URBAN
TERRA PRETA

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Blue Responsibility Award
Manufacturing for a Sustainable Terra Preta Sanitation System

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Introduction

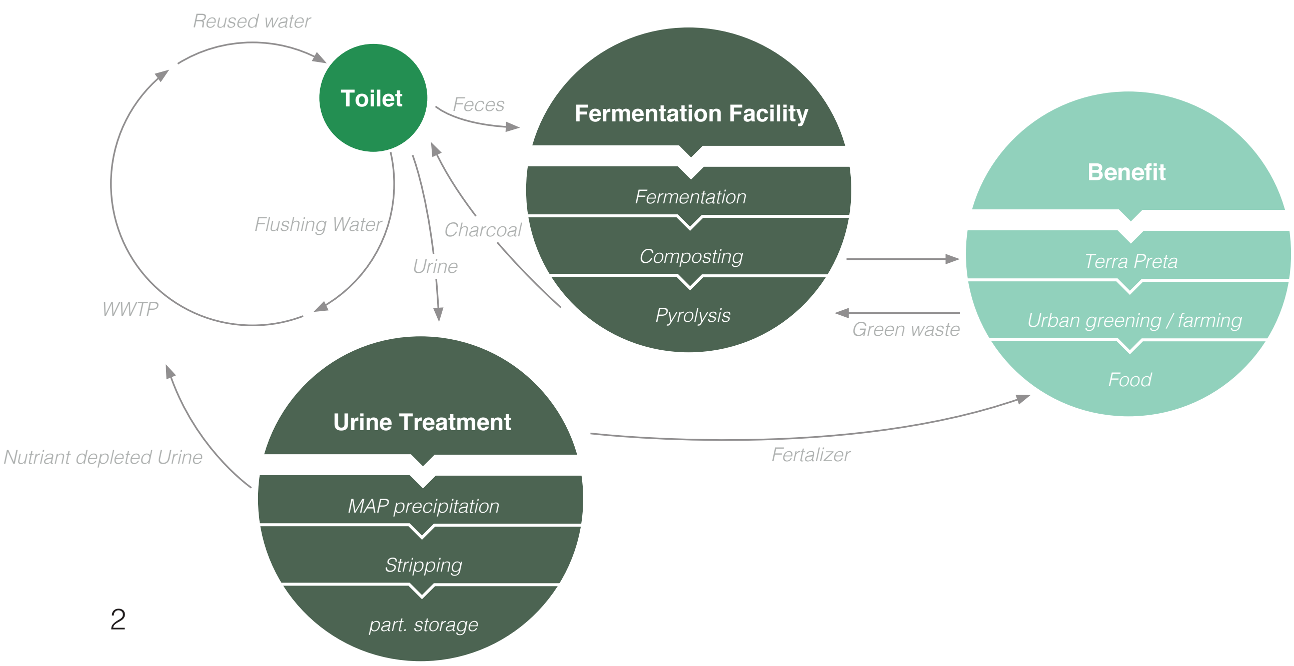
Terra Preta Sanitation can create a fundamental shift in our modern urban areas and guide us to a real sustainable future. With the transformation of fezes organic matter and charcoal we can create a valuable product which is both a nutrient rich substrate for food production and a carbondioxid sink. In contrast to a water based system where the maximum effect is a reduction of pollution for the effluent, a *Terra Preta* system achieves a significant rise of the endproduct quality. There exist many reasons why we should change to *Terra Preta* – the question is how?

In our concept we basically focused on the design of a new source seperated toilet, which is the very first “interface” for users. The idea is to create a toilet, which can be implemented easily in the urban context and fulfil above all the criteria of functionality and a hygienic and save usage. To increase the users acceptance, the toilet should provide a comparable comfort in usage compared with conventional flush toilets. Furthermore the visual design should be attractive to make potential user willing to integrate the toilet in their bathrooms. Regarding the other aspects of the *Terra Preta* process chain we give ideas how to implement a *Terra Preta* sanitation system in an urban district in Berlin.

