From resource draining to maintaining:

A research on improving urban metabolism

with urban farming methods.

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Acronyms

CEA =	Controled Environment Agriculture
MFA =	Material Flow Analysis
WTE =	Waste To Energy
WWTP =	Waste Water Treatment Plant
CHP =	Combined Heat and Power
HVAC =	Heat, Ventilation and Air-Conditioning
MSW =	Municipal Solid Waste
OFMSW =	Organic Fraction of Municipal Solid Waste
SW =	Sewage Waste
NPK =	Nitrogen (N), phosphorus (P), and potassium (K), macro-nutrients used by plants to grow.
PPM =	Parts Per Million
J =	Joules
GJ =	Gigajoules (J x 10^9)
TJ =	Terajoules (J x 10^{12})
PJ =	Pentajoules (J x 10^{15})
W =	J / s
kW =	Kilowatt (W x 10^3)
MW_{th} =	Megawatt (W x 10^6) thermal energy
MW_e =	Megawatt (W x 10^6) electric energy
KWh =	Kilowatt hour (3600 KJ)
T =	Tonnes (1000 kg)
ha =	Hectar (10.000 m^2)

Abstract

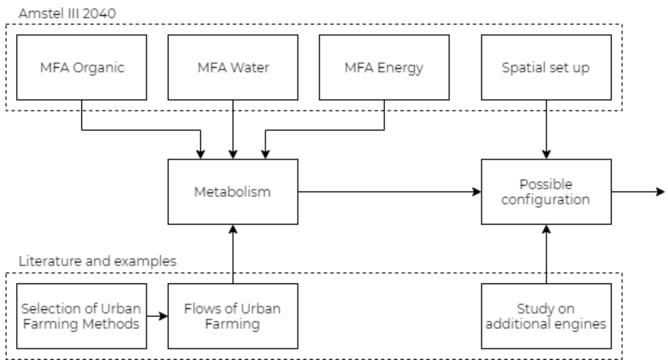
The area of Amstel III will drastically change by 2040 into a lively urban district. This change allows for the rethinking of the urban metabolism of the area, to shorten the material cycles and by better utilization of resources. Through estimation and calculations on potential flows related to energy, water, and organic material the potential impact of urban farming is given with a plausible configuration for the 2040 scenario. Organic waste flows are significant enough to provide the necessary nutrition for about 4250 tonnes of food yearly, which is a large portion of the diet consumed in Amstel III. To enable this food production urban farms of 70 ha of arable land and 80 ha of CEA need to be integrated into the urban plan, and additional engines such as a local biodigester, CHP and simple WWTP are necessary. Furthermore, there is much potential in the harnessing of solar, wind and thermal energy in the district, potentially making the district for nearly 75% independent on energy. The impact of the proposed configuration of the metabolism could save valuable depletable mineralized fertilizers, for example about 12 tonnes of phosphorus and 29 tonnes of nitrogen can be recovered each year in the form of digestate, as well can 15000 tonnes of carbon dioxide be captured from the organic waste to be utilized for food production in CEA.

Introduction

This paper explores the potential of the development of urban farming methods in the Amstel III area as a means to improve the circularity and self-sufficiency of its urban metabolism. This as the groundwork for the development of strategy and design intervention for the area. Currently, the Amstel III area is starting to transform from an entertainment, vacant office and business area to a lively mix of different kinds of functions with the introduction of housing, a transformation with the characteristics of a small city. One of the ambitions set by the municipality is to develop the area into a sustainable district. An honorable ambition which should also be a necessity these days. (ZO!City, & Gemeente Amsterdam. (2015)) The existing plans look at the utilization of excess heat for housing and there are plans for the harnessing of wind energy, but an all-inclusive plan is not been made on the overall sustainability of the district.

The scale and program of Amstel III offer a new approach to the topic of sustainability, more according to the concept of urban metabolism and with a broader range of topics. Looking beyond the built environment and think about the use of the area becomes a new chapter in sustainability. Could for instance Amstel III not only become an example of sustainable energy, but also a front runner on the topic of nutrition management? This as a way to extract more from waste streams and save valuable nutritional resources from exhaustion (Fixen, P. E. (2010)).

It is proven that since the industrialization modern cities have become absorbers of resources extracted from elsewhere, became detached from their hinterlands and the natural cycle of resources. They developed an urban metabolism that is characterized as being linear. Exemplary, Amsterdam, unfortunately, incinerates most of its waste, including most organic waste, with it a large fraction of depletable nutritions still present in the matter (Kool, A., Marinussen, M. & Blonk, H. (2012)). At the same time, the world becomes more and more urbanized, a trend that brings with it the rise of food-illiteracy. The first purpose of this paper is to visualizes the energy, water and organic material flows of Amstel III, secondly it researches the potential impact of urban farming and thereby aims to give an alternative strategy in which urban farming can be used to improve the metabolism. Furthermore, a potential configuration of urban farming is made including the essential engines to set up the scheme.



Research Framework

1
Metabolism of Amstel III 2040

The purpose of this research is to determine the hypothetical role of different methods of urban farming in its urban metabolism and to deliver a strategy, the research will focus on the flows related to urban farming. Therefore it extends to three different topics that are affected by urban farming. This way the MFA is narrowed down to the topics energy, water, and organic material flows. Conclusions made out of the total of the three MFA's are on the scale of Amstel III as a single system, this done because three different fields have different subsystems to take into account which cannot be compared directly with one another. This scale is chosen since the area exist out of many different actors and is based on a prognosis of Amstel III in 2040, a thorough research on for example on building scale would not only surpass the goal for an overall strategy of the area but it would be a task too complex with too many uncertainties to deliver hard conclusions. Therefore the different subsystems of Amstel III are simplified into a maximum of four to six elements for each MFA when the data is not available for this scale an area sized estimation is given on the total of Amstel III based on comparable researches. Also, subsystems who are not directly related to urban farming such as traffic and indirect flows that pass through the system but do not interact are not included in the final MFA's.

1.1 Energy

For the input, the different energy flows analyzed are electricity, natural gas, thermal (cold/heat) and potential local renewable energy sources. Biomass as an energy source will be handled in the organic MFA. The function analysis of the area (Appendix I.II & II.II) shows the most important actors in the area in the field of energy. These are summarized as the industry and offices of the area of Amstel III, the Medical Center (AMC), the multiple data centers and the entertainment boulevard (Bijlmerpoort West). For the situation of 2040, an extra subsystem is included, which is the addition of 15,000 households (ZO!City, & Gemeente Amsterdam. (2015))

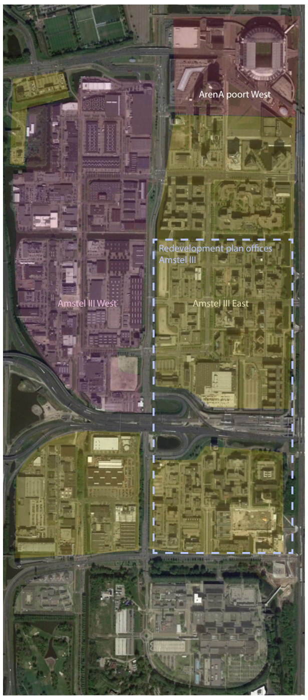


Figure A, Appendix I.II Program map

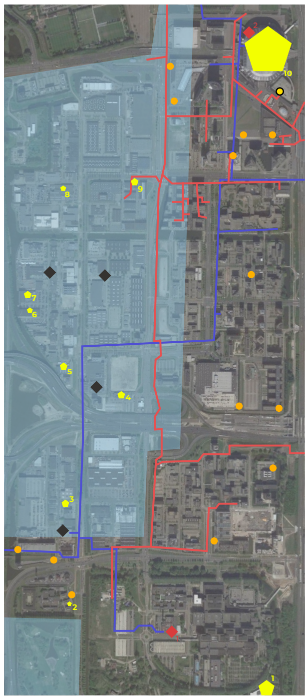


Figure B, Appendix II.II Energy network

1.1.1 Natural gas
It is clear that the current situation is still heavily dependent on natural gas, the MFA (Appendix II.VIII) shows the drastic changes that need to take place to make Amstel III 2040 proof.

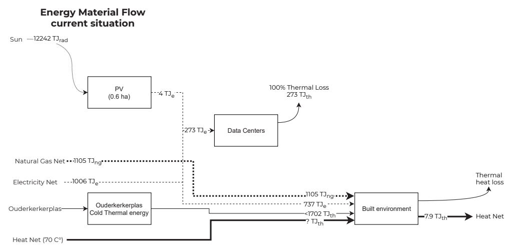


Figure C, Appendix II.VIII current energy MFA

Amsterdam wants to get rid of its dependence on fossil fuels for the energy of the city by 2050 (Gemeente Amsterdam,(n.d.)). Amstel III consumes 4% of the total natural gas of Amsterdam, which has a caloric value of 1105TJ. (Appendix II.I) In the current situation, the largest consumer of natural gas is the AMC. The city block it is part of (city block 22656) consumes nearly halve the natural gas demand of the area. (Appendix II.I), as it is partly being used to generate electricity for the building. Natural gas is now primarily being used for heating of buildings. (Choi, C., & Van Heeswijk, T. (2014)) The municipality's strategy is to replace natural gas by district heating in combination with better insulation of buildings as an alternative. (Voskamp, I. M. (2017))

1.1.2 Electricity
Currently, Amstel III is responsible for 6% of the total electrical energy consumption of Amsterdam, about 1006 TJ (Appendix II.I). According to Choi, only 6% of this energy is considered sustainable,

furthermore, about three quarters comes from a Waste To Energy (WTE) plant (AEB). Which makes the label sustainable energy for the mentioned flow disputable. Specifically, Amstel III requires relatively more electricity as opposed to natural gas probably due to the 4 data centers in this area. (Appendix II.II) Locally the renewable electrical energy is delivered by a collection of PV-pannels, most of them are positioned on the roof of the J.C. ArenA. (Appendix II.II) As by now, only a small fraction of the solar power in the area is being used delivering about 4 TJ in 2017. If all of the 85 ha rooftop (Appendix III.IV) would be covered with PV-pannels with an efficiency of 15% about 410 TJ yearly would be reachable. (Appendix II.III)

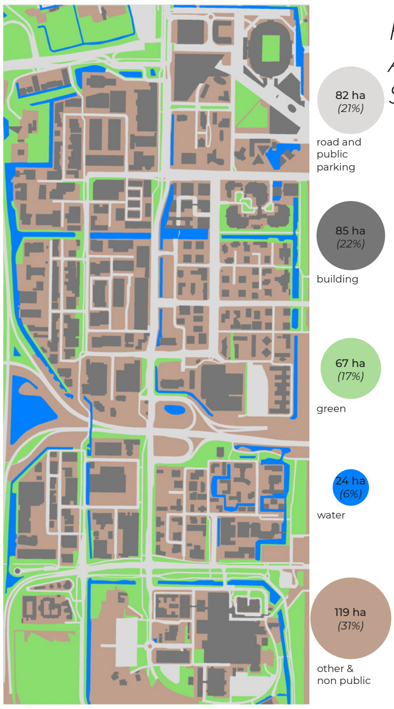


Figure D, Appendix III.IV Surface types

The western part of Amstel III is suitable for the harnessing of wind energy as seen in figure B, Appendix II.II. According to maps.amsterdam.nl, it has the potential of generating 389 TJ yearly.
In the future, the demand for electrical energy for the area will probably increase due to the coming of a fifth data center and the addition of housing to the area. (Restwarmte datacenters voor nieuwbouwproject Amstel III. (n.d.)) (Voskamp, I. M. (2017)) On the other hand, the average energy demand per function will drop due to better building physical properties, such as isolation, ventilation, more efficient equipment, and heat recovery units.

1.1.3 District heating

Underneath the ground of Amstel III, there is a network of tubes for heat and cold energy distribution. (Appendix II.II) The area is one of the first in Amsterdam to have received district heating. Its network is connected to the districting heating of Amsterdam Zuid, Zuid-Oost and Amstelveen. The Diemercentrale is the main provider with 1.8 PJ to 19 thousand users of the total network in 2018, this number is expected to grow to 33k users with a capacity of 2.3 PJ in 2023. Currently, this thermal energy is a product of natural gas as Diemercentrale is a Combined Heat and Power plant (CHP), however, policy is to move to renewable sources in the future (ECN & TNO (2019)). Vattenfall, the owner of the plant, had plans to built a new biomass-fueled power plant to deliver heat energy and electrical energy, however, these plans are in jeopardy due to critique on the sustainability and local environmental impact of the plant.
In Amstel III numerous office buildings on the eastern side are connected to the district heating and using the warmth, the amounts they use are not given. According to maps.amsterdam.nl there are two local suppliers of heat energy; the J.C. ArenA and the AMC, together with good for 8 TJ of thermal energy in 2017 (figure C, Appendix II.VI). The data centers in the area do not seem to provide thermal energy to the net, this is an opportunity still to be utilized. According to an article on this topic on the data centers in Amstel III, it can provide for thermal heat of about 30 C°. From data on heat production by data centers and the total surface area it is estimated in Appendix I.III to be that these facilities could provide for 163 TJ of heat energy in 2040. (Netherlands Data Centers & Colocation (n.d.)).

Heat energy produced

production	https://maps.amsterdam.nl/energie_restafval/	
AMC	1576800	KWh
ArenA	630000	KWh
total	2206800	KWh
	7944.48	GJ

Electrical Energy Usage Data Centers		
	3.5	MWh/m2/y

Current Situation

	ft2	m2	MWh/y	TJ/y	
EQUINIX AMSTERDAM AM5	64,583	6000.0	21000	75.599426	
EQUINIX AMSTERDAM AM1 AM2	90,956	8450.1	29575	106.47107	
INAP AMS LUTTENBERGWEG 4	-	4000.0	14000	50.4	*estimated
EQUINIX AMSTERDAM AM7	36,597	3400.0	11900	42.839636	
Total		21850	76475	275	

2040 Situation

	ft2	m2	MWh/y	TJ/y	TJ recovery (50%)	
EQUINIX AMSTERDAM AM5	64,583	6000.0	21000	75.599426	38	
EQUINIX AMSTERDAM AM1 AM2	90,956	8450.1	29575	106.47107	53	
INAP AMS LUTTENBERGWEG 4	-	4000.0	14000	50.4	25	*estimated
EQUINIX AMSTERDAM AM7	36,597	3400.0	11900	42.839636	21	
NEW DATA CENTER	-	4000.0	14000	50.4	25	*estimated
Total		25850	90475	326	163	

Figure E, Appendix II.VI Thermal energy

1.1.4 District cooling

South-west from Amstel III lies the Ouderkerkerplas, a man-made lake that is now being used to extract cold thermal energy due to its dept. The lake cools down in the winter, creating a buffer for cold energy in the summer as cold as 12°C. This method of cold extraction can be regarded as an efficient and nearly passive way to supply for the cold demand of the area. Through a system of tubes, a large area of the Amstel III area is covered. (Appendix II.II)
Plans for the system were set up by energy company NUON in 2007 and the system was put in use in 2010. Users of the system would be the AMC, office buildings in Amstel III in Bullewijk and Amsterdam Poort. (Appendix II.IV) It was estimated that the area would demand 54 MWth average, this amount

of thermal actual energy would translate to saving about 68TJ yearly of electrical energy compared to a standard Energy Recovery Ventilation systems used in offices with an efficiency of 2.5. (Eilering, J. A. M., & N.V., N. W. (2007)) Interesting is that only about 36% of an average year's cold capacity of Ouderkerkerplas was being utilized in this plan. Furthermore the use of Gaasperplas, which lies further to the east of Amstel III, as cold source was taken into account, however, the website of www.amsterdam.maps does not show a cold-net including Gaasperplas in the system. In an article from 2016 a representative of NUON mentions that the demand for cold energy was lesser than expected in 2007 due to the canceling of the construction of new offices during that time and less utilization of the cold energy by the connected buildings. (Bouw en Uitvoering (2016)) This implies that there is still huge potential for using the cold capacity of Ouderkerkerplas, probably about 80% which is untapped.

1.1.5 Future waste energy and energy saving

The efficiency in which the energy is utilized is influenced by the insulation, use, equipment and installations of the buildings. According to Dirk Sijmons (2014) in his book Landscape and Energy, in the current situation, about 20 % of the energy is unused in utility building. This is factor resembles the data analysis of ECN & TNO. (2019) in Rapport Monitoring Warmte 2017. This mostly escapes as excess heat. For the scenario of 2040, energy demand for heating is taken to be reduced with 20% due to better utilization of heat and better isolation. (Figure C and F, Appendix II.VIII and II.VIV)

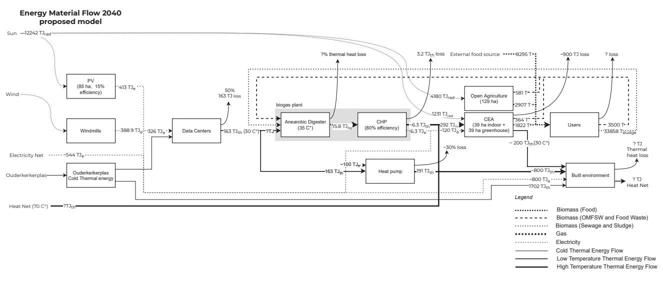


Figure F, Appendix II.VIV energy MFA 2040

1.2 Water

On the topic of water two flows are analyzed, these are the flows of precipitation and that of drinking water. The scope of this study is to first know the quantities of water and secondly to discover where these lead to.

1.2.1 Precipitation

According to www.climate-data.org the average amount of precipitation in the area of Amsterdam is 805 mm yearly. For the total 377ha of the area researched (figure D, appendix III.IV) this about 3 hm³ of water, equivalent of 600 Olympic pools.
It is interesting to know where this amount ends up to know what can be done with it. There is no clear data on the flows of water in the area of Amstel III. So it estimated based on research on infiltration rates of precipitation in urban areas and hardscapes. (Markovič, 2014)(Butt, 2014) The research makes a distinction between three types of surfaces, natural, 50% impervious and 75-100% impervious. As to be expected the water ends up in different percentages in different flows, that are:

-Evapotranspiration, which is a combination of evaporation and transpiration by plants that end up in the atmosphere.
-Infiltration into the soil, in the paper of Butt a distinction is made between deep infiltration and shallow, for the scope of this research, this distinction is not made.
-Runoff, this is water that does not infiltrate or evapotranspirates, mostly ends up in storm drains or open water.

