in the river transport sector by providing suitable port infrastructure. Professionals can benefit from these facilities through a subscription and a single tariff. The project will help to avoid the pollution created by generators, as well as reducing noise and odour pollution for local residents.

To date, 44 charging points have been installed along the Seine, avoiding the emission of 4,300 tonnes of CO2 per year. For example, three charging stations have been installed in the Yvelines département, as well as in Le Havre, Rouen, Gennevilliers and the port of Grenelle.

By the end of 2024, 82 additional terminals will be installed on the Seine and Oise axis, mixing terminals for freight (16A, 32A, 63A), cruising (400A), wintering (125A), and entertainment and leisure (125A). By 2026, the objective is to reach 132 quayside terminals in the Seine basin, to meet the needs of users. This project to equip water and electricity supply terminals, led by VNF and HAROPA PORT, represents a total investment of €9.2 million, supported by Europe and the Ile-de-France Region.

The project will cost €9.24 million and will be funded by the European Union to the tune of €1.8 million, representing 20% of the total budget.

5. Transshipment points mapping (per region)

5.1 Germany

Historical Development of Inland Waterways in the Ruhr-Rhine Area

The Ruhr-Rhine area's historical development of inland waterways is evidence of the region's changing economic environment and its importance as a transportation hub. This section looks at the canal construction throughout the Industrial Revolution, the early commerce routes, and the post-war developments that brought these waterways up to date.

In the Ruhr-Rhine region, the roots of inland waterways date back thousands of years. One of the longest rivers in Europe, the Rhine, was vital to Roman trade because it made it easier for products to travel between different locations. The Rhine was a major commercial route in the past due to the trading of luxury items, textiles, and agricultural supplies.

Basic navigational methods were developed as a result of the requirement for effective transit as towns along riverbanks increased. The Ruhr-Rhine region's advantageous location makes it a major crossroads for trade, tying together different markets and promoting economic exchanges. The expansion of ports and cities along the Rhine, such as Cologne and Duisburg, improved trade dynamics and created the framework for upcoming infrastructure projects.

Canal Construction and the Industrial Revolution

The Ruhr-Rhine region's inland waterways saw significant change during the 19th-century Industrial Revolution. The need for effective raw material and completed goods transportation developed significantly as industrial operations expanded, especially in the manufacturing of coal and steel. Large sums of money were invested in building canals to augment river transportation as a result of this increase in demand.

During this time, important developments included:

Building of Canals: Notable canals were built to make it easier to convey large cargo, including the Dortmund-Ems Canal (1899) and the Rhine-Herne Canal (1973). These canals greatly improved logistics capacity by creating direct connections between important industrial areas and the Rhine.

Infrastructure Development for Navigation: The installation of locks, ports, and loading docks along the waterways increased the efficiency and safety of navigation. The region's logistics environment changed because of this infrastructure, which made it possible for larger ships to reach the industrial core.

Integration of Transport Modes: A multimodal transport framework was established by integrating the canal network with the current rail and road networks. Supply chains were further streamlined by this integration, which made it possible for items to be transferred between various means of transportation efficiently.

The Ruhr-Rhine region became a major hub for heavy industry and logistics in Europe as a result of the building of canals and industrial expansion.

Overview of nowadays Ruhr-Rhine Waterway Network

The Ruhr-Rhine region boasts one of Europe's most extensive inland waterway networks, centered around the Rhine River. This network plays a crucial role in the area's economic vitality.

Major Rivers and Canals:

1. **Rhine River**: The network's backbone, stretching from the Swiss Alps to the North Sea.
2. **Ruhr River**: A major tributary flowing through the heart of the Ruhr industrial region.
3. **Rhein-Herne Canal**: Connecting the Rhine to the Dortmund-Ems Canal.
4. Wesel-Datteln Canal: An important east-west connection in the northern Ruhr area.
5. **Dortmund-Ems Canal**: Linking the Ruhr region to North Sea ports.
6. **Hamm-Datteln Canal**: Facilitating transportation to the Dortmund-Ems Canal, Wessel-Datteln canal and Rhein-Herne Canal.

Key Ports and Terminals:

1. **Duisburg Port (Duisport)**: World's largest inland port, handling over 130 million tons of cargo annually.
2. **Cologne Port**: Major hub for container and bulk cargo.
3. **Neuss Port**: Specialises in grain and animal feed logistics.
4. **Düsseldorf Port**: Known for container and bulk cargo handling capabilities.
5. **Datteln Port**: Major hub and connections of all the four canals at this point.

Lock Systems and Navigable Depths:

1. **Rhine**: Free flowing in this region, depths varying from 2.5 to 6.5 metres.
2. **Rhein-Herne Canal**: 7 locks, minimum depth of 2.8 metres.
3. **Wesel-Datteln Canal**: 6 locks, depth of 3.5 metres.
4. **Dortmund-Ems Canal**: 8 locks. depth 3.5 meters.
5. **Hamm-Datteln Canal**: 2 locks, depth 2.8 meters.

Current Freight Volumes (as of 2022):

1. **Total freight on the Rhine**: Approximately 200 million tons annually.
2. **Duisburg Port**: Over 60 million tons of waterborne cargo per year.
3. **Container traffic on the Rhine**: About 2.5 million TEUs annually.

Modal Split in Regional Logistics:

1. **Waterways**: 15% of total freight transport.
2. **Road transport**: 70%.
3. **Rail transport**: 15%.
4. **For bulk goods (coal, ores, agricultural products)**: Inland waterway transport up to 30-40%.

On the following Table a list of the navigable waterways in the Ruhr-area are presented.

Name	Length	Barge-type	Start	End
Emscher	83 km		Holzwickede (Kreis Unna)	Rhein mouth in Voerde
Issel	81,5 km		Raesfeld	River mouth in Ijssel in Doesburg (Gelderland)
Kalflack	35,5 km		Between Sonsbeck und Alpen	Rhein mouth by mmerich
Lippe	220 km	Up from Datteln Vb until Uentrop Euroschiff	Bad Lippspringe	Rhein mouth by Wesel
Moersbach	30 km		Krefeld-Traar	Rhein mouth by Rheinberg
Rhein	1232,7 km	Big Rheinschiff (Va oder Vb)	Schweize Kanton Graubünden	North See
Rhein-Herne-Canal	46 km	Vb und IV	Dortmund-Ems-Canal	Duisburg Ruhrorter Port
Ruhr	219,3 km	From Rhein until Mühlheim a.d.R. Bundeswasserstraße until Essen Landeswasserstraße	Rothaargebirge	Rhein mouth in Duisburg-Ruhrort

Schifffahrtsweg Rhein-Kleve	8,5 km	Bundeswasserstraße	City Kleve	Rhein mouth just before the Netherlands
Wesel-Datteln-Canal	60 km	Bundeswasserstraße (Vb)	Rhein	River mouth in Dortmund-Ems-Canal by Datteln

Table 6: Navigable waterways in Ruhr-area

About the transshipment points, in a research project of the associate partner DST with the title DeConTrans (Section 3.1.) identified up to 105 potential sites. This included some other Waterways not in the area of focus but as well reachable from the rivers and canals being considerate for WISTAR in the Ruhr-area.

