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SUSTAINABILITY AND CIRCULAR ECONOMY APPROACH IN PORTS

How do port facilitate and gain from the implementation of Circular Economy model?

What will be the role of the ports?

Dr Fabio Ballini

7 October 2020

CONTENT

- ➢What is the Circular Economy ?
- ➢The Effect Impact of Circular Economy transition on Ports
- ➢The Impact of Circular Economy transition on Ports
- ➢What are the opportunities and challenges for Ports?
- ➢Copenhagen Malmo Port (CMP): CE case study application of Waste to Energy

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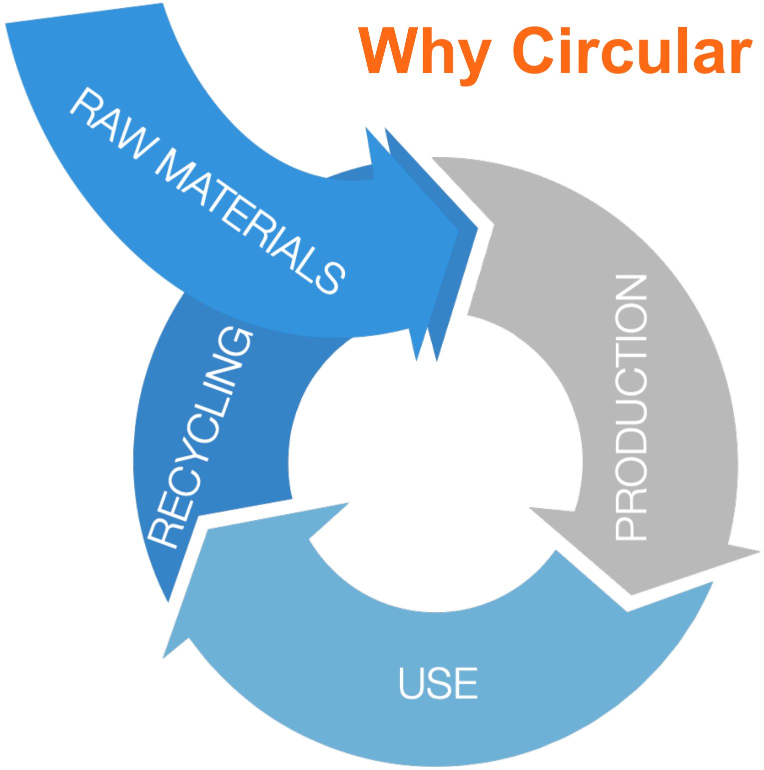
FROM LINEAR TO CIRCULAR ECONOMY



Why Circular Economy?

- The world's population is expected to peak at 10bn in 2050. Our resources, the earth's raw materials, are not limitless. (UN, World Population Prospects 2019)
- Circular economy business opportunities can offer new ways to mitigate these risks to allow your business to grow and diversify.
- In a circular economy, products and materials keep circulating in a high value state of use, through supply chains, for as long as possible.

FROM LINEAR TO CIRCULAR ECONOMY

What is the Circular Economy concept?

In 2013, the Ellen MacArthur Foundation defined Circular Economy (CE) as:

"An industrial system that is restorative or regenerative by intention and design. It replaces the end-of-life concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and business models".

Circular Economy Drivers

Direct potential profit and competitive position for companies.

Societal awareness of the need to increase the sustainability of the economy, which leads to policies to promote sustainability

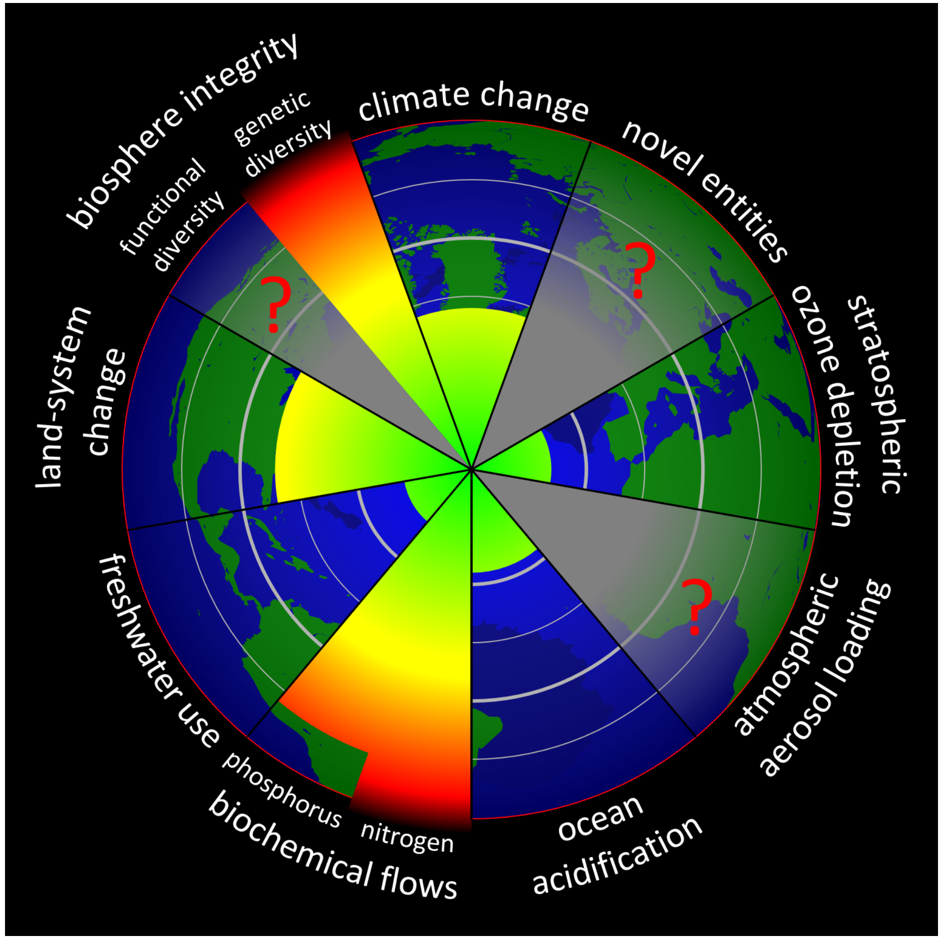
For Circular Supply chains to be fully sustainable, the energy use also needs to be based on renewables.

LINEAR ECONOMY VS. CIRCULAR ECONOMY

- Current linear economy which is "take-make-waste", structured on the extraction of numerous amount of low price available raw materials and also energy, which is about reaching its planetary boundaries .

