A Study on the Revitalization of Urban Water Reuse through MFA (Material Flow Analysis)

By

KIM, Tae Guen

CAPSTONE PROJECT

Submitted to

KDI School of Public Policy and Management

In Partial Fulfillment of the Requirements

For the Degree of

MASTER OF PUBLIC MANAGEMENT

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Committee in charge:

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Executive summary

Various urban problems are occurring due to urban development caused by rapid urbanization. To solve these urban problems, Europe recently attempted to analyze urban problems through MFA (material flow analysis) from the perspective of urban metaphysical view of cities as living organisms.

In this study, the MFA analysis on the material circulation (water focus) of the city resulted in the conclusion that the re-use of rainwater should be increased by comparing the apartment complexes in the east side of Stadionbuurt in the Netherlands and Songsan Green City in korea. However, to increase the utilization rate of rainwater, institutional and non-institutional support will be needed, such as in the Netherlands.

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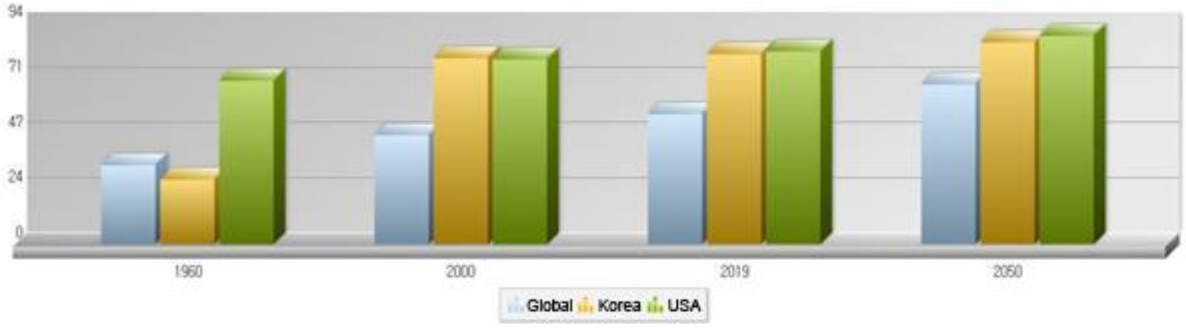
1. Introduction

Urbanization refers to a concept that refers to the concentration of population from rural to urban areas and the resulting regional and social changes. Urbanization is a term that refers to the percentage of the population living in a city of the entire population of the country. The global urbanization rate has risen sharply from 33.8 percent in 1960 to 55.7 percent as of 2019, while Korea's urbanization rate has grown faster than the global average from 27.7 percent in the 1960s to 81.7 percent as of 2019. (KOIS, 2019) In a country with rapid economic development, the rate of urbanization is growing faster to gain more jobs and educational opportunities.

Rapid economic development and urbanization can have many side effects, including environmental problems such as waste disposal and water pollution, as well as social problems such as resource conflicts and inflation. (Park, 2010)

Figure 1. Urbanization Rates (National Statistical Office, 2019)



Various stories are being made around the world to address the damage caused by rapid urbanization. In particular, the United Nations has formally adopted international guidelines. At the 2016 UN Habitat III World Congress, the New Urban Agenda presents universal goals, such as sustainable development of densely populated cities without harming the environment or the redevelopment of temporary dwellings in cities accompanied by residents' participation. "Urbanization is proceeding at an unprecedented speed and scale, and 3.7 billion people are now living in cities," says Juan Clos, secretary general of the UN Habitat III World Congress. "It's expected to grow to 7 billion in the next 2050." Also, the growing population will cause problems with services such as energy, food and water resources, and to solve these problems, cities should be made resilient and sustainable.

What should we do to make the city resilient and sustainable? Experts say the view of cities should first be different from the view so far. Cities are not a stagnant and stationary concept. Cities are viewed as dynamic organisms with constantly changing properties in the course of evolution, growth and development, and research into urban metabolism is actively carried out as theories that can identify the organic characteristics of these cities. Sustainable urban metabolism is defined as a 'cyclic system consisting of Input-Output Usage-Reuse' for materials (resources, energy) injected into cities for the same benefit of current and future generations in the 'Input-Output Production-Consumption' system. (Ban, 2018) It is as if we are living in order to identify and prescribe water circulating in our bodies, food, etc., to identify urban problems and to seek sustainable cities, we need to analyze the material flow of the major elements (energy food, water) that make up the city.

In advanced European countries such as the Netherlands, MFA (Material Flow Analysis) seeks to address urban problems and draw improvements in terms of Metabolic, a city that sees the city as a living creature. Analyzing material flow at the city level requires data on key city components. It is necessary to accumulate data of the main factors (energy, food and water) related to the pattern of production and consumption of materials, the characteristics of the city, the characteristics of the inhabitants. However, in Korea there are no cases of material flow analysis at the city level, only partially used for material flow analysis of unit natural resources such as minerals. Therefore, through the example of Dutch cities where data can be collected for each component, MFA analysis on sustainable cities will be conducted to derive the process of creating a sustainable city, and the necessary and suggested items for application to Korea.

This report consists of five parts. The first part consists of an explanatory section on the concepts and necessaries of material flow analysis and a review of related literature. Description of approaches to material flow analysis at the city level, objective and objective quantification, and relevant literature review sections developed to date. The second part is the demographic, statistical and brief history of the stadionburt region of Amsterdam, the Netherlands, and the songsan green city east side district. The third part is the input and output part of the material flow analysis. Description of detailed material flow analysis of the production, territorial conservation and emissions of each urban component, through data collected at the target location. The fourth part is the composition of the parts to be proposed to the target site Amsterdam Stadium, Netherlands and songsan green city east district, through material flow analysis. Depending on the mass flow, problems per element are identified and suggested. Finally, the fifth part will be part of future research projects. Compared with the Netherlands, we will propose the institutional and non-institutional methods that should be reflected for urban water reuse through conclusions of the problems and improvements of the eastern district of Songsan Green City.

2. Literature Review

In order to solve the problem of urban cities caused by rapid urbanization, it is necessary to apply appropriate measures through the material flow analysis (hereafter referred to as MFA) of the main components (Such as water, food, energy etc.) of cities. Modern cities are confronted with social problems such as rising crime rates as well as environmental problems, including air and water pollution, that result from the destruction of nature and the depletion of resources due to overcrowding (Lee, 2015). So, many international organizations and institutions have offered sustainable solutions in social and environmental parts.

Sustainable development can be interpreted in many meanings, but from the perspective of urban areas, it means development that achieves ecological diversity, circulation, independence and stability, taking into account the economic and social environment (Sa, 2007). From the perspective of the urban metabolism, cities are human blood vessels, with organs are circulating in conjunction. However, urban problems have occurred due to overuse of urban components such as water and energy, and sustainable development will only circulate smoothly after reducing these waste elements (Ferrao P, Fernandes J.E., 2013).

Urban metabolism uses MFA as a method of urban analysis to create sustainable development. Material flow analysis is a method of evaluating the effectiveness from information obtained from material flow balances (Zhang, 2006). For the first time in the 1970s, the theory of the balance of matter and energy was introduced (Ayres, 1970). Since the 1990s, research on the developmental potential of social and environmental aspects in specific areas has been conducted at the urban level (Kennedy, Pincetl, & Bunje, 2012). It currently applies to all areas of human activity such as environmental engineering, resource management, waste management, industrial ecology, and urban engineering.

To apply MFA in urban settings, we can utilize both total urban elements and specific elements valuation methods. The total urban elements valuation method is a way to analyze an entire space by identifying tangible materials such as energy, water, and food, and intangible things such as quality and ecological services. The specific urban elements valuation method analyzes the place around the most important elements of the urban, taking into account its regional characteristics.

Regarding cases of total urban elements valuation, the spatial analysis of Amsterdam as a circular metabolism reports presented the sustainability and developmental potential of urban areas by analyzing MFA on materials, energy, ecosystems and quality of life. They also classified urban areas, exploring regional characteristics and their roles (Gerard, 2017). Eindhoven Internationale Knoop reports analyzed MFA from the initial planning stage of urban development, which incorporated strict requirements such as easy-to-use building materials, active rainwater use, and active use of natural energy (Tamara, 2019).

Regarding cases of specific urban element valuation, Circular Rottedam reports implemented MFA, focusing on waste, a specific component of the city. With the goal of reducing material consumption by about 50% by 2030, the report emphasized that reducing waste is not just for the environment, but also an opportunity to utilize waste in the most effective way (Peter, 2018). The world's first circular festival reports on 2017 shows how wastes from annual festivals in Amsterdam, through MFA analysis, can be recognized as a resource rather than as a waste (Martin, 2017). The details of each studies are shown in the below table.

Table 1. Urban Material Flow Analysis (MFA) Categorization by Element

Item	Main elements	Title	Author	Year
Analysis by Total element	Energy, Material, Ecosystem, Quality of life	Spatial analysis of Amsterdam as a circular metabolism	Gerard	2017
	Water, Biology diversity, Material, Energy	Eindhoven Internationale Knoop	Tamara	2019
Analysis by Specific element	Material consumption	Circular Rottedam	Pieter	2018
	Trash	Towards the world's first circular festiva	Martin	2017

In summary, the studies in this field initially began with an MFA analysis of the total urban elements. However, recent trends are increasingly focused on specific urban elements and their regional characteristics and competitiveness. In addition, MFA results are being reflected in new urban development direction, guidelines, and regulations.

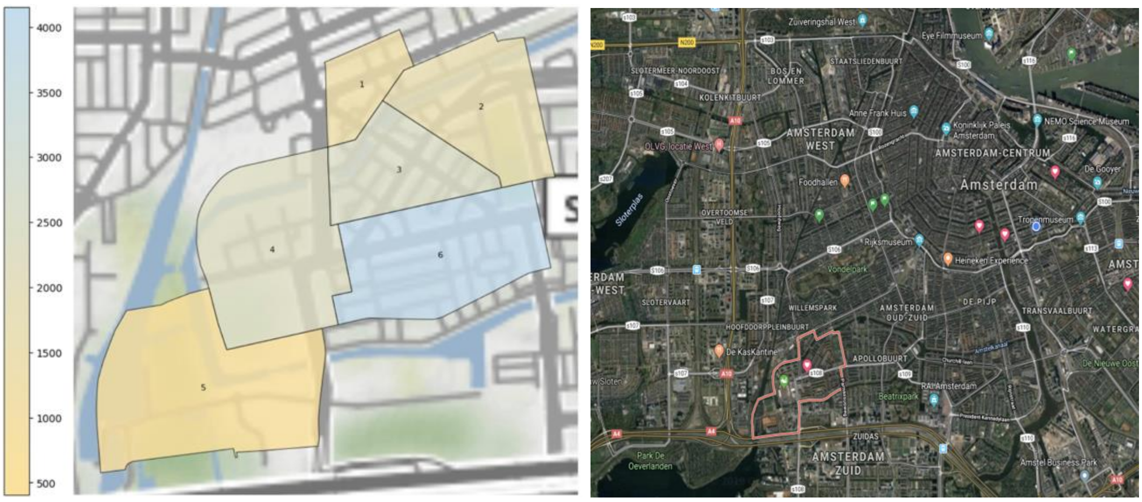
In Korea, the Ministry of Environment conducted MFA for each resource in 2008 and classified them into biological, mineral, and energy sources in order to increase resource recycling rates, solve environmental problems as well as conserve resources (The Ministry of Environment, 2008). Subsequently, analyses on metal materials and waste were carried out, but material flow analysis of the urban unit has not been performed until now. So, this study aims to explore improvements and suggestions when applying MFA to Korean cities through comparing to European Urban case.

3. Target area introduction

1) Stadionbuurt

The Stadionbuurt is a neighborhood within the Zuid District and province of Noord-Holland in Amsterdam, Netherlands. In the early 20th century, the former director of the Amsterdam Municipal Housing Service (Arrie Keppler) planned to build around 1,750 new homes in the neighborhood in order to combat the housing shortage during this time period. The Stadionbuurt is primarily a residential area that is bordered by the neighborhoods of Willemspark (to the north), Apollobuurt (to the east), Zuidas (to the south), and Schinkelbuurt (to the west). The Stadionbuurt contains a few large public green spaces (such as Park Schinekeleilanden) and sports arenas (including Sporthallen Zuid), which reflect much of the recent urban planning and development in Amsterdam South.

Figure 2. The Stadinbuurt



(Left): The Stadiobuurt is broken down and divided into six sub-residential regions called Bertelmanpleinbuurt (1), Marathonbuurt Oost (2), Marathonbuurt West (3), Olympisch Stadion en Omegeving (4), IJsbaanpad en Omgeving (5), & Van Tuyllbuurt (6).

Source: allecijfers.nl

The Stadionbuurt can roughly be divided into the *Bertelmanplein* neighborhood and *Marathon* neighborhood, which are comprised of smaller, social homes that were built during the 1920's-1930's. For example, *Van Tuyllbuurt* is an area in the Stadionbuurt that consists of private rental homes and a small minority of owner-occupied homes. The neighborhoods west of the *Amstelveenseweg* and south of the *Olympiakanaal* consist of a houseboat colony (called *Ijsbaanpad)* and the *Olympic Quarter* (a district with over 900 new-build apartments, recently built between 2004 and 2008). The residential population of the Stadionbuurt has been growing steadily at an annual rate of 2-4% since 2015. The Stadionbuurt is also accessible via public tram lines 6 and 24 or and is located about 20-25 minutes from Amsterdam Central Station.

