A comparative study on the adoption of the circular economy in European port cities.

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A COMPARATIVE STUDY ON THE ADOPTION OF THE CIRCULAR ECONOMY IN EUROPEAN PORT CITIES.

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List of abbreviations

ARC: Amager Resource Centre
CC: Circular City
CCRI: Circular Cities and Regions Initiative
CE: Circular Economy
EC: European Commission
EEA: European Environment Agency
EMF: Ellen MacArthur Foundation
EU: European Union
FAO: Food and Agriculture Organization of the United Nations
IEA: International Energy Agency
ILO: International Labour Organization of the United Nations
KK: Københavns Kommune
OECD: Organization for Economic Cooperation and Development
SDG: Sustainable Development Goal
UIA: Urban Innovative Actions
UN: United Nations[1]
USEPA: United States Environmental Protection Agency
WCED: World Commission on Environment and Development

[1] The United Nations is an international organization of independent states that was formed after the second world war in 1945, to promote peace and international cooperation and security.

1. Introduction

Planet Earth functioned naturally in a circular manner for billions of years. The Industrial Revolution triggered a shift from this circular economy to a linear one: "take-make-waste" model. At the present time, a linear system is still soaked up in our daily lives (Circularity Gap Report [CGR], 2022).

More especially, cities are the main responsible for global warming. Cities around the world consume almost 80% of the world's energy and release more than 60% of greenhouse gas emissions in the atmosphere. (United Nations [UN], 2022). Cities are therefore the culprit of climate change, but they can also be an enabler of sustainability and implement powerful changes more rapidly than national governments can (CGR, 2022). Considering the influence of cities in the transition towards a sustainable world, United Nations Members reflected their importance by adopting the 11th goal of the 17 UN Sustainable Development Goals[2]: "Make cities and human settlements inclusive, safe, resilient and sustainable". (UN, 2015).

One of the underlying objectives of this 11th goal is to make cities circular. To define the circular city in the research, the definition of the Circular Cities Declaration is retained: "A circular city is one that promotes the transition from a linear to a circular economy in an integrated way across all its functions in collaboration with citizens, businesses and the research community" (Circular Cities Declaration [CCD], 2020).

Another complementary goal to achieve the circular economy in a city is to promote responsible production through businesses, and sustainable consumption through citizens. This is the 12th goal of the SDGs: "Ensure sustainable consumption and production patterns" (UN, 2015). In the circular city, materials are kept in the loop as it was naturally done in the past, which is therefore a step back of a few hundred years in our consumer habits. Indeed, the circular economy is not a revolutionary innovation (Corvellec et al, 2022).

The main research question of this study is: **"What are the differences between circular city strategies and initiatives implemented in European port cities?".** In the field of the circular economy, possible areas of improvement in our current society are numerous. We are still impregnated in a society of plastics consumption, food wastage, fast fashion, energy mismanagement, private means of transports, and in a more general way, in a linear "take-make-waste" model. Even if challenges are plentiful, the focus of this research is on three main challenges that cities encounter at the present time: waste management, energy transition and material reuse.

To sustain the research question, two European port cities are analysed: Copenhagen and Antwerp. Those cities are comparable in terms of their population, surface area and port activity, but they are at a different stage in terms of sustainability progress (Arcadis, 2022). This research is therefore conducted through two case studies and data is collected using semi-structured interviews with stakeholders from both cities.

The ReSOLVE framework (Ellen MacArthur Foundation [EMF], 2015) is the starting point for the analysis of the circular dimensions of the projects and strategies implemented within the cities. This model classifies the circular practices according to six dimensions: *Regenerate – Share – Optimise – Loop – Virtualise – Exchange*. Those categories are not exclusive, and a same project can include many interrelated dimensions. In this study, the *Regenerate*, *Loop,* and *Exchange* dimensions are observed the most.

[2] The SDGs were developed by the United Nations in 2015. More information is disclosed in *Sub-section 2.5.1.*

Furthermore, this framework is supplemented by the Checklist for Action (Organization for Economic Cooperation and Development [OECD], 2020) in which the different roles of local and regional authorities in the shift towards the circular economy are considered: *Promoter – Facilitator - Enabler*. This framework supplements the ReSOLVE framework and is relevant as this study focuses only on top-down change (i.e., institution-driven initiatives, and not on business- or community-driven initiatives). In this study, it is observed that policymakers mainly take the role of *Enablers* by using *Financing*, *Regulation*, *Capacity building* and *Innovation* to foster the CE. They also act as *Facilitators* by promoting *Stakeholder engagement* and as *Promoters* by establishing a clear *Strategic vision* and by raising *Awareness and transparency* on the CE.

Although previous research studied circular cities strategies, components of the circular city are still elusive in the literature. After the analysis of various articles on the circular city, the presence of a literature gap is observed. Indeed, some articles mention that future research should investigate cities in divergent geographical and economic context to explore their adoption of the circular economy (Williams, 2021). Other articles mention the importance to provide insights on how the policymakers could support citizen and community initiatives related to the circular economy (Prendeville et al, 2018). Furthermore, some papers state the necessity to analyse further circular cities, as they still remain few in number (Fusco Girard & Nocca, 2019). To humbly fill this gap, this work aims at giving further insights on the different opportunities available to the policymakers of European port cities to implement circular strategies and initiatives on their territory, taking a focus on the fields of waste management, energy transition and material reuse.

The most important papers on the circular city supporting this study are discussed in *Section 2. Literature Review* and mainly consist in the articles of Prendeville et al in 2018, Byström & Continenza in 2018, Fusco Girard & Nocca in 2019 and Williams in 2021. Those articles explore several dimensions of the circular city including the implementation, assessment, and benefits of the circular economy at the city-level. Regarding the concept of the circular economy, main papers supporting this study are, among others, Ellen MacArthur Foundation reports and articles, Circularity Gap Reports 2022 and 2023, and European Commission directives and programs.

The final aim of this study is to compare circular strategies and initiatives implemented at the macro-level by both cities. This final comparative analysis is twofold: first, it compares the advancement in circular economy in both cities, second, it highlights the different approaches taken to implement it. Based on the findings of this study, more developed circular initiatives are observed in the City of Copenhagen than in the City of Antwerp. By contrast, the Port of Antwerp-Bruges is more advanced in the field of circular economy than the Port of Copenhagen-Malmö. This research also underscores the different approaches taken to implement the circular economy in the city, with Copenhagen focusing on ecological aspects whilst Antwerp prioritises technological aspects.

Overall, this study analyses how the circular economy can be applied at the city-level. To make the circular city a reality, consumption and production patterns must drastically change. If the circular economy intends to become a new model for our societies, or at least if it intends to be part of the solution, a real shift in the global system of the city is required. To do so, an adaptation of local authorities' strategy is required to integrate a new model for the city: the circular city. Before diving into this study, the reader is invited to think about the following quote: "A developed country is not a place where the poor have cars. It's where the rich use public transportation." – Gustavo Petro[3].

[3] This quote is largely attributed to Gustavo Petro, the former mayor of Bogotá, now president of Colombia.

2. Literature review

2.1. Key concepts

Before getting to the heart of the matter, it is important to review the current scientific literature to define and differentiate main concepts discussed in this research. Sustainability, sustainable development, city, sustainable city, circular economy, circular city, and strategy are all interrelated but divergent notions. Those concepts are defined in this section. Furthermore, the fields of interest of this study are discussed: waste management, energy transition and material reuse. A brief overview of the link between the circular economy and the port is also present in this chapter.

2.1.1. Sustainability and Sustainable Development

Sustainability is the starting point to introduce the concept of the circular economy. If circular economy contributes to a more sustainable world, not all sustainability initiatives contribute to the circular economy (Het Groene Brein, 2021). Indeed, sustainability is a broader concept than circular economy. Before diving into the concept of sustainability, it is interesting to notice that no consensus exists on the definition of sustainable development among interested persons.

The concepts of sustainability and sustainable development are sometimes considered as distinct by some researchers whilst they can be considered as similar by others. In both cases, sustainability is defined as "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (UN, 2015) whilst no consensus exists on the definition of sustainable development.

First, those concepts can be considered as distinct: sustainable development is considered by many researchers as promoting economic growth, whilst at the same time, economic growth is done at the expense of sustainability (Redclift & Springett, 2015). According to these stakeholders, sustainability is not related to economic growth due to its assimilation with environmental degradation. This is the point of view adopted in this research.

On the contrary, those concepts are sometimes assimilated. Indeed, the Brundtland Report[4] defines as well sustainable development as "meeting the needs and aspirations of the present without compromising the ability to meet those of the future" (World Commission on Environment and Development [WCED], 1987). From this point of view, sustainable development calls for a radical change in our ways of production and consumption (Redclift & Springett, 2015) as it is assimilated to the concept of sustainability.

Now that both concepts have been defined, a further exploration of the concept of sustainability is supported by the theory of The Doughnut of social and planetary boundaries. The essence of the Doughnut model is to become the new compass for the 21st century by switching from a GDP-driven to a sustainability-driven model of society (Raworth, 2017). This model is represented by two rings: the inner ring; the social foundation, setting up the fundamental needs that must be accessible to all for a decent life, and the outer ring; the ecological ceiling, representing the limits beyond which we should put no further pressure on the planet (Raworth, 2017). Between those two rings lies a safe and just space for all, symbolising the sustainability of our society and planet.

[4] The Brundtland report, officially named "Our Common Future", was released in 1987 by the WCED.

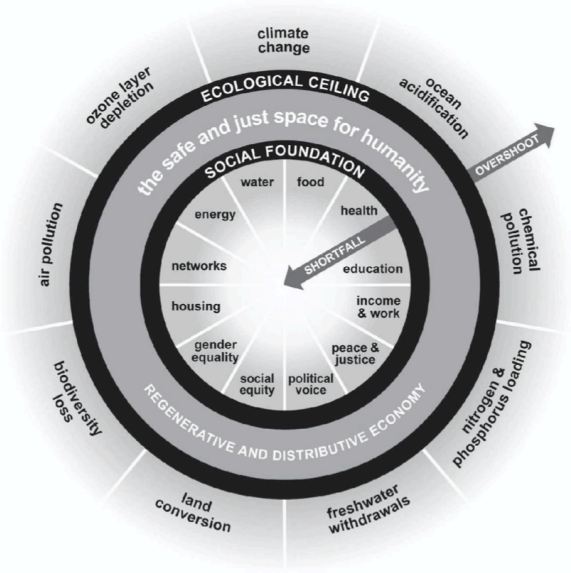

Figure 1. The Doughnut - Raworth (2017). *DOUGHNUT ECONOMICS. Seven Ways to Think Like a 21st-Century Economist (p.43).* Random House Business Books.

2.1.2. City

To define a city, six international organizations (i.e., European Union, OECD, World Bank, FAO, UN-Habitat, ILO) agreed on the "Degree of Urbanization" classification in order to have common criteria around the globe about what a city is. A city is thus a concentration of contiguous grid cells with a population of at least 1,500 inhabitants per km^2 and a population of at least 50,000 inhabitants (European Commission [EC], 2023c).

2.1.3. Sustainable City

Now that sustainability and city are defined, the definition of the sustainable city is introduced. The sustainable city is defined as the one dedicated to achieving green sustainability, social sustainability, and economic sustainability (UN, 2015). Those three pillars are referring to the famous "Triple Bottom Line" (Elkington, 1997), promoting an equilibrium between three dimensions: People – Planet – Profit.

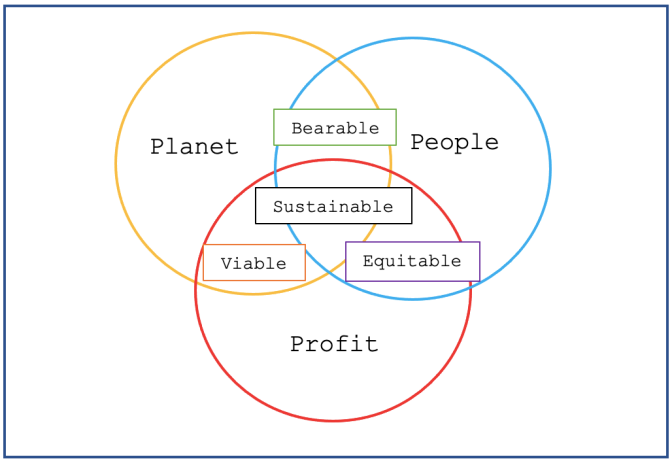

Figure 2. Triple Bottom Line (3P's) – Elkington (1997)

2.1.4. Circular Economy (CE)

To understand the concept of circular city, it is important to define the circular economy. In the literature, the concept of circular economy has a multitude of definitions and none of those is commonly accepted among the scientific community (Corvellec et al, 2022). Although no consensus in reached on the definition of the CE, an analysis of 114 definitions of the circular economy in 2017 highlighted economic prosperity as the main objective of the circular economy (Kirchherr et al, 2017).

In this research, the objective of the circular economy is far from economic prosperity. Indeed, the definition adopted in this study is the one given by the Ellen MacArthur Foundation[5] (2017) in which the circular economy consists in:

- Eliminating waste and pollution,
- Circulating products and materials,
- Regenerating nature.

Together, those three principles aim at reintegrating the economy into our planet's system and creating a society that is restorative as well as regenerative (EMF, 2015). Those three principles measure the circular economy and can be synthetised into the "Butterfly diagram" (EMF, 2015), that is inspired by the cradle-to-cradle philosophy (Braungart & McDonough, 2002). The cradle-to-cradle framework, as opposed as the cradle-to-grave framework, close the loops for renewables and finite materials, respectively through the biological cycle and the technical cycle (Braungart & McDonough, 2002).

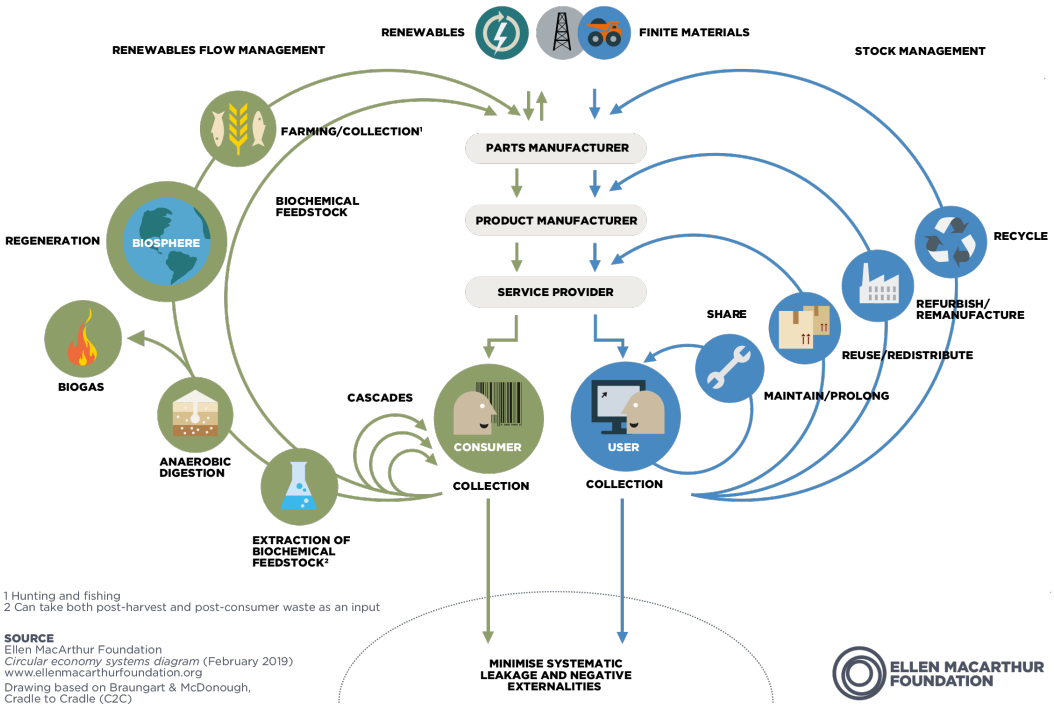

Figure 3. Butterfly Diagram – EMF (2019)

On the left-hand side, the biological cycle is the process to restore nutrients into the biosphere whilst rebuilding natural capital. On the right-hand side, this diagram shows the technical cycle in which

[5] The Ellen MacArthur Foundation is a charity working to accelerate the transition to a circular economy.

products and materials are kept in the economy as long as possible by being shared, maintained, reused, remanufactured and recycled. Both butterfly wings, including the biological cycle on the left and the technical cycle on the right, are complementary to implement circular economy in our society.

This definition has been chosen because first, Ellen MacArthur foundation is by far a reference in the matter, and second as the definition fits perfectly the different dimensions explored in this research: waste management (i.e., eliminating waste and pollution), energy transition (i.e., regenerating nature) and material reuse (i.e., circulating products and materials).

2.1.5. Circular City

The idea underlying the concept of circular city is to apply the previously defined circular economy and its three principles, but on a larger scale beyond the micro-level. Before the Circular Cities Declaration clarified the concept of circular city as "one that promotes the transition from a linear to a circular economy in an integrated way across all its functions in collaboration with citizens, businesses and the research community" (CCD, 2020), no clear definition of the circular city existed (Fusco Girard & Nocca, 2019). Although other definitions of the circular city exist, this definition is the one retained in this study as the integration of all stakeholders appears important to achieve the circular city. The circular economy implemented on a specific territory, including all citizens, research community, NGOs and companies, is considered as circular city. However, the concept of the circular city can be seen as unclear and ambiguous for many policymakers when they want to implement the circular economy in day-to-day practices (Prendeville et al, 2018).

2.1.6. Strategy

Now that the circular city is defined, the focus is on what it aims to implement on the macro-level: a strategy. The term strategy finds its origin in Greek: "stratos" that means "army", and "ageîn" that means "to run" (Neysen & Berthon, 2017). Therefore, the first appearance of the notion of strategy was in the military context: to run an army. Although many definitions of the term "strategy" exist in the literature, it is generally observed that the strategy examines the "what" and "how" (Neysen & Berthon, 2017). Indeed, the elaboration of a strategy is often done in two steps: first, the reflexion; "what objective do we want to reach?", and subsequently, the action; "how are we going to reach this objective?" (Neysen & Berthon, 2017).

At the macro-level, the same sequence applies. First, strategy is integrated into the political agenda of local, regional, national, and supranational authorities: the "what". As a next step, the strategy is translated into concrete initiatives, projects, and campaigns: the "how". It is important to highlight that those guidelines are implemented at the city-level, meaning that they have a broad scope as they concern businesses, public institutions, NGO's, citizens, etc. Collectively, all stakeholders will contribute to reach the strategy set up by authorities that have been democratically elected by its citizens.

A risk that is worth to be mentioned when referring to the strategy at the macro-level is the tendency of many political campaigns to focus on short-termism (Prendeville et al, 2018). Indeed, most of the boards of aldermen are re-elected every four years which triggers strategies only designed for this period (Prendeville et al, 2018). However, the path towards sustainability should be encompassed in a long-term perspective. Indeed, the definition of the sustainability is "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (UN, 2015) and thus includes a very long-term perspective by being careful with our impact on the next generations. For that reason, short-termism in the context of politics is a barrier to implement long-term and impactful initiatives to reach a more sustainable world.

2.1.7. Waste management

Waste management is a crucial challenge for municipalities. The total waste produced in the European Union for the year 2020 came to about 5 tons per inhabitant (Eurostat, 2023). This substantial amount raises the question of the consequences on our societies. The impact is twofold. On the one hand, the lack of an efficient waste management system implemented by local authorities trigger health issues for citizens (Kumar, 2010). On the other hand, a waste management system which is not eco-friendly (e.g., poor sorting activities, waste incineration, massive use of landfills, exportation of hazardous waste to developing countries, etc.) entails environmental degradation (Kumar, 2010). The 12th goal of the SDGs, "Responsible Consumption and Production", is related to waste management. Indeed, waste prevention, recycling and reusing options all contribute to more responsible consumption and production.

2.1.8. Energy transition

At the present time, the switch to green energy is a top priority in the political agenda of many governments. This massive focus on energy, and more especially on fossil fuels reduction, can be questioned due to the subsequent negligence of other major sustainable initiatives (CGR, 2022) even though energy transition remains a major economic and political challenge on top of the ecological one. Affordable and clean energy is the 7th goal of SDGs: access to energy can be considered as the starting point for economic and human development (UN, 2015). The main objective of this goal is to achieve global access to reliable, affordable, and modern energy services, everywhere around the world, within the limits of the planet boundaries.

2.1.9. Material reuse

Material reuse refers to the 12th objective of the SDGs: achieving a responsible consumption and production (UN, 2015). Closing the loop is the core of the circular economy. This dimension refers to many concepts, sometimes very creative, such as recycling, upcycling[6], repairing, reusing, redistributing, repurposing, refurbishing, remanufacturing, or reducing. Material reuse is a crucial challenge to tackle. On average in Europe for the year 2021, recycled material only accounted for 11.7% of total material used (European Environment Agency [EEA], 2023). The degree of utilisation of products is also problematic, with an approximate utilisation of 8 percent for cars and less than 40 percent for offices during their productive life (EMF, 2015). Consequently, innovative and relevant strategies designed by local authorities to promote circular models of production and consumption are discussed in this research.

2.1.10. Port cities

This research will analyse two cities that have important port activities on their territory. Port activity has an important impact on a city: seven out of the ten most powerful[7] cities in the world are seaport cities (Zheng et al, 2020). Furthermore, many ports cities are working on the circular economy: indeed, port areas can assume an important role to implement the circular city model as they are responsible for the generation of many negative externalities (Fusco Girard & Nocca, 2019). There is a real conflict between the port and the city: ports are a driving force for the economic wealth, but those economic benefits are accompanied by waste and pollution, which impact the environmental and social

[6] UpcycleThat.com defines upcycling as: "The act of taking something no longer in use and giving it a second life and new function".

