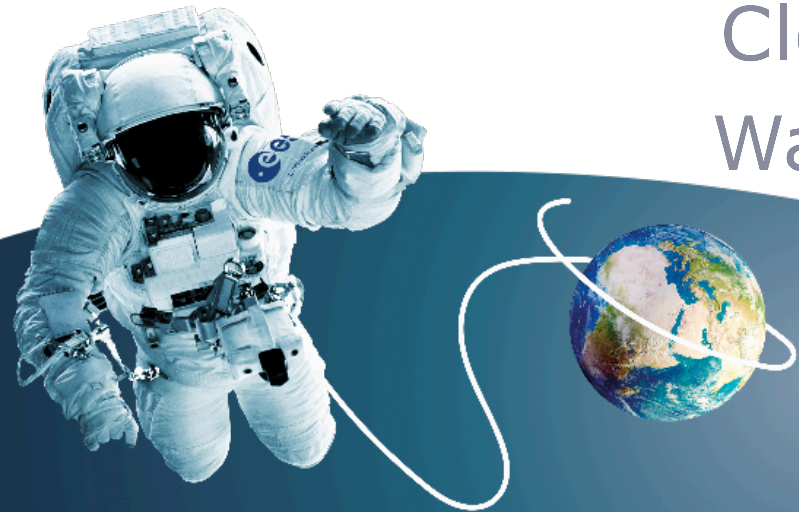
FROM WASTE TO RESOURCE

Closing the loops in the Urban Water, Energy and Food Nexus



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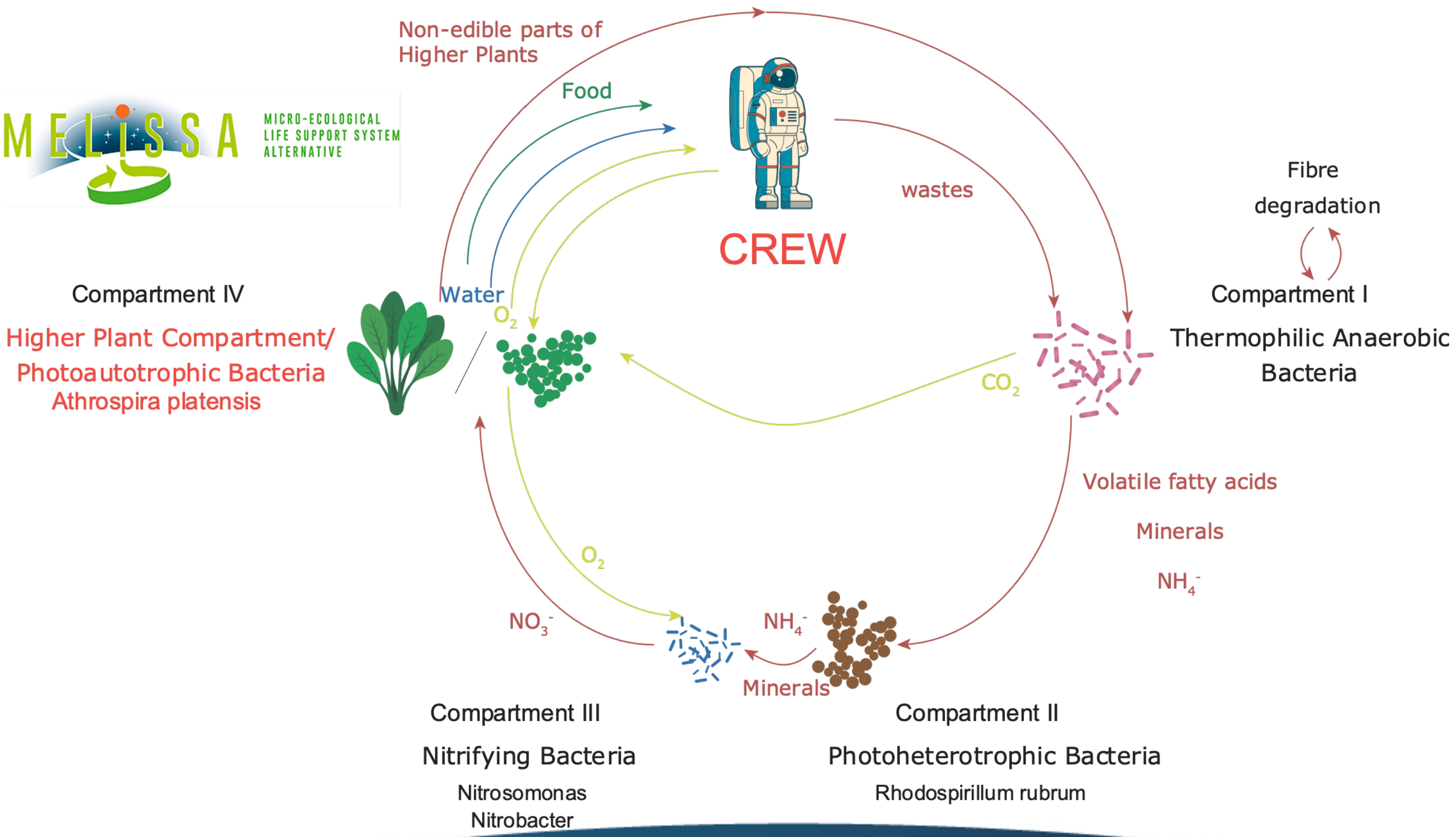
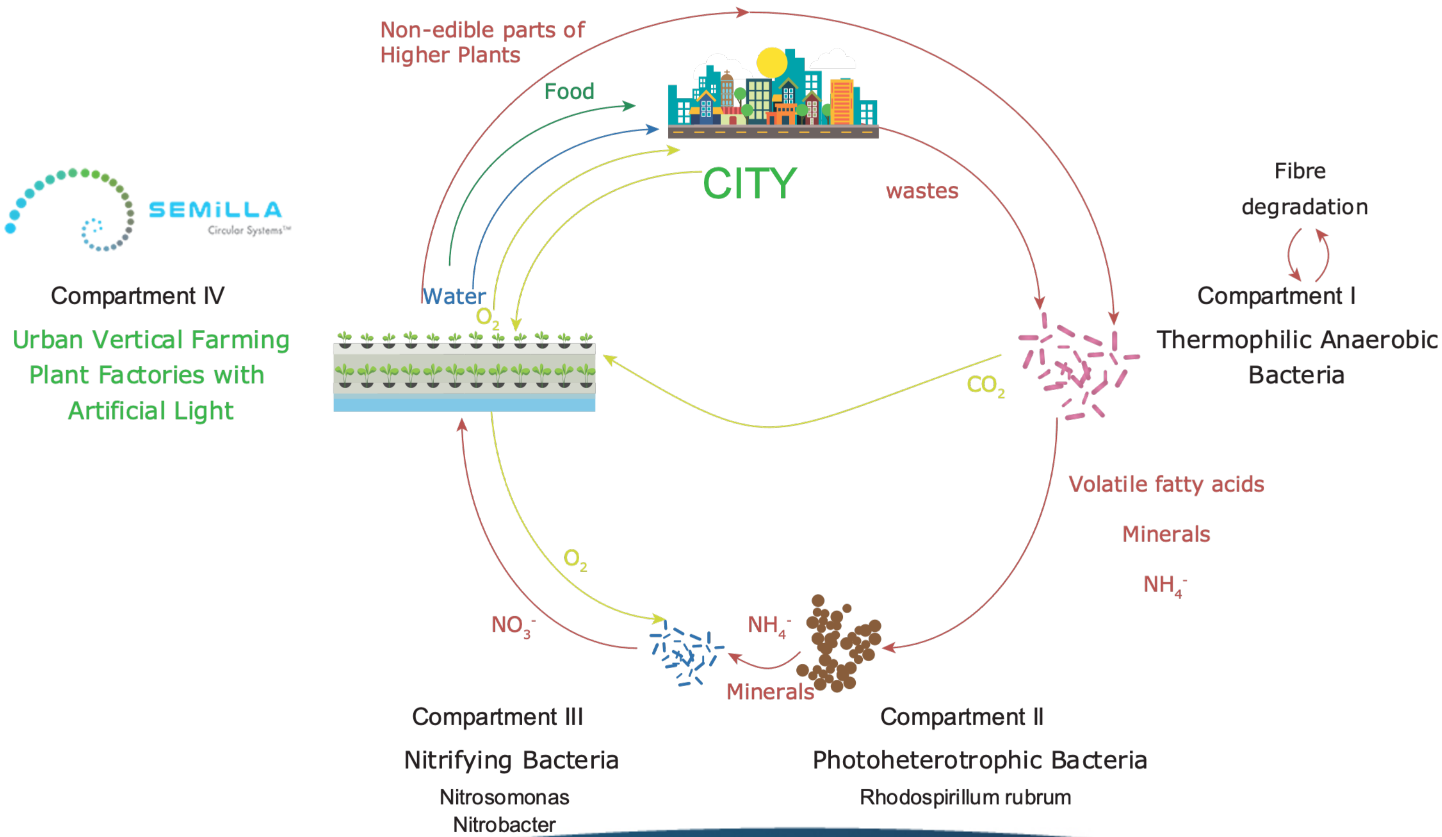
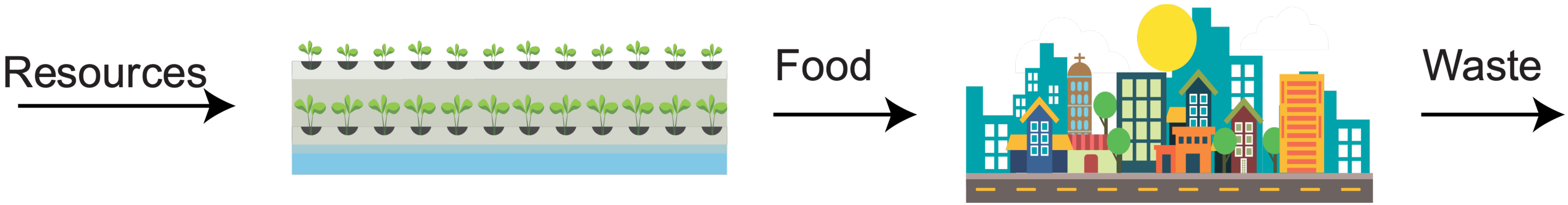
ESA - MELiSSA Space Heritage



