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DECARBOMILE

Decarbonise last mile logistics

DELIVERABLE 4.1

INNOVATIVE LAST MILE LOGISTICS EQUIPMENT FOR THE LIVING LABS

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Nature of the Deliverable		
R	Document, report	X
DEM	Demonstrator, pilot, prototype	
DATA	Data sets, microdata, etc.	
OTHER	Software, technical diagram, etc.	

Dissemination Level		
PU	Public, fully open and automatically posted online	X
SEN	Sensitive, limited under the conditions of the Grand Agreement	
CI	Classified information: RESTREINT UE (Commission Decision 2015/444/EC)	
	Classified information: CONFIDENTIAL UE (Commission Decision 2015/444/EC)	
	Classified information: SECRET UE (Commission Decision 2015/444/EC)	

Quality procedure			
Date	Version	Reviewers	Comments
07/02/2024	V0		
11/02/2024	V1	CARA	NGS contributions were added
23/02/2024	V2	IMT	INT contributions were added
28/02/2024	V3	IT	Final version

PROJECT SUMMARY

Gathering 31 partners from 10 different countries, DECARBOMILE aims to trigger an unprecedented improvement of the green last mile logistics in Europe. To reach that goal, DECARBOMILE relies on a strong experience of decarbonising urban logistics through European initiatives such as CIVITAS. Partners will build upon all previous results to develop improved delivery methods, tools, and methodologies, and implement them across Europe. The solutions developed in DECARBOMILE will demonstrate the full potential of decarbonised last mile logistics in 4 living labs (in Hamburg – Germany, Istanbul – Turkey, Logroño - Spain, and Nantes – France), and 4 satellites (Getafe - Spain, Ghent – Belgium, Sarajevo - Bosnia and Herzegovina, and Tallinn - Estonia) will be involved at a smaller scale to test and study the solution in their own local contexts.

OBJECTIVE AND EXECUTIVE SUMMARY OF THE DELIVERABLE

The objective of the DECARBOMILE project is to focus on and enable the full potential of green last-mile logistics, notably by developing and implementing comprehensive tailored technological solutions which meet the needs and business requirements of European cities. To showcase this potential, the project focuses on four Living Labs (LL) and four Satellite Cities (SC) with different technical, environmental, and local socio-economic contexts:

- Hamburg (HAM), Istanbul (IST), Logroño (LGN), Nantes (NANTES) as LLs
- Getafe (GETAFE), Ghent (GHENT), Sarajevo (SARA), Tallinn (TLN) as SCs

The aim of this **D4.1 Innovative last-mile logistics equipment for the living labs** is to look at technical developments on the hardware equipment to be developed and tested as part of the project, namely: a barge, cargo-bikes, parcel lockers and micro-containers aggregators.

This deliverable focuses on presenting the development and production of the LLs' vehicles and equipment, the combination with digital tools, as well as their implementation and proper adaptation to multimodal requirements in city contexts.

At the time of writing the deliverable (28/02/2024), logistics equipment in the framework of DECARBOMILE includes:

	Developed by	Tested in
Barge	OHB	GHENT and HAM
Cargo-bikes	FLEX	NANTES and LGN
Parcel lockers	INT	GETAFE and LGN
Micro containers	FLEX	NANTES

This logistics equipment is meant to be adapted to (1) the ICT and digital tools requirements (WP3) to ensure proper coupling and compatibility, (2) local stakeholders' requirements (WP2) and legal frameworks (regulations, LEZs, safety, etc.), and (3) logistics requirements in terms of load, flows, multimodality, integration into the energy grid, etc.

Based on the benchmark of innovative equipment, including micro containers, parcel lockers and freight vehicles (done by IT as part of this WP4, T4.1), an asset acquisition plan for LLs and SCs has been developed (by TMTX and FLEX) and is presented in the second section of the document.

In parallel and to complement, **D4.2 Technological Platform for delivery exchange** will investigate the development of an intelligent bikes' warehouse and a network of bikes-boxes in Getafe.

ACKNOWLEDGEMENT

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More information on the project can be found at https://www.decarbomile.eu

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ABBREVIATIONS

Abbreviation	Description
BLE	Bluetooth Low Energy
CCTV camera	Close Circuit Television cameras
FLEX	FlexiModal
GNSS	Global Navigation Satellite System
HAM	Hamburg Living Lab
ICT	Information and Communication Technology
IMEI code	International Mobile Equipment Identity code
INT	Intelligent Parking
IoT	Internet of Things
IST	Istanbul Living Lab
IT	Interface Transport
IW-NET	Inland Waterways Transport Network
LEZ	Low Emission Zone
LGN	Logroño Living Lab
LL	Living Lab
LU	Logistics Unit
NGS	New Generation Sensors
NOx	Nitrogen Oxides
OHB	Opleidingscentrum Hout & Bouw
PLC	Programmable Logic Controller
PM10 or PM2.5	Particulate Matter 10 microns of 2.5 microns
SARA	Sarajevo Satellite City
SC	Satellite City
SLA	Service Level Agreement
T/H	Temperature and Humidity
TLN	Tallinn Satellite City
TMTX	Transmetrics
UCC	Urban Consolidation Centre
VHF radio	Very High Frequency radio
VOCs	Volatile Organic Compounds

INTRODUCTION

This deliverable aims at giving technical specifications and detailed functionalities of the different equipment developed in the frame of the project, as well as a definition of the context in which they will be used (use cases of the project).

As such, this document is based on the asset acquisition plan developed as part of the project, which aims to help the end user of the equipment define their needs and the technical specificities of the equipment acquired. This document is also supported by the work previously done in tasks T4.1, T4.2 and T4.3, including the benchmark conducted on innovative equipment development (vehicles, containers, and hubs).

In the consortium of the project, three partners are fully involved in the design and development of innovative hardware equipment:

- **FlexiModal** (FLEX)

French company developing products for professionals on bikes, FLEX designs and produces professional cycle mobility solutions for both last-mile logistics operators (delivery and waste collection) and craftsmen (services on bikes), with the special feature that the trailers and tricycles include an innovative lifting system to facilitate transloading in urban logistics. The hardware designed is low-tech, easy to maintain to minimize the cost of maintenance and produced in France. By 2024, more than 180 cycle-mobility actors are using FLEX equipment worldwide, including Heppner, Les Triporteurs Français and DB Schenker. In the project, FLEX oversees the development of **cargo-bikes** (through the development of the TricyLift), **micro-containers** and an **aggregator solution**.

- **Opleidingscentrum Hout & Bow** (OHB)

This Dutch research and innovation centre works on different topics in the wood and construction sector. Their centre for training and development also aims at helping professional in smart logistics and green energy. OHB is involved in several European projects involving urban waterways logistics (Interreg North Sea Region, CUMULUS, ICON, …) which allows them to work on different topics such as ship design for urban vessel, logistics solutions, maritime technology, alternative fuels for small vessels, etc. In DECARBOMILE, OHB is leading the development of the **electric barge** for logistics purposes.

- **Intelligent Parking** (INT)

Spanish company which manages controlled-access parking via the design of an intelligent access control system called PVerde, INT is currently managing car, bicycle, motorhome parking as well as offices and protected spaces (for example control access of the Trabucador beach to limit car pollution). As their main activity, their car parking network covers more than 6’000 parking spots under the access-control of PVerde. INT is usually reached out by municipalities wanting to provide citizens with facilities to promote green mobility. In the frame of the project, INT is focusing on the development of **parcel lockers** and **micro consolidation centres,** as a new equipment in their production line.

This document will present for each partner the different equipment developed as part of DECARBOMILE, with technical product sheets and description of the services proposed.

1 CONTEXT

The hardware developed in the frame of the Work Package 4 (WP4) is a key component to the success of the use cases to be implemented in the project. Parcels and goods delivered will travel through and thanks to the different hardware equipment so it is necessary for the development phase to have a clear understanding of how the equipment will be used and who will be the end users / operators.

The development of the equipment is scheduled from month seven (M7) to month twenty-four (M24) of the project. This timeline corresponds to 18 months of development, from March 2023 to August 2024. For each equipment, a dedicated time frame will be presented, considering the different challenges that the technical partners have or will have to face and the potential risks.

The different pieces of hardware will be tested in different use cases, in coherence with the context of the city where they will be used. Thus, **OHB** will test the **electric barge** on the inland waterways of **Ghent** and **Hamburg**, **INT** will install **micro-hubs** and **parcel lockers** in the Spanish pilot cities of the project: **Logroño** and **Getafe**, while **FLEX' containers** will be tested in **Nantes** and the **TricyLift** in **Logroño** and **Nantes**.

In the process of developing the equipment, **Getafe,** and **Ghent**, both SCs of the project, have the role of pre-testing the solutions (**electric barge** in **Ghent**, **micro-hub,** and **parcel lockers** in **Getafe**). These tests aim at minimizing the risks which may appear during the use cases implementation when launched at a larger scale in the different LLs.

1.1 MICRO-CONTAINERS

1.1.1 BENCHMARK

The micro-containers development is quite a new and innovative concept, and as such, not a lot of previous experiences could be found in the literature. Experience from FLEX has shown that the micro-containers for urban logistics currently available on the market are essentially proprietary products of each brand of vehicle and do not allow the easy handling of already loaded pallets. Their external format is no longer compatible with the dimensions of standard vehicles, and they have not been designed to facilitate their storage, especially in Urban Consolidation Centres (UCCs) and the transhipment of micro-containers between different types of vehicles is not addressed in a unitary or standardised manner.

In the frame of the project, the development of a standardised container should facilitate handling operations during a load break between a conventional truck and a cargo-bike. With the current trend and development of cycle-logistics across Europe, we can assume that this kind of micro-container, designed to be integrated into intermodal logistics, will get more and more common and used in the logistics sector.

The early development of cycle-logistics vehicles in the DHL fleet was made possible thanks to the test of e-trikes (Figure 1) in cities where the company was also delivering mail, stored in small containers on the bike. Below is a picture of a MIFA e-trike still in use since 1950, date when was first tried the e-trikes by DHL in Hamburg.

Figure 1: DPDHL e-trikes used since 1950, source: DPDHL

Later on, DHL collaborated with the cargo-bikes manufacturer, Rytle[1], for two experimentations, one in Miami and one in Berlin (within the Solar Boat project[2] scope). Through these experimentations, they operated last-mile deliveries with **MovR3 cargo-bikes** (Figure 2), which consist of a cargo-bike associated with a container of a Euro pallet-size. This container can carry up to 180 kg on 1.8m3 in the *Rytle Box*. The cargo-bike is also equipped with an electric transport fork and a loading bay to facilitate the handling operations.

Figure 2: Rytle cargo-bike, source: IT

[1] https://www.rytle.com/en/
[2] https://www.exberliner.com/english-news-berlin/dhl-solar-powered-delivery-boat/

1.1.2 APPLICATION IN THE DECARBOMILE USE CASES

Standard micro-containers based on the Europe palette format (including with an isothermal declination) and an **aggregation solution** to allow several micro-containers to be transported at the same time and ease their handling in the transport chain (Figure 3), are specific equipment developed as part of the project. These innovations will be made compatible with the **TricyLift**, the first cargo-bike developed by FLEX – who was until then focusing on developing trailers and adapted modules. These innovative standard micro-containers should help optimize the loading of delivery vehicles by providing a standard loading unit and help in the handling operations between massified transport modes (trucks, barges, trains, etc.) and last mile urban logistics (see figure below).

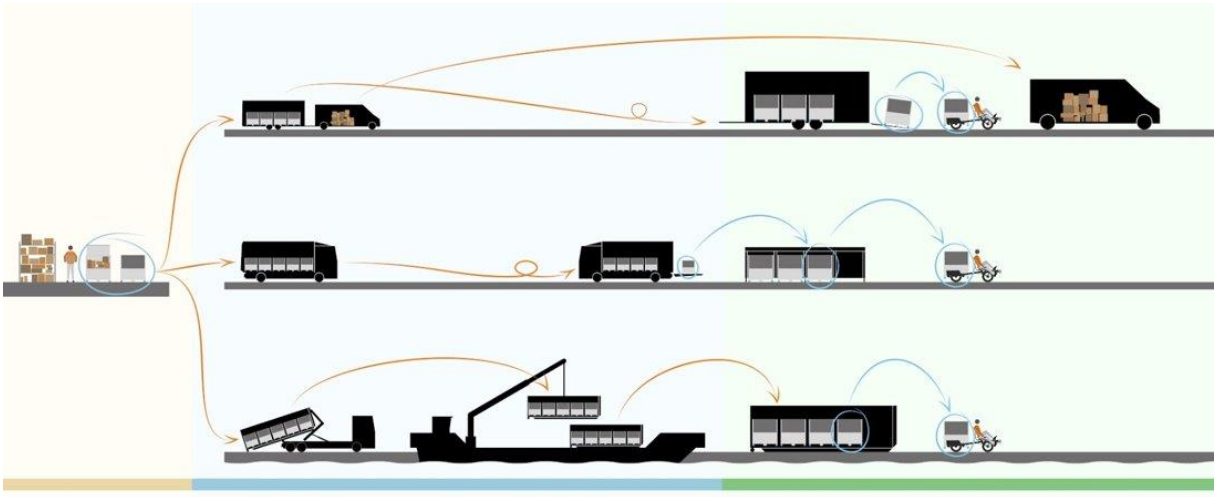


Figure 3: Container in the logistic chain, source: FlexiModal

The **micro-containers** are supposed to be tested in **Nantes**, as well as the **TricyLift**. While the use cases there are still being finalised, the main concepts are already validated. As such, the main idea is to create several **consolidation hubs** (either on public parking or in bus depots), with a load break between trucks and cargo-bikes as well as flows consolidation to optimize deliveries. The format of the microcontainer will allow to preload it with goods at a warehouse outside of the city centre, before sending it by truck towards the urban micro hub and load it there on cargo-bikes for the final leg of the journey. With its lifting mechanism, the **TricyLift** will facilitate the transhipment of microcontainers, limiting the load break impact and being time- and economically efficient.