[7] Among the factors determining the power of a city, some criteria are economic strength, research and development, cultural interaction, livability, accessibility, and environment (Fleming, 2019).

development of the city (Fusco Girard & Nocca, 2019). This observation corroborates the opinion maintained throughout this study, as disclosed in *Sub-section 2.1.1.*: economic growth is done at the expense of sustainability. Indeed, maritime transportation activities have a considerable carbon footprint and port activities pollute the air of the adjacent city (Zheng et al, 2020). This substantial impact on the environment implies that ports are key to foster the shift towards sustainability in the city in which they are located (Zheng et al, 2020). To solve this issue, the circular economy can be a solution to the major impact that port activities have on sustainability. In this research, circular initiatives set up in ports to reduce their environmental impact on the nearby city as well as on the environment are discussed.

2.2. Previous studies

In recent years, different studies have been carried out to analyse some aspects of the circular city: how to implement circular initiatives at the city-level (e.g., Byström & Continenza in 2018), which actions are established in specific locations through case studies (e.g., Prendeville et al in 2018), how to assess circular actions when they are functional (e.g., Fusco Girard & Nocca in 2019), and what are the resulting benefits of those initiatives on the society (e.g., Williams in 2021).

Those studies, even though very limited and few in number, give some first explorative insights to support the policymakers during their path towards the circular city. They propose the potential steps to take to implement the circular economy, they give some guidance to the policymakers to benchmark their city against other cities in terms of circular economy, they support them in assessing their own circular strategy by proposing multi-dimensional circularity indicators and they also highlight the potential benefits of the circular economy on the city. Furthermore, previous research also studied the role and impact of the port in a circular city (e.g., Fusco Girard & Nocca, 2019). However, it is important to mention that all those studies are only a first exploration of the concepts linked to the circular city and that a lot of research still needs to be done to have a more comprehensive view of this emergent concept.

First, a theoretical framework on circular strategies is available to guide cities through their circular transition. Indeed, cities' policymakers can find inspiration using the "15 circular steps for cities" thought by Byström & Continenza (2018). This framework discloses the practical steps to reach circular economy within the city. The model starts with the action plan: policymakers should assess the current context of their city, spot and prioritise the options with a circular potential, and subsequently establish a clear circular strategy. As a next step, they should act: the possibilities to reach circular economy are numerous (e.g., connect resources, extent product life cycle, implement regulations, use ICT[8] tools, etc). Finally, the city should mobilize the citizens: connect stakeholders, educate the residents on the circular economy, learn from circular pioneers, etc. Therefore, this model discloses a detailed process that can inspire policymakers when implementing the circular economy within their territory.

The paper written by Prendeville et al (2018), "Mapping Six Cities in Transition", explores how cities integrate circular economy as a strategy through six case studies. This study highlights the importance of the leadership agenda (i.e., including a long-term adaptable strategy), the use of living labs, the support of digital and data-driven approaches, the engagement of urban stakeholders and the consideration of city's context when implementing circular city practices. The research also points out the risk that concepts such as the circular economy are used as buzzwords and related to greenwashing when implemented poorly in the city.

[8] Information Communication Technology

Other studies focus on assessing circular practices within cities. The dynamic assessment framework, developed by Fusco Girard & Nocca in 2019, is a good example of a human-centred model evaluating the circular city strategies. This framework perceives the circular city as a comprehensive multi-dimensional challenge and includes qualitative as well as quantitative indicators that monitor circular cities' effectiveness. This evaluation framework assesses the effectiveness of the circular city strategies thanks to a matrix of indicators related to social, wellbeing, economic, environmental, and financial impacts that put the human being at the centre of all dimensions.

Potential benefits of the circular economy applied at the macro-level are expected to be plentiful according to the Ellen MacArthur Foundation (2015): an increase in productivity and GDP, a rise in employment and growth, a decrease in resource dependence, a decline in CO_2 emissions, a better welfare, all those gains on the condition that changes are supported by new and disruptive technologies. However, substantial transition costs are expected to support this major shift that could be considered as the second major European political economy project after creating the internal market (EMF, 2015).

Some authors complemented this analysis of the benefits of the circular economy within cities, using the Triple Bottom Line (Elkington, 1997) to classify them into social, ecological, and economic benefits. The research from Williams in 2021 discloses the potential benefits as well as the synergies between the three following circular actions: looping actions and circular economy; ecological regeneration and nature-based solutions; urban resilience and adaptation. Benefits of the circular economy are numerous according to the authors even if they could trigger rebound effects (e.g., efficient looping systems reduce the cost of the resource which fosters an overall increase in resource consumption) and they might not be spread equally across society, mainly benefitting the wealthiest population (Williams, 2021).

In addition to a very comprehensive analysis of several aspects of the circular city, the scientific community also studied the relationship between the port and the circular city. The conflicted relationship between the port (i.e., financial- and economic-driven) and the city (i.e., social- and environment-driven) highlights the substantial importance of the port to achieve sustainability and to implement the circular economy within the city (Fusco Girard & Nocca, 2019).

2.3. Criticisms of the Circular Economy

Although there is a clear consensus on the fact that our current models of consumption and production have detrimental effects on the society and environment (Millar et al, 2019), the scientific community is not unanimous regarding the relevance of the circular economy as a new model for our societies. Many authors also question the benefits retrieved from the circular economy and disclose the potential drawbacks that this concept would have on the society.

A critique of the current circular economy frameworks is that they are too idealistic (Prendeville et al, 2018). Indeed, from a practical point of view, implementing a model of the circular economy that does not produce any waste, that is only composed of closed material loops and that recycles in an infinitely manner all products, is simply impossible (Corvellec et al, 2022). This affirmation corroborates the article written by Millar et al in 2019 disclosing that "closed material loops are practically and theoretically impossible". It can be referred to as the "myth of eternal return" (Corvellec et al, 2022).

Moreover, some criticisms are done regarding the lack of human consideration in the model of the circular economy whilst over-focusing on the environmental dimension in the circular economy model. Indeed, it is argued that human wellbeing (i.e., social cohesion, good quality of life, human rights, etc), health and living conditions are neglected in the circular economy model (Fusco Girard & Nocca, 2019)

and that a broader interpretation including social factors is needed in the circular economy frameworks (Prendeville et al, 2018) due to the absence of consideration of the social pillar (Corvellec et al, 2022). Some authors even consider that the circular economy is "virtually silent on the social dimension" in the literature (Millar et al, 2019).

In addition to the criticisms regarding the lack of consideration of the social dimensions, some scientists even reconsider the positive impact that the circular economy has on the environment. Indeed, it is argued that natural systems can become suffocated by receiving indefinitely the same biological nutrients as the cradle-to-cradle framework suggests (Prendeville et al, 2018). Furthermore, it is stated that in practice, it is impossible to recycle indefinitely materials and energy without efficiency losses (Prendeville et al, 2018).

Authors also state that the circular economy is not a comprehensive model that includes all the specificities of a society but rather a model that focuses on industrial production and consumption (Corvellec et al, 2022). The critique is that considering resource efficiency measures in isolation from the other dimensions of society is detrimental because the specificities of consumer behaviour are not sufficiently considered (Prendeville et al, 2018). This opinion is corroborated by other authors that consider that not enough attention is paid to how customers value and respond to circular business models (Corvellec et al, 2022).

Furthermore, discourses on the circular economy consequences range among the different scientific papers. For instance, some authors state the circular economy supports decent jobs (Fusco Girard & Nocca, 2019 & EMF, 2015) whilst others argue that there is uncertainty on whether the future jobs in the circular economy sector will be secure and well paid (Williams, 2021).

Other criticisms are due to the various shortcomings that the circular economy models can have on cities. First, the benefits of the circular economy can have rebound effects. For instance, efficient looping systems that reduce the cost of the resource are also responsible for triggering an overall increase in resource consumption (Williams, 2021). This downside effect prevents the circular initiative to achieve its initial objective: to reduce consumption. Furthermore, the implementation of the circular economy within a territory can lead to the green gentrification[9] phenomenon. As a result, the benefits from the circular economy might not be spread equally across society, mainly benefitting the wealthiest population (Williams, 2021).

To put it briefly, most of the critiques addressed to the circular economy are related to its idealism and non-comprehensiveness: its exclusion of social factors, its over-focus on the environment whilst simplifying its consequences on it, and its consideration of the resource efficiency but in isolation. In addition to that, many critiques are addressed to its several downside effects on the society.

The opinions regarding the suitability of the circular economy as the model applied to our societies diverge. This section must only be seen as a non-exhaustive overview of different stakeholders' critical opinions on the circular economy model. This controversial debate is still ongoing.

In the present study, circular economy is not considered as the only model that must be applied to our current societies, but it is considered as part of the solution in order to achieve sustainability in cities.

[9] The green gentrification refers to the process of implementing an environmental planning agenda related to green spaces that lead to the increase of property values on a territory and thus to the exclusion of vulnerable residents.

2.4. European Regulations and Action Plans

In this research, the strategy as well as on the concrete initiatives and projects implemented to meet the objectives defined in the strategy are discussed. However, this section will be dedicated to the first step to implement the CE on a territory: the strategy.

Many laws and regulations regarding the circular economy are established at the European level. The directives must be translated by the Member States in their national law and respect the content of the regulation. For that reason, it is relevant to have an overview of the decisions on the circular economy taken at the European level since the Cities will have to consider them when implementing their own local circular strategy.

The picture hereunder represents the complementarity of the different levels of initiatives exposed in the present chapter.

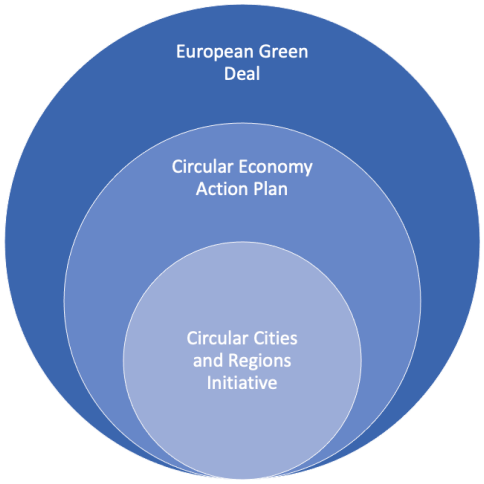

Figure 4. Circular European Regulations – Author's own

2.4.1. European Green Deal (2019)

The European Green Deal is a set of initiatives that aims to "transform the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy where there are no net emissions of greenhouse gases in 2050 and where economic growth is decoupled from resource use". The circular economy, translated into the Circular Economy Action Plan, is one of the building blocks of the European Green Deal.

2.4.2. Circular Economy Action Plan (2020)

The Circular Economy Action Plan is part of the European Green Deal. This action plan is divided into different levers for action. First, this action plan discloses a 'sustainable products' policy (e.g., prioritising reducing and reusing over recycling), it targets to empower consumers and public buyers (e.g., by giving them trustworthy and relevant information on products) and it promotes circular economy in the industry (e.g., by promoting the tracking, tracing, and mapping of resources) (EC, 2020a). Furthermore, the focus of the plan is on product groups which are identified as particularly crucial and requires urgent and comprehensive actions: among those resource-intensive components are electronics, batteries, vehicles, packaging, plastics, textiles, building materials, food, water, and nutrients (EC, 2020a). The action plan also concentrates on waste management. One of the targets of this plan is to halve the amount of residual municipal waste by 2030 in comparison with 2020 (EC,

2020a). To do so, one of the projects is to harmonise separate waste collection systems (EC, 2020a). Finally, this action plan mentions the Circular Cities and Regions Initiative will provide key assistance to Cities: more details on this initiative can be found in the following section.

2.4.3. Circular Cities and Regions Initiative (2020)

The Circular Cities and Regions Initiative (CCRI) is part of the Circular Economy Action Plan. Although both initiatives have the same final aim (i.e., fostering a circular economy), this plan focuses on the local and regional level instead of the national level. This initiative is a comprehensive support over local and regional circular economy initiatives: it provides financial support, technical support, dissemination[10] opportunities and it fosters knowledge sharing through multi-stakeholder collaboration on circular matters (EC, 2020b). This plan is particularly relevant within the scope of this study as it has an impact on the circular initiatives implemented at the city-level.

2.5. Partnerships at the core of the concept of the CE

Although not issued by the European Union, other initiatives are taken to promote the circular economy. On the one hand, the SDGs, initiated by the United Nations, contribute to the circular economy and circular city notably through SDG N°11; Sustainable Cities and Communities, and SDG N°12; Responsible Consumption and Production. On the other hand, the Circular Cities Declaration was launched by a collaboration between various stakeholders to collectively act towards the implementation of circular initiatives in cities around the world.

2.5.1. The Sustainable Development Goals (2015)

The SDGs are 17 universal objectives set up by the United Nations in 2015 to reach social, economic, and environmental sustainability by 2030 (UNDP, 2023). The United Nations insist on the importance to bring together all stakeholders (i.e., governments, companies, citizens, NGOs, etc) to collectively meet this target through SDG N°17: “Partnerships to achieve the goals”.

2.5.2. Circular Cities Declaration (2020)

The Circular Cities Declaration is a partnership between various stakeholders with the aim of accelerating the transition from a linear to a circular economy in Europe (CCD, 2022). Although the initiative is not a direct initiative from the European Union, different European authorities support the initiative including the European Economic and Social Committee & the European Committee of the Regions (CCD, 2022). At the present time, the CC Declaration gathers 74 signatories committed to lead actions by using the circular economy to bring resilience to their cities (CCD, 2022). In the Circular Cities Declaration Report 2022, 40 signatories reported on the key interventions taken and main challenges encountered when implementing circular initiatives at the city level.

[10] In this context, dissemination refers to the process of spreading information, knowledge, or research findings on circular economy to relevant stakeholders.

2.6. Theoretical framework

2.6.1. Local governments initiatives: Top-down change

The implementation of the circular economy in a city can either come from the top or from the bottom (Prendeville et al., 2018). In the first case, initiatives are institution-driven; strategies, regulations and policies are decided and implemented by authorities. In the second case, changes come from citizens, communities, NGO's, companies, etc. In this research, the focus will be put on top-down change, and more specifically on the initiatives undertaken by local authorities to promote the circular economy on their territory. However, a combination of initiatives coming from both sides is fostered to reach effective circular practices in the long run, and a collaboration between divergent stakeholders is the key to success towards a circular city.

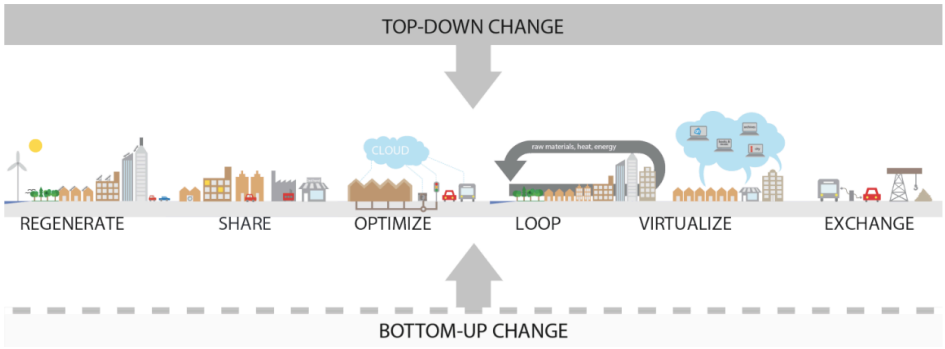

Figure 5. The circular city Framework, adapted from the ReSOLVE Framework (EMF, 2015)
Prendeville, S., Cherim, E., & Bocken, N. (2018). *Circular Cities: Mapping Six Cities in Transition.*

2.6.2. ReSOLVE framework

In this work, the reference model is the "ReSOLVE framework". This conceptual framework has been co-developed by the Ellen MacArthur Foundation and the McKinsey Centre for Business and Environment (2015). The idea behind this framework is that society as a whole, including businesses, governments, and citizens, should take steps towards circular economy by implementing six major actions: **Re**generate, **S**hare, **O**ptimise, **L**oop, **V**irtualise, and **E**xchange. Indeed, the three principles of circular economy, mentioned in a previous section, can be translated into six concrete circular initiatives.

To have a deeper understanding of these concepts, McKinsey & Company (2016) describes them in a report with concrete actions:

- **Re**generate: promote clean energy, switch to renewable materials, preserve ecosystems sustainability, and give back to the biosphere what was employed. For instance, urban regeneration consists in projects to rebuild old buildings or neighbourhoods into productive area for the communities (Enel X, 2022). Another insightful example to testify the increasing switch to renewable materials and clean energy among businesses is the Danish company Ørsted (Conference 4). In the past, the firm was exclusively a fossil fuel producer. Led by the CEO's conviction, the company completely changed its core business and decided to abandon its polluting business to focus on green energy (Conference 4). This strategic decision made Ørsted become one of the world's leading renewable energy companies.

- **S**hare: optimise products' lifespan by organizing peer-to-peer sharing of privately/publicly owned products, reuse products whilst they are still operational (e.g., second-hand stores), improve their lifespans thanks to maintenance, fix them if they are broken and design them using a sustainable process. Products to be shared can be rooms, cars, clothes, offices, bikes, etc. For instance, the Flemish Government established the "Green Deal Shared Mobility" to boost the growth of shared mobility through car-sharing, carpooling and bike-sharing (Green Deal Shared Mobility Flanders, 2017). Furthermore, innovative private platforms, such as Airbnb[11] for accommodations and BlaBlaCar[12] for transportation, are enablers to foster sharing philosophy among citizens.

- **O**ptimise: boost the performance of products, pull out waste from supply chains, exploit big data, use remote detection/steering and automation. It is important to mention that none of these initiatives imply to change the product or the technology in itself: for example, optimising logistics to reduce a company's carbon footprint by using ships instead of planes is an initiative falling into this category. In the context of the circular economy, big data could be useful to analyse and draw conclusions about consumer habits related to their daily circular actions. The underlying idea of the latter is not to create big data, but to use it appropriately, in order to foster the circular economy.

- **L**oop: close loops containing materials and give priority to internal ones, remanufacture components, recycle them if this is the last alternative, digest anaerobically, and extract biochemicals from organic waste. Bring wasteful packaging to a close, foster reuse and maximise recycling are all part of the European Green Deal, that aims to make the EU the first climate-neutral continent by 2050 (EC, 2019). European directives are transposed at the national-level, and all countries must comply with the new regulations. For instance, there are now restrictions to avoid overpackaging, to limit unnecessary packaging, to promote reusable packaging options, and to add clear labels on products to help consumers in the recycling process (EC, 2022).

- **Virtualise**: dematerialize by going virtual to replace existing ways of consuming. Deliver books, music, and shopping virtually. Major sectors are already impacted by changes in the way of consuming: phone applications for periodical newspapers substitute their paper version, digital music services such as Spotify[13] or Deezer[14] take over from physical CD's, e-commerce replaces traditional stores, to give just a few examples. Another concrete example of virtualisation is the progress in autonomous vehicles technology.

- **E**xchange: switch to new technologies, substitute old products with modern and renewable ones. In this study, the concept of new technologies includes not only the latest advancements but also technologies that became more popular or have become more affordable and accessible, despite not being extremely recent. As an example, to highlight this shift towards more modern and sustainable ways of producing and consuming, Brussels is a leader in requiring the passive house standard for all new construction (Conference 2). The Passive House Law, that became government mandate after January 1 in 2015, implies that new construction or major renovation of most buildings in the region of Brussels Capital must comply with the passive standard (International Energy Agency [IEA], 2017). Passive buildings are energy-efficient and are defined as "buildings for which thermal comfort, as defined in ISO 7730, can be achieved solely by post-heating or post-cooling of the fresh air mass, which is required to achieve sufficient indoor air quality conditions – without the need for additional recirculation of air" (Passipedia, 2018).

[11] Airbnb is an online platform that connects individuals renting their properties with travelers.
[12] BlaBlaCar is an online platform that connects drivers to passengers who are traveling in the same direction.
[13] Spotify is a digital music platform that provides access to songs and audio content on a digital application.
[14] Deezer is a digital music platform that provides access to songs and audio content on a digital application.

This model is suitable within the scope of this research regarding its completeness and its relevance. Indeed, the framework explores various dimensions that can enhance the circular economy throughout technological as well as traditional solutions. The scope of this model is broad and can therefore include very diverse initiatives. Furthermore, the model is relevant as each component promotes, in a way or another, the same final objective: the path towards the circular city. Finally, this framework has been recognised as a useful tool to engage policymakers in the CE discussion in previous research (Prendeville et al, 2018).

However, the border between those dimensions can be considered as unclear. Indeed, some initiatives can correspond to different categories at the same time: the dimensions of the conceptual framework are non-exclusive. Although this characteristic can be seen as a weakness of the model, this interrelationship also leads to a reinforced global impact of the initiative. For instance, a platform dedicated to the sharing of bikes fits both the *Share* and the *Virtualise* dimensions. Consequently, this double-fit drives to an even more positive impact than if the initiative promoted exclusively one dimension.

2.6.3. Checklist for Action

As mentioned previously, the ReSOLVE framework is suitable and relevant in this research to integrate all projects and initiatives related to the circular economy. But this model could be adjusted to integrate the key roles of the public authorities in those initiatives. Indeed, because this study focuses on the strategy and initiatives implemented by the local governments (i.e., top-down change), it is relevant to integrate in the analysis the roles that they play in the implementation of the circular projects.