These infiltration rates are seen in Appendix III.III (figure G).

surface infiltration	Into soil	runoff	evapotranspiration
Hard	*15%*	*55%*	*30%*
Natural	*50%*	*10%*	*40%*
Mixed / half hard	*35%*	*30%*	*35%*

Figure G, Appendix III.III surface infiltration

These are quantified over analyses on surface types in the area Appendix III.IV. The outcome of the type of infiltration is depicted in a Sankey diagram in figure H.

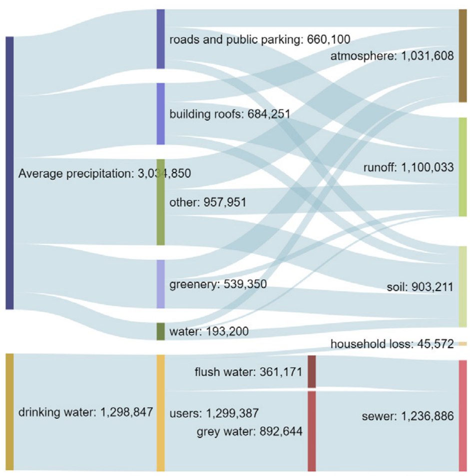


Figure H, Appendix III.IV water MFA in Amstel III in 2040 (in m³)

Hardscapes such as building roofs normally are problematic for the existing infrastructure that deals with rainwater. Due to the ambitions of the developers on a higher building density, this could become a problem for the area.

Expectations for 2040 on the amount of precipitation are unsure, it is hard to say if the average yearly amount is going to change, however, it is sure that the weather will get more extreme with more heavy rain and longer periods of droughts. (KNMI - Hoeveel meer regen gaat de toekomst brengen? (n.d.).) Therefore, in the water MFA of 2040, the input of precipitation is taken the same as in 2019, however, it can be expected that the climatic changes influence the flow of the water when it hits a surface. But since it is too speculative to assume how, this is neither changed in the diagram of 2040.

1.2.2 Drinking water

The drinking water use is also based on the average use of water by inhabitants. Most drinking water ends up in the sewer, it is being used for practices within buildings such as cleaning which leads it to become grey-water or to flush the toilet which makes it black-water. Only a small fraction of Amsterdam's drinking water, about 4%, does not end up in the sewer, this is lost. (Van der Hoek (2017)) (Appendix III.II)
In Amstel III the total amount of grey- and black-water produced is about 89,000 m³ and 346,000 m³, by 2040 this is expected to rise to 120,000 m³ and 467 m³. (figure H)(Appendix III.IV)

1.3 Organic

As mentioned earlier, the current waste management system revolves around the use of the waste-to-energy plant, which incinerates the organic with the inorganic providing for electricity and heat energy. However, in this process resources are lost.
In this MFA (Appendix IV.XV) the organic waste streams of Amstel III are analyzed for a couple of reasons, firstly to determine the nutritional value it contains for agricultural purposes and secondly the amount which is consumed in the area. Lastly to see what amount of energy it could provide for.

1.3.1 Organic flows related users Amstel III

Figure C shows the amount of food consumed currently in Amstel III. In Appendix I.II the different actors are shown which are analyzed to give an estimation of the current situation and the future, these are summarized in Appendix IV.I. Currently, nearly 10 million kg of solid food and about 20 million kg of liquid food is consumed in Amstel III yearly. Most of this is consumed by the workers and recreational visitors to the area. With the coming of 15000 households, the amount of solid and liquid food consumed in 2040 is estimated to increase with about 1/3. (Figure I and Appendix IV.I)

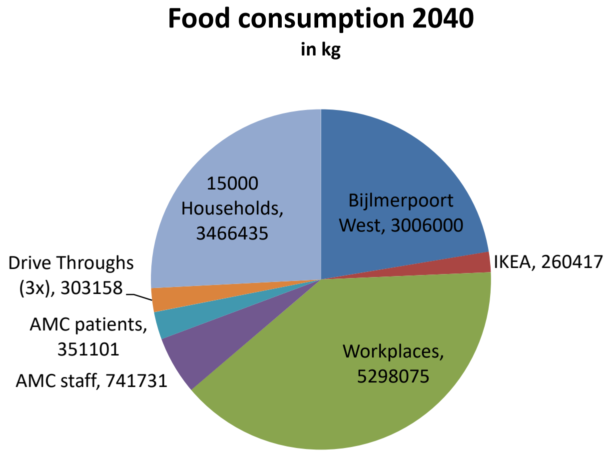


Figure I, estimated food consumption in Amstel III in 2040

Per person, we consume about 3.1 kg of food daily and we throw away about 62 kg of solid food and 57 kg of liquid food yearly. (Inname alle macronutriënten | Voedselconsumptiepeiling. (n.d.).), (Milieu Centraal, 2017) Solid food waste makes up for the largest part of the Organic Fraction of Municipality Waste (OFMSW). In Amsterdam, only a relatively small fraction of the organic waste comes from households gardens, this is about 1/7 of the OFMSW per inhabitant. Liquid food waste ends up in the sewer system. Per person we defecate about 0.1 kg feces and 1.5 kg of urine daily, this is flushed down the sewer. (Ons dagelijks (afval)water - NEMO Kennislink. (n.d.)). The other 1.5 kg is mostly lost through transpiration. (Figure J, Appendix IV.III)

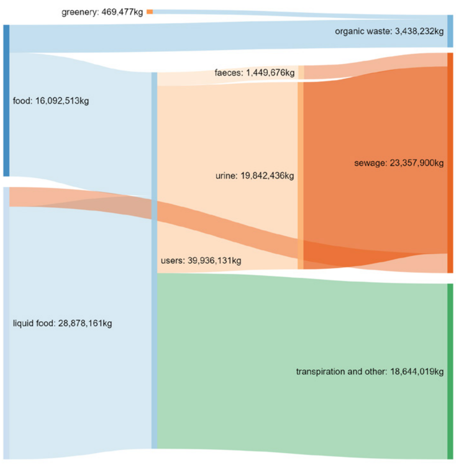


Figure J, Appendix IV.III organic MFA of Amstel III in 2040.

1.3.2 Potential energy extraction from organic waste

The calorific value of the biomass determines the amount of energy it contains. Theoretically, this can be by looking for organic carbon in the organic structure (43. Frijns, J., Hofman, J., & Nederlof, M. (2013)). Especially high amounts of fatty-acids imply a high calorific value, cellulose like organic material such as fibers also contain energy. However, these are harder to obtain.
Extracting energy from biomass can be done in

multiple ways. The most straight forward method is by burning the matter, this is already done by the WTE plant in Amsterdam West (AEB). About half the input for this waste to energy plant is OFMSW. Burning organic matter releases all the energy. However, it requires the waste to dry at first, this requires additional energy. Especially for sewage sludge, this is a problem. According to Frijns, this requires nearly as much as it generates.

If all organic waste would be treated separately from other MSW. It could be more efficient to make use of anaerobic digestion instead of the current WTE plant. Anaerobic digestion is a biotechnological process by which a complex organic feedstock is first converted into a range of simpler water-soluble organic compounds that are subsequently converted into methane-containing biogas. (Kleerebezem, R. (2014).) The process of anaerobic digestion has the advantage to separate the organic carbon into gasses (biogas) from the organic matter. Biogas consists of 50 to 70% vol.% of methane, 30 to 50vol. % carbon dioxide as well as small amounts of water, hydrogen, and hydrogen sulfide. Biogas can be upgraded to greengas (~90% methane) and be used as natural gas replacement for households or can be used directly in for example CHP plant for heat and electrical energy. In Appendix III.VII (figure K) a calculation of the potential for anaerobic digestion is shown according to the research paper of R. Kleerebezem and J. Frijns.

DATA (Paper, Kleerebezem)	
Normal volume of 1kmol gas (m3)	22.4
E (n,CH4) (MJ*m^3)	36.5
Efficienty electricity generation	40.00%
MJ*kmol^-1	818

	molaire mass
C	12.011
H	1.0079
O	15.999
N	14.0067

DATA properties waste	biodeg %	H	O	N	ODM (g / kg)	Biogas (L/kg	CH(%)
OFMSW	50%	2.1	0.96	0.024	270	106	53%
Food	75%	2.32	0.85	0.019	270	169	58%
Sewage sludge	35%	2.18	0.94	0.057	45	24	55%

INPUT	yard/garden (OFMSW)	food (%)	sewage sludge (%)	other (OFMSW)	amount (kg/d)	ODM (kg)	Biodeg(%)
Garden	100.00%	0.00%	0.00%	0.00%	1299	**350.60**	50.00%
Food waste	0.00%	100.00%	0.00%	0.00%	8258	**2229.70**	75.00%
Sewage sludge	0.00%	0.00%	100.00%	0.00%	92762	**4174.29**	35.00%
				Total:	102319	**6755**	**38.42%**

Properties feedstock	C	H	O	N	Molaire Mass
Resort organic	1	2.1	0.96	0.024	29.8227908
Local organic	1	2.32	0.85	0.019	28.2146053
Greenhouse waste	1	2.18	0.94	0.057	30.0456639
Total feedstock	**1**	**2.190**	**0.933**	**0.054**	**29.89505037**

Substrate	CH4	CO2	NH4HCO3	H20
Produced	0.56	0.43	0.05	-0.08
kmol/day	48.66325029	36.9801737	4.645287568	-6.908258667
kg/day	780.6850592	1627.46047	362.5475071	-124.4508982

Quantity	kmol/day	kg/day	m^3/day	CH4	CO2
Biogas	85.64342403	2408.14553	1918.412698	56.82%	43.18%

OUTPUT EL	hour	Daily	Weekly	Yearly
biogas (m^3)	80	1918	13429	700221
MJ (bruto)	1658	39787	278510	14522282
kWh (bruto)	460	11052	77364	4033967
kWh (netto)	**184**	**4421**	30946	1613587

OUTPUT CO2	hour	Daily	Weekly	Yearly
CO2 (in biogas) (m^3)	34.51482882	828.355892	5798.491242	302349.9005
CO2 (due combution) (m^3)	45.41903361	1090.05681	7630.397646	397870.7344
total CO2 (m^3)	79.93386243	1918.4127	13428.88889	700220.6349
total CO2 (kg)	**158.7486508**	**3809.9676**	**26669.77333**	**1390638.181**

Figure K, Appendix IV.XII, Calculation Gas, Electricital and Carbon Dioxide potential from organic waste stream Amstel III 2040 through anaerobic digestion and gas turbine.

Higher amounts of food waste result in higher amounts of biogas, sewage contains less organic carbon per kg thus has a lower calorific value. With the expected amount of waste produced in 2040, a total maximum of 14.5 TJ of energy can be obtained compared to the current natural gas demand would be about 2% of the demand, converted with an efficient CHP (40% efficiency) this would be 5.8 TJ of electrical energy which is not even 1% of the demand.

1.3.3 Potential nutritions extraction from OFMSW and SW

Another, and for the case of urban farming more profound argument for the processing of organic waste is based on resources management. The processing of organic matter through anaerobic digestion and using the residue for agricultural practice is advocated by Wageningen University and Research PHDer Meino Smit. From the perspective of sustainable agriculture, she argues for the use of all organic waste streams to counter the nutritional depletion of our food system. (Trouw, 2018)
The primary nutrients for plants are NKP (Nitrogen, Phosphorus, Potassium), most crops need all or most of these nutrients added in the form of fertilizer to be able to grow. In our current global food system these nutritions come mostly from fossil fuel or are mined minerals, they are delivered in the as mineralized fertilizer. 80% of N in the form of ammonia (NH_3) is obtained from natural gas. It costs huge amounts of energy to produce, 35 GJ/ton ammonia. The phosphate in P-fertilizers originates from mined phosphate rock and/or synthetically produced phosphoric acid, Potassium (K-fertilizer) comes from different forms of minerals. Especially phosphate reserves are getting more scarce. (Kool, A., Marinussen, M. & Blonk, H. (2012)).
Currently, the municipality of Amsterdam recovers a fraction of the phosphate and smaller fraction of Nitrogen from the SW. This is done in an installation called Fosfaatje in Amsterdam West. According to van der Hoek sewage sludge is to some extent digested in a biodigester to extract biogas, the residual sludge is afterward been reacted in the installation to extract the Phosphorus and some Nitrogen in the form of struvite ($NH_4MgPO_4{\cdot}6H_2O$), used as fertilizer. Unfortunately, only a small part of the nutritions are recovered (16% of the Phosphorus). Also, most organic matter is not been digested, plausible due to the lack of organic carbon in the feedstock, and ends up in the incinerator of the WTE and is therefore not recoverable. (van der Hoek, J. P., Struker, A., & de Danschutter, J. E. M. (2017)) (figure L, Appendix IV.VI)

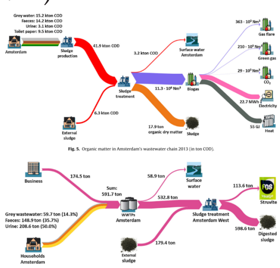


Figure L, Appendix IV.VI

Nutrition recovery by using the sludge more directly would be an interesting alternative. By taking the same values as the calorific value of the biomass from the paper of Kleerebezem. The amount of usable Nitrogen can be calculated in the mix of feedstock by calculating the amount of ammonia (NH_4) (figure M, Appendix IV.XIII t/m/ IV.X), which is about 4 tonnes of N yearly.

form	DM (%)	N(total) (kg/m3)	NH4 (kg/m3)	NH4 share (% of N)	P205 (kg/m3)	k2O (kg/m3)
Liquid digestate	6.5	5.1	3.2	62.7	2.3	5.5
Liquid separated fraction	5.7	4.9	3.1	63.3	2	5.4
Solid separated fraction	24.3	5.8	2.7	46.5	5	5.8

NITROGEN	N (g*kg-1)	amount daily (kg*d)	yearly (kg)	N(total) (kg)	N(absorbed) (kg)
Garden (OFMSW)	3	1299	473960	1422	892
Food	2.5	8258	3014228	7536	4725
Sewage sludge	1.2	92762	33858134.9	40630	25475
total		102319	37346324	49587	31091

PHOSPHORUS AND POTESSIUM	factor	kg yearly
P2O5	0.4509804	22363
K2O	1.0784314	53476

form	% in mass (m3)	N(total) (kg)	NH4 (kg)	NH4 share (% of N)	P205 (kg/m3)	k2O(kg)
Liquid digestate	100	49587	31091	62.7	22363	53476
Liquid separated fraction	95.7	49391	31265	63.3	24611	52124
Solid separated fraction	4.3	1875	872	46.5	9421	46442

Figure M, Appendix IV.XIII t/m/ IV.X

According to Fachverband Biogas in their magazine, Biogas Know-how on an issue on the use of digestate from biodigester data is given on the absorption of Nitrogen by crops. Direct absorption within a year's time frame is about 50% for liquid digestate and 30% for solid digestate, however, following years about 10% of the total is delivered in subsequent years. (Wilken, D., Rauh, S., Fruhner-Weiss, R., Strippel, F., & Bontempo, G. (2018, November)) This means the effective use of Nitrogen is about 2.6 tonnes. Amounts of P and K values in the feedstock are not given in the paper of Kleerebezem. Therefore it is assumed that the digestate in the issue of Biogas Know-How is similar in consistency of N and KP values, the consistency of liquid digestate in the issue is:

5.1 N = 3.2 NH_4 (62.7% share)
3.2 (NH_4) - 2.3 (P205) - 5.5 (K_2O)

The total amount of N in the calculated digestate of Amstel III would be 32.7 T yearly. This would translate to 23.5 T of P205 and 56.3 T of K_2O. According to the same source the total amount of PK is being absorbed by the crops and thus has a 100% use:

NPKdigestate = 32.7 TN, 23.5 TP, 56.3 TK

In the calculation of Appendix IV.XII on the potential energy, the amount of carbon dioxide (CO_2) produced is also given. CO_2 is in large demand in the horticultural industry and worth to be utilized in the scheme, as an extra benefit it means that carbon emission of the organic material cycle can be reduced. By upgrading biogas into greengas and the burning of the methane, the gas can be obtained and usable for commercial purposes. Every year the organic MFA could account for 14,000 tonnes of CO_2.

2
Flows of Urban Farming

Within this chapter, a distinction has been made between the different forms of (urban) farming. The first part of this chapter briefly explores some variations and secondly generalizes these to be able to determine the related flows and restrictions.

2.1 Agricultural methods

A distinction is made between different methods of agriculture based on their potential crop output and physical demands. These methods are later-on related to the diet of Amstel III and simplified to determine the related flows and relate the methods of farming to the urban metabolism of the area. The three main methods are:

- Arable farming, a method of farming more related large scale farming. It requires plowing of the land and produces staple crops such as grains, potatoes, flax, sugar beets, rapeseeds and some types of beans.
- Horticulture, originally the practice of garden cultivation. Since horticulture also includes the cultivation of decorative plants this research will only narrow down on the cultivation of edible plants. Horticulture ranges from open gardening and orchards to Controlled Environment Agriculture (CEA). When thinking about urban farming, this practice is most commonly done. The main edible outputs are fruits, vegetables, and nuts.
- Animal husbandry includes all breeding of animals for products for consumption such as meat, dairy, and eggs.

2.1.1 Categorization

To be able to calculate the flows, required surfaces and food production possible in Amstel III.
These different methods are generalized into two categories, first is CEA (controlled environment agriculture), which implies greenhouses, indoor farming, and vertical farming, and the second is open agriculture, meaning all arable agriculture and exposed horticulture. Animal husbandry is been calculated by feedstock (maiz) required per kg of meat, thus been seen as arable agriculture.

The biggest distinction in the application of the methods within the urban situation is the difference between earthbound and methods which are more applicable in a flexible manner such as a rooftop, vertical or indoor farming. Arable agriculture and orchards are for example unlikely to be placed in or on buildings. But CEA with the use of hydroponics or drip irrigation requires not a lot of soil and can be placed nearly anywhere for example. CEA can be done with or without the use of artificial lighting. When placed within buildings, artificial lighting is required of course.