- This model has not only degraded natural sources **<u>but has also posed extensive damage to the environment and human health</u>**

Planetary boundaries



Source: Science 13 Feb 2015:. Vol. 347, Issue 6223, 1259855

CIRCULAR ECONOMY

The Circular Economy seeks to shift activity from a linear to a circular model by making better use of materials, by keeping materials in circulation through reuse and recycling, **industrial symbiosis** and other efforts to divert material from landfill.

The four principles of a circular economy are:

1) minimize waste,
2) use renewables,
3) study feedback loop to optimize production and
4) maximize the usage value of products (Rizos et al., 2015; Stegeman, 2015).

One goal is to create a circular economy, which is producing no waste and no pollution, by design or intention – not just by re-using and recycling things – but also by repairing them, designing them to last longer

FROM LINEAR TO CIRCULAR ECONOMY

Circular Economy activity and opportunity around the world

- The CE is about expanding the practice of using waste as a secondary resource.
- The CE is also about using intelligent design and engineering to enable products to have multiple lifecycles and be reused.
- Eventually, the CE affects not only waste management policy but also product design standards and extended producer responsibility.

Source: Sustainability 2019, *11*(20), 5837; https://doi.org/10.3390/su11205837

WORLD PORT SUSTAINABILITY PROGRAM

Climate and Energy

Potential topics
- energy efficiency,
- circular economy,
- bio-based economy,
- renewable energy,
- CO2 and infrastructure,
- clean ship incentives,
- deployment of alternative transport fuels

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ESPO POSITION PAPER ON EU GREEN DEAL

On 19 February, ESPO published its Position Paper on the European Green Deal objectives in ports.

European ports are a strategic partner in making the European Green Deal happen

"Around 40% of all goods shipped to and from European ports are energy-related . European ports are crucial nodes in Europe's energy supply network. Energy transition is a real game changer for many ports. **At the same time, the energy transition agenda offers new business opportunities to many European ports** (including production and supply of renewable energy, off-shore renewable energy projects, bio-fuel industry, carbon capture and storage, **circular economy**). Consequently, many European ports are an essential business partner in guiding Europe's economy and society through the energy transition.» ESPO 2020

[…]

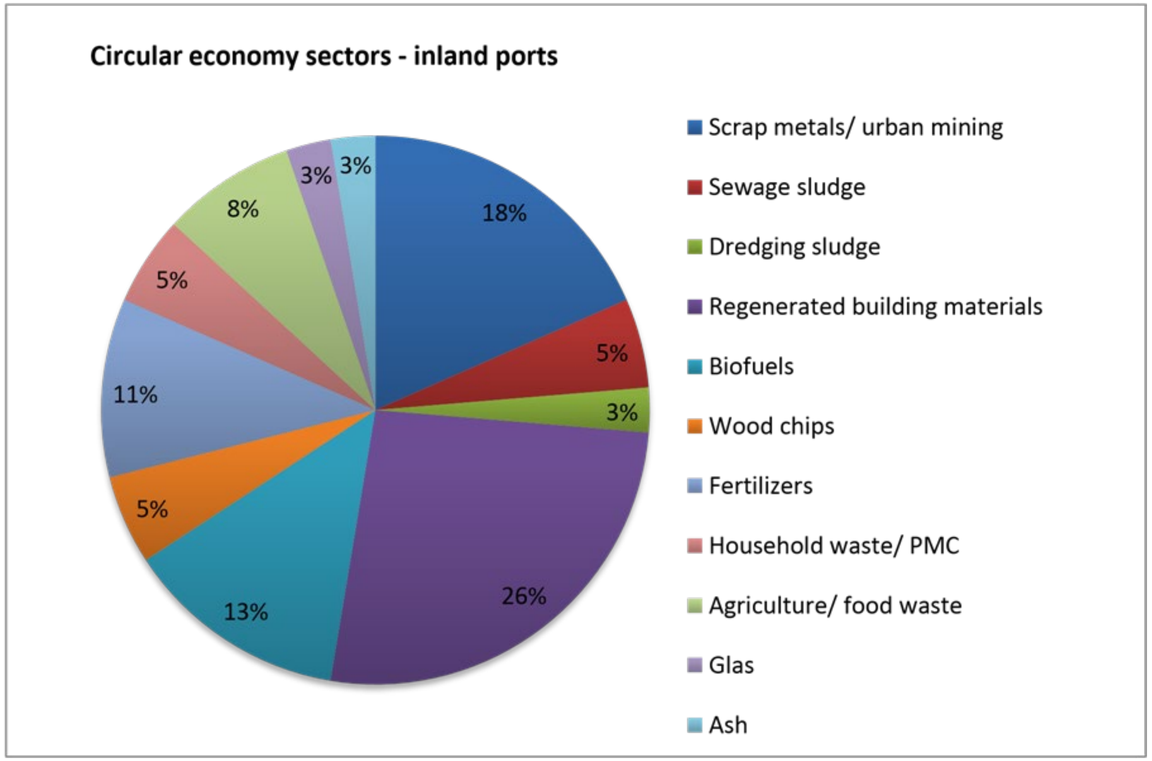
In addition, ports are an ideal location to develop circular economy projects. Both the presence of industry and the proximity to large urban agglomerations make them ideal places to turn waste into products.

THE CIRCULAR ECONOMY AND INLAND PORTS

European Federation of Inland Ports

Inland ports has an important potential for Circular Economy;

- Proximity to cities, industries and the terminals can providers of the supply for the recycling installations.
- Inland ports provide crossing points; between transport modes of waste streams with connections to hinterland and onsite industrial activities and a nearby urban setting and have access to significant quantities of bio wastes, surrounding bioenergy resources, biomass from crossing supply chains and energy from intensive activities.
- Opportunity to emerge circular economy’s business in inland ports to create jobs and profit.



Source: EFIP, 2016

THE CIRCULAR ECONOMY AND INLAND PORTS

European Federation of Inland Ports

MAIN CHALLENGES

- The lack of space;
- Dependency on the final market;
- Lack of enough critical waste mass;
- Negative public opinion to the waste
- Synergy and co-operation between stakeholders

NEXT ACTIONS

- Support for the role of inland ports as intermediate and matchmaker;
- Diminish conflicting regulation;
- Reduce Bureaucracy;
- Change mindset about waste and valorization them more as a resource;
- Increase of knowledge and information about value-added applications of waste resources;
- Promote and incentivize innovative measures;
- Standardization and quality schemes for secondary raw materials;
- A stable and long term investment;
- Harmonized safety requirements and regulatory framework.

