AALBORG UNIVERSITET

CLOSING LOOPS IN CLOUD CITY: A ZERO-ORGANIC WASTE DISTRICT IN AALBORG

Erick Zimbrón Escutia
Aalborg University
Department of Development and Planning
Joint European Master in Environmental Studies – Cities and Sustainability

Image taken from the report "Spritfabrikken I Aalborg" by Bjarke Ingels Group (2016)

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Title

Closing Loops in Cloud City: A Zero-organic Waste District in Aalborg

Author

Erick Zimbrón Escutia

Supervisor

Martin Lehmann – Aalborg University

Co-Supervisor

Xavier Gabarrell- Universitat Autònoma de Barcelona

Aalborg University

Department Development and Planning

Joint European Master in Environmental Studies – Cities and Sustainability

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1 Preface

This thesis is submitted as a requirement for the completion of the Joint European Master's program in Environmental Studies – Cities and Sustainability. The work period started in February 2017 and ended in the beginning of June 2017.

The interest for the topic emerged from two factors. Firstly, from the observation of a lack of solutions in terms of organic waste treatment in the city. Secondly, from the desire of the author to develop knowledge in a local context. Not only to learn about the local culture and environment, but also to develop know-how information that can bring benefits to the city in the long term.

Due to the multidisciplinary nature of the master's program and the topic, it was decided to approach this work on the same manner. It was intended to have a learning process through social sciences, through a more numerical approach, and finally through a solution oriented approach. Hence, the present work includes social theories in the framework, flow calculations in the results, and the basis of a solution proposal in the discussion.

Finally, it is intended that the present work encourages future research.

2 Acknowledgements

Firstly, I would like to give my gratitude to Martin Lehmann for providing guidance and inspiration for completing this work. I would also like to thank Xavier Gabarrell, for a brief, but fruitful, co-supervision of my work.

Secondly, I would like to thank Dorte Ladefoged, from Aalborg Municipality, for giving some of her time for an interview. I would like to include here my gratitude for Zacharias Brix Madsen, who provided me with the resources for carrying out the interview in the first place.

Thirdly, I want to give my most sincere thanks to my JEMES colleagues, from which our constant discussions always brought inspiration, guidance and positive feedback.

Lastly, and most importantly, I want to give my most gratitude and recognition to my family. I am thankful for the unconditional support, the trust and the motivation. Thank you for your guidance. Mother, Father, Brother, I love you.

3 Abstract

Waste treatment has been a relevant topic in environmental agendas for at least the past 20 years. Particularly in Europe, waste treatment practices have been guided through the EU Directives and most lately through the Circular Economy Package. Generalizing, the guiding principles are based on the waste hierarchy. In 2014, Denmark was the EU country producing the most municipal waste per capita and the second regarding municipal waste incineration. Under these conditions, waste reuse and recycling becomes a necessity within the country. In the city of Aalborg, organic waste is collected inside the “refuse” category (containing non-recyclable materials) which is treated by incineration. Thus, there is a wide opportunity to take advantage of an under-used resource while possibly aiding the city in complying with its sustainability goals. Given the situation, it was decided to understand the problem’s context and then to select a case study for designing an organic waste treatment proposal. To provide context, the paper analyzed Aalborg in terms of ecological modernization and institutional theory. Overall, the city of Aalborg is currently in a moderate ecological modernization process. In the case of waste, the transition appears to be slowed down by some institutions. Two actors were identified that might be influencing the transition process: the waste/energy sectors and local politicians. The selected case study is Cloud City. The Cloud City project, which is being developed in Aalborg’s city center, will transform a non-working industrial area into a multifunctional urban center. Cloud City’s inherent characteristics creates an opportunity for innovative design that focuses in closing loops in the organic waste stream. Hence, this research focuses in closing the organic loops within Cloud City to develop a zero-organic waste district. To achieve this purpose, two main tasks were addressed: a) analyze the organic flows inside Cloud City, and b) proposing a treatment solution to the waste output. The Material Flow Analysis concept was used as a base for analyzing the organic flows. In the end, the analysis was limited to the organic waste outputs only. The research design included data collection in a local context through contact with multiple stakeholders (via interviews and surveys). However, due to multiple challenges, no data was obtained through the initial design. All calculations were done through literature review assumptions. The total organic waste output in Cloud City is calculated in 16.7 tons per month. Considering a 25% reduction, due to potential future prevention strategies, the total estimated output is 12.8 tons per month. The treatment solution for the waste in Cloud City was based on the concept of Circular Economy and value creation. For this, the data was obtained solely by literature review. The proposed method includes an anaerobic digestion pilot plant, where the produced biogas is used for transportation. It is proposed to locate the pilot plant next to the local waste water treatment plan. Furthermore, it is proposed to deliver the digestate to the island of Egholm. Finally, the overall value (benefits) are described in terms of the triple bottom line: environmental, social and economic. Since the proposal was developed in a conceptual level only, the general feasibility is not analyzed in any way. Nevertheless, some recommendations for future considerations were established in terms of regulation, environment, economics and society. The main challenge of the proposed plant is the small amount of treated waste and, consequently, the biogas output. Both factors complicate the feasibility in terms of economics and technology.

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4 Figures and Tables

5 Introduction

5.1 Population Growth and Cities

The world's population is migrating to cities. This process, which began since the industrial revolution, has increased exponentially in recent decades causing an exceptional concentration of people in specific areas. The United Nations (United Nations, 2014a) estimate that 54% of the population live in urban areas nowadays. Furthermore, if the trend continues, it is expected that the number could increase to 66% by 2050. However, the growth process is expected to occur mainly in the Global South; polarizing the population growth phenomenon. Growth trends can be explained, among other factors, by current urbanization levels of the different regions. The less urbanized, the higher the population growth in cities. According to the United Nations (United Nations, 2014b), the most urbanized regions are North-America, Latin America & the Caribbean, and Europe with 82%, 80% and 73% respectively. The least urbanized are Africa and Asia with 40% and 48%. In this scenario, it is estimated that population growth, from 2015- to 2050, will concentrate mainly in nine countries (United Nations, Department of Economic and Social Affairs, 2015). From those nine, only the United States is located in the Global North. Five, out of the other eight, are situated in Africa (Nigeria, Democratic Republic of Congo, Ethiopia, Tanzania and Uganda). This situation positions the African continent as the fastest growing area; contributing with more than half of the expected additional population. In contrast, Europe is projected to have a shrink in their numbers. The following figure (Figure 1) shows a global map with the projected population growth from 2015 to 2050:

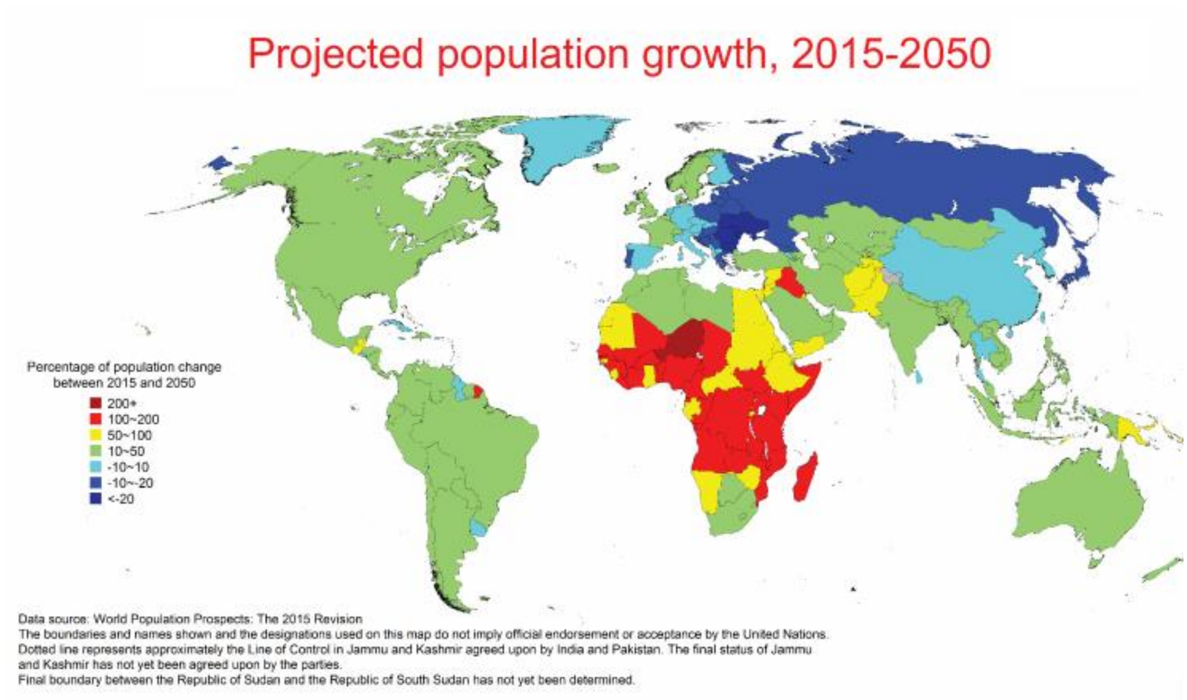

Figure 1- Project population growth, 2015-2025. Source: (United Nations, 2015b)

Hence, it is expected that most challenges, regarding increasing population cities, will happen in the Global South.

Independently of the location, population concentration in cities creates a set challenges and opportunities regarding urban development and the whole concept of sustainability. Cities, as centers of politics, economics and culture, require inputs of resources to survive and develop (ex. energy, water, food). Furthermore, the processing and consumption of such resources generates outputs that need to be managed (ex. Waste, greenhouse gases). According to the World Cities Report (UN-Habitat, 2016), "*cities account for between 60 and 80 per cent of energy consumption, and generate as much as 70 per cent of the human-induced greenhouse gas emissions*". Moreover, it is estimated that cities consume up to 75% of the natural resources while producing 50% of global waste (UNEP, 2012). Under these circumstances, it is possible to acknowledge the importance of having cities inside the most relevant sustainability agendas. As an example, the UN Sustainability Development Goals include an urban-specific category, "Sustainable cities and communities", as one of their seventeen categories to "*protect the planet, and ensure prosperity for all*"(United Nations, 2015a).

Since Cities are complex systems, analyzing the internal processes separately becomes essential. For the purpose of this paper, waste is going be analyzed further. First in a general approach, and then in a European context.

5.2 The Waste Challenge

Among the various aspects of sustainability, waste, specifically reduction and treatment, stand as one of the many imperative topics to be addressed. According to Hoornweg, Bhada-Tata and Kennedy, (Hoornweg, Bhada-Tata, & Kennedy, 2013) , "*waste is being generated faster than other environmental pollutants, including greenhouse gases*". If this is not worrying enough, it is calculated that global solid waste generation could triple in the following century if a "business as usual" system is maintained; going from 3.5 million tonnes per day in 2010, to 11 million tonnes per day in 2100 (Hoornweg et al., 2013). The excessive generation trend, along an inefficient treatment, is already causing relevant phenomenon such as the marine-debris "Great Pacific Garbage Patch" between Japan and the US west coast. Examples of other challenges caused by waste include: nuclear waste management, greenhouse gases emissions from organic waste in landfills or the increasing -poorly regulated- electronic waste disposal and management in Asia. Under this context, it is possible to identify waste and its management as a "*critical matter of public health, environmental quality, quality of life, and economic development*" (The World Bank, 2013).

Waste generation rates vary depending on the region's characteristics. According to Hoornweg and Bhada-Tata (Hoornweg & Bhada-Tata, 2012), solid waste "*generation rates are influenced by economic development, the degree of industrialization, public habits, and local climate*". The following table (Table 1), based on Hoornweg and Bhada-Tata data, shows the average waste generation per capita in different regions of the world:

Table 1- Waste Generation per Capita per Region. Source: (Hoornweg & Bhada-Tata, 2012)

Region	Average (kg/capita/day)
Sub- Saharan Africa	0.65
East-Asia and Pacific region	0.95
Eastern and Central Asia	1.1

Latin America and the Caribbean	1.1
Middle East and North Africa	1.1
OECD	2.2
South Asia	0.45

By observing the data, it is possible to relate the waste generation rates with the level of economic development and urbanization. The OECD group, which in the study accounts primarily for European countries, has the most waste generation per capita with 2.2 kg/day (Hoornweg & Bhada-Tata, 2012). This accounts for 44% of the total waste generation. Therefore, it becomes relevant to analyze the European countries; not only due to their high waste generation rates but also due to their high percentage of population living in urban areas. Moreover, it is possible that solutions arising in European context, part of the Global North, could aid in the development of the Global South which is in face of a considerable urban population growth challenge.

To further understand the challenge of waste in European context, it is needed to analyze current policy.

5.2.1 Waste policy in the European Union

In Europe, waste management practices have been guided by the EU Directives and more recently by the Circular Economy Package. The main EU Directives on waste are: the EU Directive on Landfill (1999/31/EC), the EU Waste Directive (2006/12/EU) and the revised EU Waste Directive (2008/98/EC). The Circular Economy Package, which contains revised legislation proposals, was adopted in 2015. Overall, the Directives and the Package are based on the Waste Hierarchy (Figure 2). The latter establishes a priority order for waste prevention and management actions that "*minimizes adverse environmental effects and optimizes resource efficiency*" (The European Union, 2017a). In general, the hierarchy prioritizes waste prevention as waste is avoided in the first place. If waste is unavoidable, the order prioritizes reuse, recycling, recovery and then disposal.

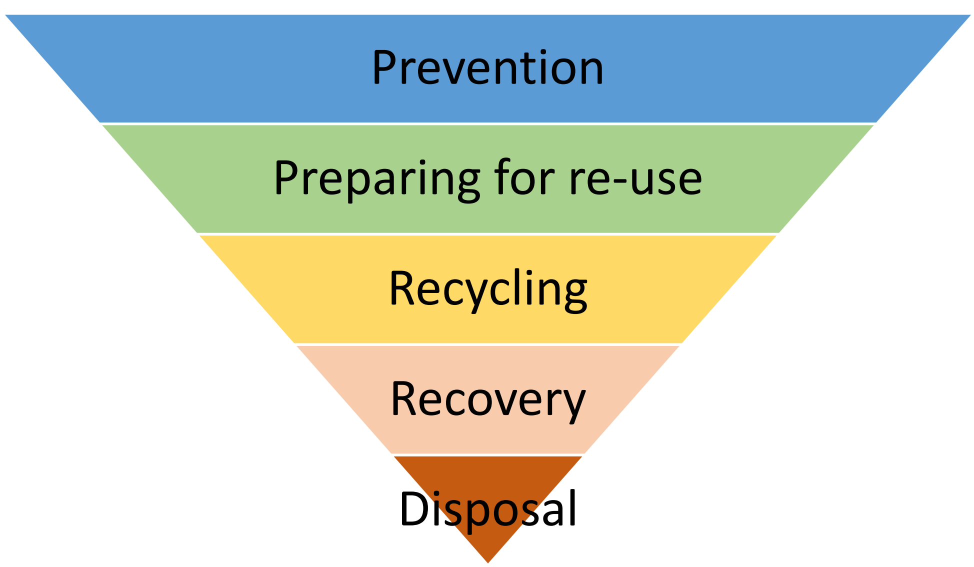

Figure 2- Waste Hierarchy

The link between the Circular Economy Package and the Waste Hierarchy is clear when analyzing them in more detail. The package contains proposals "*on waste, with long-term targets to reduce landfilling and increase recycling and reuse*" (The European Union, 2017b). Furthermore, some of the revised legislation on the package includes a target for recycling 65% of municipal waste by 2030, a target for recycling 75% of packaging waste by 2030, a ban on landfill of separately collected waste, and measures to promote re-use and stimulate industrial symbiosis (The European Commission, 2017).

Considering that the Circular Economy Package represents the latest "vision" regarding waste in the European Union, it can be expected that it contains the main guiding principles regarding waste prevention and management. Hence, summarizing, the emphasis falls on waste prevention, reuse and recycling, while opening the opportunity for adding value to the "re-circulated" materials. This principles become relevant in a context where 43% of the waste is disposed to landfills and 6.5% is incinerated (Data for EU-28 in 2014) (Statistics Explained Eurostat, 2014).

Considering the broadness of the waste challenge, and the need for adopting the guides from the waste hierarchy and the circular economy concept, it becomes necessary to narrow down the discussion to specific waste sources. Waste can be classified in different ways due to the vast multiplicity of activities and processes that dispose unused material. Furthermore, the classifications vary according to regulatory entities such as governments or International bodies such as the European Union. However, overall, waste can be classified by its source and its properties (Sustainability Exchange, 2017). For the purpose of this paper, municipal waste (source), specifically the organic fraction (properties) will be analyzed.