2.2 Energy flows of farming methods

Gas and electricity are being used for growing in CEA. It is primarily being used for artificial heating and installations such as lighting, ventilation, IT and pumps. Arable agriculture generally does not demand direct artificially applied energy.
Natural gas is been used in large quantities in the greenhouse industry, it is used for heating and the production of CO_2. In standard greenhouses in the Netherlands use about 31 m3/m2 of natural gas yearly, more modern greenhouses could reduce the use to 12 m3/m2 by implementing isolated glazing and screens and making use of other sources of CO_2. (Gasverbruik in onderzoekskassen onder 40% van praktijkgemiddelde. (n.d.))
Electrical in CEA differentiates a lot per method. It is estimated to be about 50 KW/ha average. (Figure N, Appendix II.VII)

Amount rooftop GH	38 ha

Gass

type	nat gas /m2	energy / m2	total energy
Modern greenhouse	12 m3/m2	380 MJ/m2	144 TJ
Standard greenhouse	31.25 m3/m2	989 MJ/m2	376 TJ

https://www.onderglas.nl/gasverbruik-in-onderzoekskassen-40-procent-van-praktijkgemiddelde/

EL	av. demand per ha	av. demand total	total energy * y
Greenhouse	50 KW	1900 KW	60 TJ

Passive Solar	rad per/m2	total rad GH
Gross Solar Energy	3.24 GJ	1231 TJ

Figure N, Appendix II.VII
CEA energy demand

2.3 Nutritional flows of farming

The key factor in knowing the potential impact of urban farming within the framework of the urban metabolism is by calculating the nutritional demand of farming methods in order to relate these to the organic material flows present in the area.

2.3.1 NPK flow and agricultural demand

To estimate what could potentially be produced with the supply of organic material in Amstel III, it is necessary to know the nutritional demands of different types of crops. In a report from 1995 of Agrarisch Telematica Centrum (ATC) key numbers on NPK usage for crops are given per tonne of fresh produce (Figure O, Appendix V.I).
What is clear is that the NPK flow of Amstel III will not be sufficient to fertilize the demanded crops to

feed the users. Especially not if the diet is continuing to be largely consisting out of animal products. See figure D. (inname alle macronutriënten | Voedselconsumptiepeiling. (n.d.)).
In the last chapter, it was estimated that NH_4, P205, and K_2O values are 2663 kg, 1915 kg and 4580 kg. The NPK values of the Amstel III 2040 with the same diet as now would be 608 T, 217 T, and 741 T. This is largely due to the meat, dairy, and other animal products. Compared to the vegetable demand Amstel III (3511 kg, 2809 kg and 8953 kg) the amount of NPK available in the area has more impact. It is to be noted that in the NPK flow of waste for animal products are not calculated, this accounts for a significant fraction of nutritions in the form of manure that can be reclaimed.

2.3.2 CEA
Controlled Environment Agriculture (CEA) has pros and cons compared to open horticulture and agriculture. Horticulture was historically being done to extend the growing season by trapping the heat of the sun under glass. Due to the competitive agri- and horticultural market it evolved into high-tech greenhouses we have nowadays. (Viljoen, A., & Howe, J. (2005)) Greenhouses are characterized by their high yield rates in a partly or completely sealed off environment. Arguments for CEA opposed to arable or open horticulture are the management of resources which in most (modern) greenhouses is being done with hydroponics. It allows for better control of fertilizer and less spilling into the environment. Unfortunately, nearly all hydroponic farming is nowadays being done with mineralized fertilizer, thus unsustainable nutrients, this because it is more convenient to dose with mineralized fertilizers. But it is possible to grow with hydroponics system and the liquid fraction of digestate as a study on the growing of a type of lettuce shows in 2019 with a combination of solid and liquid digestate. (Ronga, D (2019)) A better understanding of the nutritional and microbiological consistency of digestate will make it even more commercially feasible in the future.

2.3.3 CEA and CO_2 dosing
Just as with humans in a closed-off and crowded room, plants can suffocate. For plants, this is the case by a lack of CO_2. Therefore it is necessary to ventilate with outside air or dose CO_2 in CEA's, the latter is done by most commercial greenhouses to even stir up the amounts of CO_2 above the amounts found in outside air. This to increase yield rates. In natural air, the amount of CO_2 is about 350 ppm, but it is common to increase the amount to 500 ppm or even 1500 ppm, in this case, yield rates can go up by 30% depending on the type of crops, light, humidity and other nutritions. Keeping such high ppm is necessary for a competitive market such as the Dutch horticultural industry. It is a practice that is highly disputable as the primary resource for CO_2 for a lot of greenhouses is the burning of natural gas. Extracting the CO_2 from biomass is a way more sustainable option as it uses the carbon already in the cycle. (RSFGV (1999)) According to RSFGV a greenhouse with a dosing of 40 - 80 m^3 of CO_2 and a height of 5 meters, would use about 32.3 kg of CO_2 per m^2 per year. This would mean that with the earlier calculated supply of 1500 tonnes CO_2 a year, about 4.6 ha of greenhouse area could be supplied.

2.4 Suggested set up
In Figure P, a plausible configuration is given of different types of crops that could be produced within Amstel III. The set up is determined by the utilization of NPK and the diet demands of the area, with the urban context in mind.
It consists of 35ha of orchard for fruits and nuts. 77 ha of CEA for the production of beans and vegetables. 106 ha of arable agriculture for potatoes, animal feed, and grains. Producing about 4829 tonnes of food yearly.
This has been calculated by taking into account the nutritional and biomass energy recovery of waste produced by farming.

Average diet nutritional needs

Demand	PP in grams	Tot. Amstel III in tonnes	Feed per kg	N (kg)	P205 (kg)	K2O (kg)	kCal (10^6)	ha required	*notes*
Meat, dairy, animal products	305	4087	22	409976	142600	534751	10538	2469	*estimation based on 1/2 chicken, 1/4 pork, 1/4 cow meat, area is estimated as factor 0.1 of feed*
fish	16	214	-	-	-	-	-	-	
Grain products	194	2600	-	51992	22097	13258	8553	325	*based on grain*
Potato	72	965	-	3184	1061	4921	801	21	
vegetables	131	1755	-	3511	2809	8953	509	61	*based on brocolli*
fruits and nuts	130	1742	-	6968	3484	3484	1655	18	*based on apple from orchard*
beans	5	67	-	2814.02	643	871	48	4	*beans grown with CEA*
other	119	1595	-	-	-	-	-	-	
Total	972	13025		478445	172694	566238	22103	2898	

Figure O, Appendix V.IV, NPK and ha demands of producable food of the diet of Amstel III.

Possible production	Meat, dairy, animal	Grain products	Potato	vegetables	orchard (fruit/ nuts)	beans	TOTAL	*available in Amstel III*
tonnes	100	200	965	1755	1742	67	4829	
N(kg)	10031	4000	3184	3511	6968	2814	30508	*31091*
P2O5 (kg)	3489	1700	1061	2809	3484	643.2	13186	*22363*
K2O (kg)	13084	1020	4921	8953	3484	871	32332	*53476*
land (ha)	60	25	21	73	35	4	219	

Figure P, Appendix V.IV, Possible production based on the available nutritiens.

3 Configuration of the Metabolism

In this chapter, the MFA's of Amstel III are related to the flows and methods of farming. The strategic implementation is given based on the boundaries and potentials given in chapter 1 and the conclusions on requirements of urban farming methods in chapter 2. Furthermore, the additional engines and other requirements that are necessary to close the scheme are being highlighted.

3.1 Arguments on the strategic implementation of urban farming in Amstel III

To what extent the Amstel III area can provide the necessary input for its metabolism to become more self-sufficient on the topic of food is being determined by the resourcefulness and spatiality of the area. Furthermore, the NPK nutrients, CO_2 and excess heat could provide for numerous ha of agriculture and greenhouse but cannot fulfill the complete demand of the area. The goal is not to make the area completely self-sufficient on the topic of food production but should be focused on utilizing available biomass and space to the full extent for farming and energy production. This enables a closed-loop and less loss of valuable resources in the different MFA's.

3.1.1 Selection of Urban Farming

Many different combinations of food production methods are possible. However, some restrictions and demands set the boundaries for a possible configuration. Based on diet and NPK availability a plausible selection of several crops and methods is given. (Figure P)

Looking at the different current organic and energy MFA's it becomes clear that there is an opportunity in the excess heat energy (30 C°) of the data centers in the area in combination with a large amount of potential CO_2 obtainable from the produced biomass, this is good for 43 ha of greenhouse.

3.2 Additional Technical Engines

3.2.1 Biogas plant

Converting the organic waste streams to biogas or greengas purely as a source for sustainable energy does not have a fairly significant impact (14TJ) as opposed to the harnessing of potential wind (389 TJ) and solar energy on roofs (413 TJ) in Amstel III. However, it is beneficial to implement an anaerobic biodigester for the argument of maintaining NPK nutrients in the urban metabolism of the district and as a source of carbon dioxide for greenhouses. The organic waste flow through this medium could potentially provide for about 77 ha and 128 ha of fertilizer for CEA and arable land and is good for valuable CO_2 supply for 42 ha of CEA.
Although its potential ecological footprint is not been calculated compared to current practice, it can be expected that implementing this system has a significant impact on the overall direct and indirect carbon emission of the area due to the saving of natural gas as source for nitrogen, the energy-demanding acquiring of potassium and phosphorus and the burning of methane combined with the direct use of exhaust carbon dioxide.
To make use of anaerobic digestion a digester plant is of course necessary. The question rises where to place this facility. The processing of waste is normally not been done within the urban boundaries due to reachability, nuisance by smells and the necessity of flaring. Anaerobic digestion plants normally are a hindrance due to the leaching of ammonia, however, modern biodigester plants are being equipped with exhaust air washers which filter the ammonia. Furthermore, it is most common to have a mesophilic digester, this means a temperature of about 35° C for the bacteria to thrive in. (Kleerebezem, R. (2014).)

Figure Q, biogas plant Groengas Gelderland (source: www.nextgarden.nl)

Figure R, bio-bed of 1000m2 of Groengas Gelderland. (source: own image)

An example plant is Groen Gas Gelderland plant figure Q. A plant that processes 72,000 Tonnes biomass yearly into greengas, thick and thin digestate and carbon dioxide for agricultural purposes. The exhaust air is being washed and the ammonia and other smells are biologically filtered by a bio-bed. (figure R) This is done by blowing in the air underneath the bed, the bacteria living on the surface of the wooden substance of the filter consume and process the smells. (Groengas Gelderland (2019))
When too much biogas is being produced due to for example errors made in the feeding of the plant, it might be necessary to flare excessive biogas.
It is probable that by 2040 technology to reduce the nuisance of biogas plants is even better and could be placed within the city boundaries. Still, it will be not likely that a biogas plant can be placed in the near proximity of housing for safety reasons.
Carbon dioxide extracted from the biogas and from the exhaust of a potential CHP or boiler would need to be transported and buffered before utilizing it. This can be achieved by liquidizing the CO2 and / or with piping.

3.2.2 Other source for CO_2

The total demand if all 77ha CEA needs to be dosed requires about 25 kT CO_2. (Figure S, Appendix V.V)

Average Greenhouse			
Demand	32.3	kg/m2	(RSFGV, 1999)
CEA in Amstel III			
Surface area doced	77	ha	
Demand	24978	T(CO2)*y	

Available

Biogas plant		
OFMSW + SW	1391	T(CO2)*y
percentage use	100%	CO2

Users Amstel III		
Occupation	125381	pp
Av. CO2 human	1	kg/day
CO2 produced	45764	T(CO2)*y
percentage use	52%	CO2

Figure S, Appendix V.V, CO_2 demand and supply

About 4.6 ha can be supplied by the biogas plant. An option is to just ventilate the other 72.4 ha with outside air to ensure enough CO2. This is an option for crops that do not require much extra heating and would result in a lower yield. To utilize the conditions in a CEA to a higher extent, it is interesting to look for an extra source of CO2. In the urban context, it would be interesting to look at exhaust air from buildings, Amstel III has an average occupation of about 125000 people in 2040. An average human produces about 1 kg of CO2 daily, this would mean 46kT of CO2 gross is being produced by humans in Amstel III yearly. About half of this amount would need to be recovered through HVAC systems to supply the total food production within the CEA.

3.2.3 Waste water

Another facility is necessary to use the sewage for biomass. This would be for the dehydration of the sewage water. A way to reduce the amount of water mixed with the biomass is by using vacuum-toilets. Vacuum toilets use significantly less water. In the area, this would reduce the amount of flushed drinking water by about 300.000 m3. It is even possible to separate solid from liquid with a sorting toilet. (TU Hamburg, Vacuum toilet-biogas plant system) However, it is also possible to implement a simple WWTP with a sand filter as being proposed in the paper of van der Hoek.

3.2.3 Thermal Energy Storage

The thermal energy demand and supply will have an imbalance between the summer and winter periods. As mentioned in chapter 1, the data centers are a source of thermal heat energy due to their need for the cooling of processors. Due to that the source medium for cooling for the centers is about the same temperature all year round (the Ouderkerkerplas), the outgoing thermal heat flow will be constant all year round. In the winter, this heat energy will be in high demand and be utilized by the greenhouses, biodigester, and buildings in the area. However, in the summer this heat will be in lesser demand and could be stored in a thermal-energy storage.

3.2.5 Heat pump and second heat grid

The temperature of the available residual heat energy is around 30°C by the data centers, which is enough for floor and wall heating in well-insulated houses but cannot provide for all utilities such as hot tap water (60°C) or to some of the demand of the heat energy by greenhouses (60-70°C). To reach this temperature efficiently a central heat pump needs to be implemented and a secondarily heat grid, or decentralized multiple heat pumps.

3.3 Comparing the MFA's

In figure T and U, the different MFA's are depicted based on previous chapters and the additional engines, these are compared with a MFA of the current situation.

3.3.1 Organic MFA

In the current management of organic material, much of the nutrients are lost in the WTE, only a part of the NPK from the wastewater is recovered (16% of the phosphorus and some nitrogen), none is recovered from the organic waste. In the suggested model, the gross amount of the nutritions available in both waste streams can be recovered, furthermore, the CO2 released can be utilized for food production. In total 28.5 T, 12.4 T and 31.8 T of NPK can be reused.
By combining urban farming and a biogas plant, CO2 repurposed in this model is about 25kT yearly, which will be absorbed by the crops. On top of that comes