To provide some context, local authorities can agree on action plans and strategies to promote the circular economy within their territory based on 12 key governance dimensions (OECD, 2020). Indeed, they have the power to influence citizens' behaviour towards the circular economy by acting on different leverages: they can act as *Promoters*, *Facilitators*, and *Enablers* of the circular economy (OECD, 2020).

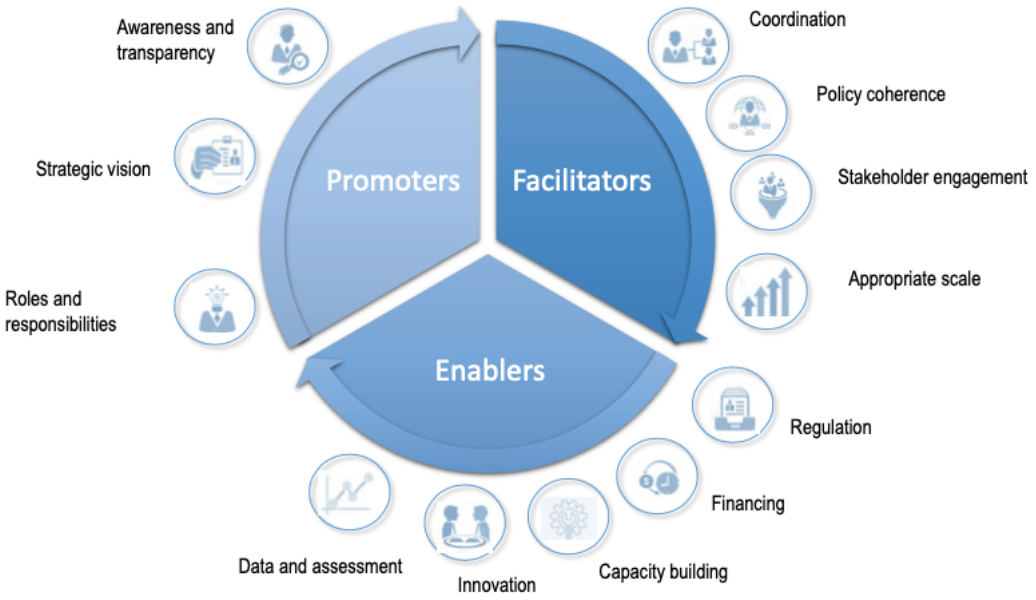

Figure 6. A Checklist for Action - OECD (2020).
The Circular Economy in Cities and Regions: Synthesis Report (p.139). OECD Urban Studies.

2.6.3.1. Promoters

The city's authorities can take the role of *Promoters* of the circular economy through three pillars: *Roles and Responsibilities*, *Strategic vision*, *Awareness and transparency*. More concretely, cities can lead by example (e.g., by adopting green public procurement) and establish clear responsibilities at the city-level (e.g., deputy mayors responsible for the implementation of the CE), set precise goals and action plans (e.g., develop a clear strategy on the CE), raise awareness on the CE (e.g., launch communication campaigns on the CE) and promote a trustworthy environment (e.g., introduce a label for local circular activities)(OECD, 2020).

2.6.3.2. Facilitators

The local authorities can also act as *Facilitators* based on four pillars: *Coordination*, *Policy coherence*, *Stakeholder engagement* and *Appropriate scale*. The main ideas are to make the implementation of circular initiatives easier by implementing effective multi-level governance to coordinate the local, regional, and national governments (e.g., launch joint projects on the CE), fostering system thinking (e.g., engage with internal and external stakeholders to create synergies), facilitating collaboration amongst public and private actors (e.g., create coworking spaces to bring stakeholders together) and adopting a functional approach (e.g., identify industrial symbiosis opportunities) (OECD, 2020). This dimension mainly relies on the creation of synergies between all the stakeholders involved in the processes.

2.6.3.3. Enablers

When the authorities take the role of *Enablers*, they can act on five pillars: *Regulation*, *Financing*, *Capacity building*, *Innovation* and *Data and assessment*. In more details, they can update the regulatory instruments (e.g., give environmental permits), allocate financial resources (e.g., reduced value added tax on products labelled as circular), adapt human and technical resources through training programs (e.g., finance pilot projects on the CE), foster business innovation (e.g., provide experimental spaces for circular entrepreneurs or create incubators for CE projects) and use information system (e.g., map empty buildings to avoid new constructions) (OECD, 2020).

Through all those different roles, local authorities can act on different leverages to foster the implementation of circular initiatives within their territory.

2.6.4. Customised framework

In the customised framework, the six circular dimensions of the ReSOLVE framework (EMF, 2015) as well as the Checklist for Action (OECD, 2020) are considered. Indeed, the customised framework describes the different types of circular practices and the contribution of the local authorities in their implementation. The resulting comprehensive framework is the following:

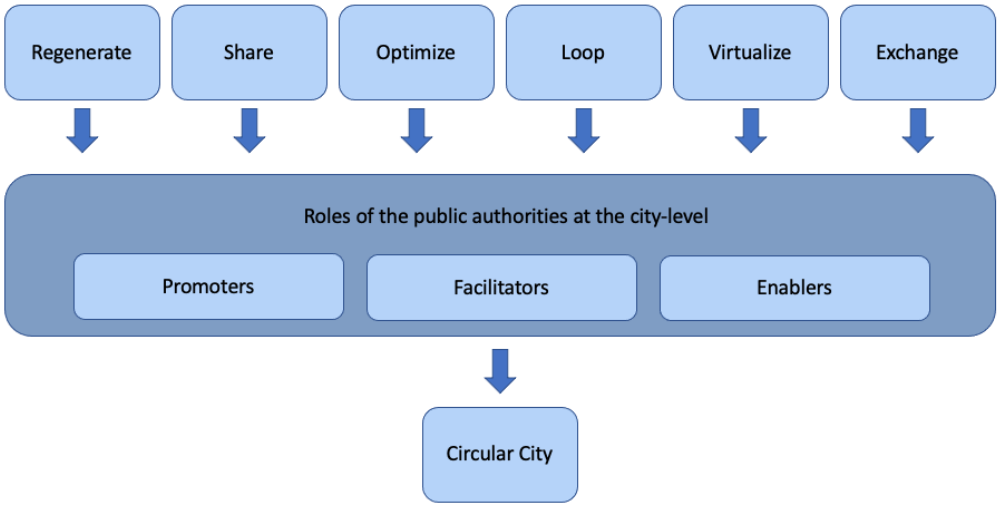

Figure 7. Customised framework – Author's own

3. Methodology

To answer the research question, the methodological choice of this study is qualitative research. This approach seems the most relevant regarding the aim of the research, which is to perform an in-depth analysis of the implementation of circular strategies and initiatives at the institutional level in different cities. The main objective of this study is first to identify and describe the phenomenon through a descriptive approach, and subsequently to carry out a cross-case analysis of the findings. The methodology of this research is inspired by the one used in the paper written by Prendeville et al (2018), described in a previous section.

Case study is the main research strategy for this work: an analysis of the phenomenon in its very own context is done in two cities, Antwerp and Copenhagen. The use of case studies is relevant as they are appropriate to study new and emerging topics, which is the case of circular cities (Prendeville et al, 2018). Those cities have been chosen for their comparability in terms of population, surface area and port activity even though they are considered at a different stage in terms of sustainability advancement (Arcadis, 2022). More information on the cities is disclosed in next section *4. Cities*.

Regarding the data collection technique, semi-structured interviews have been conducted. This choice is relevant within the scope of this study as it allows comparability of the information collected whilst at the same time giving the flexibility to adapt the line of questioning (Kvale & Brinkmann, 2009). Target stakeholders are mainly people working for the local authority, in the field of the circular economy. In the respect of GDPR, names of the respondents are not disclosed in this work, but their respective functions and work organisations are available in *Appendix 2.* The main interview guide is standardised for all respondents even though some specific questions were added on a case-by-case basis to allow deeper understanding of the topic. The standardised interview guide is disclosed in *Appendix 1*. Stakeholders were first contacted by email or Linkedin and the interview conversations were conducted via videoconferences on Teams because of the non-proximity of the cities analysed. After requesting consent of the respondents, interviews were recorded. On average, an interview lasts 42.33 minutes.

Subsequently, intelligent verbatim is carried out: every word is transcribed, excepted for filler words as well as repetition of the same words because not relevant. The feature “Dictée” on Word is the starting point to help with the transcription. To analyse the interview, thematic analysis is performed as the objective is to understand respondents’ views, knowledge and experience on the phenomenon. The process of coding is as follows: first, identification of relevant data, second, grouping into the six categories of the ReSOLVE framework (i.e., as this research is deductive), finally, draft of relevant conclusion. All details about the topic, duration, language, date, communication mean and key words for each interview are disclosed in *Appendix 2.*

Another major support for this study is the existing scientific and non-scientific literature. Main databases used are Google Scholar and ULiège library website. Grey literature on the subject is also used mainly for public reports of well-known institutions (e.g., Ellen MacArthur reports, Circularity gap reports, Brundtland report, etc). Non-scientific articles are also helpful, such as the official websites of public-owned companies dedicated to circular practices (e.g., Circular Copenhagen and Circular Flanders, among others) and management reports (e.g., Antwerp Circular South journals, The Arcadis Sustainable Cities Index 2022, etc).

An important source of information for this study was the opportunity to join a Belgian delegation on a trip of four days to Copenhagen, organised by Agoria[15] in November 2022. This experience consisted in assisting to conferences devoted to sustainability, cleantech, smart cities and green transition. Among all sessions given during the stay, six of them were particularly relevant within the scope of this research: Digital Hub Denmark[16], hub.brussels[17], Ørsted[18], State of Green Denmark[19], BLOXHUB[20] and Amager Resource Centre[21]. During this trip, a visit of CopenHill was organised, a plant transforming waste into energy. It will be discussed in the section *5.1.4.1 Amager Bakke.*

On the one hand, learning opportunities helped to acknowledge systems and structures put in place to promote the shift towards the circular economy implemented mainly by local and public organizations. On the other hand, interaction opportunities were guidance to better understand the Danish context: beliefs, mindset, and habits in terms of sustainability. Sources retrieved from this experience are thus mainly coming from notetaking during conferences, supported by slides, as well as informal conversations, and on-site visits. *Appendix 3* discloses an overview of the information about the conferences attended: the organization, its mission, the speakers, their roles, the topic, the key words of the conference, the language, the date, and the time.

Overall, this study is supported by complementary means to collect data: semi-structured interviews, document review/project mapping and on-site conferences. As regards to the research approach, it is deductive. It means that case studies are undertaken based on existing theory and more precisely on the conceptual ReSOLVE framework (EMF, 2015). As explained previously, this framework is complemented by the Checklist for Action (OECD, 2020) categorising the roles of the local authorities in the implementation of the CE in the city.

Further, it is important to mention that this study is cross-sectional: the phenomenon is analysed at a specific point in time, in the academic year 2022-2023, meaning that recent initiatives are disclosed which can add up-to-date content on the subject. However, it is important to acknowledge that the information provided in this study, as it reflects the state of the ongoing projects at the latest in May 2023, will have changed in the next weeks, months, and years.

Finally, the nature of this research is descriptive as well as comparative. The first step is to explain and discover concrete circular city initiatives implemented in those target cities to bring additional information on the topic to the literature. Subsequently, the final and main objective of this research is to undertake a comparative analysis of both cities in order to identify the main similarities and divergences between their strategies and initiatives to implement the CE at the city-level.

[15] Agoria is the Belgian federation of the technology industry, gathering around 2,000 technology companies across Belgium.

[16] Digital Hub Denmark is a non-profit organization working as a platform to connect startups, companies, and investors in Denmark in the field of technology.

[17] Hub.brussels is a public organization that connects entrepreneurs, researchers, non-profits and public authorities to pursue social innovation in Brussels.

[18] Ørsted is the largest energy company in Denmark providing green energy solutions.

[19] State of Green Denmark is a non-profit and public-private ownership promoting global collaboration between key players towards progress in green sustainability.

[20] BLOXHUB is the Nordic Hub for sustainable urbanization, matching its members and potential partners, sharing knowledge and create business opportunities in the field of clean urbanization.

[21] ARC is a public-owned company managing and treating waste with a sustainable focus in five Danish municipalities.

4. Cities

In this research, two European port cities are studied: Copenhagen and Antwerp. To carry out relevant case studies, the idea is to choose comparable cities in terms of location, population, surface area and port activity, even though they are at different stages in terms of sustainability advancement.

Key figures are shown in the following table:

	Copenhagen	Antwerp
Member of the EU	Yes	Yes
Population	644,431 inhabitants[22]	530,630 inhabitants[23]
Surface area	179.8 km^2	204.5 km^2
Country	Denmark	Belgium
Capital of the country	Yes	No
Port activity	Yes	Yes
Sustainable Cities Index 2022[24]	N°4	N°27
Covenant of Mayors for Climate & Energy	Signed in 2009	Signed in 2009
CC Declaration	Signed in 2020	N/A

Table 1. Cities' information – Author's own

It can be noticed that both cities are similar in terms of their population. The presence of port activity in both cities enables comparisons and will be discussed even if the focus of this study is put on the city as a whole, and not only on its port.

Although Antwerp is not the capital of Belgium as Copenhagen is the capital of Denmark, the city has been chosen due to its advancement in terms of sustainability. Indeed, Antwerp takes the 27th position in the Sustainable Cities Index whilst Brussels takes the 38th position (Arcadis, 2022). Moreover, choosing Antwerp instead of Brussels allows comparability due to all criteria disclosed in the previous table.

Another common point between those cities is that they both signed the Covenant of Mayors for Climate & Energy in 2009. The EU Covenant of Mayors for Climate & Energy is an initiative of the European Commission inviting local governments of the EU to join and to commit to the implementation of EU climate and energy targets within their territory (EC, 2023d). However, it is important to note that Copenhagen is one of the signatories of the Circular Cities Declaration whilst Antwerp has not taken part in the initiative yet.

[22] Data retrieved from Statista on https://www.statista.com/statistics/1303909/population-copenhagen/
[23] Data retrieved from City Population on https://www.citypopulation.de/en/belgium/antwerpen/antwerpen/11002__antwerpen/
[24] The Arcadis Sustainable Cities Index ranks 100 global cities on three pillars of sustainability: Planet, People and Profit. Note that Arcadis is an international firm providing design, engineering, and consultancy services.

5. Findings

5.1. Case 1: Copenhagen

Denmark is considered as a leader in terms of its GDP per capita, life expectancy, social trust, generosity and anti-corruption, ranking as the second happiest nation of the world (Cable News Network [CNN], 2022). Regarding its commitment in preserving the environment, the capital of Denmark is part of the C40 Climate Leadership group and was even awarded as one of the world's greenest cities in 2017 by the global network of C40 cities[25] (Lloyd-Smith, 2022). The main objective of the C40 group is to make cities develop and implement policies and programs that generate measurable reductions in both greenhouse gas emissions and climate risks (Prendeville et al, 2018). The city is indeed at a high stage of development in terms of sustainability, taking the 4th position in the ranking of the Sustainable Cities Index, right after Oslo, Stockholm, and Tokyo (Arcadis, 2022).

As regards to its strategy, the City of Copenhagen has established a formal circular plan: the *Resource and Waste Management Plan 2024.* In this plan, the city of Copenhagen has written down clear objectives for the city in the field of the circular economy. The City also issued the *CPH Climate Plan 2025* which targets to make Copenhagen the first carbon neutral capital by 2025 (Københavns Kommune [KK], 2023). On top of that, Danish government signed its first legally binding *Climate Act 2020* applicable at the country-level (KK, 2020).

Furthermore, Copenhagen is one of the founding signatories of the Circular Cities Declaration (CCD, 2020) and became signatory of the Covenant of Mayors in 2009 (EC, 2023a).

In this research, numerous initiatives undertaken by the city of Copenhagen to become a better circular city are analysed. Interviews from stakeholders working on the circular economy were very useful in the writing of this research, and complemented the information retrieved on the internet.

5.1.1. Resource and Waste Management Plan 2024

To introduce this section on Copenhagen, it is important to understand the strategy of the city regarding the circular economy. As supported by Byström & Continenza in 2018, crafting a circular strategy with clear circular targets is one of the first steps. In Copenhagen, the circular strategy is clear and well-defined through the *Resource and Waste Management Plan 2024* which is the formal written strategy of Copenhagen to implement the CE on its territory. This document establishes the key targets to be met on a time horizon of 6 years. The plan discloses three concrete targets to be reached by 2024: 70% of household, industrial, and commercial waste will be collected for recycling; 59,000 less tonnes of CO_2 will be emitted; and reuse will be tripled. In this chapter, many circular initiatives and projects aiming at meeting the objectives established in the *Resource and Waste Management Plan 2024* are disclosed.

[25] C40 cities is a global network of mayors taking urgent action to confront the climate crisis.

5.1.2. Circular Copenhagen

Circular Copenhagen is an “online platform to call for partnerships” (Interviewee 2). This platform is responsible for reaching the goals set up in the *Resource and Waste Management Plan 2024* (Interviewee 1). This public organization works on many projects in close collaboration with private actors, thus creating synergic public-private partnerships (Interviewee 2). From the words of Interviewee 2, the organization responds to the challenges of the circular economy by asking itself the question “How can we find solutions for tomorrow together?”. The key to success of this initiative is definitely its ecosystem, using an industry-approach in which all partners are involved to close the loop (Interviewee 2).

5.1.3. Waste management

As per the statistical data retrieved from Eurostat[26] in 2023, Danes produced 3,453 kg of waste per capita in 2020. This amount is lower than the European mean for 2020 which amounted to 4,808 kg per capital (Eurostat, 2023). In order to manage this amount of waste, Danish government implemented a clear strategy through its *Resource and Waste Management Plan 2024* to promote a more responsible waste disposal system in the country.

One of the main challenges to be tackled by the northern country is that many objects go to incineration even if they still have a recycling value (Interviewee 2). This section aims at describing the strategies decided at the institutional level regarding resource and waste management from 2018 to 2024. As mentioned previously, public-private partnerships are essential to reach the target set up by the city, and a major player in the waste management industry is Amager Resource Centre (ARC), a public-owned company managing and treating waste with a sustainable focus in five Danish municipalities.

5.1.3.1. The Waste Hierarchy

In 1975, the EU Waste Framework Directive introduced a 'hierarchy' to be applied by EU Member States in waste management (EC, 2023b). In this inversed pyramid, waste prevention is at the top whilst landfill is at the bottom: the objective is to go from the bottom up in the waste hierarchy.

The main objective of the *Resource and Waste Management Plan 2024* is thus to move waste upwards in the waste hierarchy (Conference 5). For that reason, Circular Copenhagen implements initiatives at different stages of the waste hierarchy.

[26] Eurostat is the statistical office of the European Union (EU).

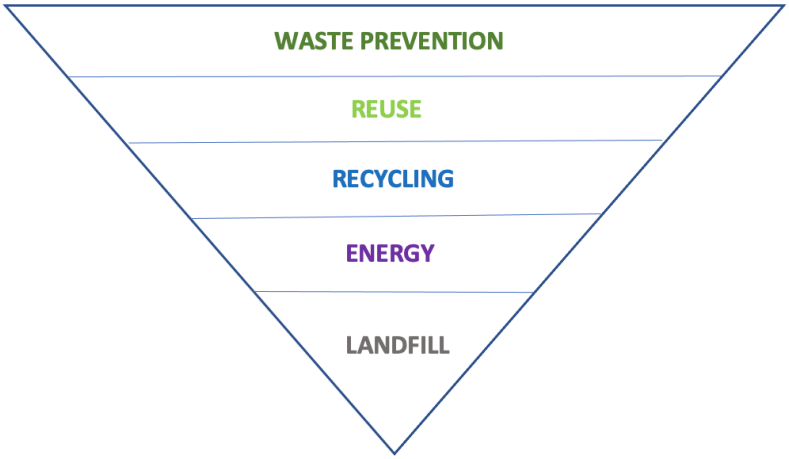

Figure 8. Waste hierarchy – EC (1975)

Regarding **landfills**, only 2% of the waste recovered by ARC ends up in landfills. However, they are safer and have less environmental impact than traditional landfills (i.e., no organic materials, very little methane, etc.) (Conference 5). Concerning the **energy** level, CopenHill, also known as Amager Bakke, is a famous waste-to-energy plant implemented in Copenhagen by ARC. In this waste incinerator, a specific process converts waste into energy, and energy into electricity and heat, at the disposal of approximately 85,000 nearby households (Conference 5). **Recycling** is also part of the *Resource and Waste Management Plan 2024*. Copenhagen has currently five reuse stations, as well as many local reuse stations on a small-scale, supplementing the household collection (Interviewee 1). In one of these stations, a brand-new initiative emerged: the Sharing zone. This concept intervenes at the **reuse** level of the waste hierarchy and is explained in more details in *Section 5.1.6.1.* Due to our current models of overconsumption, less initiatives of **waste prevention** are concretely in place yet even though Circular Copenhagen works on analysing behavioural and social aspects in order to assess the self-reflection of consumers regarding their consumption habits and the resulting waste (Interviewee 2).

Now that the hierarchy levels have been briefly explained, concrete initiatives related to the waste management system of the city are analysed in this chapter.

5.1.3.2. Smart sensors

In an ideal world, all bins of Copenhagen would have smart sensors able to diffuse real-time data about the bin's emptying state. Circular Copenhagen is currently making tests on ATR (i.e., Automated Emptying Registration) to discover how data could be used to *Optimise* bin lorries' collection route (Interviewee 2). It means that trucks would not go to empty bins: it would reduce CO_2 emissions and increase collection efficiency. It is important to not confound this initiative with the smart bins: in this case, the focus is put on the bin's emptying state, different from the concept of smart bins, in which bins sort garbage by themselves. As this initiative would be dematerialised, it would fit the *Virtualise* dimension. The *Regenerate* dimension would also fit as the initiative would reduce CO_2 emissions.