MELiSSA - Earth Application



Circular Food Systems - FS context



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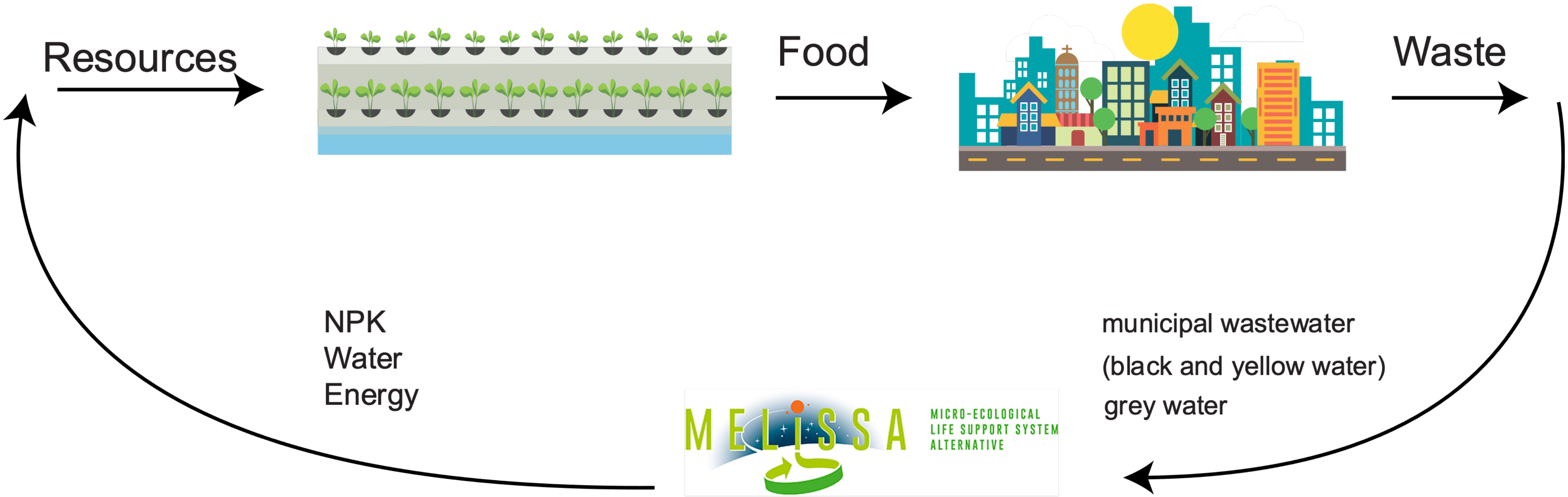
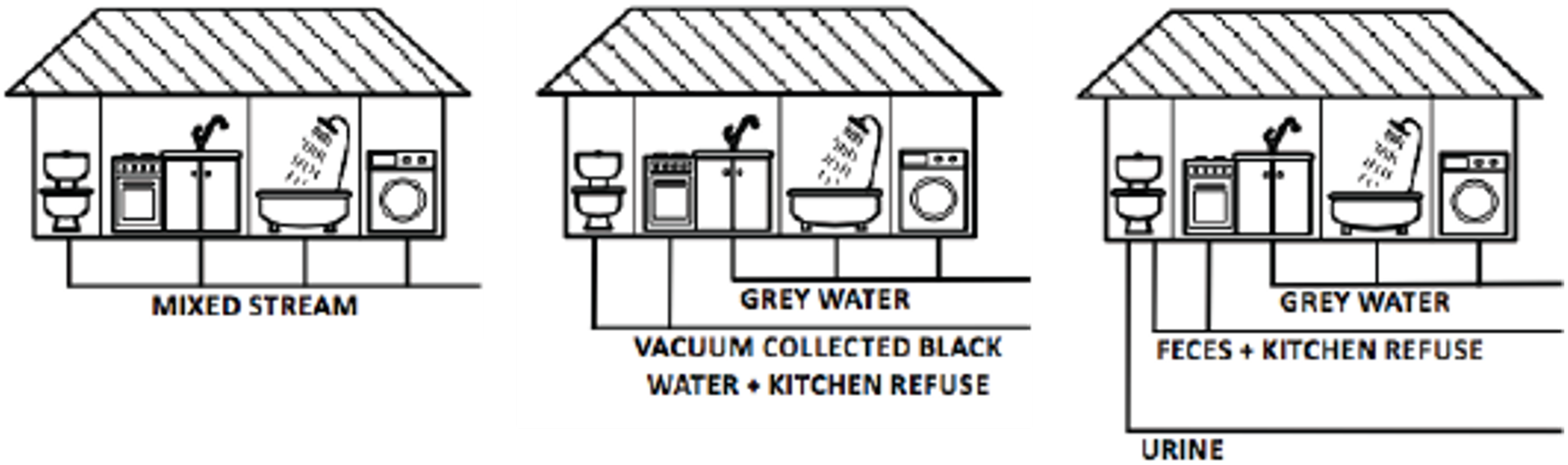