In **Logroño**, the **TricyLift** should also be tested in at least one of the three use cases prefigured, all of them operating cyclo-logistics for different types of goods (fresh food, dry food, pharmaceutical products, waste, social deliveries, etc.). In the same vein, the use cases will aim at facilitating loading and unloading operations to consolidate flows and improve urban logistics in dense areas of the city.

1.1.3 TIMELINE OF DEVELOPMENT

TricyLift:

- September 2022: first prototype launched for internal use only.
- July 2023: 3 prototypes available for tests by third parties mostly during fairs (all functionalities not optimized yet).
- April 2024: 10 pre-production units available for tests by clients in real-life conditions.

Micro-containers:

- Micro-containers are still in the conception phase. They will be ready for tests in 2025.

Aggregation solution:

- Aggregation solutions are still in the conception phase, waiting for requirements based on the use case definition. They will be ready for test in 2025

1.2 ELECTRIC BARGE

1.2.1 BENCHMARK

One of the main experiments used as a reference for the barge construction within this project has been the Interreg North Sea Region **AVATAR** project which consisted in the construction and implementation of a barge in Ghent (by OHB) for transhipment and waste returns (Figure 4). This barge is powered by an electric propulsion system and a battery pack. The vessel is designed for shallow water with a low draft and a low construction above deck to pass under low bridges. This basic version can be loaded with up to 25t of goods. Tests have been done with delivery of construction material and waste collection from wharfs.

Figure 4: AVATAR barge in operation, source: northsearegion.eu

With ambitious modal shift goals at the European level[3], similar projects and experimentations are actively being tested across Europe. In France, XPO Logistics has been operating river logistics for dry food deliveries to Franprix shops in the inner Paris since 2012. More recently, in 2019, Strasbourg was one of the first cities to support the implementation of fluvial urban deliveries with ULS, who since then has extended its operations to Lyon, Mulhouse and Rouen. Similarly, the project **Ecofluv** will be launched in 2024 in Lyon, with the use of an electric solar-powered boat (called *Evoli*) for urban deliveries and wastewaters collect from other boats. The *Evoli* boat (Figure 5) has been designed with particular attention to the existing infrastructure in Lyon in a way that handling operations at quay do not require additional infrastructure, and all equipment is already placed onboard: forklift, loading arm

[3] Mobility Strategy - European Commission (europa.eu)

and automatic dock access ramps – all designed and developed in the frame of the project. This 27m long boat differs from the usual barges as the storage area (150m²) is covered with solar panels placed on the roof to supply for the need of onboard services.

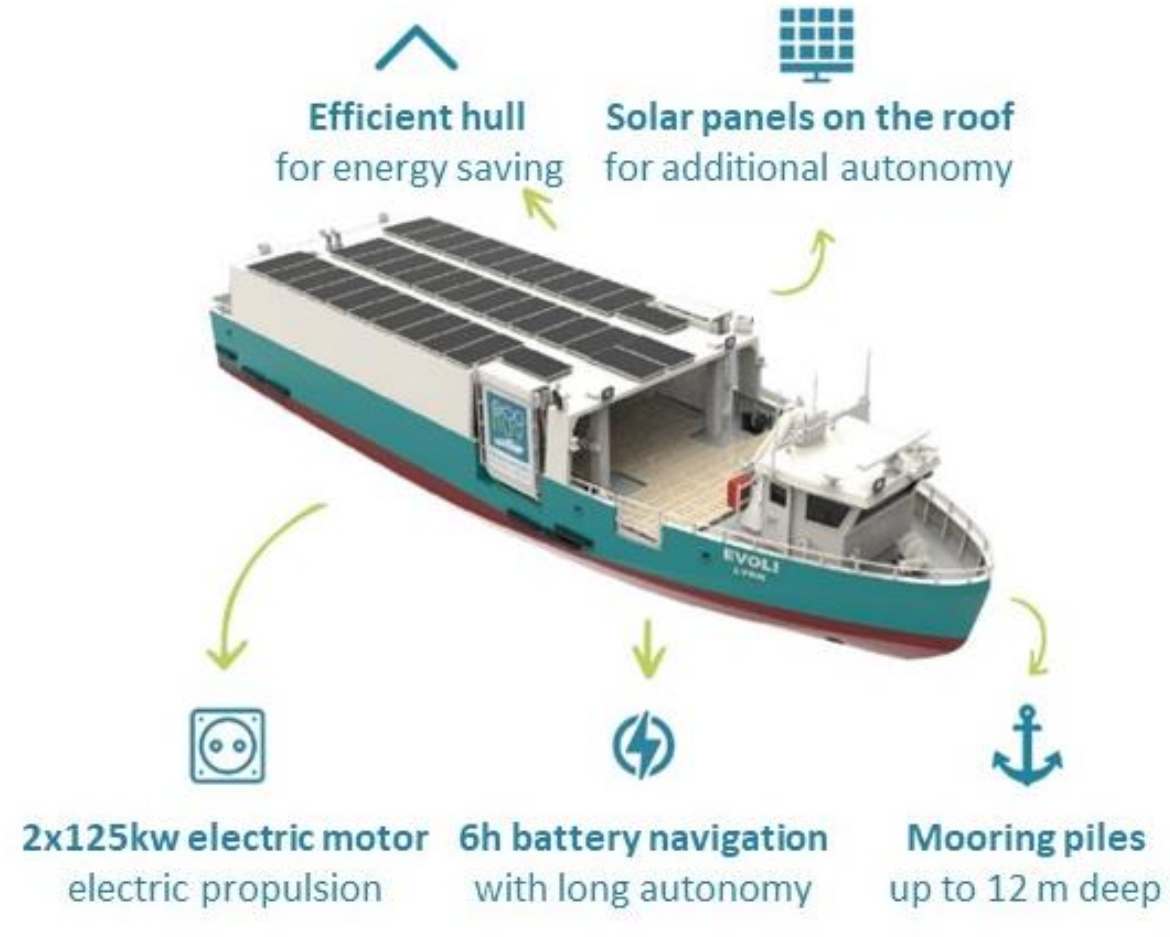


Figure 5: visual for the Evoli prototype, source: ecofluv.fr

In Berlin, the **Solar Boat project** has been operated by **DPDHL** for one year between October 2022 and October 2023. It consisted of an urban delivery scheme for parcels with a ship powered by solar energy on the second-last mile and e-cargo-bikes on the last-mile. Some technical adaptations had been made to the boat to make it suited for urban logistics purposes: for example, a hatch had been added to the roof to lift out parcel containers. Despite successful operations, with no issues declared on the equipment, DPDHL struggled during the experiment with bureaucratic challenges, many contact persons within authorities and many property owners, leading to the termination of the experimentation.

1.2.2 Application in the DECARBOMILE use cases

The barge construction within DECARBOMILE is based on previous work led by OHB, with the participation in the AVATAR project and the Green Wave project, both part of the Interreg North Sea Region programme, aimed at developing river logistics on inland waterways. This work has been a great experience to build upon for the electric barge of DECARBOMILE, while OHB still had to face technical constraints on the barge adaptation to the river constraints in the local context of Hamburg.

Indeed, the AVATAR barge, currently being used for urban logistics purposes in the SC of **Ghent**, had originally been considered for the use case implementation in **Hamburg**. However, following a site visit in September 2023, several meetings with the Port Authority of Hamburg, DPDHL, the Senate of Hamburg representatives, skippers, and vessel owners, OHB concluded that the urban vessel as currently designed and foreseen at the moment of writing of the proposal (2021), is not fit for the test case in Hamburg. The reasons are the following: high waves at certain periods (more than 1 m), strong tidal influence and current in the river Elbe and Alster (up to 13 kms/hr), and unbalance of the ship in case of installation of a scissor table lift to un/load DHL containers to and from the ship to the quay. OHB therefore decided to start with a new building plan, taking in consideration all the above-mentioned challenges to design a vessel with more power at the propulsion line and battery pack, a wider and stronger hull and dedicated loading equipment. In addition, it is also studied to develop a tidal-based sailing schedule and to foresee an alternative route via the Elbe River.

The electric barge will thus be constructed and pre-tested by **OHB** before being transported to the **Hamburg** LL to experiment good transportation on the inland waterways of the city for four months in summer 2025. The use case (Figure 6) is defined as follow: the barge will be loaded in Billbrook district with **DHL** parcels, to be transported to the city centre, in the Hamburg Mitte district. A micro-hub will be placed near the unloading quay to store parcels before their final delivery by cargo-bikes (provided by DHL). To complement, a parcel locker unit will be placed near the micro-hub, to offer an additional collecting point to final consumers. The barge will potentially be used as well during the return trip, but the reverse logistic process still needs to be detailed.

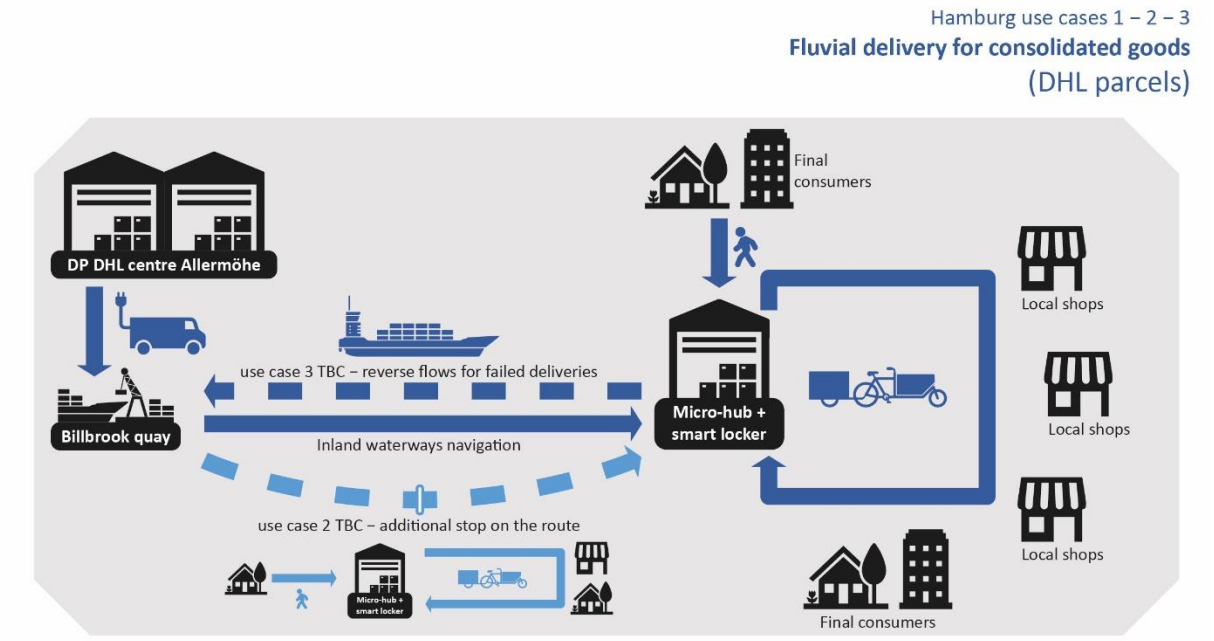


Figure 6: HAM use cases, source: IT

1.2.3 Timeline of development

At the time writing the deliverable (January 2024), the new design of the ship fit for the Hamburg use case is almost ready. After price comparisons on the raw materials market, a batch of aluminium was purchased to carry out the construction of the hull, which is meant to start in the same month. The **expected delivery date of the hull is set for July 2024**.