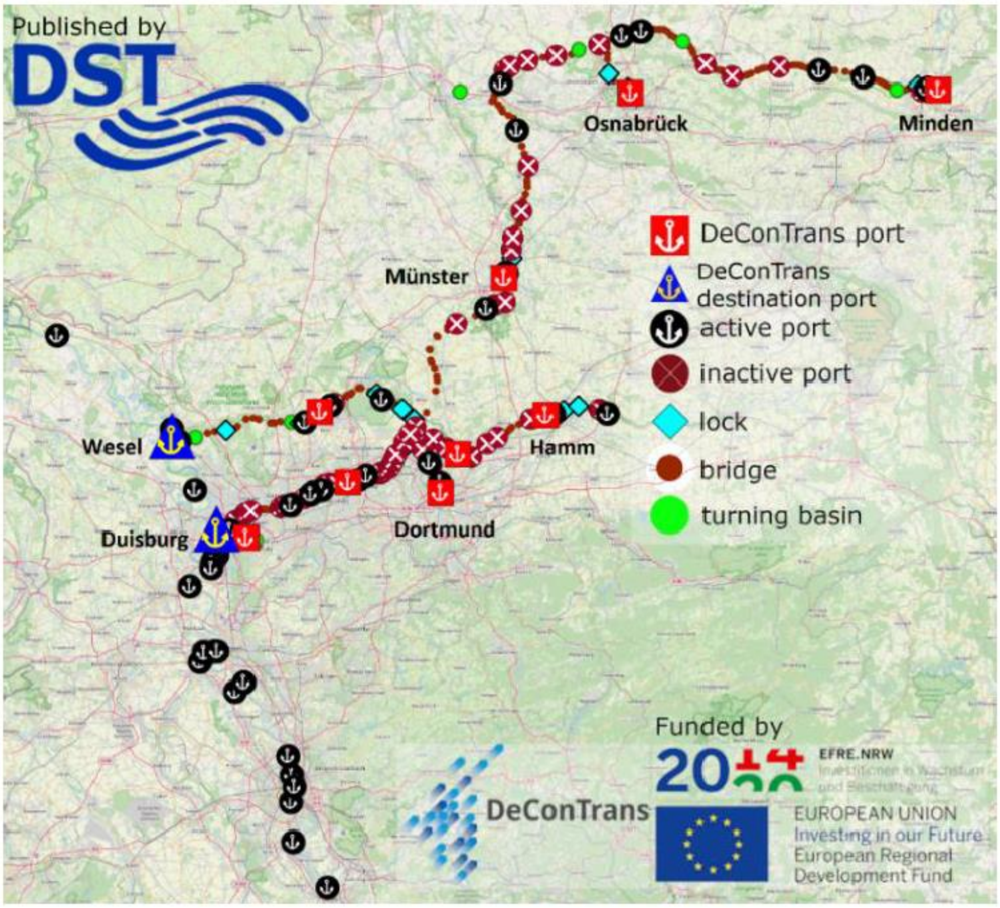

Fig 5.1 : Map of the transshipment locations for DeConTrans network

Recent Infrastructure Investments

Some important investments in infrastructure have been done in the region.

Modernisation of Locks:

- €600 million program for Rhein-Herne and Wesel-Datteln Canals.
- New lock at Oberhausen (Rhein-Herne Canal): Completed 2021, cost €120 million.

Port Expansion and Upgrades:

- Duisburg Port: Over €300 million investment in container handling facilities.
- Cologne Port: €70 million modernisation program for multi-modal connections.

The following figure (Fig. 5.2) shows the handling equipment available on several transshipment point locations on the DeConTrans network.

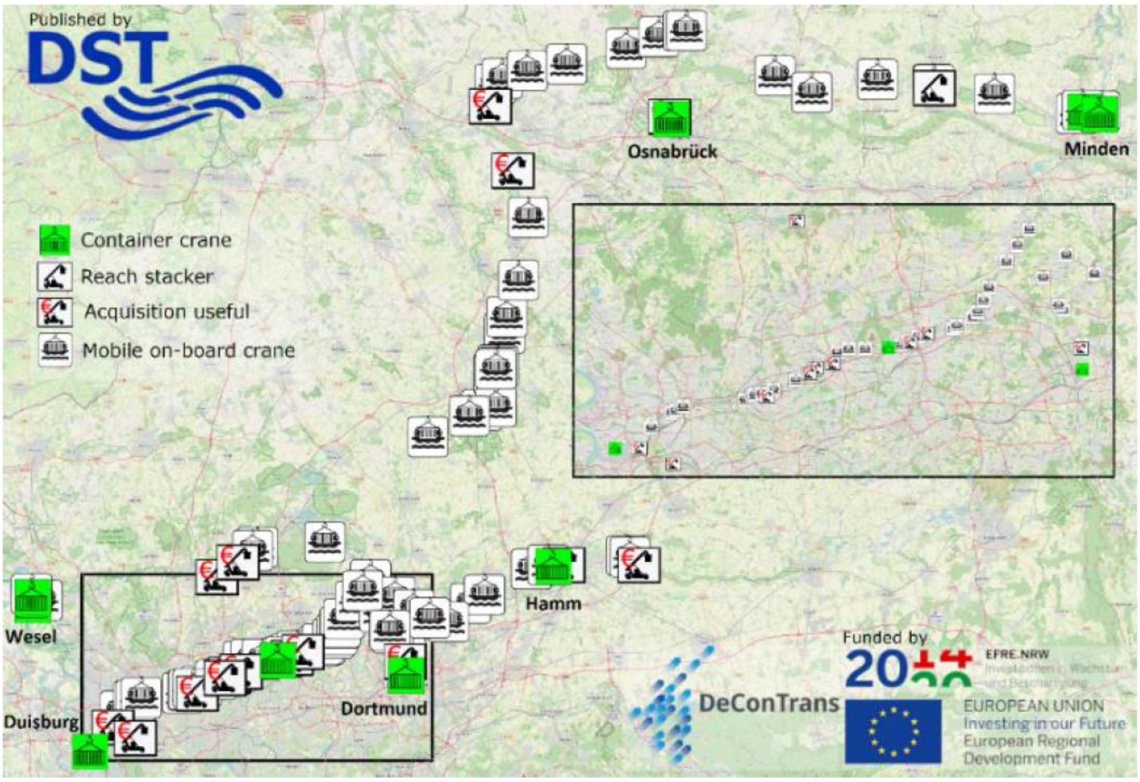

Fig 5.2 : Handling equipment at each location

These investments aim to increase the inland waterway network's capacity, efficiency, and sustainability. However, challenges remain in addressing climate change impacts on water levels and further integrating waterway transport with other modes for seamless multi-modal logistics chains.

The inland waterways in the Ruhr region, particularly the Rhine-Herne Canal and the Dortmund-Ems Canal, are among the most frequented in Germany. They play a crucial role in transporting goods, including agrifood products, thereby alleviating road congestion and reducing greenhouse gas emissions. The German government has recognized the potential of inland navigation to enhance the efficiency of urban and interurban freight transport, especially in metropolitan areas like the Ruhr.

Importance of Inland Waterways for Agrifood Logistics

Environmental benefits: The most important is that the carbon emissions through road transportation and inland waterways are more environmentally friendly. They significantly reduce CO2 emissions and other pollutants, which lead to preserving climate change.

Integration with urban agriculture: In the Ruhr area, we found good agriculture land, and with the potential inland waterways channel, we can provide a sustainable supply chain network to all areas. The network can create very vital links between rural and urban areas, leading to an enhanced supply chain for the farmers. It gives a boost to small businesses and contributes to the climate goals for Germany.

Port and Terminal Interfaces

Duisburg Port is the world's largest inland port, which plays a very crucial role in forming links between the industrial and agricultural regions of the Ruhr and Rhein rivers. The strategic location of the port and the modern infrastructure are the main reasons for transporting bulk goods every day. Ports play a very crucial role in inland waterways, but the development of ports can be very much costlier. It is the primary physical interface where agriculture foods are transferred between modes of transport. If we are to transport argi foods in shallow waters, we must design and develop the transshipment points. The transshipment points will hold strong importance in inland waterways transportation. This point handles the bulk of agrifood products as well as processed food products. Storage facilities and refrigeration units are part of their specialized infrastructure which is important in maintaining the quality of perishable goods. Smaller ports or transshipment points throughout the Rhine and its tributaries support regional businesses through their availability at inland water routes. These ports are often connected to local supply chains, allowing rural businesses to access broader markets.