Circular Food Systems - FS context

	Production [kg m $^{-2}$]	Wateruse [l m $^{-2}$]	Nutrients [g l $^{-1}$]		
Crop			N	P	K
Tomato	65	900	2.42	0.57	3.74
Cucumber	85	900	1.67	0.36	2.37
Pepper	35	800	3.64	0.62	4.50
Lettuce	25	400	2.97	0.65	4.50

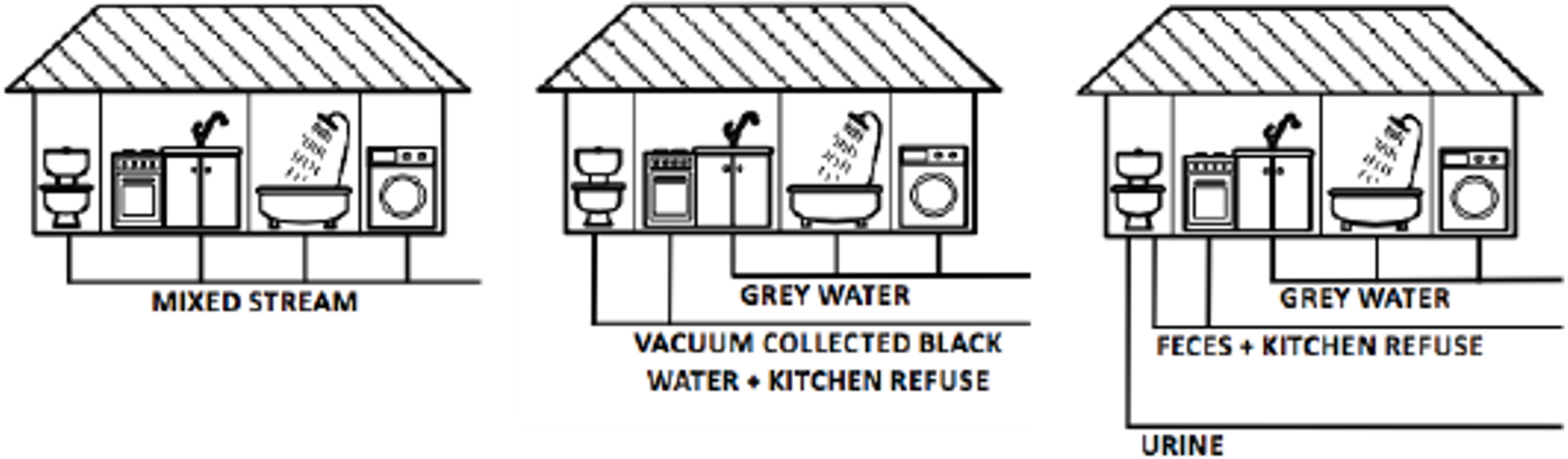
Amsterdam Wastewater - FS context



Source: i)Mixed, ii)BW + GW, iii)BW + YW + GW

Data[p^{-1} d^{-1}]: Volume, COD, BOD, TN, TP, K, TSS, Ca, Mg, Na

