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Executive summary

The main objective of this study is to present best practice examples on the implementation of the complex model of industrial ecology for Danube ports.

What is industrial ecology?

Industrial ecology, also known as circular economy is an environmentally sustainable model for managing industrialized/logistic zones. In a closed loop system, activities, functions, and services are connected, instead of being separated from each other. This means that if a manufacturing activity generates by-products and waste as well, besides the main product, by-products and waste must be handled and reused by other units to avoid, or at least to significantly reduce, the volume of pollution. It is not serviceable to have environmentally friendly technology installed in the industrial zone, if other activities are harmful for the biosphere (soil, air, water). Economy and natural environment (industry and ecology) are connected, embedded into each other: industries use natural resources as inputs and during production, they generate outputs that are deposited into the natural environment as well.

Why is industrial ecology good for Danube ports?

Economic actors of Danube logistics promote inland navigation and inland waterway transport (IWT) as the most eco-friendly mode of transportation. Still, the share of IWT in the modal split is the lowest in comparison to other modes (road and rail). Certainly, there are plenty of issues starting with low water periods and infrastructural conditions of navigation through the availability of financial sources to unequal circumstances in competition among different modes of transportation that cause this low share. However, implementing the regime of industrial ecology in a port can contribute to strengthening the picture of being the most environmentally sustainable mode, to attract additional partners and clients to the sector, and to create more and more jobs by adapting eco-innovative solutions. As a result, traffic volume and national turnover on IWT can be risen.

Main results of the report – the best external and internal practices

The best external practices of sustainability in ports searching to attain a successful circular economy are presented below. They can be examined with the key findings of the interviewed DAPhNE ports.

Duisburg

The Port of Duisburg has been developing its infrastructure and has been tending to conform with climate change and decrease impacts of climate change on a local level (Duisport, 2018). There is an open discussion between different stakeholders including individuals, civil society, the science community, economical actors, and public administration. They are involved in the development of a climate change mitigation strategy. The regime of industrial ecology is continuously being implemented in the port.

Port management realized that different spots can provide different ecosystem services around buildings. And, although, German cities are also often in need of sources both financially and in the field of human resources, many of the logistics actors already feel the need of change and work for reaching more sustainable solutions. For example, the following measures are taken to reach the goal of sustainability:

- Photovoltaic solutions are introduced
- Trees and bushes are planted to have cooling effect on the surroundings and filter pollutants
- Environmentally sustainable port functions (such as: protection of water quality, waste and wastewater disposal, economical use of raw materials, reduction of pollutants of all kinds and modern waste management) are connected to each other.

Antwerp

The port of Antwerp has incorporated sustainability into their platform as a mean of reducing their impact on both the society, and the environment, by creating more prosperity and growth, owing to them believing that sustainable enterprises are efficient ones. Serving as Europe's second-busiest container port, its environmental impact is important, which is why it promotes all aspects of Industrial Ecology, like sharing models, so that there is more space for partners to benefit from each other and attract new investments (Port of Antwerp, 2017). It also offers support to entrepreneurs who value working by balancing economic development, people, and the planet.

In the case of Antwerp, their community too is engaged in the movement towards living more environmentally consciously by adopting Sustainability Reports, where they have published the port's commitment to operating as sustainable as possible and working to contribute to the United Nations' 17 Sustainable Development Goals (Port of Antwerp, 2018). They will do so through transforming residual heat to heating, wood chips into biomass, and recycling each other's products, as well as their waste.

Ennshafen

Ennshafen port in Austria invested in noise reduction, water quality control and maintains a district heating service based on biomass processing and waste reusing. In the framework of a project called S-PARCS logistics centres e.g. the Port of Ennshafen are improving their energy efficiency and reduce their emission. This purpose is supported also by LNG terminals in the port serving vehicles with a more environment-friendly fuel.

Vienna

Port of Vienna in Austria has a main role in establishing industrial ecology in Danube ports. Through cooperation with R&D institutes and the city of Vienna, the port invests into green logistics and renewable energy production and the reduction of energy and waste usage

installing windmill and hydroelectric power station and providing the conditions of import, storage and transhipment of biomass for energy purposes. That is the reason the port is a project partner in INTERREG DTP Energy Barge.

Baja

One of the largest public ports in Hungary, Baja managed the installation of the first investment in a Green Port in the country. As an important component of a sustainable, circular economic model, the Green Port serves vessels to deposit their waste, bilge, oil barrels, etc. on an environmentally responsible and safe way.

Based on the expert interview, Public Port of Baja and logistics service provider companies settled in the port also plan to cooperate with the municipality, sewage works and heat plants in terms of investing in renewable energy supply.

Adaptability

Adaptation of the model of industrial ecology in a port, especially large public ones, where *several companies* are settled, is managed by a *port authority* reporting frequently to the *water authorities* and *statistical offices* prerequisites a close partnership and clarified responsibilities among these actors when investing in new technologies.

In case of supportive legislation (regulations, limited administrative barriers), governmental engagement (managing authorities, ministries), investing in environmentally friendly and eco-innovative, sustainable solutions can be beneficial in middle and especially in long term.

Methodology

In the framework of DAPhNE Work Package 5 – Port Development, New Market Opportunities for inland ports are being discovered including these 4 fields:

- industrial ecology
- Physical Internet
- LNG as cargo on the Danube
- container market.

After completing single reports on each field, an overall summary will contain the most important conclusions. Thus, the four reports to have a common structure, DAPhNE partners responsible for certain topics completed basic info sheets, '*onepagers*' on the core of their own field and aims of their analysis and reports.

Based on the general objectives of the study, and after prior consultations with DAPhNE partners on the theoretical background and frame of the research work, a question list was developed in line with the final goals of the New Market Opportunities report. See Annexes.