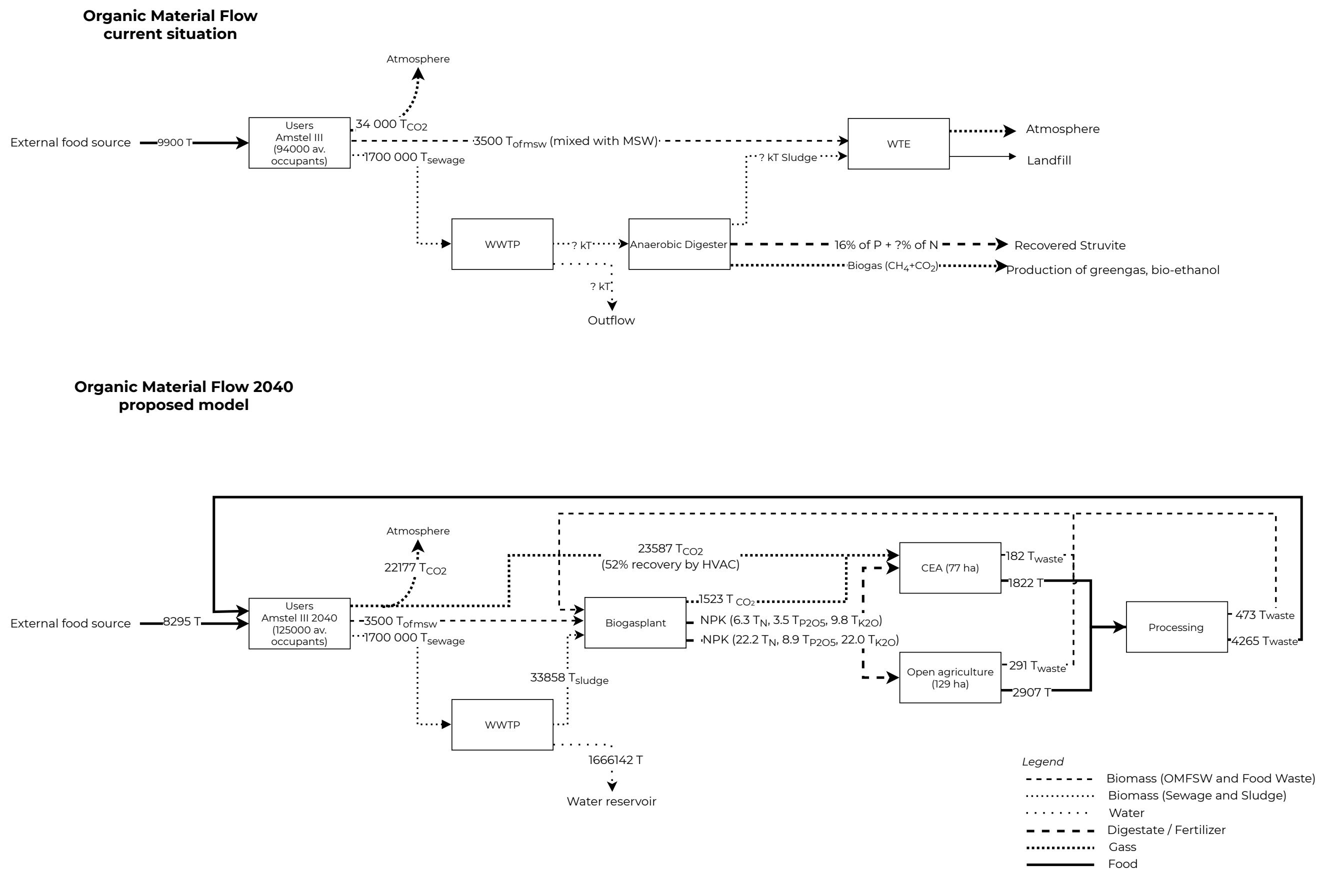


Figure T, Organic MFA comparison

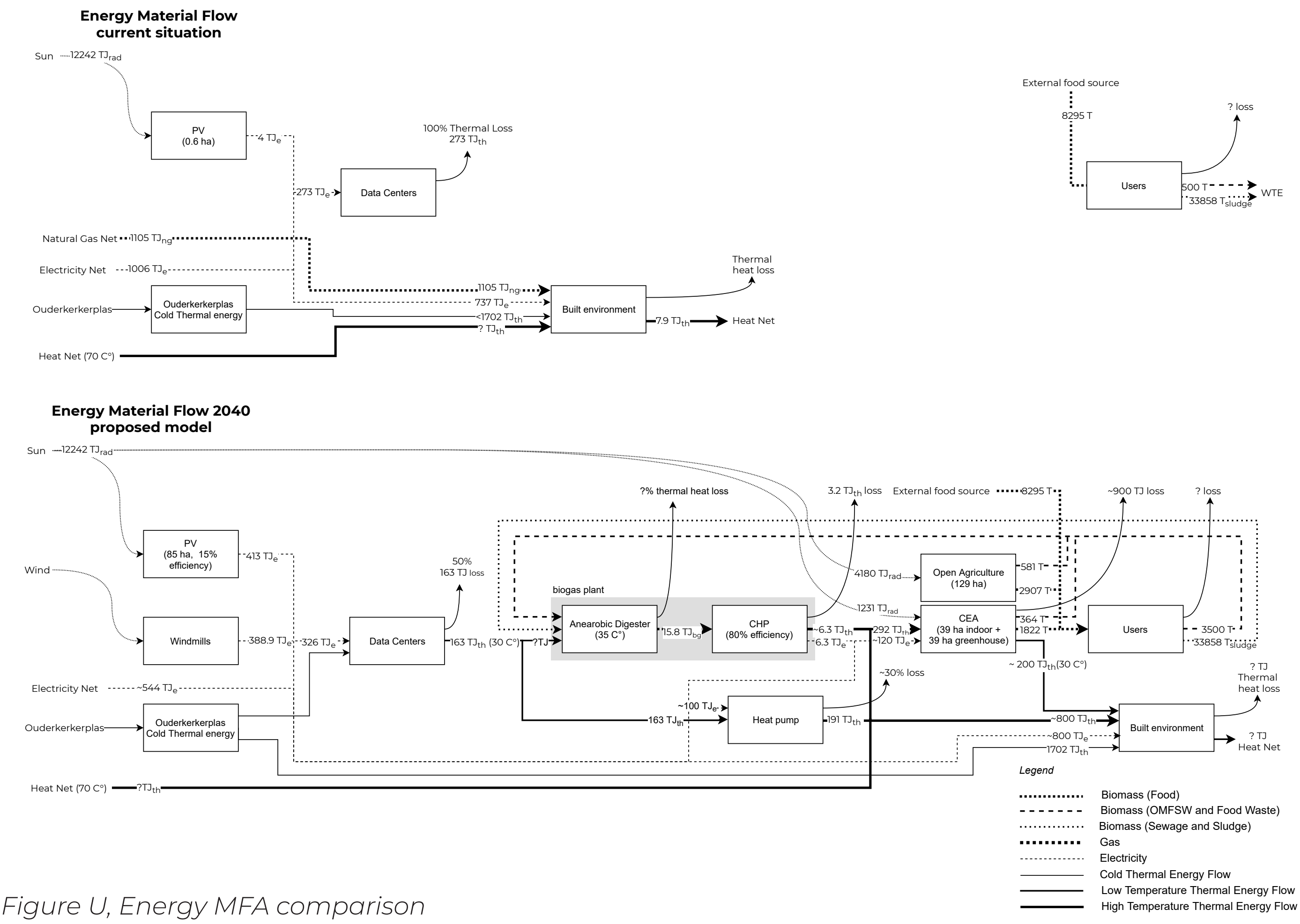


Figure U, Energy MFA comparison

the carbon emission reduction by preventing the use of mineralized fertilizers and natural gas.

3.3.1 Energy MFA

With better use of excess heat of the CEA and Data Centers and capitalizing the available renewable energy sources, Amstel III could become largely self-sufficient. It would require thermal batteries/storage in the area. But could reduce the import amount of gas to zero and would require about 0.5 PJ electricity from elsewhere, which is half of the current electrical energy demand, it would be a remarkable outcome considering the data centers in the area.

3.4 Additional requirements

For this configuration to work it is not only necessary to look at the technical aspects, but it needs to be economically feasible and managed as well. Especially in the Netherlands, conventional agriculture is a highly competitive market with minimal margins for the farmer. In our industrialized agricultural practice terms such as; economies of scale, efficiency, optimization, risk, and yield are parameters that determine the feasibility of their business. It all leads back to the costs and revenue per hectare. Unfortunately, this is exactly one of the major causes restricting urban farming from breaking through. Exemplary is the reflection made on the bankrupted rooftop greenhouse, The New Farm, in Den Haag by established horticultural experts such as Bernadette Bijman Kroon and Rob Baan, in the newspaper Trouw they both highlight the high price of products coming from this particular project. (Trouw (2018)) Suggested is to look at a social and economically feasible business model for these projects. Successful (urban farming) projects hold a strong connection with their urban context and work differently from the standard food supply chain, capitalizing on local for local product and marketing it such. This farm-to-fork principle would mean higher feasibility, a good example of local for local is the Bijlmer success of Brewery Kleijburg (Appendix VI.V). Other aspects to look at are the required work, management and knowledge to set up urban food production. A possible solution to this model is the example of Herenboeren (Herenboeren – Samen duurzaam voedsel produceren. (n.d.)), where cooperations of customers hire a farmer which directly provides food for the costumers.

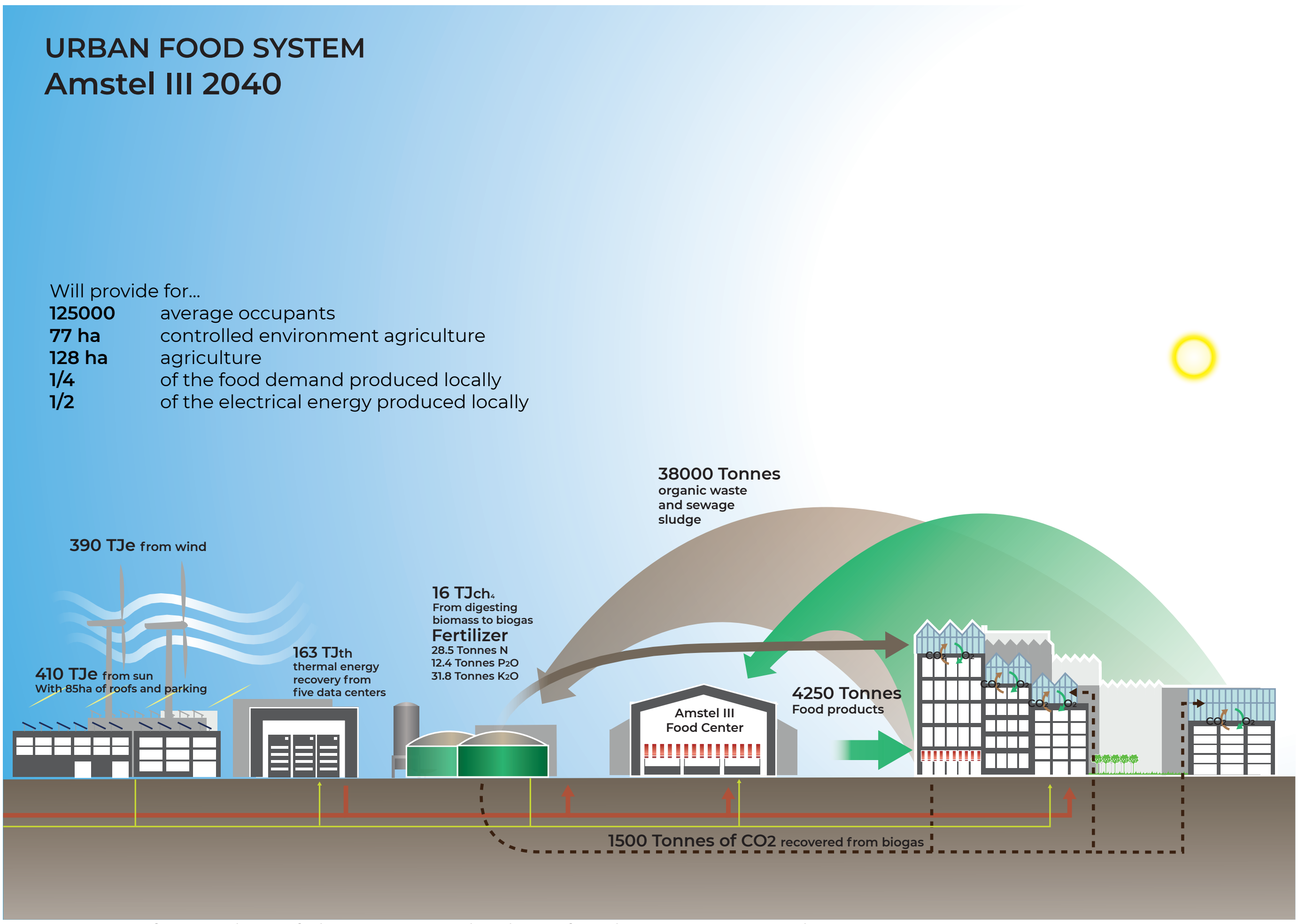


Figure V, Infographic of the proposed urban food system Amstel III 2040

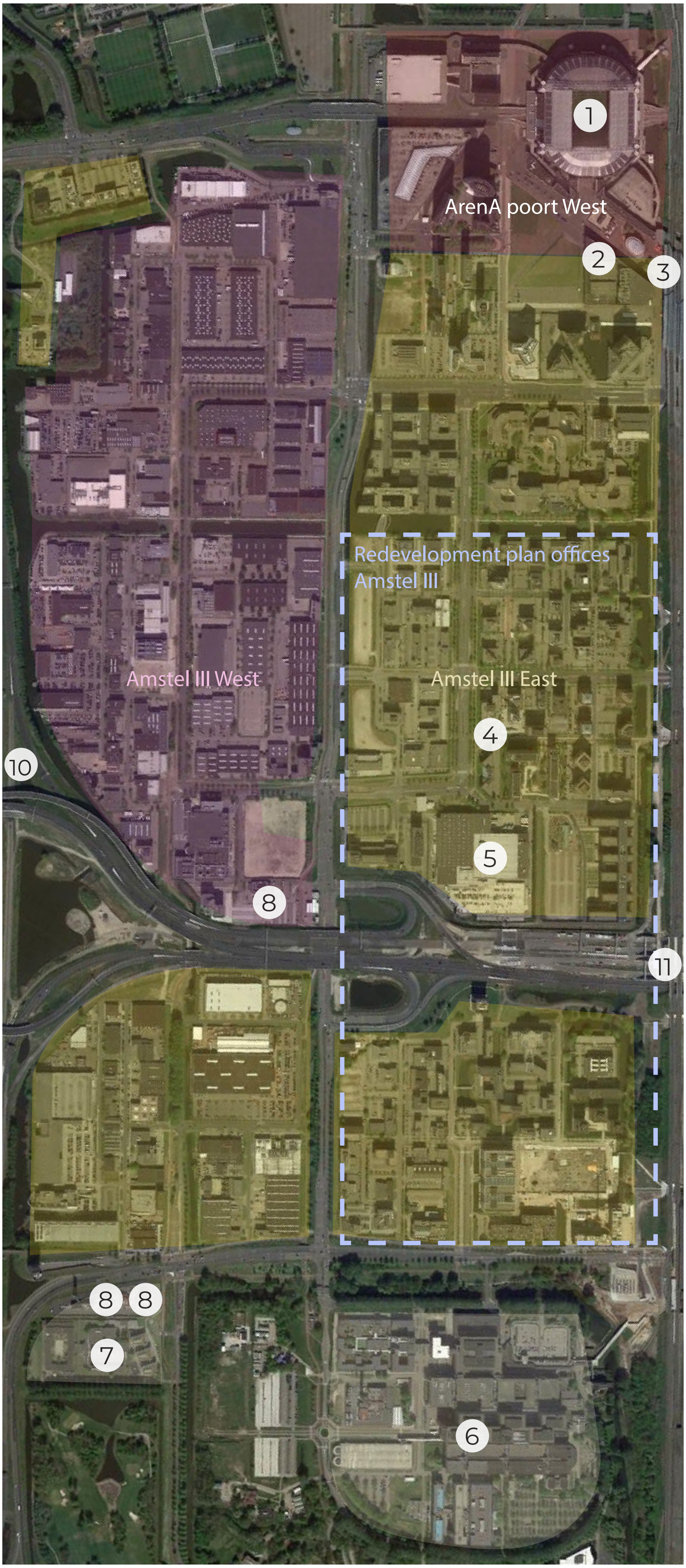
Appendix

From resource draining to maintaining:
A reconfiguration of agricultural flows with the urban metabolism of Amstel III Amsterdam in 2040.

I
Program

I.I Researched area revered to as Amstel III in this paper

I.II
Program map
of Amstel III



Functions

1 J.C. ArenA
2 Ziggo Dome / AFASlive
3 Trainstation
4 Plan: Hondrugspark
5 IKEA
6 AMC
7 Special Ed. instution
8 (3x)Drive-through restaurant
9 Allotments
10 Highway A2
11 Highway A58

Program

Culture - Leisure
Businesses
Mixed: office and housing
Social

Numbers 2040

Office space: 720 000 m^2
Workers: 50 000

Households: 15 000

1) www.ruimtelijkplannen.nl

2) Google.maps.nl

3) gebiedsplan 2018

II
Energy

II.I Energy demand

Electricity Consumption (2017)

block nr	EL (KWh)
16098	3538010
16100	4688808
16101	818165
16103	6110850
16105	557940
16108	869946
16109	957555
16112	661674
18062	203844
18066	737855
18076	2672530
18077	469243
18078	184806
18079	284256
18080	503574
18081	544984
18082	160524
18084	6095060
18096	129768
18097	132072
18098	67176
18099	330946
18156	3464280
18158	11001780
18179	894928
21352	4031181
21354	598090
21356	337530
21357	194400
21359	43576740
21360	17569405
21368	4946767
21375	6355671
21377	2026130
21378	2016056
21379	6775620
21381	3614598
21382	220125
21383	3185262
21385	1974406
21388	915117
21389	10765096
21399	2048076
21499	122472581
TOTAL:	**279703425** KWh
TOTAL:	**1006932** GJ

Amsterdam Total*

4530000000 KWh EL

*Staat van Amsterdam Energie- en grondstof transitie

Percentage of Amsterdam

6.1745 %

Gas Consumption (2017)

block nr	Gas (m3)	KWh
12808	34215	342150
12984	31260	312600
12990	93680	936800
12992	17478	174780
12999	36980	369800
13006	50507	505070
13007	27888	278880
13009	72471	724710
13010	59041	590410
13011	60400	604000
19100	14424	144240
19155	41587	415870
21681	5208	52080
21923	100710	1007100
21924	71875	718750
21925	124200	1242000
21926	374605	3746050
21927	167585	1675850
21928	381925	3819250
21929	343440	3434400
21930	142180	1421800
21931	188385	1883850
21932	828885	8288850
21939	132762	1327620
21940	783465	7834650
21941	113754	1137540
21942	171426	1714260
21944	186288	1862880
21945	212375	2123750
22541	190104	1901040
22542	81592	815920
22656	15927695	159276950
23118	3283595	32835950
23363	92680	926800
23364	110215	1102150
23365	292288	2922880
23366	1092828	10928280
23367	409938	4099380
23368	606294	6062940
23369	583443	5834430
23370	353691	3536910
23371	98940	989400
23372	52542	525420
23373	262644	2626440
23374	261120	2611200
23375	837970	8379700
23384	871370	8713700
23564	424207	4242070
TOTAL:	**30702155**	**307021550** KWh
TOTAL:		**1105278** GJ

Amsterdam Total*

730000000 M3 Gas

*Staat van Amsterdam Energie- en grondstof transitie

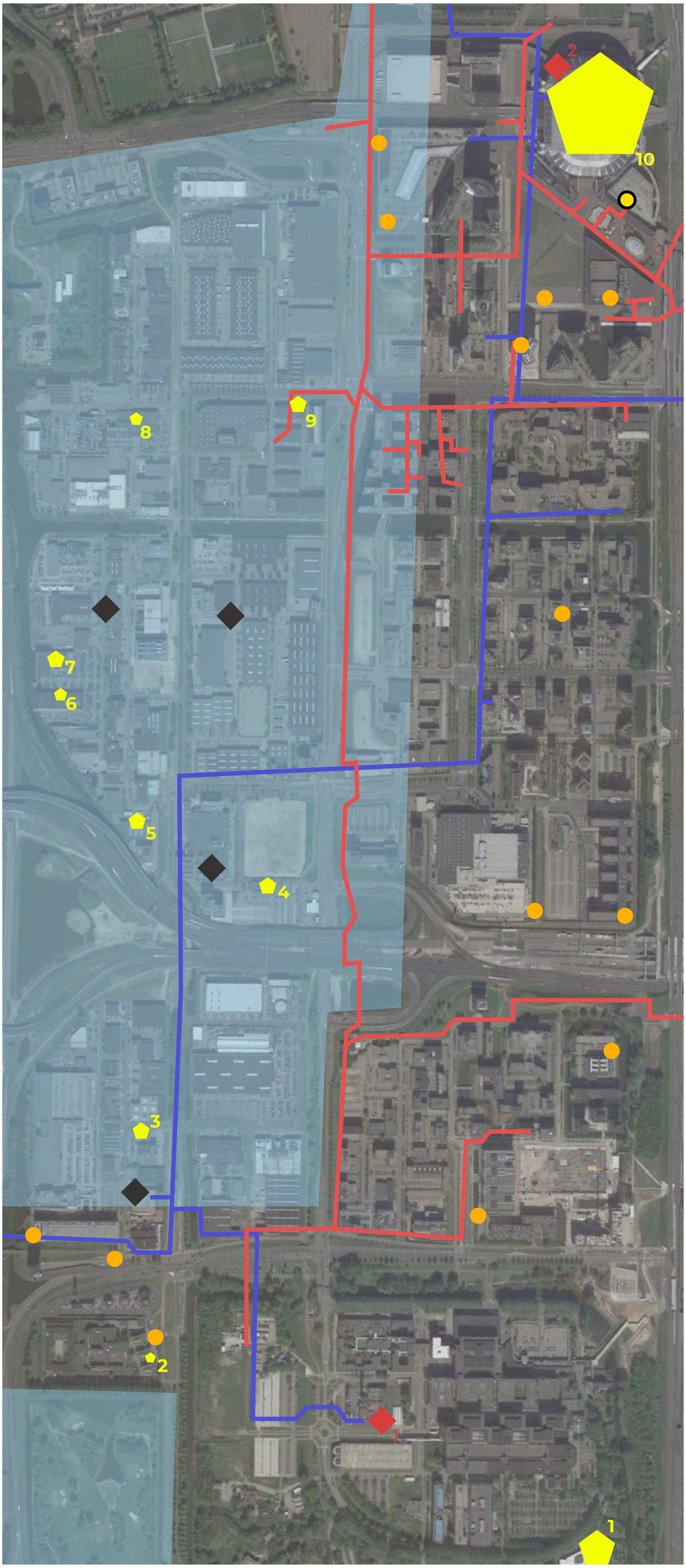
Percentage of Amsterdam

4.2058 %

1) https://maps.amsterdam.nl/radar/?LANG=nl

2) Staat van Amsterdam Energie- en grondstof transitie - gemeente Amsterdam (2018)