Amsterdam Wastewater - FS context

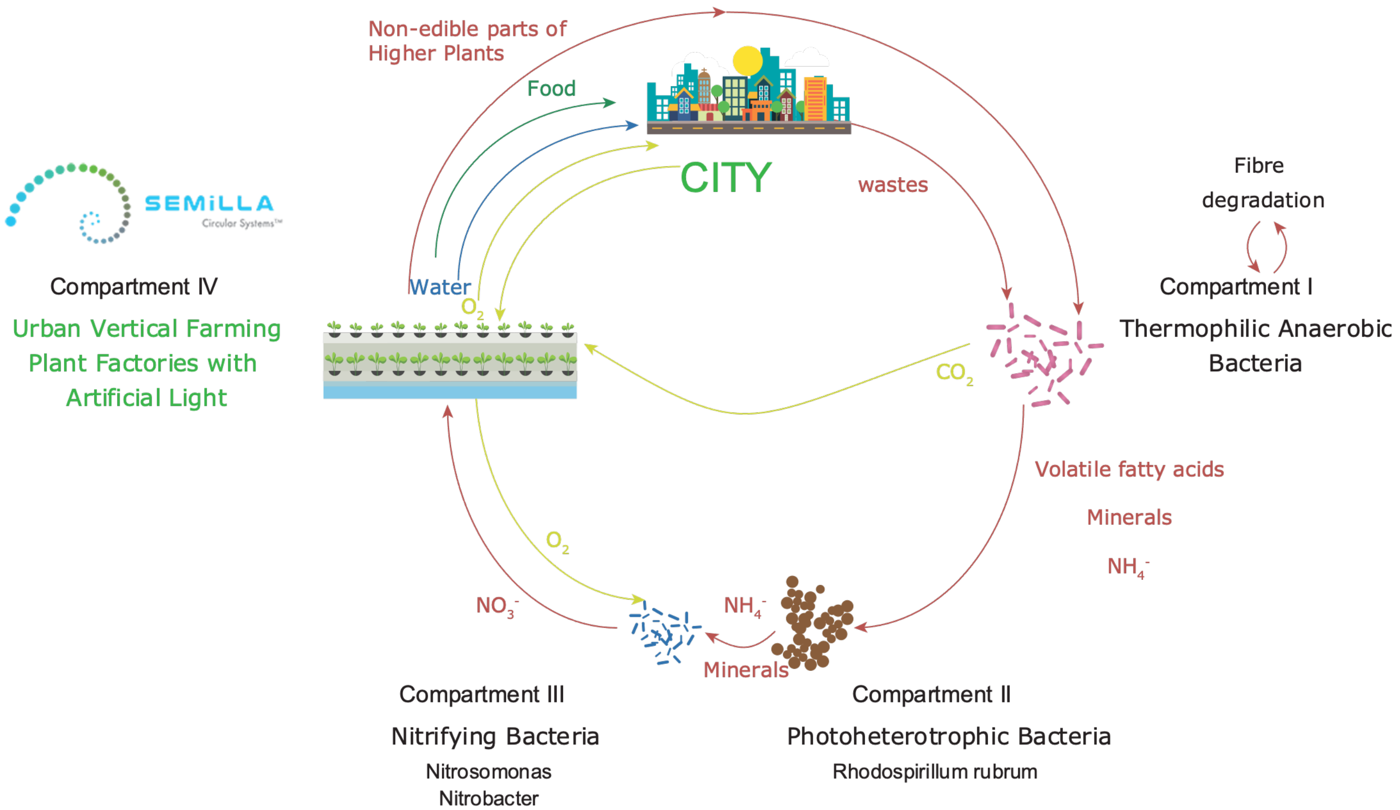


Source: i)Mixed, ii)BW + GW, iii)BW + YW + GW

Data[p^{-1} d^{-1}]: Volume, COD, BOD, TN, TP, K, TSS, Ca, Mg, Na

MELiSSA output [p^{-1} d^{-1}]: Irrigation water, Fertilizer (NPK), Energy

From waste to resource concept



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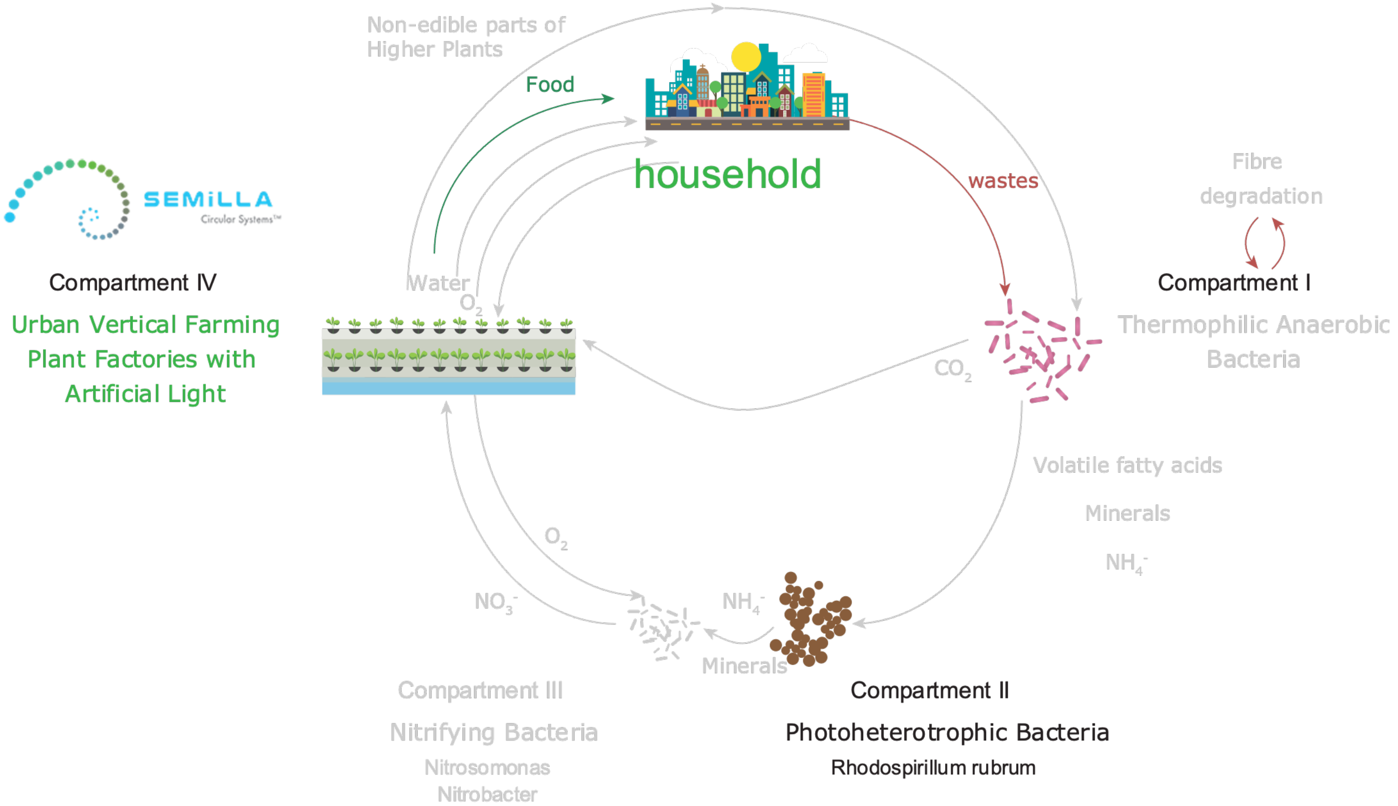
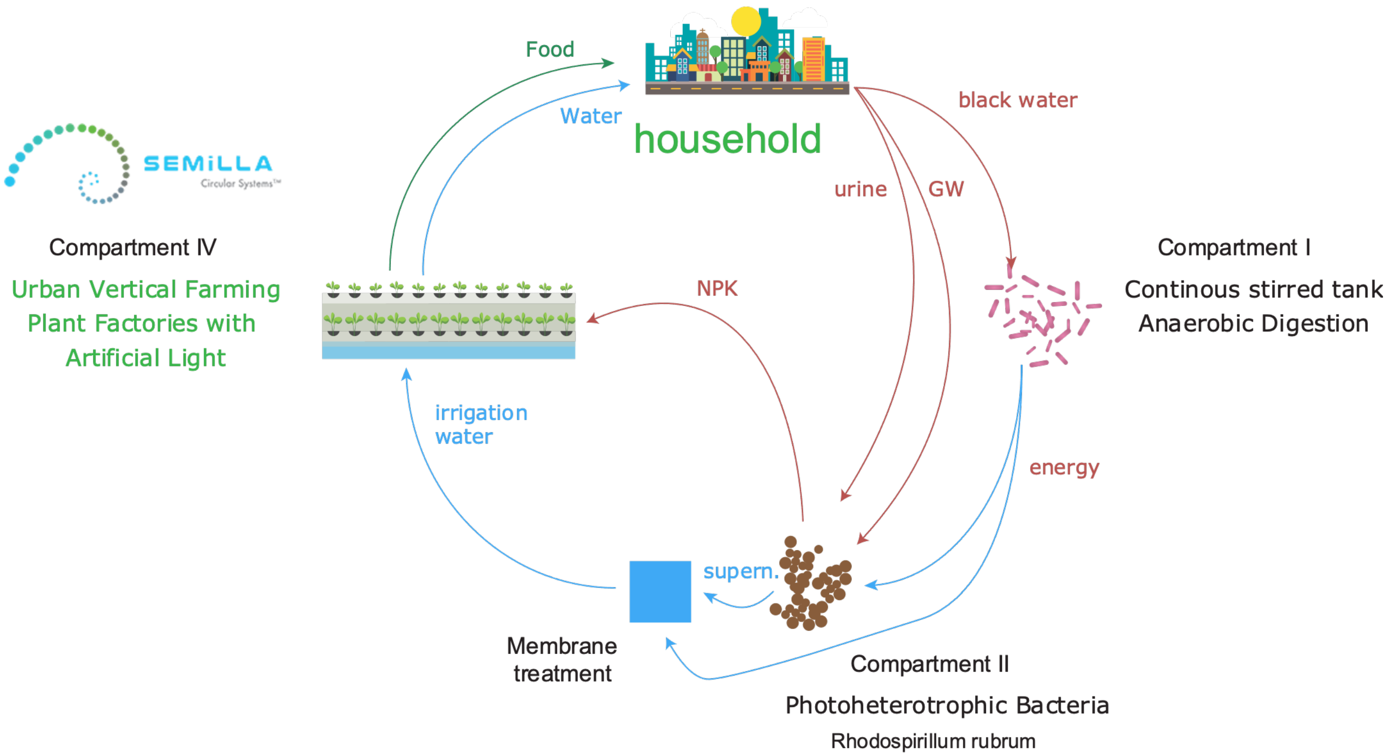