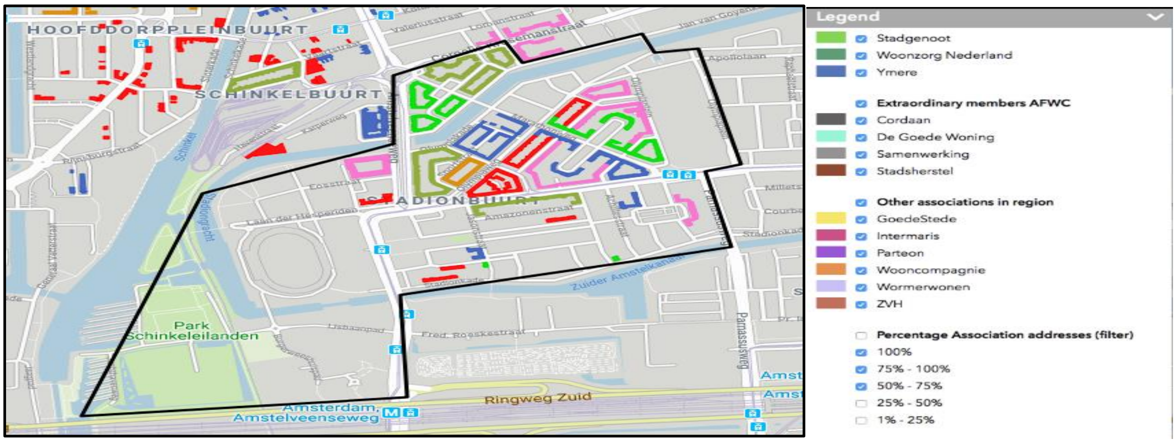
The Stadionbuurt was named after a national stadium designed by Harry Elte, a Jewish-Dutch architect, who helped promote the Amsterdam-School style of architecture in the area. In 1919, the Dutch government had also adopted a 'Middle Class Decree,' which promoted the construction of more medium-sized houses (via municipalities), housing associations, and other private builders in this area. As a result, the Public Works Department issued many building plots to private builders, and the construction of middle-class and middle-sized homes in Amsterdam South grew significantly. Jan Gratama (lead architect during the period of reconstruction in the Stadionbuurt) adopted the idea that houses and street walls should be integrated into a cohesive architectural design, which was a concept that became popular and admired amongst multiple architects in this region.

The Stadionbuurt currently has around 11,790 inhabitants, whom are distributed amongst 6,500 households. This means that there are about 1.81 persons per household in this neighborhood. Nearly half (49%) of the homes in the Stadionbuurt are rented from cooperative housing associations, whereas only 18% of homes are owner-occupied. More than 80% of the houses are smaller than 80 m^2, and the total area of the neighborhood is around 109.14 hectares . There are nearly 1400 businesses that are currently established in the Stadionbuurt; the primary industries and occupations for residents in this neighborhood include *businesses services* (such as municipality, law, and medicine) as well as secondary industries such as *cultural recreation* (which include restaurants, bars, and coffee shops).

Figure 3. Stadionbuurt pictures

There appears to be a geographical separation of housing within the Stadionbuurt neighborhood. For example, social housing cooperatives are almost exclusively located in the North-East part of the Stadionbuurt, whereas the Southern part is a residential area likely occupied by more upper-class, educated residents. Moreover, this demographic is also reflected amongst many of the upscale restaurants, grocery shops/markets, schools, and public green spaces that frequent the neighborhood. These green spaces are often decorated with rotating public art installations. Newly-built communities near IJsbaanpad include floating houses on the canal that seem to reinforce this presence of wealthier demographics within sub-neighborhoods located to the south of the Olympisch Stadion.

Figure 4. The Stadionbuurt housing type



Source: allecijfers.nl

(Above): Various social housing corporations of Stadionbuurt are represented by different colours from different companies. These highlighted housing area constituted of more than 50% of social housing in terms of surface area in the neighborhood. The rest of residential space in the neighborhood is considered residential private property housing.

Lastly, the ethnic demographic composition of the Stadionbuurt consists of Dutch/Westerners (48.4%), Morrocan (10.7%), Suriname (11%), Turkish (5.5%), and a Mixed/Unknown population (21.3%). The average annual income for residents living in the Stadionbuurt is 33,400 euros, which also represents a middle/upper-class, professional, and educated demographic within the Netherlands.

2) **Songsan green city east district**

Songsan Green City is a new city established in accordance with the Industrial Location and Development Act on the tidal flats on the south side of Sihwa Lake in Songsan-myeon, Namyang-eup, and Saesol-dong, Hwaseong-si, Gyeonggi-do, Korea. The project operator is

Korea Water Resources Corporation. The project period is from 2007 to 2030, with an area of 55.59㎢, the planned population is 60,000 households and 150,000 people, and the total project cost is 9.4 trillion won. Divided into three stages, the first stage will be developed in the east (Eco-residential living zone), the second stage in the south (automobile-related high-tech industry), and the third stage in the west (tourism, leisure, housing).

Figure 5. Songsan Green city

Source: Songsan Green City Implementation Design Report (K-water internal data)

The east side of Songsan Green City began construction in 2012. The planned population of the eastern district is 2.4 million. Resident occupancy began in 2018, and the data of the multi-family housing complex in which you live now are as follows. According to the resident registration demographics of the Ministry of Public Administration and Security in November 2019, there are 17,670 inhabitants in 5,909 households, and the population per household is about 2.99. Currently, the finishing work of some multi-unit houses is underway, and tenement houses and single-family houses are moving in before commencement. In addition, some commercial facilities are in operation around the apartment complex.

Table 2. Planning of the Apartment Complex in the East Side of Songsan Green City

Apt name	block	Top floor	Generation	When they move in
Humanville	EAA1	20	750	2018.1
Lakeville	EAA2	20	782	2018.1
Y City	EAA3	20	680	2018.10
Noble land Ⅱ	EAA4	20	426	2019.8
Ivy Park	EAA6	20	980	2018.1
Pentium	EAA7	20	692	2019.10
Noble land Ⅱ	EAA8	20	872	2018.6
Noble land Ⅲ	EAA9	20	585	2019.8
Miraedo	EAA10	20	533	2020.8
Richel	EAA11	20	390	2019.7
Total			8,072	

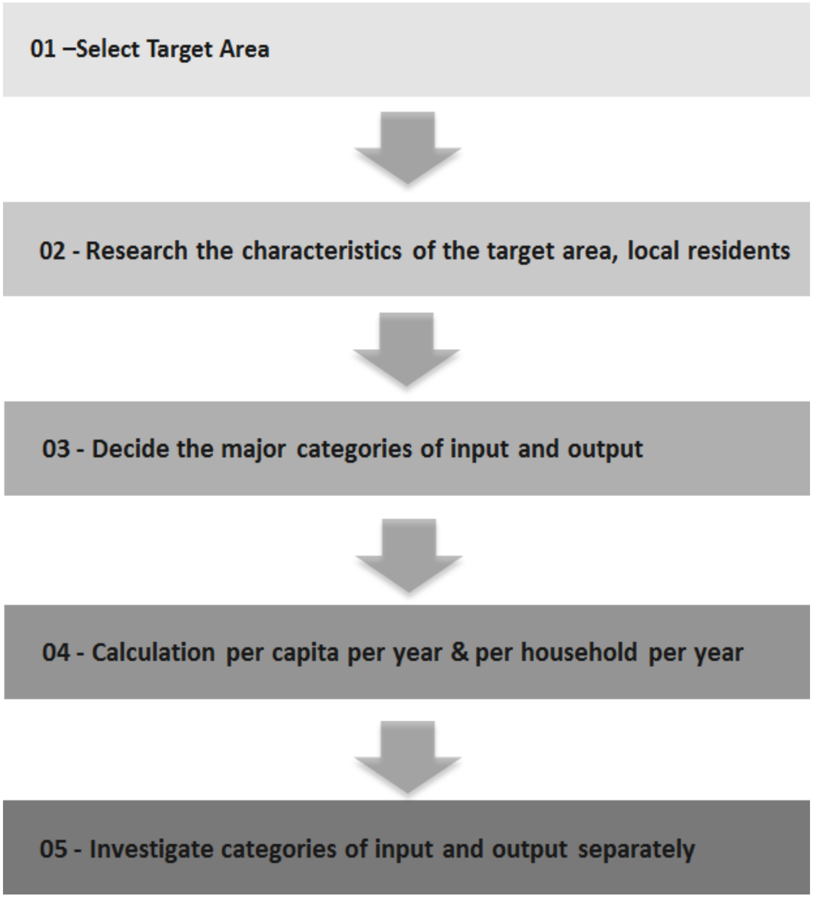
4. Methodology

Material flow analysis for a sustainable city should begin with the concept of a circular economy. A circular economy can be defined as “an economic model that satisfies the needs of the population, impairs the function of the biosphere or imparts resources fairly without crossing planetary boundaries” (Metabolic, 2019). A circular economy (or circular) often plays a role in neutralizing environmental emissions (Green House Gas) by reducing essential resources and materials, reusing, recycling and eliminating waste production. This basic economic model is available through renewable and productive, innovative and innovative systems and solutions, relying on renewable energy sources (solar, wind, nuclear, geothermal, hydropower, etc.) to support sustainable green. In other words, a sustainable city aims to smoothly circulate material in the city.

Material flow analysis quantifies and classifies essential resources into and out of a specific space (city). This method also relies on a spherical paradigm based on the ongoing dynamics between the production and consumption of essential resources and materials by humans (Hodson, 2012). Quantification of such material flows can be broken down using life cycle analysis (LCA). Life cycle analysis classifies how individual resources and materials are used at different points within a lifecycle phase. The most common stages of the product life cycle include the production stage (raw material), construction stage (manufacturing and transportation), stage of use (production) and end of life stage (building, demolition, secondary material reuse).

The main purpose of the MFA is to optimize both technological and socioeconomic processes within the geographic sector to generate productivity, reduce waste and generate energy (Kennedy, Pincetl, & Bunje, 2011). This analytical method also enables key planners to identify the most influential and important aspects of systematic interventions over the life cycle of raw materials by optimizing environmental efficiency and moving closer towards sustainability and economic goals.

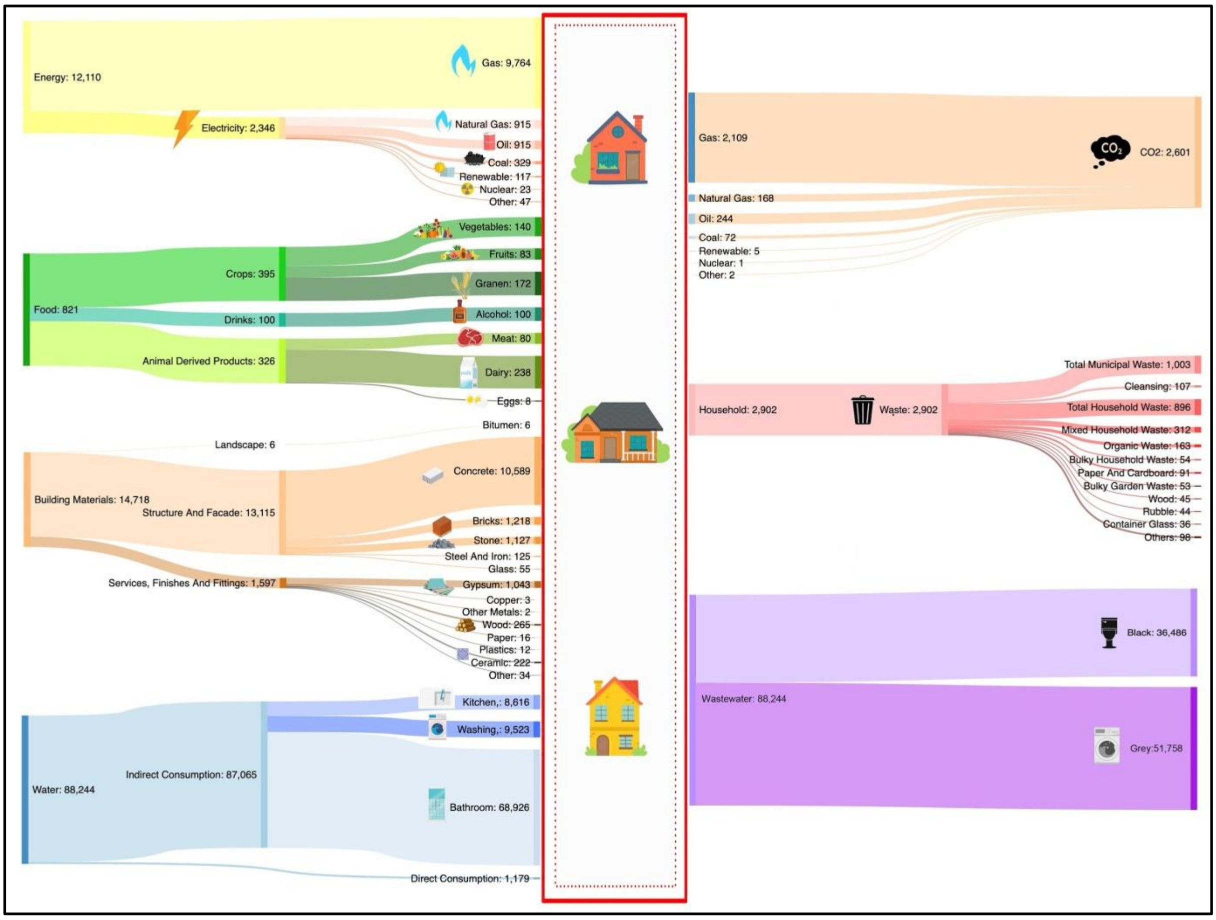
Figure 6. The process of MFA



5. Results of MFA

1) The stadionbuurt

Figure 7.The result of MFA in the stadionbuurt.



MFA represents the quantities of inputs (energy, food, building materials, and water) and outputs (emissions and waste) that move across and throughout the average Dutch household in the Stadionbuurt neighborhood of Amsterdam.