Logistics and Transshipment Points Interface

Intermodal logistics hubs are crucial for optimizing the flow of goods in the supply chain. It will be responsible for the seamless transfer of goods between different transport modes. These hubs ensure that agricultural and food products can be efficiently moved from inland waterways to other modes of transport with minimal delays, reducing spoilage risks and maintaining supply chain continuity. One of the most important and difficult interfaces is the storage and handling infrastructure of goods. Water as well as agricultural products transported through inland waterways need sufficient storage and handling facilities at their interfaces for their volume and variety to be managed. From elevators and cold storage to warehouses, facilities that ensure proper agrifood quality during transportation are quite important. Efficiently loading and unloading goods can be done with the use of cranes and conveyors. To develop infrastructure, we must select the transshipment points after collecting data about the demand and supply of agricultural foods. To cater to small rural businesses, WISTAR promotes simplified and cost-effective transshipment points that are easier to access and operate. These points reduce the complexity of logistics for small businesses, helping them integrate into larger supply chains without significant upfront investment.

Digital and Technological Interfaces

This means that an electronic and mechanical connection will be used to collect information about the product in its current state. This leads to making inland water transport more efficient due to instant access to information about movement of any vessel on the inland channels to optimize logistics processes and give navigation instructions while moving. Internet of Things (IoT), sensors for tracking everything, blockchain which provides traceability on goods' journey from suppliers to consumers as well as artificial intelligence for logistics planning are some of the technologies which can contribute towards improving this process. It will also help in overseeing the situation of perishable commodities, monitoring shipments and making sure they are delivered on time.

Interface in Economical and Market sector

Finally, we can speak about the economy and markets interface. The freshwater arteries on land in Ruhr are very important links connecting rural little entrepreneurs with city markets. This way, small businesses located in rural areas can access significant marketplaces much more effectively thus increasing their economic potential and enhancing their customer base. The project provides sufficient support to the small business in an energy-efficient way. In the Ruhr area, the network of canals is well developed, thus forming a solid basis for efficient inland waterway transport. The WISTAR project places emphasis on optimizing return trips through the development of a continuous loop that connects major cities with key transshipment points along the canals. The intention is to increase supply chain efficiency through minimization of empty trips and increased utilization of vessels, with simultaneous reduction of overall costs of operation. By strategically coordinating cargo movements and aligning schedules, the project ensures that ships are consistently loaded during both outbound and return journeys. Besides, the loop system enhances connectivity between urban centers and rural areas, allowing for smooth integration of the supply chain. Furthermore, the small vessels increase deployment flexibility to test different types of network configurations just as lines, frequencies and type of goods.

Environmental Interface

The next significant interface turns out to be that of sustainability and environment. For instance, the e-ships which are propelled by renewable energy sources form part of the Wistar project which seeks to cut down the amount of carbon emissions generated from transport in Ruhr. Another goal of this program is to construct a system that delivers goods employing renewable sources of energy thus enhancing rural based enterprises. Moreover, transshipment points will run on renewables too. Introduction of e-ships capable of shallow waters powered with green energy necessitates construction of specific docks for them. This is important since it enables small rural companies in the region to benefit from eco-friendly transport options. Slow internet connectivity on rivers is bound to change if boat charging stations are put up hence improving the walkability index for navigators on round trips.

Now the given map shows the Ruhr River catchment area, highlighting various geographic features, land uses, and infrastructure, such as lakes, urban areas, arable land, forest, and monitoring stations. Here's how this map can relate to the WISTAR project and the use of inland waterways in the Ruhr area for promoting sustainable transportation:

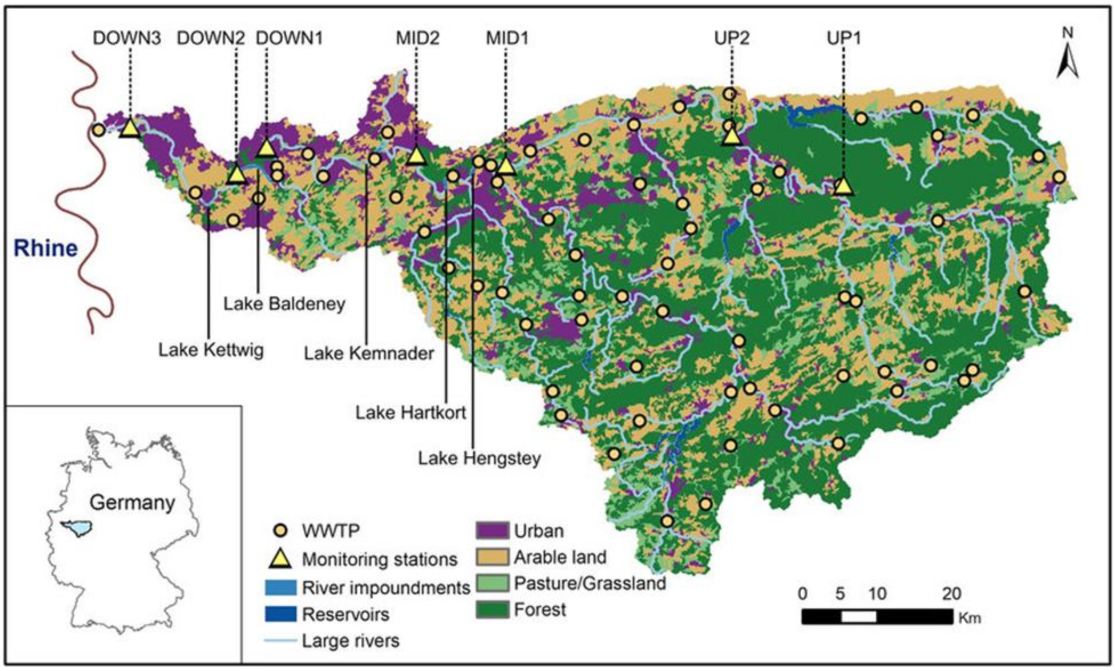

Fig 5.3: Map of the Ruhr River catchment

A thin blue line marks the stream network. Yellow triangles indicate the sampling sites, whereas orange dots indicate the location of wastewater treatment plants (2013). Also note the five river impoundments in the mid and downstream reach of the river.

Key Components from the Thicket Concerned with the WISTAR Project: Ruhr River as well as Its Secondary Streams:

The Ruhr River in addition to its secondary streams are exhibited as main waterways within the catchment area. These rivers are fundamental for river-sea transport, offering a natural transport system which can be utilized for the movement of farming items and other products in a manner that is sustainable. The river's connection to Rhine which is an important waterway in Europe explains why this region is of strategic importance for transnational transport routes supporting WISTAR focusing on inter-border co-operation.\

Lake and Reservoirs:

Various lakes and reservoirs appear on the map including Lake Baldeney, Lake Hengstey, Lake Kemnader, Lake Kettwig and also Lake Harkort. Such water masses could play some role in managing water levels for navigation to ensure that the waterways remain navigable during dry seasons. Reservoirs and normal impoundments can be applied to manage flood flows making possible operation of shallow-draught e-vessels utilized in novel ways under WISTAR project.

Land Use Distribution:

The map distinguishes urban regions, arable land, pasture/grassland, and woodland. The extensive agricultural land (arable land) is an indicator of the possibility for integrating inland waterway transport into agricultural products to urban centers. The mix of land uses highlights varied economic activities in the Ruhr area from which WISTAR project can help link rural producers especially from arable and pasture lands with urban consumers.