However, Copenhagen is a densely-build city and reality is way more complicated than that (Interviewee 2). It is difficult to plan a dynamic collection route: indeed, it would lead to more driving in some cases, for example if full bins are spread around the city. Consequently, it would trigger more pollution, more CO_2 emissions, more time in traffic jam for trucks, and it would impede the initial ambition to optimise the collection system. This project is still ongoing.

5.1.3.3. Waste sorting process

Regarding the use of new technologies, robotics and automation are key in the waste sorting process of the city (Interviewee 2). For plastics sorting, the only manual handling is at the end of the process, to refine the output coming from the automatic sorting. A test plant is currently investigating how to improve robots' ability in the waste treatment process by using machine learning and artificial intelligence (Interviewee 2). The waste sorting process is therefore an example of a switch to new technologies, *Exchanging* old systems with modern ones. This automatic sorting is also responsible for *Optimising* current processes by boosting their performance thanks to new technologies.

5.1.3.4. Electric collection trucks

Another initiative under investigation is the implementation of electric garbage collection trucks: this shift from traditional fossil fuel to electric powered public transportation is part of the *Exchange* dimension (Interviewee 2). This initiative aims to be aligned with the CO_2 emissions reduction strategy. However, some obstacles raise concern about the effectiveness of this initiative, including the energy source of the electricity in the charging stations. Indeed, does the electricity produced come from renewable energy or from fossil fuels? Electric vehicles powered by brown energy could raise the question of the relevance of this strategy on the environmental level. However, if electricity comes from renewable energy, there would be a shift from extraction to *Regeneration*, and this initiative would comply with this dimension of the framework.

5.1.3.5. Diapers recycling

One of the current projects of Circular Copenhagen is to implement a city-wide collection system of used diapers. Indeed, diapers release great amounts of greenhouse gases in the atmosphere when incinerated (Circular Copenhagen, 2022c). Thanks to the collaboration between investors, recycling technology companies and the City of Copenhagen, a test of nappies waste collection was launched in Autumn 2022 and the results of this pilot project were promising (Circular Copenhagen, 2023). This positive result encouraged the City of Copenhagen to further develop this initiative and set the objective of recycling 2,500 tons of diapers annually by 2024 (Circular Copenhagen, 2022c). This collection scheme for diapers is accompanied by a separate pilot project on the potential for composting diapers in selected kindergartens which started in Autumn 2022 (Circular Copenhagen, 2022c). Those initiatives refer to the *Loop* dimension of the framework as their main objective is to recycle diapers in the most ecological manner.

5.1.3.6. Circular mattresses

Every year, Danish residents dispose of approximately 500,000 used mattresses which produces 10,000 to 12,500 tons of waste (Circular Copenhagen, 2022b). However, mattresses have a recycling value and a technology that is ready to get scaled up (Interviewee 2). In order to achieve its objective to recycle 70% of municipal waste by 2024, the City of Copenhagen initiated a collaboration between several actors to find circular solutions for discarded mattresses (Circular Copenhagen, 2022a). The ambition of the city is to make the most of the technology available in Europe and to recycle up to 85% of the materials contained in the mattresses (Circular Copenhagen, 2022a). Due to the success of the collection trials, in which mattresses could be recycled up to 80% compared to 22% in the past, the initiative is scaling up (Circular Copenhagen, 2022b). Furthermore, a Danish company is developing a new product using the PUR foam retrieved from the discarded mattresses, applying the concept of the circular economy to its business (Circular Copenhagen, 2022b). Those actions close the *Loop* of materials by reusing and recycling components of the mattresses.

5.1.3.7. Resource-awareness programs for children

One of the objectives of the *Resource and Waste Management Plan 2024* is to raise awareness among the children on waste sorting and circular economy. An "extensive educational package" was created from the collaboration between the City and the teachers to provide pupils with teaching material on waste sorting (Interviewee 2). Furthermore, the incineration plant and recycling stations provide free course services for the Copenhagen school kids programs (Interviewee 2). Moreover, "kindergartens are now fitted with the same bins as they [children] have in their households" (Interviewee 2). The final objective of those initiatives is to have an awareness-raising impact and to even make some pupils become local waste ambassadors (KK, 2019). All those waste sorting initiatives correspond to the *Loop* dimension of the framework.

5.1.3.8. Laws on waste sorting

To achieve a more responsible waste disposal system in the country, the government passed different laws. Most of them are interpretation of the EU laws, translated at the national level. In some cases, Copenhagen is even setting higher requirements than the national law. One of the laws, as an interpretation of the EU directives, made mandatory in Denmark to collect food waste from the households (Interviewee 2). However, Denmark pushes the regulation one step further and since 2020, all Danes must sort their waste into ten fractions at home (Conference 3). Those fractions are plastic, paper, food, residual, hazardous, metal, glass, cardboard, textile, and food/drinking cartons (Plus Pack AS, 2022). The same regulation applies to companies. Furthermore, "dialogue-based" audits are undertaken by public actors to advise those firms on their waste management system (Interviewee 2). All those regulations make the waste sorting process stricter and thus promote the *Loop* dimension of the framework.

5.1.3.9. Nudge campaigns

Denmark, Norway, and Sweden have decided to harmonise their waste management policy and set up a common system of pictograms, i.e., icons and colours, to be put on both collection bins and packaging (Seeling, 2020). By doing so, they comply with one of the goals of the Circular Economy Action Plan: harmonising separate waste collection systems. Denmark was the first country to implement the pictogram system in 2017 (Seeling, 2020). Indeed, at the present time, it is mandatory for all Danish cities to put waste symbols on all bins, helping the consumers to sort waste correctly (Interviewee 2). However, pictograms on packaging are still a voluntary basis from the producers (Interviewee 2). This initiative is part of the nudge effect: the final aim is to motivate the consumers to sort their waste fractions into the right bin. Indeed, the nudge effect is known as "making it easy to do the right thing" (Clean Europe Network, 2016): disclosing the same symbols on both collection bins and packaging makes sorting easier for consumers and foster the path towards a cleaner city. Illustrations of the common pictograms established are displayed in *Appendix 4a*. Furthermore, the City of Copenhagen carried out a very successful nudging campaign between 2012 and 2015. The campaign was called "Pure Love" and consisted in using nudging to make bins visible and accessible especially in litter-likely environment: for instance, green footsteps led to the closest bin which was decorated by a heart logo representative of the campaign (Clean Europe Network, 2016). The evaluation report of the initiative demonstrates the beneficial effect of the campaign on the city's degree of cleanliness (Clean Europe Network, 2016). Some pictures of the "Pure Love" campaign are displayed in *Appendix 4b*.

Those nudge campaigns have the final aim to improve the quality of the waste sorting system of the city and correspond to the *Loop* dimension of the framework.

5.1.4. Energy transition

5.1.4.1. Climate Act & Climate Plan

Energy transition towards renewable and green energy seems to be a top priority for the Danish government, both at the city- and country-level.

On the one hand, at the country-level, Danish authorities signed their first legally binding *Climate Act* in 2020 to cut emissions by 70% by 2030 (KK, 2020). Denmark's goal in the long term is to become 100% independent of fossil fuels by 2050 (Conference 3) to comply with the European Green Deal (EC, 2019). On the other hand, at the city-level, local authorities established the *CPH 2025 Climate Plan* aiming to make Copenhagen the first carbon neutral capital by 2025 (KK, 2023). This action plan is based on four key pillars: energy consumption, energy production, mobility with reduced emissions and city administration initiatives (KK, 2023).

The underlying idea is to let the nature *Regenerate* by using renewable energies grown in a regenerative way instead of extracting finite materials from the ground (EMF, 2017). New technologies are also used to *Exchange* traditional means of energy production with renewable ones.

Furthermore, the government supports organisations such as *State of Green*: it is a public-private partnership promoting global collaboration between Danish and international key players towards progress in the fields of energy transition, circular economy, water management and green cities (Conference 3). This non-profit organization also aims at providing solutions to tackle environmental challenges, maintaining Denmark as a leader in green transition and making this country an example to follow for other countries around the world.

Denmark is a small country and emits only 0.1% of the global greenhouse gases in the world (Conference 3). However, the country is involved in reducing its own carbon footprint and aims at becoming an example to follow for others polluting nations by providing them concrete solutions. Denmark's Energy Mix for 2021 was the following (IEA, 2023a):

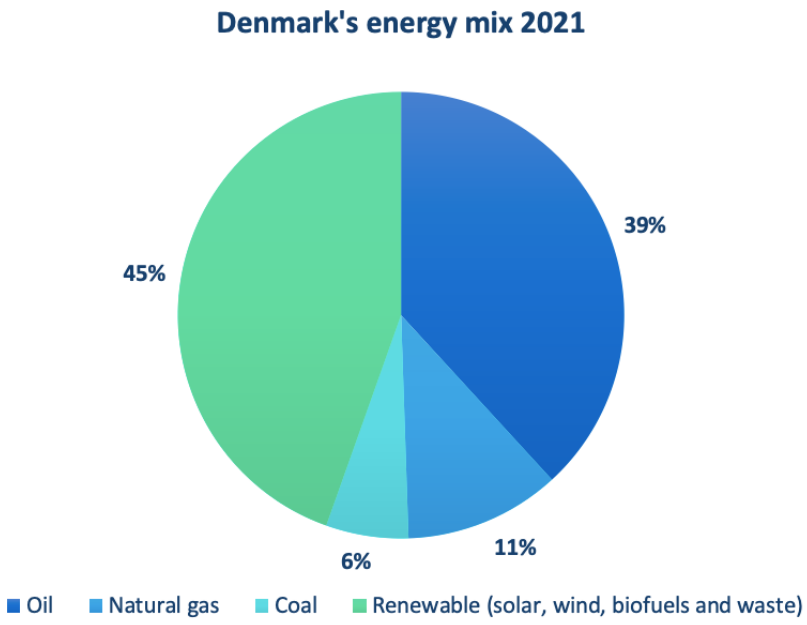

Figure 9. Denmark's energy mix 2021 – IEA (2023a)

In this graphical representation, solar, wind, biofuels and waste energy are all considered as renewable energy sources. One will notice that the major proportion of the total energy used in the Nordic country comes from renewable energy (45%), with a large part coming from wind energy, which is not surprising regarding the fact that the world's first offshore wind farm was installed in Denmark in 1991 (Conference 3). Oil remains intensively used by the country (39%), followed by natural gas (11%), and coal to a lesser extent.

The *Climate Act 2020* is the written and formal strategy of the country to reduce its CO_2 emissions. Same applies to the *CPH 2025 Climate Plan,* applicable at the city-level. In this sub-section on energy transition, some concrete initiatives and projects aiming at meeting the targets established in the *Climate Act 2020* as well as the *CPH 2025 Climate Plan* are disclosed.

5.1.4.2. RecyclableBlade

Even if wind turbines provide clean energy, a question raises when it comes to the recyclability of their components, in the case in which ageing offshore wind farms are decommissioned. This challenge is part of the *Loop* dimension of the framework accompanying us along this research. Indeed, it is currently possible to recycle only 85% of wind turbines' components, because dissolving the resin used to merge the different components of the blade together is not yet possible (Conference 3). For that reason, Siemens Gamesa[27], in their Danish factory, developed a sustainable solution by creating turbine blades with a new type of resin which is resistant as well as dissolvable (Conference 3). This innovation thus also contributes to the *Exchange* dimension. In the future, thanks to this finding, specific parts of the turbines will be separated and re-used in other sectors, instead of ending up in landfills. This project, called RecyclableBlade, is therefore a solution to allow a fully circular solution loop when it comes to the recyclability of wind turbines' parts. This solution is expected to be commercially used on wind farms by 2024 (Conference 3).

This initiative is relevant within the scope of this research due to the ownership structure of the company: Siemens Gamesa is owned at 41.8% by general public, 38.4% by private companies, 19.7% by institutions and 0.1% by private companies (Yahoo!, 2023).

5.1.4.3. Energy islands

Regarding offshore wind farms, the Danish's government agreed in June 2020 on a pioneering project, consisting in the construction of two energy islands (Conference 3). The combined capacity of both islands will be up to 5 GW by 2030. They will be located in the surrounding seas of Denmark to exploit wind resources as much as possible. This broad political agreement, led by the Danish Energy Agency, will provide green electricity to at least five million households. This initiative forms part of the *Regenerate* dimension of the framework, replacing traditional fossil fuel-based energy production by renewable energy solution.

Moreover, to comply with their zero emissions strategy, Danish politicians in power agreed in 2020 to end new oil and gas exploration in the Danish North Sea (Conference 3). This decision also positively affects the *Regenerate* dimension of the framework. To conclude this section, Danish politicians are involved in the field of the energy transition, and they establish concrete initiatives towards green energy at the institutional level.

[27] Siemens Gamesa is a company working in the renewable energy industry, leader in providing offshore and onshore wind turbines and services.

5.1.5. Waste Management & Energy Transition

As mentioned previously, waste management, energy transition and material reuse are the dimensions of the circular economy analysed in this research. An interesting fact is that those dimensions can be combined in some initiatives: indeed, it is possible to dispose of waste, and at the same time, recovering the energy from the garbage. That is the main activity of Amager Bakke, and this is called the anaerobic digestion.

5.1.5.1. Amager Bakke

CopenHill, also known as Amager Bakke, is a waste incinerator implemented in Copenhagen. This waste-to-energy plant officially opened in 2019 and transforms waste coming from 645,000 citizens and 68,000 companies at the present time (Conference 5). The goal of Amager Bakke is to move upwards in the waste inversed pyramid, by producing energy from garbage instead of getting rid of it in landfills. This plant is particularly interesting in terms of the circular economy and corresponds to different dimensions of the ReSOLVE framework.

In CopenHill, the residual waste collected is processed in a digester, which is a closed space where there is no air and therefore no combustion (United States Environmental Protection Agency [USEPA], 2022). This natural process implies that microorganisms break down materials (USEPA, 2022): this is called anaerobic digestion. During this process, biogas mostly composed of methane (CH_4) and carbon dioxide (CO_2) is generated (USEPA, 2022). The resulting gas is purified (Interviewee 2): carbon dioxide and other gases are removed and only the primary component of natural gas, methane, is kept (USEPA, 2022). The gas emitted thanks to this process contributes to the gas distribution of the city.

Five dimensions of the conceptual framework can be highlighted in this centre: *Loop, Regenerate, Optimise, Exchange* and *Share*.

At the end of the process, even if it is efficient, 17 to 20% of the waste cannot be burned (Conference 5). The solid reject from the treatment, called the "slag[28]", is not thrown down the landfill. Instead, metals and biochemicals are extracted from the slag and when purified, the solid reject can legally be used as a fertilizer on agricultural soil (Interviewee 2) or for road filling underneath asphalt (Conference 5). The residue is therefore reused for another purpose, and the *Loop* for this resource is closed.

Furthermore, there is a *Regeneration* of the resource: it is used to a new purpose, which is providing "clean" energy. However, it is crucial to mention that this process cannot be considered as 100% clean. On the one hand, the incineration of residual waste emits CO_2. On the other hand, because the gas emitted will be burned to create energy, CO_2 is released into the atmosphere as well (Conference 5). To reduce its carbon footprint, ARC launched a pilot project to *Optimise* its current processes and catch the CO_2 emitted from the incineration of residual waste. This development project is supported by new technologies, which refers to the *Exchange* dimension of the framework.

Finally, as mentioned previously, the gas emitted in the end of the anaerobic digestion contributes to the gas distribution of the city. The energy created by Amager Bakke's process is shared amongst residents of the Copenhagen's district as it provides 30% of the electricity and 70% of the heat necessary to the whole district (Conference 5). Therefore, CopenHill also contributes to the *Share* dimension of the framework.

[28] Consists of ash, sand, gravel, metals.

5.1.6. Material reuse

This section on material reuse focuses on the reuse level of the waste hierarchy. The associated dimension of the ReSOLVE framework is therefore mainly the *Loop* one: the underlying idea is to keep products in the loop by repairing, refurbishing, or directly reusing them.

5.1.6.1. Sharing zones

This new concept of "sharing zones", supported by Circular Copenhagen, is an ongoing project consisting in the implementation of different centres, spread around the city, in which people can donate and/or pick up stuff (Interviewee 1). Their motto is "One man's trash, another man's treasure" (Conference 5).

Currently, there are five major reuse stations in Copenhagen. In one of those stations, Circular Copenhagen opened the first sharing zone, and in another one, the organization tried the concept of a store. Regarding the fact that those initiatives were initially pilot projects, those zones were constructed under tents. Due to the success of the initiative, three new sharing zones are expected to be opened soon in the other reuse stations, but in permanent building materials this time (Interviewee 1).

Within the sharing zone, inhabitants from Copenhagen can find different types of departments, each gathering specific types of objects. There is the zone for the small stuff (i.e., hobby, kids' toys, books, kitchen and living room stuff), one for the furniture, another one for building materials, and finally a zone gathering garden stuff (Interviewee 1). All kind of people, regardless of their age, gender, occupation and so on, take actively part in this project because "all people have their own personal motivation" (Interviewee 1). Inhabitants of Copenhagen seem very enthusiastic regarding this initiative: "People love just the thought that their donation makes other people happy" (Interviewee 1).

One of the major advantages of this project is that, even if citizens are aware of the green agenda and would like to promote circular economy, they can struggle to really act because of their busy lives (Interviewee 1). Therefore, the sharing zone acts as a platform that gathers donors on one side, and beneficiaries on the other side, in order to facilitate the reconciliation between both actors to fulfil an exchange.

Regarding the dimensions of the conceptual framework**,** the *Share* dimension is obviously the most prominent related to this initiative. Root concept is to share objects in order to reduce the amount of waste: it is at the heart of the initiative. Keeping objects circular in the *Loop* is one of Copenhagen municipality's objective. Reusing them, thanks to sharing zones, is therefore a way to keep them in the loop instead of throwing them into landfills.

5.1.6.2. Material recollection

Another example of keeping objects in the loop is linked to material recollection. Currently, in 2022, two trucks are mandated to find good stuff from bulky waste all around the city of Copenhagen. On average, each truck gathers approximately three tons of reused furniture every week and bring them to the store (Interviewee 1). In total, since the beginning of this initiative in 2021, the two trucks recollected roughly 800 tons of saved bulky waste. Due to the success of the initiative, three more trucks are expected for next year (2023) and will bring recollected materials also to the new sharing zones. In the past, products would have been crashed or burned. Nowadays, they are reused. Once again, this process closes the *Loop*.

5.1.6.3. Circular entrepreneurs

Another initiative from the municipality to promote material reuse is to subsidise circular entrepreneurs (Interviewee 1). Indeed, approximately ten entrepreneurs are currently investigating "how can we [entrepreneurs] reuse stuff from the store and redesign it to do something differently with it", taking the words of Interviewee 1. They are allowed to create new products and to sell them, under the condition that they are made with reused materials only. This initiative is aligned with the objective of keeping materials in the *Loop,* from cradle-to-cradle. The municipality subsidise those entrepreneurs by providing them a wood shop for free, in which they can carry out their circular activities. As this place is shared with other entrepreneurs, this project contributes to the *Share* dimension of the model. The only compensation required for this grant is that entrepreneurs must do one workshop per month, accessible to the public, to update citizens about their findings and to teach them new sustainable skills.

5.1.7. Port of Copenhagen-Malmö

As disclosed in the previous sections, the City of Copenhagen integrates the circular economy in its strategy and in many initiatives related to waste management, material reuse and energy transition. In the port of Copenhagen-Malmö, the importance of sustainability seems to be acknowledged too. The organisation claims it integrates many pillars of the SDGs as part of its strategy. Furthermore, the port signed the UN Global Compact[29] in 2020 (UN Global Compact, 2023). The port wants to be seen as a hub fostering synergies, collaborations, and knowledge-sharing between various stakeholders (Copenhagen-Malmö Port [CMP], 2022b). Some examples of the integration of the circular economy in the port's initiatives are disclosed in this section.

5.1.7.1. Waste Management

- Recollection of marine plastics

Regarding waste management, one of the port's initiatives is to collect plastics and waste from the surrounding port basins of the port (CMP, 2022b). The objective is to protect the marine environment pursuant to SDGs 6 (i.e., Clean Water and Sanitation) and 14 (i.e., Life Below Water). This action reduces the amount of waste present in the port area. It can be classified in the *Loop* dimension as the final aim of this initiative is to dispose of the garbage in a more respectful manner (e.g., recycling the plastic collected) than dropping it in the sea without any treatment.

- Plastic reduction in the canteen

The elimination of disposable plastics does not limit itself in the surrounding water of the port. Indeed, the port also aims to reduce the use of plastic products in its own support activities. More especially, the canteen of the port is making effort to reduce its carbon footprint. In the last years, the canteen focused on sorting as much as possible, and now works on cutting its plastic consumption (CMP, 2022b). For example, the cookers foster the use of small containers instead of plastic wraps to maintain the food in the fridge. Thanks to this shift, the CMP canteen has eliminated approximately 25% of its disposable plastic products (CMP, 2022b). This action can be classified into the *Loop* category.

5.1.7.2. Energy Transition

- Quays' inspection by drone

The port of Copenhagen-Malmö uses new technologies to inspect its quays (CMP, 2022b). When comparing the use of the drone with the traditional ways of inspection, the reduction in CO_2 emissions is substantial. Indeed, in the past, the staff had to use boats to do the inspection: obviously, this solution had a negative impact on the carbon footprint of the port (CMP, 2022b). This innovation can categorize itself in the *Exchange* dimension as modern technologies are used, in the *Regenerate* one as it supports a decrease in the carbon emissions emitted, and in the *Virtualise* as quays' inspection is dematerialised.