(1) Input

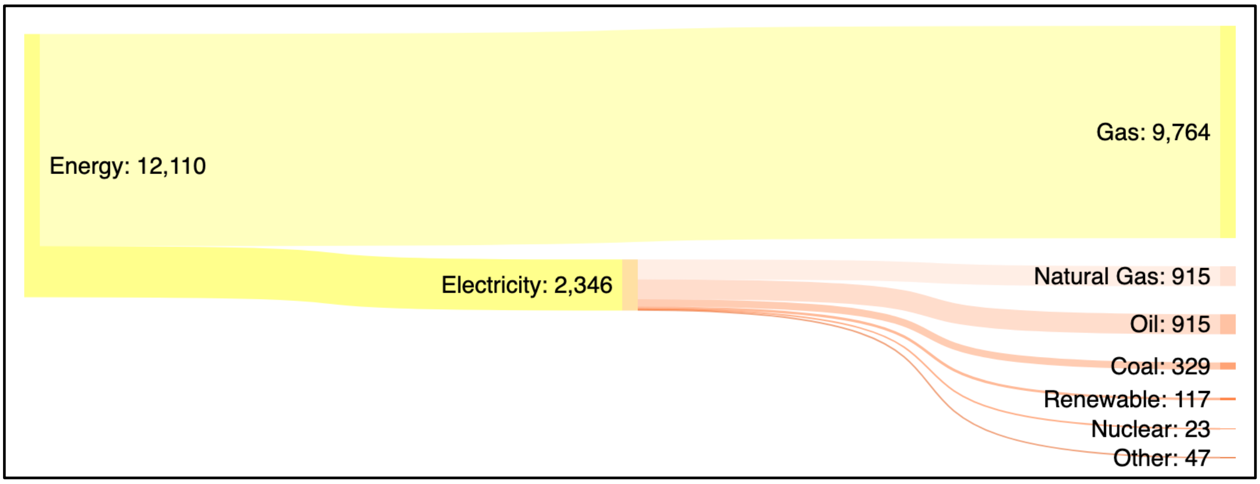
A. Energy

The energy flow into the households of Stadionbuurt were analyzed based on data from the energy management company *Liander*. The dataset features two main distinctions in the consumption of energy in the city of Amsterdam, which include electricity and gas consumption, where the latter is used for heating solely. More specifically, the number of connections to electricity or gas per postal code are also featured. By connecting the dataset on energy consumption with the postal codes from Stadionbuurt - which were based on data from the city of Amsterdam itself - the observations were reduced and confined to this specific neighborhood of interest. In a second step, the distribution of energy consumption by type of usage were plotted to get a sense of the extreme outliers within the dataset. This analysis led to the dropping of ten observations, whose electricity consumption of energy was above 8000 kWh per year. Considering a mean electricity consumption of around 2500 kWh with a standard deviation of roughly 1000 kWh per year, observations of above 8000 kWh in electricity consumption are clearly out of the ordinary and would distort the household averages eventually resulting in less informative results. The dataset from *Liander* however does not feature the source of the electricity consumed. Using a breakdown of the sources of energy consumption per household in the Netherlands by the energy initiative EBN (2018) we extrapolated the sources of energy consumption for the neighborhood of Stadionbuurt in Amsterdam, making the assumption that the share of energy sources for the whole of the Netherlands are representative of the neighborhood of Stadionbuurt. Lastly, in order to create a visually easy interpretable flow of energy, the gas consumption for household heating were transformed from cubic meters into kWh according to the following formula based on the best practice suggestion of the energy consultancy *de energieconsultant BV* (2019):

$$\mathbf{1\ m^3 = \frac{35.17\ MJ}{3.6\ MJ} = 9.769\ kWh}$$

Based on this methodology the inflow analysis of energy consumption for Stadionbuurt can be seen in Figure 8 below.

Figure 8. Energy(input)

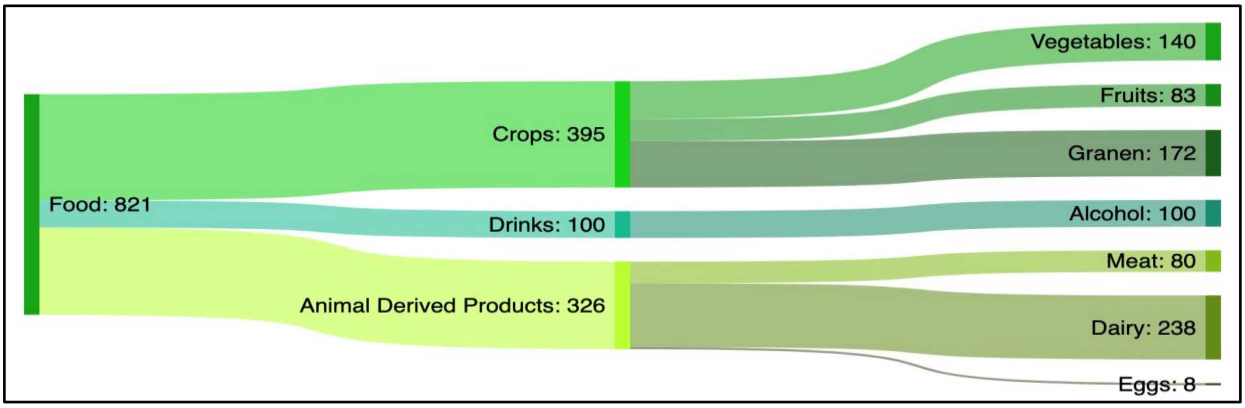


As shown in Figure 8.0, gas consumption for the heating of households easily presents the largest share of energy consumption in Stadionbuurt. Out of a total energy consumption of 12,110 kWh per household per year almost 10,000 kWh were used for heating. The remaining 2,346 kWh that were used for electricity were mostly produced by natural gas and oil, each accounting for 39% of electricity generation. Renewable energy only contributed 5% to the electricity consumption of households in Stadionbuurt.

B. Food

The average food input in households of Stadionbuurt represents the total amount of food consumed per year by an average household in kilograms. The value of above 800 kg/household/year (see *Figure 9*) was extrapolated from a database published by the National Institute for Public Health and the Environment. The online resource gives an overview of absolute and relative food consumption of the citizens of the Netherlands as a whole. The assumption that Amsterdam inhabitants had similar dietary habits as Dutch average citizen was necessary to establish this input flow. For clarity purposes, the food flow was sub-categorized into crops (vegetables, fruits, grains), animal-derived products (meat, dairy, eggs) and drinks (alcohol).

Figure 9. Food (input)



C. Building Materials

The evaluation of building materials consumption within Stadionbuurt was undertaken by first gathering information on the proposed building projects within the area. The City of Amsterdam's Interactive Maps (https://maps.amsterdam.nl/grabbel/) showed three major development projects being proposed between 2019 and 2027:

- Verdi NW-ZW-ZP Kwadrant

  To be constructed in 2023 - 2027, classified as "change of use" (assumed refurbishment), comprising of 1115 apartments on a shared ownership model

- Verdi Tripolis

  To be constructed in 2022 - 2024, classified as "change of use" (assumed refurbishment), comprising of 144 social-rent apartments

- Stadionweg 267

  To be constructed in 2019 - 2020, classified as "change of use" (assumed refurbishment), comprising of 4 own-build apartments

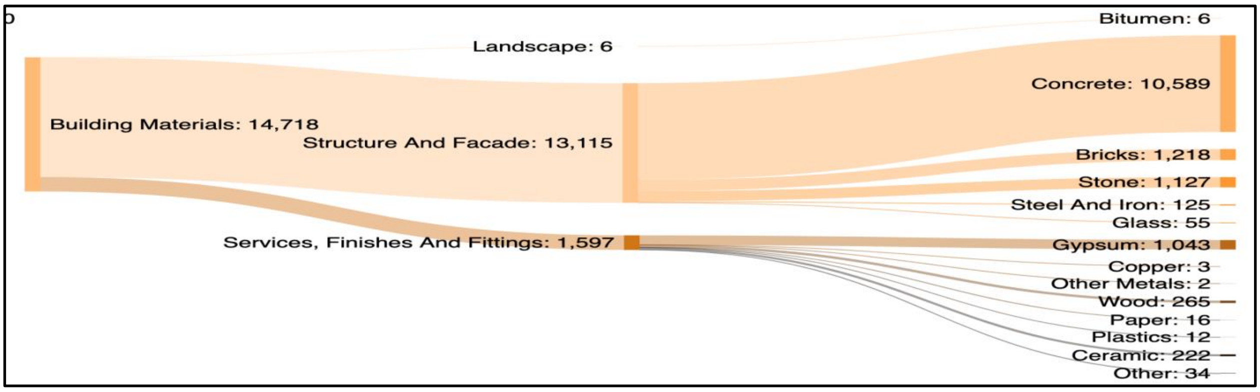
This resource does not capture the complete picture however, leaving out for example large projects currently without planning permission or not included in the database, and small projects not requiring major planning permission (e.g. self-builds). For the purpose of this study, these additional building material consumption sources are deemed negligible.

To calculate material consumption of the above building projects, reference was made to Metabolic's building materials per gross floor area table. Assumptions were applied to convert the information from new-construction to refurbishment cases:

- Bitumen: 10% of new construction consumption
- Sand & soil: 0% of new construction consumption
- Concrete, bricks, stone, steel, iron and glass: 70% of new construction consumption
- Ceramic: 80% of new construction consumption
- All other materials: 100%, i.e. same consumption in the case of refurbishment or consumption.

Residents of Amsterdam also have 49m2 of living space per person. Considering the average household in Stadionbuurt has 1.81 inhabitants, the average apartment size in Stadionbuurt can be estimated to be 88.7 m2. This contradicts statistics from allecijfers.nl that shows more than 80% of the residences are smaller than 80m2. Applying those figures to the material flow analysis for building materials, we have the figures demonstrated in Figure 10

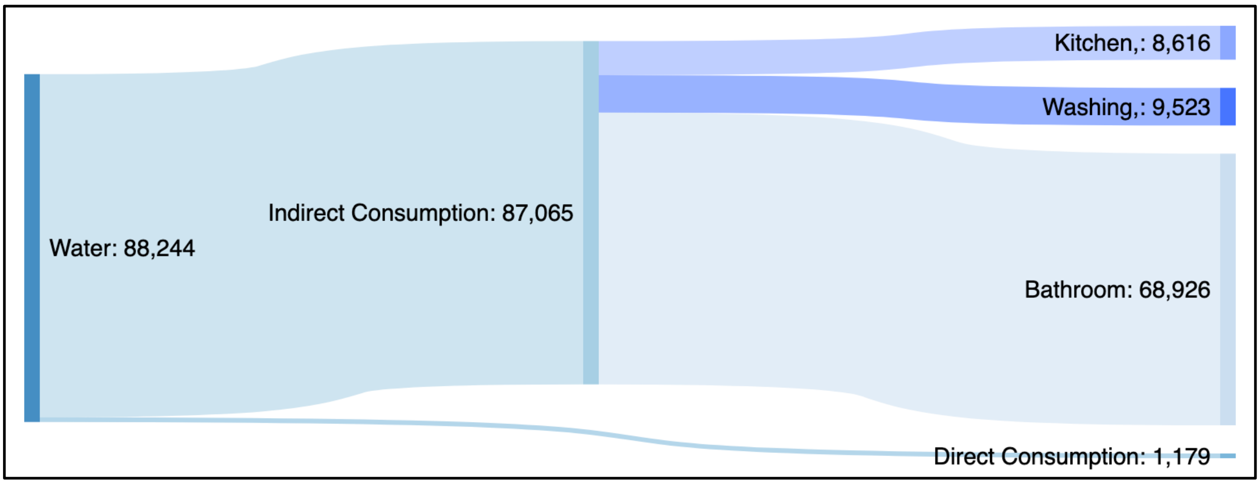
Figure 10. Material (input)



D. Water

The average water input flow represents a total amount of almost 90 000 liters per household per year. This total amount of consumed water is the result of a minor direct consumption flow (water for human consumption) and a major indirect consumption flow. The latter was subdivided into 3 different contributors: bathroom water use representing more than two thirds of the indirect consumption, clothes washing and kitchen activities (see *Figure 11*). The data were provided by the online source of Waternet, the water utility company of Amsterdam.

Figure 11. Water (input)

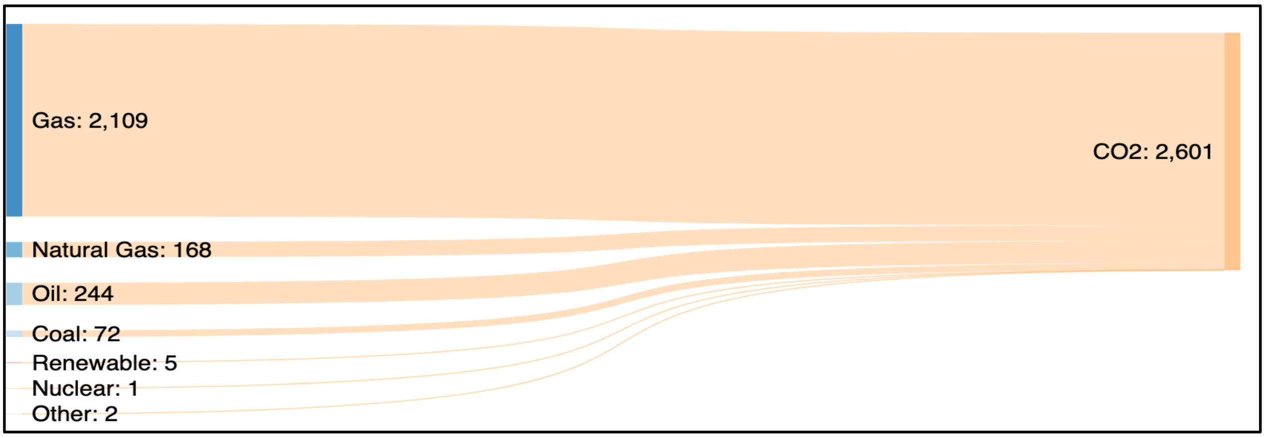


(2) Output

A. Emissions

The emissions caused by the consumption of energy per household in Stadionbuurt are extrapolated directly from the data on the consumption of energy per household based on the IPCC conversion rates of kilograms of CO_2 emission according to type of energy source. Accordingly the outflow of energy emissions can be visualized in kg of CO_2 per household per year.

Figure 12. Emissions (output)



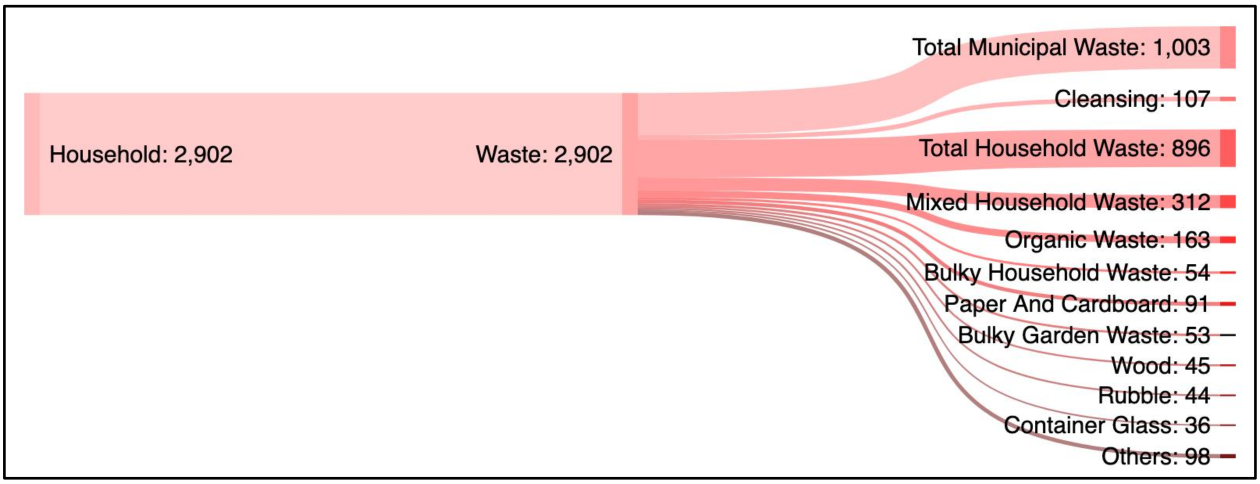
Unsurprisingly, gas emissions take up the largest part of the average household's CO2 emissions in Stadionbuurt. That is, heating with gas was already the main energy consumption factor. The second largest contributor to CO2 emissions per household per year is oil with 244 kg of CO2. However, compared to 2,109 kg of CO2 emitted by heating with gas per household per year the CO2 emissions of electricity consumption are relatively negligible.