5.2.2 Municipal Waste and the Organic Fraction

Waste produced in urban areas, and which is normally managed by local governments, is referred as Municipal Waste. More accurately, municipal waste is "*waste collected by or on behalf of municipalities*" (OECD, 2015). The sources of this waste, according to Eurostat, include "*households, though similar wastes from sources such as commerce, offices, public institutions and selected municipal services are also included*" (Eurostat, n.d.). In this matter, the OECD calculates that municipal waste accounts for approximately 10% of the total waste produced (OECD, 2015). And although the percentage is relatively small, the "*prevention of this waste has the potential to reduce its environmental impact not only during the consumption and the waste phases but also throughout the whole life cycle of the products consumed*"(European Environment Agency, 2016). Moreover, solid waste management represent the largest budget expenditure and largest employer for many cities (The World Bank, 2013).

Municipal waste is also classified into different waste streams. Categories vary depending on the current regulation at local and international level. Nevertheless, there are some classifications which are common due to their particular characteristics. One of these classifications include organic waste. For this paper, a specific focus will be given to the latter. The following paragraphs will explain organic waste in more detail. Finally, food waste will be addressed as it comprises a main fraction inside organic municipal waste.

According to Eionet, organic waste is "*waste containing carbon compounds, derived from animal and plant materials*" (Eionet GEMET Thesaurus, 2017). On a global average, the organic fraction in municipal solid waste is 46% (Hoornweg & Bhada-Tata, 2012). This not only represents the biggest fraction in this category, but also it leads by a considerable difference when compared to other fractions ("others" and "paper" follow with 18% and 17% respectively). The next figure (Figure 3) shows the Global solid waste composition.

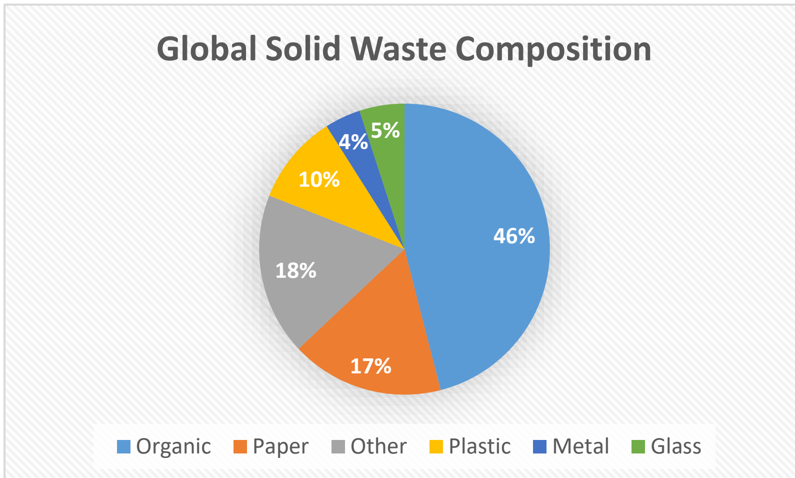

Figure 3 - Global Solid Waste Composition. Source: (Hoornweg & Bhada-Tata, 2012).

Moreover, the importance of organic waste in cities falls on two additional phenomena. Firstly, organic waste is linked to climate change. According to the EU, the importance of managing organic waste resides in avoiding the methane production and emission that happen when decomposition takes place in landfills (European Commission, 2016). Secondly, organic matter is concentrating in cities -due to urban area's high resource consumption- with nutrients not being returned to the soil. This is causing soil degradation on a global scale, affecting one quarter of land globally with a cost of USD 40 billion per year (Ellen MacArthur Foundation, 2017).

Inside organic municipal waste, food represents one of the most important fractions. This is not only due to the amounts that are wasted globally but also due to its overall impacts. The following section will analyze food waste in more detail.

According to the Food and Agriculture Organization of the United Nations, one-third of edible food, made for human consumption, gets wasted globally (Gustavsson, Cederberg, Sonesson, van Otterdijk, & Meybeck, 2011). This wastage creates a series of impacts in many sectors. According to the Fusions report from the EU, some of the impacts are the following: economic (resource efficiency, consumption, waste management), environmental (energy, climate change, resource availability -land, water-), and social (equality and health) (Stenmarck, Jensen, Quested, & Moates, 2016). According to FAO, food waste has impacts on "*food security of poor people, on food quality and safety, on economic development and on the environment*" (Gustavsson et al., 2011). Due to all the involved effects, food waste has attracted a lot of concern in the last years. For example, goal 12 from the UN Sustainable Development Goals regarding sustainable consumption and production patterns, established the target of reducing global food waste in 50% by 2030 (United Nations, 2015a).

It is relevant to mention that food waste is generated through all the life cycle of the products. The stages where food waste is generated according to the Fusions report (Stenmarck et al., 2016) include: primary production, processing, wholesale and retail, food service and households. Since this present paper deals with organic municipal waste, it should be noted that the relevant stages of food waste generation are: the wholesale and retail, food service and households.

No specific number was found which gave an approximation for the relation between organic municipal waste and food waste. However, it is possible to use other data to make a gross calculation with the purpose of showing the importance of food waste. If we consider 173 kg/person as the average amount of food waste in EU-28 in 2012 (Stenmarck et al., 2016), and 475 kg/person as the average amount of municipal waste in the EU in 2014 (Eurostat, 2016), it is possible to say that, in average, food waste corresponds to approximately 36.6% of municipal waste in Europe.

Summarizing, municipal waste might represent one of the most important waste sources due budget expenditure reasons. Moreover, within municipal waste, the organic fraction holds the biggest share (in global average) and its relevance is linked to climate change and soil degradation. Thus, it becomes relevant to manage organic municipal waste in a way that avoids disposal (which generally is in landfills), through prevention, reuse, recycling or recovery.

Since the present work is analyzing the European setting, the following sections will provide further detail in: a) municipal organic waste policy in the European Union and, b) Municipal Waste in Europe State of the Art.

5.2.3 Municipal Organic Waste Policy in the European Union

To understand the context of organic municipal waste in Europe, a brief summary of policy highlights is given in the next section. It is important to mention that the policy targets the organic stream specifically. Thus, the next section will mention the term "organic waste" only and not as organic municipal waste. However, all legal framework for organic waste covers the organic municipal waste as well.

Previously, it was mentioned that waste practices are guided by the Waste Hierarchy, the EU Directives and the Circular Economy Package. Therefore, in the following lines, a summary of how these specific regulations link with organic waste will be provided.

In an organic waste context, the Waste Hierarchy includes actions such as composting and anaerobic digestion for recycling, incineration with high energy recovery for Recovery and landfill as disposal (The European Union, 2017a). It is important to highlight that after the literature review, the prioritization between organic waste recycling and recovery can be confusing or slightly blurred. Hence, even though in the waste hierarchy there is a higher "preference" for recycling, waste recovery is regularly mentioned as a relevant management tool; particularly in waste-to-energy solutions. In the words of the European Commission "[…] *for the management of biodegradable waste diverted from landfills, there seems to be several environmentally favourable options. While the waste management hierarchy also applies to the management of bio-waste, in specific cases it may be justified to depart from it as the environmental balance of the various options available for* *the management of this waste depends on a number of local factors*" (European Commission, 2016). However, in this same topic they also mention "*In the future, more consideration should be given to those processes, such as anaerobic digestion of biodegradable waste, where material recycling is combined with energy recovery. Conversely, the role of waste incineration – currently, the predominant waste-to-energy option - needs to be redefined to ensure that increases in recycling and reuse are not hampered and that overcapacities for residual waste treatment are averted*" (The European Union, 2017a). In this context, and following the principles of Circular Economy along with the waste hierarchy, it was decided that, for the purpose of this work, organic waste prevention, reuse and recycling are going to be considered as the best solutions.

Within the EU directives, relevant points related to organic waste can be found as well. Some of the highlights are mentioned in the following lines in chronological order. The EU Directive on Landfill (1999/31/EC) (Council Directive, 1999), establishes that member States shall set up strategies to reduce organic waste going to landfill through means of "*recycling, composting, biogas production or materials/energy recovery*". Moreover, the EU Waste Directive (2008/98/EC), article 22 (European Commisssion, 2008), encourages the "*separate collection of bio-waste with a view to the composting and digestion*", and the "*treatment of bio-waste in a way that fulfills a high level of environmental protection*".

As mentioned before, the Circular Economy Package contains proposals to increase recycling and reuse. And, even though the Circular Economy package involves all waste streams, the whole concept is applicable and relevant to organic waste. Moreover, following the Circular Economy Package, in 2016, a new regulation proposal for "use of organic and waste-based fertilizers" was proposed. The new regulation was meant to ease access to "*organic and waste-based fertilisers to the EU single market*" (Pietila & Caudet, 2016). Later on the same year, the European Commission established the EU platform on "Food Losses and Food Waste" as a way to comply with UN's Sustainable Development Goals (Goal 12 specifically) (The European Union, 2017b).

Considering the EU regulation, it is possible to summarize the following present needs regarding organic waste: a) overall reduction of biodegradable waste going to landfills, b) implementation of infrastructure for separate collection schemes, c) prioritization of solutions according to the waste hierarchy, d) adoption of circular economy principles, and e) consideration food waste as a core target for waste management solutions.

5.2.4 Municipal Waste Treatment in Europe State of the Art

According to Eurostat (Statistics Explained Eurostat, 2014), in 2014, the waste generated by EU-28 amounted to 2,598 million tonnes (including all economic activities and households). This is equivalent to having 5,118 kg of waste per inhabitant. For the same year, an average of 475 kg per inhabitant (around 9.3%) corresponded to waste coming from the municipal fraction (Eurostat, 2016). The country generating the most municipal waste was Denmark with 759 kg/person, followed by Cyprus with 626 kg/person (Eurostat, 2016).

Regarding municipal waste treatment, the averages in the EU were: 28% recycling, 28% landfill, 27% incinerated and 16% composted (Eurostat, 2016). However, waste activities vary considerably among the member states. Based on the same report (Eurostat, 2016), in terms of national percentages, Slovenia and Germany were the countries with more recycling (49% and 47% respectively). In contrast, Latvia and Malta stand out in landfill with 92% and 88% respectively.

Additionally, Austria was the country with more composting with 32%. In terms of incineration, Estonia and Denmark stand out with 56% and 54% respectively. Considering the categories of recycling and composting (which are highlighted in the Waste Hierarchy and the Circular Economy concept), the countries with best performance are Germany, Slovenia, Austria, Belgium and the Netherlands.

If policy targets, included in the EU Directives and the Circular Economy Package, are to be fulfilled, many actions will need to take place. Specially in those countries having big percentages in landfill. However, Denmark can be highlighted due to its particular present characteristics. Denmark is not only the country with more municipal waste generation in the EU, it is also the second one regarding waste incineration. These certain characteristics contrast with the positive outcomes the country has in other areas. For example, Denmark was ranked in the fourth place in the Environmental Performance Index (Environmental Performance Index, 2016). And although the index measures the areas of protection of human health and protection of ecosystems, it does provide evidence that the country might arguably be a country putting efforts towards sustainability. Moreover, the country performs lower, in waste treatment terms, than economically similar countries. Denmark can be considered a high-income country, with similar GDP per capita in 2015 to Germany and Austria (Statistic Explained Eurostat, 2017). In this context, Germany and Austria performed better than Denmark in recycling and composting respectively. Under this context, and considering EU policy, it becomes attractive the analysis of a possible shift from an incineration dominated country, to one focusing on prevention, reuse and recycling.

5.3 Denmark and Waste

In general terms, waste management in Denmark has evolved from seeing waste as a health problem, to considering waste as a resource (Andersen & Mortensen, 2014). In the 1960's, landfilling outside big cities was a common practice. Later, in the beginnings of 1980's, incineration and composting became the main treatment solutions. It was until the 2000's, that waste started to be considered as a resource. In the last years, and supported by EU regulation, Denmark has a focus on "moving up" in the waste hierarchy into more prevention, reuse and recycling.

According to the Waste Statistics report from the Ministry of Environment and Food of Denmark, the total primary waste generated in Denmark, for 2014, was approximately 11.74 million tonnes (Toft, Fischer, & Bøjesen, 2016). In the same report, the overall waste treatment in the country was calculated as follows: 67.1% recycling, 26.7% incineration, 4.1% landfill and 2.1% for others. When comparing the previous numbers, with the treatment in 2012, the trend shows an increased recycling -of about 2%- and a decreased incineration. However, the total amount of waste going to incineration, in 2014, is slightly higher than that on 2012. This shows that percentage values can be misleading sometimes. Furthermore, it is worth mentioning that during the same period, there has been an increased amount of waste imports for incineration -accounting for 7.6% of total incineration in 2014- (Toft et al., 2016).

The treatment of municipal waste varies significantly when compared to the overall treatment percentages. The municipal waste treatment configuration in Denmark, in 2014, was: 27% recycling, 17% composting, 54% incineration and 1% landfill (Eurostat, 2016). When compared with the overall average of the country, differences can be highlighted. In general, for municipal waste, the recycling percentage is decreased by 40, while the incineration category is increased by the same amount.

The following figure (Figure 4) compares the overall waste treatment and the municipal waste treatment in Denmark for 2014. It should be noted that, to make the comparison, the categories of recycling and composting, in municipal waste treatment, have been grouped together.

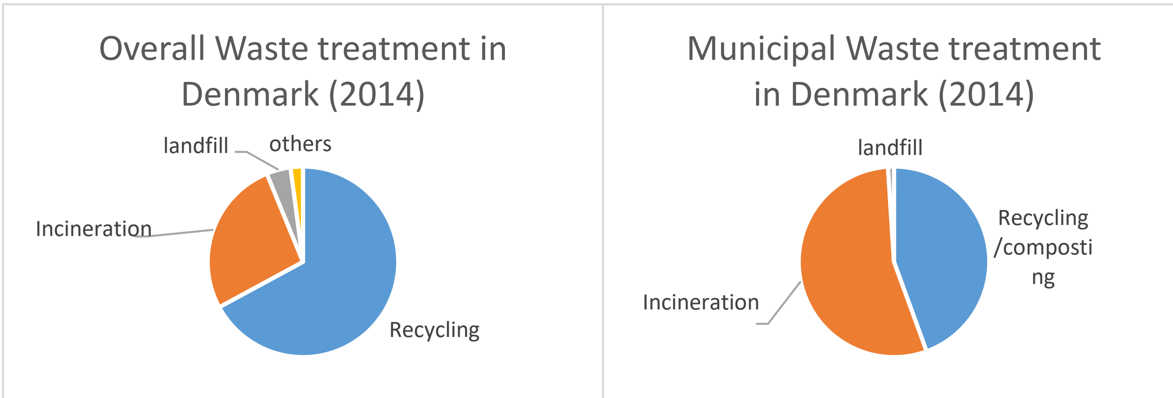

Figure 4 - Comparison between overall waste treatment and municipal waste treatment in Denmark (2014)

Under these circumstances, and in the context of EU regulation and the need to improve waste treatment under the Waste Hierarchy, the Danish Government decided to take a new approach to waste management. On 2013, a new resource strategy "Denmark without Waste" was implemented. With a motto "*Recycle more- incinerate less*", the Danish Government opted to promote a series of actions, focused on household waste recycling, to modify waste management in Denmark in a 10-year period (from 2012- to 2022). A core goal of the strategy is to achieve a 50% recycling rate in household waste -up from 22% in 2011- for selected waste streams (organic waste, paper, cardboard, glass, wood, plastics and metals) (Government, 2013). With the strategy initiatives, it is expected to reduce a total of 820,000 tonnes from going to incineration by 2022 (Government, 2013). As a follow-up, in 2015, the government expanded their objectives with a new strategy "Denmark without Waste II". This new waste strategy focuses on prevention and aims "*to reduce wastage of resources and to prevent valuable resources from becoming waste in households and businesses in Denmark*" (Government, 2015). This latest strategy has five action areas which were identified and defined due to their potential for waste prevention and stakeholder engagement. One of the areas is related to reduction in food waste.

Considering the government's waste strategies, it is evident that Denmark is in a process of waste treatment transition. However, the process will take place at different rates across the country. This is mainly because "*Municipalities are primarily responsible for the waste area, specially for household waste*"(Government, 2013). And different municipalities may decide to take different approaches into fulfilling targets and objectives. In this context, the Denmark Without Waste Strategy specifies: *"[…] the strategy contains no new requirements for individual municipalities. It will still be up to the individual municipality to set the level of service and organization of waste management*" (Government, 2013). Therefore, focusing in a specific location, or municipality, becomes relevant when analyzing waste management further.