2.1 Conception and technical design

Basic Principle

The *Terra Preta* sanitation system can be divided into the processes (1) collection, (2) transport, (3) treatment and (4) reuse. The toilet is the central element of collection. Human excrements are collected by a source separating toilet divided in urine and feces. Both substrates are stored for further transport or treatment. By a wheel based pick-up service urine and feces are transported to a central treatment unit where the feces undergo a one-month fermentation followed by another month of worm composting. Urine is either transported and stored at the treatment unit or treated on-site. As reuse products we can get fertile and humus-rich soil as *Terra Preta*, Urine as fertilizer and reused grey water for service water purposes (see graph).

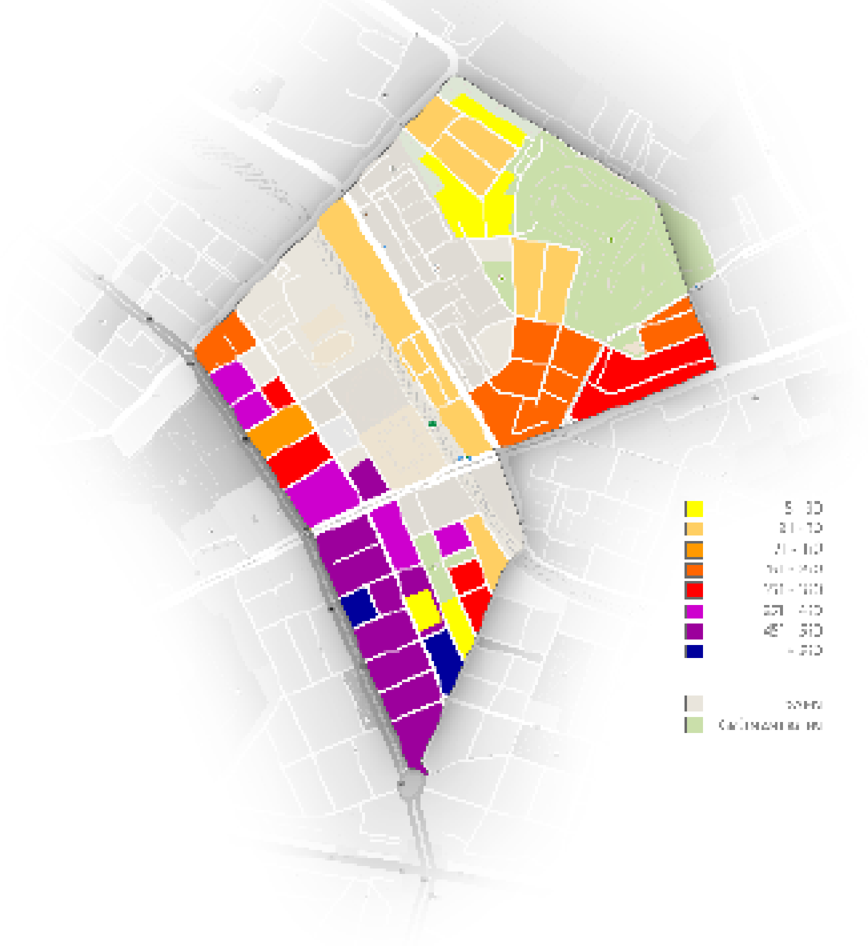


2.1.1

Site choice for case study

In order to develop a case with a realistic geographic reference we choose a study area in Berlin, which is located on both sites of the circle-metro line near the station “Landsberger Allee”. Due to its central location and heterogenic building structure and mixed landuse, the settlement reflects sufficiently the character of a central urban district. In 2013, about 20000 citizens* lived in the area with a total area of 82.6 ha *(google maps)*. The quarters within the circle-line have higher population densities and consist mainly of renovated old building in perimeter block style, whereas the multi-storey buildings outside the metro line have lower population densities.