In **February 2024**, loading elements (including loading bridge and scissor lift) has been ordered, based on the foreseen use case and tasks to be performed. Once the hull is received, the installation of the

propulsion and electric system can begin. The **powertrain should be ready by September 2024**, after which the battery components can be installed. Since the propulsion line and battery packs have doubled, additional days are provided for testing and adjusting the systems.

Construction of monitor and management systems is planned from October to December 2024. Extensive **testing and adjustment of engines and Energy Management Systems are planned in the first months of 2025**.

After all the production steps, the ship can be transported to Hamburg for the implementation of the use case, as planned between June and October 2025.

1.3 PARCEL LOCKER

1.3.1 BENCHMARK

The smart parcel locker market size was valued at €750 million in 2022 and is projected to grow from €840 million in 2023 to €2,000 million by 2030[4]. With several environmental and economic advantages (reduced handling effort, decreased failed delivery rate, reduced costs, etc.), smart lockers are more and more being installed in our cities.

The use of the **Kargopark** parcel lockers (Figure 7) is one of the many inspiring examples for the development of this equipment in the project. Indeed, Kargopark' lockers are provided with a control system by Bluetooth and a pin code. Thus, final customers can pick up their parcels via a mobile app or a code sent to them. Also, the parcel lockers have rechargeable batteries which work by adopting an environmentally friendly approach, without requiring an electric connection and supported by solar energy.

This type of parcel lockers can be bought by economic actors who want to offer this service on their commercial area; it can also be placed on metro stops, fuel stations, public living areas, workplaces, chain markets and universities, and be shared by different type of users[5]. For example, **MIGROS** has been offering this equipment in almost 50 of their stores since 2020. They placed lockers next to their shopping malls or in their store parking lots, provide the energy supply needed and rent these services to logistics operators. MIGROS is also providing areas for other smart lockers brand: **Trendyol cargo automats** and **Pudo lockers**, which are being used in 20 additional stores.

[4] Smart Parcel Locker Market Size, Share, Trends Analysis [2030] (fortunebusinessinsights.com)
[5] https://kargopark.com/wp-content/uploads/2023/05/230504-I%CC%87ngilizce-Kargopark-Bu%CC%88lteni.pdf

Figure 7: Kargopark smart lockers (maxi and mini), source: kargopark.com

However, it is interesting to note that despite the rising trend, delivery process via parcel lockers is still not widely known among e-commerce users in Turkey, and there is a high need to explain and promote it to users. Although the system is very simple to use, there is always a guidance request within the store which creates an additional workload for the staff. However, after the first use of the equipment by the final consumer, and thanks to both promotional material and user training, the issues encountered are solved and final customers increase their usage of the smart lockers.

Parcel lockers provided by **INT** (PVerde) are a new way to promote clean mobility. Lockers are installed into a big bike-hangars or bike warehouses (Figure 8) to achieve a better security against vandalism and to encourage the use of bikes or cargo bikes. Combined to several added-value services (such as scooters, bike or cargo bike rental schemes, parcel lockers, logistics lockers, electric charging points for micromobility vehicles, etc.) these bike hangars aim to become micro hubs in the city centres. The smart lockers installed will be used both by logistics operators for parcels deliveries, and by citizens for general pick and return.

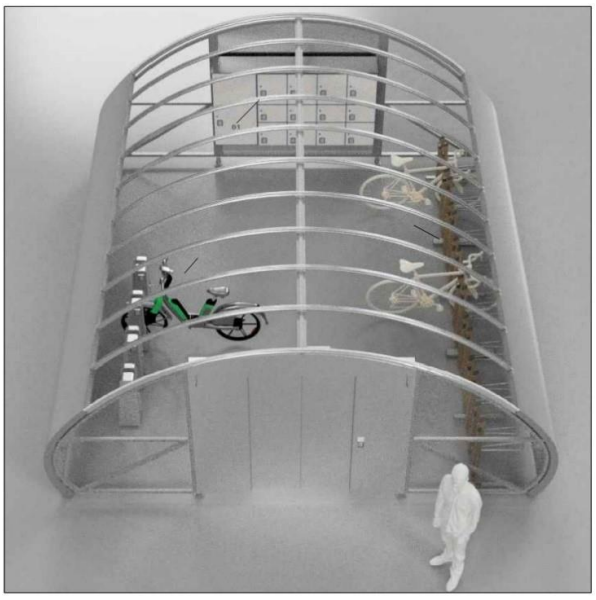


Figure 8: INT micro hub with parcel lockers, source: INT

1.3.2 APPLICATION IN THE DECARBOMILE USE CASES

The overall equipment developed by INT is planned as **parcel lockers** to be placed inside **micro consolidation hubs** (Figure 9). These lockers will be of two types: some for **logistic operators** to use it as a load-breaking point and some for **final consumers** to pick-up their packages directly from the lockers.

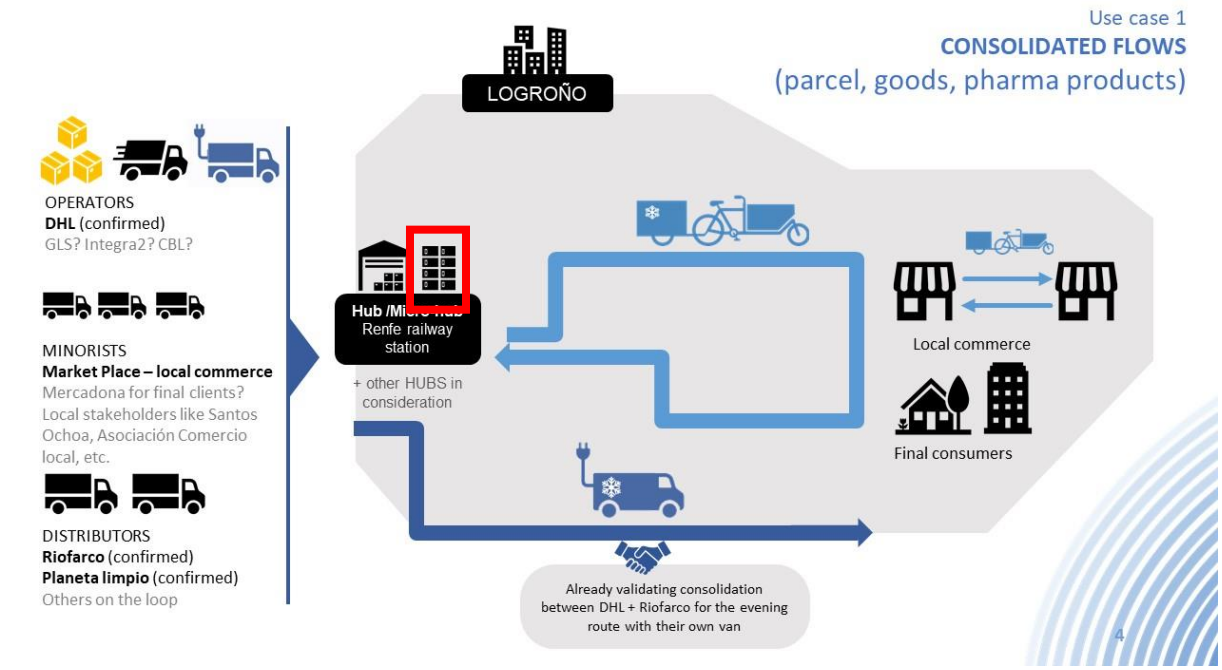


Figure 9: LGN main use case which includes smart lockers installation, source: IT

The access to the micro-hubs will be controlled thanks to the technology developed by **INT**, called PVerde. This technology is already used by INT to control the access to their existing car and bike parking, and it will be adapted to allow external carriers and final consumers to retrieve parcels from the lockers. INT will use its experience in the manufacturing of bike parking (Figure 10) to help developing these micro hubs and parcel lockers. One locker unit of 12 cells will be pre-tested in the SC of **Getafe**, and afterwards, two similar units will be installed in the LL of **Logroño** (originally planned to be installed respectively from March 2024 until February 2025 in Getafe, and from March 2025 in Logrono for an 18-month test case).

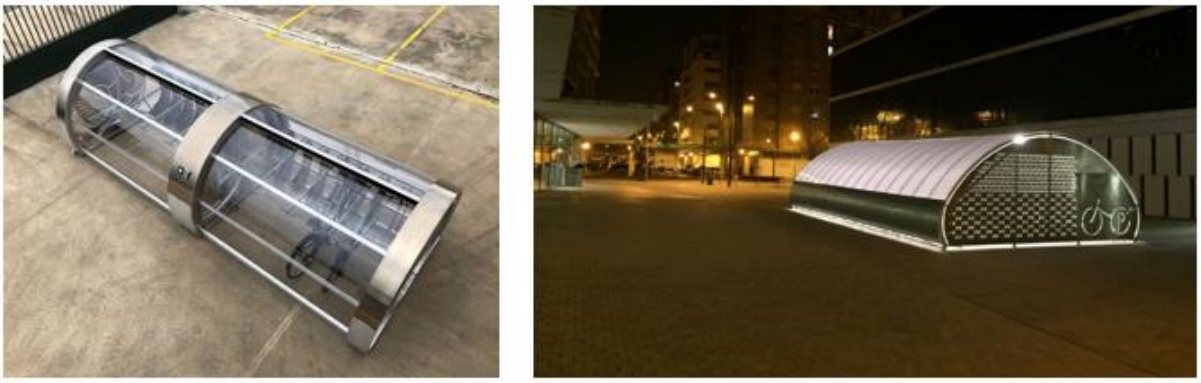


Figure 10: INT bike parking, source: INT

Micro hubs will offer services and resources to make the parcels and goods deliveries more sustainable. They will offer safe parking to bike and cargo bike users, thus promoting green urban mobility and transport, as well as provide electric charging points for electric vehicles. Micro hubs will

be able to be used as standalone micro hubs or combined with: (i) a bike parking, (ii) a bike parking with electric charging, (iii) a bike parking with parcel lockers to collect and/or return items.

The lockers module has 12 connected doors (one per parcel locker). Regular users like citizens or logistics companies will use PVerde smartphone application to open the doors and pick-up or leave parcels and goods.

1.3.3 TIMELINE OF DEVELOPMENT

Lockers are still in the design phase, in cooperation with **Getafe** and **Logroño** municipalities to find the most suitable characteristics, depending on the operators who will use the hub, the volume of flows and the final users' needs.

The **micro hub** is meant to be installed on Thursday 7th or Friday 8th of March in Getafe. Up and running phase, with testing, will start during the first 15 days of March by activating all systems (access, lockers, charging points).

During the test phase INT will collect information and data regarding users, goods, parcels, logistics use, etc. In coordination with Getafe Municipality, there will be a promotion among local shops and business to explore collaborations and heavy testers.

2 FUNCTIONAL DESCRIPTIONS

2.1 MICRO-CONTAINERS AND AGGREGATORS

Micro-containers and aggregator solutions are developed by **FLEX** with the objectives of facilitating the handling operations of freight. To be adapted to different kinds of flows, micro-containers can take different forms.

The first solution is a **protection for European pallets already loaded**, to facilitate the inclusion of pallets on open air vehicles like barges or bikes by protecting them from the elements or theft. Two approaches (Figure 11) will be explored in depth, depending on the use cases that emerge. The first approach is a **lightweight solution** based on the principle of a pallet cover, adaptable to load heights. The second approach is a **rigid solution** providing a higher level of security, but which is more complicated to handle on loaded pallets.

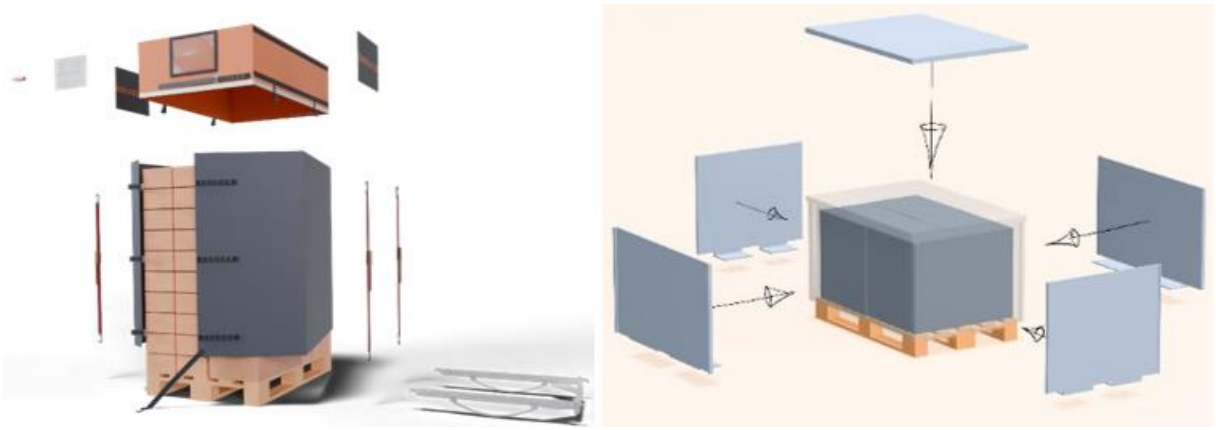


Figure 11: first approach on the left, second approach on the right, source: FLEX

The next solutions propose **micro-containers for parcels or fresh goods**, to relocate parcel delivery round preparation to logistics platforms which have the appropriate sorting tools and surface areas, and thus limit the need for built-up land in city centres for round preparation (Figure 12).