It should be noted however, that due to data limitations the emissions presented here are only based on energy consumption and not on indirect CO2 emissions that arise through the consumption and usage of other goods and services such as food, digital devices or furniture.

B. Household Waste

The average output flow of household waste is expressed in terms of kg/household/year. As shown in *figure 13.0*, it is constituted of two different flows: the total household waste and the cleansing. The latter represents the total amount of waste resulting from the common spaces and municipality maintenance, divided by the total amount of household. The result is equivalent to the average responsibility of a household in waste for the common good. The second flow encompasses all individual household waste. Its major components are mixed household waste (plastic packaging as major part), paper and cardboard, bulky household and garden waste, wood, rubble, container glass and others. The category interestingly, the organic waste share accounts for one fifth of total household waste, representing the second largest contributor to household garbage. Despite its potential for composting, no efficient collection system has been implemented in Amsterdam these last decades.

Figure 13. Household waste (output)



C. Waste Water

The average output flow of water is expressed in terms of L water per hh per year. It consists of two flows as shown in the figure. Blackwater in a sanitation context denotes wastewater from toilets, which likely contains pathogens. Blackwater can contain feces, urine, water and toilet paper from flush toilets. Greywater is wastewater generated in households from streams without fecal contamination, i.e. all streams except for the wastewater from toilets. Sources of greywater include, sinks, showers, baths, clothes washing machines or dishwashers. Most of the water is used in toilets and bathrooms. Recycling this water could reduce water consumption. However, due to the limitations of the data, it could not reflect the flow of recycled water.

Figure 14. Waste water (output)

2) Songsan Green city east district(Water)

For the MFA analysis of Songsan Green City, data on unit production and consumption of each material is needed. However, since data on food, energy, and matter could not be collected in Korea, the analysis was conducted only on water where data could be collected.

The average use of water and sewage in Songsan Green City was calculated by taking into account the number of people in 2019 and the number of planned generations by utilizing the Ministry of Public Administration and Security's statistics on resident registration.

The total usage and average annual usage per generation were calculated by utilizing the Ministry of Environment's water statistics (2017) and internal data from the Songsan sewage treatment plant operated by K-water.

Table 3. The use of water in korea

Toilet	Kitchen	Washing	Bath	Washbasin	Etc.
25%	21%	20%	16%	11%	7%

Source: http://water.nier.go.kr/front/waterEasy/knowledge02_02.jsp

Table 4. Data of water use

Month	Household	Population	population per household	Water supply		Sewage	
				Daily average	Yearly average	Daily average	Yearly average
1	3,658	10,991	3.005	173	1,901,443	196	2,152,000
2	3,744	11,264	3.009	173	1,948,672	184	2,072,000
3	3,791	11,399	3.007	173	1,972,027	191	2,177,000
4	3,815	11,492	3.012	173	1,988,116	200	2,294,000
5	3,839	11,560	3.011	173	1,999,880	226	2,608,000
6	3,855	11,607	3.011	173	2,008,011	238	2,760,000
7	3,863	11,658	3.018	173	2,016,834	230	2,685,000
8	4,234	12,837	3.032	173	2,220,801	234	3,002,000
9	4,830	14,563	3.015	173	2,519,399	240	3,496,000
10	4,827	16,419	3.401	173	2,840,487	210	3,455,000
11	5,912	17,677	2.990	173	3,058,121	206	3,635,000
Avergae	-	-	3.046	173	2,224,890	214	2,757,818

Table 5.Calculation result of water use

Population per household	Water supply		Sewage		Etc.
	daily	yearly	daily	Yearly	
3.046	527 L	192,367 L	652 L	237,597L	

Source: water-supply statistics (2017), K-water internal repert

Figure 15. Songsan water (input)

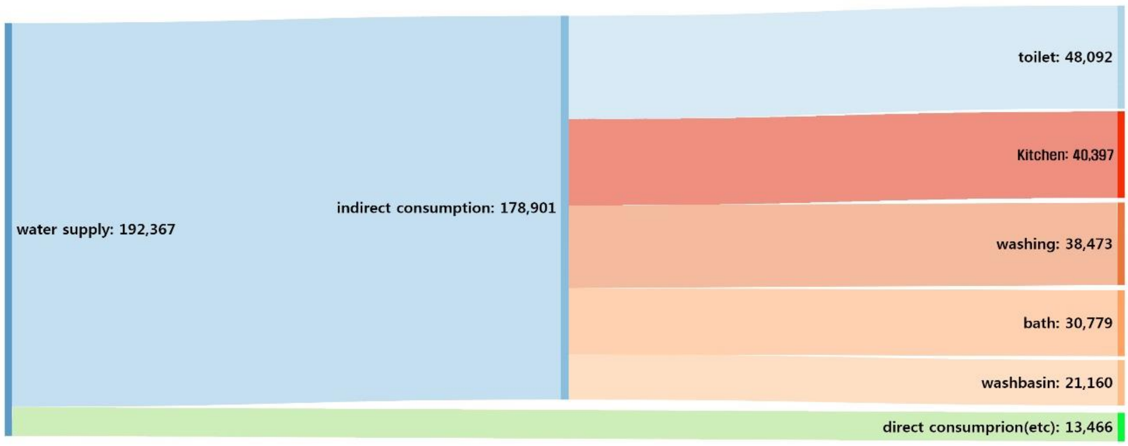


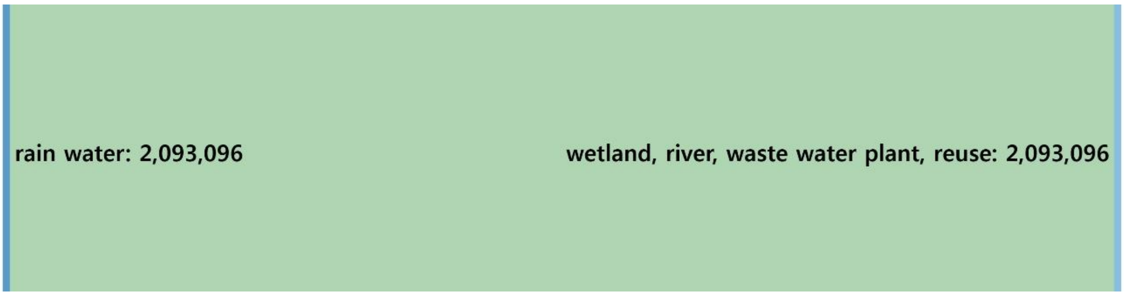
Figure 16. Songsan water (output)

Comparing the flow of water usage in Amsterdam, the Netherlands, the usage pattern is similar, but the usage per household is more than double that of Songsan Green City.

According to the analysis of water consumption, sewage throughput is estimated to have a similar proportion of black and gray water in the city of Amsterdam, but unidentified sewage treatment is estimated to be discharged into the stream through the reservoir.

Figure 17. Songsan rain water

Figure 18. Stadiobuurt rain water.



The annual rainfall calculated from the average rainfall in Songshan Green City and the Netherlands Stadium Butte area is as follows. The amount of rainwater available per year compared to the unit area is estimated to be 1.5 times more than Songsan Green City. However, in both areas no data were available on the specific flow and use of rainwater.

6. Suggestions & Limitations

MFA analysis of water in Korea and the Netherlands shows that Korea uses about twice as much water supply as the Netherlands. The reason why Korea's water consumption is high is because of the demand for water space created by rapid urbanization and economic development, green space near residential complexes and landscaping water for water supply and leisure water for amusement are needed. Many studies have shown that landscaping and leisure water can be used by recycling rainwater. In Korea, however, most still use water supplies (Kim & Lee, 2004).

In the case of the Netherlands, the whole city is sponged against rainwater based on institutional and non-institutional devices to utilize rainwater.(Dai, van Rijswick, Driesen, & Keessen, 2017).Prevent excessive water discharge by keeping and storing the area as long as possible. This is done through measures such as placing green roofs and water reservoirs in the garden on public infrastructure, such as water squares in public places, and private land.

For these measures, the Netherlands clearly presents parts of the collection and treatment of rainwater in a systematic way in accordance with Article 3.5 of the Dutch Mystery and provides opportunities for more investment by local governments to provide the most effective subsidies in an uninstitutional way (Mees, Driesen, Runhaar, & Stamatelos, 2012) and to manage revenues such as taxes to give authority to the most responsible local governments (Dai, Wörner& Rijswick, 2018).

Figure 19. Netherland rain water use case

<Rain roof garden> <Rain beer>

<Multipurpose Space(detention pond, sports facilities)>

To protect the city from flooding, increasing the landscape of sewer pipes or building additional dams requires a huge budget. And the proliferation of rainwater recycling facilities can play an important role in urban water use (landscape and leisure) as a useful water source for the city.

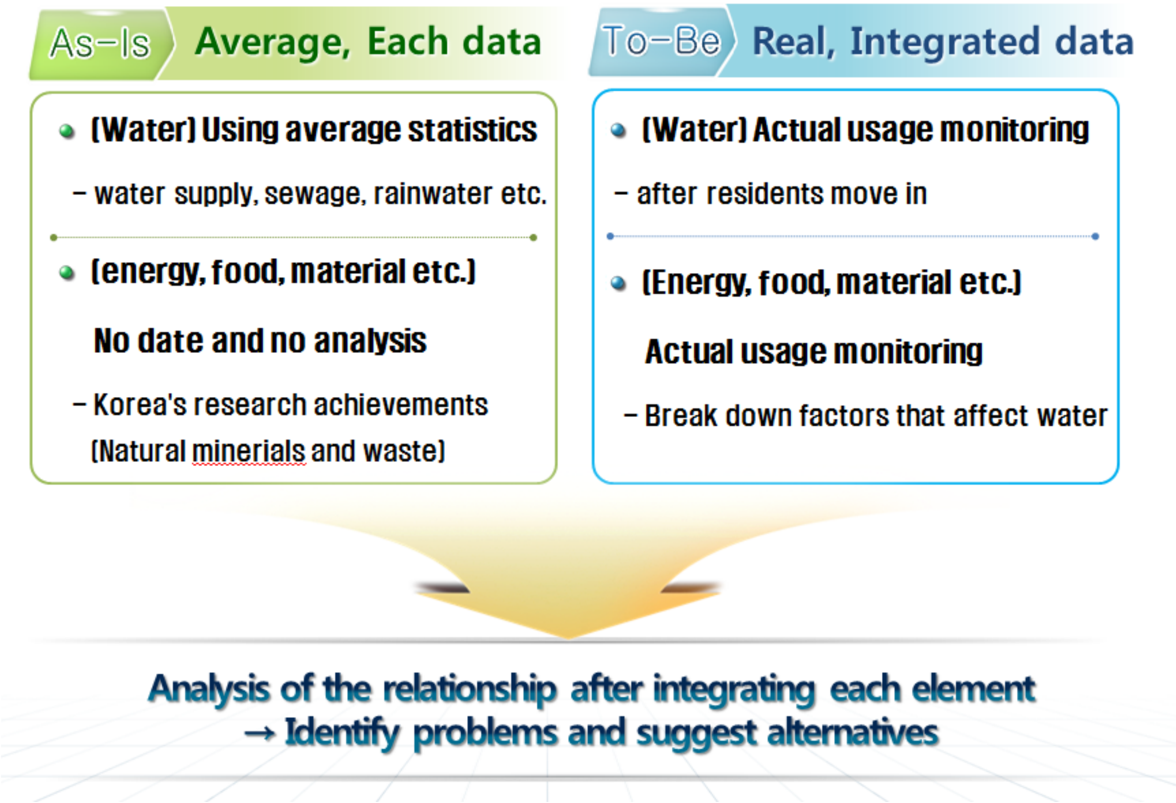
The Netherlands is committed to promoting the use of rainwater by the following laws, municipalities and subsidies: Of course, Korea is also implementing various policies to promote rainwater use through laws and subsidies etc.. In Korea, however, full-scale research has been conducted since the 2000s. At the urban level, monitoring is conducted through a few pilot cases. In the case of the Netherlands, the establishment of governance for cooperation and participation of governments, local governments, companies, civic groups and individuals for practical solutions is ahead of Korea.

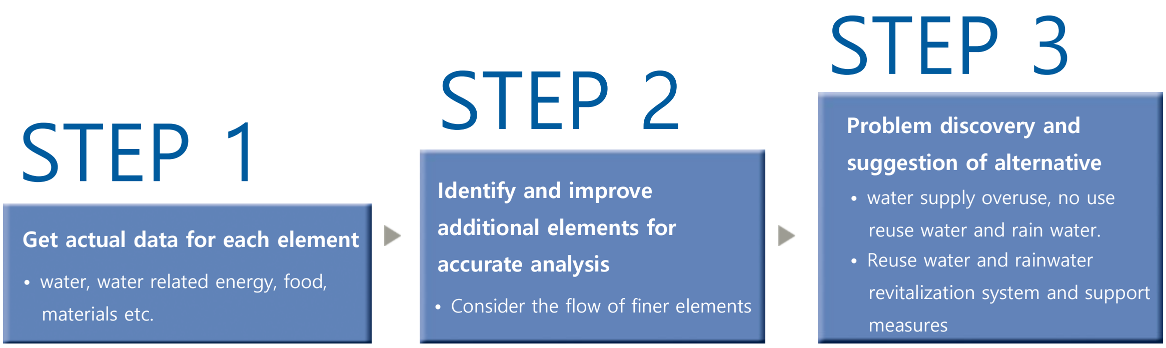
Table 6.Comparison of rainwater institutions between the Netherlands and Korea

Netherlands	Law	·The spatial planning act 2.1, 3.1 ·The Environment management act 3.6, 4.22, 4.23, 10.33 ·Dutch water act articles 3.5, 3.6
	Subsidy, incentive	·Smart roof
Korea	Law	·Act on the Promotion and Support of Water Reuse
	Subsidy, incentive	·Reduction of sewerage system usage fee. etc.