Urban Areas:

There are highly concentrated urban areas on certain parts of the map that show likely conditions for high demand for goods. The neighborhoods of these urban centers being close to river networks indicate that there is a possibility that goods could be transported through inland waterways directly to these urban markets and make less reliance on road transport possible. This project can work towards optimizing transport routes between these urban centers and rural production areas so as to leverage on waterways while minimizing CO2 emissions.

Wastewater Treatment Plants (WWTP):

The presence of monitoring stations and WWTPs indicates ongoing environmental management and monitoring efforts in the region. These infrastructures are crucial for ensuring that the waterways remain viable for transport without compromising water quality. WISTAR can collaborate with these existing environmental initiatives to ensure that increased use of waterways for transport does not negatively impact the environment. The data from these monitoring stations can be used to optimize shipping schedules and ensure that transport activities align with environmental regulations.

Integration with E-Ships and Sustainable Infrastructure:

The map's detailed layout of waterways and infrastructure supports the implementation of shallow-draft e-ships, which are part of WISTAR's strategy for sustainable transport. The project can assess the suitability of different segments of the river and lakes for these vessels, ensuring that they can operate efficiently and with minimal environmental impact.

5.2 France: Seine Axis

History of inland waterway transport on the Seine axis

The Seine axis, which connects Paris to Le Havre via Rouen, has been a strategic waterway for France since medieval times. As early as the twelfth century, the Seine played an essential role in the transport of foodstuffs such as wood, cereals, and wine to Paris. With the Industrial Revolution, the axis saw gradual modernization, especially with the widening of canals and the development of river ports to meet the growing needs of industrialization and trade. The construction of the Tancarville Canal in 1963 reinforced access between the Seine and the seaport of Le Havre, becoming a nerve center for import-export.

Key figures and types of goods

Today, the Seine is one of the most active river corridors in France. In 2023, nearly **20 million tons of goods** were transported on this axis, 50% of which are made up of construction materials (gravel, sand, cement). Other main segments include agricultural products (30%), petroleum products, and a growing share of containers (around 5%), especially between the ports of Le Havre and Gennevilliers. The Seine axis is also known for its ability to transport massive convoys, with barges of up to 4,400 tons, the equivalent of 220 trucks.

Transshipment points and major infrastructure

Several logistics platforms and multimodal ports line the Seine axis, promoting transshipment between river, rail and road modes:

- **Port of Gennevilliers** : The leading river port in Île-de-France, specializing in containers and construction materials, it serves the Paris region.
- **Port of Rouen** : The main grain port in Europe, it plays a key role in agricultural exports.
- **Port of Le Havre** : Thanks to HAROPA (merger of the ports of Le Havre, Rouen and Paris), it is a major logistics platform for maritime and inland waterway trade.
- **Triel-sur-Seine and Limay** : These local ports are crucial for aggregate flows and urban logistics.

Below are the container terminals on the Seine axis:

Fig 5.4: Le Havre Port area

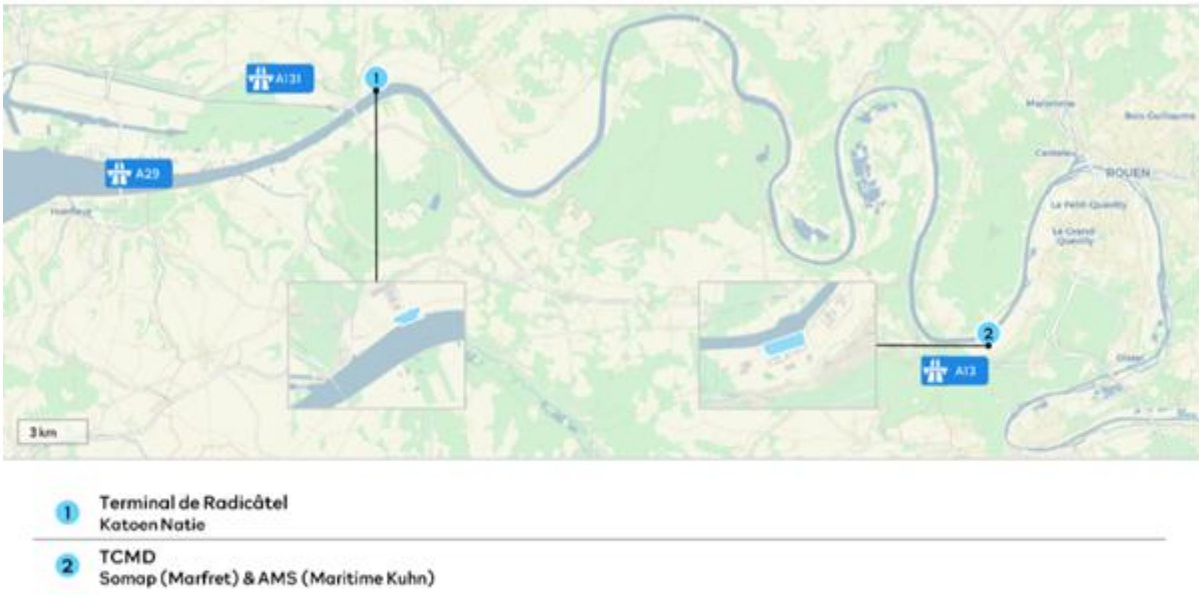

Fig 5.5: Rouen port area

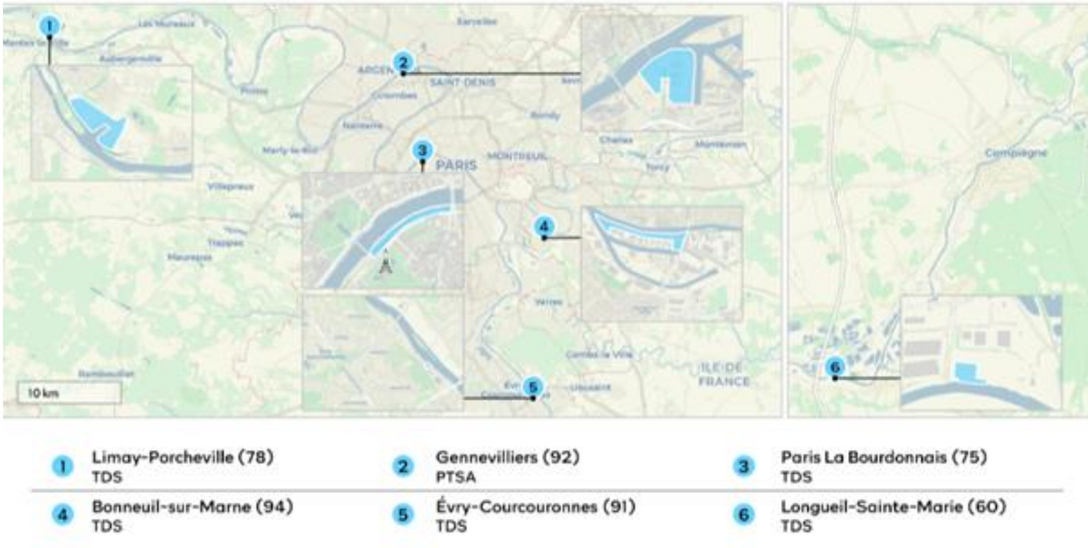

Fig 5.6 : Paris port area

Environmental issues and sustainable development

River transport on the Seine is a key tool for reducing CO_2 emissions related to logistics. With an energy consumption per ton-kilometer 4 to 5 times lower than that of road transport, it is an eco-responsible solution, particularly in the context of European climate objectives. Projects to expand river capacity are underway, in particular to improve access to the port of Le Havre via larger vessels.