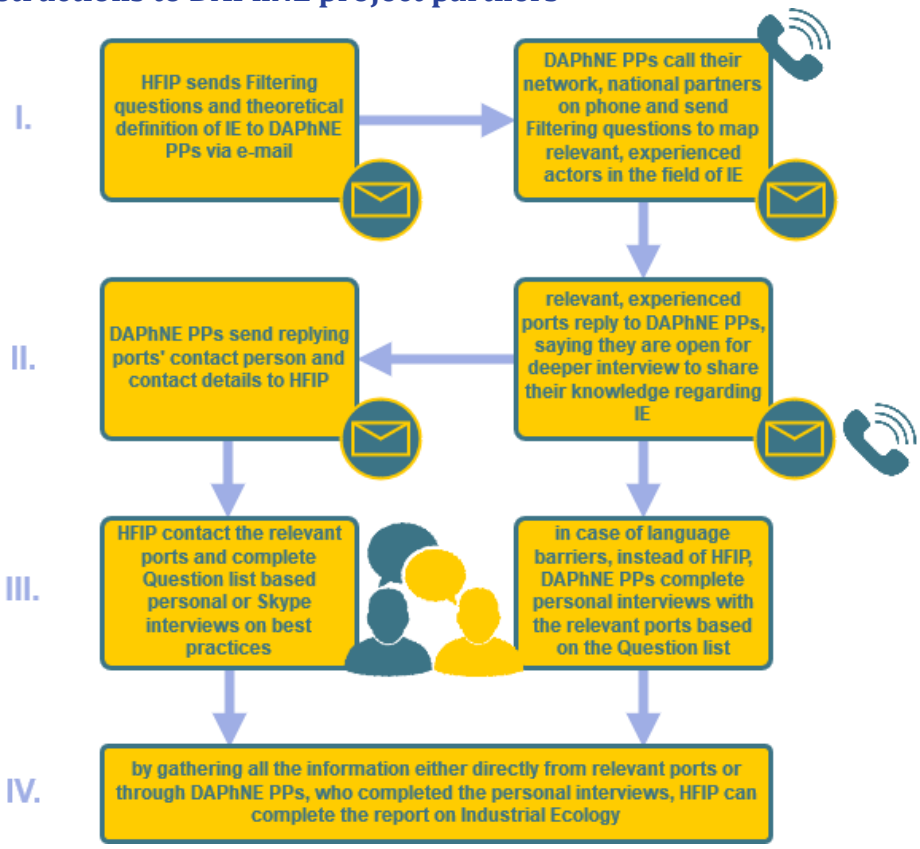
Once the interview guideline (question list) was ready, target groups had to be defined. Port owners, port managers, port authority, port operator companies, shipping companies, and other players in the inland waterway logistics sector in the Danube region were defined as the target group.

HFIP prepared a letter with the methodology and question list attached and with a request for the DAPhNE PPs to help finding relevant, experienced actors among their network (port authorities, management, owners, etc.) in the field of industrial ecology. HFIP asked PPs to contact their national partners on the ***phone*** about this survey then via ***email*** (forwarding the methodology and question list) asking them the following ***filtering questions*** to share their knowledge and experience in the framework of a more complex interview.

- ❖ What kind of environmentally friendly solutions do You have or plan to have in the port?
- ❖ What did motivate You to invest in Industrial Ecology? / What motivates You to invest in it in the future?
- ❖ How much does it cost to manage Your port as a circular economy?
- ❖ How could You describe the benefits for Your organization from managing the port as a circular economy?

Relevant ports are those who could provide detailed answers to the ***filtering questions***, based on which PPs could presume, whether these ports are experts of industrial ecology and experienced in managing their ports as circular economies. Afterwards, DAPhNE PPs helped HFIP completing the personal interviews with their national partners.

Instructions to DAPhNE project partners



Sources of information

- *interviews* with Ports of Ennshafen, Vienna (AT), Baja (HU)
- *Conference* in Nijmegen (NL), 12-13 April 2018: Ports and the City – smart and health
- *studies*, reports

1 Definitions, main areas and background of Industrial Ecology

1.1 Theoretical background

Studies of industrial ecology (IE) clearly state that instead of linear (open loop) industrial process systems, there is a circular one, a closed loop system with loads of feedback with process elements that impact one another. In an open loop system, resource and capital investments move through production to become main product and waste, and there is no problem with that at all, since the production system, technological system, and basically the whole economy is separated from social and environmental systems, in other words: from the biosphere. Meanwhile, circular processes, according to theory of IE, exist due to the fact that society and technology or industrial systems are subsystems of the biosphere, embedded into it.

To create an environmentally, but also socially and economically sustainable regime, policy-makers, market players, and any other stakeholders shall take care of the followings as long as industrial ecology researches focus on:

- material and energy flow studies
- dematerialization and decarbonization
- technological change and the environment
- **life-cycle planning, design and assessment**
- design for the environment
- **extended producer responsibility**
- product oriented environmental policy
- **eco-efficiency**
- **industrial symbiosis**

Fields, which are of high interest for ports because they are mostly related to trade and such ecosystems that ports might have are marked above in **bold**. As a part of supply chains, ports and freight transportation companies shall take care of life-cycle planning and extended producer responsibility from the perspective of IE.

1.1.1 Principles

Logistics and industrialized zones such as ports are not the cleanest and most eco-friendly areas. In the case of having manufacturing activity settled in the port, by-products and waste are generated. In the case of inappropriate storage and loading conditions, and improperly handled goods, dangerous products may pollute all parts of the environment: soil, water, and air. In the case of inappropriate handling of waste, sewage water and bilge water, these are at risk of polluting the river.

Water pollution is mostly caused by the inappropriate loading of oil vessels, the removal of bilge water and leakages (OECD 2013). Oil spills appear due to regular activities, accidents and illegal dumping practices.