*Senat Berlin/Umweltatlas/FIS Broker



2.1.2

Data collection

Table 1 Population data

parameter	unit	value	source
persons in settlement	[p]	20,050	[1]
persons per household in Germany	[p/hh]	1.88[a]	
households	[hh]	10,638	

[a] prognosis for 2030

Table 2 Input data (Germany)

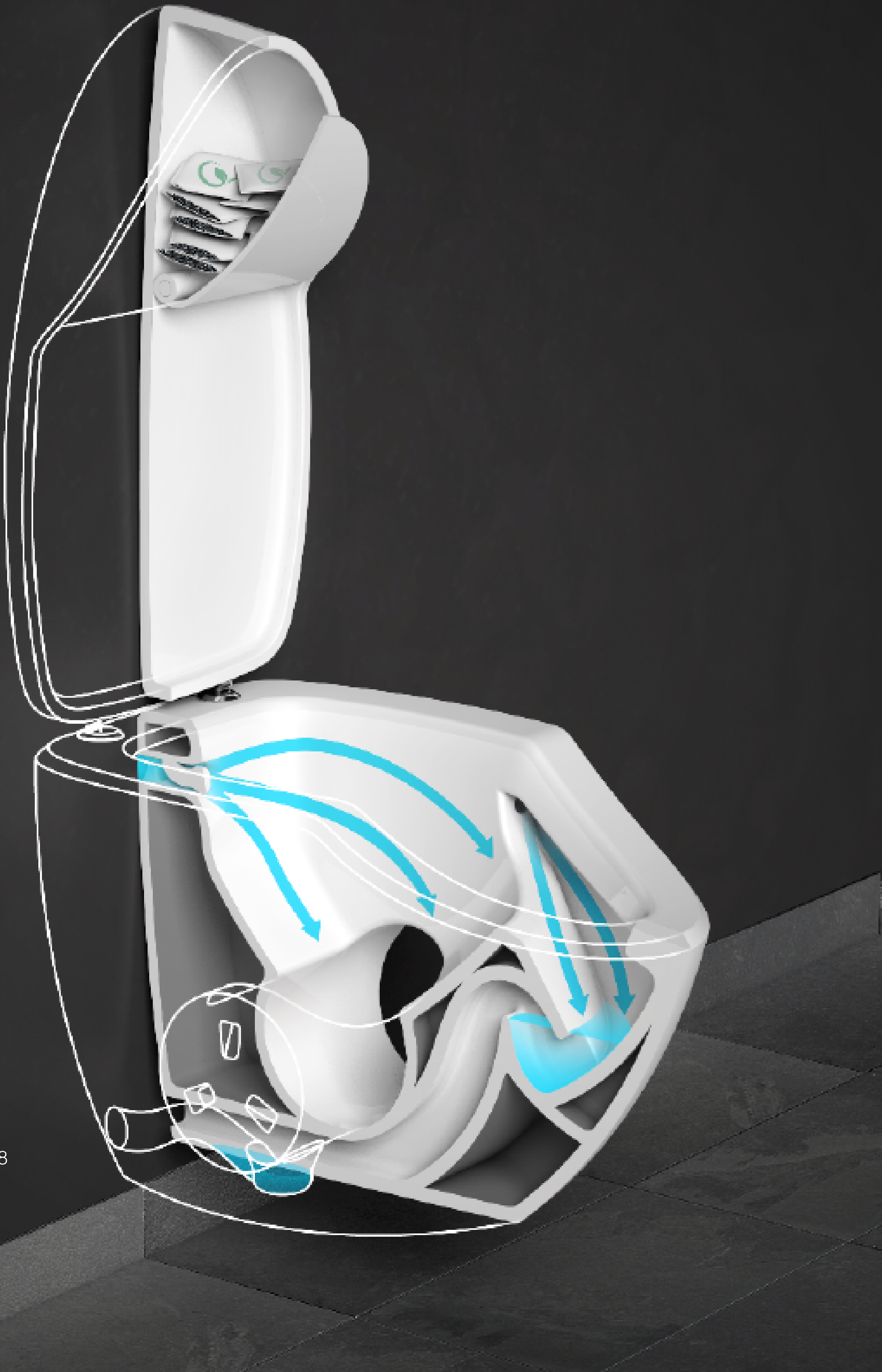
parameter	unit	values			source
		faeces (fresh matter =FM)	charcoal (20% of faeces)	bio waste (FM)	
per-capita mass	[l/p/d]	0.140	0.028	0.2	[2],[3]
per-household mass	[l/hh/d]	0.263	0.053	0.376	
water content	[%]	75	0.16	0.56	[4]
Nitrogen mass	[g/kg FM]	10.71	-	5.59	[4]
Phosphorus mass	[g/kg FM]	3.57	-	0.92	[4]
Potassium mass	[g/kg FM]	5	-	2.68	[4]