CIRCULAR ECONOMY IN EU PORTS

Seaports throughout Europe are realising their potential and several have set out visions for their transition to the circular economy. The bio-based economy is already emerging in a number of ports, and the many initiatives to support this development include the introduction of wind and solar power and the production of biomass and waste-based energy production (ESPO, 2016). Several European ports have already engaged in the circular economy process through regional initiatives and strategies.

Ports	**Existing circular and bio-based economy clusters**	**Strategies**
Rotterdam	Renewable energy cluster	Towards 2030 Rotterdam
Antwerp	E-waste and recycling	
Zeeland	Bio-park	Sustainable development strategy
Ghent	Bio-refinery, bio-park	
Amsterdam	Recycling	Vision 2030 & Circle City Scan

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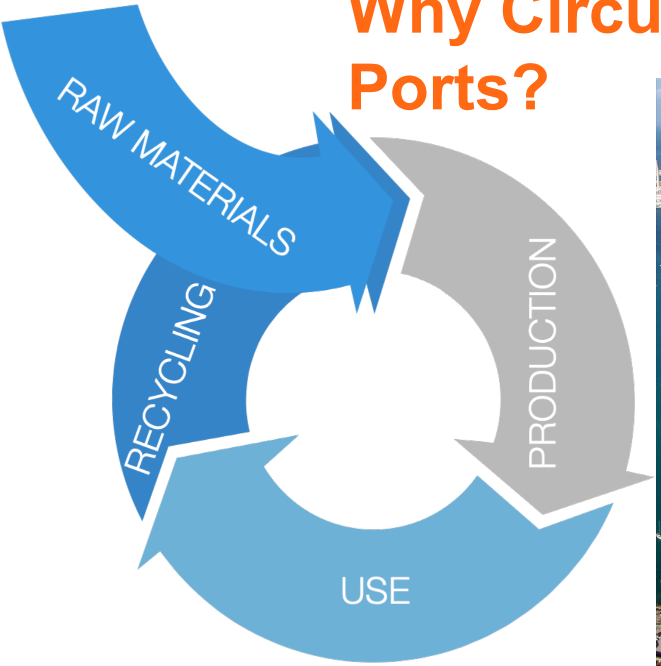
FROM LINEAR TO CIRCULAR ECONOMY

Why Circular Economy in Ports?



- Sustainable port cities contribute to closing the flows of material and energy resources through circularized processes and synergies between stakeholders.
- Opportunities are introduced by circular economy to port cities is to increase the economic benefits from ports while mitigating the negative impacts of port activities on urban surrounding areas.
- The shift towards CE can be a driver in order to protect port businesses and services from market fluctuations and geopolitical risks.
- A factor that facilitates this transition is consumer-preferences that are also shifting away from the ownership of goods and information towards models where they are willing to share information or use of products in closed loops instead of owning them.

CLOSING THE LOOP: THE IMPACTS ON PORT

Specific elements for ports:
The geographical scale of supply chain: **global supply chain** rather then regional, national or local

Steel and Paper

Shipped internationally between source areas and production locations

Glass

More often recycled in regional or national supply chains

The effect of CE on volumes handled in ports

The opportunities CE provides for attracting new logistics and industrial activities to ports.

CLOSING THE LOOP: THE IMPACTS ON PORT

Ports handle a huge volume of non-renewable primary resources.

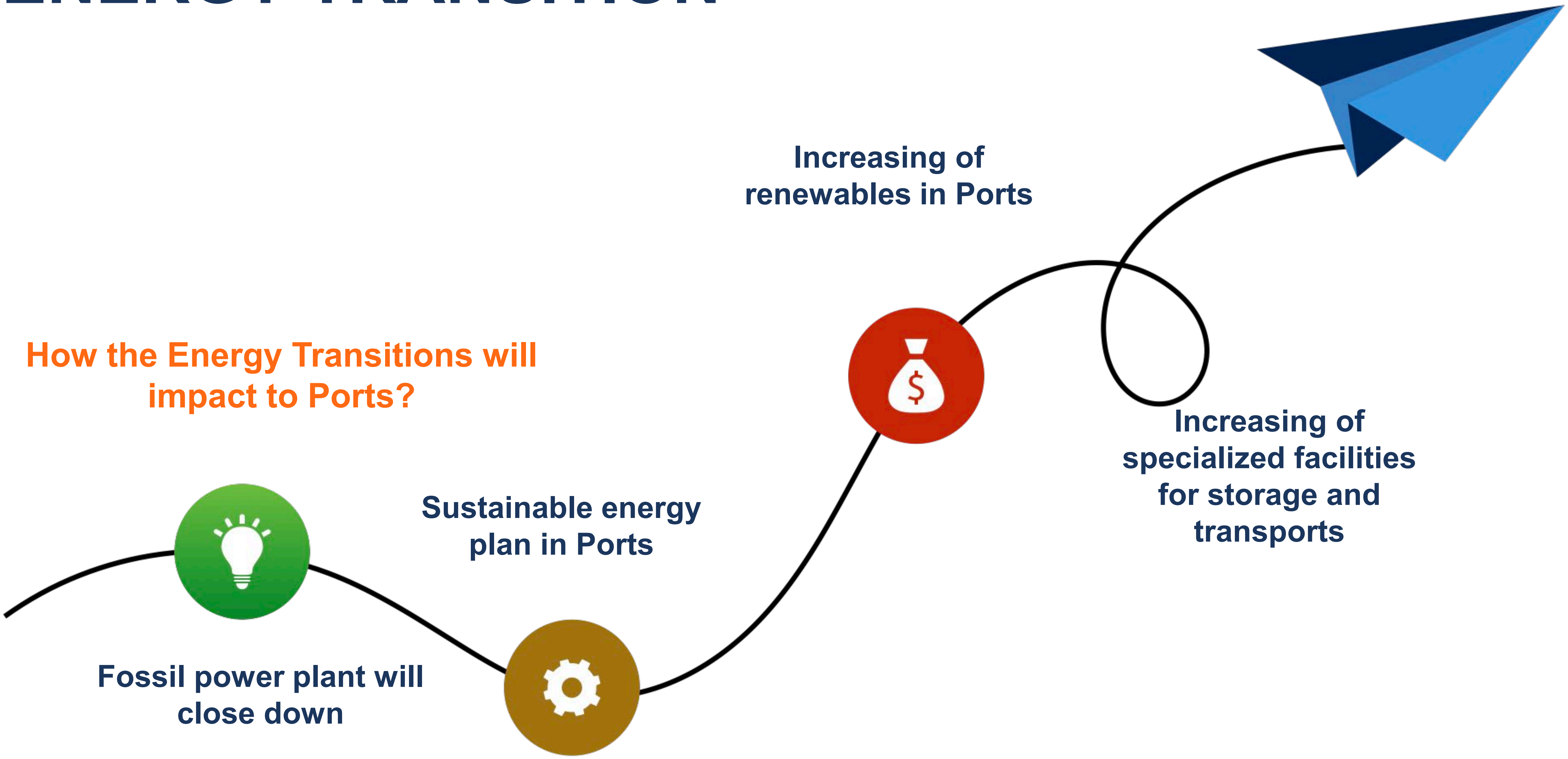
Majority of the remaining (nonfossil) imports and exports are mostly “linear.” A huge part of the remaining volumes handled consists of intermediate chemical products, which in general are not recycled.