From waste to resource concept



C1 - liquefying compartment

model by TU Delft

Input:
Volume: 2l p^{-1} d^{-1}
COD: 27250 mg $l^{-1}p^{-1}d^{-1}$

Model: BioWin (TU Delft)

System Design:
Volume: 100 people equivalent
HRT: 3 d
Temperature: 35 ºC
Methane: 65% COD d^{-1}
Electricity: 25% Methane

Output:
Biogas rate: 1771.25 m^3 CH_4 d^{-1}
kWh Methane: 19438.75 kWh d^{-1}
Electricity: 4870.93 kWh d^{-1}
Electricity: 48.70 kWh p^{-1} d^{-1}

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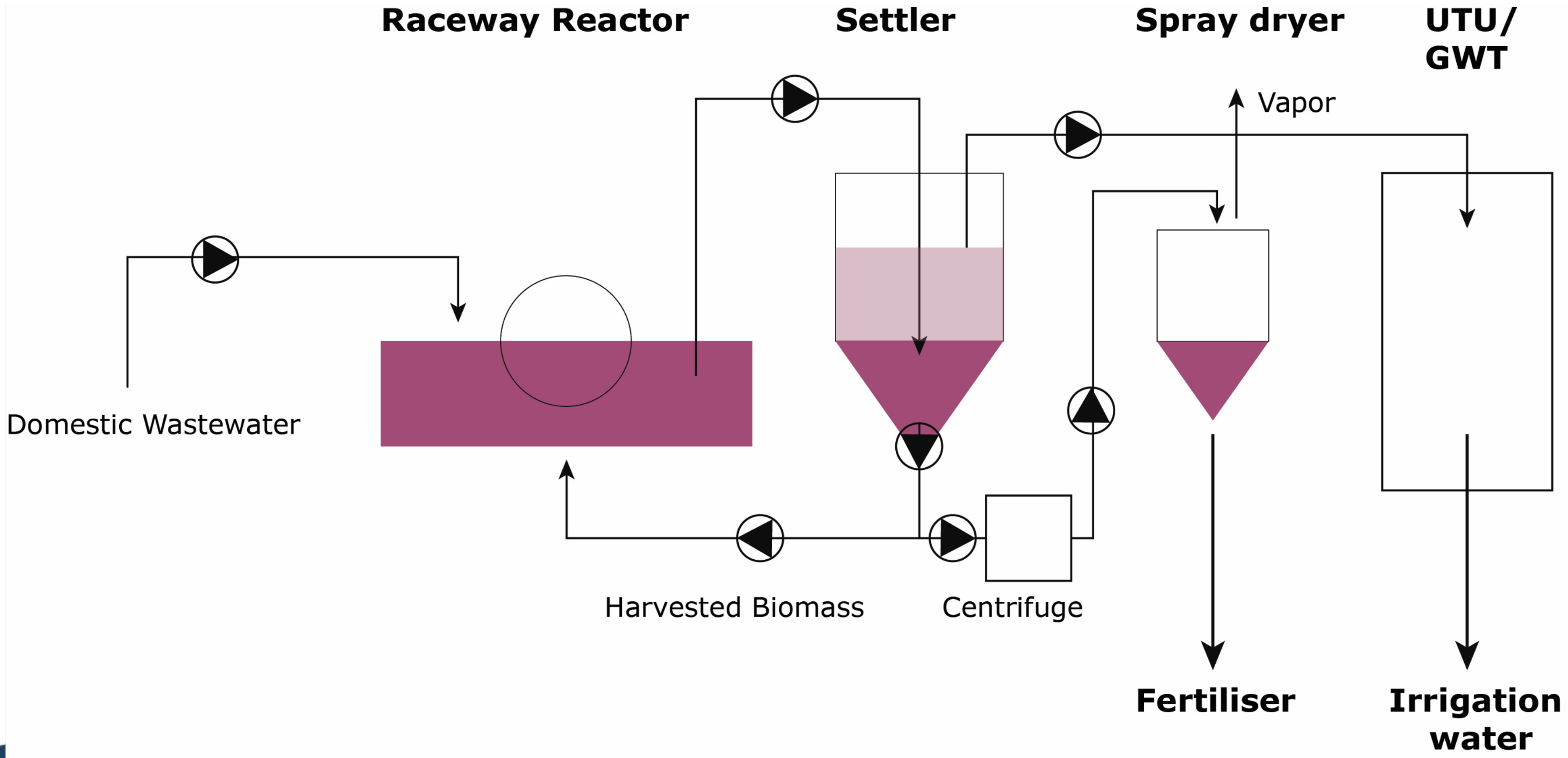
Electricity: 48.70 kWh p^{-1} d^{-1}