Challenges and prospects

Despite its advantages, the Seine axis faces challenges, including siltation of certain sections, increased competition from road transport, and the need to invest in modern infrastructure. However, initiatives such as the development of digital solutions for flow monitoring (e.g., HAROPA smart platforms) and the extension of multimodal capacities promise a dynamic future for this strategic waterway.
River transport on the Seine axis embodies a convergence between history, logistics performance, and sustainability, positioning this axis as a backbone of the French and European supply chain.

6. Requirements specifications

6.1 Germany

To conduct an exploratory user requirements specification, interviews with 15 practitioners on the IWT in Germany were conducted. The inputs from the following companies are represented: Smile Engineering, Short Sea Shipping Inland Waterways Promotion, Tervolt AG, Neue Ruhrorte Schiffwerft, MSG, Rhenus Logistics, Federal Association of the Independent Inland Shipping Department e.V., torqeedo, Logistik NRW, Contargo, HGK, Walter-Eucken-Berufskolleg, North Rhine-Westphalia Transport and Logistics Association e.V., Association for European Inland Shipping and Waterways e.V. and Federal Association of Public Inland Ports.

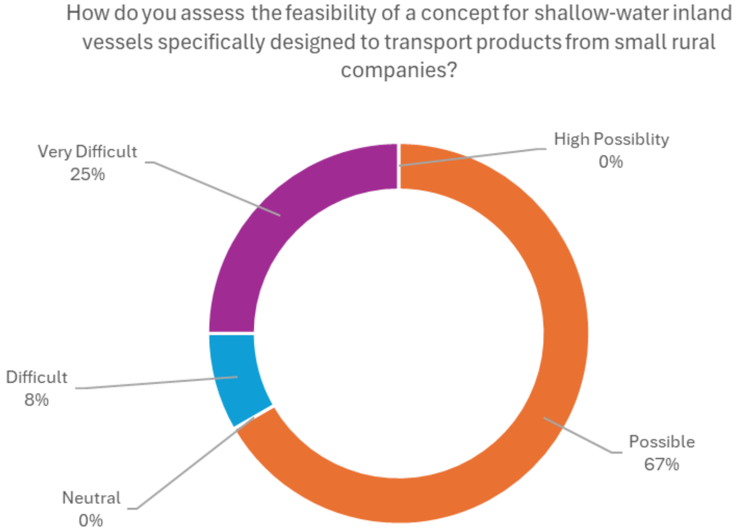

Fig 6.1: WISTAR feasibility

Participants were asked to evaluate the feasibility of a concept designed for shallow draft inland vessels, specifically for transporting goods from small rural businesses. The feedback indicates a generally positive outlook, with many practitioners recognizing the potential benefits of such vessels in enhancing local logistics and accessibility.

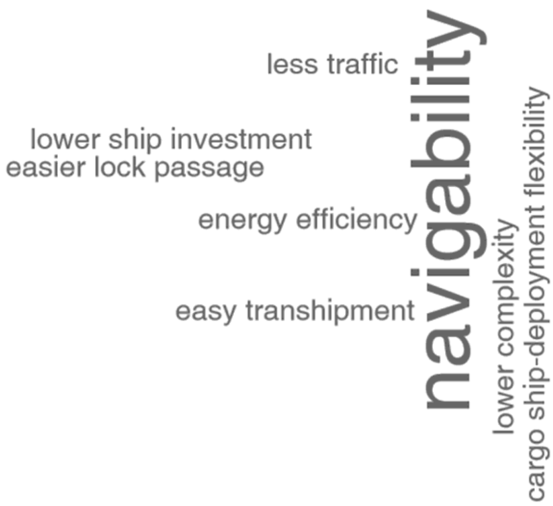

Fig 6.2: Advantages of shallow water barge

The advantages highlighted about the use of shallow water barge mentioned include:

- **Increased Accessibility**: Shallow water boats can navigate areas that are otherwise inaccessible to larger vessels, facilitating transport in rural regions.
- **Cost Efficiency**: Lower operational costs compared to traditional shipping methods were noted, making it economically viable for small businesses.
- **Environmental Benefits**: Participants pointed out the potential for reduced carbon footprints due to smaller engines and optimized fuel consumption.
- Flow Management Benefits: Due to the small dimensions of the barge benefits for an easy lock passage, lower complexity with more flexibility for cargo-ship deployment and easy transshipment processes are expected.

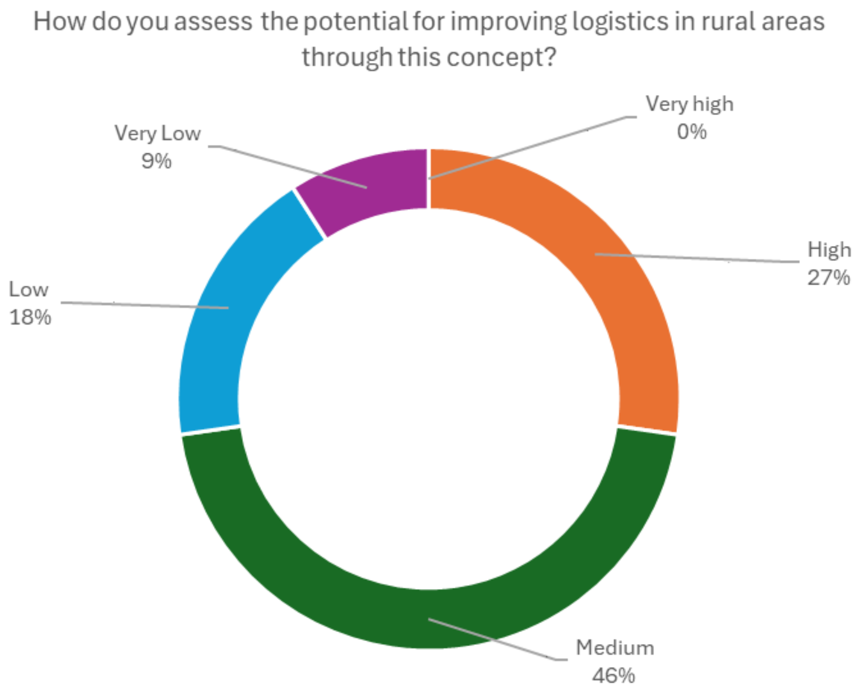

Fig 6.3: Potential WISTARs for rural areas

Practitioners expressed optimism regarding the potential for improving logistics in rural areas through the WISTAR concept. Key points included:

- **Streamlined Supply Chains**: The ability to transport goods directly from producers to consumers can reduce intermediaries and enhance efficiency.
- **Support for Local Economies**: By enabling better access to markets, small businesses could thrive, contributing positively to local economies.

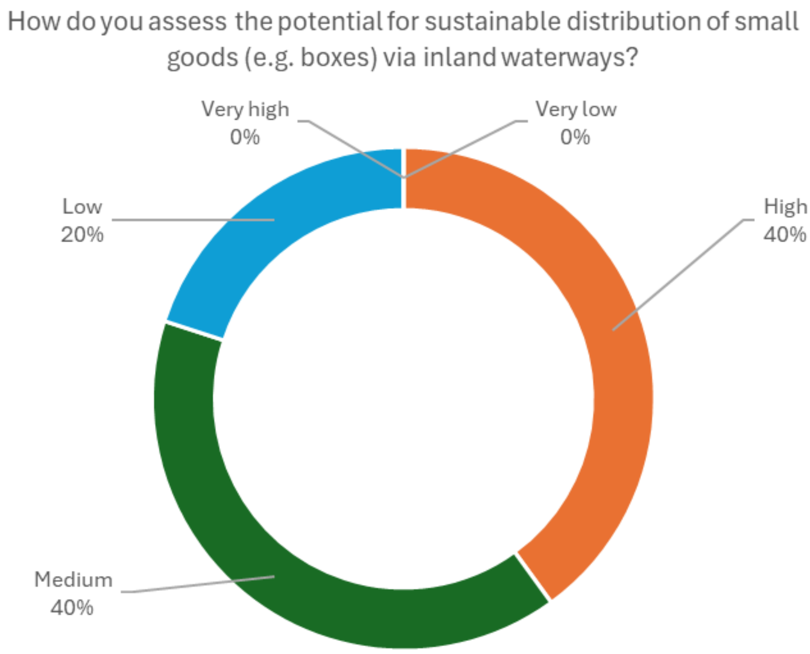

Fig 6.4: Potential distribution small goods via inland waterways

During the interviews we also explored the feasibility of sustainable distribution models for small scale products, such as box deliveries via inland waterways. Respondents indicated:

- **Positive Reception**: There was significant interest in utilizing waterways for sustainable distribution methods, which could reduce road traffic and associated emissions.
- **Community Engagement**: The concept could foster community involvement and support for local products.