Generally the share of recyclables cannot be directly assessed, some major recyclables (waste paper and steel scrap) appear in the commodity statistics.

Source: Peter de Langen et al, 2019. DTU, Denmark

ENERGY TRANSITION

How the Energy Transitions will impact to Ports?



WASTE VOLUME IN EU28 (2014)

TABLE 5.1 Waste Volumes in the EU28 in 2014

Waste	Total Waste	Recyclable Wastes	Animal and Vegetal Wastes	Mineral and Solidified Wastes	Mixed Ordinary Wastes
All NACE activities plus households (million ton)	2.495	235	89	1.796	286
Mining and quarrying	28%	0%	0%	39%	0%
Manufacturing of which	10%	28%	27%	6%	8%
• Manufacture of food products, beverages, and tobacco products	2%	2%	26%	0%	2%
• Manufacture of paper and paper products; printing and reproduction of recorded media	1%	4%	0%	0%	2%
• Manufacture of chemical, pharmaceutical, rubber, and plastic products	2%	2%	1%	2%	1%
• Manufacture of basic metals and fabricated metal products, except machinery and equipment	3%	7%	0%	2%	2%
Electricity, gas, steam, and air conditioning supply	4%	0%	1%	5%	1%
Water collection, treatment, and supply; sewerage and other waste management services	1%	0%	0%	1%	1%
Waste collection, treatment, and disposal activities; materials recovery	8%	19%	5%	3%	29%
Construction	34%	13%	2%	46%	3%
Services (except wholesale of waste and scrap)	4%	14%	13%	1%	11%
Households	8%	16%	35%	0%	46%

Source: Eurostat (2017a).

The European Union (EU) distinguishes between animal and vegetal waste, mineral and solidified waste, and mixed ordinary waste (mainly household waste). In addition, the EU has a specific category for recycled waste.

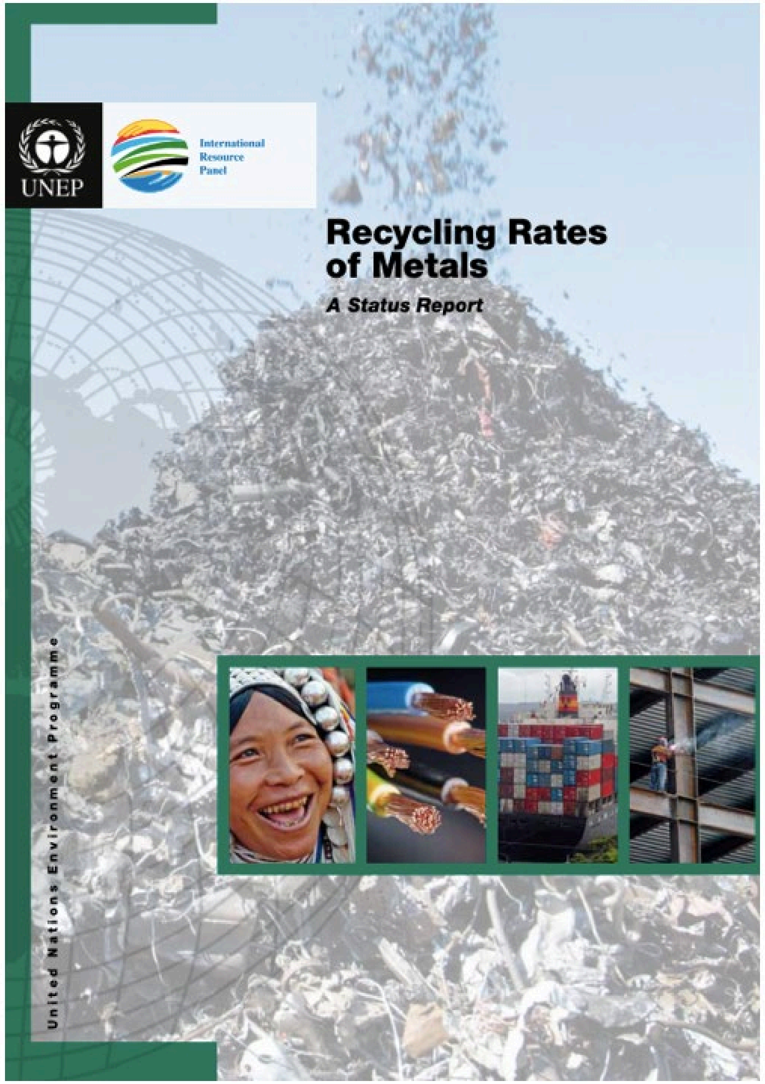
*Statistical classification of economic activities in the European Community (NACE), 2014

RECYCLING MATERIAL

A UN report by Gradel et al. (2011) showed that 18 of 60 metals have recycling rates over 50%, three have recycling rates in the range 25% - 50%, three more in the range of 10% - 25%, while for the majority, there are virtually no effective recycling efforts in place.