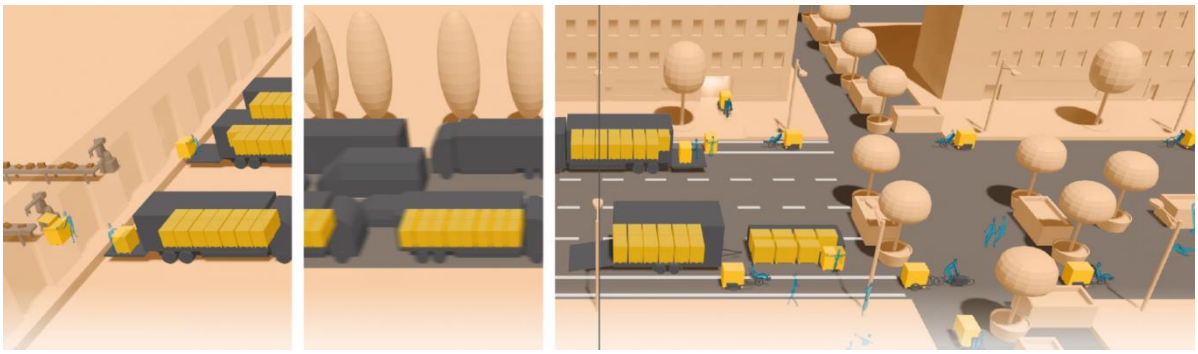


Figure 12: micro-containers for parcel visual, source: FLEX

Because FLEX has already developed solutions of this type, the proposal is to test the **parcel container** (Figure 13) and the **Roll O'City** (Figure 14) if relevant with the use cases defined in the Living Labs. The Roll O'City is a **container for temperature-controlled transport** in the form of passive containers (no active cold generation integrated). They can also be tested according to the LLs' use cases, and be the

subject of technical optimization with, for example, the integration of temperature monitoring tools, etc.

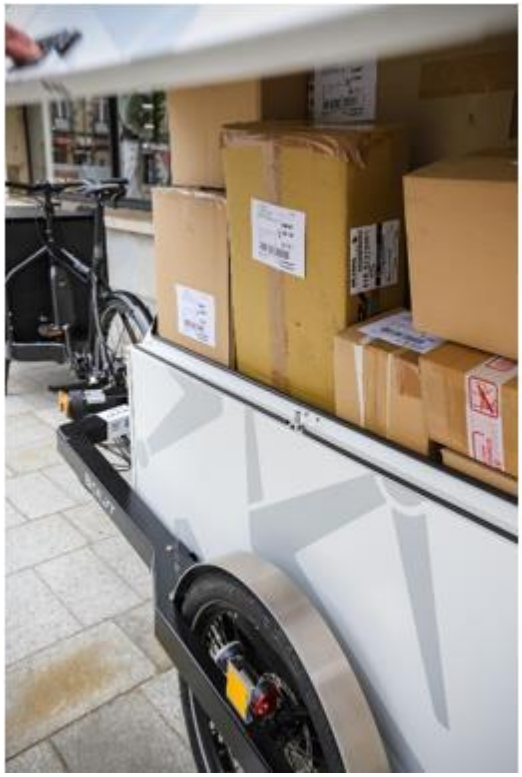


Figure 13: Parcel container, source: FLEX

Figure 14: Roll O'City, source: FLEX

The finalisation of the use cases details will provide more information on the number and kind of micro-containers needed and their application in the logistics chain.

Another interesting point is the **aggregation system solution** to optimize the **transshipment of several micro-containers at once** as part of a multimodal logistics chain (particularly in the case of open vehicles such as ships). The **aggregation system** is still under discussion because for now (therefore no visual are available). The use cases definition in **Nantes** and **Logroño** will not use multimodal chains,

so the aggregation of containers is not an added value. The only use case using a multimodal chain is Hamburg, but DHL already has its own supplier. Alternatively, a mobile logistics hub in the form of a van trailer could be tested to facilitate the transfer of prepared goods from the stakeholder's warehouse.

Maintenance and security

Micro-containers require **regular maintenance inspection**, depending on the frequency of use to increase its lifespan. A **technical manual** and a **maintenance checklist** are provided by FLEX with the micro-container. The equipment is under the legal manufacturer warranties and **for 24 months** can be sent back to FLEX if some manufacturing failures are discovered. Otherwise, the operator or a specialised partner can take care of the maintenance.

Moreover, **no specific training** is needed to use this type of equipment. On the **security** norms, the draft European standard EN17860 currently under discussion will provide a framework for safety standards relating to the use of this equipment.

2.1.1 ICT TOOLS FOR MICRO-CONTAINERS

The ICT tools to support the micro-containers of FLEX aim at implementing the following functionalities:

1. **Consolidation support**, giving the possibility of linking the items with the container, or the container with the cargo bike, or the logistics units (e.g., a pallet) with the cargo bike.
    - Exploiting a mobile app by NGS, it will be possible to associate the container (and its tracker) with the goods to be consolidated on it, reading their barcode.
2. **Tracking, tracing, and monitoring** the goods on the container, supporting proactive optimisation and fact-based decision making.
    - Having the list of items consolidated on the cargo bike, it will be possible to provide added value information regarding their position, their delivery time, and evaluate the way they are handled (e.g., for perishable goods, monitored in terms of temperature). Such information can be used to proactively optimise the delivery process and to enable fact-based decision making.

Micro-containers could be used to consolidate, thus, to evaluate the functionalities of the Smart Boxes, detailed in section 2.1.1.1 The Smart Box.

2.1.1.1 The Smart Box

The smart box is a reusable asset equipped with an IoT device capable to monitor and identify (and in the future, to track and trace) the asset itself as well as the goods consolidated in it. The solution can be seen as an as-a-service smart box for last mile shipment. The objective of such equipment is to implement a secure and reusable box, reducing the usage of disposable cardboard boxes.

The security of the box is guaranteed by the following three characteristics:

1. It is based on SecurBox[6] (Figure 15), developed by UTILPLASTIC[7], an NGS partner. It is a practical and secure container based on a special material capable to highlight tampering attempts. It supports security locking system and the possibility of being sealed.
2. It can be sealed with an identified plastic seal (Figure 16), where each seal is identified with a unique ID and can be associated to a shipment.

[6] https://www.utilplastic.it/en/products/securbox-en/
[7] https://www.utilplastic.it/en/

3. It is equipped with an IoT device capable to: (i) identify the asset, (ii) detect its status (open/closed), (iii) monitor the goods consolidated in it. Currently, this device is the Teltonika Eye Sensor (Figure 23), but we aim at implementing a much powerful battery-less device for the special purpose.

Figure 15: The SecurBox, source: NGS

Figure 16: Example of seal, source: NGS

The solution is thought to be completely managed by the sender, who can rent a box, and with a mobile app can:

1. Identify the asset, associating it to a shipping code (GSIN code[8] in the GS1 coding[9]),
2. Consolidate the goods (GTIN[10] or SSCC[11] code in the GS1 coding) inside of it, creating a logistics unit (SSCC code in the GS1 coding),
3. Associate a seal, scanning the barcode.

At the end of this process, the magnetic sensor on the Eye Sensor device detects the "Box closed" status and, through the app, notify the start of the shipment, as well as special handling limitation for the goods (e.g., range of temperature in case of fresh chain), notarised in an SLA. The box periodically notifies messages regarding the box, real-time detecting SLA violation and tampering actions. On the recipient side, the reading of the codes of the box, of the seal and the "Box open" status will notify the Proof-of-Delivery.

This solution could be tested in **Hamburg** (in the **barge** leg), as well as in **Nantes** consolidating it with the **Micro-Containers**. Possible additional tests could be performed by **NGS** exploiting test shipments done exploiting traditional couriers.

2.1.1.2 Components

Each container will be equipped with the proprietary tracker (Figure 17), capable to implement monitoring functionalities (with on board sensors as well as collecting from other IoT devices), gather **position and time information** (through on board GNSS module), and dispatch remotely such an information exploiting mobile connectivity.

[8] https://www.gs1.org/standards/id-keys/gsin
[9] https://www.gs1.org/standards/id-keys
[10] https://www.gs1.org/standards/id-keys/gtin
[11] https://www.gs1.org/standards/id-keys/sscc

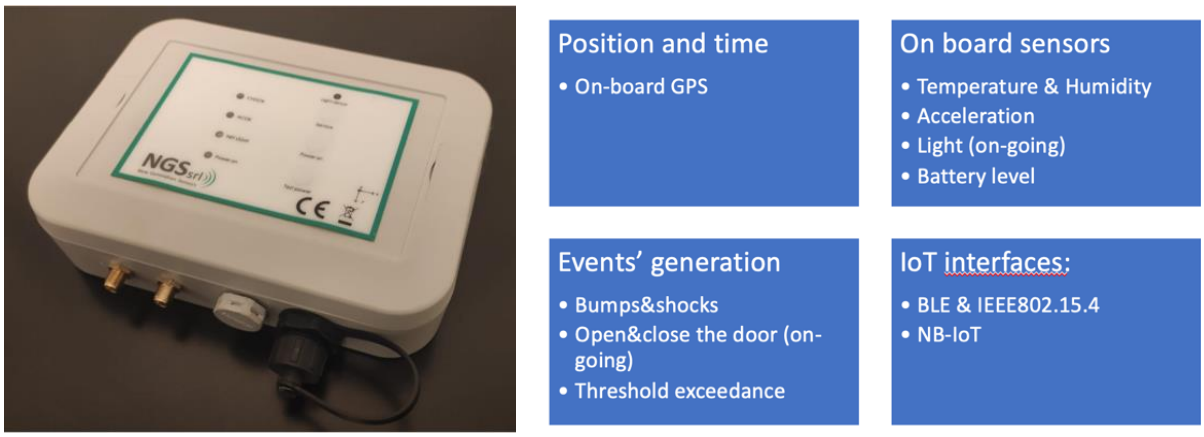


Figure 17: NGS tracker and characteristics, source: NGS

The mobile app will be developed by NGS to be installed on handheld devices as well as on mobile phones. This will oversee reading barcodes or QR-codes to support both the consolidation and the characterisation activities (interacting via Bluetooth with the weighting system – see section 0), as well as to dispatch this information through the mobile connectivity.

2.1.1.3 Timeline for development

The NGS tracker is under production and ready to be installed. It will be equipped with a rechargeable battery capable of sending data at 0,1Hz for at least one day. The app development will start in March 2024. **ICT tools will be ready for deployment by the end of August 2024.**

2.2 TricyLift cargo-bike

The TricyLift cargo bike is not developed as part of the project but deserves its own section in this document as it will be used in two out of four LLs. The TricyLift is developed by **FLEX** to be easy to handle and **perfectly adapted for containerization**. It is **113cm large x 255cm long** and has an empty weight of 70kg. The TricyLift can **load up to 200kg** thanks to the Lift system, patented by FLEX and have a 250W power capacity. The materials used for the TricyLift are **mainly steel**, and small parts of aluminium and plastic. It is not yet known how many TricyLift will be used in the DECARBOMILE use cases, and in which operational conditions.

Figure 18: visual explaining the adaptation of the Lift system on the Tricy, source: FLEX

The cargo-bikes are equipped with a **lithium battery** to allow them to have 20 km (with a full charge) of autonomy. They are powered by electricity and will be charged overnight at the logistics service provider location.

Maintenance and security

This type of equipment needs **regular maintenance inspection**, depending on the frequency of use to increase its lifespan. A **technical manual** and a **maintenance checklist** are provided by FLEX with the cargo-bikes. The equipment is under the **manufacturer's legal warranties for 48 months** and can be sent back to FLEX in case of manufacturing failures. Otherwise, the operator or a specialised partner can take care of the maintenance.

On the **security matter**, the couriers have to pass a short training (demonstration on how to use the equipment by FLEX) to learn the best practices and the safety measures to respect. A draft European standard, the EN17860, is currently under discussion and will set safety standards for the use of this kind of equipment.

2.2.1 ICT TOOLS FOR CARGO BIKES

The ICT-tools for cargo bikes involve the realisation of components for their **tracking and tracing**, as well as the development of an on-board **weighting system**.