Table 3 Process data Terra Preta

parameter	unit	values			source
		Lacto fermentation	Worm-composting		
			tank	compost heap	
process duration	[d]	30	30	30	[4]
volume	[%]	-10	-45	-45	[4]
water content	[%]	+10	-15	-15	[4]
nitrogen	[%]	-30	-10	-25	[4]
phosphorus	[%]	-	-	-15	[4]
potassium	[%]	-	-	-15	[4]

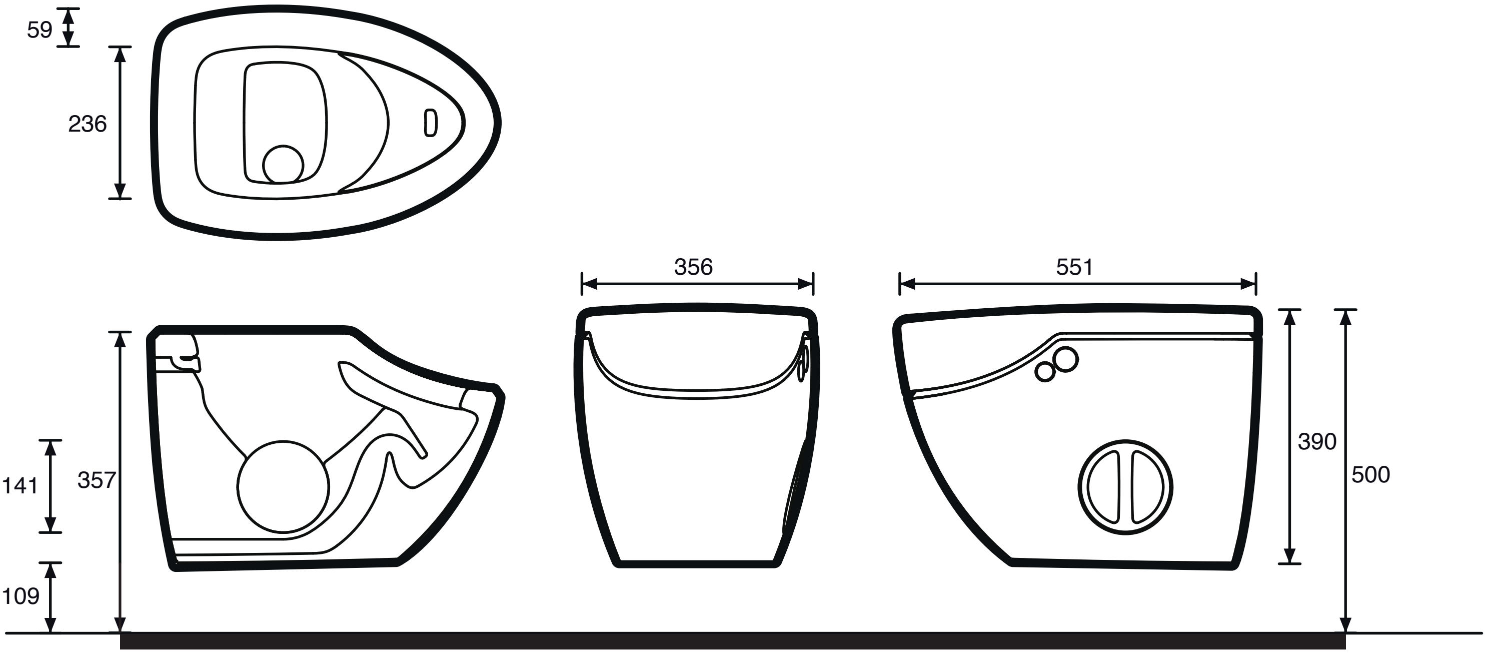
+ = gain, - = loss

2.2.1 Design



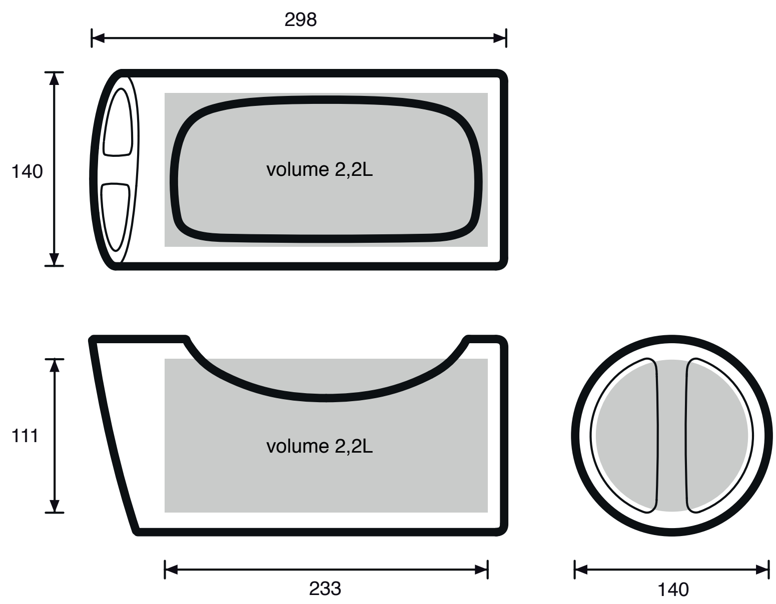