Food production demand:
Lettuce demand: 27.44 kWh kg^{-1} d^{-1}
Graamans et al. (2015)

Electricity produced: 48.70 kWh p^{-1} d^{-1}
Energy demand: 170%
Production: 1.7 kg p^{-1} d^{-1}

C2 - Photoheterotrophic bacteria (PNSB)

model by University of Antwerp



C2 - Photoheterotrophic bacteria (PNSB)

model by University of Antwerp

Input:

Greywater

Volume: *49.4 l p^{-1} d^{-1}*

COD: 1052.6 mg l^{-1}

BOD: 566.8 mg l^{-1}

TN: 28.3 mg l^{-1}

TP: 10.1 mg l^{-1}

TK: 20.2 mg l^{-1}

TSS: 1109.3 mg l^{-1}

Urine

Volume: *2.4 l p^{-1} d^{-1}*

COD: 3750 mg l^{-1}

BOD: 1875 mg l^{-1}

TN: 3583 mg l^{-1}

TP: 291.7 mg l^{-1}

TK: 750 mg l^{-1}

TSS: na

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Volume: 49.4 l p^{-1} d^{-1}

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COD: 3750 mg l^{-1}

BOD: 1875 mg l^{-1}

TN: 3583 mg l^{-1}

TP: 291.7 mg l^{-1}

TK: 750 mg l^{-1}

TSS: na

System design:

HRT: 1.5 d

SRT: 5 d

Max. COD removal efficency: 80%

Max. COD removal rate: 1667 mg l^{-1}

Biomass yield:

0.37 $gCOD_{biomass}$ $gCOD_{removed}^{-1}$

Surface to volume ratio: 5 m^2 m^3

COD:VSS: 1.42 gCOD $gVSS^{-1}$

C2 - Photoheterotrophic bacteria (PNSB)

model by University of Antwerp

Output:

Greywater

Biomass dryweight: 12.5 g p^{-1} d^{-1}

Fertiliser:

N - 1.06 g p^{-1} d^{-1}

P - 0.3 g p^{-1} d^{-1}

K - 0.06 g p^{-1} d^{-1}

Urine

Biomass dryweight: 2.27 g p^{-1} d^{-1}

Fertiliser:

N - 0.19 g p^{-1} d^{-1}

P - 0.05 g p^{-1} d^{-1}

K - 0.01 g p^{-1} d^{-1}

[kg $^{-1}$ p $^{-1}$ d $^{-1}$]	Tomato			Cucumber			Pepper			Lettuce		
	N	P	K	N	P	K	N	P	K	N	P	K
GreyWater	1.5	1.9	0.05	3.5	4.7	0.1	1	1.6	0.04	1.1	1.4	0.04
Urine	0.2	0.3	0.009	0.6	0.7	0.02	0.1	0.2	0.006	0.2	0.2	0.006

C2 - Photoheterotrophic bacteria (PNSB)

model by University of Antwerp

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Biomass dryweight: 12.5 g p^{-1} d^{-1}

Fertiliser:

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P - 0.3 g p^{-1} d^{-1}
K - 0.06 g p^{-1} d^{-1}

Effluent:

Greywater (49l)

COD: 211 mg l^{-1}
TN: 8 mg l^{-1}
TP: 3 mg l^{-1}

Urine

Biomass dryweight: 2.27 g p^{-1} d^{-1}

Fertiliser:

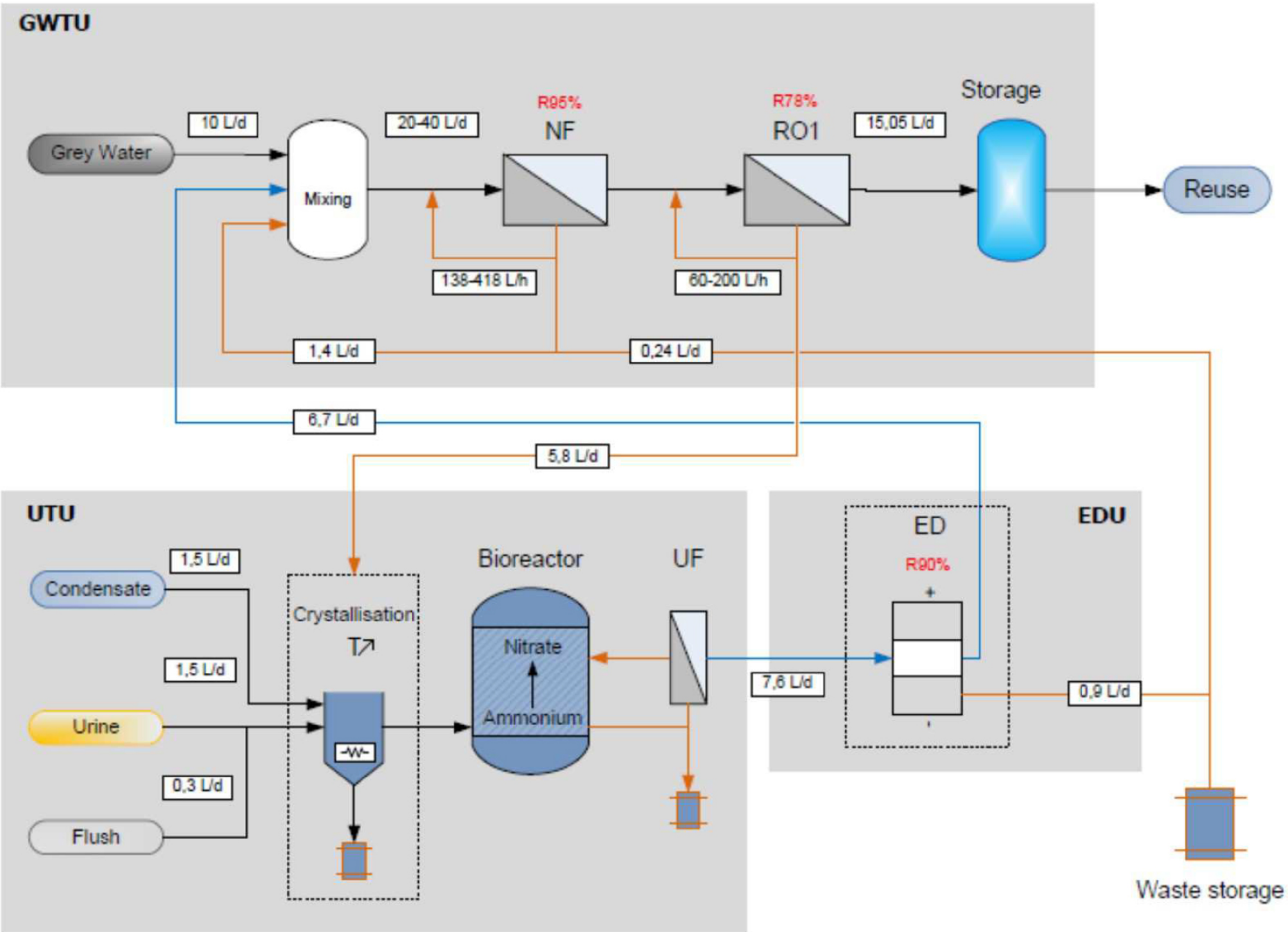
N - 0.19 g p^{-1} d^{-1}
P - 0.05 g p^{-1} d^{-1}
K - 0.01 g p^{-1} d^{-1}

Urine (2l)

COD: 1250 mg l^{-1}
TN: 3253 mg l^{-1}
TP: 272 mg l^{-1}

Membrane water treatment

model by GHENT UNIVERSITY



Membrane water treatment

model by GHENT UNIVERSITY

Influent: PNBS Effluent

Model: UGhent (Lindeboom *et al.* 2020)

Three iterations - 70% - 80% water recovery to ESA hygienic standard

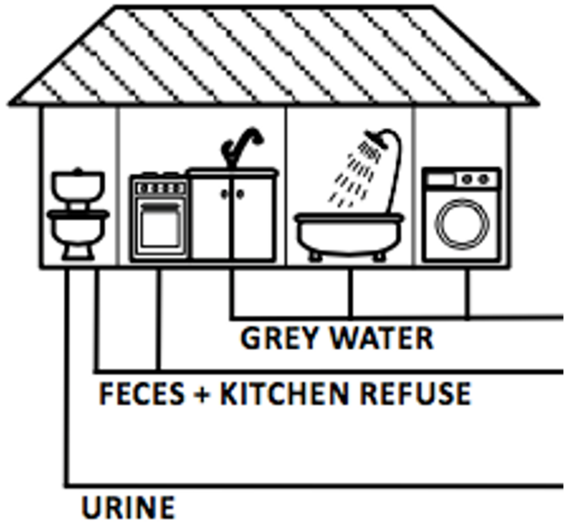
System set up: *ED 80%, NF 95%, RO1 70%, RO2 85%*

Output:

	ED	NF	RO1	RO2
Volume [l d^{-1}]	15.9	65.6	45.9	41.3
COD [mg l^{-1}]	32	153.2	1.5	0.2
TN [mg l^{-1}]	86.1	40.8	1.6	0.1
TP [mg l^{-1}]	0.3	6.2	0.1	0.0
TK[mg l^{-1}]	3.3	15.5	0.5	0.0
Recovered [%l d^{-1}]			90	80.9

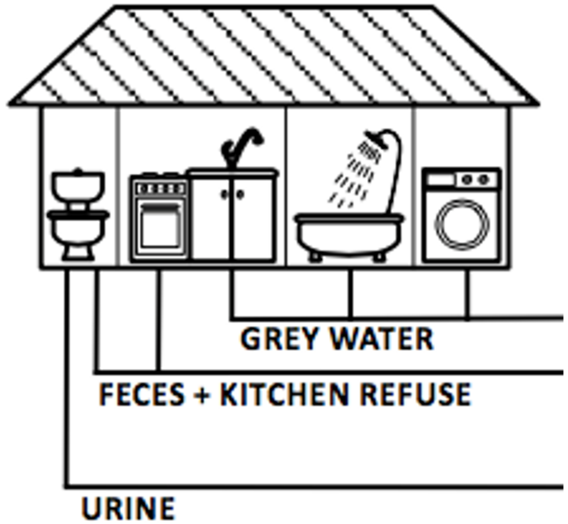
Closing the loop – best case scenario

Waste stream	MELiSSA	Resource
Black water →	C1 AD →	Energy
Grey water →	C2 PNSB →	Nutrients
Urine → (C2 PNSB)	↓ effluent	
	Membrane →	Water



Closing the loop – best case scenario

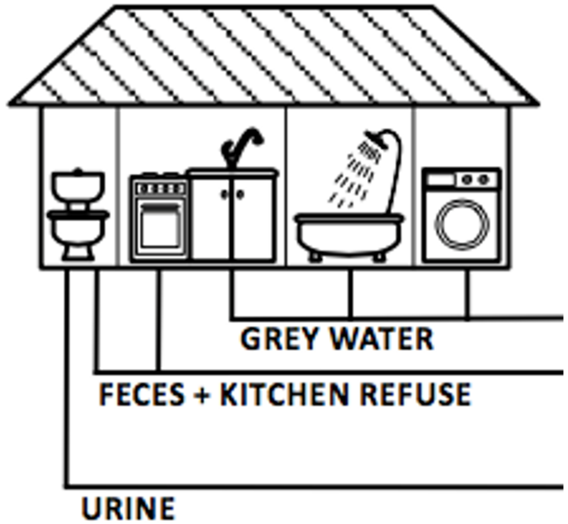
Waste stream		MELiSSA		Resource
Black water	→	C1 AD	→	Energy
Grey water	→	C2 PNSB	→	Nutrients
Urine	↗ (to C2 PNSB)	↓ effluent		
		Membrane	→	Water