2.2.1.1 Tracking and tracing tools

Regarding the **tracking and tracing** of the cargo bikes, two different scenarios are foreseen:

1. Tracking and tracing the vehicles to collect frequent data to charact**erise the route to optimise it.** This approach foresees the integration of a **tracker** on the cargo-bike as depicted in Figure 19.
2. Monitoring features to **evaluate the status of the perishable goods during the trip**. This approach foresees the integration of a **tracker** and a **beacon** on the cargo-bike as depicted in Figure 20.

Regarding the tracker, two options can be considered: the battery powered one (the Teltonika, TAT100, see Figure 21) or the cargo-bike supplied (the Teltonika FMB930, see Figure 22). The beacon will oversee measuring **temperature, humidity, bumps/shocks, open/close doors** (see Figure 23).

Figure 19: Tracking and tracing a cargo bike, source: NGS

Figure 20: Tracking, Tracing and Monitoring a cargo bike, source: NGS

Figure 21: Battery powered tracker (Teltonika TAT100), source: NGS

Figure 22: Teltonika FMB930, source: NGS

Sensors	Temperature Humidity Movement Magnet detection
Scenarios	Temperature tracking, Mobile objects tracking, Door status monitoring, Management of heavy-duty vehicles, Goods tracking
Sleep mode	Hibernate
Configuration and firmware update	EYE APP

Figure 23: Teltonika Eye Sensors and characteristics, source: NGS

In the **Istanbul LL**, the proposed ICT tools aim at the **optimisation of the delivery operations as well as the implementation of fleet management policies**. The LL implementation has been delayed because of the import problems of IoT devices based on mobile connectivity. In fact, each mobile

device (i.e., its IMEI code) equipped with a SIM card must be registered at Technologies and Communications Authority (BTK) by MIGROS. Three devices (i.e., FMB930) are already provided, and the other ten will be provided as soon as possible to have a system ready for the end of **March 2024**.

For the **Logroño LL**, the main objectives of the implementation of the ICT tools are:

- **Tracking and tracing** the goods and the transport means during the delivery operation,
- **Monitoring the goods** considering various parameters as, for example, T/H, open/close the door, etc.,
- **Extracting features and meta-data** to characterise the services as well as to enable fact-based decision making,
- Harmonising the cooperation among the logistics city stakeholders.

The Logroño LL is the most advanced in terms of integration. In fact, the DHL data collection campaign has already started. In the following figures (Figure 24, the main results of the data collection (at 0,1Hz) and processing are provided. Particularly, the results are focused on the analysis of the stop-time of the courier, trying to understand the most efficient delivery paradigm in an historical town as Logroño.

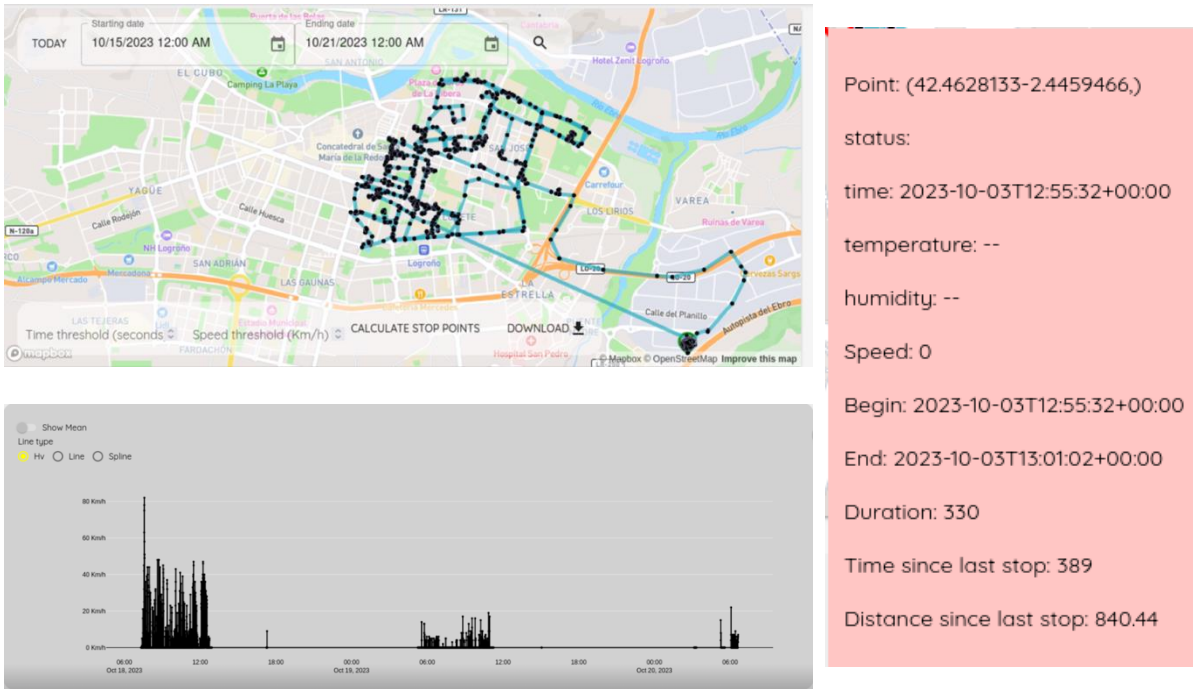


Figure 24: The data collection in Logroño, source: NGS

2.2.1.2 Characterisation tools

Together with **FLEX**, **NGS** is evaluating the feasibility of a dedicated **on-board weighing system** based on load cell technology. Particularly, it is being analysed how to integrate load cells on the FLEX solutions. This dedicated system will be controlled with an embedded system developed by NGS capable of retrieving the weight, visualising such information in a screen, and interacting with a mobile app in charge of linking the weight with the container/loading unit identifier, thus dispatching the data remotely. On the other hand, the device could be equipped with GNSS and mobile connectivity components to directly track and trace the cargo bike. The weighting system is under feasibility analysis.

While the ICT components can be implemented exploiting the NGS devices and competences, the mechanical parts must be evaluated by NGS domain expert and by FLEX. If the feasibility study succeeds, it is foreseen to complete the development at the end of 2024.

2.3 ELECTRIC BARGE

The boat designed by **OHB** should be small enough to be able to sail on the inland waterways of the city, but with a powerful engine to support the strong currents of the Elbe. The boat will be 19.9 m long for 4.5 m large (specially adapted for the Hamburg's inland waterways) and will be able to **load up to 25t** of goods. OHB used for the construction only **aluminium**.

The boat should be **electrically powered**, with an autonomy **up to 10 hours of sailing** with calm water and a **max speed of 10 km/h** in the first version. In the Hamburg port area, more speed is needed (up to 13 km/hr), so the propulsion line and powerpack have been adapted. No recharge should be necessary during the deliveries because the boat will be charged overnight (7 to 8 hours of slow charging) at the loading bay by DHL workers (b. d. Grünen Brücke 3, in Hamburg). Some construction works need to be done beforehand on the quays for proper installation of the charging infrastructure. Also, the boat will have **two engines** to be able to sail all the waterways of Hamburg.

Maintenance and security

The electric engine used in the vessel does not need a lot of **maintenance**, but a specific list of **equipment needs to be checked before every departure of the vessel**, to ensure everything is working perfectly. This list will be checked by DHL's workers and includes a verification of:

- The power units,
- The status of the engines,
- The battery pack,
- Loading of the vessel,
- The equipment on board for the crew (lifesaving vests, saving belt),
- The connection with VHF radio for skippers.

Concerning the **crew security**, they will be **trained by a professional sailor** experimented with cargo vessels. This training can take from half a day to three and a half day and will teach the crew the security rules to respect while sailing and best practices to apply when handling freight (theoretical and technical training).

2.3.1 ICT TOOLS FOR ELECTRIC BARGES

In the electric barge scenario, the following services will be aimed at:

- The **logistics service**, in charge of **tracking, tracing, and monitoring** smart containers or smart boxes during the river shipment.
- The **fleet management and monitoring service** for the barge itself.

For implementing such services, a horizontal environment will be exploited, capable of collecting data from different devices and to dispatch them toward the Cloud using the 5G connectivity, following up the findings of the IW-NET project[12]: a multiprotocol gateway capable to collect information regarding the logistics units as well as the barge itself.

Internal discussions are conducted in relation with **data protection and confidentiality** since the GPS tracking is included in the sensors planned.

[12] https://www.inlandwaterwaytransport.eu/iw-net-project/

2.3.1.1 Last mile delivery service: envisioned scenario

The barge equipped with the **IoT gateway** will be capable of managing data from the BLE beacon deployed in the Smart Containers or Smart Boxes (see section 2.1.1.1 The Smart Box), as depicted in Figure 25. The data collected will be dispatched by the gateway toward the Cloud **components geo & time referenced**, exploiting 5G communication.

Figure 25: The logistics service, source: NGS

The main components considered to implement such a use case are:

- **Horizontal gateway**, capable of managing monitoring functionalities too. To be implemented by NGS exploiting proprietary solutions.
- **Beacon** to be installed on the containers and boxes. Based on commercial devices as the one depicted in Figure 26 and Figure 27.

Size	Dia 47mm*15mm	BLE version	BLE4.0/BLE5.0
Material	ABS+Silicone	Protocal	iBeacon&Eddystone
Color	White(Other colors can be customized)	OTA	Yes
Weight	25g (without battery)	Button	1 button
Battery	CR2477(replaceable)	LED	N/A
Battery Life	48 months (Base on Broadcast Interval 1s and TX power 0dBm)	Sensor	Acceleration sensor;temperature sensor, error:+/-3℃ ,-40℃~70℃;
Accessory	1*3M sticker	Buzzer	N/A
Waterproof	IP65	Working temperature	-40℃~+70℃
Chipset	Noridc nRF52 serie	Storage temperature	10℃~+25℃, ≤65%RH

Figure 26: K beacon and characteristics, source: NGS

Sensors	Temperature Humidity Movement Magnet detection
Scenarios	Temperature tracking, Mobile objects tracking, Door status monitoring, Management of heavy-duty vehicles, Goods tracking
Sleep mode	Hibernate
Configuration and firmware update	EYE APP

Figure 27: Teltonika Eye Sensor and characteristics, source: NGS

2.3.1.2 Last mile delivery service: as-is scenario

Currently, a set of devices are already provided to **OHB** for implementation:

- A **preliminary gateway**, capable only to manage **only the logistics**.
- A set of **beacons** (K beacons, see Figure 26), to be improved in number in the future.

The data collection will start when barges will be ready to flow.

2.3.1.3 Fleet management and monitoring for barges: envisioned scenario

The proposed solution is an improvement of what was implemented in the IW-NET project[7], acknowledging its lessons learnt. In such a project, several bottlenecks were found in implementing narrow-bandwidth wireless nodes in charge of managing high frequency measurements. To increase the system performance, a **hybrid and open solution** based on both cabled and wireless nodes will be implemented, as depicted in Figure 28. In such a scenario, a MASTER[13] component will oversee implementing a local application with a graphical interface capable of visualising all the data gathered.

The high frequency measurements are implemented using IoT nodes that behave as PLCs but are easy to configure and equipped with on board processing power, since based on Raspberry PI[14] architecture (i.e., Iono PI[15]). Such an approach will be based on the NGS findings coming from the Tuscan Region Project, IDROSMART[16]. On the other hand, to maintain the flexibility and the non-invasiveness, the exploitation of wireless devices is considered to measure low frequency parameters.

[13] Master–slave is a common terminology for a model of asymmetric communication or control where one device or process (the master) controls one or more other devices or processes (the slaves) and serves as their communication hub. In some systems, a master is selected from a group of eligible devices, with the other devices acting in the role of slaves.