These differences are partly explained by:

- the value of the metals involved
- to the product quantities at the end of the lifecycle and the costs of recycling technologies. **Life Cycle Analysis and Life Cycle Costing are important.**



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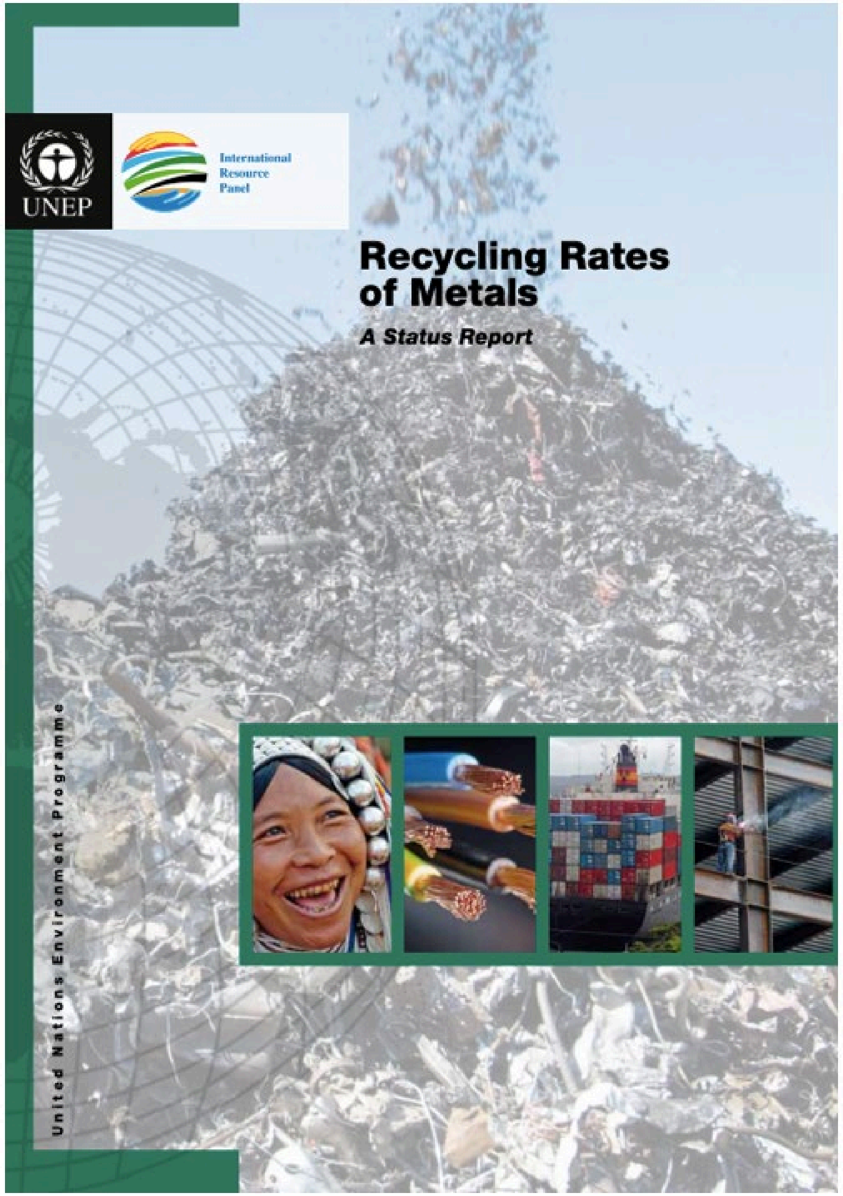
RECYCLING MATERIAL

Recycling does not, in all cases, lead to an effective reduction of materials use; energy requirements for recycling can be high and secondary material can be of relatively low quality.

Currently, only about 6% of all materials processed by the global economy are recycled materials (Haas et al., 2015).

This low percentage is explained by two effects:

- first the “stock” of materials in use, for example, in buildings and equipment, is growing rapidly
- a huge chunk of global material use is for energy generation.



RECYCLING MATERIAL AND PORTS

- Ports handle huge volumes of raw materials, intermediates, and finished products.
- Ports are also locations for logistics and manufacturing activities that may be severely affected by the transition toward CE.
- Ports, according to the European Parliament, serve as matchmakers, bringing together producing and recycling industries, and crossing-point for all kinds of waste and industrial flows, act as logistical hubs for the import and export of waste materials, accommodate industries that are active in the treatment, collection, and shipment of waste and stimulate the emergence of innovation circles

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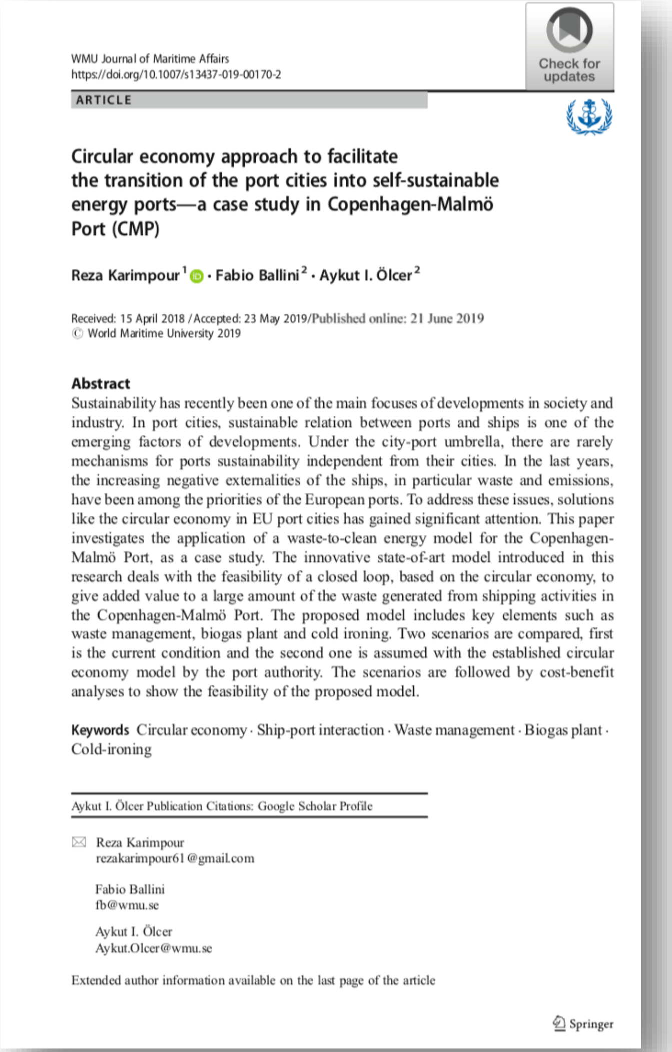
CE OPPORTUNITY FOR PORTS