To increase the accuracy of the MFA analysis, monitoring of rainwater must precede. However, in the Songsan Green City east side, there is no result of monitoring the amount of storage and reuse for rainwater. Also, since the city has been established for about a year, it cannot be considered as stable use and throughput. To conduct accurate and reliable analyses, analysis is required through data collected after some time has passed since residents moved in.

Figure 20. Road map for MFA





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A Study on the Revitalization of Urban Water Reuse through MFA (Material Flow Analysis)

- Comparison between Netherlands Stadionbuurt and Korea Songsan Green City -

Capstone Project

Submitted to

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Executive summary

Various urban problems are occurring due to urban development caused by rapid urbanization. To solve these urban problems, Europe recently attempted to analyze urban problems through MFA (material flow analysis) from the perspective of urban metaphysical view of cities as living organisms.

In this study, the MFA analysis on the material circulation (water focus) of the city resulted in the conclusion that the re-use of rainwater should be increased by comparing the apartment complexes in the east side of Stadionbuurt in the Netherlands and Songsan Green City in korea. However, to increase the utilization rate of rainwater, institutional and non-institutional support will be needed, such as in the Netherlands.

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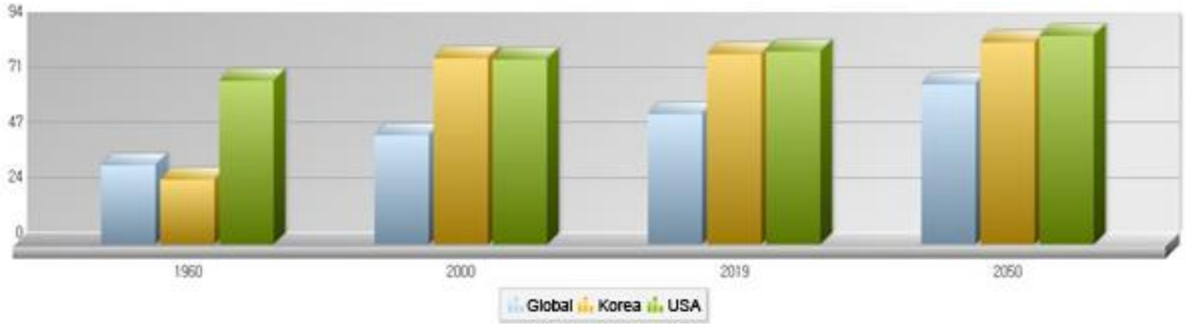
1. Introduction

Urbanization refers to a concept that refers to the concentration of population from rural to urban areas and the resulting regional and social changes. Urbanization is a term that refers to the percentage of the population living in a city of the entire population of the country. The global urbanization rate has risen sharply from 33.8 percent in 1960 to 55.7 percent as of 2019, while Korea's urbanization rate has grown faster than the global average from 27.7 percent in the 1960s to 81.7 percent as of 2019. (KOIS, 2019) In a country with rapid economic development, the rate of urbanization is growing faster to gain more jobs and educational opportunities.

Rapid economic development and urbanization can have many side effects, including environmental problems such as waste disposal and water pollution, as well as social problems such as resource conflicts and inflation. (Park, 2010)

Figure 1. Urbanization Rates (National Statistical Office, 2019)



Various stories are being made around the world to address the damage caused by rapid urbanization. In particular, the United Nations has formally adopted international guidelines. At the 2016 UN Habitat III World Congress, the New Urban Agenda presents universal goals, such as sustainable development of densely populated cities without harming the environment or the redevelopment of temporary dwellings in cities accompanied by residents' participation. "Urbanization is proceeding at an unprecedented speed and scale, and 3.7 billion people are now living in cities," says Juan Clos, secretary general of the UN Habitat III World Congress. "It's expected to grow to 7 billion in the next 2050." Also, the growing population will cause problems with services such as energy, food and water resources, and to solve these problems, cities should be made resilient and sustainable.

What should we do to make the city resilient and sustainable? Experts say the view of cities should first be different from the view so far. Cities are not a stagnant and stationary concept. Cities are viewed as dynamic organisms with constantly changing properties in the course of evolution, growth and development, and research into urban metabolism is actively carried out as theories that can identify the organic characteristics of these cities. Sustainable urban metabolism is defined as a 'cyclic system consisting of Input-Output Usage-Reuse' for materials (resources, energy) injected into cities for the same benefit of current and future generations in the 'Input-Output Production-Consumption' system. (Ban, 2018) It is as if we are living in order to identify and prescribe water circulating in our bodies, food, etc., to identify urban problems and to seek sustainable cities, we need to analyze the material flow of the major elements (energy food, water) that make up the city.

In advanced European countries such as the Netherlands, MFA (Material Flow Analysis) seeks to address urban problems and draw improvements in terms of Metabolic, a city that sees the city as a living creature. Analyzing material flow at the city level requires data on key city components. It is necessary to accumulate data of the main factors (energy, food and water) related to the pattern of production and consumption of materials, the characteristics of the city, the characteristics of the inhabitants. However, in Korea there are no cases of material flow analysis at the city level, only partially used for material flow analysis of unit natural resources such as minerals. Therefore, through the example of Dutch cities where data can be collected for each component, MFA analysis on sustainable cities will be conducted to derive the process of creating a sustainable city, and the necessary and suggested items for application to Korea.

This report consists of five parts. The first part consists of an explanatory section on the concepts and necessaries of material flow analysis and a review of related literature. Description of approaches to material flow analysis at the city level, objective and objective quantification, and relevant literature review sections developed to date. The second part is the demographic, statistical and brief history of the stadionburt region of Amsterdam, the Netherlands, and the songsan green city east side district. The third part is the input and output part of the material flow analysis. Description of detailed material flow analysis of the production, territorial conservation and emissions of each urban component, through data collected at the target location. The fourth part is the composition of the parts to be proposed to the target site Amsterdam Stadium, Netherlands and songsan green city east district, through material flow analysis. Depending on the mass flow, problems per element are identified and suggested. Finally, the fifth part will be part of future research projects. Compared with the Netherlands, we will propose the institutional and non-institutional methods that should be reflected for urban water reuse through conclusions of the problems and improvements of the eastern district of Songsan Green City.

2. Literature Review

In order to solve the problem of urban cities caused by rapid urbanization, it is necessary to apply appropriate measures through the material flow analysis (hereafter referred to as MFA) of the main components (Such as water, food, energy etc.) of cities. Modern cities are confronted with social problems such as rising crime rates as well as environmental problems, including air and water pollution, that result from the destruction of nature and the depletion of resources due to overcrowding (Lee, 2015). So, many international organizations and institutions have offered sustainable solutions in social and environmental parts.

Sustainable development can be interpreted in many meanings, but from the perspective of urban areas, it means development that achieves ecological diversity, circulation, independence and stability, taking into account the economic and social environment (Sa, 2007). From the perspective of the urban metabolism, cities are human blood vessels, with organs are circulating in conjunction. However, urban problems have occurred due to overuse of urban components such as water and energy, and sustainable development will only circulate smoothly after reducing these waste elements (Ferrao P, Fernandes J.E., 2013).

Urban metabolism uses MFA as a method of urban analysis to create sustainable development. Material flow analysis is a method of evaluating the effectiveness from information obtained from material flow balances (Zhang, 2006). For the first time in the 1970s, the theory of the balance of matter and energy was introduced (Ayres, 1970). Since the 1990s, research on the developmental potential of social and environmental aspects in specific areas has been conducted at the urban level (Kennedy, Pincetl, & Bunje, 2012). It currently applies to all areas of human activity such as environmental engineering, resource management, waste management, industrial ecology, and urban engineering.

To apply MFA in urban settings, we can utilize both total urban elements and specific elements valuation methods. The total urban elements valuation method is a way to analyze an entire space by identifying tangible materials such as energy, water, and food, and intangible things such as quality and ecological services. The specific urban elements valuation method analyzes the place around the most important elements of the urban, taking into account its regional characteristics.

Regarding cases of total urban elements valuation, the spatial analysis of Amsterdam as a circular metabolism reports presented the sustainability and developmental potential of urban areas by analyzing MFA on materials, energy, ecosystems and quality of life. They also classified urban areas, exploring regional characteristics and their roles (Gerard, 2017). Eindhoven Internationale Knoop reports analyzed MFA from the initial planning stage of urban development, which incorporated strict requirements such as easy-to-use building materials, active rainwater use, and active use of natural energy (Tamara, 2019).

Regarding cases of specific urban element valuation, Circular Rottedam reports implemented MFA, focusing on waste, a specific component of the city. With the goal of reducing material consumption by about 50% by 2030, the report emphasized that reducing waste is not just for the environment, but also an opportunity to utilize waste in the most effective way (Peter, 2018). The world's first circular festival reports on 2017 shows how wastes from annual festivals in Amsterdam, through MFA analysis, can be recognized as a resource rather than as a waste (Martin, 2017). The details of each studies are shown in the below table.

Table 1. Urban Material Flow Analysis (MFA) Categorization by Element

Item	Main elements	Title	Author	Year
Analysis by Total element	Energy, Material, Ecosystem, Quality of life	Spatial analysis of Amsterdam as a circular metabolism	Gerard	2017
	Water, Biology diversity, Material, Energy	Eindhoven Internationale Knoop	Tamara	2019
Analysis by Specific element	Material consumption	Circular Rottedam	Pieter	2018
	Trash	Towards the world's first circular festiva	Martin	2017

In summary, the studies in this field initially began with an MFA analysis of the total urban elements. However, recent trends are increasingly focused on specific urban elements and their regional characteristics and competitiveness. In addition, MFA results are being reflected in new urban development direction, guidelines, and regulations.

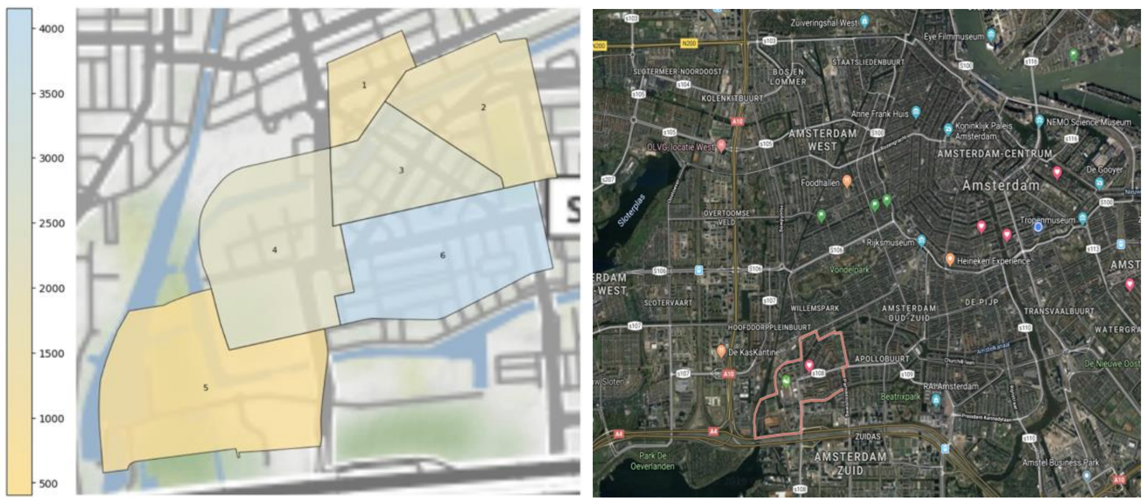
In Korea, the Ministry of Environment conducted MFA for each resource in 2008 and classified them into biological, mineral, and energy sources in order to increase resource recycling rates, solve environmental problems as well as conserve resources (The Ministry of Environment, 2008). Subsequently, analyses on metal materials and waste were carried out, but material flow analysis of the urban unit has not been performed until now. So, this study aims to explore improvements and suggestions when applying MFA to Korean cities through comparing to European Urban case.

3. Target area introduction

1) Stadionbuurt

The Stadionbuurt is a neighborhood within the Zuid District and province of Noord-Holland in Amsterdam, Netherlands. In the early 20th century, the former director of the Amsterdam Municipal Housing Service (Arrie Keppler) planned to build around 1,750 new homes in the neighborhood in order to combat the housing shortage during this time period. The Stadionbuurt is primarily a residential area that is bordered by the neighborhoods of Willemspark (to the north), Apollobuurt (to the east), Zuidas (to the south), and Schinkelbuurt (to the west). The Stadionbuurt contains a few large public green spaces (such as Park Schinekeleilanden) and sports arenas (including Sporthallen Zuid), which reflect much of the recent urban planning and development in Amsterdam South.

Figure 2. The Stadinbuurt



(Left): The Stadiobuurt is broken down and divided into six sub-residential regions called Bertelmanpleinbuurt (1), Marathonbuurt Oost (2), Marathonbuurt West (3), Olympisch Stadion en Omegeving (4), IJsbaanpad en Omgeving (5), & Van Tuyllbuurt (6).

Source: allecijfers.nl

The Stadionbuurt can roughly be divided into the *Bertelmanplein* neighborhood and *Marathon* neighborhood, which are comprised of smaller, social homes that were built during the 1920's-1930's. For example, *Van Tuyllbuurt* is an area in the Stadionbuurt that consists of private rental homes and a small minority of owner-occupied homes. The neighborhoods west of the *Amstelveenseweg* and south of the *Olympiakanaal* consist of a houseboat colony (called *Ijsbaanpad)* and the *Olympic Quarter* (a district with over 900 new-build apartments, recently built between 2004 and 2008). The residential population of the Stadionbuurt has been growing steadily at an annual rate of 2-4% since 2015. The Stadionbuurt is also accessible via public tram lines 6 and 24 or and is located about 20-25 minutes from Amsterdam Central Station.