For narrowing down the scope, municipalities and cities were considered. On one hand, Denmark's biggest municipalities, in 2017, are: Copenhagen (602,481 inhabitants), Aarhus (335, 684 inhabitants) and Aalborg (211,937 inhabitants) (Statistics Denmark, 2017). Larger municipalities not only represent a challenge in terms of the systems complexity, but also an opportunity to analyze a particular location that has an importance, in terms of population and economy, on a national level. On the other hand, according to the OECD, the core city-regions in Denmark are: Copenhagen, Aarhus, Odense and Aalborg (OECD, 2016). Considering the most important municipalities and cities in Denmark, and the researcher's specific location and desire for generating local knowledge, the present work will focus on the city of Aalborg.

5.4 Aalborg, Denmark

Aalborg is the name of both: the municipality and the city. Aalborg municipality is located in North Jutland and is Denmark's third largest municipality. The city of Aalborg is the largest city in the municipality but also it is North Jutland's capital. According to Danish statistics, on January 2016, the municipality had a population of 210, 316 while the city had 112,194 (Kommune, 2016).

Aalborg has been through a transformation from an industrial town into a city of global perspectives on knowledge, culture and sustainability. Regarding sustainability, the municipality has taken an active role in promoting and facilitating the city's green transition. For example, the municipality created in 2013 "The Center for Green Transition" which contributes to the city's sustainability agenda. Examples of initiatives within the Center for Green transitions are: Aalborg sustainability Festival, The Green Agents (which support an inclusive approach for citizen-driven sustainable initiatives), and SMART Aalborg (which promotes growth and development through collaborations among different stakeholders). Moreover, the city of Aalborg has actively participated in the European Conference on Sustainable Cities & Towns; events that have concluded in urban sustainability initiatives in the form of the Aalborg Charter in 1994, the Aalborg Commitments in 2014, and the Basque Declaration in 2016. In the latter, although many topics and scopes are mentioned, there is a strong connection with the concept of circular economy. This can be observed in some of the pathways statements stablished in the Declaration: "*We will turn the challenges in front of us into opportunities for our local economies*", "*We will create and close local value chains*", or "*We will pursue the development towards a Circular Economy*" (Declaration, 2016).

As mentioned before, circular economy is intrinsically linked with waste. Hence, considering the EU waste policy, Denmark's waste strategies, and the sustainability approach in Aalborg's municipality, it becomes necessary to analyze the state of the Art regarding waste and incineration in Aalborg.

5.4.1 Waste and incineration in Aalborg

Aalborg Forsyning, among many activities, is the company in charge of supplying Aalborg Municipality with heating, gas, water and waste collection services. The specific area in charge of waste management is called "Aalborg Renovation" and it is property of Aalborg Kommune. According to Renovation, approximately 129,000 tons of household waste were collected in Aalborg municipality in 2014 (Forsyning, 2014). This corresponds to 1,256 kg per household. According to the same report, the waste treatment for the same year was: 50.5% incineration, 44.4% recycling and 5.08% Landfill. In more detail, the amount of household waste that was incinerated was 65,324 tons, 57, 401 tonnes for recycling and 6,571 tonnes to landfill. Since incineration is the dominant waste treatment for household waste, it will be analyzed further in next lines.

In Aalborg, waste incineration is carried out by the company Reno Nord; which is in charge of some of the waste management of different municipalities (Brønderslev, Jammerbugt, Mariagerfjord, Rebild y Aalborg). According to the company's web information, the company owns two incineration plants, a landfill area and a recycling facility (Reno Nord, 2017). One incineration facility is located in Hobro and has a capacity of 4 tonnes per hour. On the other hand, the second facility is located in Aalborg with a capacity of 22,5 tonnes per hour (180,000 tonnes per year)(Reno Nord, 2017). The latter was commissioned to Reno Nord in 2005, and has two furnance/boiler lines (line 3 & 4). Line 3, which was supplied in 1991, works now as a replacement (Babcock & Wilcox Vølund A/S, 2017). Line 4, which is the main furnace, works with an efficiency of 100% and generates 18 MW of electricity (approximately supporting 16,000 houses) and 43 MW of heat for the District Heating Network in Aalborg (which approximately support 30,000 houses) (Babcock & Wilcox Vølund A/S, 2017). According to Reno Nord's "Environmental report", in 2015 in Aalborg's incineration plant, 180,341 tonnes of waste were incinerated (including refuse waste, bulky waste, waste from businesses, hazardous and imported industrial waste) (Reno Nord, 2015). Out of this number, 91,278 tonnes (or ~51%) came from the various municipalities refuse waste collection.

From all the waste incinerated by Reno Nord, the waste coming from Aalborg's municipality in 2014 came primarily from the "refuse" category and from fuel waste (~72% and ~28% respectively)(Forsyning, 2014). The refuse category, which is entirely incinerated, refers to municipal waste that is left after separating things to recycle -such as paper, carton, plastics, metal, glass- and hazardous waste. Household organic waste is considered as non-recyclable, and therefore is separated within the refuse fraction along with items such as dipers, pizza boxes and multi-layered containers (chips, milk and juice cartons).

The exact amount of organic waste inside the refuse category in Aalborg is not known[1]. However, the estimates for a typical Danish household waste composition, provided by the Ministry of Food and Environment (Miljø og fødevareministeriet), are the following: organic 43%, paper 20%, waste used as fuel 21%, plastics 10%, metals 3%, glass 2% and others 1% (Miljø og fødevareministeriet, 2014). If only organic waste and waste used as fuel is considered, the organic fraction would represent ~ 67% of all refuse waste.

It is important to highlight that there is a separate collection and treatment for "garden waste". This waste is normally composted or used for biofuel production. The following diagram (Figure 5) shows the municipal organic waste treatment Aalborg:

[1] Reno Nord was contacted by email, while Aalborg Renovation by phone. Neither had the calculations for organic waste coming from households.

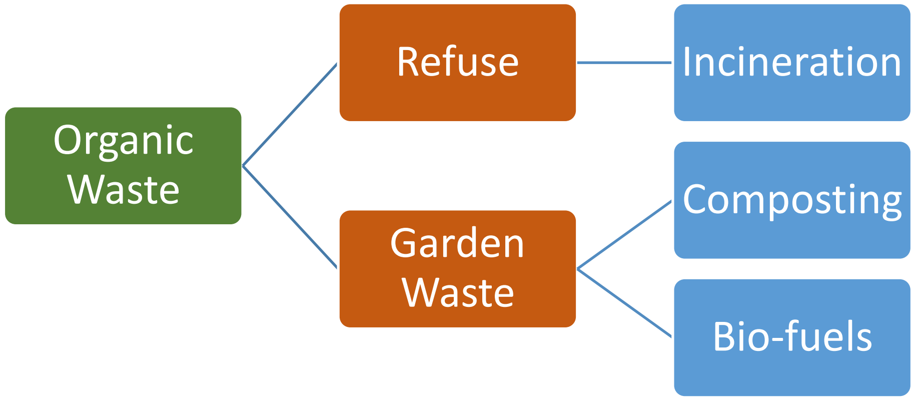

Figure 5-Organic Waste Treatment in Aalborg

But why is incineration relevant in Aalborg? Reno Nord is one of the main contributors to Aalborg's District Heating system along with Aalborg Portland and Nordjylland Power Station (Nordjyllandsværket). According to Aalborg Varme (from Aalborg Forsyning), in 2014, the heat supply to the District Heating system was as following: Nordjylland Power Station with 56%, Reno Nord with 23%, Aalborg Portland with 18%, and 3% coming from the reserves (Aalborg Forsyning, 2017b). In this context, Aalborg District Heating supplies heat to 34,000 metering points and has a turnover of 700 million Danish crowns (Danish Board of District Heating, 2017).

Therefore, considering on one hand the link between municipal waste and incineration, and on the other hand the link between incineration and district heating, it becomes evident that the waste topic influences the energy sector. Hence, it is possible to expect that any relevant changes in municipal waste treatment (specifically in the refuse fraction) may affect the city's energy (heat) supply. The next figure (Figure 6) simplifies the link between household organic waste with the incineration and the district heating system.

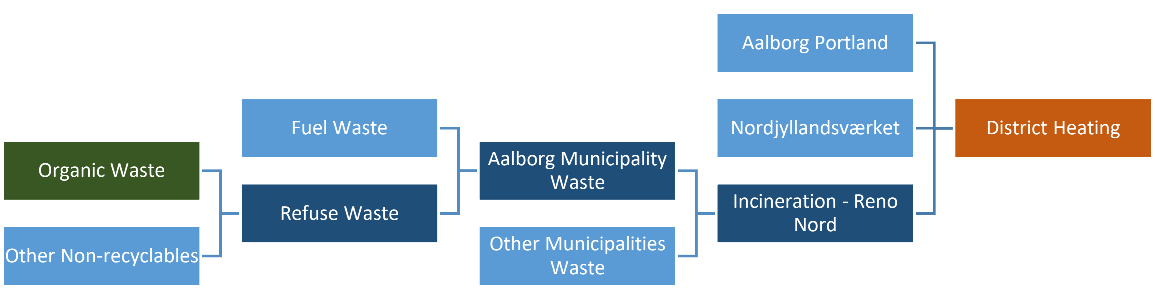

Figure 6- Simplification of Household Organic Waste flow in Aalborg and its relationship with district heating

To make the connection between waste and energy sectors clearer, the following diagram (Figure 7) will show the present situation in Aalborg based on numerical assumptions. The diagram is built on the statistics reported previously in this section (180,341 tonnes of waste incinerated in total) from the year 2015, and considers only the incineration plant in Aalborg. The energy output was taken from the Reno Nord Environmental Report 2015 (Reno Nord, 2015).

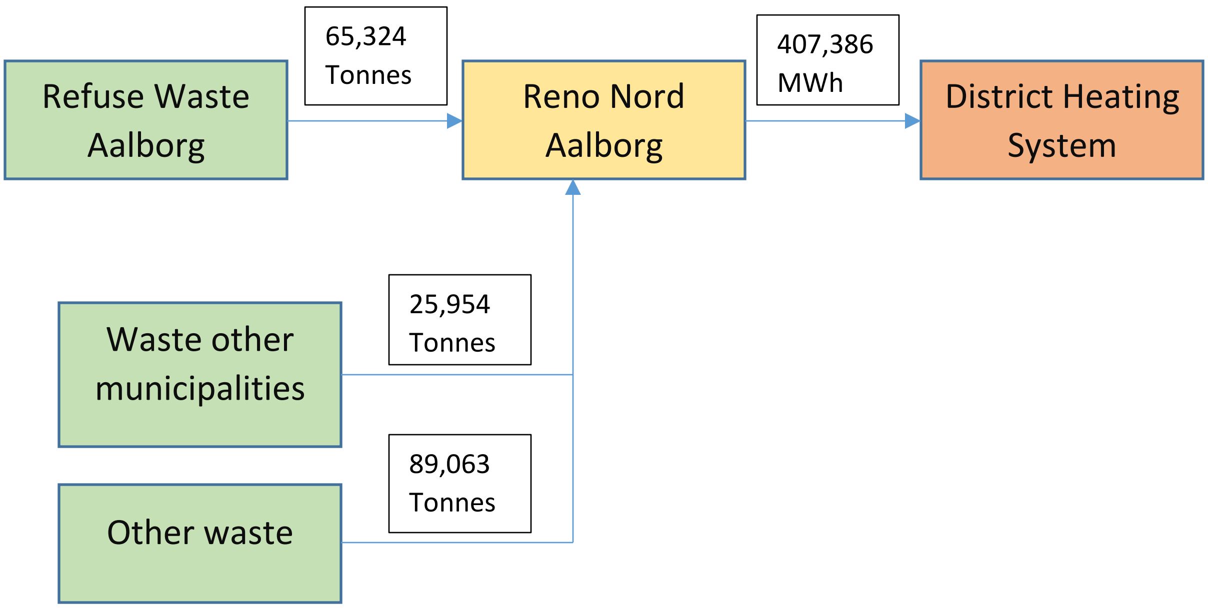

Figure 7- Waste and Energy relationship in Aalborg

Considering this close connection between waste and energy, it is possible to argue that the system becomes complex. If a reduction on waste happens, there is an immediate need to supply energy from new sources. In this sense, it would be relevant to ask what solutions can take place to address the "missing" energy due to "losses" in waste. The following diagram (Figure 8) will show how the system would look with a 50% reduction in the organic waste input (assuming that 67% of refuse waste comes from organic material). The purpose is to inform the reader of the need to replace the energy demands if less waste is incinerated. The relationship between waste input and energy production is assumed to be lineal[2].

[2] This assumption might not be true since organic waste is generally wet. This means that the energy output of organic waste might not be as high as compared with other types of waste such as plastic (Ladefoged, 2017).

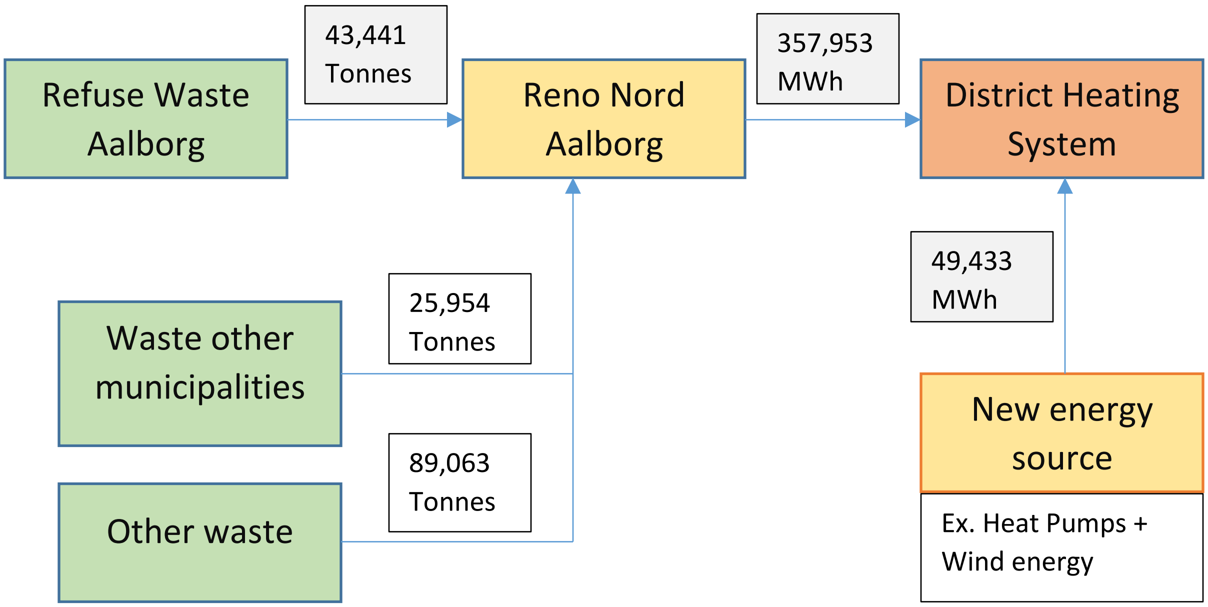

Figure 8- Waste and Energy relationship in Aalborg with organic waste reduction of 50%

The multiplicity of factors involved in the "how" to promote a green transition within waste becomes vast. And with it, the number of possible solutions, inside different contexts, also increases. It is clear that the energy sector is in need of changes; however, for this paper, the focus will remain in organic waste and the need of prevention, reuse and recycling.

Hence, summarizing, if we consider Aalborg's waste treatment composition, it is possible to observe that the numbers follow the same distribution as the average treatment for municipal waste in Denmark (with an incineration percentage greater to 50%). Therefore, municipal waste treatment in Aalborg can be seen as a typical Danish case; where, considering the EU policy and the Danish latest waste strategies, there is a need of replacing incineration by other waste treatment options. However, it should not be forgotten that possible changes, in current paths or trends, will have conflicts with various institutions and stakeholders (as showed with the energy sector).

6 Problem Identification

A process of increasing urbanization is happening globally. In this context, the high concentration of people in urban areas creates a set of challenges that need to be addressed if efforts are going to be directed towards sustainability. One of these challenges is waste. Proper waste management is a necessary element to consider when working towards sustainable cities.

European countries, which are already highly industrialized and urbanized, produce the most waste per capita. The waste management strategies to deal with this waste are shaped based on EU policy Directives, the Waste Hierarchy and lately by the concept of Circular Economy. In general, the principles stablish a prioritization to waste prevention, reuse and recycling over recovery and disposal. Considering cities as the point of analysis for the present work, municipal waste becomes relevant due to its economic and environmental impacts. In global average, the organic fraction has the biggest share inside municipal waste composition. Its relevance is also highlighted since organic waste is directly linked to greenhouse gas emissions when disposed in landfills and to land degradation due to lack of nutrients brought back to farm lands. Moreover, rather than a waste stream, organic matter can be considered as a resource due to its potential to be recycled.