The presence of port modifying natural coastal sediment transport causes erosion in soil (OECD 2013). On the one hand, it can produce a degradation of natural impact and harm local biodiversity. On the other hand, it can also barren portions of land that could otherwise be utilized as recreational or productive places.

Besides air, water, and soil pollution; waste, health and land issues; and noise and traffic impacts, land use impacts could all have dangerous consequences on biodiversity.

Speaking of polluting activities, there might be polluting non-activities as well, if non-acting elements are unsustainable from the view of the natural environment. For instance, in such an industrialized zone as a port, there might be underutilized brown fields or rust-belts that must be cleansed, and their functions must be redesigned; new companies bringing new activities could settle there.

In a circular economy, there are no (as few as possible) separated activities and functions. Having solar cells installed on the top of each warehouse and offices and having exclusively electric vans and trucks in the fleet of port logistics companies are very modern and environmentally favoured solutions. However, in the case of deposition of waste into the river or inappropriate loading of dangerous cargo, the port is not a part of industrial ecology.

Therefore, it is important to take care of different activities in the port area. Functions should be connected, waste and by-products not only deposited or *recycled*, but *reused* in a port adapting the regime of industrial ecology.

The regime of industrial ecology is an environmentally sustainable regime that helps ports become greener, eco-friendlier, more eco-innovative, thus creating new jobs, providing various services widening their partners' network, and generating higher volumes in turnover and traffic.

1.1.2 Renewable energy production and or heat supply

Renewable energy is congruent with industrial ecology because it falls within its realm of sustainability. Using different types of renewable energy production, such as solar energy, wind energy, and energy production from biomass, ports can operate without polluting or harming the environment. Solar panels and wind farms give ports an independence from destructive energy supply. Biomass for heat supply and energy purposes is a renewable energy source in case of sustainable forest management. As for heat supply, recycling residual heat to transform it into heating follows the structure of industrial ecology, with no waste being left out, and by-products being used as materials for something else.

1.1.3 Health and land issues

Much of the damage caused by ports is a result of cargo handling operations. Whether it is through handling dry bulk cargo that produces dust, or handling liquid bulk that results in potential leaks, emissions, and spillages, the impact may be direct, as is the case for toxic substances, or indirect, as is the case for organic-rich substances that result in oxygen depletion. Fuel and oil spills cause soil erosion, making the land infertile. This impacts not only the health of the people living, working, and surrounding the port, but it also impinges on the arable land around the port (UK Marine, 2001).

1.1.4 Waste management

Since waste is one of the biggest contributing factors of contamination at ports, port management has developed an array of measures to prevent it from happening. These methods include but are not limited to: a continued education and motivation for port users, as well as port workers; producing waste management plans and provisions of adequate reception facilities; contingency plans for the preparation and implementation of oil and chemicals; and the following of guidelines to prevent non-native species and pollutants from being introduced into the water.

Following industrial ecology's platform, waste management can also take place through the recycling of waste within the companies at the port. Producing and processing ports that house a variety of companies can benefit from resource recovery by using each other's by-products and waste as raw materials. Through adopting this, and focusing on using circular/renewable raw materials, companies manage their waste without harming the environment.

1.2 Practical background

In the frame of the project Danube Inland Harbour Development, under the South East Europe Transnational Cooperation Programme, a report mentioned general factors, such as emission data (GHG, air pollution, noise), building concepts, technologies, and equipment of the port to be collected to estimate the amount of negative impact a certain port has on its natural environment (DAHAR 2014). The study also notices good port-specific practices contributing to a more sustainable environment, showing an environment protecting habit, e.g., by installing photovoltaic panels, solar thermal collectors, planting wind farms and looking for the possibility to introduce LNG as a fuel source within the port area.

It is important to note that for partner ports to apply such systems, their transformation into logistics hubs must be supported by targeted investments facilitating and appropriate economic conditions (DAHAR's policy recommendations). To achieve this, 'same river – same rules' principle shall be accepted.

In the case a certain port community (member of associations or clusters) wishes to develop a scale to measure their ports' impact on the natural environment, or a scale showing 'how

well the regime of industrial ecology is implemented', the referred DAHAR study provides useful information and methodology. However, this report covers only two ports' answers from expert interviews meaning that the critical mass for developing such a quantitative scale have not been reached within the framework of this study.

There have been steps taken to attain more environmentally friendly economic systems in North America as well, but European and Asian port-cities are ahead in the adaptation of the regime of industrial ecology (OECD 2013). The system has been interpreted as a key factor for economic growth. Dutch ports, for instance, mainly adapt industrial ecology for generating businesses and to become more competitive. The port of Rotterdam, in the frame of a project, supplied horticultural businesses with residual CO_2 by Shell in the port site, utilizing an out of usage pipeline. Smaller new pipes were also built-in to have a more than 130 km long distribution network.

Most port cities adapting the regime of industrial ecology and analysed in the OECD study (OECD 2013), are focusing on energy, waste, chemicals, petrochemicals, water management, construction materials, metallurgy and agricultural products, and feeding stuff. In the following chapters, before presenting the key findings of the primary research work, two European ports already implementing different forms of industrial ecology are briefly introduced – as best practice providers.

1.2.1 Duisburg

The Duisburg port (also known as Duisport), located in Germany, is the largest inland container port in the world. Being responsible for 30% of Germany's total foreign direct investment, it juggles 30 million consumers that spend €600 billion, has access to 300,000 companies within a 150km radius (Chan, 2016), and has connection to 80 destinations in Europe, Asia, and 360 freight trains a week (Jochum, 2018).