[14] https://www.raspberrypi.org/

[15] https://sferalabs.cc/product/iono-pi/

[16] Only in Italian: https://ngs-sensors.it/en/2022/07/07/idro-smart-soluzioni-avanzate-per-la-gestione-e-il-recupero-di-materia-negli-impianti-di-trattamento-acque-reflue/

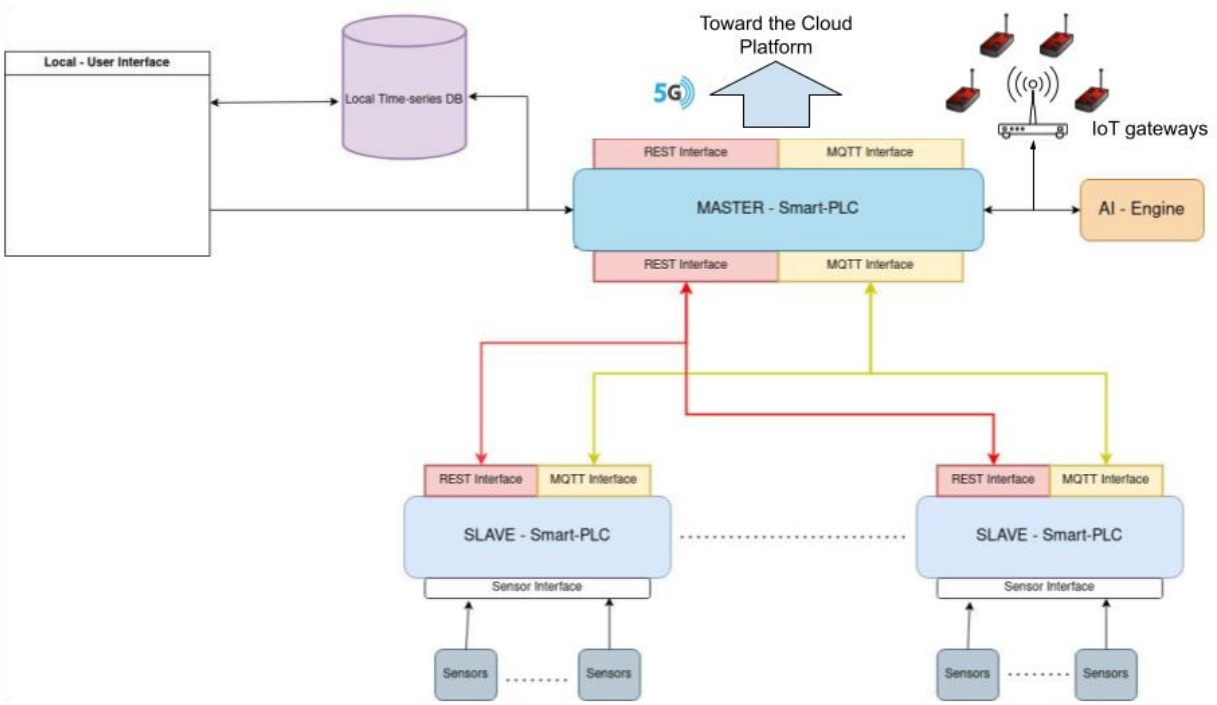


Figure 28: ICT tools for barges architecture, source: NGS

As in the IW-NET project, a variety of sensors are considered for the DECARBOMILE project in order to implement essentially two functionalities:

1. **Fleet management and monitoring**, having real time information about the position and the status of the barge. The monitoring functionality enables added value services for monitoring the barge functionalities supporting predictive maintenance programs. In such a scenario, electric engines (accelerometers), electric control panels (temperature), batteries (temperature), flooding.
2. **Environmental monitoring**, transforming the barge in a moving sensor thus sampling environmental parameters all along the rivers. Considered sensors: pollution sensors (i.e., NOx, PM10, PM2.5) and water temperature.

The main components considered to implement in such a use case are:

- Horizontal gateway, capable of managing monitoring functionalities too. To be implemented by NGS exploiting proprietary solutions.
- Smart PLCs based on Iono PI commercial component (**Erreur ! Source du renvoi introuvable.**).
- IoT wireless nodes, based on SensOne board, by NGS (**Erreur ! Source du renvoi introuvable.**).
- Other commercial devices can be considered.

Figure 29: The Iono-PI, source: NGS

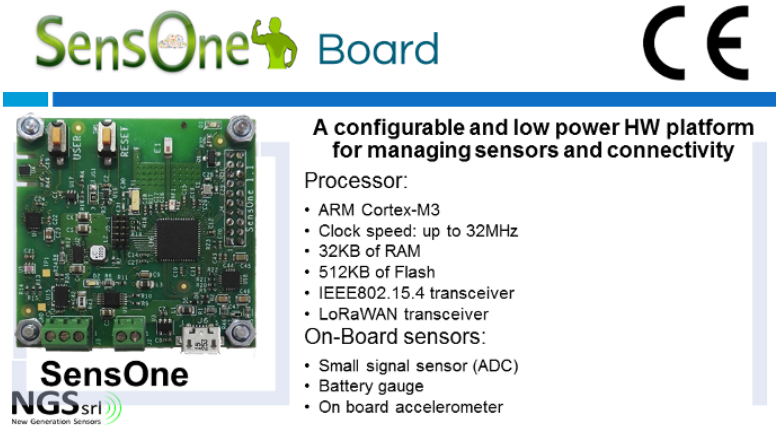


Figure 30: The SensOne board, source: NGS

2.3.1.4 Fleet management and monitoring for barges: as-is scenario

Currently, we are developing the improvements described in the previous section merging the IW-NET and IDROSMART results. We have selected the sensors to be considered, which will be bought and integrated in the following month.

In the following, the list (not completed) of sensors to be installed will be considered.

1. **Water-level.** This sensor aims at real-time monitoring the barge draught to avoid navigation problems as well as flooding (with the risk of damaging the transported goods or the barge itself). This sensor will be acquired and shared at a rate of 1Hz, thus managed with the Iono PI component.
2. **Temperature sensor**. This sensor will be used to monitor the temperature of the water, of the engine and of the battery. It can be sampled at very low frequency; thus, it can be implemented as wireless IoT node.
3. The **pollution sensor** will be capable of measuring an accurate of various environmental parameters, such as particulate matter, volatile organic compounds (VOCs), oxidizing gases, such as nitrogen oxides (NOx), as well as humidity & temperature. It can be sampled at very low frequency; thus, it can be implemented as wireless IoT node, that can be easily integrated on the barge outside zone.
4. The **accelerometer**, used for predictive maintenance purposes, must be capable to collect and process continuously data gathered from the engine at high frequency (e.g., 200Hz) thus it will be managed exploiting the Iono PI component.

5. The **flooding sensor** to understand whether the water is entered inside the barge. It can be sampled at very low frequency; thus, it can be implemented as a wireless IoT node that can be easily integrated in different zones inside the barge.

The testbed is not ready since the barge is still not assembled; thus, the data collection activity has not started yet. **The development will be completed by August 2024**.

2.4 PARCEL LOCKER

Three parcel lockers units will be developed by **INT** and implemented in Getafe (1) and Logroño (2).

Lockers' structure will offer 12 spaces of different sizes (Figure 31: INT lockers, source: INT. The dimensions are 158x152x40 cm. Locker's type distribution is:

- 5 lockers of small capacity (30x30x40 cm)
- 4 lockers of medium capacity (40x40x40 cm)
- 3 lockers of high capacity at the bottom (50x50x40 cm).

The materials used in the construction is mainly **steel** and **aluminium** (Figure 32).

Parcel lockers fulfil the following standards:

- UNE-EN 13724:2003 about "Postal services - Apertures of private letter boxes and letter plates - Requirements and test methods."
- UNE-CEN/TS 17457:2020a about "Postal services - Digital, optional online connected, opening and closing systems for parcel receptacles for home use with free access for the delivery and collection operators and consumers (Endorsed by Asociación Española de Normalización in April of 2021)"

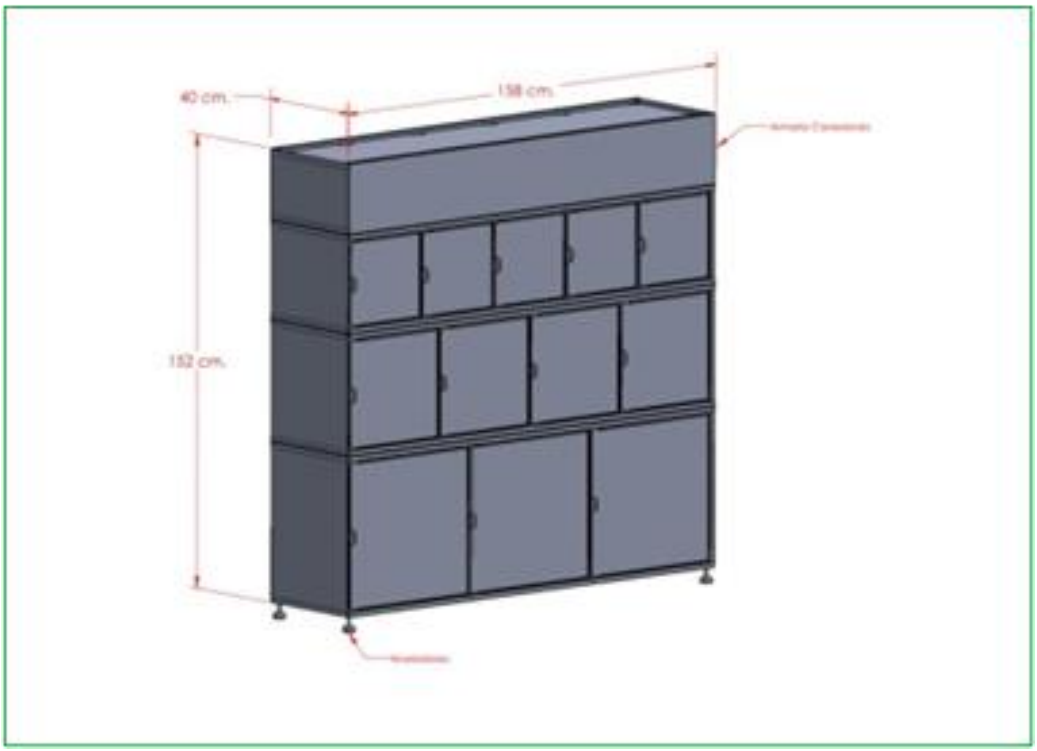


Figure 31: INT lockers, source: INT

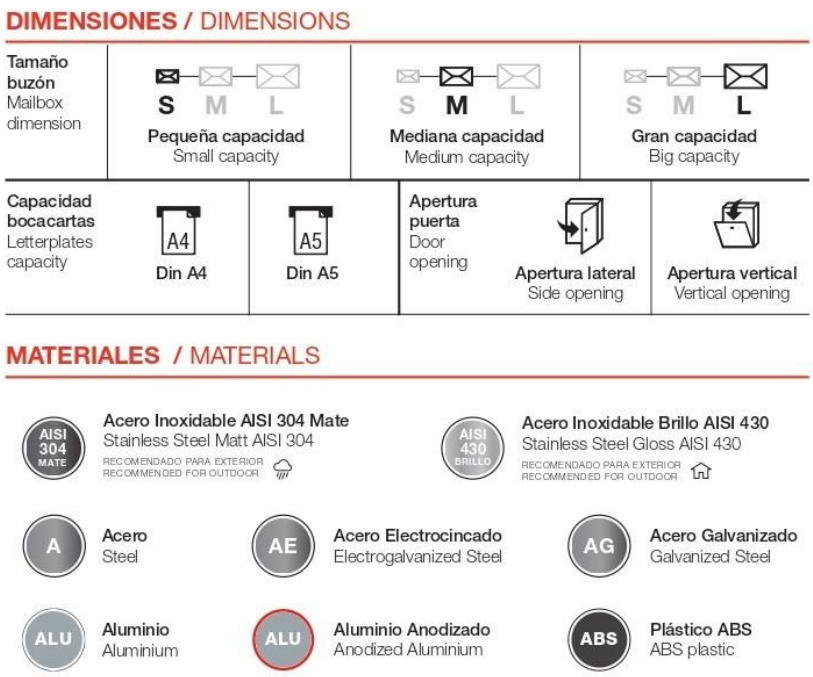


Figure 32: INT lockers dimensions and materials, source: INT

Electricity is needed (standard domestic of AC 230V 50Hz) to supply the parcel lockers which are unmanned and equipped with a controlled access.

Maintenance and security

About **the security of the equipment**, the location of the parcel lockers will be covered with a CCTV camera, to prevent vandalism and theft on the equipment. It is an autonomous video surveillance system, with high quality digital recording, also in total darkness (IR). The recording area includes the interior of the parking lot as well as the access door to it. High-capacity storage, complying with current legislation on video surveillance. The system and video data management fulfil all the requirements about General Data Protection Regulation (GDPR).

A regular **maintenance** of the equipment is needed to increase its lifespan and prevent breakdown, especially with smart lockers connected to the final consumers and with an electronic controlled access:

- **Regular cleaning will be done every month**, as well as regular inspection of the locking mechanisms (an external expertise is recommended).
- **Regular software updates** to ensure accurate tracking and reporting of parcel deliveries will be effectuated more often, as the status of the lockers are shared live with the end-users. Updates of the app will be done every time there is an improvement or a bug fixed.

In the framework of the DECARBOMILE project, these maintenance efforts (micro-hub cleaning and maintenance service) will be provided by INT for the 24 months duration of the implementation.

Finally, it is important to provide clear **instructions** and **guidelines** for users (final consumers and logistics operators) on how to use the locker system and what to do in case of any issues or problems by:

- Writing the instruction guidelines on the surface of the unit or within the interface used to retrieve items and/or placing a number to call if someone encounters problems.