When comparing economically similar countries (through GDP per capita) in the European Union, differences arise regarding municipal waste treatment. Germany stands out in recycling, while Austria does the same with composting. Both stand out as countries with best performance in the EU. In contrast, Denmark highlights as the country producing the most municipal waste per capita and also as the second country regarding incineration. Not to diminish the country's efforts towards sustainability since huge advancements have happened in other areas. However, changes are needed in the area of waste if compliance is going to happen with the EU policy.

On the waste topic, Denmark is already taking action with its Strategy "Denmark without waste" (2013) and "Denmark without waste II" (2015). In more detail, "Denmark without waste" establishes an objective of achieving 50% recycling from household waste, for selected waste streams, by 2022. To comply with the objectives, individual municipalities will select their own approaches and strategies.

Aalborg municipality is one of the biggest and most important municipalities in Denmark. Regarding waste, the municipality is still strongly dependent on incineration (>50%) as a waste treatment solution. Incinerated waste comes from various sources. However, municipal waste composes more than 50% of the total incinerated material. The totality of the organic fraction of household waste is included inside the collected municipal waste that is incinerated. In this situation, it is possible to observe that the organic waste fraction is: 1) not collected separately and 2) it's collected inside the refuse category which normally contains non-recyclables. Thus, the organic fraction not only makes up an important element of the incineration process, but also becomes an underused resource. In this context, and as expressed by the EllenMac Arthur Foundation: "*Although municipalities currently view organic waste management as a cost, it could be an attractive source of revenue*"(Ellen MacArthur Foundation, 2017).

The following graph (Figure 9) shows the incinerated refuse waste in Aalborg's plant (with data until 2015) and a linear forecast until the year 2022. A second line has been established to show the expected decrease in incinerated refuse waste if 50% of organic waste is being recycled by 2022 (considering that organic waste recycling nowadays is 0%). This percentage was selected since it would represent a direct relationship with the "Denmark without waste strategy" of recycling 50% of household waste by 2022 (which includes organic waste). The target point for 2022 is based on data for 2012 (when the strategy started) and was calculated assuming that organic waste corresponds to 67% of all refuse waste. The target value in 2022 is ~60,500 tonnes.

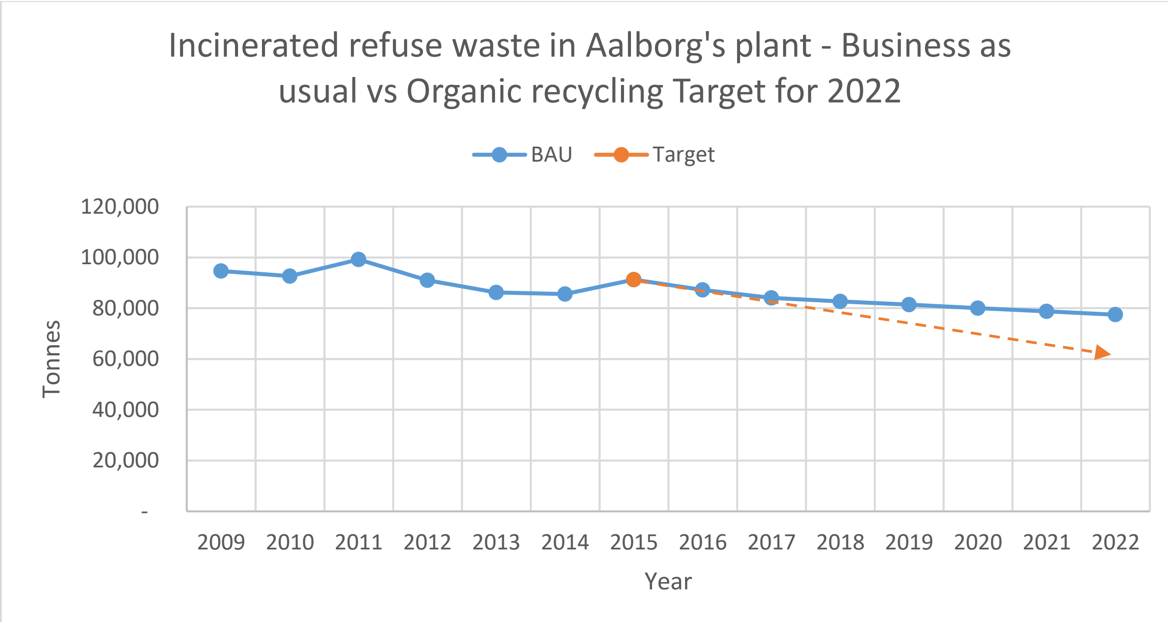

Figure 9- Incinerated refuse waste in Aalborg's plant - BAU vs Organic recycling target for 2022

Considering both scenarios, there is an area of opportunity that can be addressed through the design and implementation of innovative solutions. The solutions should be focused in the promotion of waste prevention, reuse and recycling -closing loops- above other options. Moreover, proposed solutions should not only need to be innovative, but should be able to break the present waste treatment trends on which the City, and the country, are at the moment. Therefore, a general question can be formulated:

How to close loops regarding organic waste in Aalborg through innovative solutions?

However, before taking the role of solution design, it's necessary to understand this problem holistically. The next section will provide an analytical framework in two areas:

1. Explaining the situation in Aalborg through Ecological Modernization (Mol & Sonnenfeld, 2000) and Institutional Theory (Scott, 2001). This section will provide a deeper understanding of the present situation of Aalborg regarding relevant institutions and how they influence the city's ecological modernization process in terms of waste. Furthermore, this section can function as inspiration for further research.
2. A brief description of the concept of Circular Economy and its link with Value Creation in the organic waste treatment setting. This section will provide the basis for understanding the proposed solution that is being developed in the present research (thus will include information regarding organic waste treatment).

Once the framework is explained, the problem definition is going to be stablished. From there, research questions will be designed and the research will be carried out. In the end, a proposal is expected to be developed for organic waste treatment in a case study.

7 Analytical Framework

7.1 Ecological Modernization

The sociological theory of Ecological Modernization will be used to provide a general framework on the current situation in Aalborg regarding its green transition. Furthermore, this analysis will provide the basis for analyzing the relationship among relevant institutions and how they are influencing the transition towards a future less dependent on incineration. It should be highlighted that it is not the purpose to engage in a theoretical questioning or development approach; but simply into a descriptive task. Most of this section is based on the work of Mol and Sonnenfeld (Mol & Sonnenfeld, 2000) and Mol and Spaargaren (Mol & Spaargaren, 2000). Both texts provide an introduction and review of Ecological Modernization theory through an analysis of multiple authors and publications.

According to Mol and Sonnenfeld (Mol & Sonnenfeld, 2000), Ecological Modernization appeared as an attempt to provide explanations regarding environmental transformations in practices, discourses and institutions. The theory was first developed in the beginnings of the 1980's, and has been, since then, under constant transformations due to multiple scientists contributing with various publications. Nevertheless the constant changes, at the core, "*the theory tries to analyze how contemporary industrialized societies deal with environmental crisis*"(Mol & Sonnenfeld, 2000).

Aalborg's green transition can be partially described in the terms of Ecological Modernization. In order to support this statement, the theory will be analyzed further by identifying some of its core elements which sometimes contrast (and can be compared) with other theoretical approaches. It is important to highlight that some points of comparison were left out, since they were not considered relevant in this paper. Some examples refer to various critiques that question the very existence of "environmental problems", as they see them as social constructions. The general assumption here is that environmental problems exist, and that addressing them is relevant when considering green transitions.

To visualize core elements, a table (Table 2), which is based on the work of Mol and Spaargare (Mol & Spaargaren, 2000), will be used. Moreover, this will allow to relate the core elements with the present situation in Aalborg.

Table 2- Relevant theoretical elements in Ecological Modernization Theory

Ecological Modernization Theory elements	Detail
1. **Definition of the border between the social and the natural.**	• Social systems cannot be explained without considering its relationship with the outside -natural- world. • This contrasts with the post-war sociological theories, which were closely linked to the industrial institutions of consumption and production. • Environmental factors need to be considered inside the institutional clusters of production and consumption.

2. Radical approaches vs moderate	• Traditional critiques center on de-industrialization process or the "dismantling of institutions". Ecological Modernization supporters claim that some fundamental transformations are needed, but that this does not mean that modern society institutions need to be "dismantled". • Ecological Modernization Theory supports the idea (along eco-centrists) that consumption and production processes need to be improved regarding impacts on the environment. However, it does not give environmental objectives a priority above social objectives. • Ecological Modernization Theory sees the environment as an independent concept. This supports the conception that a capitalistic system can thrive without necessarily contradicting environmental improvements or reforms. Thus, reforms can be developed within the current institutional context.
3. **Institutional Transformations**	• Sometimes, environment-induced transformations, within institutions and societal practices, are underestimated (Ex. radical ecologism). Furthermore, such transformations are becoming legit. In this context, a radical/moderate tension arises on whether transformations on existing systems is better than the radical "ultimate" environmental state of mind. But, as explained by Mol and Spaargaren (Mol & Spaargaren, 2000), "*the opening up of windows for realistic utopian models for the future seems a better alternative than either the noncommittal attitudes towards radical ecologism, or the business as usual scenarios*".

Aalborg, as many other European cities and countries, can be identified within a process of Ecological Modernization. The current situation of Aalborg is going to be described considering the previous table.

In general terms, it can be argued that the approach in Aalborg is that of relating the "social" with the "natural". The very creation of the Center for Green transition (Center for Grøn Omstilling) in 2013, shows how the institutional context is constantly evolving due to environmental-induced changes. This approach is influenced by the EU policy, the Danish strategies and the city's commitments (Ex. Basque declaration), and is reflected in the specific approach of Aalborg's municipality. The municipality's sustainability strategy is focused on "*consumption and resources and how SMART solutions based on circular economy can create green growth and social development in the municipality*" (Aalborg Kommune, 2017). In general, the strategy aims to benefit citizens, businesses and the environment at the same time. Moreover, other initiatives, such as the

Green Agents (Grønne Agenter) -which support to citizen-driven initiatives- and the Green Stores (Grøn Butik) -an environmental labelling scheme-, relate the social and the natural within the already stablished institutions. Considering this context, it is possible to argue that the approach of the city is closer to a moderate position rather than a radical one. The municipality's sustainable initiatives support the idea of a need for reforms and transitions, but always within the current capitalist system. Furthermore, apparently, the sustainable strategy does not prioritize the environment above or below the social; rather they seem to have the same importance. In the municipality's web information it states when referring to the sustainability strategy focus: "*it combines the desire for a sustainable transition with the citizens' well-being and quality of life*" (Aalborg Kommune, 2017).

In the context of waste, changes towards an ecological transition are evident. Regarding household waste; paper, cardboard and glass were already being separately collected by the municipality. And just recently, the streams of plastic and metal were added up to this list. This recent institutional change facilitates the possibility of increasing recycling and reducing incineration. However, when analyzing in greater detail, this is not the case for organic waste yet.

In general terms, although the city appears to be through a holistic process of ecological modernization (supported by EU policy, Danish policy and the municipality's strategies), there appears to be conflict that slows down the progression in terms of organic waste. Considering that plastics and metals are currently being recycled in a higher percentage, a further reduction in waste going to incineration could represent a challenge in terms of energy supply. In this case, involved institutions could influence the path the city is going to take in the future. Moreover, political aspects influence the process as well. According to Dorte Ladefoged (Ladefoged, 2017), Waste Planner from Aalborg's Municipality, the city is planning on implementing biogas solutions in the close future. However, there are two reasons that prevented a separate collection of the organic fraction during the last years:

1. There is concern about the cleanness of the pulp (due to the presence of plastic material) produced in anaerobic digestion processes. The presence of plastic complicates the process of defining the "accepted values" for disposing pulp in the soil, along with defining where or to whom is the pulp going to be delivered. In this matter, currently there is no regulation in Denmark that stablishes limits. Thus, the decision is taken by the local government.
2. Joined to the previous point, future government changes also slow down the process. Elections are happening in 2017, and a new government bureau is expected for 2018. In this case, certain decisions, such as organic waste treatment, will be addressed until the new government comes (in order to avoid contradicting points of view between the past and new administration).

All things considered, a combination of circumstances is creating conflict among stakeholders that slows down the ecological modernization process in the waste setting. This conflict might be explained by the combination of both: the relationship of the waste and energy sectors, and the current political uncertainty (including future changes and the definition of limit values for pulp from anaerobic digestion processes).

The previously mentioned aspects involve the interaction of different institutions in Aalborg. These institutions might be competing to each other. Even more, certain institutions might be influenced by multiple factors the slow down the process of ecological modernization in terms of waste. Therefore, in order to describe and analyze this conflict, institutional theory will be used.

7.2 Institutions in Aalborg

As with Ecological Modernization Theory, the use of Institutional Theory in this section is to provide a context -description- on the current situation in Aalborg (rather than creating a theoretical discussion). The purpose of providing context is to answer the question of: How are institutions connected and how they influence Aalborg's green transition towards a future with less incineration? Answering the question will allow the reader to comprehend the complexity of the waste challenge in Aalborg in a holistic way. However, it should be highlighted that the present research, on the following sections, will address waste in a more specific and restrictive way; addressing waste through numeric analysis and a solution proposal.

The present analysis is primarily based on the work of Richard Scott (Scott, 2001) since it comprises an analysis of several scientists and publications. First, an overview of Institutional Theory will be given. Second, a brief description of the three pillars of institutions will be presented. Finally, the framework of Institutional Theory will be used to analyze the current situation in Aalborg.

In general terms, Institutional theory analyses the structures in society that shape and guide human behavior through systems such as laws, norms, common beliefs, etc. Such structures, which might seem static, can arise, transform and even disappear. Institutions are part of these structures. Moreover, institutions have been linked with the concept of organizations. Historically, according to Scott (Scott, 2001), in the 1940's the topic of Organizations consolidated as an ordered field of research. In this context, scholars "*began con connect institutional arguments to the structure and behavior of organizations*" (Scott, 2001). Later, in the 1960's, Open systems theory established the importance of considering a "wider context" or environment when analyzing organization's development. It was until the 1970's, that researchers recognized the influence of wider social and cultural forces within the action of organizing (referred as the Institutional Environment). As any other theory, Institutional Theory has been subject to many changes and modifications due to constant contributions across time. In the latter years, ideas came to be known as NeoInstituional Theory, influencing different research fields such as economics, political science and sociology.

But what is an Institution? According to Scott (Scott, 2001), there is no single definition; however, institutions do have common characteristics: a) they are social structures with a high level of resilience, b) they are composed of elements, activities and resources that provide stability and meaning to social life, c) they operate on different levels of jurisdiction; from world systems to interpersonal relationships, d) they connote stability but are subject to change (though legitimacy and deinstitutionalization). Furthermore, the concept of legitimacy needs to be considered as a relevant characteristic for institutions. According to Scott et al. (Scott, Ruef, Mendel, & Caronna, 2000), legitimacy refers to the conditions of "*Organizations require more than material resources and technical information if they are to survive and thrive in their social environments. They also need acceptability and credibility*".

According to Scott, the institutional characteristics are given by the "building blocks": regulative, normative and cultural-cognitive elements. The regulative, normative and cultural-cognitive elements conform what is known as the three pillars of Institutions. All of them are related to each other and sometimes they fall on a process of mutual reinforcing. Nevertheless, they are often separated since scholars, with different approaches, usually give a primary importance to a single pillar. Based on the work by (Scott, 2001), the following table (Table 3) will show the characteristics of each pillar.

Table 3- The three pillars of Institutions - Characteristics

Pillar	Characteristics
Regulative	• Institutions seen as regulators of behavior by rule setting, monitoring and sanctioning (formal or informal). • Force, fear and expedience as central ingredients; though tempered by rules. • When laws are controversial or ambiguous: an occasion for sense making and collective interpretation might arise. Thus, laws may rely more on the normative and cultural-cognitive elements (rather than coercive) for its effects. • Must do.
Normative	• Emphasis is given to "*normative rules that introduce a prescriptive, evaluative and obligatory dimension to social life*" (Scott, 2001). • Includes Norms (which define the means to reach a valued objective) and Values (preferred or desirable behavior compared to standards). • Give rise to roles (specific expectation to particular individuals) through prescriptions -normative expectations. • Impose constrains to behavior, but also provide power to social action. • Ought to do.
Cultural-cognitive	• The actor's subjective interpretations (which are shaped by external cultural frameworks) must be considered in analysis. • It is about shared conceptions of social reality. Relates to how meaning is collectively made. • Include behavior that is just "taken for granted"- routines. • What we usually do.

In order to simplify the information in the previous table, a second table (Table 4), taken from Scott (Scott, 2001) will be showed.

Table 4- Three Pillars of Institutions Summary

	Regulative	Normative	Cultural-cognitive
Basis for compliance	Expedience	Social obligation	Taken-for-grantedness. Shared understanding.
Mechanisms	Coercive	Normative	Mimetic

Indicators	Rules, laws, sanctions	Certification, accreditation	Common beliefs, shared logics of action
Basis of legitimacy	Legally sanctioned	Morally governed	Comprehensible, recognizable, culturally supported.