Duisport holds a sustainable domain that applies to noise and light protection, protection of water quality, waste and wastewater disposal, economical use of raw materials, reduction of pollutants of all kinds and modern waste management. Operating their own solar power system actively reduces the use of fossil engagement, as well as encompasses the responsible handling of resources through suitable work and health safety measures. Duisport prides itself in the embedding of sustainable logistics within their business model, putting an emphasis on linking technical innovation with sustainability, as well as connecting adept use of areas with ecological transportation chains (Duisport, 2018).

The RWE's Supply & Trade (Rheinisch-Westfälisches Elektrizitätswerk), together with Duisport, have jointly committed to creating an infrastructure that is necessary to use LNG (liquefied natural gas) in the Duisburg port. The objective of this implementation is the distribution and utilization of LNG (RWE, 2017).

Due to the possibility of liquefying LNG, a natural gas, its volume can reduce to about 1/600 of regular natural gas volume at normal pressure. This, in turn, makes the transportation of large quantities of natural gas feasible. Although the application of this method does not eliminate all forms of contamination and waste, it is eco-friendlier and more sustainable, since greenhouse gasses emissions are lower than other fuels (RWE, 2018). Considering that Duisport already holds environmentally friendly methods striving to adopt industrial ecology, the application of LNG will strive to promote, as well as use, this alternative gas.

A study investigated operational costs and pollutant emission reduction for a 33,000 DWT tanker ship after LNG implementation. The results exhibited that LNG leads to a reduction of 35% of operational costs and 25% of CO_2 emissions, demonstrating that it is beneficial both cost wise and ecologically (Burel, 2013).

RWE Supply & Trading and Duisport have designated an LNG fuel station as their first step, with the goal of installing a mobile fuelling station so that it can be relocated rapidly and easily if needed. This station will provide for port vehicles, alongside any forward freight trucks (INDanube, 2017).

1.2.2 Antwerp

The Port of Antwerp, in Belgium, is the second-busiest container port in Europe. This port is another great example of a city engaged in transitioning towards becoming more sustainable and environmentally friendly. Through incorporating different programmes: Operation Clean Sweep and Zero Pellet Loss, the Port of Antwerp is striving to eradicate all forms of contamination and pollution in their port. To achieve this, they are investing in the circular economy (Port of Antwerp, 2017).

This port is Europe's largest petrochemical cluster, as well as, the home of many waste processing companies who have a great deal of storage facilities, which sets the perfect scheme to establish principles of the circular economy. Due to the amount of different companies with expertise in different areas operating close to each other at the port, numerous opportunities to, mutually, feed from each other's by-products and waste, as well as cooperatively use the sites exist. Residual heat is converted into heating, wood chips into biomass, and on goes the list for the gamechangers that allow them to work away from their previous linear model (Port of Antwerp, 2018).

Antwerp is the first port in Europe to adapt the "Zero Pellet Loss" initiative. Since this port is the main hub for production, handling, and distribution of polymers (in the form of tiny pellets), it has become a top goal for the whole port community to prevent any waste, pollution or spillage of them – especially into the water (Port of Antwerp, 2017).

Operation Clean Sweep's aim is similar to that of "Zero Pellet Loss" since it also seeks to prevent plastic litter material from getting into the maritime environment. However, since "Zero Pellet Loss" is focused more towards pellets, Operation Clean Sweep focuses more on

eradicating all sorts of plastic litter (Port of Antwerp, 2017). They plan to do so through monitoring this weekly, so that pollution will be traced back to its source through discovering where plastic is found, and action will be taken to clear it up.

Apart from these two initiatives, the sector seeks to also focus on promoting more sustainable production and processing of polymers. Through a consultative platform, they seek to allow participants to exchange practices that make the plastics sector more sustainable (Port of Antwerp, 2018). Not only will plastic pollution be eradicated through these initiatives, but knowledge will be shared that will allow these companies to become eco-friendlier in every aspect and area of their company.

In the case of the Port of Antwerp, it is not only the port that is engaging and committing to pursue a sustainable system of operation, the city too has adopted their fourth Sustainability Report, where they report that the companies that work at the port have vowed to operate as sustainable as possible by contributing to 17 of the United Nations' Sustainable Development Goals (Port of Antwerp, 2017).

2 Results of the interviews

In this chapter, interviewed ports are briefly introduced and the current situation regarding their location, infrastructure, *environment* and *technical background* are shortly presented as well.

Table 1 Core data on the ports interviewed

Basic info	Ennshafen port	Port of Vienna	Public Port of Baja
Name of organization	Ennshafen OÖ GmbH	Wiener Hafen GmbH & Co KG	Bajai OKK Kft.
Name of port/country	Ennshafen Port/Austria	Port of Vienna/Austria	Bajai OKK/Hungary
Year of foundation	1994	1978	1992
Annual turnover (ton)	500,000	6,800,000	800,000
Contact person	Werner Aurer	Rojko Peter	László Nagy
Companies settled in the port	55 companies in retail logistics, manufacturing, waste-industries (feeding stuff, wood, stone/soil, metal, agricultural, paper products	120 companies	4 companies handling agricultural and wood-based products
Quay length, meter (vertical)	630	-	1380 (444)