- The transition also provides new business opportunities to ports which enables reuse of materials and energy, through utility infrastructure between companies. For example:
  - The use of waste heat for cooling systems is most efficient where the heat source is close to the cooling facilities, as physical colocation minimizes the cost of pipes and insulation as well as heat loss (Preston, 2012).
  - Many ports have developed into such industrial and logistics clusters (De Langen, 2004) and may be well positioned to develop into so-called “eco-industrial parks.”
  - Use ship waste for producing energy for port and city.
- Adoption of Sustainable and Environmental strategy Plan an Policy for ports
- Enhancing the link and collaboration with Cities and Municipality (Ship-Port-City interface)

WASTE TO ENERGY

CIRCULAR ECONOMY APPROACH TO FACILITATE
THE TRANSITION OF THE PORT CITIES INTO SELF-SUSTAINABLE ENERGY PORTS—
A CASE STUDY IN COPENHAGEN-MALMÖ PORT (CMP)


WMU Journal of Maritime Affairs
https://doi.org/10.1007/s13437-019-00170-2

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ARTICLE

Circular economy approach to facilitate the transition of the port cities into self-sustainable energy ports—a case study in Copenhagen-Malmö Port (CMP)

Reza Karimpour[1] · Fabio Ballini[2] · Aykut I. Ölcer[2]

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Abstract
Sustainability has recently been one of the main focuses of developments in society and industry. In port cities, sustainable relation between ports and ships is one of the emerging factors of developments. Under the city-port umbrella, there are rarely mechanisms for ports sustainability independent from their cities. In the last years, the increasing negative externalities of the ships, in particular waste and emissions, have been among the priorities of the European ports. To address these issues, solutions like the circular economy in EU port cities has gained significant attention. This paper investigates the application of a waste-to-clean energy model for the Copenhagen-Malmö Port, as a case study. The innovative state-of-art model introduced in this research deals with the feasibility of a closed loop, based on the circular economy, to give added value to a large amount of the waste generated from shipping activities in the Copenhagen-Malmö Port. The proposed model includes key elements such as waste management, biogas plant and cold ironing. Two scenarios are compared, first is the current condition and the second one is assumed with the established circular economy model by the port authority. The scenarios are followed by cost-benefit analyses to show the feasibility of the proposed model.

Keywords Circular economy · Ship-port interaction · Waste management · Biogas plant · Cold-ironing

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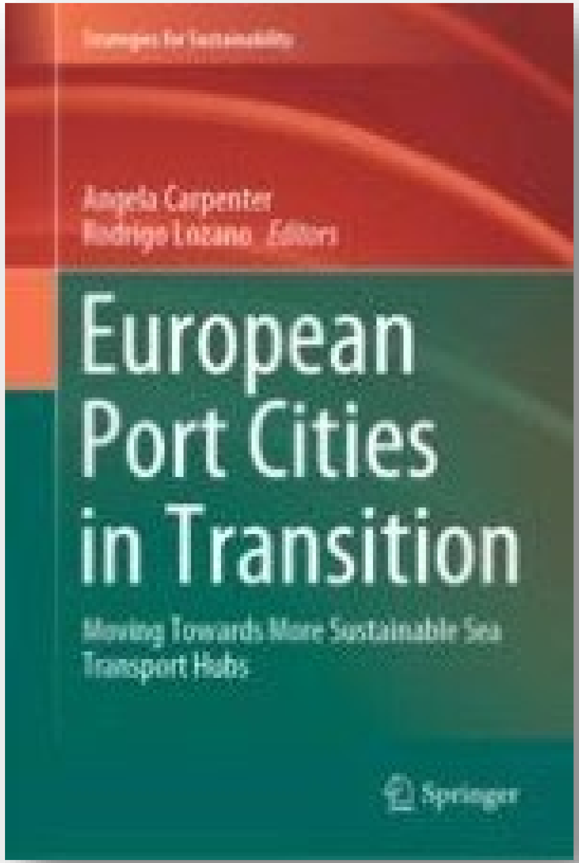

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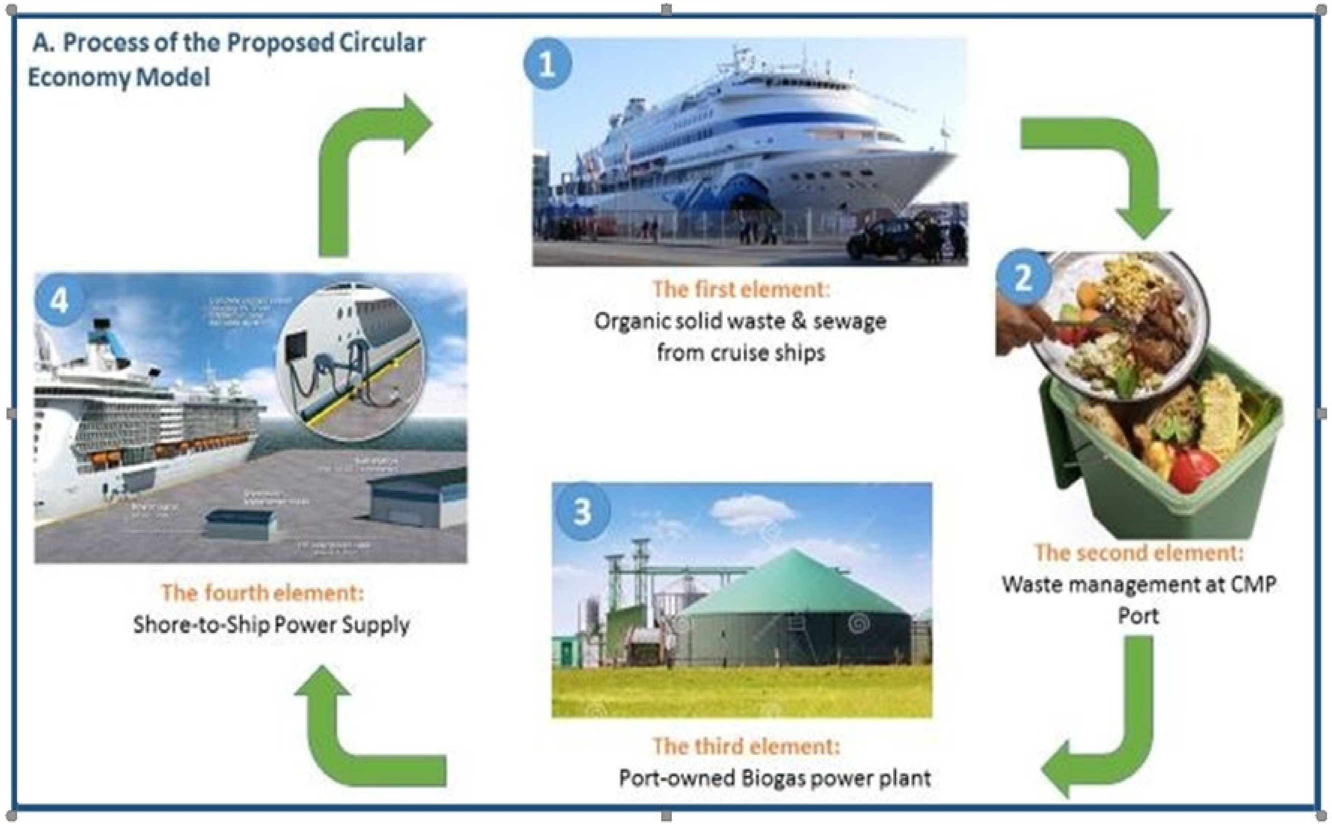
CIRCULAR ECONOMY APPLICATION AT COPENHAGEN-MALMÖ PORT (CMP)