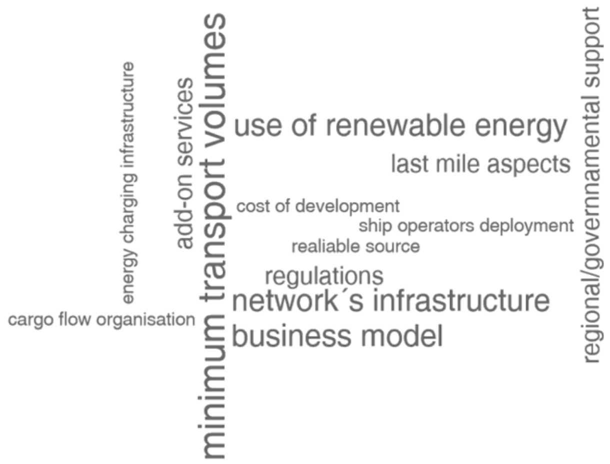

Fig. 6.5: Important factors for successful concept implementation WISTARs

The analysis identified several critical factors necessary for the successful implementation of the WISTAR project, including:

- Critical Minimum Volume of Cargo: to achieve a profitable operation.
- **Infrastructure Development**: Adequate docking facilities and maintenance of waterways are essential.
- **Regulatory Support**: regulations and support from governmental bodies would facilitate smoother operations.
- Robust Business Model: Engaging various stakeholders, including local businesses and government agencies, is crucial for this formulation.

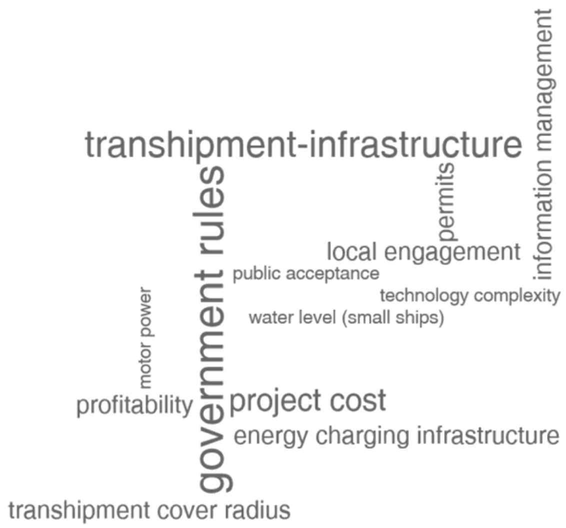

Fig 6.6: Possible obstacles to tackle

Despite the positive feedback, several obstacles were identified that could hinder the project's success:

- **Funding Limitations**: Securing adequate funding for infrastructure and operational costs remains a significant challenge.
- **Market Acceptance**: Convincing local businesses to adopt new transportation methods may require extensive outreach and education.
- **Permits:** for the new transport concept could pose additional hurdles.

In summary, while there is considerable enthusiasm for the WISTAR concept among practitioners in the inland waterway sector, addressing funding, regulatory challenges, and market acceptance will be vital for its successful implementation. On the following we addresses these topics.

6.1.1 Challenges and Opportunities

Infrastructure Challenges

The inland waterway network in the Ruhr-Rhine region faces significant infrastructure challenges that hinder its efficiency. Ageing locks and bridges are a primary concern, as many were built decades ago and require substantial renovation. The Central Commission for the Navigation of the Rhine (CCNR) report (2019) indicates that outdated lock systems can lead to increased maintenance costs and operational delays, impacting transport reliability.

Fluctuating water levels due to climate change also pose challenges. Wiegmans and Konings (2017) note that extreme weather events can significantly affect navigability, with low water levels in late summer reducing cargo capacity by up to 50%. Conversely, high water levels in spring can lead to navigation restrictions, creating unpredictability in logistics planning.

Further, better integration with other transport modes is needed. Despite advancements in developing multi-modal hubs, many inland ports need more infrastructure for efficient transfers between waterways, roads, and rail networks. This integration is vital for ensuring smooth last-mile delivery of agri-food products.

Operational Challenges

At an operational level, the sector grapples with fragmented governance. The involvement of multiple states and municipalities complicates decision-making processes, leading to inconsistent policies and regulations (Sys & Vanelslander, 2021). This fragmentation can result in inefficiencies in customs procedures and safety inspections.

Additionally, the inland waterway sector needs more skills. The CCNR report (2019) highlights an ageing workforce and difficulties attracting younger talent as significant barriers to growth. This skills gap affects all areas, from vessel operation to logistics planning.

Moreover, competition from road transport remains a significant challenge. Despite the environmental benefits of inland waterways, road haulage is often preferred for shorter distances due to its flexibility and door-to-door service capabilities (Wiegmans & Konings, 2017). This competition necessitates improvements in IW transport efficiency to remain viable.

Opportunities for Growth

Despite these challenges, there are substantial opportunities for growth in the IW logistics sector. The increasing demand for sustainable transport presents a significant advantage for inland waterways, which have a lower carbon footprint than road transport. Sys and Vanelslander (2021) emphasise that EU policies promoting sustainable transport will likely drive further investment in IW logistics.
There is also potential for new markets and products. The strategic location of the Ruhr-Rhine region allows for increased use of IW transport for high-value agri-food products beyond traditional bulk goods. Developing specialised handling facilities for premium products could open new market segments.
Technological advancements offer additional opportunities for enhancing efficiency. Innovations like IoT devices for real-time tracking and blockchain technology for supply chain transparency are being adopted (Sys & Vanelslander, 2021). These technologies can improve operational efficiency and reliability in transporting temperature-sensitive agri-food products.
In conclusion, while the Ruhr-Rhine area's inland waterway logistics face significant challenges related to infrastructure and operations, there are also considerable opportunities for growth driven by sustainability demands, technological advancements, and market expansion. The region can enhance its position as a leader in innovative agri-food logistics solutions by addressing these challenges through targeted investments and policy reforms.

6.1.2 Policy Recommandations

Infrastructure Development

To address the infrastructure challenges facing the Ruhr-Rhine region's inland waterway network, it is crucial to prioritise the modernisation of key waterway infrastructure. This should involve implementing a comprehensive program to upgrade ageing locks and bridges, focusing on critical bottlenecks identified in the CCNR report (2019). A long-term funding mechanism should be developed to ensure continuous maintenance and modernisation of IW infrastructure. Additionally, investments should be made in climate-resilient infrastructure to mitigate the impact of fluctuating water levels, as highlighted by Wiegmans and Konings (2017).
Investing in multi-modal connectivity is essential for improving the efficiency of agri-food logistics in the region. This should include enhancing intermodal transfer facilities at key

inland ports, focusing on efficient connections between waterways, rail, and road networks. Standardised container handling equipment should be developed across modes to reduce transfer times and costs. Furthermore, creating dedicated "agri-logistics corridors" linking major production areas with urban centres via IW and other modes would significantly improve the overall logistics network.
Support for developing specialised agri-food handling facilities is crucial for enhancing the competitiveness of IW transport in the sector. Incentives should be provided to construct temperature-controlled storage and handling facilities at strategic locations along IW routes. Investments in specialised loading/unloading equipment for perishable goods would help reduce handling times and maintain product quality. The development of innovative solutions such as "floating warehouses" for temporary storage and distribution of agri-food products in urban areas could further enhance the flexibility and efficiency of the logistics chain.