Total area (ha)	350	300	21
Berth	2,112	-	1,479+140 and 1,480+900
Terminals	13	4	9
Loading capacity (ton/year)	678,670	-	2,000,000
Container handling (TEU)	314,502	440,000	-
Main activities, profiles	The port of Enns is the largest connected industrial area on the upper Danube More than 55 companies with more than 2,200 employees are settled and doing business in the port area and the business parks Enns and Ennsdorf Trimodal logistics hub linking waterway, railway and road	crane for handling up to 84 tonnes storage boxes, bulk cargo warehouses with 44,000 m^3 capacity, raw material warehouses with 3,000 m^3 capacity, outdoor storage space GMP+ certified conveyor belt system, excavators, dredgers and wheel loaders may be used according to individual requirements loading silo for bulk cargo unloading gutter for bulk cargo wagons weighbridges, rail connection	all kind of port and logistic services loading/unloading ships, barges, trains, trucks (all kind of goods, except hazardous goods) loading/unloading special sized and weighted goods, warehousing, storing bonded warehousing, (for bulk goods as well) ware receipt giving container handling, repairing and depot all kind of customs services, customs clearance

		loading/unloading of cargo to or from trucks, railway wagons and ships transhipment of big-bags by truck, rail and ship loading of silo trucks container storage capacity: 8,000 TEU container overhead cranes (lifting power per overhead crane: max. 45 t) transshipment platforms for block trains modern motor pool container handling and storage 120 block trans per week trading, repair and cleaning of containers trucking and customs service 4,000 m2 area for handling heavy cargo at Albern handling of loads of up to 450 t in regular operation RO-RO ramp roofed loading zones	transporting (road, rail, waterway, container, Ro-Ro) packing of goods foreign trade, customs entry point, office for veterinary and plant health inspection and control, Ro-Ro services (ramp, parking), electricity and drink water supply bilge water and waste unloading facility

Source: ennshafen.at, hafen-wien.com and hfip.hu

2.1 Market opportunities – society, politics, legislation, economics, institutions

Major findings on market opportunities, societal, political, legislative, economical and institutional frameworks are presented in this section based on the interviews.

Many aspects influence market opportunities when investing in industrial ecology and, in general, eco-innovative solutions in inland ports. Based on the expert interviews completed in spring 2018, we can state, that the most important components are labour force, supportive legislation and governmental pressure for creating environmentally sustainable industrial zones and working environment.

Due to the very broad variation of industries in the business parks of Ennshafen port, for instance, all kinds of professions and expertise are necessary. From feeding stuff production to container handling at the container terminal and cargo handling companies each level of profession according to the industry is needed. Management, administration office personal, cleaning staff and crane driver must be all responsible for the natural environment when making business decisions, or when completing operational works.

Due to the very high standards concerning measures regarding industrial ecology in Austria, these measures are basics in industrial regions such as the one surrounding Ennshafen port:

- Noise protection measures in the port
- Permanent improvement of water purification, water surface, sludge sump quays
- Technical advancement of infrastructure for the rapid processing of customer related processes to avoid congestion in the city
- Development of business models to reduce traffic in the port-city
- Enabling the construction of renewable energy plants
- Networking through an urban mobility lab with decision-makers from the port-city to develop innovation in the green logistics sector

Taxation is not tailored to develop circular economies neither in Hungary nor in Austria, but there are granting opportunities concerning noise reduction and measurements regarding industrial ecology on a very high level in Austria. National grant agencies are supporting these measurements (e.g. KPC – Kommunalkredit Public Consulting, SCHIG – Schieneninfrastruktur-Dienstleistungsgesellschaft mbH, AWS – Austria Wirtschaftsservice Gesellschaft, CEF – Connecting Europe Facility etc.)

There are several development projects going on with the involvement of companies in Ennshafen port and the port management as well as e.g. S-PARCS in the framework of Horizon 2020 as well as LNG development.

In the framework of an INTERREG DTP project ENERGY BARGE, Port of Vienna plays a key role to become a biomass logistics hub providing a perfect location for port logistics companies and R&D institutes dealing with energy biomass as a renewable energy source.

S-PARCS project – Envisioning and Testing New Models of Sustainable Energy Cooperation and Services in Industrial Parks aims to develop *'a sound concept for reducing energy costs and consumption in industrial zones, while increasing renewable on-site energy production at the same time'* (CORDIS 2018).

2.2 Attractiveness of the market

The market that industrial ecology represents creates an investment climate for developing and providing innovative services. In a circular economy, companies can work together which increases efficiency and profit, leading to potential investments.

The market attracts businesses with less environmental fees in case of support from the state and with a cooperative atmosphere, where companies can use each other's by-products as raw materials.

In the following, the key findings concerning sustainable solutions and establishment in inland ports based on the expert interviews are presented. Austrian Danube ports interviewed have been benefitting from running their ports as circular economies. Good public relations have been created resulting cost reduction. Emissions have been decreasing too. Investing in IE and having a well-developed renewable energy supply, as well as utility networks, influences companies' business decisions to choose the ports of Ennshafen or Vienna as their location to settle, as was discovered in the processed interviews.

In case of Baja, there are initiations to become a more eco-innovative and environmentally friendly logistics hub, however, without governmental support and administrative barriers, major investments are expensive and not beneficial only on a very long term.

2.2.1 Raw materials from waste deposited in the Baja Green Port

There are two operating green ports in Hungary – Budapest and Baja (the one in Budapest was designed based on Baja Green Port) and there will be a third green spot developed in the Public Port of Győr-Gönyű. However, the legislative framework ruling the operations and management in Hungarian ports is not satisfied when looking at German practices.

In Germany (a non-DAPhNE-partner country), fuelling vessels pay environmental product fees. The *polluter-pay principle* serves to charge whoever purchases gasoline and pollutes the natural environment so that the German government can support inland ports (green ports) that collect used oil, waste, etc., as a compensation for providing eco-innovative services, which can be more expensive due to investments in the beginning. Environmental product fees guarantee that vessels can deposit their waste for free at green ports. In Austria, where a mobile system is applied, special ships collect waste, bilge, etc., from barges and vessels when

floating with them for a while on the river (5-10 km). See also project WANDA mapping business opportunities on collecting waste from ships (KTI, 2010 and DoRIS, 2017).

Waste collector companies provide a certificate to the vessel depositing its waste, bilge, and used oil. Based on operational hours, the amount of waste generated aboard can be calculated: it is documented in a 'green book' controlled by police and at state-borders.