II.II
Energy network in Amstel III



Aquifer Thermal Energy Storage (ATES)

- closed system
- open system

District Heating / Cooling

- heat
- cold

Data center

m2 = 630000 KWh

Source district heat

1 1576800 KWh
2 630000 KWh

Renewable energy sources

Wind energy potency

PV - panels

1	517
2	6
3	63
4	31
5	126
6	9.4
7	106
8	61
9	206
10	4156

1) MER StadskoelingAmsterdam Zuidoost: Ouderkerplas. NUON Warmte N.V. 5 oktober 2007 110623/CE7/215/000535 - Arcadis

2) https://maps.amsterdam.nl/radar/

3) https://maps.amsterdam.nl/zonnepanelen/?LANG=nl

4) https://maps.amsterdam.nl/energie_zonwind/

5) https://bouwenuitvoering.nl/duurzaam/nederlandse-koudenetten/

6) https://www.duurzaamplus.nl/energie/restwarmte/restwarmte-data-centers-voor-nieuwbouw-amstel-iii/

7) https://baxtel.com/data-center/netherlands

II.III Solar Energy

Solar Power Harvest (2017)

		Panels	peak (Wp)	yearly energy (kWh)
1	AMC	517	132000	112200
2		6	1000	850
3		63	16000	13600
4		31	8000	6800
5		126	32000	27200
6		9.4	2000	1700
7		106	26000	22100
8		61	15000	12750
9		206	50000	42500
10	Arena	4156	1018000	865300
	TOTAAL	5281.4	1300000	**1105000**

1)https://maps.amsterdam.nl/energie_zonwind/

https://maps.amsterdam.nl/zonnepanelen/?LANG=nl

Solar Energy Amsterdam		
1000	W/m2	During optimal solar
900	hrs	optimal sun

file:///C:/Users/SvanS/04%20Msc4/01%20Amstel%20III/Energy/3144_defrapportAdB.pdf

Potential total Amstel III
Size Amstel III
3770000 m2
Bruto Solar Energy on Surface of Amstel III
12214800 GJ
Harvestable solar Energy with 15% efficiency
1832220 GJ

Potential roofs Amstel III
Size Amstel III
850000 m2
Bruto Solar Energy on Surface of Amstel III
2754000 GJ
Harvestable solar Energy with 15% efficiency
413100 GJ

II.IV Cold Net Ouderkerkerplas, Amstel III

	Cold E demand	thermal yearly	Efficiency (ERV)	electrical energy yearly
AMC	15 MW(th)	131400 MW(th)h	2.5	52560000 KWh
Bullewijk	35 MW(th)	306600 MW(th)h	2.5	122640000 KWh
Amsterdamse poort	10 MW(th)	87600 MW(th)h	2.5	35040000 KWh
Gross total	60 MW(th)	525600 kW(th)h	2.5	210240000 KWh
correction factor (0.9)				
Net total	54 MW(th)	473040 MW(th)h	2.5	189216000 KWh
Average capacity yearly				530000000 KWh

MER Stadskoeling Amsterdam Zuidoost: Ouderkerplas. NUON Warmte N.V. 5 oktober 2007 110623/CE7/215/000535 - Arcadis

II.V Summary Energy use and potential in Amstel III

	amount	unit	energy (kwh)	energy (GJ)	capacity / potential (kwh)	capacity / potential (GJ)	percentage used
Electricity							
Electricity Used	-		279703425	1006932	-	-	-
Electricity production (PV)	1300000	kWp	1105000	3978	114750000	413100	1%
Electricity production (Wind)	0	GWh/y	0	0	108000000	388800	0%
				4308			
Fossil Energy							
Gas consumption	3.1E+07	m3	307021550	1105278	-	-	-
Thermal							
Cold energy production (as predicted 2007)	473040	MW(th)h	189216000	681178	530000000	1908000	36%
District heat energy production	-		2206800	7944	182206800	655944	1%

II.VI Heat energy

Heat energy produced

production	https://maps.amsterdam.nl/energie_restafval/	
AMC	1576800	KWh
ArenA	630000	KWh
total	2206800	KWh
	7944.48	GJ

Electrical Energy Usage Data Centers		
	3.5	MWh/m2/y

Current Situation

	ft2	**m2**	**MWh/y**	**TJ/y**	
EQUINIX AMSTERDAM AM5	64,583	6000.0	21000	75.599426	
EQUINIX AMSTERDAM AM1 AM2	90,956	8450.1	29575	106.47107	
INAP AMS LUTTENBERGWEG 4	-	4000.0	14000	50.4	*estimated
EQUINIX AMSTERDAM AM7	36,597	3400.0	11900	42.839636	
Total		21850	76475	275	

2040 Situation

	ft2	**m2**	**MWh/y**	**TJ/y**	**TJ recovery (50%)**	
EQUINIX AMSTERDAM AM5	64,583	6000.0	21000	75.599426	38	
EQUINIX AMSTERDAM AM1 AM2	90,956	8450.1	29575	106.47107	53	
INAP AMS LUTTENBERGWEG 4	-	4000.0	14000	50.4	25	*estimated
EQUINIX AMSTERDAM AM7	36,597	3400.0	11900	42.839636	21	
NEW DATA CENTER	-	4000.0	14000	50.4	25	*estimated
Total		25850	90475	326	163	`

https://www.duurzaamplus.nl/energie/restwarmte/restwarmte-datacenters-voor-nieuwbouw-amstel-iii/

https://baxtel.com/data-center/netherlands

II.VII Greenhouse Energy use

Amount rooftop GH	38 ha

Gass

type	nat gas /m2	energy / m2	total energy
Modern greenhouse	12 m3/m2	380 MJ/m2	144 TJ
Standard greenhouse	31.25 m3/m2	989 MJ/m2	376 TJ

https://www.onderglas.nl/gasverbruik-in-onderzoekskassen-40-procent-van-praktijkgemiddelde/

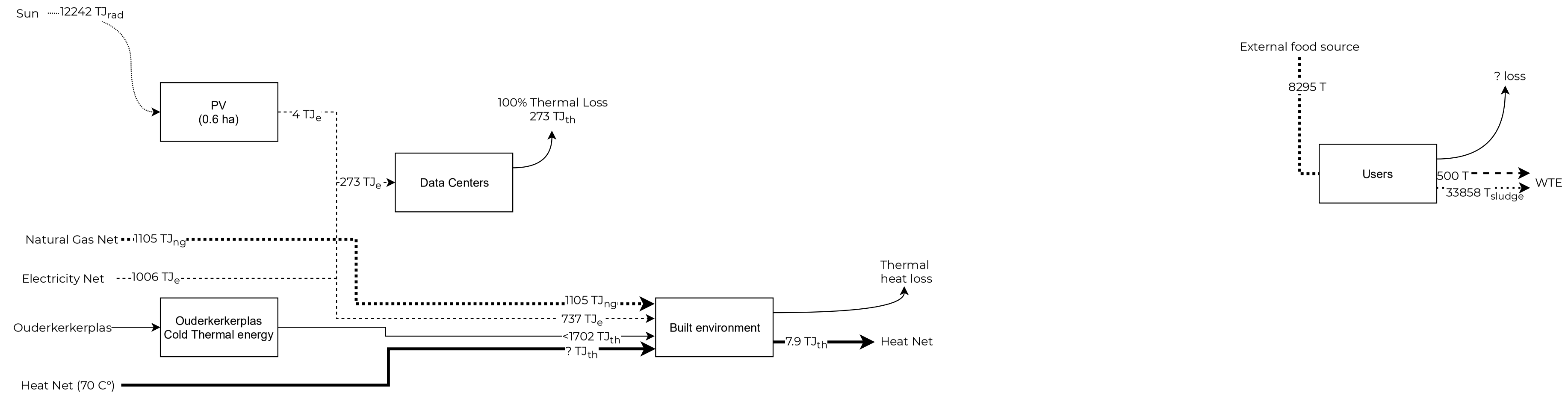
https://www.onderglas.nl/gasverbruik-in-onderzoekskassen-40-procent-van-praktijkgemiddelde/

EL	av. demand per ha	av. demand total	total energy * y
Greenhouse	50 KW	1900 KW	60 TJ

Passive Solar	rad per/m2	total rad GH
Gross Solar Energy	3.24 GJ	1231 TJ

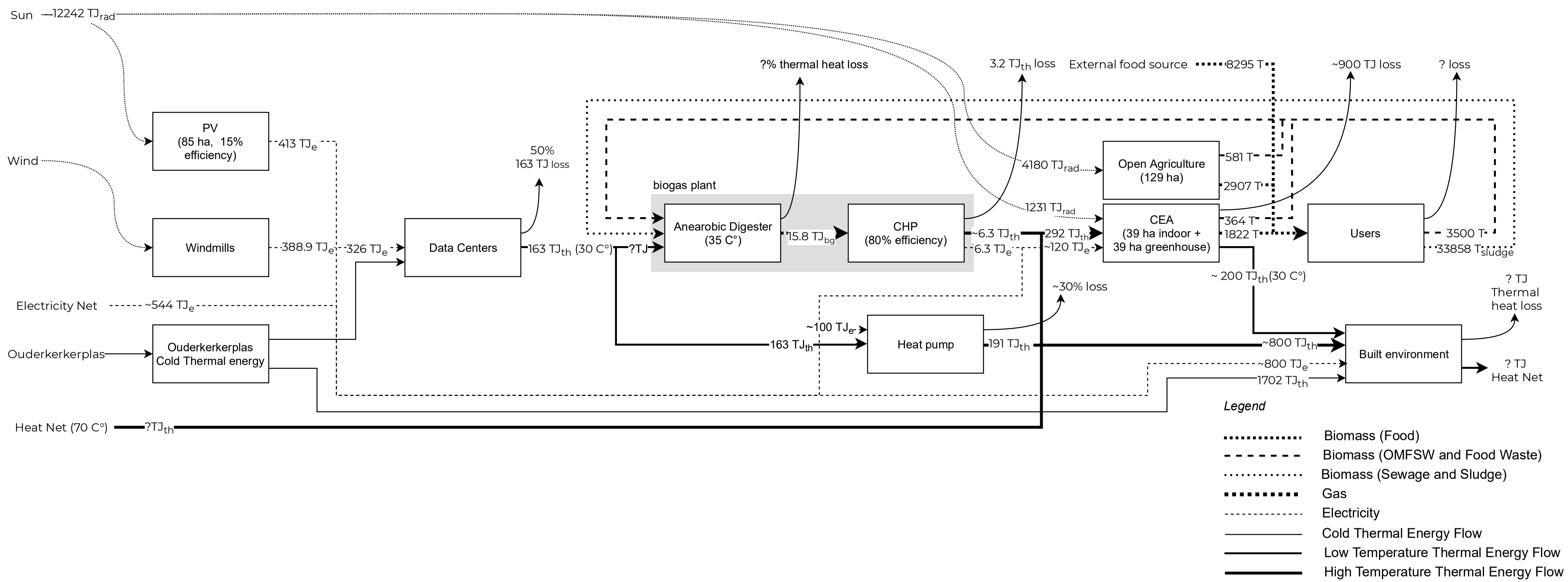
II.VIII Current energy MFA

Energy Material Flow current situation



II.VIV Proposed MFA

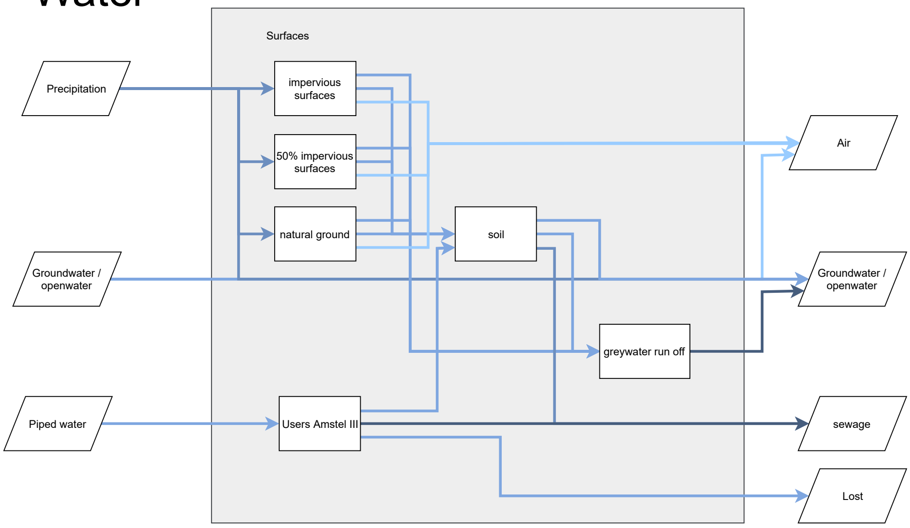
Energy Material Flow 2040 proposed model



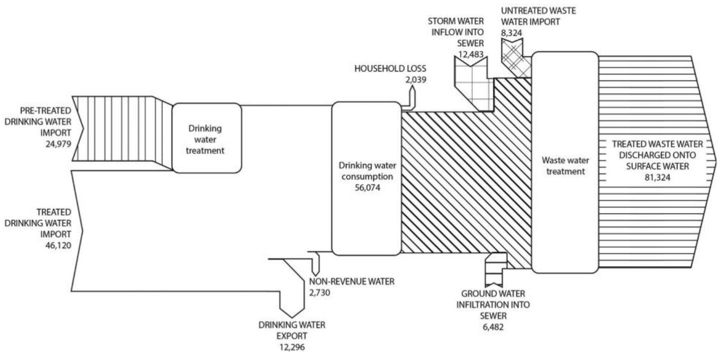
III
Water and land usage

Water

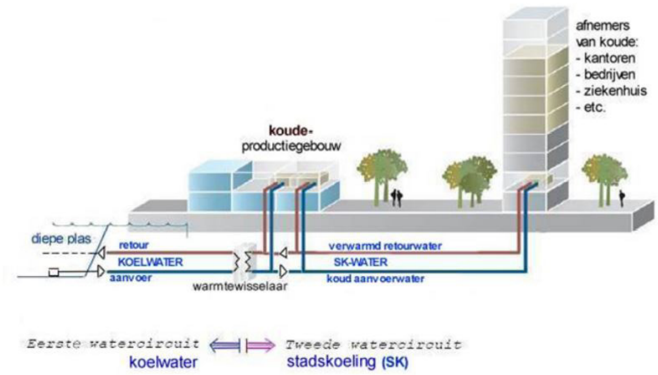
III.I Water flows in Amstel III



III.II Water metabolism of Amsterdam



Source:



Stadskoeling (1)Arcadis, 2007)