- Providing employees or customers, with best practices through an email or through the app[17].

2.4.1 ICT TOOLS FOR PARCEL LOCKERS

The ICT tool implemented on the parcel lockers is a system to control the access to each locker, allowing only logistics service providers to access the smart lockers and the final consumer to retrieve their packages. This system has been developed by INT and is called PVerde: www.parkingverde.com.

The parcel lockers will be located inside a micro hub structure, building on the secure bike parking product proposed by INT. It has an access control module, called IM, which can connect to PVerde with a bidirectional connection through 3G mobile telephone network, using M2M card. If occurs a failure in Internet connectivity, the system continues to allow access to the micro hub because it stores the data of authorized users in a cache, available offline.

2.4.1.1 Micro hub and parcel management console

INT will be the manager of the micro hub activity, its users, the access, etc. As manager of the micro hub using the Backoffice console (Figure 33), it is possible to:

- View the micro hub location in a map,
- Know the real-time occupancy, with the identification of the bicycle-users / customers that are inside,
- Display data of each user registered in the system (including among others: name, surname, telephone number, email, PVerde app installed (or not) on the phone, credit/debit card configured),
- Display bicycles registered by each user (including among others: brand, colour, description, frame number, photograph, QR sticker code, etc.),
- Set fares and payments per use,
- Visualize events, with the possibility of applying filtering and performing searches (opening attempts and the used access method, user registrations, subscription purchases...),
- Monitor the connectivity of the IM devices installed in each micro hub (like lockers), with the possibility of remote control (e.g. allowing remote opening of the doors),
- View statistics, with the possibility of filtering between dates, and the possibility of exporting the data to Excel (among other data, possibility to consult the number of accesses by access method, estimated duration of each stay, amounts charged, etc.),
- Send “push” messages (they will be received in the PVerde app), to be able to communicate incidents or news.

[17] https://debourgh.com/maximizing-the-lifespan-of-smart-lockers-maintenance-guide/

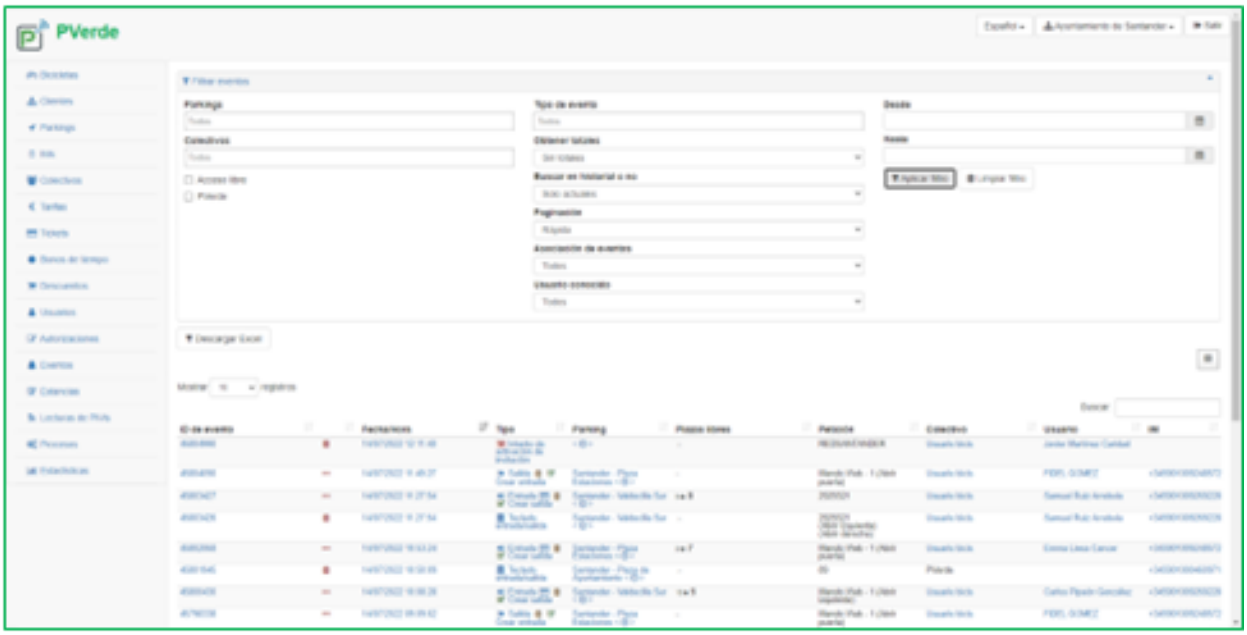


Figure 33: INT console manager interface, source : INT

2.4.1.2 Access to the micro hub

Customers need to be registered as users of PVerde app, INT' ICT tool. The **access to the micro hub** (Figure 34) can be done in three different ways:

1. introducing a personal code in the keyboard,
2. making a phone call to 24h Call Centre,
3. or using the app (Figure 35).

To **exit** from the inside there is a button to open the door.

Logistics and transport companies can use the PVerde app or use an Application Programming Interface (API) provided by INT. In this case a **third way to access** is a code, unique code for only one use (door and locker).

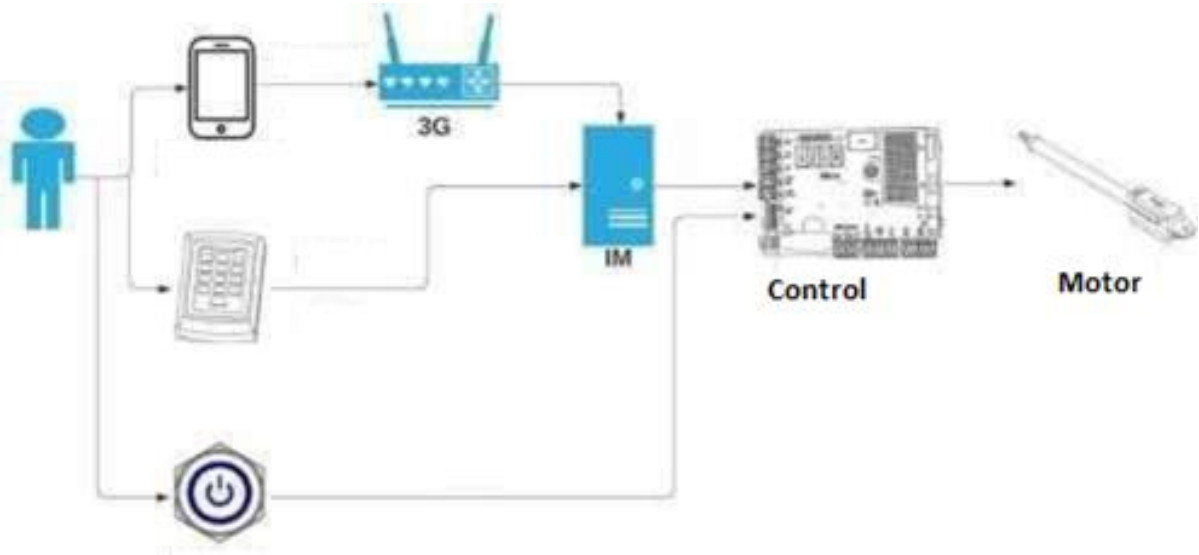


Figure 34: INT micro hub access system diagram, source: INT

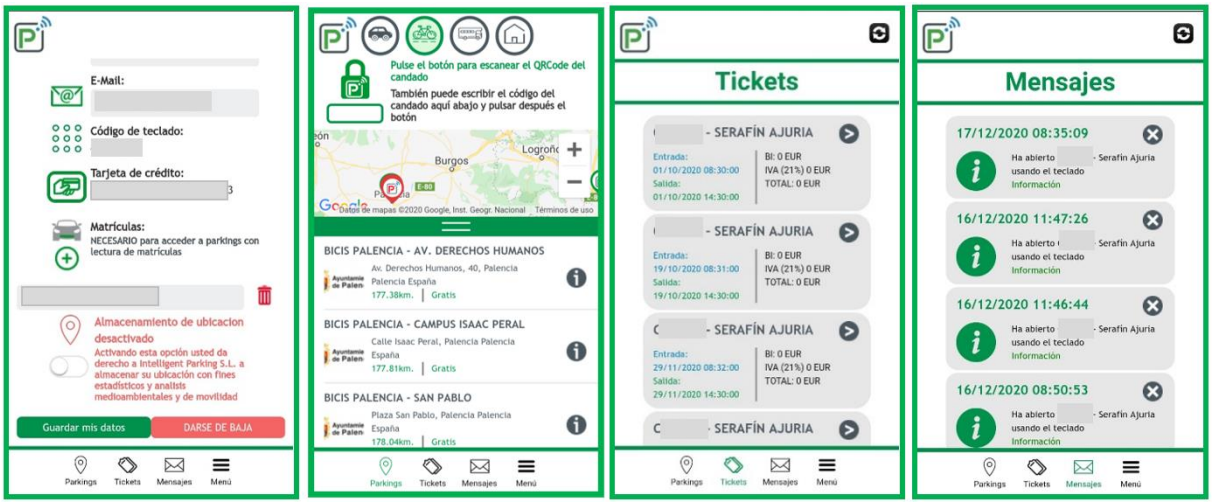


Figure 35: INT ICT tool user interface, source: INT

2.4.1.3 Parcel use management for operators and customers

For the **logistics operators** to use the parcel lockers, the system administrator will grant the different companies access to a dedicated locker (authorization which can be extended to the different workers who would need access).

The **authorised transport companies** will then generate a specific code for each delivery, which will be communicated to the **end customer**. The companies will also be notified via push notification when their dedicated locker is opening.

The security system of the parcel lockers will allow the end **customers** to collect their packages directly, with the generation of specific temporary numerical code for each delivery.

Detailed step by step process of collection/return items by customer or operator:

1. The courier or **authorized personnel of the logistics operator** will have access to all the micro hub lockers, with the PVerde app they can open the chosen locker to **leave the package**.
2. Once the package has been delivered, the **final customer must be authorized and notified** that the package is ready for collection in the corresponding locker. There will be two ways of notification:
    a. From the PVerde Backoffice console, the user, identified or not by their mobile number, will be authorized to open the corresponding locker and the parking door for a limited time .
    b. From the API (to be managed by operators) an authorization will be created with the same data.
3. When the authorization is created, a **numerical code will be automatically generated** to allow the opening of both the micro hub door and the corresponding ticket office. This code will be notified to the end user automatically if we have the necessary data: mobile (SMS and push communication if you are a registered PVerde user) and/or email (Figure 36). If this data is not recorded when authorizing the communication of the code, it will be up to the logistics operator.

Figure 36: INT ICT tool notification, source: INT

4. The customer will have three methods to **open the access door** to the micro hub and the locker (1. provided numerical code, 2. call to the 24h Call Centre from the registered mobile; 3. use the PVerde application).
5. Once the locker is opened, the customer will have a configurable period to open it (e.g. 3 minutes). After this time the authorization will automatically expire. All openings and closings of the lockers and openings of the access door to the micro hub are recorded in the system so that they can be viewed in the Backoffice and immediately notified through the API to the logistics operator. The operator will view all the micro hub events and the user will be able to view their own openings.
6. **Return cases**: The customer may request the return of a product through the PVerde app. This request will be notified via the API to the operator and logged in the Backoffice. Once the return has been evaluated, if it is accepted, an authorization will be created for the customer to access a corresponding locker, in the same way as for collection. When the customer has used the locker, the logistics operator will be notified so that they can proceed with its withdrawal.

CONCLUSIONS

The development and implementation of the electric barge, the parcel lockers, and the micro-containers (associated to the cargo-bikes) within the framework of DECARBOMILE represent significant added value from the project towards the objective of testing innovative and green last mile logistics solutions.

The newly constructed **electric barge** offers a promising horizon for delivery via inland waterways in choppy water with a strong current. Cities such as Bremerhaven, Caen, Terneuzen, etc. are already interested in the results of the DECARBOMILE use case in Hamburg, and in the new design of the electric barge. The **parcel lockers**, strategically placed in Getafe and Logroño, will serve as convenient pickup points for both end consumers and logistics operators, helping for a better consolidation of the deliveries in crowded city centres, making smart use of available space, and fostering greater efficiency in last-mile logistics. Additionally, the integration of cargo-bikes with **pallet-seized containers** presents an innovative approach to parcel transport, minimizing handling operations and optimizing time management during transfers and load breaks at consolidation centres. Together, this equipment not only addresses current challenges in the logistics industry, such as transport environmental impact and related costs, but also paves the way for a more agile delivery ecosystem.