Figure 1. Baja Green Port is in fact painted green

Source: Súgóparti Hírek (2017)

Bajai OKK Kft. (port authority) has been operating a Green Port within its territory since 2011. It is the first floating establishment in Hungary for vessels to deposit their bilge water, oil, and waste gathered on board.

In Budapest, in front of the University of Technology and Economics, there is another 'green island': a military boat was reconstructed to receive social and household wastes. It is also a mobile system docking onto ships, using a Ro-Ro facility. However, the green island in Budapest is more geared towards serving passenger cruise ships, while the green port in Baja is firstly serving cargo vessels.

Either the shipping company or the port operator company settled in Baja inform the port authority Bajai OKK Kft. on the waste deposition. Baja Green Port is equipped with oil filtering facilities; therefore, oil barrels can be deposited there as well. In the case of maximum 5% water concentration, shipping companies pay for depositing used oil to Baja Green Port. In the case of more than 5% water concentration, Baja Green Port pays when receiving waste.

Used oil, accumulator, oil boxes, nylon, acids, cooking oil, iron and steel, packing materials are loaded onto pallets. Elevator takes these materials from the port, and a forklift takes them to the processing plant. There are special units for processing acidic and alkaline materials.

Port operator and logistics service provider companies settled in the Public Port of Baja deposit dangerous waste annually, communal waste monthly and the generated general waste and by-products weekly. Latter one is due to the main activity of Baja port-based companies handling grain and agricultural products.

If cargo ships deposited 10-20 cubic meter of waste, used oil, etc. on a weekly basis, a mid-scale plant could be operated. However, the floating establishment was designed for handling two vessels per week, therefore, this volume is unreachable.

2.2.2 Agricultural by-products-based biomass plants for heat and electricity

There are 35-40 tons of dust generated in silos in the Port of Baja that could be fired in a biomass-based unit. Pellet's calorific value is almost reaching wood's, meaning that this amount would be enough to supply heat for the office. Furthermore, dust is a biodegradable pollutant. Nevertheless, administration processes are complex and expensive to receive all the licenses and permission to operate such an establishment. Not implementation costs, but administration costs exceed possible benefits. Therefore, the entire amount is thrown out as waste. Moreover, transhipping dust is a paying service.

It means, transhipping waste costs millions of Hungarian Forints, but it is still not as much costly, as the installation of a biomass boiler requiring a HUF 100 million one-time investment returning in 5 years plus additional costs.

Another solution in the fields of renewable energy utilization and eco-innovative waste management could be bioethanol production from sewage water deposited by passenger cruise ships.

However, due to administrative barriers, complicated and inflexible legislative framework, there are no exact steps made so far by port operators in Baja, but their activities are in line with regulations, certificates, and permissions.

Secondly, compliance to environment protection issues require permanent staff, an environmental engineer to be employed and additional costs emerge.

Although, there is a specialist engineer already at the Green Port regularly contacting the fire department, civil protection, disaster management etc.

One of the grain handler companies in the port of Baja (ÁTI) has an old boiler with a 15-meter high chimney for seed processing. In order to correspond to environmental regulations, stainless steel liners need to be constructed inside, costing HUF 1 million to have a biomass-based plant. Besides, this investment would return in 5 years taking only operations in consideration. Joint investment with other depos and inland ports into a mobile pelletizing,

equipment transportable on truck could be also an option, since in the case of Port of Baja, it does not generate enough energy biomass raw materials for heat production. Sunflower seed flames well, though its ash content is too high.

2.2.3 Wood-based biomass plants for heat and electricity

Carpenters and lumberyards could become raw material suppliers, however ÁTI requires more complex technology. A sustainable model would be based on wood briquet, if Gemenc Forestry provided cheaper wood. Though, taking current prices into account, investment would return in 15 years, which is quite a long term. It would be worth investing in such a plant, only if it operates in 8 hours a day throughout the entire year, which is hardly manageable due to lack of stock.

2.3 Challenges and opportunities

Almost all the companies settled in the Port of Baja, generate enough waste and by-products to switch from gas supply to a renewable based one. However, there would be numerous challenges ensuing:

No matter, what scale of plant would be installed, the above mentioned administrative barriers and unsupportive legislative framework makes the implementation hardly possible.

It would be a more complex operational and maintenance system, since supply service needs to be provided as well as it requires further permissions and certificates. When it comes to settling a larger scale plant, it would be worthwhile to construct it in an industrial park, draining current and future companies from the port.

Once a new public utility supply system has been constructed, the entire port could be supplied. Moreover, supply would exceed demand; thus, generated heat and energy could not be utilized.

Sewage waterworks in Baja and its area shall be contacted; cooperation with port operators, by-product and waste generators and heat plant should be facilitated by either the port authority company or the Municipal Government.

Decades ago, there used to be a state-owned oil company (present MOL Zrt.) that had bunkers under the ground in the port. During the socialism epoch, environmental protection was not in focus. As a result, oil pollution abatement is still being managed. Rehabilitation is in full swing again since vertical quay construction works has been going on and oil lenses must be cleansed before reaching the river through the soil in large volumes. The biggest oil company in Hungary, MOL Zrt. manages rehabilitation works where subcontractors take samples from the ground monthly and pumped out oil is transported. As a result of common goals, ongoing construction works of the vertical quay in the port are co-financed by MOL Zrt.

2.4 Cost structure and available infrastructure

Although, it is hard to define an exact sum to invest or run a certain port as an industrial ecology, especially because partners have different socio-economic backgrounds resulting various policies and market conditions making ongoing regimes impossible to compare, partners still could estimate the expenditures of managing their ports in a more environmentally sustainable way. Waste Water management of vessels in Ennshafen port, for instance, is the responsibility of an external disposal company dealing with waste water. Costs have to be paid by the vessel owner.