Technical drawing

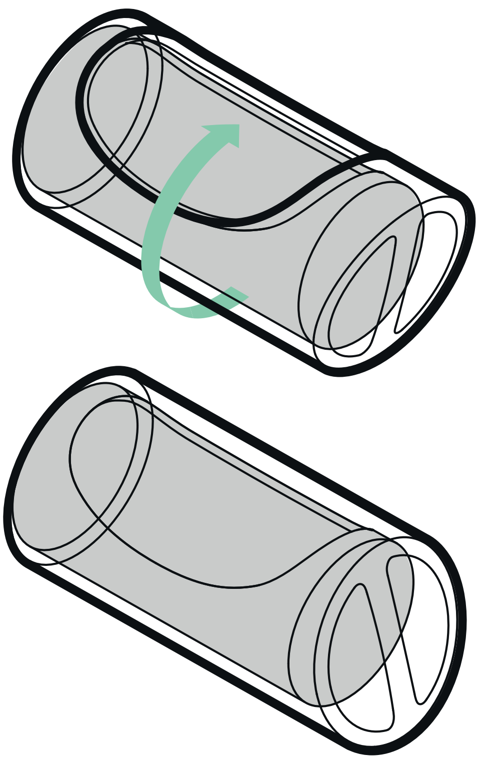
toilet



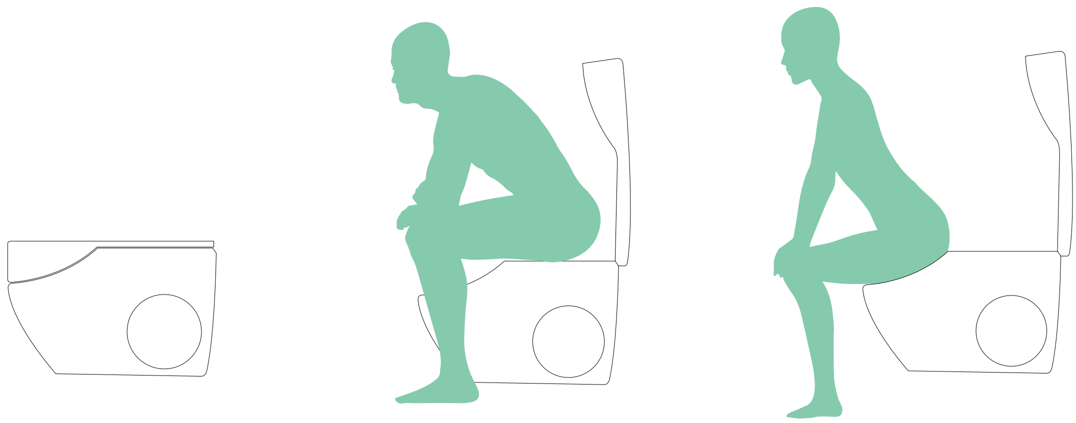
Technical drawing

feces tank





Position



For the reliable seperation of urine and feces a pleasant and logical seating position is of advantage.
To get into the correct sitting position, especially for women, a predetermined recess serves as a visual and physical help both.