In addition to the innovative equipment developed and linked to the WP3, it is important to highlight the integration of **ICT (Information and Communication Technology) tools** into the use cases definition and their coupling with the hardware developed. The incorporation of open-source ICT tools will assist logistics operators in optimizing their operations and making better informed decisions by providing real-time tracking and monitoring capabilities. By leveraging data analytics and predictive algorithms, logistics operators will indeed be able to define the best delivery routes, minimize idle time, and improve overall logistics efficiency. On the other hand, these ICT tools can also enable municipalities to gather relevant data on urban freight movement, providing valuable insights into traffic patterns, delivery routes, and environmental impact.

As we move forward, continued investment and collaboration in such initiatives will be essential to foster sustainable growth and meeting the evolving needs of decarbonising the logistics sector. In that sense and in the frame of the project, we are also supporting the use of larger electric vehicles (electric light commercial vehicles) by providing insights on the existing charging infrastructure. We undertook an analysis and mapping of the network of electric fast charging stations (see in the ANNEXES) which should help stakeholders make the transition towards less polluting vehicles in their larger fleet and creating a holistic ecosystem which promotes cleaner and more efficient urban logistics.

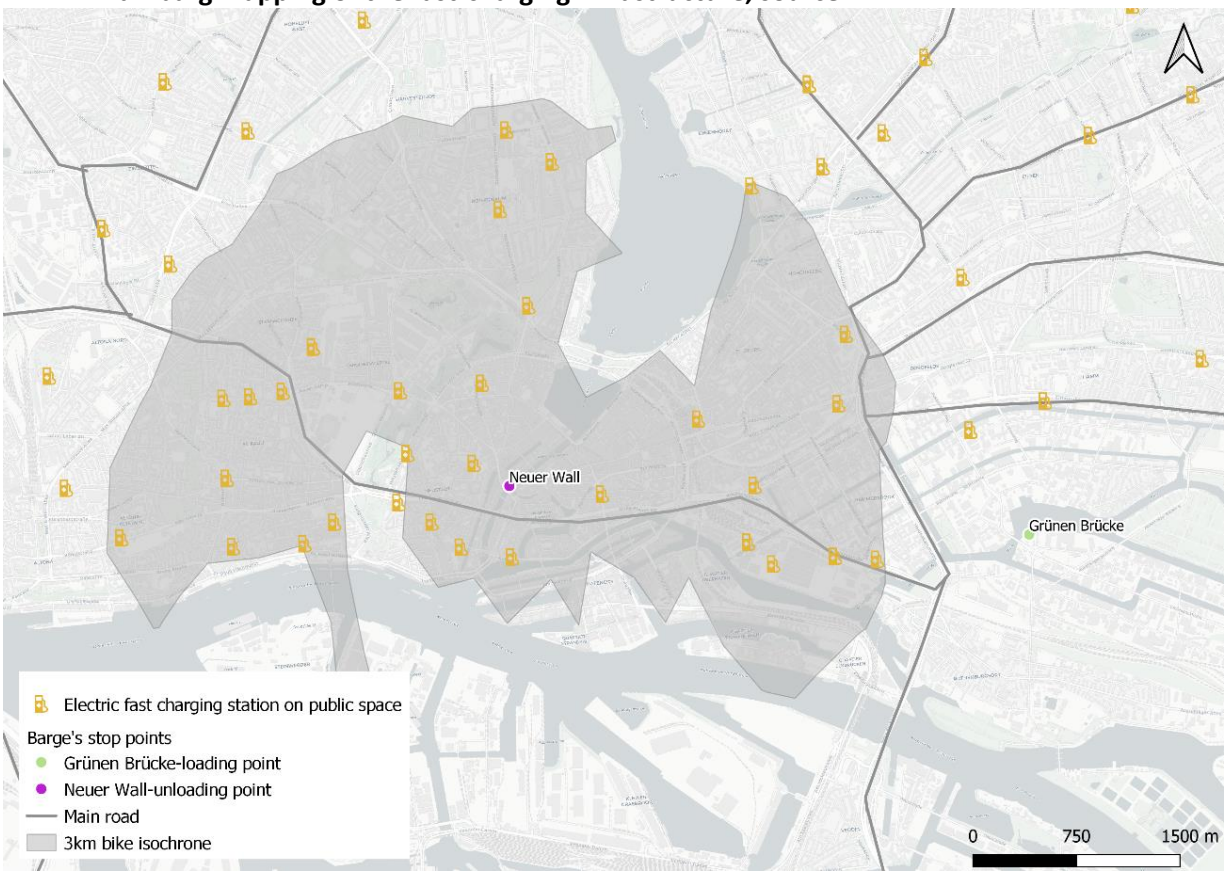
ANNEXES

As discussed in the conclusions, below are presented the maps elaborated in the frame of the T4.2, on the coupling of vehicles with ICT tools in real conditions.

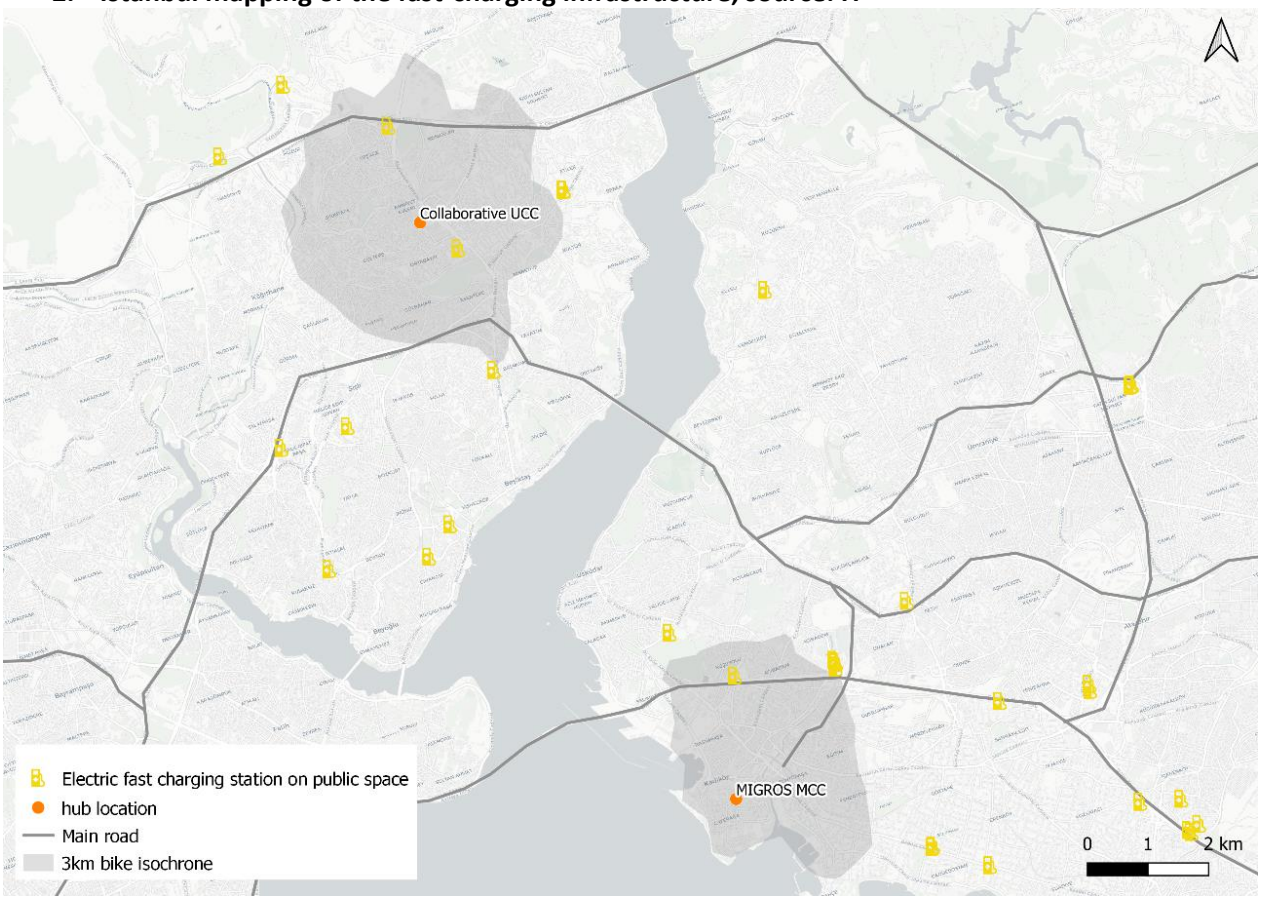
In the frame of the T4.1, a SWOT analysis (Strength, Wickness, Opportunities and Threats) had been conducted to analyse the different alternative energies and multimodal options which could be used for the project. Among the energies analysed (electricity, hydrogen and natural gas), electricity came out as the alternative best fitted for urban logistics.

Building on this work, T4.2 thus conducted a technical study to analyse public electric charging network and map the existing infrastructure in each LL. These maps aim to support last mile logistic operators consider the use of electric vehicles for their operations, in complement to the zero-emission equipment presented in this deliverable. It is also a tool for municipalities to have an overview of their infrastructure dedicated to logistic operations.

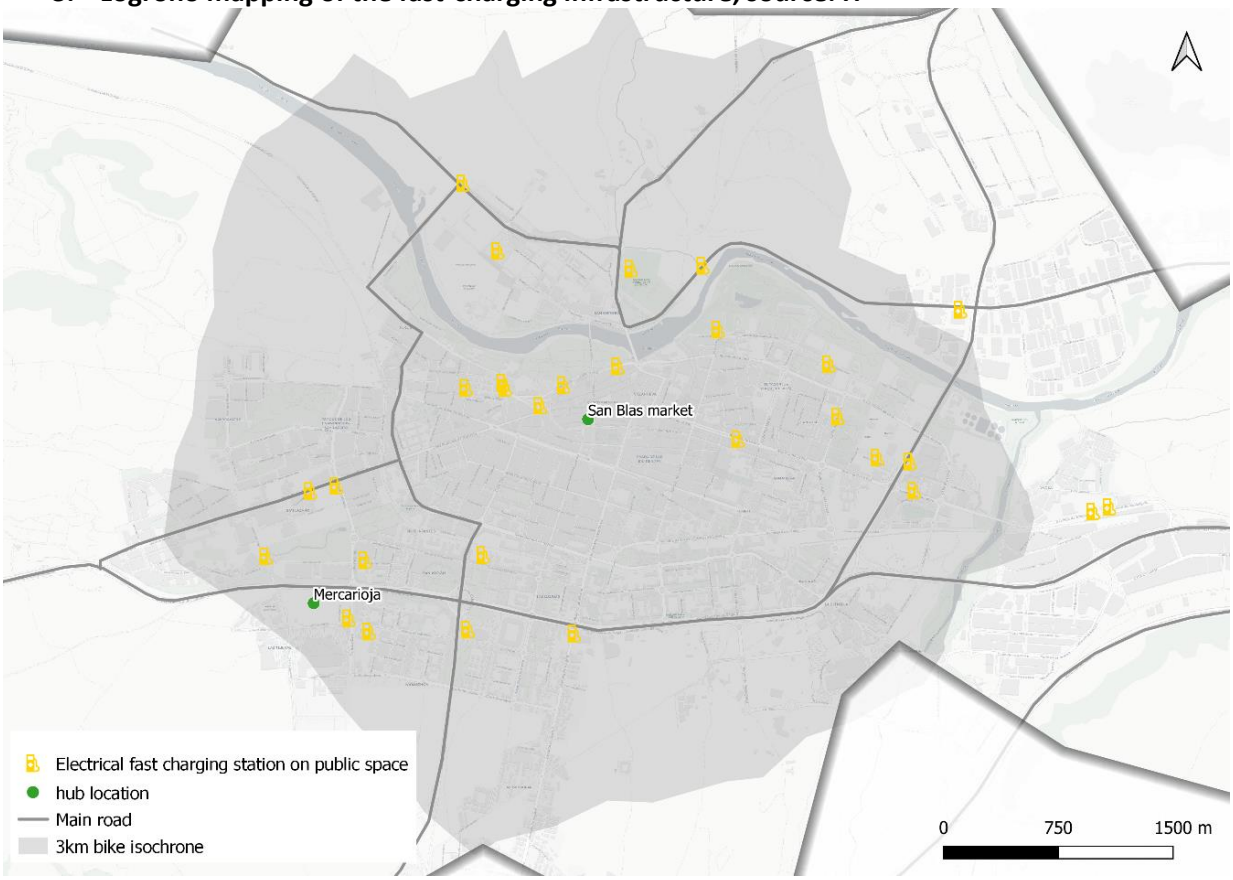
1. **Hamburg mapping of the fast-charging infrastructure, source: IT**



2. Istanbul mapping of the fast-charging infrastructure, source: IT



3. Logroño mapping of the fast-charging infrastructure, source: IT



4. Nantes metropolis mapping of the fast-charging infrastructure, source: IT