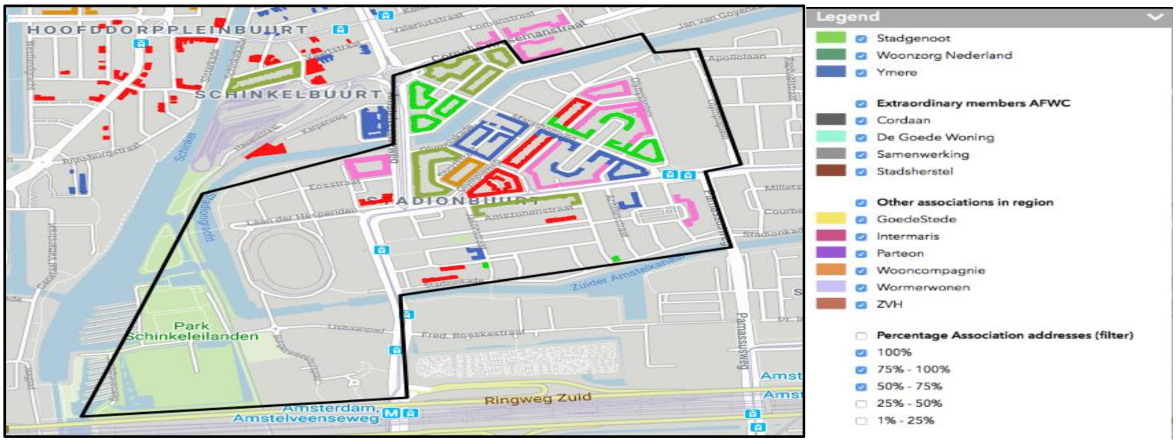
The Stadionbuurt was named after a national stadium designed by Harry Elte, a Jewish-Dutch architect, who helped promote the Amsterdam-School style of architecture in the area. In 1919, the Dutch government had also adopted a 'Middle Class Decree,' which promoted the construction of more medium-sized houses (via municipalities), housing associations, and other private builders in this area. As a result, the Public Works Department issued many building plots to private builders, and the construction of middle-class and middle-sized homes in Amsterdam South grew significantly. Jan Gratama (lead architect during the period of reconstruction in the Stadionbuurt) adopted the idea that houses and street walls should be integrated into a cohesive architectural design, which was a concept that became popular and admired amongst multiple architects in this region.

The Stadionbuurt currently has around 11,790 inhabitants, whom are distributed amongst 6,500 households. This means that there are about 1.81 persons per household in this neighborhood. Nearly half (49%) of the homes in the Stadionbuurt are rented from cooperative housing associations, whereas only 18% of homes are owner-occupied. More than 80% of the houses are smaller than 80 m^2, and the total area of the neighborhood is around 109.14 hectares . There are nearly 1400 businesses that are currently established in the Stadionbuurt; the primary industries and occupations for residents in this neighborhood include *businesses services* (such as municipality, law, and medicine) as well as secondary industries such as *cultural recreation* (which include restaurants, bars, and coffee shops).

Figure 3. Stadionbuurt pictures

There appears to be a geographical separation of housing within the Stadionbuurt neighborhood. For example, social housing cooperatives are almost exclusively located in the North-East part of the Stadionbuurt, whereas the Southern part is a residential area likely occupied by more upper-class, educated residents. Moreover, this demographic is also reflected amongst many of the upscale restaurants, grocery shops/markets, schools, and public green spaces that frequent the neighborhood. These green spaces are often decorated with rotating public art installations. Newly-built communities near IJsbaanpad include floating houses on the canal that seem to reinforce this presence of wealthier demographics within sub-neighborhoods located to the south of the Olympisch Stadion.

Figure 4. The Stadionbuurt housing type



Source: allecijfers.nl

(Above): Various social housing corporations of Stadionbuurt are represented by different colours from different companies. These highlighted housing area constituted of more than 50% of social housing in terms of surface area in the neighborhood. The rest of residential space in the neighborhood is considered residential private property housing.

Lastly, the ethnic demographic composition of the Stadionbuurt consists of Dutch/Westerners (48.4%), Morrocan (10.7%), Suriname (11%), Turkish (5.5%), and a Mixed/Unknown population (21.3%). The average annual income for residents living in the Stadionbuurt is 33,400 euros, which also represents a middle/upper-class, professional, and educated demographic within the Netherlands.

2) **Songsan green city east district**

Songsan Green City is a new city established in accordance with the Industrial Location and Development Act on the tidal flats on the south side of Sihwa Lake in Songsan-myeon, Namyang-eup, and Saesol-dong, Hwaseong-si, Gyeonggi-do, Korea. The project operator is

Korea Water Resources Corporation. The project period is from 2007 to 2030, with an area of 55.59㎢, the planned population is 60,000 households and 150,000 people, and the total project cost is 9.4 trillion won. Divided into three stages, the first stage will be developed in the east (Eco-residential living zone), the second stage in the south (automobile-related high-tech industry), and the third stage in the west (tourism, leisure, housing).

Figure 5. Songsan Green city

Source: Songsan Green City Implementation Design Report (K-water internal data)

The east side of Songsan Green City began construction in 2012. The planned population of the eastern district is 2.4 million. Resident occupancy began in 2018, and the data of the multi-family housing complex in which you live now are as follows. According to the resident registration demographics of the Ministry of Public Administration and Security in November 2019, there are 17,670 inhabitants in 5,909 households, and the population per household is about 2.99. Currently, the finishing work of some multi-unit houses is underway, and tenement houses and single-family houses are moving in before commencement. In addition, some commercial facilities are in operation around the apartment complex.

Table 2. Planning of the Apartment Complex in the East Side of Songsan Green City

Apt name	block	Top floor	Generation	When they move in
Humanville	EAA1	20	750	2018.1
Lakeville	EAA2	20	782	2018.1
Y City	EAA3	20	680	2018.10
Noble land Ⅱ	EAA4	20	426	2019.8
Ivy Park	EAA6	20	980	2018.1
Pentium	EAA7	20	692	2019.10
Noble land Ⅱ	EAA8	20	872	2018.6
Noble land Ⅲ	EAA9	20	585	2019.8
Miraedo	EAA10	20	533	2020.8
Richel	EAA11	20	390	2019.7
Total			8,072	

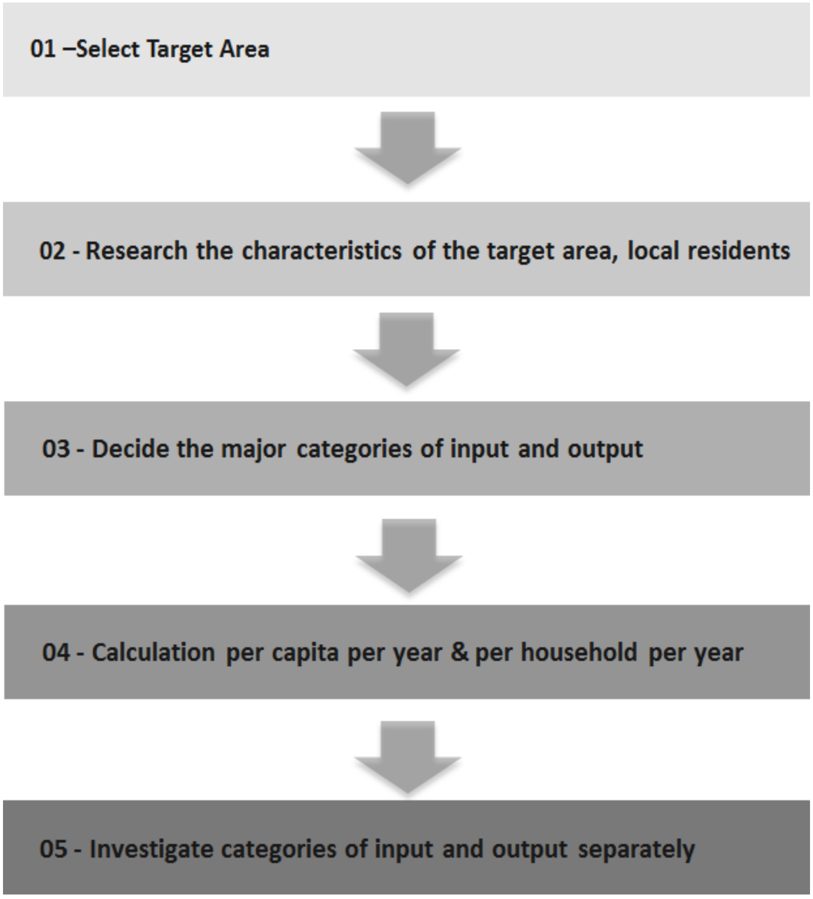
4. Methodology

Material flow analysis for a sustainable city should begin with the concept of a circular economy. A circular economy can be defined as “an economic model that satisfies the needs of the population, impairs the function of the biosphere or imparts resources fairly without crossing planetary boundaries” (Metabolic, 2019). A circular economy (or circular) often plays a role in neutralizing environmental emissions (Green House Gas) by reducing essential resources and materials, reusing, recycling and eliminating waste production. This basic economic model is available through renewable and productive, innovative and innovative systems and solutions, relying on renewable energy sources (solar, wind, nuclear, geothermal, hydropower, etc.) to support sustainable green. In other words, a sustainable city aims to smoothly circulate material in the city.

Material flow analysis quantifies and classifies essential resources into and out of a specific space (city). This method also relies on a spherical paradigm based on the ongoing dynamics between the production and consumption of essential resources and materials by humans (Hodson, 2012). Quantification of such material flows can be broken down using life cycle analysis (LCA). Life cycle analysis classifies how individual resources and materials are used at different points within a lifecycle phase. The most common stages of the product life cycle include the production stage (raw material), construction stage (manufacturing and transportation), stage of use (production) and end of life stage (building, demolition, secondary material reuse).

The main purpose of the MFA is to optimize both technological and socioeconomic processes within the geographic sector to generate productivity, reduce waste and generate energy (Kennedy, Pincetl, & Bunje, 2011). This analytical method also enables key planners to identify the most influential and important aspects of systematic interventions over the life cycle of raw materials by optimizing environmental efficiency and moving closer towards sustainability and economic goals.

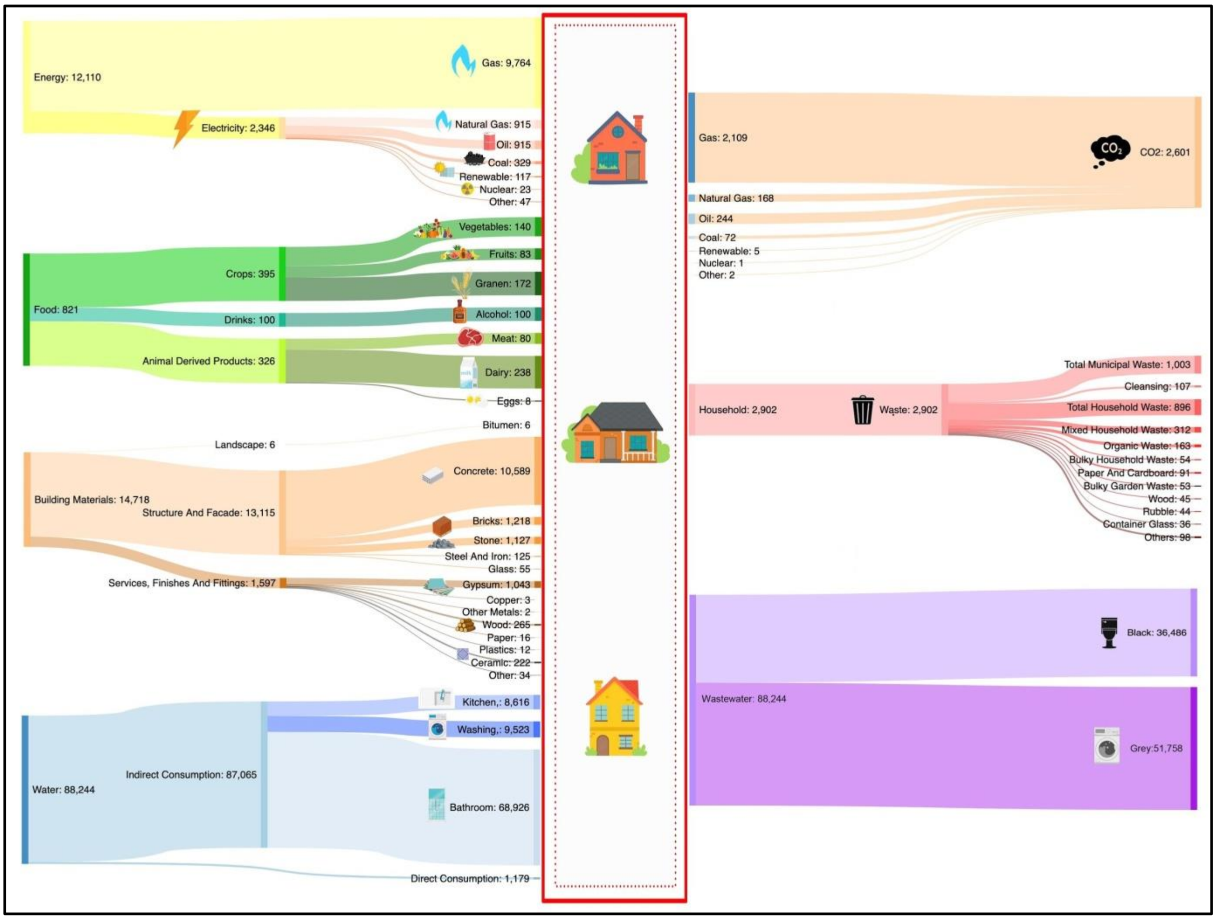
Figure 6. The process of MFA



5. Results of MFA

1) The stadionbuurt

Figure 7.The result of MFA in the stadionbuurt.



MFA represents the quantities of inputs (energy, food, building materials, and water) and outputs (emissions and waste) that move across and throughout the average Dutch household in the Stadionbuurt neighborhood of Amsterdam.