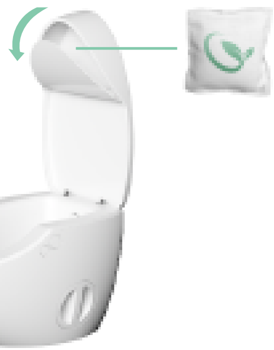
Usage

1 Toilet

2 Open the toilet

3 Use the toilet

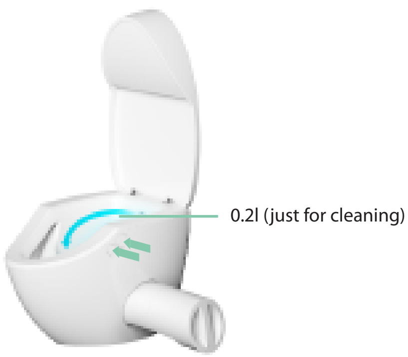
4 Open the charcoal storage



5 Add the charcoal on the feces

6 Pull out the feces drawer

7 Flush for urine and/or feces and clean with brush



8 Rotate and push in the feces drawer

9 Close the toilet

2.2.2

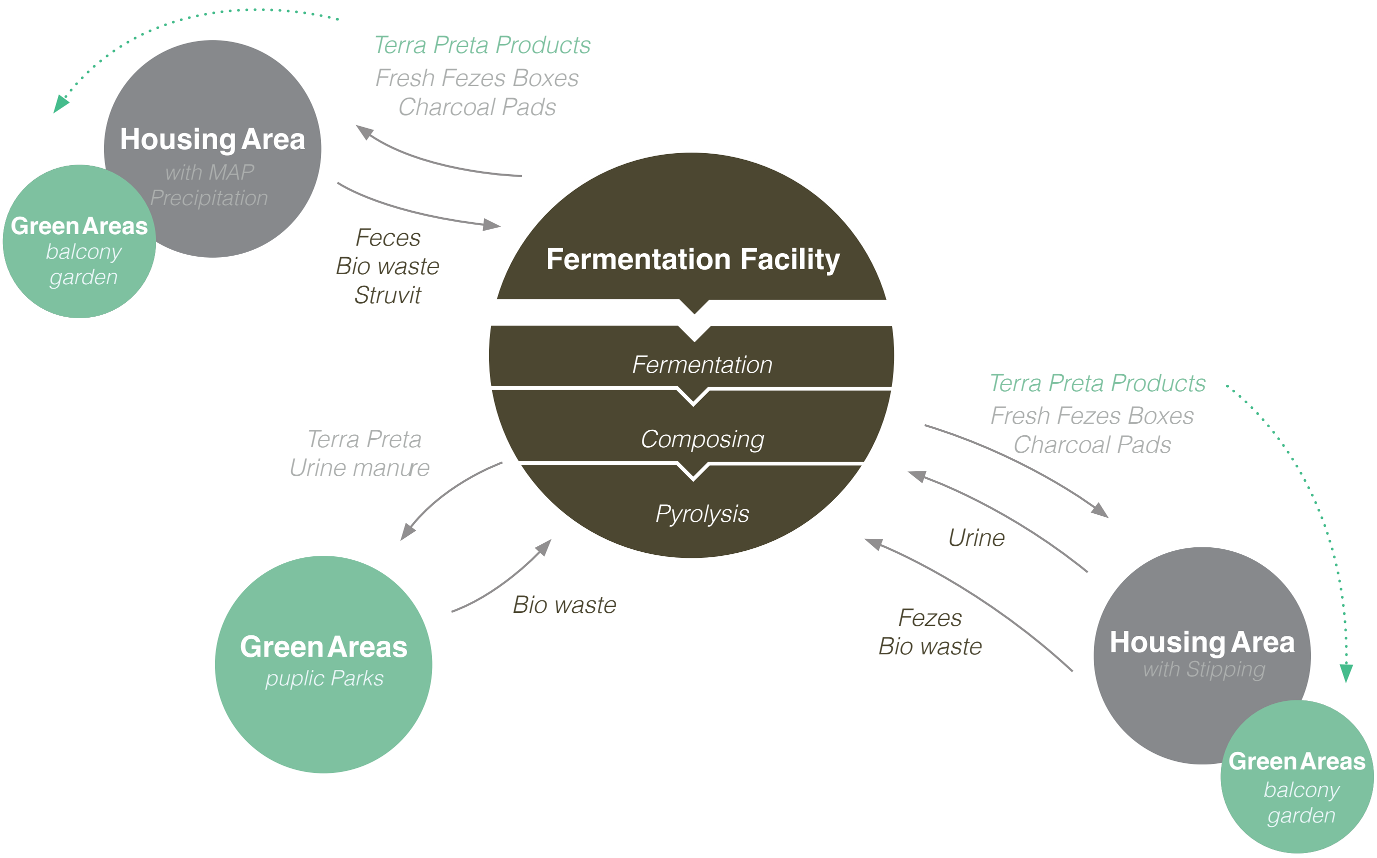
Transport/ Logistics

Existing infrastructure systems like the urban waste disposal companies could partly or even completely manage the feces and urine transport. We use shifted schedules which can easily be implemented in the waste disposal working rythms. To guarantee an efficient system, we decided to place the main treatment facilities for the *Terra Preta* production at one place within the settlement. The urine treatment is accomplished as a mixture of decentralized technical treatment units and the storage at the before mentioned semizentral treatment centre. The transport goods feces, biowaste and struvit are collected weekly by a wheel based pick up system, possibly in cooperation with a local waste disposal company, and transported to the semicentralized treatment centre. The transport of empty, cleaned feces drawers back to the user is combined with a delivery of "charcoal pads", precipitation agents for the decentralized urine treatment units as well as T*erra Preta Products*. Half of the settlements are served by a decentralized urine treatment plants. In the other half the urine is collected in the buildings basements and picked up in a weekly interval and transferred to a semicentralized urine storage place. Special transport vehicles have to be used for the urine transport.

Transport / Logistics

■	Composting area	335m²
■	Delivery zone	335m²
■	Pyrolysis station	30m²
■	Administration (20%)	280m²

Transport/ Logistics



Adopted from [5]		Urine storage half	Urine storage all	Feces+biowaste	Stuvit+NH3