Regulatory Framework

Streamlining permitting processes for IW logistics operations reduces administrative burdens and improves operational efficiency. This can be achieved by establishing a "one-stop shop" for all IW logistics-related permits and approvals. Implementing digital permitting systems would expedite application and approval processes. Additionally, harmonising permitting requirements across different jurisdictions within the Ruhr-Rhine region would simplify operations for logistics providers.
Harmonising regional regulations is crucial for creating a more cohesive and efficient IW logistics network. This should involve developing a unified set of standards for IW vessel operations, safety protocols, and environmental regulations across the Ruhr-Rhine area. Aligning customs procedures and documentation requirements for cross-border IW transport within the region would facilitate smoother operations. Creating a regional IW logistics regulatory body to oversee and coordinate regulatory efforts would ensure consistent implementation of policies.
Introducing incentives for shifting to waterway transport is key to promoting the use of IW for agri-food logistics. This could include implementing a "modal shift bonus" for companies transitioning from road to IW transport for agri-food products. Tax incentives for IW logistics equipment and facilities investments would encourage private sector participation. Developing a carbon credit system for IW transport would incentivise sustainable logistics practices and align with broader environmental goals.

Technology and Innovation

Funding research and development in IW logistics technologies is crucial for driving innovation in the sector. Establishing a dedicated research fund for IW logistics innovation, focusing on agrifood-specific challenges, would stimulate new solutions. Supporting collaborative research projects between universities, industry, and government agencies would foster knowledge exchange and practical applications. Developing autonomous vessel technologies tailored for IW agri-food logistics could address future labour shortages and improve operational efficiency.
Adopting digital platforms for logistics optimisation is essential for modernising the IW logistics sector. Providing grants or subsidies for SMEs to adopt digital logistics platforms would accelerate technological uptake. Developing a regional IW logistics data exchange platform would improve coordination and efficiency across the network. Supporting the integration of blockchain technology for enhanced traceability in agri-food supply chains would improve food safety and consumer confidence.
Supporting pilot projects for innovative agri-food logistics solutions is key to testing and implementing new ideas. Funding pilot projects for novel last-mile delivery solutions combining IW transport with urban distribution would address urban logistics challenges. Supporting trials of new vessel designs optimised for agri-food transport, including modular and flexible cargo spaces, would improve the versatility of IW transport. Encouraging experimentation with alternative propulsion systems, such as electric or hydrogen-powered vessels, would contribute to the sector's environmental sustainability.

Stakeholder Collaboration

Establishing a regional IW logistics coordination body is crucial for improving stakeholder cooperation and alignment. Creating a Ruhr-Rhine Inland Waterway Logistics Council with representatives from all key stakeholder groups would facilitate better communication and decision-making. Developing a regional IW logistics strategy with clear goals, timelines, and responsibilities would provide a roadmap for improvement. Regular monitoring and reporting mechanisms help track progress and identify areas for further enhancement.
Promoting public-private partnerships in infrastructure development is essential for leveraging resources and expertise from both sectors. Developing a framework for PPP projects specifically tailored to IW logistics infrastructure would encourage investment. Encouraging joint investments in multi-modal logistics hubs combining public funding with private sector expertise would accelerate infrastructure development. Creating risk-sharing mechanisms would attract private investment in innovative IW logistics solutions.

Facilitating knowledge sharing and best practice exchange is vital for continuous improvement in the sector. Organising annual Ruhr-Rhine IW Logistics Symposiums would showcase innovations and share experiences among stakeholders. Establishing a regional IW logistics excellence award would recognise and promote best practices. Developing an online platform for continuous knowledge exchange among IW logistics stakeholders would foster ongoing collaboration and innovation in the sector.

The long-term vision for agrifood logistics in the Ruhr-Rhine region centres on creating a sustainable, efficient, and resilient supply chain that leverages the full potential of inland waterways. Key elements of this vision include:

1. A fully integrated multimodal network where IW transport seamlessly connects with road and rail, enabling door-to-door delivery of agrifood products with minimal environmental impact.
2. Smart, autonomous vessels and ports operating 24/7, significantly reducing transit times and enhancing reliability.
3. Real-time data sharing and predictive analytics enabling proactive management of supply chain disruptions and optimising inventory levels.
4. Specialised agrifood logistics hubs along waterways, equipped with advanced cold chain technologies and processing facilities, reducing food waste and enhancing product quality.
5. A circular economy approach, where reverse logistics via IW play a crucial role in recycling and reusing packaging materials.

Achieving this vision will require continued collaboration between public and private stakeholders, sustained investment in infrastructure and technology, and supportive policy frameworks. If realised, this vision could position the Ruhr-Rhine region as a global leader in sustainable agrifood logistics, enhancing its economic competitiveness while significantly reducing the environmental footprint of its food supply chain.

6.2 France

6.2.1 SWOT analysis of fish flow logistics in Caen

The analysis of fish flow logistics in Caen provides a comprehensive overview of the potential and challenges of integrating inland waterway transport (IWT) into the city's supply chain. By leveraging IWT, particularly the use of barges, the logistics sector could significantly reduce environmental impacts, road congestion, and noise pollution, aligning with the growing demand for eco-friendly solutions and European sustainability objectives. However, the method also faces critical barriers, including infrastructure adaptation, delivery time constraints for perishable goods like fish, and competition from emerging electric truck technologies. This SWOT analysis explores the strengths, weaknesses, opportunities, and threats to provide a strategic framework for optimizing fish logistics in Caen.

Strengths	Weaknesses
Limited environmental impact: using barges, and especially electric ones will allow the reduction of greenhouse gases emissions and air pollution in city centres. It is therefore better for health and environment than road transport.	**Lack of flexibility:** IWT is dependent of meteorological conditions; low water levels can stop the navigation of ships. It cannot navigate everywhere in the city either, as there needs to be waterways adapted for inland navigation within the city centre. Consequently, IWT cannot always assure last mile delivery, another transport mode needs to be used.
Massification: vessels can transport more cargoes than road transport, allowing to do one single trip for the same quantity of fish transported. Moreover, transportation costs can be reduced thanks to the massification.	**Investment costs:** investing in IWT infrastructures can be expensive, especially if transporters wish to implement low or zero carbon solutions, using alternative fuels, which can have a higher initial cost.

Reduction of road congestion: inland navigation will allow to decongest city centre and urban environments, which are not always adapted for the circulation of trucks.	**Delivery times:** transport by barge is sometimes longer than by trucks, as it cannot always arrive directly to the client but other transport modes need to be used. Delays can be problematic for fresh food deliveries, especially fish.
Reduction of noise pollution: road transport produces lots of nuisance for locals, and especially noise pollution. On the other hand, barge, and especially electric ones, are completely silent, making them more pleasant for inhabitants.	

Opportunities	Threats
Low emission zone: the implementation of a low emission zone in the centre of Caen in 2025 will restrict the circulation of some vehicles, especially those of more than 3.5 tons. The logistic sector needs to adapt to this new regulation by adopting cleaner transport modes, including IWT.	**Concurrence of other modes of transport:** electric trucks are making their apparition, with several enterprises innovating in this sector, such as Tesla, Volvo and Nikola. New technologies are allowing electric trucks to be more efficient, with a greater autonomy of battery. New innovations should be introduced in a near future, to speed up recharge time and ensure a greater autonomy. Such trucks could bring changes in environmental policies, currently focused on rail and IWT.