Even though all three elements might be seen as divergent conceptions (mainly to underlying assumptions, mechanisms and indicators (Scott, 2001)), in this present paper an integrated approach will be used. This means that all three elements are going to be considered equally relevant. Furthermore, the description will include different levels of analysis (from world system to organization sub-system). In this way, the current institutional situation of Aalborg will be explained.

The relationship among different institutions promotes a situation where behavior is guided differently depending on particular interests. Thus, having multiple conceptions of how society should develop slows down ecological progress. In this context, institutions in Aalborg will be identified within the three pillars.

On the regulative approach, actions are guided by coercive mechanisms through rules, laws and sanctions. Regarding waste in Aalborg, regulation can be seen all the way up to EU policy (specifically the EU directives), Denmark's Waste Strategies (Denmark without waste) and the local government in Aalborg. In the case of the EU directives, behavior is shaped by formal law; which in case of non-commitment could signify sanctions. In the case of Danish strategies, behavior is shaped by rules. And even if there are no proper sanctions to failing targets, a case of non-commitment could be related to negative consequences. These two, EU and Danish regulation, are now focusing on the prioritization of waste prevention, reuse and recycling, and a general reduction on landfill and incineration. This stablishes clear objectives on the energy and waste sectors in Aalborg. However, conditions for the local government institution are not that clear. It should be considered that the waste targets are established on national level but the municipality is open to deal with the problem in their own way. In this context, according to Dorte Ladefoged (Ladefoged, 2017), in Aalborg, politicians represent the main stakeholder which decides what to do and how far to go. Coincidently, waste is now very popular in politics (Ladefoged, 2017). Thus, it is very likely that the local government implements rules and laws that fall in line with the approach taken by the regulation on EU and Danish levels. In this case, it would seem like the regulative institutions direct themselves into the same direction. However, the local government perception is influenced by other factors. This open the opportunity of decisions being made based on a normative or cultural-cognitive approach (something that might signify conflict when analyzed further).

On the normative approach, actions are guided by normative mechanisms through certifications/accreditation or pressure of social obligation. As an example, let's consider the European Union, but now through the Circular Economy Package. So far, the package is integrated by revised legislative proposals and an action plan. In this context, the proposals, as a whole, do not represent a formal rule or policy. Therefore, the European norms can be considered as something that is socially expected (through pressure of other environmental legit institutions) in a normative setting. In this context, the circular economy concept would promote a scenario with more recycling of waste. Nevertheless, in this pillar, other institutions might share, or not, the same point of view.

As mentioned before, social obligation is relevant. However, such social obligation is created by several institutions which expect to guide actions based on different approaches. As an example of this, and considering the waste-energy connection in Aalborg, the European Sustainable Cities Platform would support a transition to more recycling, while Reno Nord might support the supply of services (district heating). In the same context, such differences on what is "socially obliged" would create conflict within the local government. Politicians, in this case people deciding what is going to happen, might take different points of view. This circumstance could slow down the ecological transition process within Aalborg. Additionally, in the normative approach, a moral aspect provides legitimacy. And morality is created within society through institutions. In this matter, the cultural-cognitive is intertwined with the normative approach.

On the cultural-cognitive approach, actions are guided through mimetic mechanisms through common beliefs and shared logics/understanding. What becomes culturally supported is what guides future processes. On one hand, In Aalborg, and Denmark in general, there is a strong historical incineration approach to waste. Even more, the incineration processes are closely linked to the District heating systems which provide energy to households in a specific country with specific weather conditions. In such context, incineration can be seen as something that is taken for granted (therefore being mimicked) as the best (and maybe only) solution to the waste challenge. On the other hand, another part of the population could be aware of different methods to treat organic waste and could support their reproduction (treatment processes in other countries for example). In general, what is common belief depends almost in each person and in what they consider to be legit. This is the same case for politicians which could support different approaches to organic waste treatment.

A conflict between the three pillars of institutions is evident in Aalborg. Firstly, there is a regulative set of institutions pushing strategies that, in general terms, intend to reduce incineration. Secondly, another set of institutions, on a normative level, might legitimize actions towards circular economy but also to the supply of services -such as district heating- and the provision of jobs. In this context, it is morally accepted to incinerate waste in order to supply the city's energy demands. Thirdly, in the cultural-cognitive level, incineration could be -or not- supported by the population depending on the specific group of people. The historic use of incineration in the country could represent a solution that comes from a "common understanding". However, recent changes on regulative and normative levels, could modify these cultural-cognitive institutions into bodies that support prevention, reuse and recycling. Considering all pillars: a) the regulative might contradict the normative and the cultural-cognitive, b) the normative might have contradictions within what is morally accepted (what is socially obliged), but also might differ from the regulative and cultural cognitive, and c) the cultural-cognitive might have contradictions within what is understood as "normal behavior" and what should be mimicked; plus having differences with the normative and regulative levels.

All pillars of institutions are intertwined. Even more, differences arise within the same institutional levels (ex. variances inside cultural-cognitive). Thus, the differences, in what is considered legit, create a conflict that slows down the general sustainable transition of the city. In this context, it is necessary to initiate a new trend in a way that addresses the waste challenge considering these conflicts. Under the assumption that reducing incineration is the best option, waste treatment solutions should have as an objective to align the different institutional pillars. This means that actions towards incineration reduction should be socially accepted and validated. Support from people would provide proper legitimization, which in turn, would promote potential environment-induced changes in the present institutions in Aalborg.

7.3 Circular Economy and Value Creation

The concept of circular economy was briefly discussed in the regulation discussion. However, in this section the concept is going to be analyzed in more detail and it is going to be linked to the term of value creation in the context of organic waste.

Circular Economy is about leaving behind the linear economic model that has been around since the industrial revolution. The linear model is based on the assumption of unlimited inputs to production and consumption systems. However, recent pressure on resources, such as materials and energy, have led to the awareness that the number of available resources in the world is limited. In order to decouple resource scarcity from economic development, the obsolete linear model has to be substituted by a new approach. In this context, the concept of Circular Economy is highlighted. According to the Ellen MacArthur Foundation, Circular Economy "*is one that is restorative and regenerative by design and aims to keep products, components, and materials at their highest utility and value at all times, distinguishing between technical and biological cycles*" (Ellen MacArthur Foundation, 2015). In more detail, to keep the "highest utility and value at all times", an economic model which includes recirculation (circles rather than lines) of products, components and materials is proposed. The following figure (Figure 10), taken directly from the Ellen MacArthur Foundation (Ellen MacArthur Foundation, 2014), shows the Circular Economy System:

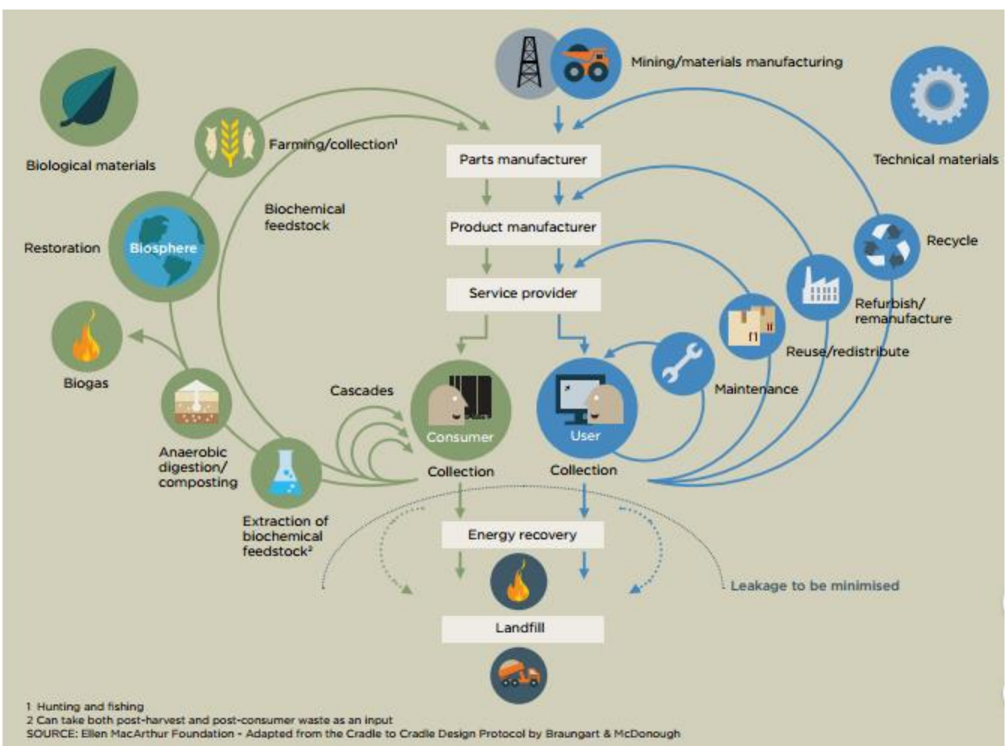

Figure 10 - The Circular Economy System

According to Ellen MacArthur foundation (Ellen MacArthur Foundation, 2015), Circular Economy is based on three principles:

1. "*Preserve and enhance natural capital by controlling finite stocks and balancing renewable resources flow*". This principle can be seen as a first step before the supply chain.
2. "*Optimise resource yields by circulating products, components, and materials at the highest utility at all times in both technical and biological cycles*". This principle describes the dynamics within the supply chain in circular economy. Circular, inner loops, are promoted through remanufacturing, refurbishing and recycling with the objective of preserving energy and value.
3. "*Foster system effectiveness by revealing and designing out negative externalities*". This principle can be seen as the last step after the supply chain. In general, it refers to reducing damage systems and managing environmental externalities.

Following the Circular Economy definition and principles, it is possible to link the circularity concept with Value Creation. If production systems are going to implement Circular Economy principles, then a restructuration of the supply chain needs to take place. It is in the new structure than value opportunities need to be identified and exploited. As mentioned by Dr. Erwin van der Laan "*If a company wants to be successful in applying Circular Economy concepts, they need to have a business model. They need to create business value*" (Van der Laan, n.d.)[3]. For example, one of the characteristics of Circular Economy is that "*waste does not exist, and is designed out by intention*" (Ellen MacArthur Foundation, 2015). In this scenario, a company may be confronted with the need to creating value for spare materials.

The sources of Value Creation in the context of Circular economy, according the Ellen MacArthur Foundation (Ellen MacArthur Foundation, 2014) are:

1. **Power of inner circle**: The faster a product returns to regular use (by repair, refurbish, remanufacture), the higher the potential to create savings in material, labor, energy and embedded capital.
2. **Power of circling longer**: Generate savings by prolonging the time within cycles (ex. the time needed before repairing) and maximizing the number of consecutive cycles (ex. the number of times a product can be repaired).
3. **Power of cascade use**: Expand reuse opportunities in the supply chain (ex. substituting virgin materials inputs with "used" material).
4. **Power of pure inputs**: "*Uncontaminated material streams increase collection and redistribution efficiency while maintaining quality*" (Ellen MacArthur Foundation, 2014).

However, the relevance of each of these value creation sources varies depending on the type of material it is dealing with. As mentioned previously, the Circular Economy model separates the biological and technical materials (see Figure 10). And in this distinction, it should be highlighted that the opportunities and mechanisms to implement the Circular Economy model in the biological cycles have been mostly unexplored (Ellen MacArthur Foundation, 2017).

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[3] Taken from the video Lecture 2.3.1 "four types of value creation" from the Circular Economy course from TUDelft OpenCourseWare.

So how to create value out of Biological Materials? The value creation source number three is highlighted: "*For biological materials, the essence of value creation lies in the opportunity to extract additional value from products and materials by cascading them through other applications*" (Ellen MacArthur Foundation, 2015). In this context, cascading refers to the potential to diversify reuse when compared to just landfilling. This becomes the only option since, in contrast with technical cycles, biological materials are "designed" to be consumed and then be used directly to regenerate the new raw materials. Nevertheless, it should be mentioned that this does not close the opportunity for waste prevention strategies.

For the specific stream of organic municipal waste, the cascading to other applications could include: the production of concentrated NPK fertilizers (such as composting), energy recovery through anaerobic digestion, and the manufacture of products and materials traditionally derived from fossil fuels (ex. biorefineries) (Ellen MacArthur Foundation, 2017). The next section will provide further information about the recycling of organic waste.

7.4 Recycling of Organic Waste

The most common organic waste recycling options are Anaerobic Digestion and Aerobic Composting. Both options are being considered not only because they've been highly explored, but also because they are economically and technologically feasible. The purpose of this section is to provide a brief knowledge base for the proposal being developed in the end of this paper.

7.4.1 Anaerobic Digestion

Anaerobic Digestion refers to the process of breaking down organic material by microorganisms in the absence of oxygen. The breaking down of material occurs in a series of chemical reactions defined as: hydrolysis, acidogenesis, acetogenesis and methanogenesis (The Official Information Portal on Anaerobic Digestion, 2017). Generalizing, this process produces biogas and a digestate material rich in nutrients. The next figure (Figure 11) shows a simplified Anaerobic Digestion process:

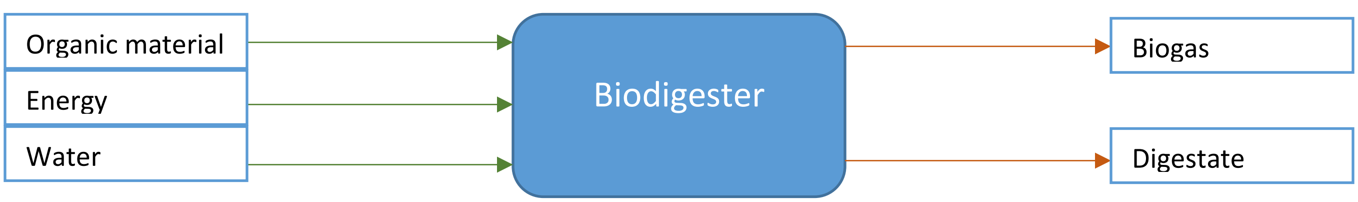

Figure 11- Simplified Anaerobic Digestion Process

Biogas can be used as a fuel to produce heat, electricity or heat and electricity through CHP plants. The production of biogas varies depending on many factors (Arsova, 2010): pH of reacting material, composition within the input waste, loading rate, retention time, operating temperature (mesophilic temperature optimum of 25-40 °C, and thermophilic temperature optimum of 50-65 °C) and the operating system (wet or dry digestion, number of reactors used in series). Commonly, biogas is estimated to be composed of methane (~60%) and carbon dioxide (~40). However, the specific amounts depend on the previously mentioned factors. If cleaned of impurities, biogas becomes biomethane (~97% methane). Biomethane can be injected in the natural gas grid or can be used as fuel for transportation.

The digestate, in terms of solid material, is normally 80% of what entered the system (Kraemer & Gamble, 2014). This material can be used as fertilizer since it normally contains Nitrogen, Phosphorus and Potassium.

7.4.2 Composting

Composting is the natural decomposition of organic material by microorganisms in the presence of oxygen. In contrast with anaerobic digestion, [aerobic] composting doesn't produce biogas. The main outputs are compost (humus) and carbon dioxide. The following figure (Figure 12) shows a simplified process of composting:

Figure 12- Simplified Composting Process

As with the digestate, the compost output is used a fertilizer. According to the Food and Agriculture Organization of the United Nations (Misra, Roy, & Hiraoka, 2003), compost is no only a nutrient rich material (nitrogen, phosphorous and potassium) but also it improves the physico-chemical and biological properties of the soil. In agricultural terms, the benefits manifest in: "*reduced cropping risks, higher yields and lower outlays on inorganic fertilizers for farmers*" (Misra et al., 2003).

7.4.3 Anaerobic Digestion and Composting

Although both options are very similar, several differences can be identified. The following table (Table 5) shows the main identified similarities and differences among the methods:

Table 5- Anaerobic Digestion and Composting: Similarities and Differences

Similarities	Most common methods for organic waste recycling. Provide a solution to direct landfilling.
	Can contribute in returning nutrients to agricultural lands. Enhance soil's health in many aspects.
Differences	Anaerobic Digestion has a positive energy balance due to the biogas output.
	Anaerobic Digestion happens at lower temperatures: weed seeds and pathogens remain , and generally the process takes longer (Misra et al., 2003).
	Composting happens at a higher temperature: kills micro-organisms and pathogens, and generally happens faster (Misra et al., 2003).
	Feedstock: leaves and yard trimmings more suitable for composting, while food waste, fats and oils more suitable for anaerobic digestion (Kraemer & Gamble, 2014). The distinction is made based on the feedstock's potential to produce biogas.
	Less area required for Anaerobic Digestion. Also, odor problems are minimized (Hartmann & Ahring, 2005).