III.III Precipitation and infiltration

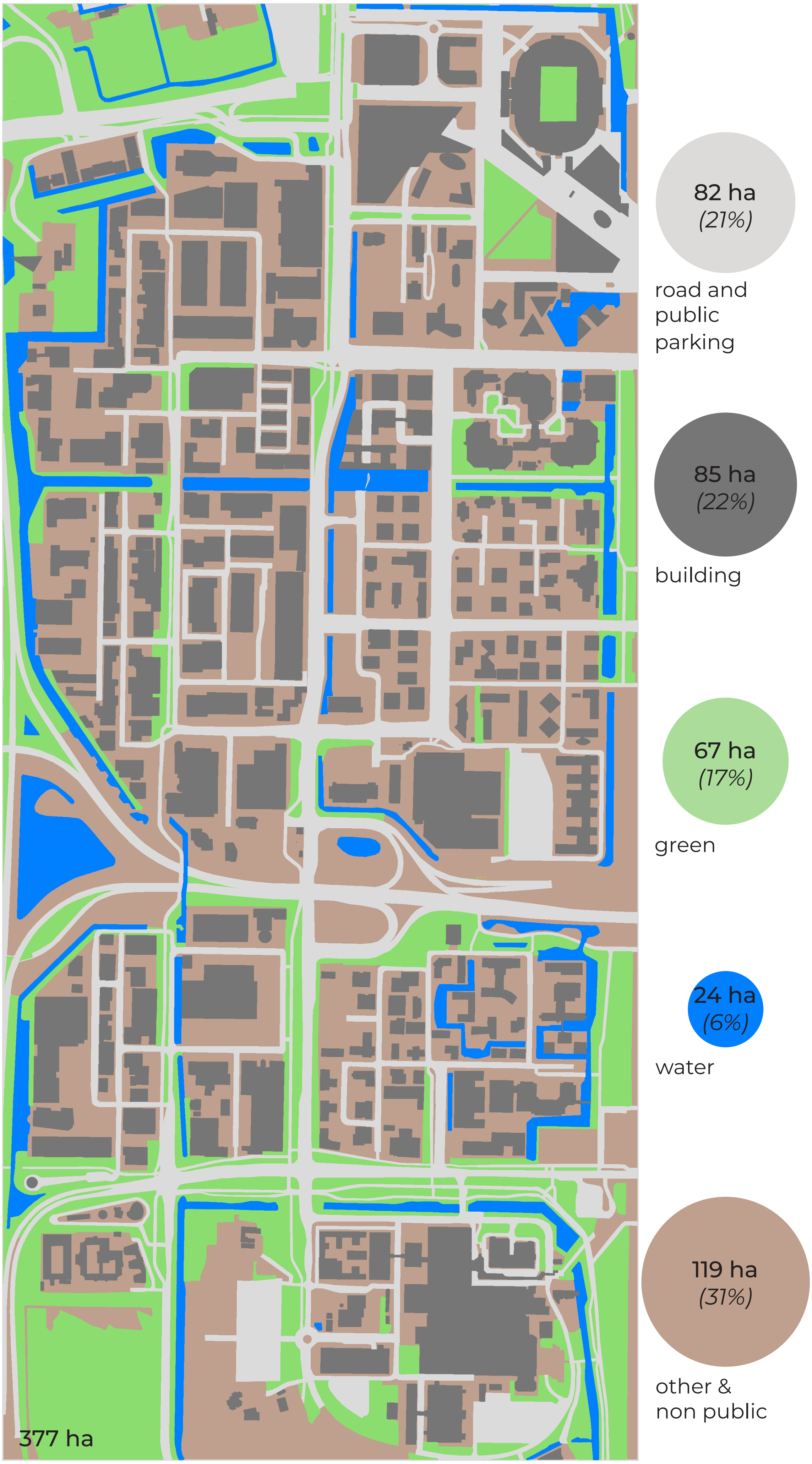
surface infiltration			
	Into soil	runoff	evapotranspiration
Hard	*15%*	*55%*	*30%*
Natural	*50%*	*10%*	*40%*
Mixed / half hard	*35%*	*30%*	*35%*

Figure X, infiltration rate of percipitation (source 2): Butt, A. A, (2018))

Calculation flows precipitation					
	type	amount (m3)	into soil (m3)	runoff (m3)	evapotranspiration
roads and public -parking	*hard*	*660100*	*99015*	*363055*	*198030*
building	*hard*	*684250*	*102637.5*	*376337.5*	*205275*
green	*Natural*	*539350*	*269675*	*53935*	*161805*
water	*Natural*	*193200*	*96600*	*19320*	*57960*
Other	*Mixed*	*957950*	*335282.5*	*287385*	*287385*
Total:		3034850	903210	1100032.5	910455

Figure X, calculation of stormwater flows based on average precipitation of 805 mm per year (source 3: climate-data.org)

III.IV
surface types

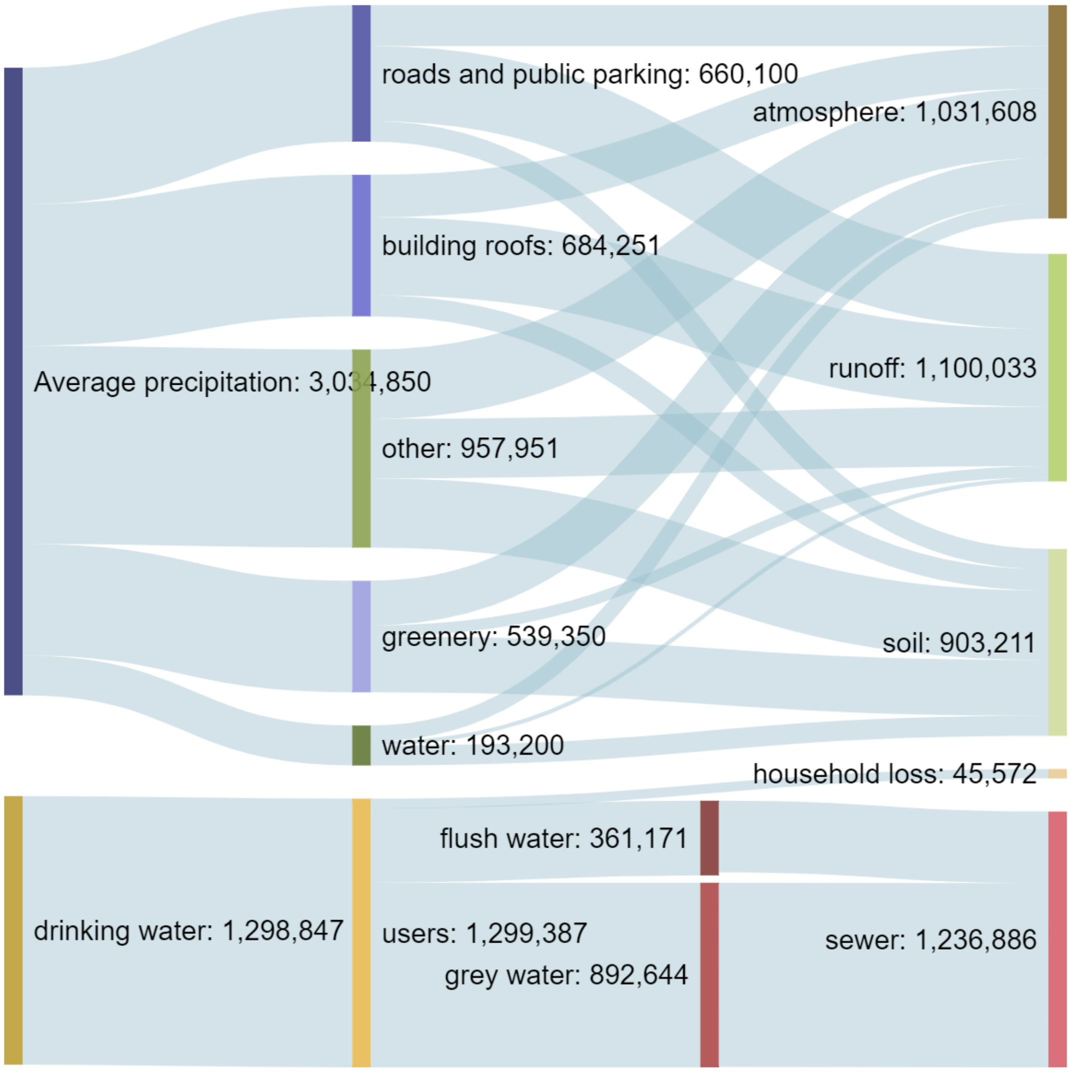


1) Enhanced Performance of the Eurostat Method for Comprehensive Assessment of Urban Metabolism A Material Flow Analysis of Amsterdam
Ilse M. Voskamp, Sven Stremke, Marc Spiller, Daniela Perrotti, Jan Peter van der Hoek, and Huub H. M. Rijnaarts

2)Butt, A. A, Harvey, J. T, Kendall, A., Li, H., & Zhu, Y. (2018). Framework for Urban Metabolism and Life Cycle Assessment of Hardscape. UC Davis: National Center for Sustainable Transportation. Retrieved from https://escholarship.org/uc/item/77g742tq

3) https://nl.climate-data.org/europa/koninkrijk-der-nederlanden/noord-holland/amsterdam-3330/

III.IV Water MFA of Amstel III



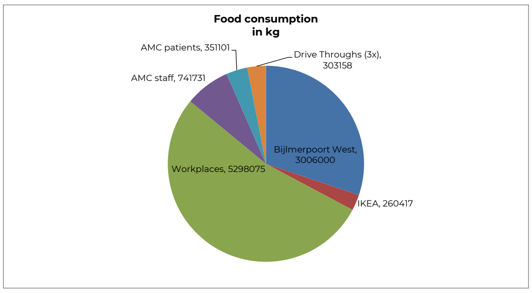
IV
Organic

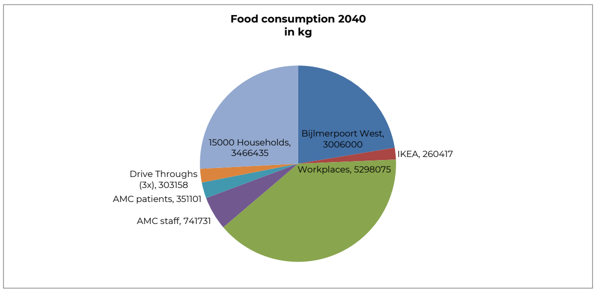
IV.I Summary table

MFA_organic User Amstel III

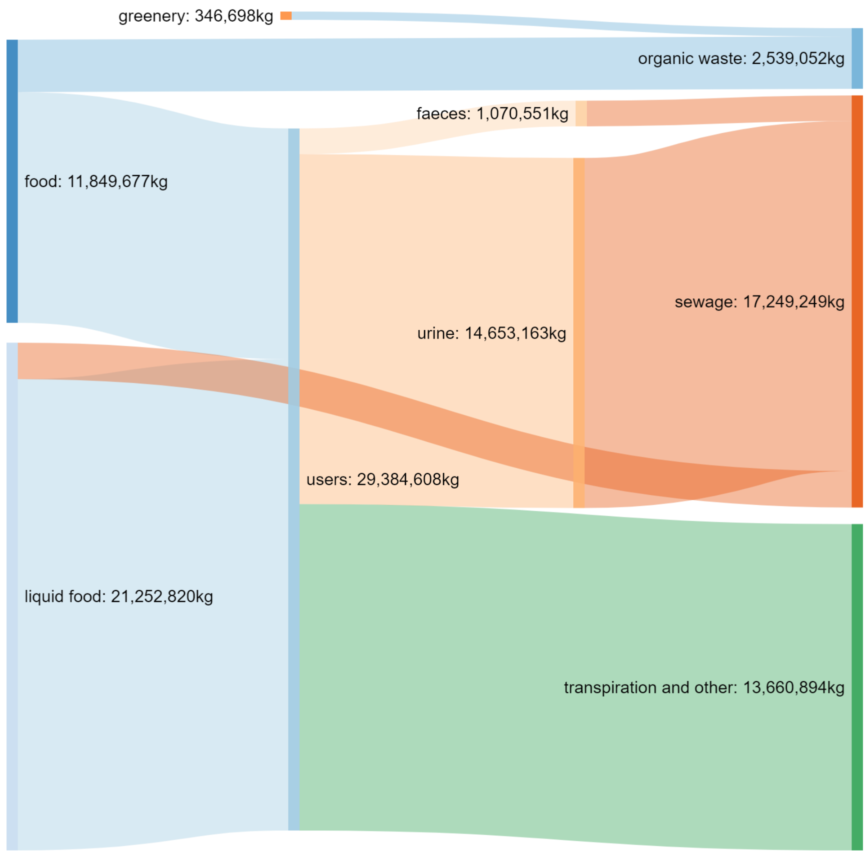
type user quantity						consumption		output							
									organic waste		Sewage				
Amstel III now	**Amount**	**type**	**average occupance per day**	**active hrs spend per type**	**awake hrs per year**	**Liquid consumed (kg)**	**Food consumed (kg)**	**Waste produced (kg)**	**Solid Food Waste (kg)**	**Garden waste(kg/year)**	**liquid food wasted in sewage (kg)**	**Urine (L/year)**	**Faeces (kg/year**	**Flush water (L/year)**	**Grey water (L/year)**
Bijlmerpoort West	16000000	visitors	43836	3	48000000	6144000	3006000	3131507	673274	106471	468493	4500000	328767	105000000	270000000
IKEA	2500000	visitors	6849	2.5	6250000	520833	260417	407748	87666	13863	61002	585938	42808	13671875	35156250
Workplaces	50000	workerspaces	32192	7.2	84600000	10828800	5298075	5519281	1186645	187656	825719	7931250	579452	185062500	475875000
AMC staff	7000	workers / students	4507	7.2	11844000	1516032	741731	772699	166130	26272	115601	1110375	81123	25908750	66622500
AMC patients	-	patients	960	16	5606400	717619	351101	365760	78638	12436	54720	525600	38400	12264000	31536000
Drive Throughs (3x)	2021053	visitors	5537	1	2021053	606316	303158	131853	45474	4483	19726	189474	13843	4421053	11368421
current situation:			**93881**		**158321453**	**20333600**	**9960481**	**10328848**	**2237828**	**351181**	**1545261**	**14842636**	**1084394**	**346328178**	**890558171**

Amstel III 2040															
15000 Households	31500	inhabitants	31500	4.8	55352250	7085088	3466435	3611166	776401	122780	540253	5189273	379125	121083047	311356406
Bijlmerpoort West	16000000	visitors	43836	3	48000000	6144000	3006000	3131507	673274	106471	468493	4500000	328767	105000000	270000000
IKEA	2500000	visitors	6849	2.5	6250000	520833	260417	407748	87666	13863	61002	585938	42808	13671875	35156250
Workplaces	50000	workerspaces	32192	7.2	84600000	10828800	5298075	5519281	1186645	187656	825719	7931250	579452	185062500	475875000
AMC staff	7000	workers / students	4507	7.2	11844000	1516032	741731	772699	166130	26272	115601	1110375	81123	25908750	66622500
AMC patients	-	patients	960	16	5606400	717619	351101	365760	78638	12436	54720	525600	38400	12264000	31536000
Drive Throughs (3x)	2021053	visitors	5537	1	2021053	606316	303158	131853	45474	4483	19726	189474	13843	4421053	11368421
future situation:			**125381**		**2.14E+08**	**27418688**	**13426916**	**13940014**	**3014228**	**473960**	**2085514**	**20031910**	**1463519**	**467411224.5**	**1201914577**

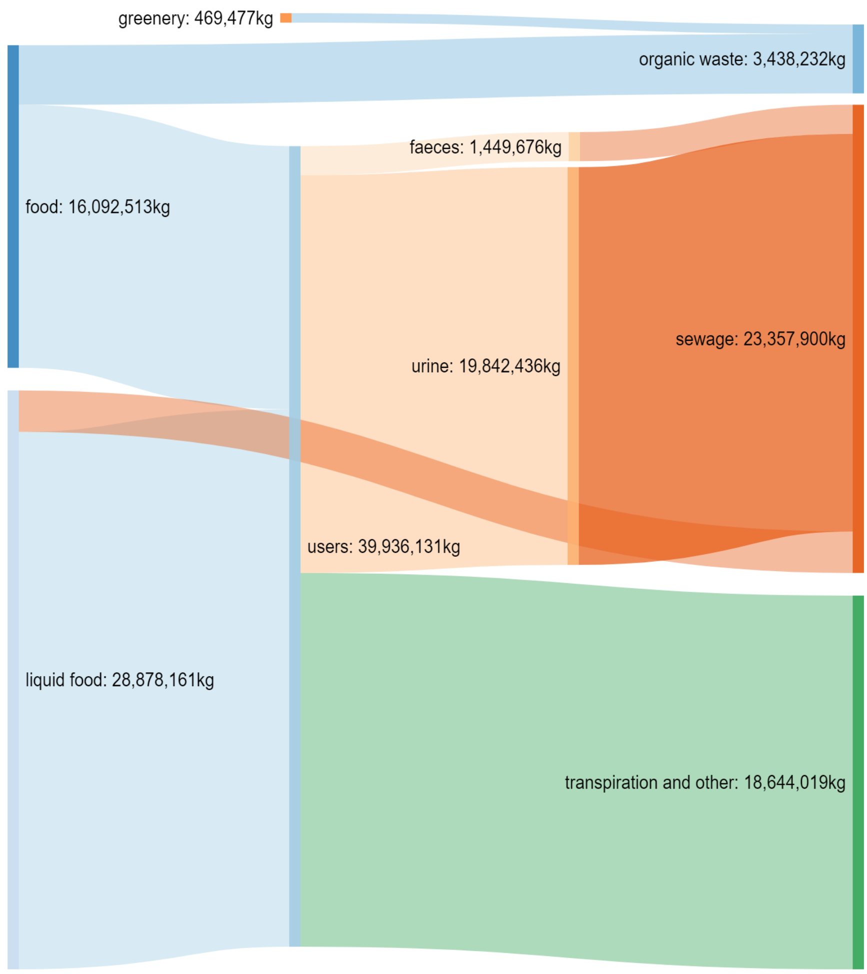




IV.II Organic MFA of Amstel III circa 2019



IV.III Organic MFA of Amstel III circa 2040



IV.IV IKEA food consumed and wasted

visitors IKEA amstel III:

2500000 https://www.stadszaken.nl/?thema=2&ow=26&article=1566

visitors IKEA world wide:

936,000,000 https://www.ikea.com/ms/en_US/this-is-ikea/ikea-highlights/2017/facts-and-figures/index.html

GLOBALLY IKEA

https://flwprotocol.org/case-studies/ikea-food-food-precious-food-waste-initiative/

Food saved from December 2016 until end of January 2019 in 247 stores of ikea, according to the source it is 20% of its food waste.