[29] The UN Global Compact provides a universal framework in the areas of human rights, labor, environment, and anti-corruption to guide all businesses in their path towards an improved corporate responsibility.

- Hydrotreated Vegetable Oil

The organisation has the ambition to become fossil-free by 2025 (CMP, 2022b). In Swede Harbour (i.e., Malmö), one of the solutions to reduce the negative impact of the port on the environment is to replace the diesel fuel with HVO (i.e., Hydrotreated Vegetable Oil) in most of the engines (CMP, 2022b). The port fosters alternative fuels and aims to avoid fossil fuels as much as possible. However, in the case of the large container cranes, electricity is used during the handling of the cargo, and diesel is still used to occasionally move them or to perform maintenance on them (CMP, 2022b). Using alternative fuel refers to the *Regenerate* dimension of the model: indeed, this switch favours clean energy. It also contributes to the *Exchange* dimension as this type of fuel replaces traditional fossil fuel.

- Electric vehicles

Another initiative to foster the transition towards clean energy in the port is to use electric cars at the terminals. There is a controversial debate regarding the use of electric vehicles. Indeed, it is important to know if the electricity produced comes from renewable source to be able to claim the cleanliness of the action. In the present case, CMP states it only uses green electricity that is generated from local renewable sources of energy (i.e., solar, wind and hydroelectric power) (CMP, 2022b). For that reason, this initiative fits into the *Regenerate* and *Exchange* dimensions within the scope of this research.

- Solar panels

The CMP is committed to promote the green transition of the port by using only green electricity coming from renewable energy sources (CMP, 2022b). For instance, solar collectors are responsible for warming the water of the staff building in Copenhagen. Those renewable sources of energy also serve to fuel the electric vehicles of the port as mentioned in the previous paragraph. This initiative refers to the *Regenerate* and *Exchange* dimensions of the ReSOLVE framework.

- Motion detectors

The port of Copenhagen-Malmö aims to reduce its electricity consumption. For that reason, new technologies are used to detect rooms' activity: motion detectors are now installed in different facilities (CMP, 2022b). Indeed, those captors turn the lights on when they detect movement and turn them off when the movement seems over. This initiative can be considered in the *Optimise* section; electricity consumption is optimised automatically, as well as in the *Regenerate* one; electricity consumption is reduced, and in the *Exchange* one; modern technologies support the initiative.

5.1.7.3. Material Reuse

At the present time, the port of Copenhagen-Malmö does not seem to disclose any initiatives directly related to material reuse on its official website.

5.1.8. Framework analysis

5.1.8.1. ReSOLVE framework

To synthetise this chapter on Copenhagen, all circular initiatives and their related dimension(s) of the ReSOLVE framework are summarised in the following table.

	Regenerate	Share	Optimise	Loop	Virtualise	Exchange
City of Copenhagen						
Resource and Waste Management Plan 2024	D/I					
Circular Copenhagen	D/I					
Waste management						
Smart sensors	D		D		D	
Waste sorting process			D			D
Electric collection trucks	?					D
Diaper recycling				D		
Circular mattresses				D		
Resource-awareness prog.				I		
Laws on waste sorting				I		
Nudge campaigns				I		
Energy transition						
Climate Act & Climate Plan	I					I
RecyclableBlade				D		
Energy islands	D					D
Waste management & Energy transition						
Amager Bakke	I	I	D	I		D
Material reuse						
Sharing zones		D		D		
Material recollection		D		D		
Circular entrepreneurs		I		I		
Port of Copenhagen-Malmö						
Waste management						
Cleaning of marine plastics				I		
Plastic reduction in canteen				I		
Energy transition						
Quays' inspection by drone	I				I	I
Hydrotreated Vegetable Oil	I					I
Electric vehicles	I					I
Solar panels	I					I
Motion detectors	I		I			I

Table 2. Circular initiatives and strategy in the city and port of Copenhagen – Author's own

Legend:

Symbol/Letter	Meaning
I	Initiatives that are already implemented in the city
D	Initiatives that are still at the development/test level, or not yet actives on the market
?	Represents controversial debates on whether the initiative corresponds to the dimension

As mentioned in the *3. Methodology* section, the nature of this research is descriptive as well as comparative. The strategies and initiatives undertaken at the city-level when related to the circular economy have been described. This section is a summary as well as a further analysis of the content related to Copenhagen's city described in the previous sections.

First, as the *Resource and Waste Management Plan 2024* establishes the strategy to promote the CE in Copenhagen, and that most of those initiatives are/will be implemented by Circular Copenhagen, the plan and the team directly or indirectly contribute to all the dimensions of the ReSOLVE framework.

The main observation is the prevalence of the *Regenerate, Loop, and Exchange* dimensions in Copenhagen.

First, the prevalence of the ***Regenerate*** dimension is partly explained by the important amount of renewable energy as displayed in Denmark's energy mix: this awareness allows nature to regenerate and limits fossil fuels' extraction. Regarding energy transition, a formal strategy has been established at the city- as well as the country-level. The high number of wind turbines in Copenhagen is an innovative and clean way of providing energy to the community. Energy islands are a good example of an ongoing project aiming at increasing even more the capacity of wind turbines in the capital and its surroundings. Clean energy is also provided by CopenHill, the major waste-to-energy plant of the city, powering the district in electricity and heat. Regarding electric collection trucks, they can be considered in this section only if the source of the electricity used to charge the engine comes from renewable energy. Finally, the port of Copenhagen is heavily investing in solutions to promote green energy (e.g., solar panels, HVO, electric vehicles) and reduce its global energy consumption (e.g., use of drones, motions detectors).

Copenhagen city seems to allow more and more resources over the years to keep products in the ***Loop*****.** Regarding waste management, various actions are implemented including circular mattresses and the diapers recycling projects, awareness-raising programs for kids, nudge campaigns, and laws on waste sorting. When it comes to energy transition, public institutions financially support a project ensuring the one hundred percent recyclability of wind turbines blades. Amager Bakke also contributes to this dimension by repurposing the solid reject of the anaerobic digestion. As regards to material reuse, measures are also taken to keep materials in the loop including the projects of the sharing zones, circular entrepreneurs, and material recollection. The port of Copenhagen also takes action to close the loop, in the waste management field, by recollecting marine plastics and reducing the consumption of plastic in the canteen of the port.

A similar conclusion as for the *Regenerate* dimension can be drawn for the ***Exchange*** one. Indeed, most of projects combine both dimensions: the use of new technologies often supports the green energy transition. In the Northern city, scientific advances impact how the city disposes of waste. Indeed, automation supports the sorting process, and electric trucks replace fossil fuel trucks. New technologies also intervene in the energy sector. Energy islands construction, Siemens's innovation, and carbon capture project in Amager Bakke are good examples to illustrate it. Finally, in the port of Copenhagen-Malmö, new technologies are heavily used to foster the transition towards green energy. The HVO fuel, electric vehicles, solar panels, motions detectors and quays' inspection by drone are only a few examples of how the port use modern technologies in its path towards a circular port.

Now that the prevalent dimensions have been pointed out, a focus is done on the remaining dimensions of the framework even though they seem to be less present when it comes to initiatives carried out by the City of Copenhagen.

The ***Share*** dimension is present thanks to new actions from local authorities: the sharing zones, the material recollection, and the circular entrepreneurs. The sharing zones allow citizens to share their belongings with others, material recollection bring interesting products to be shared among stakeholders, and circular entrepreneurs share a same space to carry out their activities. This dimension is particularly interesting because all initiatives trigger beneficial effects on the *Loop* dimension: it intervenes at the top of the inversed waste pyramid as it reduces consumption at the source. CopenHill also contributes to this dimension as the energy produced by the centre is shared among surrounding residences.

Optimisation is ongoing through projects aiming at enhancing current processes to make them even more circular. Indeed, tests and pilot projects are currently undertaken especially in the waste management field. For example, Amager Bakke recently launched a pilot project related to carbon capture to reduce CopenHill's emissions and Circular Copenhagen is currently developing projects to optimise the waste management system of the city (e.g., smart sensors and waste sorting process). Finally, motion detectors in the Port of Copenhagen-Malmö optimise energy's consumption of the port.

The ***Virtualise*** dimension does not seem to be the core of most projects. However, it is important to highlight that the City of Copenhagen spread a lot of information on the CE through Circular Copenhagen's website to raise awareness on the topic, thus using virtualisation to access the widest possible audience. Although to a lesser extent than the other dimensions, virtualisation is important in some projects. Indeed, dematerialisation is used for quays' inspection of the Port of Copenhagen-Malmö by using drones and virtualisation is also supporting the development project of the smart sensors contributing to the waste management system of the city. This limited number of initiatives could be surprising because Denmark proclaims itself as a digital frontrunner (Conference 1). Why are there such discrepancies? Is digitalization highly spread and used, but forgot when it comes to circular initiatives?

However, it is crucial to insist on the fact that the number of initiatives undertaken is assessed in this section, and not their impact nor their importance for the society. For instance, switching to electric collection trucks in the waste management plan is not an action that will have the same impact as constructing two energy islands, in terms of budget required, impact on the environment and on the community. Indeed, the objective of the first part of this qualitative analysis is to observe what dimensions seem to be prioritised by Copenhagen City in its circular strategy.

5.1.8.2. The roles of the local authorities

After we exposed the components of the ReSOLVE framework, this section will be dedicated to the different roles that the local authorities take to contribute to the circular initiatives implemented on their territory. As explained in the *2. Literature Review* section, the city can take the role of *Promoter; "*promote the circular economy", *Facilitator; "*facilitate connections and dialogue"*,* and *Enabler; "*enable appropriate governance conditions" (OECD, 2020).

As a reminder, the subcategories of the three dimensions are as follows:

- Promoter (3): *Roles and Responsibilities*, *Strategic vision*, *Awareness and transparency.*
- Facilitator (4): *Coordination*, *Policy coherence*, *Stakeholder engagement* and *Appropriate scale*.
- Enabler (5): *Regulation*, *Financing*, *Capacity building*, *Innovation* and *Data and assessment*.

Although those three main categories can be further divided into 12 subcategories, this recapitulative table will categorise the actions into the three main categories for clarity purpose.

	Promoter	Facilitator	Enabler
City of Copenhagen			
Resource and Waste Management Plan 2024	X		
Circular Copenhagen		X	
Waste management			
Smart sensors		X	X
Waste sorting process		X	X
Electric collection trucks		X	
Diaper recycling		X	
Circular mattresses		X	
Resource-awareness programs	X		
Laws on waste sorting			X
Nudge campaigns	X		
Energy transition			
Climate Act & Climate Plan	X		X
RecyclableBlade			X
Energy islands			X
Waste management & Energy transition			
Amager Bakke			X
Material reuse			
Sharing zones		X	
Material recollection		X	
Circular entrepreneurs	X		X
Port of Copenhagen-Malmö			
Indirectly - All initiatives			X

Table 3. Roles of the local authorities of Copenhagen in circular economy projects – Author's own

The City can act as ***Promoter*** in various projects. First, authorities drew their *Strategic vision* through the *Resource and Waste Management Plan 2024* and *CPH 2025 Climate Plan* at the city-level, and through their *Climate Act 2020* at the country-level. Furthermore, the *Awareness and transparency* dimension of the Checklist for Action model is also present through all the programs dedicated to educating the children on the circular economy (i.e., educational package, free visits of incineration plants, different sorting bins in kindergarten). The nudge campaigns organised by the City of Copenhagen also aimed to raise awareness of the public on the circular economy through a big communication campaign. Finally, local authorities also allow to raise awareness on the CE by requiring circular entrepreneurs to share their findings with the rest of the community.

Local authorities can take the role of ***Facilitator*.** Circular Copenhagen is a public organisation working in close collaboration with private actors, thus creating synergic public-private partnerships (Interviewee 2). For that reason, the initiatives undertaken by Circular Copenhagen make the city have the role of *Facilitator* as it connects various stakeholders together to perform common projects, thus referring to the *Stakeholder engagement* subdimension. For instance, Circular Copenhagen is currently connecting several private and public players to work on pilot and experimental projects based on the needs of the municipality including test on smart sensors, test for the waste sorting process, test of nappies waste collection, test on discarded mattresses. The sharing zones and the material recollection of objects intended to those sharing zones are also development projects implemented by Circular Copenhagen requiring the support of different actors.

Finally, local government can also take the role of ***Enabler*** of the circular economy. Indeed, the city of Copenhagen updated the regulatory instruments to promote the circular economy by implementing laws on waste sorting, thus acting on the *Regulation* subcategory of the Checklist for Action framework. The *Climate Act 2020*, because it is legally binding, also refers to this subcategory. Policymakers can also support the projects by allocating financial resources: Danish authorities are investing in the RecyclableBlade project and are financing the construction of two Energy Islands. Furthermore, the City of Copenhagen, in collaboration with four other cities[30], own the Amager Bakke Centre (Conference 5). The latter facts refer to the *Financing* subcategory of the framework. Local authorities also foster business innovation by making spaces available for circular entrepreneurs: this initiative contributes to the *Innovation* pillar. Finally, the *Capacity building* subdimension is also present in the case of the projects of smart sensors and waste sorting process because the City put at the disposal of relevant stakeholders the test plant needed to perform the pilot tests.

The circular initiatives implemented by the Port of Copenhagen-Malmö are supported by the Danish authorities acting as an ***Enabler***. Indeed, the Port receives financial resources from authorities as it is partly[31] owned by Copenhagen Municipality and the Danish government, thus referring to the *Financing* subcategory of the Checklist for Action.

[30] Dragør, Frederiksberg, Hvidovre and Tårnby cities.

[31] 50% of the shares of the Port are owned by By & Havn (CMP, 2022a), which is itself owned by Copenhagen Municipality and the Danish government (By & Havn, 2019).

5.2. Case 2: Antwerp

Antwerp, one of the biggest cities of Belgium, takes the 27th position in the Arcadis Sustainable Cities Index (Arcadis, 2022). Even if Antwerp is less advanced than Copenhagen in terms of sustainability, this city is still making important effort regarding circular practices. Antwerp is famous for its port, the Port of Antwerp-Bruges, which is taking more and more steps towards the circular economy. The city is also known to be a real chemical cluster in Europe.

Although Antwerp did not take part in the Circular Cities Declaration as Copenhagen did, Antwerp was one of the first signatories of the Covenant of Mayors for Climate & Energy in 2009 (Stad Antwerpen, 2020), the same year as Copenhagen did (EC, 2023a).

It is important to note that Antwerp does seem to have a formal written strategy on the circular economy yet.

5.2.1. Circular Flanders

Circular Flanders is the hub of the circular economy in Flanders: this platform is a partnership made of governments, companies, knowledge community and citizens to accelerate the transition towards more circular cities in the Flemish region (Circular Flanders, 2023). Through their virtual platform, Circular Flanders provide stakeholders with information on the CE and take a major focus on ports (Circular Flanders, 2023). Indeed, Circular Flanders aims at becoming the Flemish point of reference for the circular economy and ports (Circular Flanders, 2023).

This initiative seems to be similar to Circular Copenhagen as they have a common objective and they both emphasise the importance of the ecosystem. However, Circular Flanders is in place at the regional-level whilst Circular Copenhagen is implemented at the city-level. Furthermore, Circular Copenhagen is an organisation made of actors that concretely put into action the circular initiatives in the city whilst Circular Flanders seems to be more a virtual knowledge platform providing information on the CE to a wide international audience. As Circular Flanders spread information on the CE through a virtual platform, it can be categorised in the *Virtualise* dimension.

5.2.2. Waste Management

Belgian produced 5,899 kg of waste per capita in 2020: as opposed to Danes, this quantity exceeds the European mean for that year which amounted 4,808 kg per capital (Eurostat, 2023). Regarding the waste management in the city of Antwerp, as well as in other European cities, residents must sort their waste into four fractions: residual, paper, plastic, and organic food (Interviewee 5). Glass must also be disposed in the bottle banks spread in the city. No additional mandatory sorting measures seem to be in place in the city of Antwerp. However, different initiatives related to waste management are put in place in the city of Antwerp and intervene at different levels of the waste hierarchy (See *section 5.1.3*.1 for more information). Some of those initiatives are disclosed in this section.

5.2.2.1. Composting initiatives

In Antwerp, neighbourhood compost sites are spread all over the city. The city of Antwerp supports the initiative by making the composting containers available in different spots of the city. Furthermore, the City provides the compost sites on its official website to help the citizens find the closest one from their house.

Furthermore, residents can borrow a free shredder pruning from the City of Antwerp. The shredder must be booked in advance on the official website of the city and can be picked up in one of the recycling parks for a duration of one day (Stad Antwerpen, 2023). This tool is useful to dispose of garden waste as it turns the waste into smaller pieces, which makes the green waste disposal easier for the inhabitants of the city.

Finally, the City of Antwerp fosters home composting by providing home composting courses, by offering a home composting demonstration site in the garden of the EcoHuis, and by advising the residents on compost matters during activities or by appointment (Stad Antwerpen, 2023).

All those composting initiatives refer to the *Regenerate* dimension of the ReSOLVE framework as composting is giving back to the biosphere what was employed. Furthermore, those actions contribute to the *Loop* dimension: the waste, after it is transformed, can be repurposed (e.g., can be used as soil or plant fertilizer). The *Virtualise* dimension is also present because a lot of information on composting is disclosed on the official website of the city (e.g., compost sites spots, booking of shredder pruning, etc).

5.2.2.2. Loan of reusable cups on events

The City of Antwerp supports the reduction of plastic waste during events organised on its territory by providing reusable city cups free of charge for events organised by or in collaboration with the City of Antwerp (Stad Antwerpen, 2023). This action refers to the *Share* dimension of the conceptual framework. Indeed, the reusable cups shared by the city are borrowed by the organisers during their events. This initiative prevents them from buying brand new ones and has a positive impact at the top of the inversed waste hierarchy: waste prevention. It also contributes to the cradle-to-cradle instead of the cradle-to-grave model as cups are reused instead of being thrown after a unique utilisation. Therefore, it also promotes the *Loop* dimension of the framework.

5.2.2.3. Regulations on reusable cups on events

From June 2023, events' organizers will still have the right to use PET bottles and cans, but they will have to ensure a system that guarantees that at least 95% of the receptacles are collected for recycling (Stad Antwerpen, 2023). In this case, the City of Antwerp will not lend waste containers and the events' organisers are responsible for collecting and disposing of the waste (Stad Antwerpen, 2023). Except that, all single-use containers (e.g., bioplastics or cardboard cups) will be prohibited from then on (Stad Antwerpen, 2023). From January 2025, there will be a complete ban on serving drinks in single-use containers at events (Stad Antwerpen, 2023). This decision testifies Antwerp's willingness to have a positive impact on its plastic consumption and promotes a circular waste management.

Those regulations established by the City of Antwerp can be considered as enablers to act towards a cleaner city. From the point of view of Interviewee 5, "I [inhabitant from Antwerp] feel like it has been going on here a lot longer than the European legislation that made them do it". The aim of those regulations is to act on the *Loop* dimension of the framework by keeping the reusable cups in the loop, cradle-to-cradle.

5.2.3. Energy Transition

Similar to the City of Copenhagen, the City of Antwerp established a *Climate Plan 2030*. However, at the country-level, Denmark signed a legally binding *Climate Act* in 2020 whilst no such document has been signed by Belgium. Indeed, the different regions of the country (i.e., Wallonia, Flanders, and Brussels capital) all have their own specific carbon reduction targets: unlike Denmark, no consensus is reached within the country which prevents the country from achieving the expected targets (European Parliament, 2021).

5.2.3.1. Climate Plan 2030

Although the City of Antwerp has not signed a specific policy related to the circular economy yet, a *Climate Plan 2030* has been established in the year 2020. This document can be considered as the formal written strategy of the City regarding its commitment in the shift towards sustainable energy. In its previous *Climate Plan 2020*, Antwerp committed to reduce CO_2 emissions on the territory by 20% by 2020 compared to 2005, and achieved it (Stad Antwerpen, 2020). The new target of the *Climate Plan 2030* is even more ambitious: the goal is to reduce CO_2 emissions by 50 to 55% by 2030 compared to 2005 and to be a climate neutral city by 2050 (Interviewee 4) in order to respect the European Green Deal, and more especially the 2030 Climate Target Plan (EC, 2019).

In 2021, energy sources used in Belgium were as follows (IEA, 2023b):

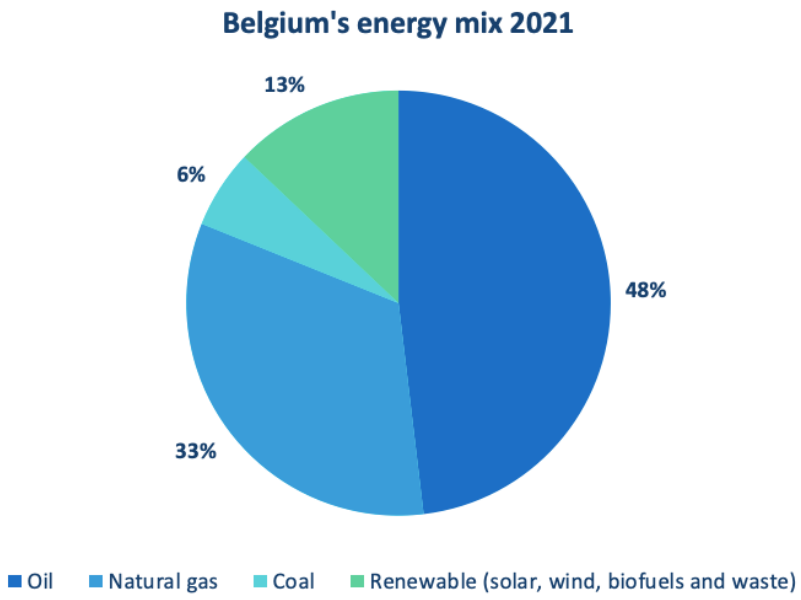

Figure 10. Belgium's energy mix 2021 – IEA (2023b)

Oil remains the most used energy source by the country (48%), followed by natural gas (33%). To a lesser extent, Belgium is partially powered by renewable energy sources (13%) and still relies reasonably on coal (6%).