Considering both methods are proven as organic waste recycling options, it becomes relevant asking which one is better. According to Kramer and Gamble (Kraemer & Gamble, 2014), the answer is "*it depends*". Each method appears to be attractive in different niches due to the specific in-situ characteristics. Even more, Kramer and Gamble (Kraemer & Gamble, 2014) suggest that a mixed solution, in some cases, might be the best option. However, in order to make a distinction between the two methods, other parameters need to be taken into account. A study by Edelmann, Schleiss and Joss (Edelmann, Schleiss, & Joss, 2000), which performed Life Cycle Analysis of technologies for treating biogenic waste, concluded that Anaerobic Digestion is the best option from an ecological point of view. This result is not only based on the positive net energy production of anaerobic digestion, but also on the theoretical assumption that composting has a considerable amount of methane emissions. Furthermore, incineration would be the least favorable solution in terms of environment and economics. On the same matter, the Food and Agriculture Organization locates anaerobic digestion on an apparent "higher" hierarchical position than composting in environmental terms. It is stated: "*Where digestion is not possible, composting represents the best fall-back option*" (Food and Agriculture Organization, 2017). Furthermore, regarding incineration it is stated: "*incineration of food waste with the energy released being recovered presents the option of last resort*" (Food and Agriculture Organization, 2017).

7.5 Bio digestion in Denmark and Aalborg

Considering Anaerobic digestion as one of the best options for organic municipal waste recycling, it becomes relevant to briefly describe the situation in Denmark and Aalborg specifically. Biogas facilities were developed in Denmark since the 1970's due to the oil crisis. Since then, the biogas sector has been significantly developed; positioning the technology as a common practice in the country. According to Energinet, biogas production in 2009 was 4 PJ, and it was forecasted to increase to 19 PJ in 2020 (which would represent approximately 10% of all the natural gas consumption) (Energinet DK, 2009). In this context , due to Denmark's historic link to agriculture, development of biogasification technology led the country to be the fifth biogas producer (per capita) in Europe in 2009 (Andersen & Mortensen, 2014). In 2015, there were around 25 centralized biogas plants in Denmark (Lybæk & Kjær, 2015). Additionally, several small biogas plants are also used on a single farm scale. In this context, the main efforts for this waste treatment option has been towards manure input (due to the country's specific high potential). Nevertheless, as stated by Andersen & Mortensen (2014), "*there is also great potential for using food waste, source separated municipal solid waste or sewage in the production processes*".

The main use for biogas in the country has been in the production of heat and electricity through CHP plants (Energinet DK, 2009). Nevertheless, different uses are being considered, mainly due to the necessity of reducing greenhouse gas emissions, such as injecting biogas into the natural gas grid or using biogas for transportation (Paul-Collinet, 2012).

In the surroundings of Aalborg's city, there is a biogas plant and two water treatments plants. The biogas plant of NGF Nature Energy Vaarst (previously known as Vaarst-Fjellerad) is located at around 20 kilometers to the south. The plant uses manure and industrial waste as feedstock. In 2015, the plant produced, in average, 7,000 m3 of biogas per day. The gas was then injected to the natural gas grid (NGF Nature Energy, 2017). Closer to the city, two water treatment plants (Renseanlæg Vest and Renseanlæg Øst) clean the residual water coming from about 225,000 citizens and from hundreds of business (Aalborg Forsyning, 2017a). The residual sludge is used to produce biogas which is then used for producing energy for the plant's own needs and for sludge drying (Aalborg Forsyning, 2013).

7.6 Organic waste highlights in Denmark

In contrast to Aalborg's situation, the municipality of Vejle has been separating organic waste for 25 years. The waste comes from 54,000-55,000 houses approximately and it is collected by a company called Komtek Miljø. The waste is then used to produce biogas, biofuels and biofertilizer[4].

The company Komtek Miljø developed the "Ecogi" system which treats source separated food waste from households, industry and retail services (including waste with high levels of contamination)(Gemidan, 2016). This is relevant since the technology, which produces a pulp for intended use in anaerobic digestion, represent a possible treatment solution for the organic fraction coming from municipal waste.

Other relevant companies include Bigadan and Daka Refood. Bigadan focuses on the construction of big scale biogas plants (some of their projects include municipal solid waste treatment), while Daka Refood focuses on the collection and recycling of organic waste from restaurants, hotels, food industry, schools, etc. These two companies are not the only ones in Denmark. Nevertheless, the importance of mentioning them falls on showing that options are arising in the country. Thus, a transition in Aalborg, to less incineration and more recycling, is most probably only a matter of time.

[4] Vejle's municipality was contacted by phone to get the information.

8 Problem Definition

The whole problem is summarized: Organic waste in Aalborg is being incinerated when prevention, reuse and recycling represent a better option. Furthermore, as context, it is clear that the system is complex since different institutions might have different approaches to what should be done with the waste. This becomes relevant since solutions should incentivize a common objective that is supported by people and different stakeholders (which might be located on different levels within the three pillars of institutions). Nevertheless, the problem in Aalborg cannot be addressed with a single action or solution. Therefore, narrowing down the scope of research, mainly due to time and complexity, becomes a necessity. In these circumstances, we return to the question formulated in the problem definition: *How to address the organic waste challenge in Aalborg through innovative solutions?*

In order to narrow down the scope and to design specific solutions that target organic waste in Aalborg, a specific location was selected. This means that the present paper won't aim at changing the whole waste system, but will only aim at initiating a transition, through changes in a specific location, into a city with less incineration of organic waste. The location is defined by a new project that is under development called Cloud City. Cloud City is located in Aalborg's city center, and is integrated by a series of activities -within specific boundaries- that will generate municipal organic waste. Since the Cloud City project is currently under development, an area of opportunity is open to bring innovation. Therefore, it was decided to analyze the organic flows with the purpose of eliminating the waste output of the area.

Once the problem and the location were identified, the research statement and the research questions were established:

Closing loops in Cloud City: A zero-organic waste district in Aalborg.

a. What are the expected solid organic waste flows in Cloud City?
b. How to treat the organic waste output and what value can it bring?

9 Methodology

The present paper will develop a Case Study. How was it defined that this particular situation is a case study? A literature review allows to determine that there is no single definition for the term. Moreover, the multiplicity of definitions considers the case study as many things: approaches, methods, or research designs. Evidently this complicates de task of determining if the researcher is working on a case or not. Therefore, in a pragmatic approach, it was decided to identify common characteristics within multiple definitions that would describe what a Case Study is. Three characteristics were identified (Gerring, 2004)(Yin, 1994)(UNSW Sydney, 2013)(Abercrombie, Hill, & Turner, 1984): a) a real-life context, b) a defined unit of analysis (such as a person, place, thing), and c) an in-depth or detailed analysis.

As mentioned previously, the present work will focus on Cloud City. Provided that the project happens in a real-life context, that it has defined boundaries -and therefore can be considered a defined unit of analysis-, and that the research will include a detailed analysis, it was determined that the present paper is indeed a Case Study. In more detail, the present Case Study will take a problem-oriented approach -focusing on the "how to act"- rather than a cause/consequence analysis.

On a different matter, the use of case studies is still questioned by what Bent Flyvberg considers "conventional wisdom"(Flyvbjerg, 2006). Many critiques consider arguments related to: lack of validity or non-capacity for validation, not useful for generalizations, tendency to bias/ lack of reliability, and reduced importance of practical knowledge (epistemology). However, for this work, we conclude as Flyvberg concludes in his paper "Five Misunderstandings About Case-study Research": *"[…] the case study is a necessary and sufficient method for certain important research tasks in the social sciences, and it is a method that holds up well when compared to other methods in the gamut of social science research methodology*" (Flyvbjerg, 2006).

9.1 Case Study: Cloud City

Cloud City is a brownfield project currently under development -with expected first-dig mid 2017- in the western area of Aalborg's City center. The name is inspired by the central art piece, by Tomás Saraceno, that is going to be installed. In general terms, the Cloud City project will transform a non-working industrial area (previously a historical aquavit distillery that finished operations in 2014) into a multifunctional urban center.

The Cloud City project is expected to become an iconic center for art, innovation, smart solutions and sustainability, while preserving the historic industrial identity of the city. The project aims at creating a vibrant space that brings life to the city by attracting residents (through housing), as well as local and foreign visitors. Furthermore, development will be divided into two: preservation of old industrial buildings and construction of new infrastructure. The following image (Figure 13), taken from the "Spritfabrikken I Aalborg" report (2016) from Bjarke Ingels Group, shows how Cloud City may look in the future. It shows the expected preserved old industrial buildings (red bricks) along with the new constructions.

Figure 13 - Cloud City Project. Source: (Bjarke Ingels Group, 2016)

Cloud City is being developed by Martin Nielsen and by A. Engaard A/S. The project is expected to include functions such as: a theater, a food market, hotels, restaurants, a micro-destillery, art gallery, housing and a chocolate factory. Including everything, the total built area is approximately 75,000 m^2, and corresponds to a building percentage of 157% (Kommune, 2015). A report from Ramboll estimates, that in the first year, 1.6 million people will visit Cloud City (Ramboll, n.d.-a). Out of this number, it was estimated that 748,000 would correspond to “unique and paying visitors”, of which 10% would be foreign. By year five, it is estimated to have 1.9 million people, with 960,759 “unique and paying visitors” (Ramboll, n.d.-b).

By looking at the multiple activities within the area, it is possible to observe that many of them will be future sources of organic waste. This organic waste, which would fall on the classification of municipal waste, would mainly come from households, commercial/services, green areas/gardening and external sources (waste brought by visitors). In this context, the area could rely on the municipality for collecting the waste, or it could implement its own approach which may initiate a more radical change by breaking present trends in waste treatment.

9.2 Data Collection

In the present work, a combination of quantitative and qualitative methods is going to be used. The methods for data collection include literature review, interviews, surveys and mathematical calculations. Different methods and concepts will be used in order to answer the main research question and sub-questions. The following table (Table 6), will specify the concepts and methods for data collection used to answer the questions.

Table 6- Methods and Concepts

Sub-questions	Concepts	Data Collection
What are the expected solid organic waste flows in Cloud City?	Material Flow Analysis.	Data collected from literature review, surveys, interviews and mathematical calculations.
How to treat the organic waste output and what value can it bring?	Circular Economy, Value Creation	Data collected from literature review.

For the first sub-question, the concept of Material Flow Analysis will be used as a guide. According to the OECD (OECD, 2008), Material Flow Analysis is "*the study of physical flows of natural resources and materials into through and out of a given system*". The study is based on the principle of mass balance, and aids in analyzing the relationship between materials, human activities and the environment. The material flow analysis utilizes organized Material Flow Accounts in order to enable calculations. According to the OECD guide (OECD, 2008), material flow accounts are based on the following identity:

$$Natural\ resource\ extraction + imports = residual\ output + exports + net\ additions\ to\ man\ made\ stocks$$

In more detail, the OCED (OECD, 2008) identifies six different types of analysis depending on the completeness, scale and detail of the study. Following this classification, a study of Organic Waste in Cloud City would be done through a Materials System Analysis. Among other uses, this type of analysis focuses on specific raw materials or semi-finished goods that could raise concern regarding the sustainability of their use.

Generalizing, and in pertinent detail, the material flow accounts in Cloud City could be calculated as it follows:

$$Organic\ material\ grown\ inside\ Cloud\ City + Organic\ material\ bought\ from\ suppliers = Organic\ waste\ outputs + Sold\ organic\ material\ (consumption) + Organic\ material\ stock\ or\ accumulation$$

In order to calculate the flows, the first step is to identify the organic waste sources within Cloud City. Sources will be identified by analyzing data provided by the developers and maps of the site. Once the sources are identified, other data can be estimated. The research design for data gathering includes: a) personal contact with relevant services in Aalborg (such as chocolate factory, hotels and restaurants), and b) contact through phone and email to services not found in Aalborg but which are present in other parts of Denmark (such as food courts). Brief semi structured interviews will be used in local services, while surveys would be done for long distance communication. It is intended to obtain information in the most "local context" with the purpose of providing validity to the calculations. Literature review will be used to obtain the missing data.

Once the estimations the flows are calculated, a proposal will be developed on how to treat the waste. This proposal is going to be described in the discussion section of the present paper and will answer the second sub-question. The proposal is going to be developed based on the concept of circular economy and value creation (see analytical framework section in page 31) and will promote an ecological transition in synergy with the local institutions. Finally, the potential value will be identified in terms of the three bottom line aspects: social, environmental and economic.

9.3 Justification

As mentioned before, Denmark is the country generating the most municipal waste per capita in the EU, and it is the second country incinerating the most municipal waste. Moreover, in the city of Aalborg, household organic waste is collected within the refuse fraction and is incinerated entirely. This dependency in incineration is confronted by EU policy, Danish strategies and by Aalborg's sustainability scope.

Furthermore, a project this size (1), with these specific activities (2), in this specific location (3), creates an opportunity for innovative design that focuses on closing loops in the organic waste stream. (1) The size opens the possibility to analyze organic waste flows in detail. Moreover, the small scale would support a possible implementation of the project since it would probably represent a smaller expected economic input. At the same time, an opportunity is created for establishing a pilot project or a Living Lab. (2) The specific activities -such as restaurants, food market and roof garden- represent processes that will generate a considerable amount of municipal organic waste in the area. (3) Furthermore, being inside a city also provides a good opportunity for research. As stated by the Ellen MacArthur Foundation, in the Urban Biocycles report, "*Cities present a major opportunity to implement circular principles in the biocycle economy due to their characteristics, which include large scale supply, high proximity between stakeholders, and a tech-savvy workforce*"(Ellen MacArthur Foundation, 2017). Additionally, the fact that the project is still in development allows for innovations to be planned and established without the need for many modifications.

Finally, studying organic waste in Cloud City not only would establish the basis for local solutions (which stakeholders in the project are already considering implementing), but could also open the opportunity to initiate a transition towards a city with less incineration. This could be expected since results might: a) prove that there are other ways to treat organic waste other than incineration, b) show that solutions may bring benefits that are in accordance with economic, social and environmental aspects, c) support the legitimization of institutions that support a transition towards more recycling, d) initiate the questioning of present assumptions regarding incineration, and e) promote further research targeting environmental solutions that address the present synergies within the waste-energy sectors (Ex. if there is less incineration, how is heating going to be supplied in an environmental way?).

10 Results

10.1 Organic Waste sources in Cloud City

To perform the flow analysis of organic waste in Cloud City, the first step was to identify the "processes" that could generate organic waste. To identify such processes, a specific procedure was carried out. First, a map of Cloud City was analyzed and buildings were identified. Then, each building was categorized in "Primary", "Secondary" or "housing". The classification was done based on the specific developers of each area and on the expected waste output. The buildings categorized as Primary and Secondary are being developed by Martin Nielsen. Primary refers to the buildings with the most expected waste output, while the secondary buildings are expected to have a small output. "Housing" is being developed by A. Engaard. All buildings in this category are houses, except for grocery store, and therefore it was decided to label them in a different category. The considered buildings were then analyzed further to identify the specific activities that are planned inside. Finally, the activities were analyzed to define the processes that could generate organic waste. The following figure (Figure 14) synthesizes the procedure in which the processes were identified:

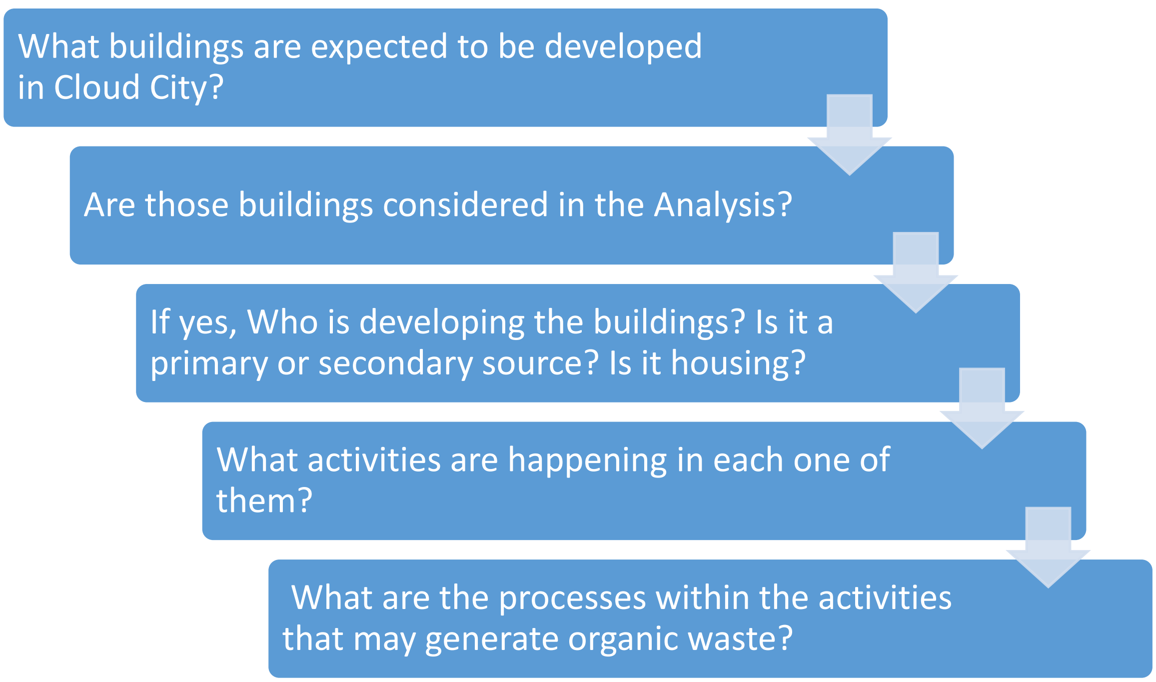

Figure 14- Classification process for identifying Activities and Processes

The following image (Figure 15)(based on the Spritfabrikken I Aalborg strategy report pg. 14) (Bjarke Ingels Group, 2016) shows the expected plans for Cloud City, and highlights the considered buildings of the project.