Aim is to go to 50% by 2020 in all restaurants

meals saved	kg
4,003,896	1,786,605

Meals served	kg served
650000000	292500000

IKEA Amstel III

Meals served	kg served		
1736111.111	781250	14.864	0.3125

Average time spend in ikea	https://eu.commercialappeal.com/story/money/business/development/2016/12/11/five-tips-best-ikea-trips/95198234/	
per person	2.5	hrs
Total visitors	6250000	hrs

Food waste per restaurant / hotel	https://doi.org/10.1016/0734-242X(83)90034-4
20% - 38%	
food waste reduction by IKEA in 2020':	
50%	
Assumed food waste:	
15%	

IV.V Drive Through food customers and food

Mac Donalds in NL

3200000	weekly visitors
247	restaurants
12955.466	weekly per average restaurant
673684.21	yearly per average restaurant

Average meal		
0.45	kg	*
Average consumption of food per restaurant		
303157.89	kg	

https://www.snackkoerier.nl/bedrijfsvoering/nieuws/2018/02/mcdonalds-nederland-groeit-naar-recordomzet-101295532?vakn

IV.VI Food and consumable liquids and food waste per person

Food and liquids per person

Average Diet

Amount consumed	
3.1	kg/day

Tabel van grafiek: **Gemiddelde consumptie in grammen per dag - VCP 2012-2016, 1-79-jarigen**

Category	Niet-alcoholische dranken	Zuiveldranken	Alcoholische dranken	Brood, granen, rijst, pasta	Zuivel-niet dranken	Groente	Fruit, noten en olijven	Vlees(producten)	Aardappelen	Bouilon	Koel en gebak	Sauzen en smaakmakers	Suiker en snoepgoed	Vetten en olien	Hartige snacks	Vis, schaal-en schelpdieren	Eieren	Peulvruchten	Total g	Total kg	Total kg per hour awake
dranken	1708	201	139																2048	2.048	0.128
voedsel				194	151	131	130	98	72	43	41	35	30	22	21	16	13	5	1002	1.002	0.062625

Fat	Carb	Protein	Other
34.7%	45.1%	15.1%	5.1%

food waste per person

Amount food wasted per person

inavoidable	21	kg/year
avoidable	41	kg/year
Total	62	kg/year
	0.010616	kg/hrs

Amount liqued wasted per person

avoidable	57	kg/year
Total	57	kg/year
	0.00976	kg/hrs

IV.VII Sewage per person

Waste water per person

Black Water

urine (l/d)	*fecies(l/d)*	*water (l/d)*
1.5	0.109589	35
urine (l/hrs)	*fecies(l/hrs)*	*water (l/hrs)*
0.09375	0.0068493	2.1875

Other

grey water (l/d)

90

grey water (l/hrs(active))

5.625

van der Hoek

The organic matter content in wastewater, Chemical Oxygen Deman (COD)

greywater	36%
faeces	34%
Urine	7%
Toilet Paper	23%

Total organic matter in Amsterdam

41.9 kton COD

Waste water without storm water

53.8 mil m3

0.078% percentage organic in waste water

https://www.snelverder.nl/v/wetenschap/tijd-en-meetkunde/hoeveel-werkdagen-in-een-jaar
https://www.nemokennislink.nl/publicaties/ons-dagelijks-afval-water/
STOWA 2005

IV.VII Household occupation and active hours per person

Household

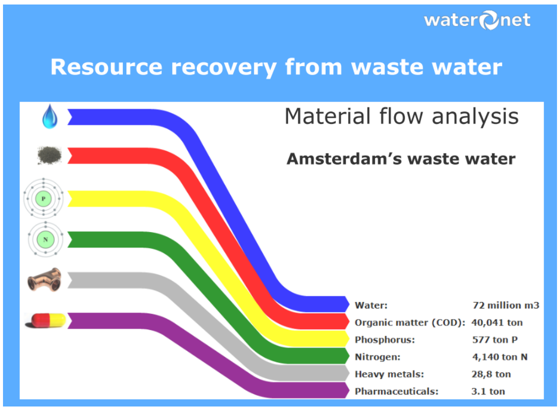
Average amount of ppl	2.1	ppl

Average free time spend home	32	hrs/weekly
Average time working at home	1.7	hrs/weekly
active hrs total per person	33.7	hrs/weekly
	4.814286	hrs/day

total per household	70.77	hrs/weekly

source:
https://www.volksgezondheidenzorg.info/onderwerp/bevolking/cijfers-context/huishoudens

IV.VIII Nutrions in waste water Amsterdam



(source: Waternet)

IV.IX Phospurus in Amsterdam SW (J.P. van der Hoek, 2016)

J.P. van der Hoek et al. / Resources, Conservation and Recycling 113 (2016) 53–64

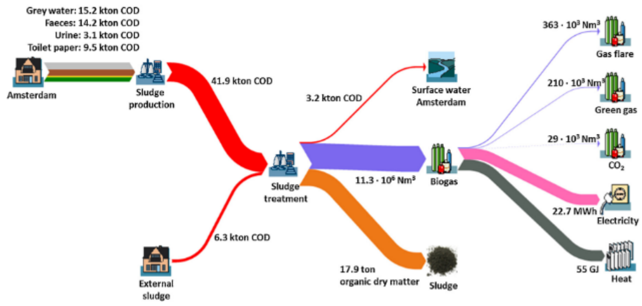


Fig. 5. Organic matter in Amsterdam's wastewater chain 2013 (in ton COD).

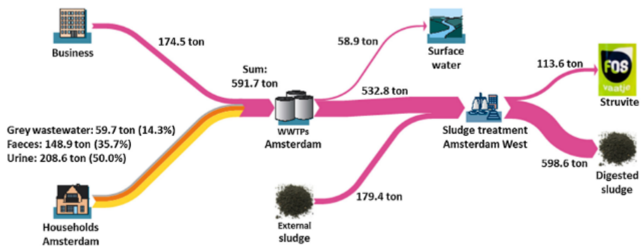


Fig. 6. Phosphorus in Amsterdam's wastewater chain 2013 (in ton P).

IV.X Stoichiometry of anaerobic digestion of biodegradable organic substrate. (Kleerebezem 2015)

$$C_cH_hO_oN_n \rightarrow \left(\frac{c}{2}+\frac{h}{8}-\frac{3n}{8}-\frac{o}{4}\right)CH_4 + \left(\frac{c}{2}-\frac{h}{8}-\frac{5n}{8}+\frac{o}{4}\right)CO_2$$
$$+\,nNH_4HCO_3 + \left(\frac{h}{4}-c-\frac{7n}{4}+\frac{o}{2}\right)H_2O$$

IV.XI Properties of feedstock for anaerobic digestion. (Kleerebezem 2015)

TABLE 14.3 Properties of typical feedstocks for the anaerobic digestion process (Batstone et al., 2002; Nasir et al., 2012a; Nasir et al., 2012b)

Feedstock	TDM ($g.kg^{-1}$)	ODM ($g.kg^{-1}$)	N ($g.kg^{-1}$)	COD ($g.kg^{-1}$)	Biodeg (%)	Composition	k_h[b] (d^{-1})	Biogas ($L.kg^{-1}$)	CH_4[c] (%)
Pig manure	200	160	7.0	176	20	$CH_{2.27}O_{0.91}N_{0.094}$	0.05	23	57
MSW	300	240	1.8	264	25	$CH_{2.08}O_{0.97}N_{0.016}$	0.20	48	52
OFMSW	300	270	3.0	297	50	$CH_{2.10}O_{0.96}N_{0.024}$	0.20	106	53
Slaughterhouse	200	180	6.0	260	80	$CH_{2.59}O_{0.74}N_{0.065}$	0.10	118	66
Maize silage	400	360	1.2	396	80	$CH_{2.05}O_{0.97}N_{0.007}$	0.20	231	51
Grass	350	315	1.1	347	60	$CH_{2.05}O_{0.97}N_{0.007}$	0.15	151	52
Sewage sludge[a]	50	45	1.2	50	35	$CH_{2.18}O_{0.94}N_{0.057}$	0.07	12	55
Food waste	300	270	2.5	351	75	$CH_{2.32}O_{0.85}N_{0.019}$	0.25	169	58

The reported values have been compiled from a wide range of literature sources and should be considered as indicative, since reported values may vary by a factor of two at least.
[a] A mixture of primary and secondary sludge is assumed.
[b] Indicative hydrolysis rate constants reported are for mesophilic digestion; typically, thermophilic rate constants are a factor of two higher.
[c] It is assumed that the biodegradable and nonbiodegradable fractions of organic carbon have the same elemental composition.

IV.XII Calculation Gas, Electricital and Carbon Dioxide potential from organic waste stream Amstel III 2040 through anaerobic digestion and gas turbine.

ACRONYMS

OFMSW	organic fraction of municipal solid waste

SYMBOLS

E	energy content of gas
ODM	organic dry matter (g/kg)

DATA (Paper, Kleerebezem)

Normal volume of 1kmol gas (m3)	22.4
E (n,CH4) (MJ*m^3)	36.5
Efficienty electricity generation	40.00%
MJ*kmol^-1	818

molaire mass

C	12.011
H	1.0079
O	15.999
N	14.0067

DATA properties waste	biodeg %	H	O	N	ODM (g / kg)	Biogas (L/kg	CH(%)
OFMSW	50%	2.1	0.96	0.024	270	106	53%
Food	75%	2.32	0.85	0.019	270	169	58%
Sewage sludge	35%	2.18	0.94	0.057	45	24	55%

INPUT	**yard/garden (OFMSW)**	**food (%)**	**sewage sludge (%)**	**other (OFMSW)**	**amount (kg/d)**	**ODM (kg)**	**Biodeg(%)**
Garden	100.00%	0.00%	0.00%	0.00%	*1299*	***350.60***	*50.00%*
Food waste	0.00%	100.00%	0.00%	0.00%	*8258*	***2229.70***	*75.00%*
Sewage sludge	0.00%	0.00%	100.00%	0.00%	*92762*	***4174.29***	*35.00%*
				Total:	102319	**6755**	**38.42%**

Properties feedstock	C	H	O	N	Molaire Mass
Resort organic	1	2.1	0.96	0.024	29.8227908
Local organic	1	2.32	0.85	0.019	28.2146053
Greenhouse waste	1	2.18	0.94	0.057	30.0456639
Total feedstock	**1**	**2.190**	**0.933**	**0.054**	**29.89505037**

Substrate	CH4	CO2	NH4HCO3	H20
Produced	0.56	0.43	0.05	-0.08
kmol/day	48.66325029	36.9801737	4.645287568	-6.908258667
kg/day	780.6850592	1627.46047	362.5475071	-124.4508982

Quantity	kmol/day	kg/day	m^3/day	CH4	CO2
Biogas	85.64342403	2408.14553	1918.412698	56.82%	43.18%

OUTPUT EL	**hour**	**Daily**	**Weekly**	**Yearly**
biogas (m^3)	80	1918	13429	700221
MJ (bruto)	1658	39787	278510	14522282
kWh (bruto)	460	11052	77364	4033967
kWh (netto)	**184**	**4421**	30946	1613587

OUTPUT CO2	**hour**	**Daily**	**Weekly**	**Yearly**
CO2 (in biogas) (m^3)	34.51482882	828.355892	5798.491242	302349.9005
CO2 (due combution) (m^3)	45.41903361	1090.05681	7630.397646	397870.7344
total CO2 (m^3)	79.93386243	1918.4127	13428.88889	700220.6349
total CO2 (kg)	**158.7486508**	**3809.9676**	**26669.77333**	**1390638.181**

IV.XIII Ingredients in typical digestate

form	DM (%)	N(total) (kg/m3)	NH4 (kg/m3)	NH4 share (% of N)	P205 (kg/m3)	k2O (kg/m3)
Liquid digestate	6.5	5.1	3.2	62.7	2.3	5.5
Liquid separated fraction	5.7	4.9	3.1	63.3	2	5.4
Solid separated fraction	24.3	5.8	2.7	46.5	5	5.8

(Fachverband Biogas e.V., 2018)

II.XIV Gross amount and absorbable amount of nitrogen of digestate of OFMSW and SW Amstel III

NITROGEN	N (g*kg-1)	amount daily (kg*d)	yearly (kg)	N(total) (kg)	N(absorbed) (kg)
Garden (OFMSW)	3	1299	473960	1422	892
Food	2.5	8258	3014228	7536	4725
Sewage sludge	1.2	92762	33858134.9	40630	25475
total		102319	37346324	49587	31091

(Nitrogen amount is calculated with key figures on feedstock of IV.VI, absorbed amount is based on issue Digestate as Fertilizer, Wilken, D., (2018))

II.XV P and K amounts based on N values in comparison with Fachverband Biogas e.V., 2018

PHOSPHORUS AND POTESSIUM	factor	kg yearly
P2O5	0.4509804	22363
K2O	1.0784314	53476

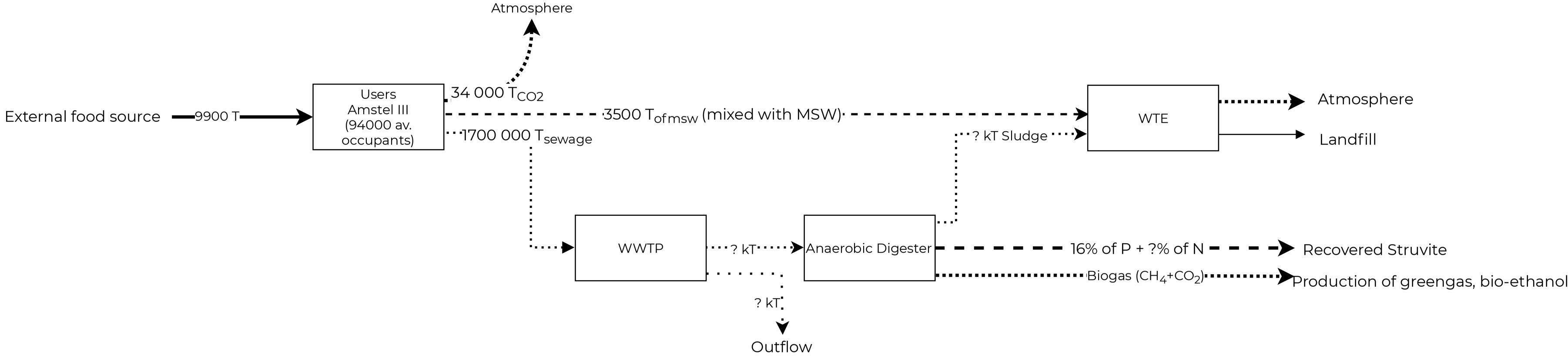
II.XVI Solid and liquid fraction by comparison with Fachverband Biogas e.V., 2018

form	% in mass (m3)	N(total) (kg)	NH4 (kg)	NH4 share (% of N)	P205 (kg/m3)	k2O(kg)
Liquid digestate	100	49587	31091	62.7	22363	53476
Liquid separated fraction	95.7	49391	31265	63.3	24611	52124
Solid separated fraction	4.3	1875	872	46.5	9421	46442

Notes figure IV.XII Calculation Gas, Electricity and Carbon Dioxide potential from organic waste stream Amstel III 2040 through anaerobic digestion and gas turbine.
Input data is taken from appendix II.I and matched with the closed type of feedstock from the paper of Kleerebezem depicted in II.III. Take note that the paper of Kleerebezem describes the Total Dry Matter (TDM) to be 50g *kg, from the total amount of sewage coming from Amstel III in appendix II.I results in a TDM of 1 g*kg, this partly due the fact that standard municipal sewage include other solids such as toilet-paper, dirt and sand. But more importantly, Kleerebezem uses a mixture of primary and secondary sludge as input. Primary and secondary sludge is pre-treated with the removal of toxic (fluids) and has a reduced weight by removing water. The mixture of his paper has a higher amount of solid then domestic sewage water.
Primary sludge is only 6 - 7% of the total sewage.
(van der Hoek, 2016)

IV.XV Current energy MFA

Organic Material Flow current situation



V Nutrional demand

V.I NPK Demand of different arable crops per tonne (Aendekerk, T., van Himste, R., & Hopman, M. (1995))

Akkerbouw-/groenteteelt vollegrondprodukten				
		gem. kg per ton vers		
	gewasdeel	N	P_2O_5	K_2O
Aardappel, Consumptie-	knollen	3,3	1,1	5,1
Aardappel, Poot-	knollen	3,3	1,1	5,1
Aardappel, Vroege consumptie	knollen	3,0	0,9	5,1
Aardappel, Zetmeel-	knollen	3,7	0,9	5,2
Andijvie	blad	2,5	0,7	4,6
Andijvie	oogstrest	1,8	0,5	5,4
Asperge	asperges	3,5	0,9	2,5
Augurk	loof	2,0	3,4	5,1
Augurk	vrucht	1,5	0,9	3,0
Bietenstaartjes	staartjes	2,5	0,0	0,0
Bladkool	plant	3,3	0,5	2,8
Bladrammenas	plant	3,0	0,0	0,0
Blauwmaanzaad	zaad	34,0	20,0	10,0
Blauwmaanzaad	stro	13,0	8,0	22,0
Bloemkool	kool	2,9	0,9	3,5
Bloemkool	oogstrest	3,3	1,1	4,9
Boerenkool	oogstrest	4,4	0,9	6,5
Boerenkool	plant	4,0	1,6	5,1
Broccoli	kool	2,0	1,6	5,1
Broccoli	oogstrest	4,7	1,6	7,0
Chinese kool	krop	1,5	0,9	3,0
Chinese kool	oogstrest	2,0	0,7	4,6
Corn Cob Maïs	kolf	9,3	4,4	3,1
Corn Cob Maïs	stro	3,0	0,9	7,6
Doperwten	zaad	7,5	1,6	3,5
Erwt, Ronde groene	stro	21,0	4,6	23,1
Erwt, Ronde groene	zaad	33,6	9,6	14,1
Graszaad	zaad	18,0	8,0	7,0
Graszaad	stro	11,0	3,0	18,9
Haver	zaad	17,0	8,0	5,1
Haver	stro	5,0	2,1	18,1
Karwij	zaad	32,0	15,1	18,1
Karwij	stro	5,0	3,0	24,1
Klaver, Alexandrijnse	plant	4,9	1,4	4,3
Klaver, Witte	hooi	17,6	5,7	27,2
Klaver, Witte	vers	5,6	1,1	3,7
Knolvenkel	knol	2,0	0,5	6,0
Koolraap, Consumptie	knol	1,5	0,9	2,5
Koolrabi	knol	2,0	0,9	4,6
Korrelmaïs	korrels	13,9	6,7	4,3
Korrelmaïs	stro	2,9	0,9	7,2
Lupinen	plant	4,5	0,9	4,6
Luzerne	plant	5,8	1,4	8,0
Peen, Bos-	plant	1,5	0,7	3,5
Peen, Fijne	wortel	1,5	0,7	3,5
Peen, Grove (Winter-)	wortel	2,4	0,9	4,3
Peterselie	blad	4,5	1,6	8,6
Prei	plant	3,0	0,9	4,0
Prei	oogstrest	3,0	0,7	4,1
Radichio rosso	krop	3,0	0,9	4,0
Radijs	plant	1,5	0,5	3,5
Rode biet	wortel	2,5	0,9	4,6
Rode Kool	kool	3,0	0,9	3,5
Rode Kool	oogstrest	3,7	0,9	4,0
Rogge	zaad	14,0	7,1	6,0
Rogge	stro	3,8	1,8	10,1
Savooiekool	kool	4,0	0,9	4,0
Savooiekool	oogstrest	3,9	1,1	5,3
Schorseneren	wortel	3,5	1,6	4,0
Selderij, Blad/Snij	plant	1,6	0,9	8,4
Selderij, Bleek-	plant	2,4	0,9	3,5
Selderij, Groen-	plant	1,0	0,5	3,5
Selderij, Knol-	knol	2,0	1,6	5,5
Selderij, Knol-	oogstrest	2,8	0,9	6,7
Serradelle	plant	4,3	1,1	6,0
Serradelle	stro	0,0	5,7	28,7
Sla, Batavia-	krop	0,0	0,7	3,7
Sla, Eikeblad-	krop	0,0	0,7	4,6
Sla, IJs-	krop	1,5	0,5	2,5