[$kg\ p^{-1}d^{-1}$]	Tomato	Cucumber	Pepper	Lettuce
Nutrients	1.70	4.10	1.50	1.20
Water	1.60	3.10	1.60	2.10
Energy	NA	NA	NA	1.70

Closing the loop – best case scenario

Waste stream	MELiSSA	Resource
Black water	→ C1 AD	→ Energy
Grey water	→ C2 PNSB	→ Nutrients
Urine	→ C2 PNSB	
	↓ effluent	
	Membrane	→ Water



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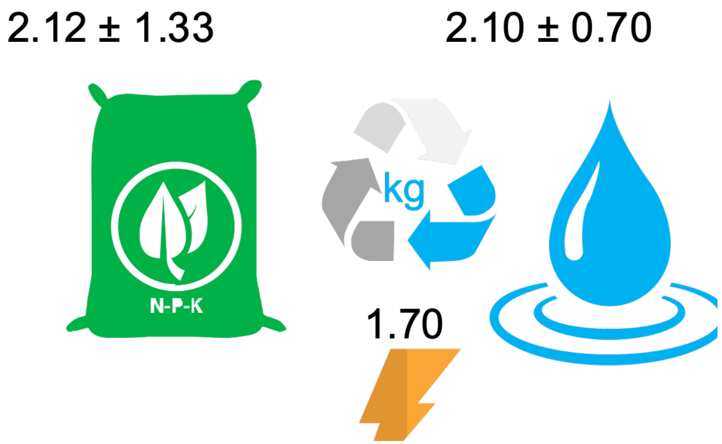
Energy	NA	NA	NA	1.70



Scale up scenario - *Bijlmerbajes Amsterdam*

Circular neighbourhood
Green Tower - Vertical Farming

~2,500 inhabitants

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Circular neighbourhood
Green Tower - Vertical Farming

~2,500 inhabitants

=> 3,000 kg lettuce d^{-1}

=> 3,600 l clean water d^{-1}

=> 121,750 kWh d^{-1}

Scale up scenario - *Bijlmerbajes Amsterdam*

Circular neighbourhood
Green Tower - Vertical Farming

~2,500 inhabitants

=> 3,000 kg lettuce d^{-1}

=> 3,600 l clean water d^{-1}

=> 121,750 kWh d^{-1}

450,000 cal lettuce d^{-1}

225 persons d^{-1}

12.4% food d^{-1}

Aknowledgements

Funded by: European Space Agency (ESA)

Realized by: SEMiLLA IPStar BV

Authors:

- Radu M. Giurgiu (SEMiLLA IPStar BV, MELiSSA Foundation)
- Ralph Lindeboom (SEMiLLA IPStar BV, TU Delft)

Supported by:

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- Christophe Lasseur (ESA, MELiSSA)

In cooperation with:

- Arjen van Nieuwenhuijzen (Witteveen+Bos, AMS)
- Alexander Laarman and Wei-Shan Chen (Wageningen UR, AMS)
- Abbas Alloul and Siegfried Vlaeminck (UAntwerpen)
- Nastassia Vilfan and Luuk Graamans (Wageningen UR)

Proof of concept (PoC)

Piloting a Raceway Reactor for the PNSB Cultivation on Domestic Wastestreams for Recovery of Nutrients and Water Treatment as Resources for Food Production

ESA Ref: 4000130940/20/NL/MH/kdj

Proof of Concept – PNSB

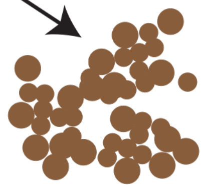
Proof of Concept – Consortium

Proof of Concept – Concept

decentral wastewater
treatment unit

discharge water
biomass production

purple bacteria
biomass

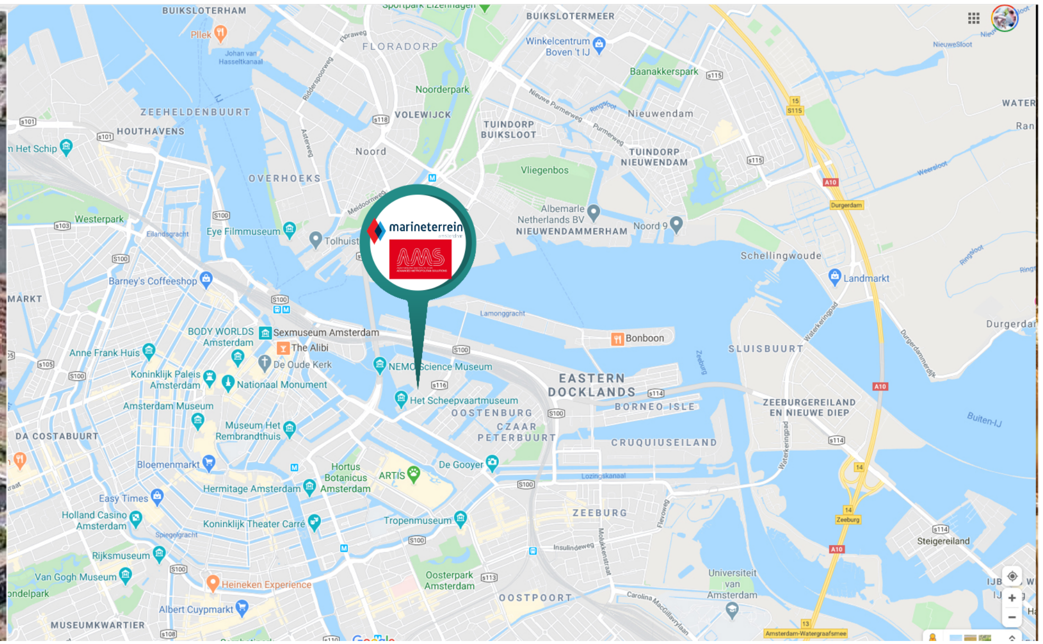


fertilizer
protein
biostimulant

Proof of Concept – Location

Marineterrein, Amsterdam, NL

Kattenburgerstraat 7
1018 JA Amsterdam

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FOR
FOOD
How we use space technology to improve circualirty in our cities?
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reuse water, biomass
waste water
biochemical refinery
How this works!
cleaned water
biomass fertiliser
This project is initiated by
esa
space solutions
MELiSSA
WAGENINGEN
Gemeente Amsterdam

MELiSSA
MICRO-ECOLOGICAL LIFE SUPPORT SYSTEM ALTERNATIVE

THANK YOU.

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