European objectives: the European Green Deal has for objective to make Europe the first carbon neutral continent in 2050. Concerning the transport sector, the European Union has created the Sustainable and Smart Mobility Strategy (SSMS), aiming at shifting freight from road to inland waterways and rail. By 2035, IWT should increase by 25%, and by 50% by 2050.	**Lack of adapted infrastructures:** current infrastructures for inland navigation may not be adapted for a significant traffic, or for loading and unloading goods (fish). These barriers could slow down the development of urban IWT.
Growing demand for eco-friendly solutions: with the threat of climate change and the increasing restrictions on road transport, demand for alternative transport modes can increase, forcing transporters to adapt to this new demand. According to a study conducted by AviCAFE, 50% of transporters start their green transition to adapt to their client demand, and the other 50% to improve their brand image.	**Social barriers:** there is a cultural preference for road transport, and transporters can therefore be reluctant to change their habits. They see IWT as less flexible than trucks, explaining their mistrust of inland navigation.
Subsidies and government incentives: in accordance with European environmental policies, the government can stimulate the development of IWT by providing subsidies and tax incentives. Those policies can allow transporters to reduce investment costs in inland navigation infrastructures.	

Table 7: SWOT analysis of fish flow logistics in Caen

The SWOT analysis highlights that integrating inland waterway transport into fish logistics in Caen presents promising opportunities to align with environmental objectives and urban regulations. While IWT offers significant benefits such as reduced emissions, noise pollution, and road congestion, its full implementation faces challenges such as investment costs, delivery delays, and infrastructural limitations. Addressing these challenges, particularly through subsidies, government incentives, and innovative logistical strategies, could position IWT as a viable and sustainable alternative to road transport. The adoption of such solutions could not only improve the efficiency of fish logistics but also set a precedent for greener urban supply chains in Europe.

6.2.2 Analysis of the constraints and regulations of local distribution of fish products

Fish, a delicate food requiring preservation in strict compliance with the cold chain.
Fish is a very fragile food, mainly because it contains a lot of water and therefore constitutes a favorable environment for the development of microorganisms, such as bacteria. When it is taken out of the water (and particularly from the sea, a quasi-sterile environment) these microorganisms are present only in its intestinal tract and gills. Only cold – or very high heat – can kill them or at least inhibit them and prevent their development in the edible parts. This is the beginning of the cold chain fish.
Highly perishable foodstuffs must be stored and transported between 0and 2°C for freshly preserved fish – allows conservation without making any changes to its appearance, texture and composition of the flesh.
A temperature between 0 and 4°C is suitable for smoked or pickled fish, which are less fragile.
Frozen food products must be stored and transported in an environment where the temperature does not exceed -18°C.
Frozen products are transported at a negative temperature down to -18° using refrigerating means (eutectic plates or dry ice) to maintain this temperature. Temperature sensors are present in each container to ensure that the temperature is maintained throughout transport.
When transporting fresh food products such as fish, the temperature must be the same as during storage. To control this thermal stabilization, it is necessary to use certain specific equipment: refrigerated trucks or insulated containers at the right temperature. These must meet the ATP standard – Agreement on the Transport of Perishable Foodstuffs – which governs the transport of fish in particular. In addition, it is mandatory to implement a Health Control Plan. This document lists the hygiene rules to be implemented, including the HACCP approach (hazard analysis and critical control point system), which targets traceability and good hygiene practices.
Refrigerated transport and insulted containers are a legal obligation for a number of perishable foodstuffs. It avoids any health risk.

Fig 6.7: Fleet of refregirated vehicules - Lequertier group, specialised in the trading and processing of seafood products, a major player in the French seafood industry; Mondeville, Normandy

Respecting the cold chain means maintaining a constant temperature for certain categories of products, from their preparation to their consumption by the end customer. The cold chain is considered to be broken when food is exposed to a temperature higher than the established storage temperature during a given period of time :

1. the core temperature of refrigerated food increases by +2°C or more for more than 30 minutes
2. refrigerated food is exposed to a temperature higher than that at which it must be maintained for more than 30 minutes.
3. frozen products reach +3°C on the surface for more than 30 minutes.

In fishmongers, there are mandatory displays that must be put in place to inform consumers about the characteristics of the products offered for sale. The origin of fish is important information for consumers because it can influence their purchasing decision based on their preferences regarding sustainability, quality or food safety.
Mandatory displays in fishmongers must be placed in a manner that is visible to customers. It is important to comply with local and national regulations regarding the mandatory display of food information.

These mandatory displays include in particular:

- of the trade name
- from the scientific name
- of the production method : “caught”, “caught in fresh water” or “farmed”
- from the fishing area or the breeding country
- of storage conditions and temperature
- of the expiry date
- Of the commercial name and scientific name of each species of fish
- Of the capture or breeding area
- Of The date of preparation or sale
- Of the use-by date (UBD)
- Of the price per unit or weight
- Of the farming methods or fishing gear used (organic, wild, etc.)

Fig 6.8: Product label with mandatory information

These mandatory displays must be updated regularly and must be readable and easily accessible to consumers.

There are several standards for mandatory display in fishmongers. These standards vary depending on where located, but they generally aim to provide consumers with clear and accurate information about the products offered for sale.

In France, fishmongers must display the Latin name and the French name of each species of fish sold, as well as the following information:

- The original fishing area
- The production method
- The freshness of the fish
- Processing information (whether it has been smoked, marinated, etc.)

In addition, fishmongers must comply with food hygiene and safety standards issued by the relevant health authorities. These standards may vary from country to country.

The rules applicable to the labelling of seafood and aquaculture products are set out in Regulation (EC) No 1379/2013 of 11 December 2013. **(24)**

7. Conclusion

This deliverable, titled **"Strategy for implementing green transportation concepts by using inland waterways,"** highlights the foundational elements needed to effectively integrate inland waterways into a sustainable and economically viable transport system. The analyses and recommendations provide concrete responses to the set objectives and strategic directions for future actions.

1. **Promotion of energy efficiency and greenhouse gas reduction** :
    - The document emphasizes the potential of inland waterways to reduce emissions, particularly through solutions such as small autonomous electric vessels, alternative fuels, and optimized transshipment infrastructure.
2. **Support for small rural businesses**:
    - The analyses demonstrate how inland navigation can address the specific needs of these businesses by lowering logistics costs, shortening delivery times, and offering competitive alternatives to traditional transport options.
3. **Creation of an environmentally friendly and economically viable transport system**:
    - The integration of renewable energy solutions, combined with the optimization of transshipment points, outlines a sustainable and scalable model at the European level.

Challenges and Next Steps
To achieve the outlined ambitions, several key areas require particular focus:

- **Infrastructure evaluation and adaptation**: Modernizing and expanding transshipment points to include flexible stops controlled by digital solutions, reducing reliance on major ports.
- **Deepening market and regulatory analyses**: Identifying opportunities to develop competitive inland waterway corridors while harmonizing legislative frameworks.
- **Experimentation with new approaches**: Conducting real-world tests of innovative technologies, including autonomous vessels and digital tools, to maximize the sustainability and efficiency of supply chains.
- **Collaboration and sharing best practices**: Strengthening exchanges with other European regions to accelerate the deployment of proven solutions and tailor innovations to local specificities.

Conclusion

This deliverable represents a crucial step in establishing a robust strategy for green waterway logistics. By leveraging emerging technologies, adapted infrastructure, and enhanced stakeholder cooperation, it paves the way for an integrated transport system capable of addressing current environmental and economic challenges while meeting the needs of both local and transnational actors.

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