Akkerbouw-/groenteteelt vollegrondprodukten				
		gem. kg per ton vers		
	gewasdeel	N	P_2O_5	K_2O
Sla, Krop-	krop	2,0	0,7	3,5
Snijgerst	plant	4,5	1,1	5,2
Snijhaver	plant	4,0	1,1	5,3
Snijmaïs	plant	4,6	1,6	6,0
Snijrogge	plant	4,5	2,1	6,5
Spinazie	blad	3,5	0,9	6,5
Spinazie	oogstrest	2,3	1,1	7,7
Spitskool	kool	4,0	0,9	3,5
Spruitkool	spruiten	5,5	2,1	6,0
Spruitkool	stammen	5,4	1,6	5,7
Stam-sperzie/slaboon	oogstrest	5,0	1,1	6,7
Stam-sperzie/slaboon	peulen	2,2	0,9	3,0
Stoppelknol	blad+knol	3,0	1,1	4,0
Suikerbieten	loof	3,4	0,7	4,8
Suikerbieten	wortel	1,8	0,9	2,5
Theunisbloem	zaad	23,5	16,5	11,1
Theunisbloem	stro	3,0	3,0	23,1
Triticale	stro	5,8	4,6	9,4
Tuinboon	bonen	42,0	9,6	13,0
Veldboon	zaad	40,0	13,1	14,8
Veldboon	plant	4,2	1,4	3,4
Veldboon	stro	10,9	2,8	16,7
Vlas	zaad	33,0	15,1	9,0
Vlas	stro	4,0	4,1	11,1
Voederbieten	plant	1,9	0,5	3,4
Voederwikken	plant	6,8	1,6	6,6
Wintergerst	zaad	17,0	8,0	6,0
Wintergerst	stro	5,4	2,1	14,9
Winterkoolzaad	zaad	35,0	15,1	10,0
Winterkoolzaad	stro	6,0	3,0	20,1
Wintertarwe	zaad	20,0	8,5	5,1
Wintertarwe	stro	5,8	1,6	14,9
Witlof	krop	1,9	0,7	2,3
Witlofwortelen	na trek	1,4	0,7	4,2
Witlofwortelen	voor trek	2,1	0,9	4,5
Witte Kool	kool	2,5	0,7	3,0
Witte Kool	oogstrest	2,8	0,9	4,0
Zaaiui (incl Picklers)	ui	2,2	0,7	1,8
Zomergerst	zaad	15,0	8,0	6,0
Zomergerst	stro	5,4	2,1	14,9
Zomertarwe	zaad	17,0	8,5	5,1
Zomertarwe	stro	5,8	1,6	14,9
Zonnebloem	plant	3,5	0,9	4,0

Gewas *	gewasdeel	gem. kg per ton vers		
		N	P_2O_5	K_2O
Eiwithoudende gewassen *	plant	4,2	1,4	3,4
Hakvruchten *	plant	3,0	1,1	5,1
Loof *	loof	3,5	1,1	3,6
Oliehoudende zaden *	zaad	32,0	16,1	9,6
Overige vollegrondsgroenten *	produkt	5,0	1,1	3,6
Overige vollegrondsgroenten *	rest	3,0	1,1	6,0
Overige zaden *	zaad	18,0	8,0	7,2
Overige zaden *	stro	3,5	0,9	4,0

* Voor een groot aantal produkten ontbreken forfaitaire getallen volledig. De genoemde getallen zijn aannames.

V.II NPK Demand of different arable crops per tonne (Aendekerk, T., van Himste, R., & Hopman, M. (1995))

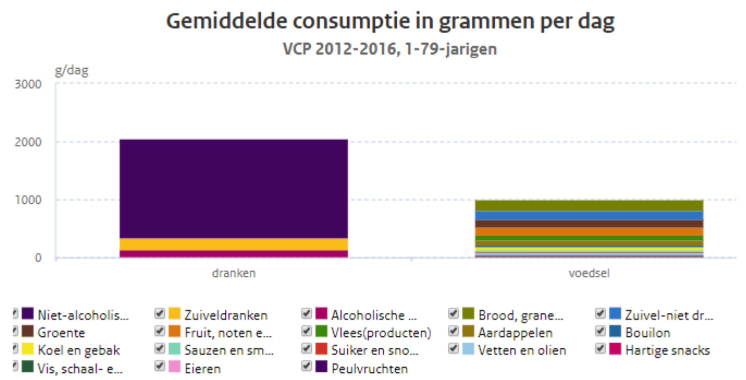
		(NKP)Average KG per tonne			yield rates			nutrion	
	crop type	N	P205	K2O	(fresh)tonne/ ha*harvest	nmbr harvest	(fresh)ton ne/ha*y	kCal (100 gr)	source
Direct consumption	**Potato**	3.3	1.1	5.1	-	-	46	83	1
	Cauliflower	2.9	0.9	3.5	14	3	42	23	3
	Broccoli	2	1.6	5.1	8	3	24	29	2
	Chinese cabbage	1.5	0.9	3	40	2	80	19	9
	Corn	13.9	6.7	4.3	-	-	15	354	1
	Pea	33.6	9.6	14.1	-	-	5	86	8
	Beans	42	9.6	13	-	-	12	71	5
	Beans (CEA)	42	9.6	13	4	4	16	71	4
	Oats	17	8	5.1	-	-	5	374	1
	Orchard (apple)	4.0	2.0	2.0	-	-	50	95	10&11*
	Grain	20	8.5	5.1	-	-	8	329	1
Feed	**Maiz**	4.6	1.6	6	-	-	40	-	1

** sources did not provide exact value for yield rates and NPK, therefor an estimation is made on the values*

		animal feed [kg]/live weight [kg]	Edible share	real animal feed [kg]/ weight [kg]
Meat	**Beef**	25	40%	63
	Pork	9.1	55%	17
	Chicken	4.5	55%	8

1 https://opendata.cbs.nl/statline/#/CBS/nl/dataset/7100oogs/table?fromstatweb
2 https://edepot.wur.nl/282860
3 https://edepot.wur.nl/252740
4 http://edepot.wur.nl/252306
5 https://edepot.wur.nl/252731
6 https://www.voedingscentrum.nl/nl/service/vraag-en-antwoord/gezonde-voeding-en-voedingsstoffen/hoeveel-calorieen-zitten-erin-/caloriechecker/gekookte-aardappelen.aspx
7 https://edepot.wur.nl/249750
8 https://edepot.wur.nl/254841
9 https://edepot.wur.nl/255027
10 https://edepot.wur.nl/211400
11 http://www.fao.org/3/ac681e/ac681e08.htm

V.III Average consumption in the Netherlands (



V.IV NPK and ha demand for producable food of diet of Amstel III

Demand	PP in grams	Tot. Amstel III in tonnes	Feed per kg	N (kg)	P205 (kg)	K2O (kg)	kCal (10^6)	ha required	*notes*
Meat, dairy, animal products	305	4087	22	409976	142600	534751	10538	2469	*estimation based on 1/2 chicken, 1/4 pork, 1/4 cow meat, area is estimated as factor 0.1 of feed*
fish	16	214	-	-	-	-	-	-	
Grain products	194	2600	-	51992	22097	13258	8553	325	*based on grain*
Potato	72	965	-	3184	1061	4921	801	21	
vegetables	131	1755	-	3511	2809	8953	509	61	*based on brocolli*
fruits and nuts	130	1742	-	6968	3484	3484	1655	18	*based on apple from orchard*
beans	5	67	-	2814.02	643	871	48	4	*beans grown with CEA*
other	119	1595	-	-	-	-	-	-	
Total	972	13025		478445	172694	566238	22103	2898	

Possible production	Meat, dairy, animal	Grain products	Potato	vegetabl es	orchard (fruit/ nuts)	beans	TOTAL	*available in Amstel III*
tonnes	100	200	965	1755	1742	67	4829	
N(kg)	10031	4000	3184	3511	6968	2814	30508	*31091*
P2O5 (kg)	3489	1700	1061	2809	3484	643.2	13186	*22363*
K2O (kg)	13084	1020	4921	8953	3484	871	32332	*53476*
land (ha)	60	25	21	73	35	4	219	

https://wateetnederland.nl/resultaten/energie-en-macronutrienten/inname/alle-macronutrienten

V.V CO_2 demand and supply

CO2 for CEA

Average Greenhouse		
Demand	32.3	kg/m2
CEA in Amstel III		
Surface area doced	77	ha
Demand	24978	T(CO2)*y

(RSFGV, 1999)

Available

Biogas plant		
OFMSW + SW	1391	T(CO2)*y
percentage use	100%	CO2

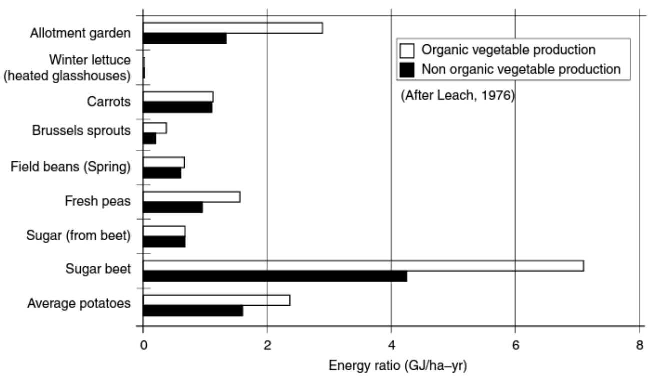
Users Amstel III		
Occupation	125381	pp
Av. CO2 human	1	kg/day
CO2 produced	45764	T(CO2)*y
percentage use	52%	CO2

V.VI Flows of conventional and organic arable farming according to Vilijoen

Organic food production: energy expenditure in terms of energy ratios (after Leach, 1976)

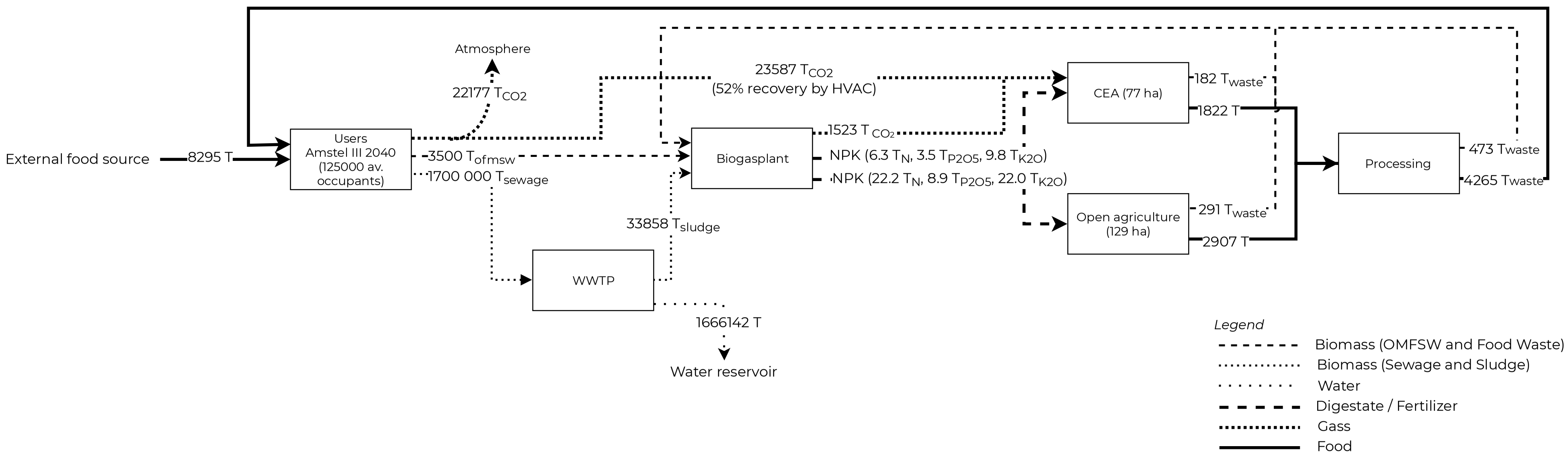
INPUTS	CONVENTIONAL PRODUCTION	ORGANIC PRODUCTION
Fertiliser N, 175 kg	14.00	
Fertiliser P, 175 kg	2.45	
Fertiliser K, 250 kg	2.25	
Field Work, fuels for tractors (to harvest)	2.85	2.85
fuels for harvester, transport	3.38	3.38
Field Work, tractors depreciation and repair	1.14	1.14
harvesters depreciation and repairs	6.70	6.70
Sprays, 13kg	1.24	
Seed shed fuels (620 MJ/t seed)	1.57	1.57
Storage (1,65 kWh/net t)	0.57	0.57
	TOTAL 36.15	TOTAL 16.21
OUTPUTS		
Gross yield t	26.3	
Net yield (less 2.5t seeds) t	23.8	
Edible yield t	17.9	at 66% of conventional 11.9
Energy output (17.9t x 3.18 MJ/kg) GJ/ha	TOTAL 56.9	TOTAL 37.95
Protein output (17.9t x 2.1% protein) kgP/ha	376	
RATIOS		
Energy out/in	1.57	2.34

An energy ratio is defined as the edible energy output of food divided by the energy input necessary to produce it.



V.V Proposed organic MFA 2040

Organic Material Flow 2040 proposed model



VI
Examples

VI.I Organoponicos

(image: www.foodurbanism.org)

(image: www.theguardian.com)

https://www.theguardian.com/environment/2008/apr/04/organics.food
Ed Ewing (2008)
Cuba – organoponicos – urban intensive agriculture – selfreliant organic farming

Cuba needed to become self-reliant after collapse Soviet Union in 1990/91. Calorie intake dropped from 2600 in the late 1980's to 1000 – 1500 in 1993 daily due to 80% decrease in import. As result of an embargo by the USA, there was no chemical fertilizer, pest control and fuel for machinery available. A consequence was that people were forced to start cultivating close to where they were living in an organic fashion to prevent soil depletion and with biological pest control. During this time 25,000 allotments popped up and dozens larger scale organoponicos. On a national scale 3.4% of urban land was used for these purposes and 8% in Havana was being used. In 2002 this was good for 3.2m tonnes of food and the total calorie intake is back at 2600 kCal. Now, this cultivation culture is in decline / under threat since the embargo is weaker and Cuba is losing its isolated position.

- Organoponics, supported through governmental control. Business Model; growers earn 50% of the sales.
- Direct link to a shop or farmers market. (In Cuba only open once a week.)
- Benefits: organic, self reliant, health benefits
- Cons: financial constraints not choice, labour intensive

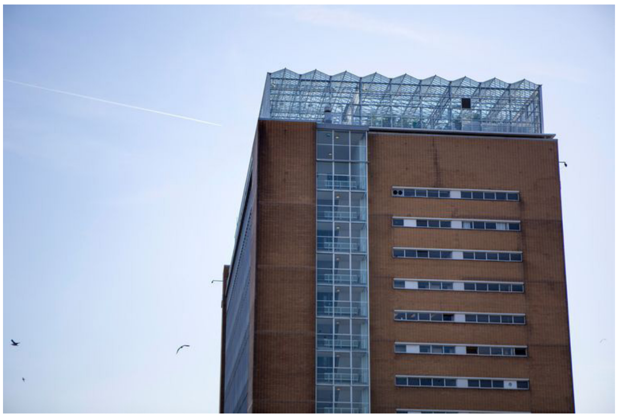
VI.II Urban farming in Rotterdam, DakAkker

(image: www.daktuinen.nu)

On top of the Schieblock office building in the center of Rotterdam the largest rooftop-farm in Europe is situated: "the DakAkker". Here fruits, vegetables and herbs are grown and honey bees are kept. (https://www.luchtsingel.org/en/locaties/roofgarden/)

- Space efficiency
- Low yield
- Organic farming
- Combined with restaurant

VI.III The New Farm



(image: www.trouw.nl)

https://www.nrc.nl/nieuws/2018/08/09/dakboeren-is-sexy-acht-euro-voor-een-kilo-tomaten-niet-a1612629

Maren Schoormans (Priva), Andreas Graber (Urban Farmers), Peter Jens (Koppert)
The New Farm – Analysis -
"Of ze hadden een ander verdienmodel nodig, zegt Van der Schans. „Leveren aan de Makro doen tuinders al. Een community rondom de boerderij bouwen niet."

Arguments:

- A. Too much attention for technical innovation, no regard for neighbourhood.
- B. Idea of the project was to show innovation.
- Supposed to be PR-project, not commercial.
- No professional grower, due to mismatch investors and sector.
- Produce of gh was matching to the demand of restaurants and supermarket. However, the produce was not standard. Exclusive products thus more expensive.
- Gamble on more lucrative selling of fish, due to EU-regulations. Gamble failed.
- Business model existed at one point for 2/3 out of hospitality (tours and weddings). This was not the initial plan.
- Use of not proven technology, risk on risk on risk. Technocratic.
- Too much food production in the NL. Hard to compete with existing market. Should look for exclusivity in NL. (Camel milker???)
- Different business model, look at community building.
- Restaurants only bought 5% of their tomatoes from the gh, due to price difference.
- Positive: future growers would like to live in city.

VI.III Bruwery Kleiburg

Local brewery in Amstel III.

- Marketable concept
- Local production
- Well known product
- Utilizing residue heat of brewery

sources

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