If the objectives of the *Climate Plan 2030* become a reality, the use of renewable energy will increase. It will contribute to the *Regenerate* dimension and the shift will be supported by the *Exchange* of our current ways to produce energy with more sustainable ones.

To achieve this purpose, the City of Antwerp discloses four pillars to cut CO_2 emissions in its *Climate Plan 2030*: to act on energy savings at home, to switch to a different way of moving around, to use more efficient energy in services and industry, and to shift to new and clean energy sources (Stad Antwerpen, 2020).

Furthermore, in the *Climate Plan 2030*, it is disclosed that the ambition can only be achieved in partnerships and the port of Antwerp is even considered as a key player in this transition. Indeed, Belgium's largest onshore wind farm is in the port area; the hundreds of hectares of warehouses on the site could be suitable to host large number of solar panels; residual heat from the petrochemical processes could be an interesting source of energy to heat city buildings; etc. (Stad Antwerpen, 2020). Initiatives of the port will be analysed in detail in section *5.2.6. Port of Antwerp-Bruges* as the port is a key player in the transition towards a climate-neutral city by 2050.

5.2.3.2. Heat Networks

The City of Antwerp, in collaboration with the Province of Antwerp, is currently working on a long-term project to implement heat networks within the city (Interviewee 5). Members of the project identify if there are any residual heat producers in the city and investigate if it would be interesting to link them with houses and companies in the area (Interviewee 5). The final objective would be to create a sustainable district heating network powered by residual heat. For instance, this project would perfectly suit an area in which a big company produces daily large amount of heat due to its business activity, without catching it. If the heat just disappears in the process, there is potential progress to be done. This residual heat could be repurposed, for instance, to warm other companies in the area or to heat a close neighbourhood with many apartments.

The *Regenerate* dimension could fit in this context. For example, as a residence, reusing the energy created by a company to power its own facilities is obviously using clean energy. Furthermore, the energy would remain in the *Loop* instead of vanishing. Finally, the *Share* dimension would also fit in the present case due to the collaboration between different entities that would share their residual energy sources.

5.2.3.3. Bike Sharing - Velo

Velo is an initiative from the City of Antwerp that grew a lot in recent years (Interviewee 5). The concept of this public organisation is simple: users pay a subscription, and whenever they find a bike available in one of the many stations dispersed in the city, they can borrow it and bike until they reach another station to let it. This concept is part of the sharing economy[32]: people shift from the ownership to the use by borrowing bikes instead of buying them. This leads into a reduction in new bikes production and intervenes at the top of the inversed waste hierarchy: waste prevention. Although this research focuses on public initiatives, it is essential to mention that different private companies working in transport sharing are also active in Antwerp, for bike sharing as well as for car sharing (Interviewee 5).

For all those reasons, the Velo business model can be included in the *Share* dimension of the conceptual framework as well as the *Regenerate* one. Indeed, bikes are shared between citizens and Velo decreases the use of polluting means of transport by encouraging the use of a sharing bike system. Furthermore, the *Virtualise* dimension is exploited as users can download the mobile application on their digital devices to benefit from Velo's services.

[32] The sharing economy is a concept in which individuals rent or borrow goods rather than buy and own them.

5.2.4. Material Reuse

5.2.4.1. Blue Gate Antwerp

In the South of Antwerp, more especially in the Antwerpen district, a climate neutral business park called Blue Gate is currently developing (BAS, 2021). This industrial site reserved to innovative companies was initially a brownfield site, and now it became the first circular park on the ground of Antwerp (Interviewee 4). The objective of this innovation hotspot is to gather like-minded businesses dedicated to undertaking circular operations (Blue Gate Antwerp, 2023). Different businesses are already implemented on Blue Gate site: BlueChem, BlueApp, DHL Express and Montea (Blue Gate Antwerp, 2023). All those businesses can refer to various dimensions of the framework, depending on their core business.

5.2.4.2. BlueChem Kickstart Fund

BlueChem is an incubator of sustainable chemistry located in Blue Gate. At BlueChem, people can rent labs for a day, a week, a month, depending on their needs (Interviewee 4). “Because you don't have that initiative everywhere, we [City of Antwerp] see that companies looking for labs are coming from far away because it's really a unique offering here in the area. It's a great success.” (Interviewee 4). This initiative maximises the utility of the labs and minimises the cost to be paid by companies at the same time. This offering is particularly useful for companies that have short-term projects or for start-ups that do not have the adapted facilities yet.

The City of Antwerp created a fund to subsidise BlueChem residents. This fund is called the “BlueChem Kickstart Fund” and it represents the willingness of the City of Antwerp to stimulate sustainable innovation in the chemical sector (BlueChem, 2023). This fund can contribute up to 80% of the total cost of laboratory’s furnishing, including for instance the purchase of revolutionary machinery and technologies (BlueChem, 2023).

This initiative corresponds to the *Share* dimension of the ReSOLVE framework. Indeed, the labs are shared across different companies and start-ups, depending on their needs. This concept is therefore part of a sharing economy in which there is a shift from the ownership to the sharing model.

5.2.4.3. BlueApp

BlueApp, an initiative of the University of Antwerp to gather industry and academic together, is a pre-incubator of sustainable chemistry (Interviewee 4). As BlueChem, it is located in Blue Gate and its field of interest is the sustainable chemistry. The aim of BlueApp is to become an open innovation hub where the various actors of the chemical innovation ecosystem, either from the industry or from the academic sector, can meet in person to follow together training programs or to work jointly on specific projects related to sustainable chemistry (BlueApp, 2023). BlueApp can suit different dimensions of the framework depending on the activities undertaken by the chemists (e.g., *Loop* dimension if their project consists in recycling molecules).

5.2.4.4. Circular Kickstart

The Circular Kickstart is an organisation active in Flanders that is working as an incubator for circular starters to help them start and grow their business, always in a circular mind (Interviewee 4). This public-private partnership partly receives financial support from Flemish Cities (e.g., Gent, Bruges, etc) including the City of Antwerp: "The Circular Kickstart, which is a private organization, we [city of Antwerp] give them financial support, they got 40,000 euros this year". Circular Kickstart is a key partner of entrepreneurs, and together, they foster the launch of circular private businesses on the Flemish market. The supported businesses can employ new technologies to start their business, but they can also integrate sustainability within their strategies without the use of disruptive technologies (Interviewee 5). This organisation fosters the *Loop* dimension of the framework. Indeed, the support is only dedicated to entrepreneurs bringing a solution to keep materials and products cradle-to-cradle.

5.2.4.5. Circular Design Research

The University of Antwerp, and more especially the faculty of Product Development, is currently working on circular design projects (Interviewee 5). This design research lab coordinates researchers, professors, and students to find innovative circular solutions to be integrated in the initial stage of creation of the products: the design. The research group has different eco-design projects ongoing. For instance, the "Ecoteam" is currently investigating the use and impact of plastic in the design of products through their main research question: "How to design for optimal plastics usage in a circular economy?" (University of Antwerp, 2023). In this context, the researchers intend to redefine the use of plastics by designing it for long-lived products instead of designing it for a single use (University of Antwerp, 2023). The main findings are disclosed on the official website of the University in order to raise awareness on the CE.

This initiative from the University of Antwerp can be included in the *Loop* dimension of the ReSOLVE framework. Indeed, the common objective of those projects is to design for a circular economy, which means to keep materials and products in the loop by making them sustainable in the initial design phase.

5.2.4.6. Industrial symbiosis

One of the ongoing projects of the Province of Antwerp is to act as a matchmaker and connect resources between businesses. From the words of Interviewee 5, "We [province of Antwerp] want to find out if we can connect resources between companies and to create that circular motion where the waste stream of one company becomes the input of another". This phenomenon, as part of the circular economy, is called the industrial symbiosis: it is a business model that improves resource efficiency and creates value from waste (Fusco Girard & Nocca, 2019).

This project is undertaken by the Province of Antwerp, which means that the scope is broader than the City of Antwerp even though many opportunities appear to be on its territory, more especially in the surroundings of the city centre. For instance, one of the investigated areas where to connect companies is Blue Gate Antwerp (Interviewee 5). The role of the Province of Antwerp in this project is of a matchmaker: public servants will detect resource sharing opportunities and will foster communication between businesses to make the resources connection happen. This initiative refers to the *Loop* dimension of the framework as its goal is to repurpose the waste stream of one company towards a new business activity. It can also correspond to the *Share* dimension since the organisations share their own resources with other entities.

5.2.5. Circular South

Not far away from Blue Gate Antwerp, starting in 2018 and concluding in 2021, an innovative project related to the circular economy took place. The Antwerp Circular South project is an initiative that was funded by UIA[33], the former EUI[34], aiming at experiencing the implementation of different circular innovations in the New South district. Although the project is now over, some initiatives such as the Circular South Community Centre (i.e., CIRCUIT) are still ongoing. This project was considered as a living lab for experimentation in co-creating offline and online actions in changing consumers' behaviour as well as testing new circular technologies on a large scale (Bonneau, 2018). For instance, the project organised activities off-line such as workshops to make homemade detergents. It also organised initiatives online, for instance through an app following residents' energy consumption thanks to a blockchain system (Interviewee 3).

All fields of interest of this research (i.e., waste management, material reuse and energy transition) have been treated during this project as well as other components such as water provision and consumer behaviour. Furthermore, all dimensions of the ReSOLVE framework have been noticed in this experiment: this is not surprising as this project aimed at covering various aspects of the circular economy that could be implemented at the city-scale in a comprehensive way.

To give a bit of context, Circular South is a project that was co-financed by different entities including the UIA, the City of Antwerp, as well as other private and public partners, in order to test innovative solutions for sustainable urban development (Bonneau, 2018). It is essential to understand the context of this experiment, which was set up in a newly built neighbourhood, even though many successful elements of this project, taken individually or collectively, could be replicable in other cities with the relevant context-specific adjustments (Interviewee 3). This technical, creative, and innovative project can therefore be a source of inspiration for municipalities around the world in their path towards the circular economy.

5.2.5.1. Waste Management

- Waste challenges

Circular South residents, and Antwerp citizens in general, were involved in different waste challenges all along the project to sensibilize them to sort and to reduce waste disposal.

The first challenge carried out was the "zero-waste challenge", also called the 100-100-100 challenge. The concept is simple: for 100 days, 100 participants target 100% zero waste (Bonneau, 2019a). This challenge was launched in October 2018 (Bonneau, 2018) by the City of Antwerp and during the 100 following days, participants weighted their waste disposal. In the end, the volunteers accomplished 68% of waste reduction (Bonneau, 2019a). Some of the participants also shared about their experience on an online platform set up by the City of Antwerp.

The second challenge was called the "FC Minder Afval". It was launched in January 2020, and it took place in August 2020 (Bonneau, 2020b). The concept is the second edition of the first challenge explained in the previous paragraph but with new tasks, recommendations, and examples (Bonneau, 2020b). The experiment gathered more than 600 participants, including 16 coming from Circular South neighbourhood (Bonneau, 2020b).

[33] UIA: Urban Innovative Actions
[34] EUI: European Urban Initiative

Both challenges were initiatives of the City of Antwerp in which citizens of the Circular South neighbourhood took part. However, the UIA project also carried out waste challenges of its own. A good example is the plastic deposit challenge. Plastic bottles and caps from residents were collected via vending machines for research purpose with the University of Antwerp on recycling and reusing (e.g., bottle-to-bottle recycling, new plastic development, reuse plastic as raw material, etc.) (Bonneau, 2020b). Therefore, this challenge was an alternative to the existing sorting system of the city (Bonneau, 2020). The objective of the challenge was also to raise citizens' awareness about their plastic consumption (Bonneau, 2020b).

Another project, the "green waste challenge", should have taken place to inform on composting. However, due to the Covid-19 crisis and the lockdown, no composting sessions could be organised (Bonneau, 2020c). However, except this failure, most of the waste challenges have been successful and potentially led to adoption of new sustainable practices (Bonneau, 2020c).

All those waste challenges refer to the *Regenerate* dimension as the objective was to preserve ecosystems sustainability. They also refer to the *Virtualise* dimension as participants could share on their experience on an online platform.

- Residual waste nudging experiment

To act on the waste pillar, the Circular South project worked on different initiatives. One of the initiatives carried out was to put in place a nudging experiment. The aim was to reduce the total residual waste in the neighbourhood by 10% (Bonneau, 2020c). During the nudging campaign, participants received several tips to decrease their amount of residual waste (Bonneau, 2020c). Although this experiment failed as 8 out of the 14 people involved noticed they even produced more waste during this experiment because it took place during the Covid lockdown in March and April 2020 (e.g., because volunteers disposed of more paper due to online shopping), awareness on waste disposal was still raised (Bonneau, 2020c). This experiment contributed to the *Regenerate* dimension for the same reason as the waste challenges and to the *Virtualise* one as virtual means were used to send the weekly tips.

5.2.5.2. Energy transition

- PVs and BIPVs

The Circular South project focused on green energy transition through different initiatives. First, the bulk of the project's funding was dedicated to the installation of photovoltaic panels and energy storage battery, even though the batteries have not been implemented in the end for logistic and timing problems (Interviewee 3). The installation of PVs (i.e., photovoltaics) and BIPVs (i.e., building-integrated photovoltaics) was a success even though the public procurement faced some delays (Bonneau, 2020c). The *Regenerate* dimension is therefore essential in the project regarding the important budget allocated to renewable energy.

- Smart meters

Furthermore, the project aimed to foster online community engagement through the creation of an application (Interviewee 3). Its main objective was to follow participants' energy consumption and to influence them to shift their consumption habits. This experiment would not have been possible without the installation of smart meters (i.e., smart plugs and smart sensors) in participants' houses in order to gather their energy consumption data (Bonneau, 2020c). By the end of the project, 61 smart

meters were installed (Bonneau, 2022). The use of this new digital device can be classified in the *Exchange* dimension of the framework due to its relationship with new technologies, to the *Optimise* dimension as its objective is to optimise participants' energy consumption by using data, and to the *Virtualise* one as the data collected by the smart meters is virtually gathered on the Circular South App.

- Energy nudging experiment

The concept was to set up the Circular South App, connected to the smart meters placed in the volunteers' dwelling in order to follow their energy consumption. For instance, the app sent notifications to inform citizens about their average consumption per household (Bonneau, 2020a). But the app went further than that: participants received reminders to use energy when it was available and congratulations messages after a positive shift, such as a decrease in energy consumption (Bonneau, 2020a). These features of the app are based on the nudge theory. Indeed, a blockchain-based reward system was implemented to recompensate green behaviour: volunteers received circular coins, known as "Circules", to reward them for their efforts. Circules were means of exchange and could be used at the City of Antwerp's facilities (i.e., swimming pool, cultural events, etc).

To link the Circular South App with dimensions of the framework, *Virtualisation* is obvious, the Circular South App being a digital platform displaying a dashboard with household tenants' consumption data. Furthermore, the use of the blockchain is a clear switch to new technologies referring thus to the *Exchange* dimension. Finally, *Optimisation* is also at the heart of the app because the final aim of this app is to optimise residents' energy consumption.

5.2.5.3. Material Reuse

- CIRCUIT

As part of the project, the Circular South Community Centre, a temporary centre at first, was launched in the end of 2018 and was slowly implemented after that date (Bonneau, 2019a). This centre was the central hub to host several actions promoting sharing, repairing, and reusing activities in the district (Interviewee 3). In more details, the centre carried out circular activities such as the leasing of tools and devices, repair cafes, second-hand shop, circular material workplace and redesign services (Bonneau, 2018). For instance, CIRCUIT played a role as incubator for start-ups and made available premises to circular entrepreneurs. This opportunity allowed "entrepreneurs to rent spaces for their activities and to benefit from local synergies" (Interviewee 3).

Although the centre was initially public initiative, it was subsequently bought by De Kringwinkel[35] and moved to a new location, on the ground floor of the Palazzo Verde, in the end of June 2021 (Bonneau, 2020c). However, the initial concept remains the same: the CIRCUIT is still a hub for circular initiatives. There is a circular concept store, a bar, shops, workshops, and free space for small-scale activities (BAS, 2021). For instance, there is a shop dedicated to bike-repairing, but also a florist, a bakery, etc. (Interviewee 3). All those units have one thing in common: focusing on recycling and/or upcycling (BAS, 2021).

This community centre corresponds to the *Share* dimension: the leasing of tools and devices, the sharing of premises and the presence of a thrift shop are all characteristics of this dimension. Furthermore, many initiatives pertain to the *Loop* dimension: circular entrepreneurs, repair cafes, and circular material workplace all contribute to the reduction of new material purchases.

[35] Kringwinkel is a social and professional reinsertion NGO in the reuse of discarded goods and recovery of non-reusable parts (Bonneau, 2018).

5.2.6. Port of Antwerp-Bruges

The Port of Antwerp-Bruges is Europe's second largest port and considers itself as a driver of the circular economy and energy transition (Port of Antwerp-Bruges, 2023c). The port hosts the largest integrated chemical cluster in Europe and is a critical hub in trade and industry worldwide (Port of Antwerp-Bruges, 2023c). The port refers to the SDGs to support its sustainability strategy and particularly emphasizes the SDG N°17[36] as it aims to be seen as a community builder genuinely committed to foster international and sustainable partnerships (Port of Antwerp-Bruges, 2023c).

Furthermore, it is important to mention that the Port of Antwerp has a formal strategy drafted regarding the circular economy: in October 2017, a roadmap with a clear focus on the circular economy was established by the Port's authorities (Circular Flanders, 2017).

5.2.6.1. Waste Management

- Floating waste collection

The Port of Antwerp-Bruges is committed to a clean port. For that reason, the port aims at reducing the litter and floating waste surrounding its maritime area. The port crew of the waste collection boat "Condor" ensures the cleanliness of the port's water by collecting any reported waste in the water (Port of Antwerp-Bruges, 2023a). To detect more easily the floating debris, the port of Antwerp-Bruges even developed a drone able to spot the waste location (Port of Antwerp-Bruges, 2023b). The use of a drone, fitting the *Optimise* and *Exchange* dimensions of the framework, allows a quicker and more efficient clean-up of the port's water by using modern technologies. Furthermore, it allows to potentially keep garbage in the *Loop* by, for instance, recycling it. Finally, the *Virtualise* dimension is also present as drones create a virtual representation of the reality.

5.2.6.2. Energy Transition

- Local green energy production

The Port of Antwerp-Bruges is a major green energy hub at present time: companies located in the port area of Antwerp as well as Zeebrugge produce great amount of renewable energy thanks to wind turbines and solar panels (Port of Antwerp-Bruges, 2023c). In more details, Zeebrugge holds 50 wind turbines providing energy to approximately 90,000 families whilst Antwerp holds 80 winds turbines supplying roughly 140,000 families (Port of Antwerp-Bruges, 2023c).

Those green energy solutions correspond to the *Regenerate* dimension: wind turbines and solar panels are producers of clean energy. Furthermore, they fit the *Exchange* dimension as well due to the substitution of traditional ways of producing energy with renewable ones.

[36] SDG N°17 refers to "Partnerships to achieve the goals".

- Hydrogen hub

Hydrogen is the most abundant chemical element in the world (Rand & Dell, 2007). Although the shift towards the hydrogen economy is beneficial to prevent climate change and atmospheric pollution, hydrogen was not used in the past partly because of the difficulty to produce it efficiently and affordably (Rand & Dell, 2007). Hydrogen is also known to be difficult to store.

However, the Port of Antwerp-Bruges and its collaborators seem to be ready to tackle these challenges and aim to build a hydrogen economy. Although hydrogen needs a lot of energy to be separated from other atoms, it has the advantage to not release any CO_2 in the atmosphere if the electrolysis is made with electricity coming from renewable energy sources (Port of Antwerp-Bruges, 2023c). Furthermore, on top of reducing carbon emissions, hydrogen can have various applications such as energy storage, fuel for transportation, energy source in industry, etc. (Port of Antwerp-Bruges, 2023c). All those reasons fostered the launch of the project towards a hydrogen economy.

On the one hand, the project consists in testing hydrogen solutions on-site. Different types of hydrogen can be produced depending on the separation process: grey, blue and green hydrogen. When the electricity used in the electrolysis comes from renewable energy sources, this process produces green hydrogen (Port of Antwerp-Bruges, 2023c). Another way to create hydrogen is to produce it with fossil fuels, but to capture and store the released CO_2 to ensure it does not enter the atmosphere (Port of Antwerp-Bruges, 2023c). The result is called blue hydrogen. The last option is to make hydrogen with fossil fuels whilst releasing the carbon emissions in the atmosphere: it produces grey hydrogen (Port of Antwerp-Bruges, 2023c). The port of Antwerp focuses its activities to produce either blue or green hydrogen.

On the other hand, the project consists in importing hydrogen from foreign countries. Although the port is an energy hub and meet the needs for renewable energy of many surrounding businesses, the energy production is not sufficient to meet the needs of Belgium and Western Europe. The latter is due to the lack of sun and wind in this part of the world. Therefore, the port is working on a project to import hydrogen from countries such as Chile, Oman, Egypt or Brazil (Port of Antwerp-Bruges, 2023c) in order to provide clean energy derived from hydrogen on a large-scale. The final aim of the port is to become a lever for the global hydrogen supply chain (Port of Antwerp-Bruges, 2023c).