Current infrastructure in Ennshafen port is built up on heat supply and export for district heating. Raw materials in the supply chain include small amounts of waste products and the recycling procedure is managed by different companies settled in the port. VFI GmbH (vegetable and fat processing company) produces press cake out of oil press later used by feeding stuff producer company Fixkraft. Wood chips for energy purposes and other industrial usage are exported outside the port area as well.

The model of industrial ecology can only be profitable in practice, if prices are market oriented and affordable. The port needs to have producers and processing companies settled with affordable prices in reusing and supplying.

Overall sum in the last five years invested in **industrial ecology** and environmentally sustainable solutions in Ennshafen port is approximately **0.5 million euros**. The port is benefitting from noise reduction, water surface treatment measures and measures against neighbourhood problems and authorities since new legal notifications and constraints became part of policies.

The overall **annual** operation cost of Baja **Green Port** is HUF 1-1.5 million i.e. **~ EUR 3,000-4,500**.

2.5 Success factors

Lessons learned for Danube ports based on the expert interviews and external examples presented in the beginning of the report, in the followings we present recommendations to take care of when developing the model of industrial ecology at a certain Danube port. In other words, these are recommendations with a complex check list that Danube ports should meet to implement the regime of circular economy.

2.5.1 Port owner, port management company's way of thinking, attitude

Depending on the certain port's size (annual turnover, physical territory, number of tenants and companies settled), port owner and/or management company (whether these two are the same organization) should involve port operators and port users when investing in industrial ecology or coordinate and manage processes. In the case port owner/management company maintains and develops the basic infrastructure (roads and rail, maybe public utility

network as well), and especially if it provides port logistics services (loading, warehousing goods), it could be the lead partner of a joint investment and projects aiming to develop a circular economy in the port. If the port owner/management company deals with business creation, networking event organization, background administration services (documentation of waybills, bill of lading, etc.) exclusively, it should rather focus on facilitating, encouraging and coordinating port operators and port users when investing in eco-innovative solutions and develop port's infrastructure and superstructure.

2.5.2 Company profiles & activities and services, functions to settle, technology

Lessons to be learned from this study are that the most various companies can be settled down in the port area to jointly develop eco-innovative and environmentally sustainable solutions. There are fundamental services manageable nearby port users in any industry e.g. limitation of noise and light pollution; water quality control and improvement are such functions to be carried out nearby any actors, however, it requires special expert engineers or R&D institutions to be hired occasionally (weekly or monthly).

On the other hand, investing in circular economy requires the settled companies and their activities to be able to link. Grain handler companies having large silos, processing cereals generating tons of dust, by-products and waste could technically easily set up agricultural residues-based biomass-boilers. Units for producing renewable energy and heat could be ensuring power and heat supply at least for establishment (warehouses, offices) within the port area. Also, through the cooperation with the local municipality, district heating company and public institutes, the plant can provide power and heat supply outside the port area.

Another solution for implementing a circular economy is a high-level waste management. Reusing and not simply recycling guarantees companies to use each other's by-product and waste. Raw materials for public utility supply within the port depends on what sort of waste and by-product is generated accidently in the port, and in what volume etc.

2.5.3 Legislative framework, political and institutional background

Regardless the technological background, capacities and financial opportunities of a given company or group of port operators, investing in ecologically innovative solutions could not be profitable if expensive administration costs and complicated, unsupportive legal framework makes development impossible.

Waste, bilge, sewage water, used oil disposal at specified ports (see Baja Green Port) need to be free of charge or the service of receiving and handling such materials should be provided on a cut price with national financial support.

2.5.4 Labour market

Depending on the companies settled, services provided, and eco-friendly technologies adapted in the port, specified water, soil and air quality controllers, environmental engineers, certified producers need to be hired in the industrial ecology. Besides, as the model of circular

economy becomes better embedded into the everyday practice and directions of development, in other words, main purpose of Danube ports, training programmes need to be offered for port operators and port managers on how to govern their ports in an environmentally and economically sustainable way at the same time.

2.5.5 Green solutions attracting shipping companies

Investing in eco-innovative, sustainable solutions that are components of a bigger picture, i.e. industrial ecology, effectively increases environmental compliance and the given port's attractiveness to shipping companies. Freight forwarding companies must comply with stringent regulations on the types of fuels their fleet uses when they choose from inland Danube ports (OECD 2013).

2.6 Target audience

As mentioned above, target group to be involved when investing in industrial ecology in a certain port depends on the size of the port, and whether one company manages the port whilst providing logistics services as well, or within a landlord model there are numerous market players and a port owner/authority only responsible for basic administration processes and core infrastructure maintenance (see e.g. Deliverable D 4.2.2). However, core target group jointly shall develop eco-innovative services are

- port owner
- port management
- port authority
- port operators
- shipping companies
- logistics service providers in the port
- producers, port users

Besides, there are several other organizations, companies and institutions to be involved outside the port area but having special interest in the port influencing its local/regional/national economy, such as:

- district heating company
- municipality
- civil society
- freight forwarders on road and rail to reduce the emission of their fleet / switch to electric vehicles
- regional, national government and policy-makers, legislative bodies providing a supportive legislation framework for investing into eco-innovations and environmentally sustainable solutions.

3 Summary

Industrial ecology also known as circular economy is an environmentally sustainable model for managing industrial, logistics zones such as ports. As presented based on literature and external examples from non-DAPhNE partner countries or even out of the Danube region or Europe, there are plenty of practices adapted around the world for running ports on an eco-innovative way in a closed loop system where industrial activities and functions run by companies settled in a port are connected, well-embedded into each other to respectfully reduce the volume of waste and by-products generated and the volume of pollution harmful for air, soil and water. The most critical aspect of this approach is not to have separated environmentally friendly solutions, but linked ones.