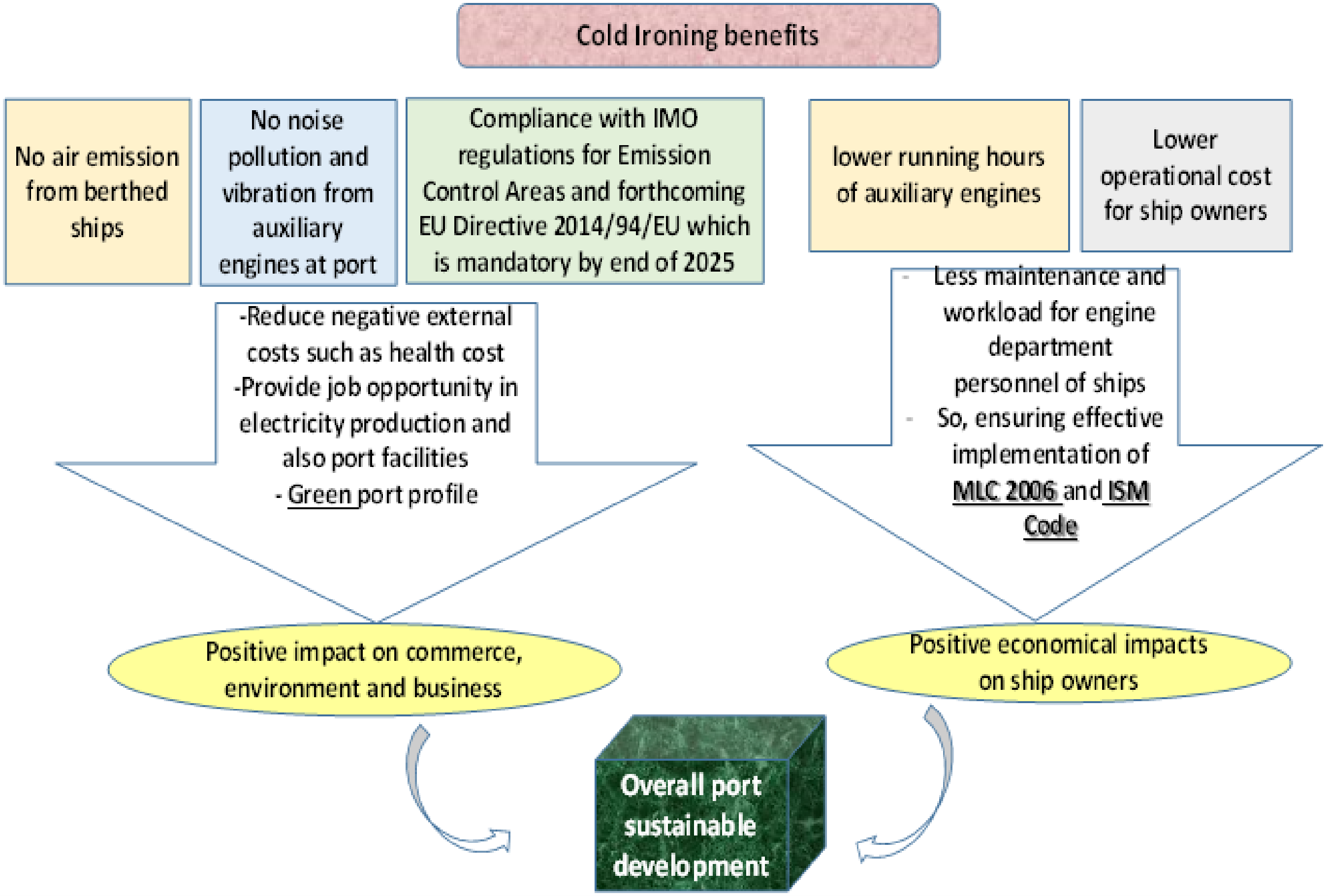
Four elements of ship-waste, port waste management, biogas plant and Shore-to-Ship power supply are used to set up the model in a closed loop.

Based on the model, to the port authority will take care of waste management from cruise ships to use the waste in a port-owned biogas plant.

The port-owned biogas plant produces clean electricity from ship waste while to some extent contributes to port energy security.

Finally, the produced clean electricity within this model will be **consumed in port for shore supply to ships or for other purposes like port buildings.**

COST ANALYSIS IN COPENHAGEN-MALMÖ PORT



Scenario 1 Applying no circular economy model, i.e. the current status of the CMP

Scenario 2 Applying a circular model using organic solid and sewage wastes from berthed ships, the port buildings, city household, and agriculture.

The methodology of the cost-benefit side of the establishment of such a model is the calculation of four related costs and four related benefits for both scenarios

COST ANALYSIS IN COPENHAGEN-MALMÖ PORT

Summarized costs and benefits

Costs	Ship-generated waste management cost in CMP	Capital and operational costs of biogas plant	Capital and operational cost of Cold-ironing installation at Oceankej-Copenhagen	Externality cost of berthed cruise ships in Copenhagen
Benefits	Saving from cutting negative externality	Saving from electrical power sale to ships	Saving from waste collection in port area	Saving from sale of produced fertilizer

Waste management costs in CMP

Waste management costs in CMP during 2016	In Danish krone (DKK)	Euro (€)
Sewage/sludge in cruise terminals	1.500.000	201,414
Dry garbage in cruise terminals	2,370,000	318,234
Total waste management costs in cruise terminals	3,870,000	519,642
Sewage/sludge in all terminals	4,350,000	584,100
Dry garbage in all terminals	3,370,000	452,510
Total waste management cost in all terminals	7,720,000	1,036,600

Provided by CMP (2017)

Scenario 1 The overall waste collection at the cruise terminal is € 519,642.