The hydrogen project fits the *Regenerate* dimension by producing clean energy that does not release CO_2 emissions in the atmosphere. Moreover, the *Exchange* dimension is relevant because the hydrogen economy is supported by renewable schemes as well as new technologies. The *Optimise* dimension is also relevant in this case. Indeed, energy storage can be an important issue for renewable energies. For instance, storing the energy produced by wind turbines is still a challenge at present time. One of the applications of the hydrogen being energy storage, the project will optimise energy production by offering solutions to store it instead of wasting it.

- NextGen District

Another ongoing project in the port is the development of a district dedicated to innovative, sustainable, and circular chemistry. This industrial site will work as an incubator for entrepreneurial innovators with projects linked to sustainable chemistry that contribute, in one way or another, to fight climate change (Port of Antwerp-Bruges, 2023c). Located in the area of the port of Antwerp, which is the largest integrated petrochemical cluster in Europe, the companies of the NextGen district will have the possibility to interact with major players working in similar sectors (Port of Antwerp-Bruges, 2023c). This potential collaboration between companies and industries of the NextGen district will create interesting synergies as well as partnerships.

This district suits the *Exchange* dimension due to its focus on companies that have new, innovative, sustainable, or circular business models. Other dimensions could be relevant depending on the activity of the businesses that will set up in this industrial area (e.g., if a company renting lab material set up in the district, it will impact the *Share* dimension as well).

- Ecluse - Antwerp North heat grid

Ecluse is the name of the industrial steam network located in the Waasland port area (i.e., an extension of the Port of Antwerp). The Ecluse is operational since 2019 and is the result of public-private partnerships (Indaver, 2023). The steam of the pipeline network is sluiced from Indaver[37] and SLECO waste-to-energy plant to five surrounding companies (Indaver, 2023). Furthermore, the Ecluse infrastructure was initially built to support twice the current steam capacity (Port of Antwerp-Bruges, 2023c). For that reason, there are still opportunities for new joiners to connect to the network (Indaver, 2023).

The advantage of this pipeline network is twofold: the waste-to-energy plants can dispose of the steam ecologically and be remunerated for it, whilst the adjacent companies can access affordable, flexible, local, and clean energy. On top of providing a great opportunity to companies, this initiative impacts positively the environment by being responsible for an annual CO_2 saving of 100,000 tonnes (Indaver, 2023).

This project refers to the *Exchange* dimension as it uses state-of-the-art technology (Port of Antwerp-Bruges, 2023c). Furthermore, this initiative fits the *Share* dimension: there is a collaboration between several companies that share energy on the same network. There is also the presence of the *Loop* dimension. Indeed, instead of disappearing in the air, the residual heat of the activities of the waste-to-energy plant is repurposed to support the activities of other companies. Even the *Regenerate* dimension is suitable to this project: by using the residual waste of an adjacent company, the beneficiaries can turn off their own gas boilers and use clean energy instead. Overall, this initiative has a positive impact on the environment by substituting grey energy by green energy. As one will notice, this industrial steam network impacts positively several dimensions of the ReSOLVE framework.

[37] Indaver is a company specialized in sustainable waste management and recycling.

5.2.6.3. Material Reuse

- Industrial symbiosis

As mentioned in a previous section, the Province of Antwerp started a project, still at the start-up phase, to explore industrial symbiosis opportunities. In more details, it investigates the potential to connect resources between entities located in a same area. The same objective was addressed in the Antwerp port area in September 2021 when the Port of Antwerp launched an open call to stimulate the circular economy (Indaver, 2023). One of the collaborations considered as the most promising was the Indaver/Marlux-Stradus partnership which won a support of 50,000€ to implement their symbiosis project (Indaver, 2023).

In more details, Indaver/Marlux-Stradus project consists in producing clinkers with processed bottom ashes. Indaver, as a waste-to-energy plant, produces annually approximately 90,000 tonnes of bottom ash (Indaver, 2023). After treatment of those ashes, there is a production of 30,000 tonnes of granules that can be used as secondary raw material to manufacture the clinkers produced by the Marlux-Stradus company (Indaver, 2023).

This symbiosis project obviously fits the *Loop* dimension by making the waste stream of one company become the input of another one. The *Share* dimension is also suitable as there is a collaboration between two companies that share their own resources.

- Circular cycle path

In the port area, there is a network of cycle paths spread on more than 200 kilometres (Port of Antwerp-Bruges, 2023c). On an 800 metres-long section of the cycle path, the port used sustainable raw materials to build the cycling road (Port of Antwerp-Bruges, 2023c). The first part of the road was entirely made of reused and recycled plastics whilst the second one was a mixture of asphalt and plastic waste (Port of Antwerp-Bruges, 2023c). This innovation will be extended to other parts of the area: the Port of Antwerp-Bruges took the decision to invest more than 40 million over the next 10 years in the cycling infrastructure surrounding the port area (Port of Antwerp-Bruges, 2023c).

This initiative is a good example of a sustainable action pertaining to the *Loop* dimension. Indeed, the plastic is repurposed to become a road filling material. Furthermore, this project is a technological first in Belgium and is supported by innovative techniques. For that reason, the *Exchange* dimension also fits this project. The *Regenerate* dimension is also relevant in this case. To produce asphalt, important amounts of carbon emissions are generated. However, by using recycled plastics instead of asphalt, those pollutant emissions are prevented. On top of that, the whole project encourages the use of a light mode of transport.

5.2.7. Framework analysis

5.2.7.1. Resolve Framework

For Antwerp's city, all circular practices addressed in this research are disclosed in the following table.

	Regenerate	Share	Optimise	Loop	Virtualise	Exchange
City of Antwerp						
Circular Flanders					I	
Waste management						
Composting initiatives	I			I	I	
Loan of reusable cups		I		I		
Regulations on reusable cups				I		
Energy transition						
Climate Plan 2030	I					I
Heat networks	D	D		D		
Bike sharing - Velo	I	I			I	
Material reuse						
Blue Gate Antwerp	(D)	(D)	(D)	(D)	(D)	(D)
BlueChem Kickstart Fund		I				
BlueApp	(I)	(I)	(I)	(I)	(I)	(I)
Circular Kickstart				I		
Circular Design Research				I		
Industrial symbiosis		D		D		
Circular South						
Waste management						
Waste challenges	I				I	
Nudging experiment	I				I	
Energy transition						
PVs and BIPVs	I					I
Smart meters			I		I	I
Nudging experiment	I		I		I	I
Material reuse						
CIRCUIT		I		I		
Port of Antwerp-Bruges						
Waste management						
Floating waste collection			I	I	I	I
Energy transition						
Green energy production	I					I
Hydrogen hub	D		D			D
NextGen District						D
Ecluse	I	I		I		I
Material reuse						
Industrial symbiosis		I		I		
Circular cycle path	I			I		I

Table 4. Circular initiatives and strategy in the city and port of Antwerp – Author's own

Legend:

Symbol/Letter	Meaning
I	Initiatives that are already implemented in the city
D	Initiatives that are still at the development/test level, or not yet actives on the market
()	The presence of each dimension of the framework will depend on the nature of the projects undertaken in the future

In this research, three main sections related to Antwerp have been approached: the City of Antwerp itself, the Circular South project and the Port of Antwerp-Bruges.

In this summary, one will notice the importance of the *Regenerate* and *Loop* dimensions, followed by the *Exchange, Virtualise and Share* dimensions in the city of Antwerp. To a lesser extent, the *Optimise* dimension is also represented in different projects.

The City of Antwerp implements several initiatives contributing to the ***Regenerate*** dimension. First, Antwerp's authorities established a clear strategy through their *Climate Plan 2030* disclosing all their ambitions to reach their target to be a climate neutral city by 2050. Regarding the waste management field, local authorities invested in composting infrastructures to give back to the biosphere what was employed. Furthermore, the authorities of Antwerp are shareholders of the main bike sharing system of the city and are currently working on a heat network project to share residual heat among different entities. The Circular South project also contributed to the *Regenerate* dimension by implementing PVs and BIPVs and by undertaking nudging experiments and waste challenges. The Port of Antwerp-Bruges is also heavily investing in clean energy to become the leading green energy port of Western Europe. Among different initiatives (e.g., local green energy production, industrial steam network, etc), the focus of the port is currently to become a real hydrogen hub.

Closing the ***Loop*** is also important for the Belgian city. In this study, different projects support the integration of the circular economy into products' lifecycle: circular design project, incubator for circular starters, circular material workplace and circular cycle path. Moreover, initiatives such as composting and reusable cups on events contribute to a better waste management. Loops are also closed through energy recovery (e.g., heat network project, Ecluse project) and the sharing of material resources through two industrial symbiosis projects (i.e., at the city-level as well as the port-level). Those projects also impact the *Share* dimension as it based on the sharing of energy or material resources between different entities. Finally, floating waste collection in the port is carried out to reduce the amount of marine litter.

The ***Exchange*** dimension is also present in this case study. In the *Climate Plan 2030*, the use of renewable, modern, and new technologies is highlighted. The City of Antwerp also supports innovative entrepreneurs and companies to develop (e.g., Blue Gate Antwerp). In the port of Antwerp, many ongoing projects contribute to this dimension such as green energy production, floating waste collection, the hydrogen hub and the NextGen District. Same applied to past projects such as Ecluse and the circular cycle path. Finally, Circular South project used modern and renewable solutions to experiment new ways of living by heavily relying on technology (e.g., smart meters, Circular South app, PVs and BIPVs).

In this research, the ***Virtualise*** dimension is mainly used to disclose information on the CE. This is done virtually through official websites of different entities in order to raise awareness on the CE and/or transmit best practices (e.g., Circular Flanders, City of Antwerp, University of Antwerp, Circular South pilot project, etc). Virtualisation is also massively used in the Circular South project, mainly through the use of the Circular South app, for different purposes. It has also been addressed through the mobile application of Velo.

The authorities of Antwerp seem to put the accent on the importance to ***Share*** and connect the resources between adjacent organizations. As mentioned previously, industrial symbiosis and the connection of energy resources contribute to this dimension. The concept of sharing is also present in the Circular South project through the community centre CIRCUIT in which sharing, repairing, and reusing activities are hosted. Blue Gate Antwerp, the emergent climate neutral business park, also fosters the *Share* dimension by accommodating companies such as BlueChem (i.e., a sharing lab company). Finally, the City of Antwerp also promotes sharing through the loan of reusable cups to events' organizers and by subsidising the bike sharing system of the city.

To a lesser extent, the ***Optimise*** dimension support some projects of the city (e.g., through Blue Gate Antwerp), the Port (e.g., use of drones and development of a hydrogen hub) and Circular South (e.g., smart meters).

5.2.7.2. The roles of the local authorities

All the initiatives explained in this chapter on Antwerp will be associated to the roles taken by the local authorities to contribute directly or indirectly to them. As explained previously, local authorities have complementary roles: *Promoter; "*promote the circular economy", *Facilitator; "*facilitate connections and dialogue"*,* and *Enabler; "*enable appropriate governance conditions" (OECD, 2020).

As a reminder, the subcategories of the three dimensions are as follows:

- Promoter (3): *Roles and Responsibilities*, *Strategic vision*, *Awareness and transparency.*
- Facilitator (4): *Coordination*, *Policy coherence*, *Stakeholder engagement* and *Appropriate scale*.
- Enabler (5): *Regulation*, *Financing*, *Capacity building*, *Innovation* and *Data and assessment*.

Similar to the analysis of Copenhagen, this recapitulative table will only categorise the actions into the three main categories.

	Promoter	Facilitator	Enabler
City of Antwerp			
Circular Flanders	X		
Waste management			
Composting initiatives	X		X
Loan of reusable cups			X
Regulations on reusable cups			X
Energy transition			
Climate Plan 2030	X		
Heat networks		X	
Bike sharing - Velo			X
Material reuse			
Blue Gate Antwerp		X	
BlueChem Kickstart Fund			X
BlueApp		X	
Circular Kickstart			X
Circular Design Research	X		
Industrial symbiosis		X	
Circular South			
Indirectly - All initiatives			X
Port of Antwerp-Bruges			
Indirectly - All initiatives			X

Table 5. Roles of the local authorities of Antwerp in circular economy projects – Author's own

The City of Antwerp can act as ***Promoter*** of the circular economy. Most of the time, this is done through the diffusion of information on the CE virtually. For instance, knowledge on composting is shared on the official website of the municipality, main findings of the Circular Design Research project are disclosed on the official website of the University of Antwerp, and insights on the CE are present on the Circular Flanders website. The final objective is to raise *Awareness and transparency* on the CE. Furthermore, the authorities at the city-level also established a clear strategy to tackle climate change through their *Climate Plan 2030* (i.e., *Strategic vision subcategory*).

Local authorities can also play the role of ***Facilitator***. In the ongoing projects of the heat networks and industrial symbiosis, the authorities are identifying the potential opportunities for industrial and urban symbiosis. Subsequently, they are connecting the relevant stakeholders together to make the resource-sharing a reality. This refers to the *Appropriate scale* subcategory as the final objective is to foster linkages between entities by identifying the potential for industrial and urban symbiosis at the appropriate scale (e.g., city district). Furthermore, Blue Gate Antwerp is a good example of an initiative for which local authorities act as *Facilitators*: indeed, the objective of this climate neutral business park is to gather and connect like-minded businesses on a same territory to foster circular operations. BlueApp also facilitates the dialogue between several actors as it is an open innovation hub connecting industrial and academic stakeholders working on chemical innovation. Those last initiatives refer to the *Stakeholder engagement* subcategory.

The municipality mainly acts as ***Enabler*** of the CE on its territory. For instance, it organises home composting courses to give the necessary tools to the citizens to create their own compost, they lend shredder pruning to the residents, they lend reusable cups free of charge to events' organizers under conditions, etc. Those actions correspond to the *Capacity building* subcategory as they provide the technical capital needed to undertake the circular actions. The City of Antwerp also supports the CE by providing financial resources to circular projects (i.e., *Financing subcategory*). To illustrate this, the City of Antwerp is acting as an incubator to promote circular economy projects through the BlueChem Kickstart Fund and the Circular Kickstart initiative. It also contributed to an ambitious circular project allowing city-to-city learning: the Antwerp Circular South pilot project. The City of Antwerp is also a key contributor of the bike sharing platform *Velo*. Finally, the City of Antwerp is a major shareholder of the Port of Antwerp-Bruges and therefore contributes indirectly to the circular initiatives implemented in the port area.

6. Discussion

6.1. Cross-case analysis

The final aim of this study is to compare how the circular economy is adopted in different European port cities. Main findings of this research are compared based on the dimensions of the ReSOLVE framework (*Regenerate, Share, Optimise, Loop, Virtualise* and *Exchange*) and of the Checklist for Action model (*Promoter, Facilitator, Enabler*). The subcategories of the latter framework will be disclosed in parenthesis for information only.

It is important to note that those conclusions are based on the information disclosed in this study which does not claim to represent an exhaustive and complete view of all the circular strategies and initiatives implemented in both cities. However, as this study is a deep analysis of both cities through two case studies, it is reasonable to draw conclusions based on the main similarities and divergences observed in this study between the two European cities.

6.1.1. Similarities

Numerous similarities have been observed in both cities. First, both cities have a formal written **strategy** regarding their commitment to tackle **climate change**: in Copenhagen; the *CPH 2025 Climate Plan*, in Antwerp; the *Climate Plan 2030*.

Regarding the **reuse of materials**, both cities support circular entrepreneurs: in Copenhagen; through facilities at the disposal of circular entrepreneurs, in Antwerp; through the Circular Kickstart, the BlueChem Kickstart Fund and the circular material workplace in CIRCUIT. Both cities also promote the reuse of materials through second-hand material: sharing zones and material recollection in Copenhagen, and a second-hand shop at CIRCUIT in Antwerp.

Regarding the **ports**, many similarities are noticed. First, both ports heavily focus on the **energy transition:** indeed, major infrastructure to produce green energy are in place in both ports. This result is not surprising as ports are known for consuming substantial amounts of energy to undertake their activities. This intense focus on energy is done at the expense of waste management and material reuse, even though some actions are taken in those fields (e.g., both ports take action to remove marine waste from their surrounding maritime areas).

Furthermore, the two ports rely substantially on new, modern, and renewable **technologies** (i.e., *Exchange* dimension) in their path towards the green energy transition (e.g., both ports use drones to perform their activities). Another common feature observed in both ports is the importance of partnerships to reach the goals. Indeed, they both highlight the relevance of creating synergies between private and public stakeholders, fostering collaboration and partnerships, sharing knowledge between key players, etc. In this **ecosystem**, they both see themselves as platforms, central hubs to coordinate all the relevant stakeholders involved in common projects.

With respect to the roles of the local authorities in circular projects, some similarities are observed. First, as mentioned previously, both cities establish formal written strategies to tackle climate change on their territory (i.e., *Strategic vision* subcategory). In doing so, they act as ***Promoters*** of the circular economy. Furthermore, they raise awareness on the CE mainly through online platforms and communication campaigns (i.e., *Awareness and transparency* subcategory). Indeed, Circular Flanders and Circular Copenhagen are both platforms set up by the local authorities to communicate and sensibilize on the circular economy. It has also been observed that the nudge effect is sometimes used

to influence stakeholders' behaviour toward the implementation of the CE (e.g., Pure Love campaign, Circular South app, etc). Overall, in number, it seems like the least present role in both cities.

On the contrary, the role of ***Enabler*** seems like the most present in both cities: local authorities use regulatory instruments (i.e., *Regulation* subcategory), provide financial resources (i.e., *Financing* subcategory), provide trainings and lend materials to residents (i.e., *Capacity building* subcategory), support circular entrepreneurs (i.e., *Innovation* subcategory), always with the aim to foster CE on their territory. An interesting observation is that for both ports and for the Circular South project, the local authorities take the role of an *Enabler*. It could mean that for substantial organisations/projects, local authorities mainly contribute to them by providing necessary financial resources (i.e., *Financing* subcategory).

Concerning the dimensions of the **ReSOLVE framework**, some similar trends are observed in the two European cities. The *Regenerate*, *Loop* and *Exchange* dimensions are very present in both cities. Another interesting observation is the interconnection between the *Regenerate* and the *Exchange* dimensions in both cities. Indeed, those two dimensions often go hand in hand in many circular operations. This observation could mean that technologies are often used to promote clean energy and to preserve ecosystem sustainability.

6.1.2. Divergences

A first major divergence is that the City of Copenhagen has a written formal **strategy** regarding the implementation of the **circular economy** (i.e., *Resource and Waste Management Plan 2024*) whilst the City of Antwerp has not established a formal circular plan yet. As regards to the ports, the Port of Antwerp-Bruges is leading as it has established a formal strategy regarding the circular economy in 2017. Indeed, a similar strategy does not seem to be established yet by its Nordic counterpart.

Although both cities issued an official **strategy** to tackle **climate change** (i.e., *CPH 2025 Climate Plan* in Copenhagen and *Climate Plan 2030* in Antwerp*)*, the objectives of those plans diverge. Indeed, Antwerp has the target to reduce CO_2 emissions by 50 to 55% by 2030 compared to 2005 whilst Copenhagen ambitions to become the first carbon neutral capital by 2025 (KK, 2023). The Nordic City seems more ambitious than its Belgian counterpart in terms of carbon emissions reduction. Furthermore, Denmark established a clear strategy to tackle climate change at the country-level through the *Climate Act 2020*. However, because each region established its own specific targets as regards to carbon reduction, no agreement on a common strategy has taken place yet in Belgium.

Furthermore, although many similarities are observed between both **ports**, practices to foster the CE seem to be on a larger scale in the Port of Antwerp-Bruges than in the Port of Copenhagen-Malmö (e.g., Ecluse; substantial industrial steam network in the port area, NextGen; entire district dedicated to circular chemistry, etc). Indeed, many ambitious circular projects are ongoing in the Belgian Port. As the Port of Antwerp-Bruges is Europe's second largest port, is there a relationship between the port's size and its level of advancement in circular economy?

Another difference observed in those two cities refers to their **waste management system**. First, Danes must sort their waste into ten fractions whilst Belgian must only sort it into four fractions. Furthermore, many initiatives are in place or in development in Copenhagen to increase the quantity of recycled waste and triple the reuse rate: diaper recycling, circular mattresses, resource-awareness programs, laws on waste sorting, nudge campaigns, etc. For the case of Antwerp, the only specific actions related to waste management disclosed in this study are composting initiatives and loans/laws on reusable cups. Therefore, based on the findings of this study, the global waste management is stricter and more modern in Copenhagen than in Antwerp.

Furthermore, the City of Copenhagen further promotes **green energy solutions** than the City of Antwerp: it supports various green energy projects including the energy islands, RecyclableBlade, wind farms, etc. This affirmation is also reflected through Denmark's energy mix 2021, which is made of 45% of renewable energy (IEA, 2023a), whilst Belgium's energy mix 2021 is only made of 13% of renewable energy (IEA, 2023b).

It has been observed that both cities act as ***Facilitators*** by connecting private and public actors to facilitate the dialogue and to potentially identify opportunities of partnerships between them (i.e., *Stakeholder engagement* subcategory). However, in number, this role seems more present in Copenhagen than in Antwerp. In Copenhagen, this role is mostly taken through the intermediary of Circular Copenhagen initiating various projects to foster public-private partnerships on different pilot or experimental projects.