(1) Input

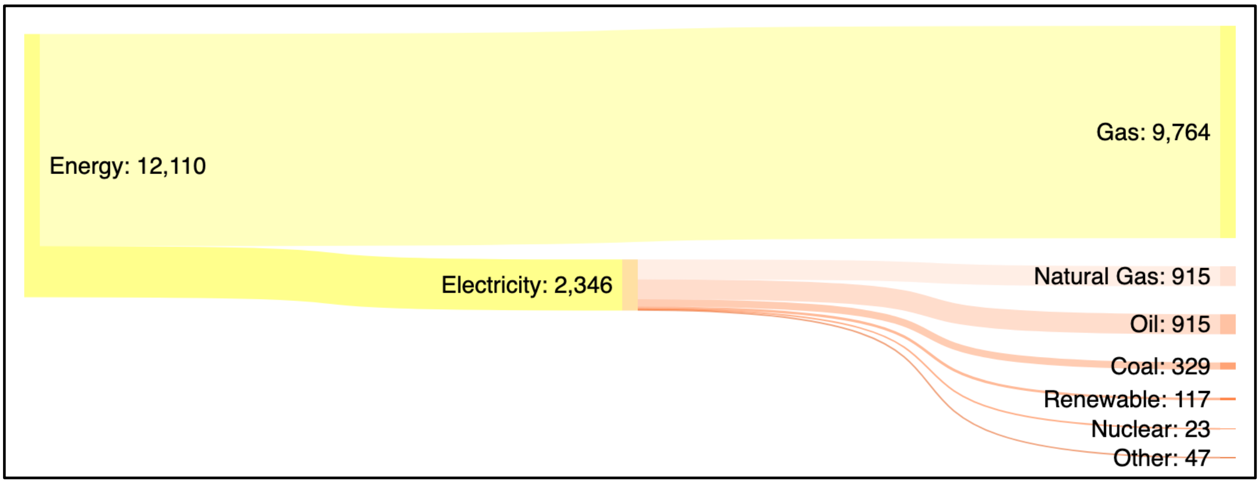
A. Energy

The energy flow into the households of Stadionbuurt were analyzed based on data from the energy management company *Liander*. The dataset features two main distinctions in the consumption of energy in the city of Amsterdam, which include electricity and gas consumption, where the latter is used for heating solely. More specifically, the number of connections to electricity or gas per postal code are also featured. By connecting the dataset on energy consumption with the postal codes from Stadionbuurt - which were based on data from the city of Amsterdam itself - the observations were reduced and confined to this specific neighborhood of interest. In a second step, the distribution of energy consumption by type of usage were plotted to get a sense of the extreme outliers within the dataset. This analysis led to the dropping of ten observations, whose electricity consumption of energy was above 8000 kWh per year. Considering a mean electricity consumption of around 2500 kWh with a standard deviation of roughly 1000 kWh per year, observations of above 8000 kWh in electricity consumption are clearly out of the ordinary and would distort the household averages eventually resulting in less informative results. The dataset from *Liander* however does not feature the source of the electricity consumed. Using a breakdown of the sources of energy consumption per household in the Netherlands by the energy initiative EBN (2018) we extrapolated the sources of energy consumption for the neighborhood of Stadionbuurt in Amsterdam, making the assumption that the share of energy sources for the whole of the Netherlands are representative of the neighborhood of Stadionbuurt. Lastly, in order to create a visually easy interpretable flow of energy, the gas consumption for household heating were transformed from cubic meters into kWh according to the following formula based on the best practice suggestion of the energy consultancy *de energieconsultant BV* (2019):

$$\mathbf{1\ m^3 = \frac{35.17\ \mathit{MJ}}{3.6\ \mathit{MJ}} = 9.769\ \mathit{kWh}}$$

Based on this methodology the inflow analysis of energy consumption for Stadionbuurt can be seen in Figure 8 below.

Figure 8. Energy(input)

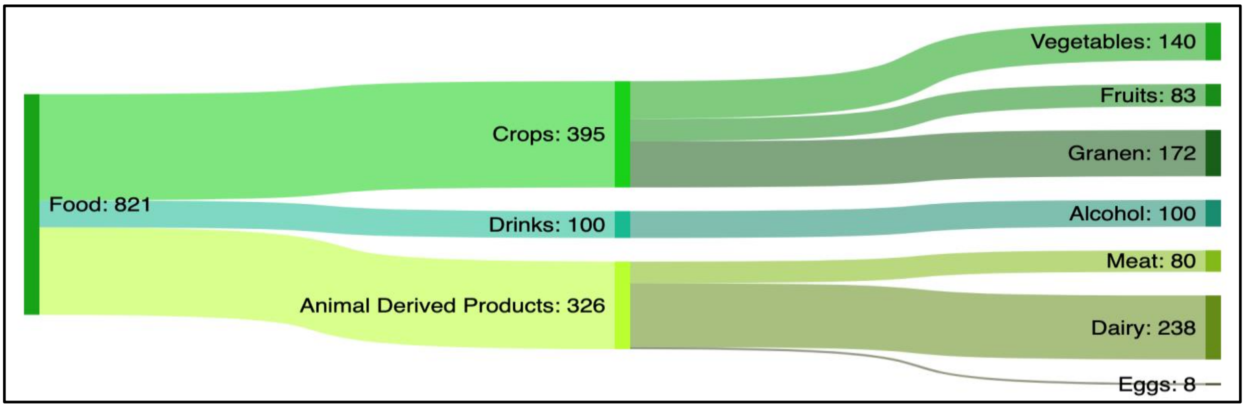


As shown in Figure 8.0, gas consumption for the heating of households easily presents the largest share of energy consumption in Stadionbuurt. Out of a total energy consumption of 12,110 kWh per household per year almost 10,000 kWh were used for heating. The remaining 2,346 kWh that were used for electricity were mostly produced by natural gas and oil, each accounting for 39% of electricity generation. Renewable energy only contributed 5% to the electricity consumption of households in Stadionbuurt.

B. Food

The average food input in households of Stadionbuurt represents the total amount of food consumed per year by an average household in kilograms. The value of above 800 kg/household/year (see *Figure 9*) was extrapolated from a database published by the National Institute for Public Health and the Environment. The online resource gives an overview of absolute and relative food consumption of the citizens of the Netherlands as a whole. The assumption that Amsterdam inhabitants had similar dietary habits as Dutch average citizen was necessary to establish this input flow. For clarity purposes, the food flow was sub-categorized into crops (vegetables, fruits, grains), animal-derived products (meat, dairy, eggs) and drinks (alcohol).

Figure 9. Food (input)



C. Building Materials

The evaluation of building materials consumption within Stadionbuurt was undertaken by first gathering information on the proposed building projects within the area. The City of Amsterdam’s Interactive Maps (https://maps.amsterdam.nl/grabbel/) showed three major development projects being proposed between 2019 and 2027:

- Verdi NW-ZW-ZP Kwadrant

  To be constructed in 2023 - 2027, classified as “change of use” (assumed refurbishment), comprising of 1115 apartments on a shared ownership model

- Verdi Tripolis

  To be constructed in 2022 - 2024, classified as “change of use” (assumed refurbishment), comprising of 144 social-rent apartments

- Stadionweg 267

  To be constructed in 2019 - 2020, classified as “change of use” (assumed refurbishment), comprising of 4 own-build apartments

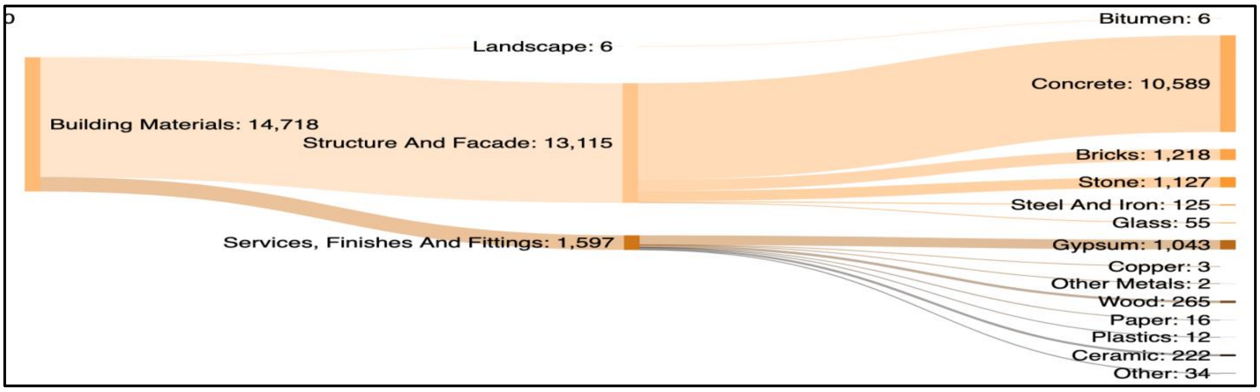
This resource does not capture the complete picture however, leaving out for example large projects currently without planning permission or not included in the database, and small projects not requiring major planning permission (e.g. self-builds). For the purpose of this study, these additional building material consumption sources are deemed negligible.

To calculate material consumption of the above building projects, reference was made to Metabolic's building materials per gross floor area table. Assumptions were applied to convert the information from new-construction to refurbishment cases:

- Bitumen: 10% of new construction consumption
- Sand & soil: 0% of new construction consumption
- Concrete, bricks, stone, steel, iron and glass: 70% of new construction consumption
- Ceramic: 80% of new construction consumption
- All other materials: 100%, i.e. same consumption in the case of refurbishment or consumption.

Residents of Amsterdam also have 49m2 of living space per person. Considering the average household in Stadionbuurt has 1.81 inhabitants, the average apartment size in Stadionbuurt can be estimated to be 88.7 m2. This contradicts statistics from allecijfers.nl that shows more than 80% of the residences are smaller than 80m2. Applying those figures to the material flow analysis for building materials, we have the figures demonstrated in Figure 10

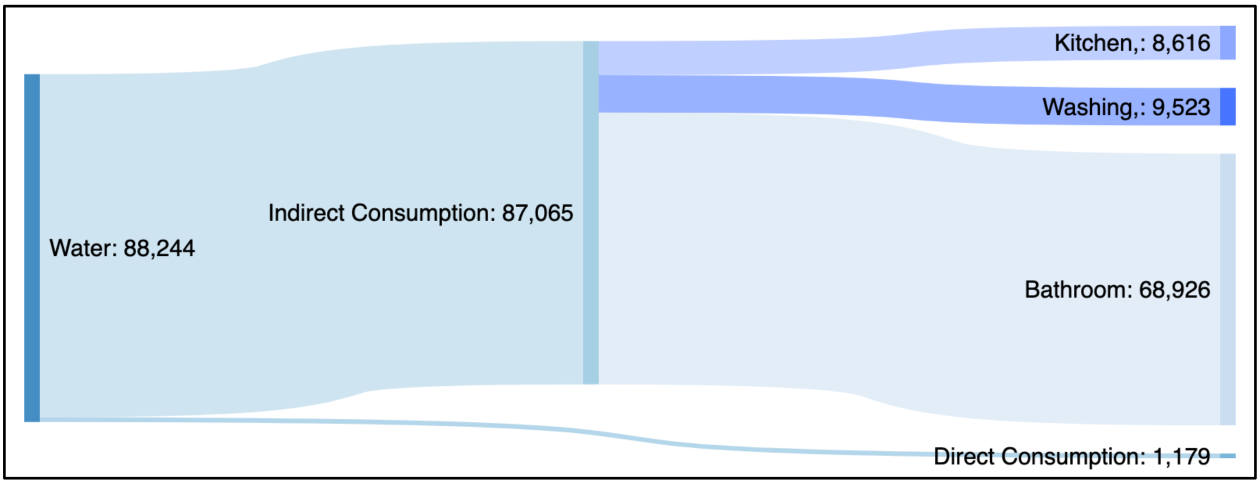
Figure 10. Material (input)



D. Water

The average water input flow represents a total amount of almost 90 000 liters per household per year. This total amount of consumed water is the result of a minor direct consumption flow (water for human consumption) and a major indirect consumption flow. The latter was subdivided into 3 different contributors: bathroom water use representing more than two thirds of the indirect consumption, clothes washing and kitchen activities (see *Figure 11*). The data were provided by the online source of Waternet, the water utility company of Amsterdam.

Figure 11. Water (input)

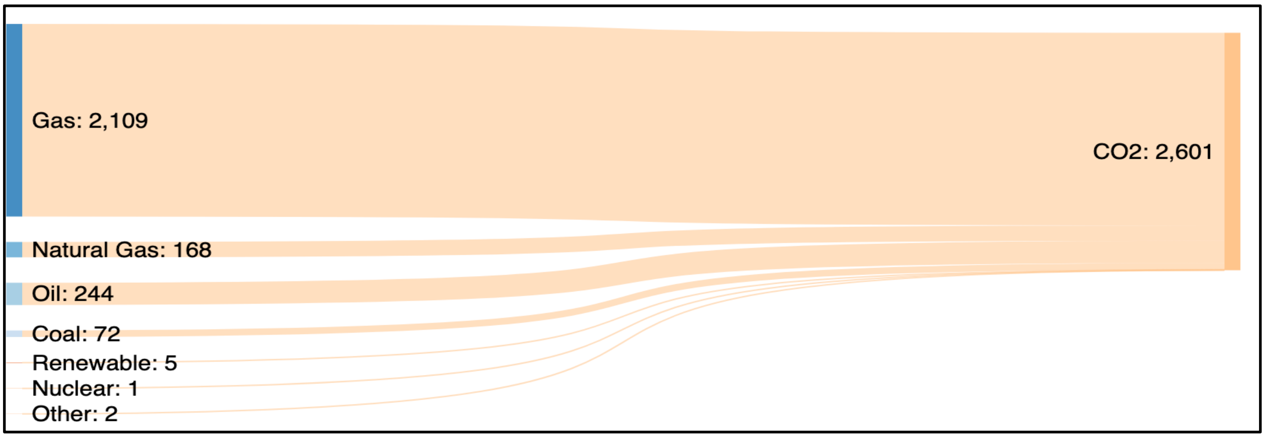


(2) Output

A. Emissions

The emissions caused by the consumption of energy per household in Stadionbuurt are extrapolated directly from the data on the consumption of energy per household based on the IPCC conversion rates of kilograms of CO2 emission according to type of energy source. Accordingly the outflow of energy emissions can be visualized in kg of CO2 per household per year.

Figure 12. Emissions (output)



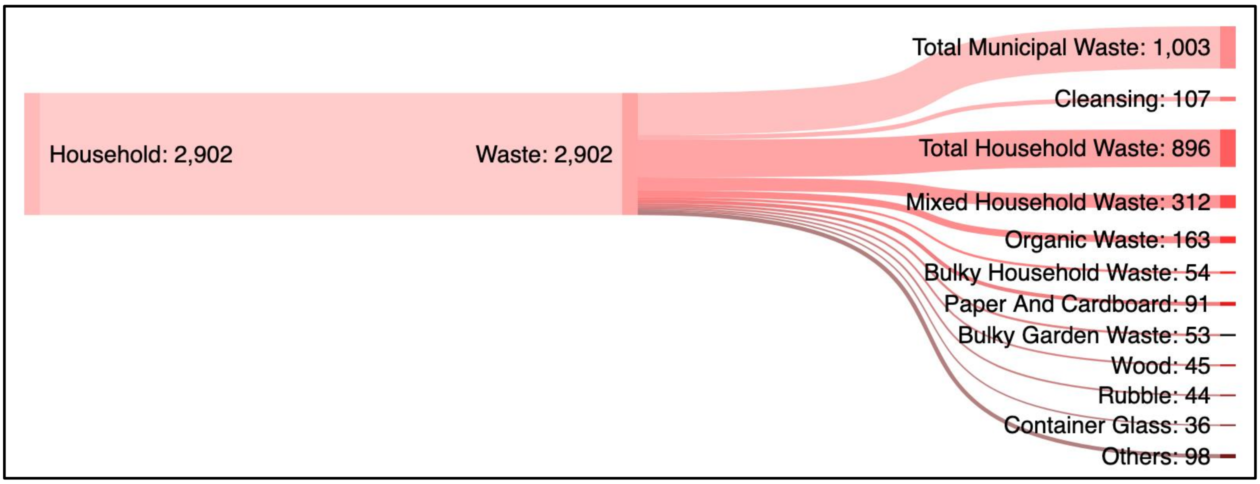
Unsurprisingly, gas emissions take up the largest part of the average household's CO2 emissions in Stadionbuurt. That is, heating with gas was already the main energy consumption factor. The second largest contributor to CO2 emissions per household per year is oil with 244 kg of CO2. However, compared to 2,109 kg of CO2 emitted by heating with gas per household per year the CO2 emissions of electricity consumption are relatively negligible.