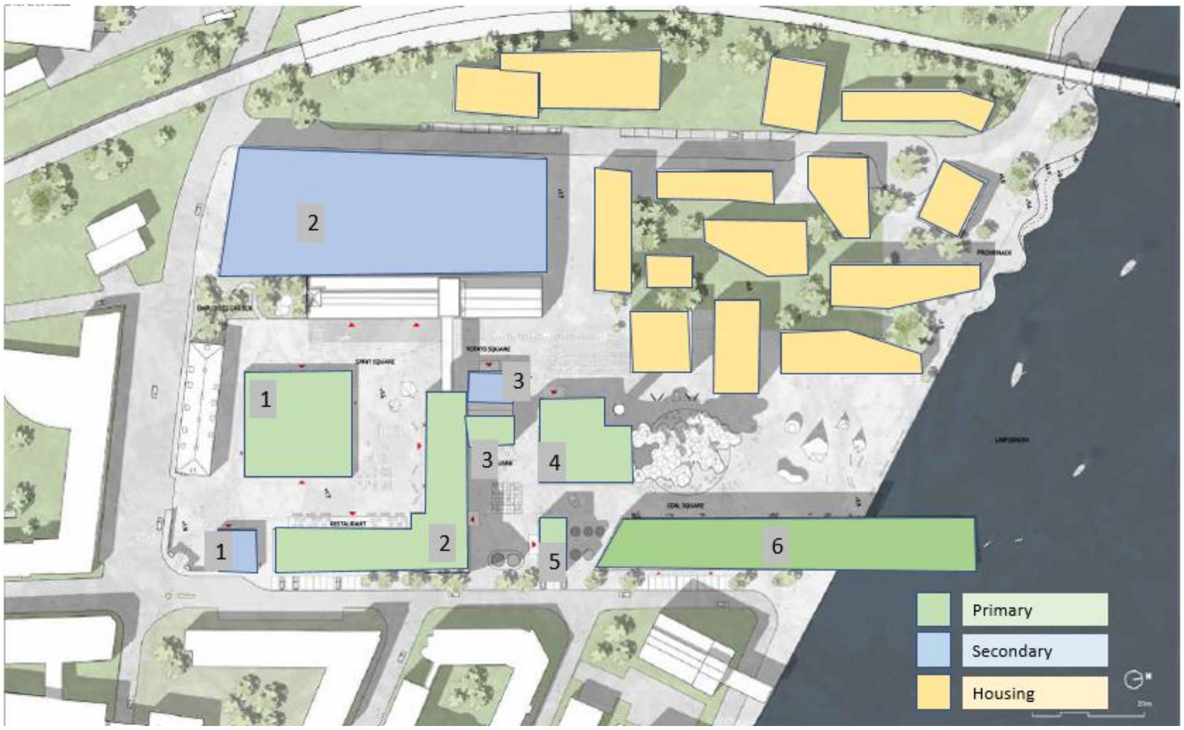

Figure 15- Cloud City considered areas

The following table (Table 7) specifies which buildings are considered.

Table 7- Considered buildings

Elements	Buildings
Primary	1) Market Hall (Torvehallen)
	2) Hotel
	3) Chocolate factory
	4) Art Hall + Coffee shop
	5) Micro-destillery
	6) Harbour Gate (Havneporten)
Secondary	1) Shop
	2) Theater
	3) Boutique Shop
Housing	1) Housing 2) Grocery Store

In more detail, each building is composed of at least one activity; and each activity of at least one process. The following table (Table 8) shows the primary buildings "processes" that were considered in the calculations. Most data was gathered from the "Spritfabrikken I Aalborg" strategy report from Bjarke Ingles Group (Bjarke Ingels Group, 2016) and by information provided by Martin Nielsen, developer of the Cloud City Project.

Table 8- Processes in Primary Buildings

Building	Activities	Processes
Market Hall	Restaurants	Kitchen, Clients (food disposal)
Hotel[5]	Hotel	Food consumption in Rooms
	Restaurants	Kitchen, Leftovers
	Apartments	Regular food consumption
Chocolate Factory	Chocolate factory	Chocolate production
Art Hall + Coffee	Cafeteria	Kitchen
Micro Destillery	Destillery	Alcohol production
Harbour Gate	Apartments	Regular food consumption
	Restaurants	Kitchen, leftovers
	Roof Garden	Garden Maintenance, garden output

Secondary elements are considered to have very small organic waste outputs. In this context, secondary elements are not going to be taken into account as organic waste sources.

The following table (Table 9) provides more details about the specific characteristics in the housing buildings:

Table 9- Processes in the Housing Elements

Buildings	Activities	Processes
Housing	Apartments	Regular food consumption
Grocery Store	Retail store	Non-sold organic material

10.2 Solid Organic Waste Outputs in Cloud City

Once the organic waste sources were identified, the next step was to estimate the waste flows in the system. Initially, it was expected to use the concept of Material Flow Analysis to describe the organic waste "digestion" in Cloud City. However, due to time constrains and the specific needs of the present work, it was decided to focus on the Organic Material Outputs only (and not consider inputs or stock). Therefore, the study didn't carry out a Material Flow Analysis, but considered only material outputs of each process within Cloud City. The decision was made since it was considered that having the output information would be enough to design a solution for organic waste recycling. In this case, having the output calculation would allow to calculate the potential energy production.

Gathering data from local sources, as expected from the research design (see Data collection section on page 39), was the main challenge. Contact in person was stablished with local hotels and chocolate shops. Contact by phone and email was stablished with a chocolate factory, hotels, a

[5] A fitness/ well-being center not included since the organic waste flows are expected to be negligible.

recycling company and food courts/food markets. No data was gathered from any of this sources since: a) they didn't have the information or b) No answer was given after several contact attempts. Therefore, the output calculation is completely based on literature review assumptions (see Annex in page 63 for full list of assumed values) and assuming the project has been running for 5 years. The expected waste outputs for the different processes are summarized in the following table (Table 10):

Table 10 - Expected Organic Waste Outputs in Cloud City

Building	Detail	Size	Organic waste output (kg/month)
Market Hall	Food Market Booths	5 booths – 33.6 m^2 2 booths – 16.8 m^2	2191.52
Hotel	Rooms	-	No Data*
	Restaurant 1	200 seats	554.76
	Restaurant 2	150 seats	416.07
	Restaurant 3	140 seats	388.33
	Restaurant 4	140 seats	388.33
	Restaurant 5 / skybar	200 seats	554.76
	Apartments	6 apartments	21.6
Chocolate Factory	Production	330 m^2	5.22
Art hall / Coffee	Coffee Shop	-	9.16
Micro Destillery	Production	880 m^2	1,071.61
Harbour Gate	Apartments	13 apartments: 65-100 m^2	205.4
		19 apartments: 101-150 m^2	431.68
		1 apartment: 350 m^2	23.2
	Restaurant 1	150 seats	416.07
	Restaurant 2	75 seats	208.0375
	Terraces	-	No Data*
Green areas	-	-	Not included**
Bins	Bins within Cloud City	-	No Data*
Housing	Youth housing	120 apartments: 50 m^2	883.2
	Small Families	120 apartments: 65 m^2	1,516.8
	Family	100 apartments: 85 m^2	1,704
	Big Family	175 apartments: 100-150 m^2	3,248
Grocery Store	-	1,200 m^2	2,458.35
Total			16, 696.15
		(Tons/month)	16.7

* No data was not found in literature review or other sources. Moreover, it was considered to be negligible and therefore was not accounted for.
**Green areas waste is not considered in the calculation since this waste can be collected by the municipality and taken into compost. This is the normal procedure for garden waste in the municipal fraction in Aalborg.

The estimated total output of organic waste, in year 5, in Cloud City is: 16.7 tons per month. However, this number might change if we consider present, and future, strategies that target organic waste prevention. For example, considering the United Nations Sustainability Goals, there is an adopted target to reduce the per capita food waste, in retail and consumer level, by 50% by 2030 (European Commission, 2017). In this matter, European countries are committed in fulfilling this target. As a second example, Denmark, in an exemplary change within the European countries, has cut down food waste in 25% in the period between 2011-2016 (Senet, 2016). If we consider both facts, and assume a target of 50% food waste reduction starting on 2011, it could be assumed that the country would need to reduce an extra 25% of food waste by 2030.

According to the Cloud City's project developers, the area is going to be managed in a sustainable and responsible way. Assuming prevention strategies are going to be implemented, and considering the targets for 2030, it was decided to stablish a 25% reduction in the calculated organic waste output number for restaurants, apartments and the food market. Therefore, the total organic waste output in Cloud City would be 12.8 tons per month, or 153.6 tons per year.

11 Discussion

The calculated amounts of generated organic waste in Cloud City are approximations. This is expected since the information, regarding the place and its planned developments, was limited. Moreover, the information which was expected to be gathered in a local environment was not provided by the stakeholders. Therefore, as a last resource, the data was calculated assuming a variety of numerical assumptions based on literature review. Most of the information was gathered from Danish sources, however, there are some sources based in other geographical contexts. In this case, the accuracy, and therefore the validity, of the numbers becomes questionable. Nevertheless, the importance of having such assumptions resides in the possibility of estimating potential treatment options and their possible impact. Even more, this could serve as a starting point for planning waste management details -such as waste collection-, or for estimating the impact of developing such a project in Aalborg.

To specify a way to treat the organic waste in Cloud City, it was decided to follow the concepts of Circular Economy and Value creation (cascading of the organic resource). In this context, and as mentioned previously in the analytical framework, two methods arise: anaerobic digestion and aerobic composting. Since both methods have benefits, and both contribute to organic material recycling, selecting one method or the other becomes a matter of choice (considering Cloud City is not developed yet, and that the specific in-situ characteristics are unknown). Additionally, there is no information that: a) would suggest a preference for certain economic characteristics, or b) would suggest regulation limitations. Thus, to determine the best method for Cloud City, it was decided to consider the literature review information. Following the recommendations of the Food and Agriculture Organization, the LCA analysis of organic waste treatment methods (See Anaerobic Digestion and Composting section in page 34), and Denmark's overall experience with biogas, it was decided to choose a process of Anaerobic Digestion. Furthermore, considering the close link between waste and energy sectors in Aalborg, the positive energy output of Anaerobic Digestion becomes an attractive asset.

Assuming an Anaerobic Digestion process, the produced biogas (or biomethane after being upgraded) can be used in diverse ways. The main identified uses are: a) heating (Ex. direct combustion), b) heating and electricity through CHP plants, c) injection to the natural gas grid, or d) as fuel for vehicle transportation. According to Dorte Ladefoged (Ladefoged, 2017), Aalborg's municipality would not consider biogas for heating since, in energy terms, incineration is a better method. Furthermore, two uses were highlighted in the interview: biogas injection to the grid and the use of biogas for transportation (both methods can share synergies).

In technological terms, both methods require to upgrade, or clean, biogas with the intention to convert it into biomethane (remove components such as hydrogen sulfide, water, carbon dioxide and trace organics (Wilkie, 2017)). Not only is this process becoming common, but it has attracted attention from many countries. In this matter, in 2013, there were 282 biomethane plants in Europe (European Biofuels Technology Platform, 2017). The attention is also showed by the creation of projects like Biogas 2020. This project, which includes Norway, Sweden and Denmark, is focused in the development of knowledge in terms of production, biogas upgrade and injection to the grid, Eolic energy storage through gas, biogas for transportation and a general commercial development.

During the last years, the use of biogas for transportation has acquired central role and therefore relevance. The use of biogas in the transport sector is linked indirectly to the EU Energy Strategy - which has the target of reducing green-house gas emissions (in reference to 1990) by 80-95% by 2050-, and directly to the target, established by the Renewable Energy Directive (2009/28/EC), of ensuring that at least 10% of transport fuels come from renewable sources (European Parliament, 2009). Many projects are already being developed in Europe. For example, BIOMASTER, BioGas Max, Urban Biogas and FaBbiogas among others (European Biofuels Technology Platform, 2017). It should be mentioned that Urban Biogas is a project working specifically with municipal solid waste, while FaBbiogas works with food and beverages. Within Europe, Sweden should be highlighted since the country is "*a green pioneer today in biogas and CNG [compressed Natural Gas], for both light and heavy transport*" (European Biogas Association, 2017). According to the European Biogas Association, Sweden is the country using the most biogas for transportation purposes in the world. Within the country, more than half of the gas powered vehicles are fueled with biogas (the rest being fueled with natural gas) (European Biogas Association, 2017). The Swedish case sets an example that shows that the technology is ready to be developed.

In the case of Denmark, the use of gas for transportation is relatively recent. According to Energinet, (Energinet, 2014), the first gas filling station was established in 2011 in the city of Odense. By 2014, the number of filling station increased to seven. This growth shows that the gas-fueled fleet is growing in the country. However, the specific interest of biogas being used for transportation seems to be relatively recent. Present strategies aim to include and distribute biogas through the national natural gas grid (Energinet, 2014). Moreover, according to Nøgaard and Tybirk (Nørgaard & Tybirk, 2014) biogas production, compared to 2014, is expected to double before 2020. The authors also estimate that in the future years, around 75% of the produced biogas will be upgraded for injection in the gas grid or for use in transportation. Currently, the inclusion of biogas is happening through Bio-natural gas certificates (which would guarantee that natural gas is being replaced by biogas)(Nørgaard & Tybirk, 2014). Considering this context, the implementation of biogas for transport becomes a solution that can be expected to happen in the incoming years.

Considering the novelty and relevance of biogas in transportation in Denmark, it was considered that an exploratory project in this area could be of benefit to the city of Aalborg.

11.1 Proposed organic waste recycling system for Cloud City

11.1.1 Overview

It is proposed to carry out a pilot project that uses the organic waste from Cloud City to produce biogas for transportation. Ideally, the vehicles using the produced biogas would be the fleet that collects the treated waste; therefore, creating a circular concept in a local environment. The project would not only have the purpose of making Cloud City a zero-organic waste district, but also of promoting development -through knowledge generation- in the area of biogas and transport. Moreover, it can be one of the innovation structures that can contribute to Aalborg's ecological transition, while creating a potential common objective among competing institutions (such as treating waste while generating energy and creating jobs).

In general terms, the project would require infrastructure for: collecting and transporting waste, waste pre-treatment, processing the waste into biogas, upgrading the gas into biomethane, filling station for the transport vehicle fleet, gas-fueled vehicles, storage, and transport for delivery of sludge to agricultural areas.

The idea of the project is based on the following considerations: a) European targets regarding waste, b) Danish targets regarding waste, c) the concepts of circular economy and Value creation for organic materials, d) the vision of the Danish government regarding biogas and its uses, e) the potential synergy between different institutions (the waste and energy sector- less waste for incineration, but increased energy sources in transport), f) the present interest in the political sphere regarding waste (Ladefoged, 2017), and g) the need to recycle organic resources to return nutrients to farmlands and to avoid possible greenhouse gas emissions.

11.1.2 Biogas output

Considering a potential project that would allow Cloud City to be a zero-organic waste district, the first step would be to estimate the amount of biogas that could be produced. As mentioned in section 7.4.1, the biogas output from a process of Anaerobic Digestion depends on many factors. Since the present work is not focused on the technological or chemical aspects of producing biogas, it was decided to make estimations (with literature review assumptions) of the potential biogas output. To make the estimations, it was decided to use a biogas calculator available in the FaBbiogas project webpage which allows to calculate average biogas yields (FABbiogas, 2017). To use the calculator, some values needed to be assumed regarding organic waste characteristics (Sustainable energy Authority of Ireland, 2017)(Sundberg et al., 2011): waste composed mainly by food, 20-30% of dry matter, 85% organic in dry solids and input temperature 0-15 °C. The following table (Table 11) shows the calculated estimations for biogas and biomethane production. The waste stream mass was calculated with the output waste of 12.8 tons per month.