Scenario 2 The waste collection at all terminals is zero.

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COST ANALYSIS IN COPENHAGEN-MALMÖ PORT

Cost of ship-originated waste management at CMP cruise terminals

Table 13 Waste management costs in CMP

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Sewage/Sludge in all terminals	4,350,000	584,100
Dry garbage in all terminals	3,370,000	452,510
Total waste management costs in all terminals	7,720,000	1,036,600

Source: Provided by the CMP (2017)

Cruise ship–originated waste in CMP

Type of ship-originated waste in CMP	Amount of waste (m^3) or (ton)
Organic solid waste including food waste and combustible materials	1086 tons
Black water (sewage)	7377 m^3
Grey water (sewage)	10,742 m^3

Provided by CMP (2017)

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COST ANALYSIS IN COPENHAGEN-MALMÖ PORT

Cost of Biogas Power Plant

For scenario 2: The total of biogas power plant is €5,590,889

Costs of different capacity of biogas plants for all scenarios

Biogas power plant	CAPEX of biogas plant	Annual OPEX of biogas plant	Generator rated/max power	CAPEX of the matched Generator with CHP €	Annual OPEX of generator	Overall cost
–	€5,375,855	€215,034	18 MW (21 MV.A)	–	–	€5,590,889

Assumption: to convert Volt-Ampere to Watt, cosφ = 0.85

COST ANALYSIS IN COPENHAGEN-MALMÖ PORT

External cost of cruise ships berthing in Copenhagen

For scenario 1: The total externality cost is €5,384,086.
For scenario 2: The total externality cost is €2,417,338.

Cost of Cold Ironing installation at CMP Oceankaj term

For scenario 1: The total cost cold-ironing installation is 0.
For scenario 2: The total cost cold-ironing installation is € 36,960,000.

Summarized costs for different scenarios

	Cost of ship-originated waste management at CMP cruise terminal-OPEX (€)	Cost of biogas power plant + generator-CAPEX (€)	Annual maintenance and operation cost of biogas power plant + generator–OPEX (€)	Cost of initial cold-ironing installation at CMP Oceankej–CAPEX (€)	Annual maintenance and operation cost of cold-ironing infrastructure–OPEX (€)	Annual externality cost of cruise ships berthed in Copenhagen consuming 0.1% sulphur or 60% ships using cold ironing with Nordic energy mix-OPEX (€)	Total cost (€)
Scenario 1	€519,642	€0	€0	€0	€0	€4,944,578	€5,464,220
Scenario 2	€0	€5,590,889	€223,636	€36,960,000	€2,956,800	€2,417,338	€44,968,227

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BENEFIT ANALYSIS IN COPENHAGEN-MALMÖ PORT

1. Savings from cutting negative externality costs (Annual Total savings if 60% vessels using shore power)

For scenario 2: The annual saving is €2,966,748

2. Savings from electrical power sale to ships

For scenario 1: The annual saving is 0.

For scenario 2: The annual saving is €3,810,719.

3. Savings from waste collection in port area

For scenario 1: The annual saving is 0.

For scenario 2: The annual saving is €1,036,600

4. Savings from selling the produced fertilizer to the agriculture industry

For Scenario 3, the saving is €7,960,140

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COST-BENEFIT ANALYSIS

Cost benefit for scenario 2

	1st year	5th year	10th year	15th year	20th year	25th year
Annual costs of waste management in terminals	0	0	0	0	0	0
Costs of biogas power plant installation (€) CAPEX	€5,590,889	€5,590,889	€5,590,889	€5,590,889	€5,590,889	€5,590,889
Annual O&M cost of biogas power plant (€) OPEX	€215,034	€1,075,170	€2,150,340	€3,225,510	€4,300,680	€5,375,850
Cost of gold-ironing installation at CMP (€) CAPEX	€36,960,000	36,960,000	€36,960,000	€36,960,000	€36,960,000	€36,960,000
Annual O%M cost of cold-ironing installation at CMP (€) –OPEX	€2,956,800	€14,784,000	€29,568,000	€44,352,000	€59,136,000	€73,920,000
Annual externality cost of ships at berth	€2,417,338	€12,086,690	€24,173,380	€36,260,070	€48,346,760	€60,433,450
Total cost	€48,140,061	€70,496,749	€98,442,609	€126,388,469	€154,334,329	€182,280,189
Annual saving from cutting negative externality cost	€2,966,748	€14,833,740	€29,667,480	€44,501,220	€59,334,960	€74,168,700
Annual saving from electricity sale (with taxation) to ships	€3,810,719	€19,053,595	€38,107,190	€57,160,785	€76,214,380	€95,267,975
Annual saving from waste management in port area	€1,036,600	€5,183,000	€10,366,000	€15,549,000	€20,732,000	€25,915,000
Annual saving from sale of produced fertilizer to the agriculture industry	€4,002,000	€20,010,000	€40,020,000	€60,030,000	€80,040,000	€100,050,000
Total benefits	€11,816,067	€59,080,335	€118,160,670	€177,241,005	€236,321,340	€295,401,675
Payback = benefit-cost	−€36,323,994	−€11,416,414	€19,718,061	€50,852,536	€81,987,011	€113,121,486

In scenario 2, there will be a year of payback between the 5th and the 10th year that shows the feasibility of the proposed model for the scenario 2.

CONCLUSION AND RECOMMENDATIONS

- In scenario 2, based on the NPV calculations, the recovery of investment is completed in the 7th year. A cost-benefit analysis of scenario 2 yielded a positive net present value (NPV). It means that the port will gain economic benefits in addition to improvement in energy security. Furthermore, this scenario includes port cold-ironing application which results in significant reduction in air pollution from berthed ships and consequently a substantial decrease in the externality costs, mainly health cost.

- In this CE modelling, waste from ships will be managed by the port authority and used in the port-owned biogas plant, which attributes to added value for the waste management at the port, and boosts the port competitiveness.

- This research aims to assess the socio-economic benefit of the implementation of a CE model in CMP Port. The gains from a circular economy for ports is not only economic but also results in the reduction of externalities, mainly health cost for the local community in Copenhagen-Malmö.

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