In Antwerp, an interesting concept is heavily exploited: the industrial symbiosis. Indeed, the City of Antwerp is currently undertaking different **industrial symbiosis** projects to connect resources between entities (i.e., *Appropriate scale* subcategory). The port of Antwerp-Bruges carried out a similar project in the past to connect resources in the port area. This concept also refers to the connection of energy resources between companies: it includes the *Ecluse* project in the Port of Antwerp-Bruges as well as the *Heat networks* project in the City of Antwerp. Except for the waste-to-energy plant in Copenhagen that distributes energy to the surrounding residences, in number of initiatives, Antwerp puts more emphasis on connecting energy and materials resources between its stakeholders.

Regarding the dimensions of the **ReSOLVE framework**, a divergence is noticed for the *Share* dimension. In this study, in Copenhagen, only a few initiatives are referring to the *Share* dimension whilst various initiatives are in place in Antwerp to share and connect material and energy resources between stakeholders, as mentioned previously. Furthermore, a major difference observed in this study relates to the *Virtualise* dimension. In this research, many circular practices use virtualisation in Antwerp, especially through the Circular South project, whilst only a few initiatives refer to those concepts in Copenhagen.

6.1.3. General trends

In general, it can be observed that Cities/Ports are starting to establish formal plans to set a clear strategy on their ambition to tackle climate change and/or to promote the CE, even though targets diverge depending on the local- or national-level and on the country. To put the strategy into action, local authorities often act as matchmakers by connecting the public and private sectors to create synergies.

In order to meet the goals set up in the strategy, local authorities seem to combine different roles ranging from raising awareness through their websites to financing major circular projects. Although their roles can take different forms depending on the project, it is generally observed that their contribution is necessary to make the project successful as they often enable the initiative.

As regards to the ports, they have a significant impact on climate change as they are responsible for emitting a substantial amount of carbon emissions. For that reason, Ports authorities seem to provide important efforts to counterbalance their impact on the environment with initiatives mainly focusing on energy transition. Potentially because they are part of an international ecosystem, ports do not work in silos, which triggers several similarities in their visions to foster the circular economy in their organisation.

This study also highlights the need for new technologies in the path towards clean energy and ecosystem sustainability. The massive presence of the *Exchange* dimension corroborates the assumption of the EMF (2015): new technologies are needed to support the transition towards the CE.

Finally, a key finding of this research relates to the major importance of collaboration between all stakeholders including private companies, NGOs, public authorities, knowledge institutions, communities, and citizens to reach the goals. This research also highlights the key role of the local authorities to allow this interconnection between the relevant actors of change. Many examples highlight how synergies can be created from those partnerships and contribute to the implementation of the CE on a territory. This observation corroborates the 17th goal of the SDGs: "Partnerships for the goals" (UN, 2015).

6.1.4. Final comparison

From the findings of this research, Copenhagen is more advanced in the implementation of the circular economy at the city-level (e.g., formal circular plan, more developed waste management system, more ambitious carbon reductions targets, etc). However, the Port of Antwerp-Bruges is leading the Port of Copenhagen-Malmö in the implementation of the circular economy (e.g., NextGen district, hydrogen hub, Ecluse, etc).

Ultimately, the key finding of this research lies not in determining the top-performing city in the realm of circular economy, but rather in comparing the unique approaches taken by each city to implement circular economy practices within their territories. From the findings of this study, Copenhagen is more **ecology-focused** whilst Antwerp is more **technology-focused.**

On the one hand, the city of Copenhagen leads in the implementation of green practices to promote the circular economy: projects on a large-scale focus on green energy transition (e.g., Energy islands, Amager Bakke), Danish authorities foster the path toward carbon neutrality by establishing formal written strategies (e.g., *Climate Act 2020* for Denmark & *CPH 2025 Climate Plan* for Copenhagen) and the Denmark's energy mix highlights the intensive use of renewable energy (e.g., 45% of renewable energy). Furthermore, a very sophisticated waste management system is in place at the city-level thanks to numerous initiatives.

On the other hand, the city of Antwerp leads in terms of technological advancement: the city is a cluster of sustainable chemistry (e.g., Blue Gate Antwerp, BlueChem, BlueApp), it undertakes innovative and technology-focused projects in the port area (e.g., NextGen District**,** Hydrogen hub) and it tests how technologies could support the shift toward circular cities by hosting substantial circular projects (e.g., Circular South project).

How could those different focus be explained? Do they find their origin in the cultural, historical, geographical, economical, or political context of the city?

7. Limitations

A main limitation of this study relates to information's availability. Indeed, no interviews with stakeholders from the ports have been performed and the information disclosed in this study was mainly retrieved from the official websites of both ports. Furthermore, no on-site visit to learn more on the circular practices of the city was made possible for Antwerp, whilst a four-days visit accompanied by several conferences on the topic took place for Copenhagen.

As mentioned in the previous section as a disclaimer, it is important to acknowledge that the information disclosed in this study does not pretend to represent an exhaustive view of all the circular strategies and initiatives implemented in Antwerp and Copenhagen. Indeed, the content of this research mainly depended on the access to information (i.e., availability of stakeholders to perform interviews, extent and content of the information disclosed on the Internet, focus of the discussions during the conferences in Copenhagen, etc).

Another aspect that must be considered is the use of semi-structured interviews to perform the data collection of this research. Indeed, some biases can arise from the intervention and the investigator.

In this research, potential biases emerging from the interventions could be to have a holistic illusion of the facts (i.e., giving unintentionally to events more coherence than they genuinely have by eliminating evidence that do not support them): a hypothesis could be that, as respondents all work in the field of the circular economy, they could be promoters of this concept and thus elude the potential negative effects/criticisms of the CE. Another bias that could have been encountered is the elite bias (i.e., overestimating information because it comes from specific elite actors): indeed, as interviewees are experts in their topic, an over-assimilation of the facts could have happened.

Furthermore, other biases could come from the investigator. First, it is important to mention that the sample was not diversified in terms of gender and age as all respondents were female in a same age range (i.e., mostly Millennials[38]): those individual characteristics could have influenced the conduct of the interviews (e.g., communication style, interview's dynamics, empathy, etc) and thus the investigator's perception on the information received.

Another potential bias is that, as respondents were able to talk in detail about the project in which they were involved, it led to more information available on their specific project. For that reason, it could have been tempting to disclose more information on it than on other projects for which no interviews were given. However, this potential bias was managed to the extent possible in order to give to all projects of a same size a comparable amount of information regardless of the opportunity of interview.

Furthermore, in this study, circular strategies and initiatives are enumerated but their impact on the sustainability of the city is not assessed. Indeed, it is important to understand that all projects will not have the same impact on the city (e.g., the circular cycle path project will not have the same impact than the hydrogen hub in the Port of Antwerp-Bruges). This limitation has been managed to the extent possible, especially in section *6.1.4. Final comparison,* in which the size/importance of the initiatives has been considered instead of their numbers to provide the final result of this study. Key findings have thus been exposed by taking a step back on the research as a whole.

[38] Individuals that are approximately between 25 and 35 years old.

As this research focuses on two case studies, it is limited in its diversity, and it cannot be generalised to broader populations. Indeed, the cities have been chosen for their comparability (i.e., population, surface area, presence of a port) and their similar characteristics could influence the outcome of this study. Therefore, this study does not represent all the cities globally and it is not guaranteed that the circular strategies and initiatives disclosed in this research could be replicable to a city in a totally different context. Anyhow, most initiatives undertaken by both cities could be replicated in a lot of other circumstances in many countries.

Finally, as the circular economy transition is a new trend evolving rapidly, lots of the projects disclosed in this research are still at the development stage. Since those projects are still ongoing, the information disclosed in this study specifically refers to the academic year 2022-2023 and it is not guaranteed that the content provided in this research will still be up to date in the weeks, months and years following its publication as the circular economy practices are in perpetual and quite fast evolution.

8. Conclusion

The main research question of this study is: **"What are the differences between circular city strategies and initiatives implemented in European port cities?".** To answer the research question, two comparable European port cities are analysed through two case studies of Copenhagen and Antwerp, by taking a focus in the fields of waste management, energy transition and material reuse. Two frameworks are combined in this research to have an overview of the dimensions to which the circular initiatives contribute as well as the role of local authorities in their implementation: respectively, the ReSOLVE framework (EMF, 2015) and the Checklist for Action (OECD, 2020). Furthermore, this study concentrates on top-down change (i.e., institution-driven initiatives). As regards to the methodology of this study, the research approach of this work is deductive (i.e., based on two frameworks), descriptive (i.e., circular city initiatives are enumerated), comparative (i.e., two case studies are compared), cross-sectional (i.e., referring to the academic year 2022-2023), and different means to collect data are used including semi-structured interviews, on-site visits, and document review/project mapping.

8.1. Main findings

The main findings of this study relate to the dimensions of the ReSOLVE framework (*Regenerate, Share, Optimise, Loop, Virtualise* and *Exchange*) as well as to the different roles that the local authorities can take to support the circular operations (*Promoter, Facilitator, Enabler*), in different fields of interest (waste management, energy transition and material reuse). The contribution of the local authorities in the implementation of circular initiatives and strategies in Copenhagen and Antwerp, as well as in their respective ports, is explained in this study.

Main findings of this study are detailed in the *6.1. Cross-case analysis* section. To put it concisely, this research highlights how cities can take a different focus to implement the circular economy on their territory: Copenhagen is more ecology-focused whilst Antwerp is more technology-focused. Furthermore, from the findings of this research, Copenhagen is more advanced in the development of the circular economy at the city-level whilst the Port of Antwerp-Bruges is leading its Nordic counterpart in this domain.

8.2. Implications

As mentioned previously, the concept of the circular city can be seen as unclear and ambiguous for policymakers when implementing the CE in day-to-day practices (Prendeville et al, 2018). For that reason, main findings of this study can be a source of inspiration to support the policymakers in the implementation of the CE on their territory. Indeed, the results of this study can provide guidance to local authorities on what to implement (i.e., through the description of circular practices) and how to contribute to them as a public authority (i.e., through the different roles that policymakers can take to support circular projects). This research thus allows other cities to get inspired by the successful circular initiatives carried out by the cities of Antwerp and Copenhagen, but it also provides to the studied cities a comprehensive overview of their current circular economy's advancement, by taking the perspective of an external stakeholder. As this study also investigates the ongoing CE projects in the ports of each city, Ports authorities of other cities could also get inspiration from the circular actions taken in the ports of Copenhagen-Malmö and Antwerp-Bruges. Furthermore, even though this study focuses on the initiatives taken by the public sector, private actors (e.g., companies, communities, NGOs, citizens, etc) could also be concerned by those circular projects as they could replicate some of those circular practices in the private sector.

8.3. Contributions

This study, through an in-depth description and comparison of circular strategies and initiatives implemented by two European port cities, gives further insights on the topics of the circular economy and of the circular city. The main contribution of this study is that it can act as a starting point for further work as it addresses various dimensions of the CE including concrete circular practices implemented at the city-level in the fields of waste management, energy transition and material reuse; the roles of the local authorities in the circular practices of the city; specific public initiatives undertaken in the cities of Antwerp and Copenhagen; an analysis of the circular practices implemented by Port authorities; etc.

8.4. Future research

This study has raised some areas for future research. Further work could undertake case studies on the adoption of the CE for other European or non-European port cities, assess qualitatively or quantitatively the impact of the circular initiatives on the society, investigate the implementation of the CE on a territory initiated by bottom-up changes (i.e., initiatives from citizens, communities, NGO's, companies, etc), study the adoption of the CE at the city-level by focusing on other fields of interest such as water management or mobility, explore the relationship between a port's size and its level of advancement in CE, inquire the individual characteristics of the experts working in the field of the CE (e.g., are they mainly female between 25 and 35 years old?), etc. Future research could also study the same topic, in the same cities, but further in time in order to investigate the evolution of all the ongoing projects disclosed in this study and the new emerging projects related to the CE. This analysis could already be relevant in a few years as things are moving really fast in this research area.

From a more general perspective, further research could investigate how the CE is adopted in a city by taking a new focus (e.g., different city, different field of interest, different actors of changes, different framework, etc), by investigating in depth a specific aspect raised in this research (e.g., individual characteristics of the experts working in the field of the CE) or by assessing the impacts of the CE on a city (e.g., benefits and drawbacks of the CE on the city).

8.5. Final word

"A developed country is not a place where the poor have cars. It's where the rich use public transportation." – Gustavo Petro[39]. Aligned with the principles of the circular economy, this statement calls for degrowth. Instead of equating development solely with economic prosperity, it suggests to considering all dimensions of the Triple Bottom Line (Elkington, 1997) by including social and environmental considerations in our current models of society, as supported by the Doughnut theory. This quote, expressed by a representative of a municipality, also highlights the essential role of public authorities in the path towards sustainability. To attain this vision, a radical restructuring of our current societal frameworks becomes imperative. With this objective in mind, the circular city can be part of the solution to achieve sustainability in our societies.

[39] This quote is largely attributed to Gustavo Petro, the former mayor of Bogotá, now president of Colombia.

9. Appendices

Appendix 1. General interview guide

General context: this research aims at describing and assessing circular cities strategies (to-be) implemented in Europe through the analysis of two cities. Cities to be analyzed through case studies are Antwerp and Copenhagen. To undertake this study, the ReSOLVE framework (McKinsey & Company, 2016) will be the starting point for the analysis of the circular dimensions of the projects and strategies implemented within the cities. This model classifies the circular initiatives according to six dimensions: Regenerate – Share – Optimize – Loop – Virtualize – Exchange. The goal of this interview is to have a deeper understanding of the projects and strategies implemented or to-be implemented in the future in your city, linked to circularity.

General questions:

1) Could you please start by introducing yourself and tell me more about your activity on a day-to-day basis?
2) What is the activity/mission of the organization you work in?
3) Could you explain me the project on which you work for currently and what is your role in it?
4) In your opinion, is your project aiming at promoting one or many of the following non-exclusive dimensions:
   - **Regenerate:** promote clean energy, switch to renewable materials, preserve ecosystems sustainability, and give back to the biosphere what was employed.
   - **Share:** optimize products' lifespan by organizing peer-to-peer sharing of privately/publicly owned products, reuse products as long as they are still operational (secondhand), improve their lifespans thanks to upkeep, fix them if they are broken and design them in a sustainable process.
   - **Optimize:** boost the performance of products, pull out waste from supply chains, exploit big data, remote detection/steering, and automation.
   - **Loop:** close loops containing materials and give priority to internal ones, remanufacture components, recycle them if it is the last alternative, digest anaerobically, and extract biochemicals from organic waste.
   - **Virtualize:** go virtual to replace existing ways of consuming. Deliver books, music, and shopping virtually.
   - **Exchange**: switch to new technologies, substitute old products with modern and renewable ones.
5) Could you think about other initiatives implemented in your city by the government that promote one or more than the previous dimensions?
6) What does your city put in place regarding waste management in terms of circularity?
7) What is put in place by the government regarding the importance of reuse? (Repair cafes, sharing zones, second-hand shops, …)
8) Do you have in mind some institutional initiatives or projects promoting green energy transition?
9) Do you have knowledge of any laws or regulations related to circular development?
10) How would you assess the motivation and implication of the citizens regarding circular economy?
11) What should I remember from this interview?

Appendix 2. Interviews Summary Table

	Interview 1	Interview 2	Interview 3	Interview 4	Interview 5
City	Copenhagen	Copenhagen	Antwerp	Antwerp	Antwerp
Interviewee	Interviewee 1	Interviewee 2	Interviewee 3	Interviewee 4	Interviewee 5
Role	Reuse spotter	Project manager and special consultant on plastic waste	UIA Antwerp Circular South expert	Project manager in digital and circular business innovation	Social and circular business advisor
Organization	Circular Copenhagen	Circular Copenhagen	UIA: Urban Innovative ACtions	City of Antwerp	Province of Antwerp
Topic	Sharing zones	Resource & Waste management plan 2024	Circular South	Circular innovation in the city of Antwerp	Circular initiatives in Antwerp
Duration	46:51	45:50	35:58	40:11	42:49
Language	English	English	French	English	English
Date	15/11/22	16/11/22	28/11/22	05/12/22	22/02/23
Communication mean	First contact by email Interview on Teams	First contact by email Interview on Teams	First contact by email Interview on Teams	First contact by email Interview on Teams	First contact on Linkedin and interview on Teams
Key words & (Number of appearances)	- Reus* (40) - Shar* (36) - Donat* (13) - Polit* (6) - Success (5)	- Partner* (13) - Motivat*(5) /Encourag* (3) - Connect* (6) - Politic* (5) - Nudg* (1) /Pictog* (4) - Collab* (4) - Team* (4)	- Impli* (13) - Marché (13) - Données (11) - Comportement (8) - Analy* (8) - Complex* (6) - Photovoltaïques (6) - Techn* (5)	- Circular* (41) - Compan* (25) - Innovat* (17) - Business* (12) - Chemistry (9) - Startups (7)	- Compan* (27) - Project (24) - Circular* (15) - Support* (13) - Product* (11) - Develop* (10) - Regulation (8)

Appendix 3. Conferences Summary Table – Trip to Copenhagen

	Conference 1	Conference 2	Conference 3	Conference 4	Conference 5	Conference 6
Organization	Digital Hub Denmark	Brussels Capital Region and hub.brussels	State of Green Denmark	ØRSTED	Amager Resource Center (ARC)	BLOXHUB
Mission	Non-profit organization working as a platform to connect startups, companies, and investors in Denmark in the field of technology.	Public organization that connects entrepreneurs, researchers, non-profits and public authorities interested in pursuing social innovation in Brussels.	Non-profit and public-private ownership promoting global collaboration between key players towards progress in green sustainability.	Largest energy company in Denmark with the vision of a world that runs entirely on green energy.	Public-owned company managing and treating waste with a sustainable focus in five Danish municipalities.	Nordic Hub for sustainable urbanization matching its members and potential partners, sharing knowledge, and creating business opportunities in the field of clean urbanization.
Speaker(s)	Karoline Bertelsen (1) Marie Gørvild (2)	Pascal Smet	Lise Holmegaard Larsen	Anne Mette Søndergaard	N/A	Jakob Norman-Hansen
Role	Office and Project Manager (1) COO (2)	Secretary of State of the Brussels Capital Region	Senior Project Manager on Renewable Energy Sources	Head of Public Affairs	Tour guide of the ARC	Head of global networks
Topic	Digitization of the public sector	Brussels, smart city #brusselsforpeople	Danish strategy towards a sustainable and resource-efficient society	Company's strategy towards 100% green business	Waste management in Copenhagen through a visit of its waste-to-energy plant	Sustainable urbanization in Copenhagen
Key words	- Technology - Connectivity - Trust - Data - Digital strategy - MitID (eID)[1]	- Passive buildings - Active roofs - Renovation - Transport - Public space - Green space	- Energy mix - Greenhouse gases - Energy islands - Circular economy - Wind turbines - Climate act	- Wind turbines - Bio energy - Solar energy - Projects - Green energy - Investments	- Waste hierarchy - Sharing zones - Energy production - Carbon capture - Heating & Electricity - Flue-gas treatment	- Ecosystem - Collaboration - Network - CO_2 emissions - Urban mobility - Resilience
Language	English	English	English	English	English	English
Date	21/11/22	21/11/22	21/11/22	22/11/22	22/11/22	23/11/22
Time	9 AM	10:15 AM	2 PM	8:30 AM	1 PM	9 AM

Appendix 4. Waste Management Nudges in Copenhagen

1. Mandatory pictograms on bins (2022)

Source: KIVO (2020, December 8). *Nordic recycling symbols link packaging to collection containers.* RINKI. https://verkkolehti.rinkiin.fi/nordic-recycling-symbols-link-packaging-to-collection-containers?lang=en

2. Pure Love Campaign (2012-2015)

Source: Clean Europe Network (2016, May 31). *Nudging: from Denmark with love*. https://cleaneuropenetwork.eu/en/blog/nudging-from-denmark-with-love/agf/

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Executive Summary

In a world of over-consumption and relentless growth, cities have a considerable impact on climate change. As part of the problem, cities can also be part of the solution. Local authorities can take action by implementing circular economy principles on their territory, transforming them into circular cities as a result. As the concept of circular city remains elusive in the literature, this study aims at shedding light onto the different opportunities available to the policymakers of European port cities to implement circular strategies and initiatives on their territory.

To answer the research question, "What are the differences between circular city strategies and initiatives implemented in European port cities?", a case study has been undertaken in Copenhagen and Antwerp, supported by semi-structured interviews of relevant stakeholders working for the city in the field of circular economy. At the heart of circular economy is a desire to contribute to climate adaptation and mitigation: although this can involve various fields of interest, this work focuses on waste management, energy transition and material use.

As supporting theories, the ReSOLVE framework (Ellen MacArthur foundation, 2015) is used to classify the initiatives into six dimensions of the circular economy whilst the Checklist for Action (Organisation for Economic Cooperation and Development, 2020) categorises the roles taken by the local authorities to contribute to each initiative.

From the findings of this research, even though the two cities are comparable on some aspects, first, they stand out in their advancement in circular economy, second, they approach the circular economy by taking distinct perspectives. In terms of advancement, the key results of this research indicate that local authorities of the city of Copenhagen demonstrate stronger support to the development of circular economy than the policymakers of Antwerp. By contrast, main findings suggest that the port of Antwerp-Bruges demonstrates more advanced circular practices than its Nordic counterpart. Regarding the focus taken in the implementation of the circular economy, Copenhagen is more ecology-focused whilst Antwerp is more technology-focused.

Practically, the main findings of this research can be source of inspiration to various stakeholders in their path towards sustainability, including but not restricted to city and port authorities. Through an in-depth description and comparison of circular practices implemented by two European port cities, this study gives further insights on the topics of circular economy and circular city to the literature. Therefore, it can act as a stepping stone for further work on those topics.

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