Best practices presented are from port cities such as Duisburg (Germany), Antwerp (Belgium), Ennshafen (Austria) and Baja (Hungary).

Duisburg adapts several environmental friendly solutions that as a whole can be identified as a well-implemented model of industrial ecology. The port maintains its own solar power system, manages noise and light protection, waste and wastewater disposal, the economical use of raw materials, reduction of pollutants, measures and controls water quality, operates an LNG-based infrastructure to reduce traditional gas and oil usage, develops technological innovations directly linked to sustainability.

Antwerp being one of the largest ports in Europe has a huge environmental impact, thus it invests in industrial ecology, especially sharing models to provide more space to partners benefitting from each other's activity, attracting new investments. The Port of Antwerp establishes the fundamental conditions for transforming residual heat to heating, wood chips into biomass and producer companies settled in the port are recycling each other's by-products to significantly reduce pollution, emission and inappropriately handled waste.

Among the relevant actors interviewed, Ennshafen port in Austria provided a growing industrial ecology. The port invested in noise reduction and LNG fuelling stations, but its greatest and most complex development is waste reusing and wood chips processing for biomass energy purposes. The port provides district heat supply for the neighbouring public.

Port of Vienna is one of the largest port with 120 companies settled, 5,000 employers and 6.8 million tons of goods loaded annually. The port invested a lot in industrial ecology, especially into renewable energy production. Windmill and hydroelectric power station are installed in the port. The port of Vienna also manages import, storage and transhipment of biomass for energy purposes. A main objective of the port activities is to reduce energy and water use for saving natural resources. Port of Vienna is a project partner in ENERGY BARGE (INTERREG DTP project) dealing with biomass energy. Cooperation with R&D institutes and the municipality of Vienna generates synergy effects, such as the steps to reduce traffic in the city,

enable construction of renewable energy plants, build network through urban mobility lab and create innovation in the green logistics sector.

Baja currently adapts an important component of a waste management logistics chain that should be developed involving further companies depositing their waste and processors reusing waste materials. The Hungarian State financed the installation of the Green Port at the Public Port of Baja in 2011 and in the first years, the port authority received national support for the operation and maintenance of the Green Port, but since, government stopped supporting this eco-friendly service of collecting waste, bilge water and used oil from vessels and barges. The port authority and the interviewed other port logistics service provider companies and grain processors are also open to any fields of cooperation and joint investigation in industrial ecology, environmental friendly technology and sustainable solutions as long as the legislative framework becomes supportive and administrative barriers disappear.

There are internal and external factors either facilitating or making it more difficult for inland ports to invest in industrial ecology or eco-innovative technologies. External factors independent from the port company are

- legislative background - whether regulations facilitate eco-innovative solutions to extend
- labour force – whom to hire, special training/further training, providing relevant information
- market demand – freight forwarding companies obligated to comply ecological requirements (less emission from their fleet, e-charger for vehicles, waste deposition, etc.) seek for inland ports offering such solutions; potential port users and port logistics service providers will choose location for their unit where the port management takes care environmental sustainability.
- institutions – cooperation with companies within and out of the sector, including R&D and academic institutions, public and private sphere

Internal success factors the port owner/port management/port authority company has influence on are the followings:

- critical mass of companies settled in the port to have various activities to technically implement a circular system of material flow and harmonize their interests to jointly finance investments into new technologies

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5 Annexes

Questionnaire / Concept of Industrial Ecology – circular economy

Name of organization:
Name of port/country:
Year of foundation of the port:
Annual turnover of the port (million tons):
Contact person/email:
Main industry/companies in the port area:

I. Market opportunities – society, politics, legislation, economics, institutions

1) What professions/expertise are needed for you in the port?
2) What sort of actions have you done so far and what are you planning to do to run your business in an environmentally responsible way? How can you influence your region to make it more sustainable?
3) What are the typical taxes your port has to deal with? Taxes in connection with environmental issues? Reduced taxes in connection with IE?
4) In what ways politics facilitate IE in your port to grow? Calls for proposals? What is granted?
5) Are you aware of/involved in any projects on the topic of IE? How do you affect it, if so?
6) How do you cooperate with regional R&D institutes, universities, chambers, companies, lobbyists to influence the region's endeavor on sustainability?

II. Attractiveness of the market

7) What are the main industries located in the port (manufacturing, recycling)?
8) What services/solutions/technology were missing before developing your circular economy? What were the barriers limiting to deal with them?
9) What kind of benefits do you expect/have you experienced from running the port as an IE?
10) How does the fact your port invested/is planning to invest in IE influence your partners'/clients' business decisions (e.g. choosing location, using your port services, etc.)?

III. Cost structure & available infrastructure

11) How much does it cost to run the port as an IE? How much money has been spent on recycling, reusing? *How is waste water of vessels handled in your port?* (waste management)?
12) *How could you describe different interests in 'rust belts'/brownfields/under-utilized lands in your port? Who and what would like to do with these lands? (leave it alone; invest in it to implement sth?)*

13) By which mode of transportation do products arrive to / go from your port (share of rail, road, IWW in ton)?
14) Please, describe your current infrastructure concerning circular economy, sustainable technology. How port operators' and settled companies' activities are connected in the circular system?
15) What is the estimated amount that you (or the authority and operators in your port together) would/could invest in environmentally friendly technologies/solutions?
16) What kind of financial devices are available for the port management and for the network of companies in your port to invest in IE?
17) How can the port be profitable by running IE? *Does the port need to have large producers, plants for recycling, reusing each other's by-products?*
18) How much does it cost per year to maintain the port infrastructure and services?
19) How much have you invested in IE? What motivated you to invest in IE? What kind of benefits do you have by managing IE in the port? (taxation, support from government, new clients, etc.)

+1) Do you have any public document, a strategy, a report or press released concerning your eco-friendly activities in the port and its surroundings?