It should be noted however, that due to data limitations the emissions presented here are only based on energy consumption and not on indirect CO2 emissions that arise through the consumption and usage of other goods and services such as food, digital devices or furniture.

B. Household Waste

The average output flow of household waste is expressed in terms of kg/household/year. As shown in *figure 13.0*, it is constituted of two different flows: the total household waste and the cleansing. The latter represents the total amount of waste resulting from the common spaces and municipality maintenance, divided by the total amount of household. The result is equivalent to the average responsibility of a household in waste for the common good. The second flow encompasses all individual household waste. Its major components are mixed household waste (plastic packaging as major part), paper and cardboard, bulky household and garden waste, wood, rubble, container glass and others. The category interestingly, the organic waste share accounts for one fifth of total household waste, representing the second largest contributor to household garbage. Despite its potential for composting, no efficient collection system has been implemented in Amsterdam these last decades.

Figure 13. Household waste (output)



C. Waste Water

The average output flow of water is expressed in terms of L water per hh per year. It consists of two flows as shown in the figure. Blackwater in a sanitation context denotes wastewater from toilets, which likely contains pathogens. Blackwater can contain feces, urine, water and toilet paper from flush toilets. Greywater is wastewater generated in households from streams without fecal contamination, i.e. all streams except for the wastewater from toilets. Sources of greywater include, sinks, showers, baths, clothes washing machines or dishwashers. Most of the water is used in toilets and bathrooms. Recycling this water could reduce water consumption. However, due to the limitations of the data, it could not reflect the flow of recycled water.

Figure 14. Waste water (output)

2) Songsan Green city east district(Water)

For the MFA analysis of Songsan Green City, data on unit production and consumption of each material is needed. However, since data on food, energy, and matter could not be collected in Korea, the analysis was conducted only on water where data could be collected.

The average use of water and sewage in Songsan Green City was calculated by taking into account the number of people in 2019 and the number of planned generations by utilizing the Ministry of Public Administration and Security's statistics on resident registration.

The total usage and average annual usage per generation were calculated by utilizing the Ministry of Environment's water statistics (2017) and internal data from the Songsan sewage treatment plant operated by K-water.

Table 3. The use of water in korea

Toilet	Kitchen	Washing	Bath	Washbasin	Etc.
25%	21%	20%	16%	11%	7%

Source: http://water.nier.go.kr/front/waterEasy/knowledge02_02.jsp

Table 4. Data of water use

Month	Household	Population	population per household	Water supply		Sewage	
				Daily average	Yearly average	Daily average	Yearly average
1	3,658	10,991	3.005	173	1,901,443	196	2,152,000
2	3,744	11,264	3.009	173	1,948,672	184	2,072,000
3	3,791	11,399	3.007	173	1,972,027	191	2,177,000
4	3,815	11,492	3.012	173	1,988,116	200	2,294,000
5	3,839	11,560	3.011	173	1,999,880	226	2,608,000
6	3,855	11,607	3.011	173	2,008,011	238	2,760,000
7	3,863	11,658	3.018	173	2,016,834	230	2,685,000
8	4,234	12,837	3.032	173	2,220,801	234	3,002,000
9	4,830	14,563	3.015	173	2,519,399	240	3,496,000
10	4,827	16,419	3.401	173	2,840,487	210	3,455,000
11	5,912	17,677	2.990	173	3,058,121	206	3,635,000
Avergae	-	-	3.046	173	2,224,890	214	2,757,818

Table 5.Calculation result of water use

Population per household	Water supply		Sewage		Etc.
	daily	yearly	daily	Yearly	
3.046	527 L	192,367 L	652 L	237,597L	

Source: water-supply statistics (2017), K-water internal repert

Figure 15. Songsan water (input)

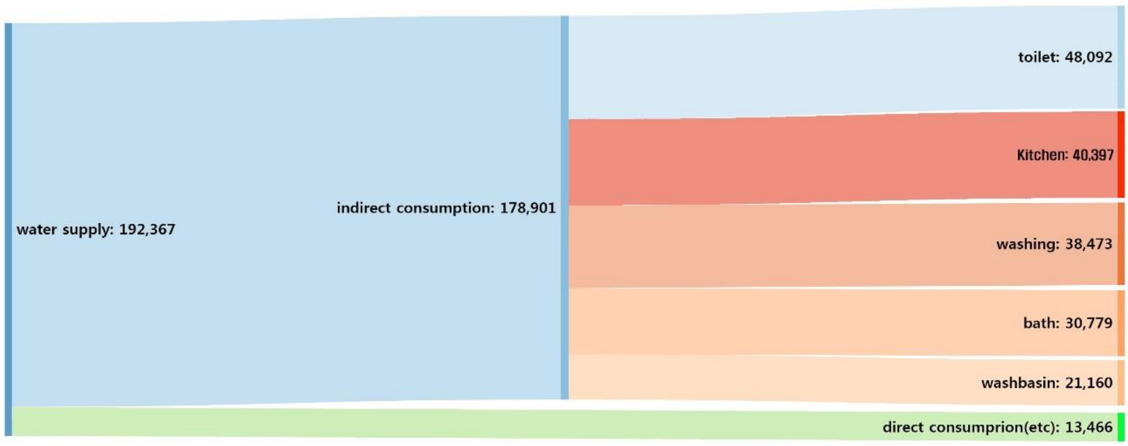


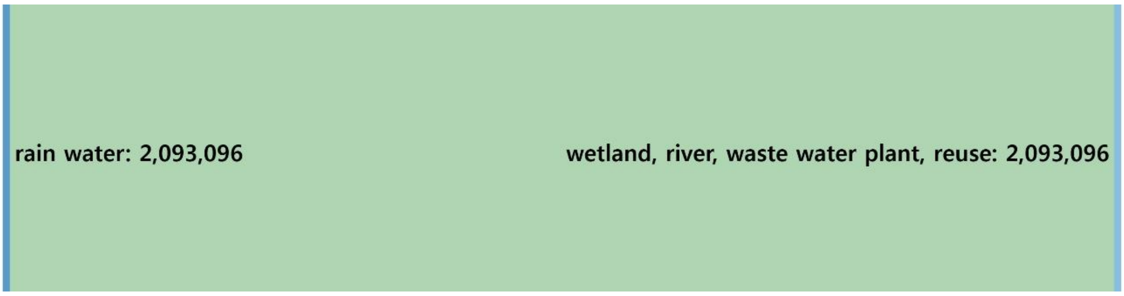
Figure 16. Songsan water (output)

Comparing the flow of water usage in Amsterdam, the Netherlands, the usage pattern is similar, but the usage per household is more than double that of Songsan Green City.

According to the analysis of water consumption, sewage throughput is estimated to have a similar proportion of black and gray water in the city of Amsterdam, but unidentified sewage treatment is estimated to be discharged into the stream through the reservoir.

Figure 17. Songsan rain water

Figure 18. Stadiobuurt rain water.



The annual rainfall calculated from the average rainfall in Songshan Green City and the Netherlands Stadium Butte area is as follows. The amount of rainwater available per year compared to the unit area is estimated to be 1.5 times more than Songsan Green City. However, in both areas no data were available on the specific flow and use of rainwater.

6. Suggestions & Limitations

MFA analysis of water in Korea and the Netherlands shows that Korea uses about twice as much water supply as the Netherlands. The reason why Korea's water consumption is high is because of the demand for water space created by rapid urbanization and economic development, green space near residential complexes and landscaping water for water supply and leisure water for amusement are needed. Many studies have shown that landscaping and leisure water can be used by recycling rainwater. In Korea, however, most still use water supplies (Kim & Lee, 2004).

In the case of the Netherlands, the whole city is sponged against rainwater based on institutional and non-institutional devices to utilize rainwater.(Dai, van Rijswick, Driesen, & Keessen, 2017).Prevent excessive water discharge by keeping and storing the area as long as possible. This is done through measures such as placing green roofs and water reservoirs in the garden on public infrastructure, such as water squares in public places, and private land.

For these measures, the Netherlands clearly presents parts of the collection and treatment of rainwater in a systematic way in accordance with Article 3.5 of the Dutch Mystery and provides opportunities for more investment by local governments to provide the most effective subsidies in an uninstitutional way (Mees, Driesen, Runhaar, & Stamatelos, 2012) and to manage revenues such as taxes to give authority to the most responsible local governments (Dai, Wörner& Rijswick, 2018).

Figure 19. Netherland rain water use case

<Rain roof garden>

<Rain beer>

<Multipurpose Space(detention pond, sports facilities)>

To protect the city from flooding, increasing the landscape of sewer pipes or building additional dams requires a huge budget. And the proliferation of rainwater recycling facilities can play an important role in urban water use (landscape and leisure) as a useful water source for the city.

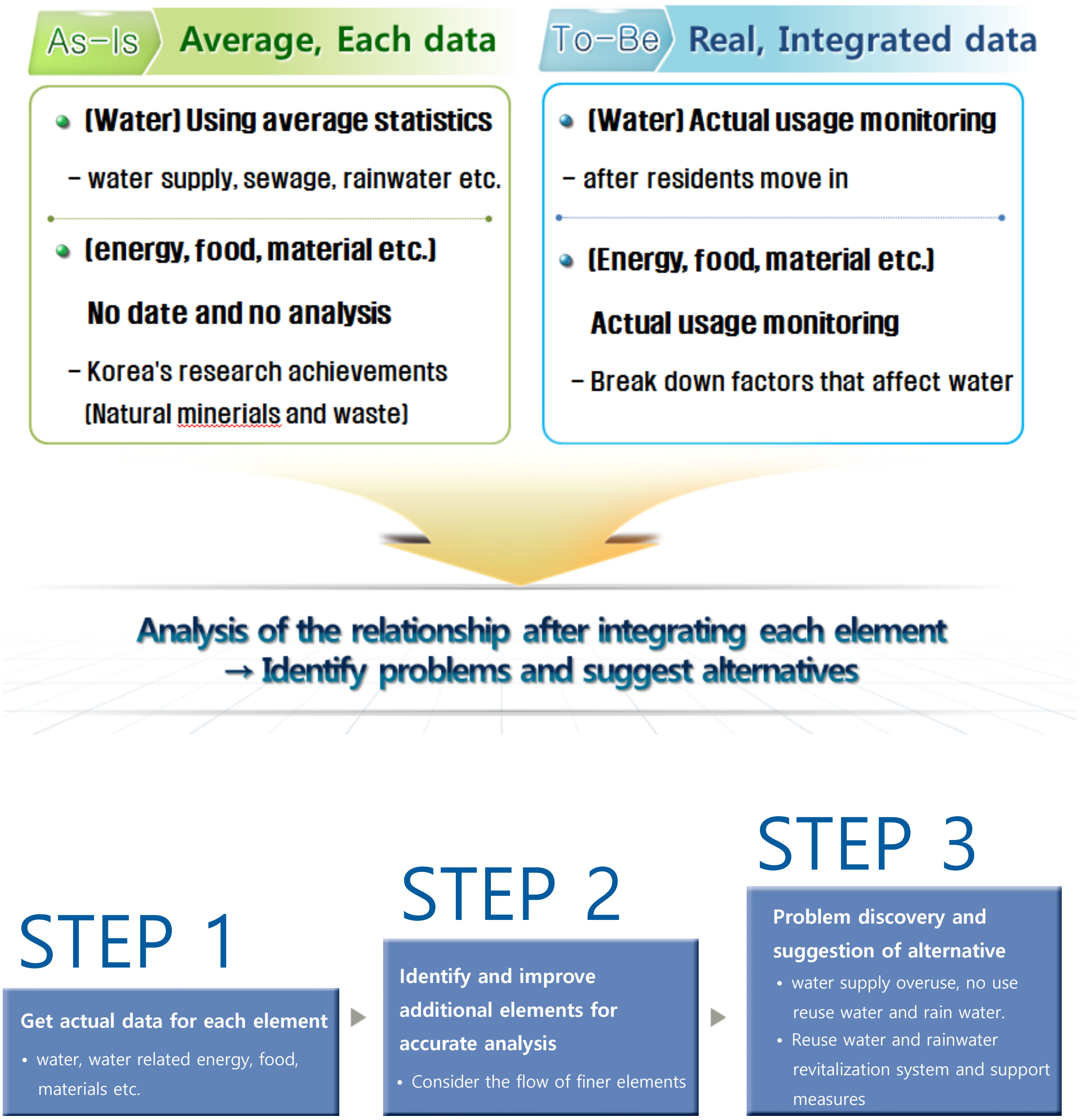
The Netherlands is committed to promoting the use of rainwater by the following laws, municipalities and subsidies: Of course, Korea is also implementing various policies to promote rainwater use through laws and subsidies etc.. In Korea, however, full-scale research has been conducted since the 2000s. At the urban level, monitoring is conducted through a few pilot cases. In the case of the Netherlands, the establishment of governance for cooperation and participation of governments, local governments, companies, civic groups and individuals for practical solutions is ahead of Korea.

Table 6.Comparison of rainwater institutions between the Netherlands and Korea

Netherlands	Law	·The spatial planning act 2.1, 3.1 ·The Environment management act 3.6, 4.22, 4.23, 10.33 ·Dutch water act articles 3.5, 3.6
	Subsidy, incentive	·Smart roof
Korea	Law	·Act on the Promotion and Support of Water Reuse
	Subsidy, incentive	·Reduction of sewerage system usage fee. etc.

To increase the accuracy of the MFA analysis, monitoring of rainwater must precede. However, in the Songsan Green City east side, there is no result of monitoring the amount of storage and reuse for rainwater. Also, since the city has been established for about a year, it cannot be considered as stable use and throughput. To conduct accurate and reliable analyses, analysis is required through data collected after some time has passed since residents moved in.

Figure 20. Road map for MFA



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