Table 11- Biogas and Biomethane expected outputs for Cloud City waste

Type of substrate	Substrate	Waste stream mass (tons/year)	Dry matter content (%)	Temperature (°C)	Biogas Volume (Nm^3 biogas/ day)	Biomethane Volume (Nm^3 CH_4 / day)
Food Waste	Leftover, low fat, wet	153.6	20	0	46	28
Food Waste	Leftover, Rich fat	153.6	20	0	55	34
Food Waste	Leftover, low fat, wet	153.6	30	0	69	41
Food Waste	Leftover, Rich fat	153.6	30	0	82	51
Food Waste	Leftover, low fat, wet	153.6	20	15	46	28
Food Waste	Leftover, Rich fat	153.6	20	15	55	34

Food Waste	Leftover, low fat, wet	153.6	30	15	69	41
Food Waste	Leftover, Rich fat	153.6	30	15	82	51

The multiple calculations were done in order to consider different substrates (low fat – high fat), a different dry matter content (20-30%) and different temperatures due to seasonal changes (0-15°C). It is possible to observe that the waste temperature changes did not influence the biogas outputs. Furthermore, the highest biogas output is generated through the combination of a high dry matter content along with the substrate "leftover, rich fat". Therefore, the biomethane output can be estimated between 28-51 Nm^3 CH_4 / day depending on the input characteristics.

The capacity of the proposed pilot plant is considerably smaller than those from the centralized plants in Denmark. In this matter, the pilot plant would be closer, in capacity terms, to a farm scale biogas plant.

11.1.3 Location

The intention of the project is to create a solution in a local context (addressing local problems through local solutions). The purpose behind this rationale is to create knowledge for the city, but also to reduce the complexity -and environmental impacts- of the systems by avoiding longs distances between the project's processes. In this context, the initial ideas for location included: inside Cloud City, in the close surroundings to Cloud City (500m), Egholm (Island located at ~4km from Cloud City), next to the west wastewater treatment plant (Renseanlæg Vest), or next to Reno Nord's incineration plant.

To narrow down the options, two challenges were considered (Ladefoged, 2017)(Nørgaard & Tybirk, 2014): a) increased traffic due to substrate transport, and b) potential odor source when handling the organic material. Taking into account both challenges, the idea of locating the biogas plant within the boundaries of Cloud City, or its close surroundings, was discarded. Mainly because odor problems are most likely to be a challenge considering the amount of housing close by. On the other hand, although the island of Egholm could represent a good option for "receiving" the digestate (since the main activity there is farming), waste transportation could create undesired and unpractical traffic in the area. This would be caused by the fact that the only available transport option from main land, to the island, is by Ferry. Lastly, a future expansion of the project, which would be translated into more waste being treated, would aggravate the traffic situation.

The location at the incineration plant and at the waste water treatment plant seem to be feasible considering the previously mentioned challenges. Nevertheless, other parameters were thought out for determining the location. Since the wastewater treatment plant already produces biogas, it is believed that possible synergies -in terms of knowhow and infrastructure- could happen by locating the pilot project there. Moreover, a future expansion of the project could involve a shared facility treatment of water and municipal waste, or a mixed use for the biogas produced from both processes. Therefore, it was decided that a location, next to the wastewater treatment plant, would represent the best option. In this case, Egholm could still be the recipient of the digestate since the traffic problem could be reduced by only delivering the necessary amount of fertilizer (and not having the need to transport the whole capacity of waste in and out of the island). Furthermore, due to the treatment plant being next to the fjord, right in front of the island, there would be the chance to connect both places through a pipeline for a shorter transportation of digestate. The following image (Figure 16) shows Egholm, Cloud City and the Pilot project location:

Figure 16- Egholm, Cloud City and the Pilot Plant

11.1.4 Created Value

The proposed project generates value to the organic waste when compared to landfilling. This means that what is considered as waste becomes a resource; mainly to produce biogas and fertilizer. However, other benefits can be observed when implementing a pilot biogas plant for transportation. Those benefits, for this paper, represent the real "value" of the project. Value is going to be discussed in terms of the three bottom line parameters: environment, society and economic. The following table (Table 12) shows the identified value for the pilot project (Nørgaard & Tybirk, 2014)(Bungaard, Kofoed-Wiuff, Herrmann, & Karlsson, 2014)(Energigas Sverige, 2011)(Paul-Collinet, 2012). It should be mentioned that some of the discussed points may share benefits into more than one category.

Table 12- Project's Value in terms of the triple bottom line

Environmental	Social	Economic
Knowledge creation: towards a less dependent city on fossil fuels in the transport sector		

<table>
<tr><td>Opportunity to bring back nutrients to farmland through the digestate (reducing land degradation).</td><td colspan="2">Job Creation: construction and operation of the plant, collection of waste, distribution of the digestate. If the technology develops, a spreading of biogas use could aid in thriving rural areas.</td></tr>
<tr><td colspan="3">Knowledge creation: development of technologies that can use, clean (upgrade) and exploit biogas. For example: this can promote solutions for challenges such as handling of manure (given Denmark's high livestock production).</td></tr>
<tr><td>May reduce greenhouse gas emissions in the transport sector (depending on the nature of the substituted fuel).</td><td>Educational tool: giving knowledge to Aalborg's citizens</td><td>Positive image creation for Cloud City: the zero-organic waste district</td></tr>
<tr><td colspan="2">May promote the ecological transition of the city in terms of waste (as an innovation structure that changes current treatment trends). The project could work as a link between different institutions; unifying efforts to common goals.</td><td>Possible business model if the right conditions are given.</td></tr>
</table>

The potential benefits of a project like this could be attractive for many stakeholders. However, there are many factors that need to be considered to define the actual feasibility of the project. These factors are going to be discussed in the next section.

11.1.5 Considerations

The present proposal is completely developed in a conceptual level. Considering the established time for developing the present project, it was not possible to investigate other aspects that would influence the proposal's real feasibility. Among the many aspects to consider, it is thought that the following could be relevant: regulation, technological, economics and social. The main challenges are identified in **black lettes**.

In terms of regulation, the following points can be considered:

- Is it possible to locate the pilot plant next to the waste water treatment plant? Are there any land use requirements? What other permits are needed?
- **What are the current taxes or subsidies towards biogas plants treating municipal waste? Are there any incentives towards biogas upgrading?** (consider that in 2013, the incentives for biogas plants expired in Denmark (Nørgaard & Tybirk, 2014). Is this still the case nowadays?). Moreover, consider the example of Sweden where the development of biomethane in transport has been greatly influenced by domestic policy instruments (Larsson, Grönkvist, & Alvfors, 2016). This includes investment support and tax exemptions.
- What is the regulation for digestate disposal and how to comply with it? Is it needed to wait for political agreements regarding digestate quality? Can this digestate be delivered in the island of Egholm?
- What is the regulation for biogas and biomethane quality and how to comply with it?

In terms of the technological aspects, the following points can be considered:

- **How is the biogas going to be upgraded?** (pressure swing adsorption, water scrubbing, chemical scrubbing and membranes (Petersson & Wellinger, 2009)). Is this process feasible considering the low biogas output?
- Considering the low biogas output, is it possible to fuel a gas-powered vehicle? If so how much?
- Is biomethane going to be compressed? Is it possible to consider liquified biogas?
- What is going to be the plant's capacity? Is it possible to consider a future expansion to treat additional waste?
- Are there any synergies between the pilot plant and the waste water plant?
- How much time is required to implement the project?
- Can the system, in that location, be connected to the natural gas grid in Aalborg?
- What are the safety measures that need to be considered?

In terms of economics, the following points can be considered:

- **How much would the project cost? Is it economically feasible to invest on a plant of that capacity? Would the infrastructure too expensive?** Consider that, according to Cooker, small scale projects (under 1 million standard cubic feet – which is approximately 28,316 cubic meters-) can be impacted by unfavorable costs due to economies of scale (including higher capital and development costs) (Cooker, 2016).
- Are biogas production plants having unconventional costs?
- Who are going to be the involved investors? How to convince investors to put resources on a pilot project?
- Considering a pilot project would not have the objective of being profitable, could the project be self-sufficient?
- Considering an expansion (more waste treated) could happen, is there an interesting business model?

In terms of society, the following points can be considered:

- Would the project be accepted by the local society? What is the citizens opinion about biogas for transportation?
- How to include society in the decision making? Can a bottom-up approach be promoted through the project?
- How to develop the pilot plant as an educational tool?
- How many jobs can be generated?
- Other than government and investors, what other stakeholders need to be considered? Would there be conflict among different institutions?

The previous points show some of the identified considerations needed to determine potential feasibility. Among the considerations, the main identified challenges (highlighted in black) are related to the small feedstock treated and biogas output. This characteristic could represent relevant challenges in terms of regulation, economics and technology. If such challenges remain unsolvable, two solutions are suggested: a) If biomethane can be produced, but not for the specific use in transportation, then it would be relevant to inject the methane output to the national gas grid, or b) If the biogas upgrading is not possible, then consider delivering the biogas to the waste water treatment plant (for internal use).

It should be noted that many other aspects would need to be considered as well. Ideally, these considerations can be used as a base, or inspiration, for further research on the topic.

12 Conclusion

Denmark, a high-income country within the European Union, is strongly dependent on incineration as a way to treat municipal waste. Incineration provides energy; an additional feature when compared with landfilling. However, following the European and Danish regulation (based on the waste hierarchy), other treatment options -which include prevention, reuse and recycling- become more desirable. Following the concept of Circular Economy, recycling methods provide the best solutions available for organic waste treatment. Currently, in the city of Aalborg, Denmark, the organic fraction of municipal waste is being incinerated. A change in this trend is, in appearance, happening already. However, the overall transition seems to be slow. One way for this transition to move forward, is by innovation that breaks the past trends and opens the opportunity for new local solutions.

The analysis of the Cloud City case is an effort to generate knowledge that could serve as a basis, or at least inspiration, for a potential solution. In this case, the proposed treatment method involves development in the topic of biogas, or biomethane, for transportation. Nowadays, this topic is of high relevance in Denmark. Not only because it complies with environmental targets, but also because it provides a better solution than the current methods. Moreover, it constitutes an approach that is in harmony with the concept of circular economy. Hence, it is to no surprise that the Danish government is already planning the implementation of such technology; making its development a matter of time. Therefore, a pilot project in this area would serve as a minor catalyst in the expected transition.

Still, the suggested solution is proposed in a conceptual level only. And under this circumstance, many factors could prove the project to be unpractical or even impossible. Among the factors, several challenges regarding economy and technology need to be further analyzed. Nevertheless, it is believed that the impact of the project is not only in its practicality. The proposed solution, initially, had the intention of creating a zero-organic waste district. However, it is thought that knowledge creation goes beyond. Such knowledge is expected to set a new path of better waste treatment in Aalborg. And in this new path, which its development seems to be just a matter of time, a set of benefits become inherent. Compliance with regulation is also achieved. But more essentially, knowledge development in this area becomes an effort towards urban resilience, urban independence and an environmentally friendly society. In other words, it becomes a step towards the goal of sustainability.

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14 Annex

Building	Details	Number	Size	Assumptions	Organic output (kg/month)
Market Hall	Big market booths.	5	33.6 m^2	Data based on Roskilde Festival and the expected visits in Cloud City[6]	2191.52
	Small market booths.	2	16.8 m^2		
Hotel	Number of rooms, types of rooms (size)	-	-	-	No Data*
	Restaurant 1	1	200 seats	748 kg/year/kitchen employee (Petersen, Kaysen, & Priess, 2014) 17.8 full time employees/ 100 seats (National Restaurant Association & Deloitte, 2010) 25% of employees working in the kitchen (Petersen et al., 2014)	554.76
	Restaurant 2	1	150 seats	748 kg/year/kitchen employee 17.8 full time employees/ 100 seats 25% of employees working in the kitchen	416.075
	Restaurant 3	1	140 seats	748 kg/year/ kitchen employee 17.8 full time employees/ 100 seats	388.33

[6] No data was found regarding organic waste in food markets. Therefore, it was decided to use data from the Roskilde Festival due to potential similarities in the type of prepared food and the logistics. Considered data: 33 tons of surplus food, 130,000 people, 1 week time period, and 960,759 visits per day to Cloud City's in year 5 (Ramboll, n.d.-b)(Roskilde Festival, 2015). Furthermore, it was assumed that 76.5% of "Unique paying" visitors are going to the market hall (based on the calculations done for year 1) (Ramboll, n.d.-a)

				25% of employees working in the kitchen	
	Restaurant 4	1	140 seats	748 kg/year/employee 17.8 full time employees/ 100 seats 25% of employees working in the kitchen	388.33
	Restaurant 5/skybar	1	200 seats	748 kg/year/employee 17.8 full time employees/ 100 seats 25% of employees working in the kitchen	554.76
	Apartments	6	-	3,6 kg/household/week. Danish average (Petersen et al., 2012)	21.6
Chocolate Factory	Production unit	1	330 m^2	0.2 kg of chocolate waste for every 100 kg in a batch process (Mohos, n.d.). [7]	5.22
Art Hall / Coffee	Coffee shop	1	-	55 kg/year/employee (Petersen et al., 2014) 2 Employees	9.16

[7] The information regarding organic waste output from chocolate production processes was not found in literature review. Moreover, there was limited information regarding the size and the specific processes happening in the chocolate factory in Cloud City (the only available data was the surface area). Thus, it was decided to assume that the total organic waste is equivalent to the accepted losses in an average chocolate batch production (0.2 kg for every 100 kg of produced chocolate). It is assumed that the factory receives the cacao butter and mass already processed (skipping procedures such as roasting, grinding and pressing). Furthermore, the assumption is based on: 7.39 kg/year of chocolate consumed per capita in Denmark (The World Cocoa Foundation, 2011), 960,000 paying and unique visitors in Cloud City in year 5 (Ramboll, n.d.-b), and a 5.4% of visitors going to the chocolate factory (which was calculated with the estimations for the first year through a linear extrapolation) (Ramboll, n.d.-a). This number should be taken with caution due to the multiple variables and assumptions. Additionally, it should be kept in mind that the number could change considerably depending on the processes which are considered within the chocolate production process. In the end, it was decided to include the factory's waste in the results since the number represents a very small percentage of the total waste (only 5 kilograms of waste per month).

Micro Destillery	Production Unit	1	880 m^2	38,3 kg/ 150 L 50,000 L / year (on the 5th year) 27,8 kg herb waste / year for every 150 L (Sanchez Levoso, Adhikari, Lameiras Barrera, & Koehler, 2016)	1,071.61
Harbour Gate	Small family apartments	13	65-100 m^2	1,58 kg/person/week (Petersen et al., 2012) 2.5 people	205.4
	Big family apartments	19	101-150 m^2	1,42 kg/person/week (Petersen et al., 2012) 4 people	431.68
	Big apartment	1	350 m^2	1,16 kg/person/week (Petersen et al., 2012) 5 people	23.2
	Restaurant 1	1	150 seats	748 kg/year/employee 17.8 full time employees/ 100 seats 25% of employees working in the kitchen	416.075
	Restaurant 2	1	75 seats	748 kg/year/employee 17.8 full time employees/ 100 seats 25% of employees working in the kitchen	208.03
	Common terrace	1	-	-	No Data*
	Private terrace	3			
Green Areas	Gardens	-	-	-	Not included**
Outside	Outside bins	-	-	-	No Data*

Housing	Youth Housing	120	50 m^2	1,84 kg/person/week. (Petersen et al., 2012) 1 person	883.2
	Small Families	120	65 m^2	1,58 kg/person/week. (Petersen et al., 2012) 2 people	1,516.8
	Family	100	85 m^2	1,42 kg/person/week. (Petersen et al., 2012) 3 people	1,704
	Big Family	175	100-150 m^2	1,16 kg/person/week. (Petersen et al., 2012) 4 people	3,248
Grocery Store		1	1,200 m^2	295 kg/1 mill DKKturnover (Ettrup & Planmiljø, 2002) 141.7 billion DKK retail turnover in Denmark (Statista, 2015b) The Grocery Store considered as a Supermarket due to its size + 367 Supermarkets in Denmark (1000-2500 m^2) (Statista, 2015a) Supermarkets with 25.9 % of total turnover in Denmark (Statista, 2015c)	2,458.35
Total					16,696.15

* No data was not found in literature review or other sources. Moreover, it was considered to be negligible and therefore was not accounted for.

**Green areas waste is not considered in the calculation since this waste can be collected by the municipality and taken into compost. This is the normal procedure for garden waste in the municipal fraction in Aalborg.