Number of served persons		10025	20050	20050	20050
Volume per day	m /d	25	50	7	2.0
Distance per week	km	61	123	18	5
Total working time per week	h	30	60	55	54
Average Fuel consumption per km	l/km	0.32	0.32	0.32	0.32
Total Fuel consumption per tour	l	20	39	6	2
CO_2-emissions per year	kg CO_2/a	8609	34435	746	56

2.2.3
Treatment

An urban *Terra Preta Sanitation system* is a source separated system. Main objective of such a system is to close the nutrient loop. The waste streams are no longer regarded as “waste“ but as resources. With regard to a *Terra Preta System* in urban areas and future developments, the chosen treatment strategy is a mixture of technical high-tech solutions (e.g. urine) and low-tech, natural practices (e.g. Terra Preta). In the following, the treatment units are described briefly.

Decentralized Urine Treatment

Due to the high volumes of urine, we decided the treat one half of the settlement (~10000p) by decentralized technical treatment facilities. The other half is to be picked up weekly by wheel based service and transported to a semicentralized place for storage. Since the majority of experiences regarding technical urine treatment devices haven‘t yet exceed lab- or pilot scale, this option have to be considered as a hypothetic scenario.
A urine treatment device have to accomplish the main objective (1) elimination of micropolutants (Hormons, Pharmacy traces) and (2) the effective recovery of nutrients (N,P) [2][5].

Further, since space is mostly a limited resource within urban areas, especially in fast growing metropolitan areas, modular technical on-site urine treatment devices might be the most sufficient solution with regard to future city development. In this case study, the technical urine treatment module consists of a MAP precipitation reactor and Ammonia stream stripping columns, respectively for P-and N-recovery. At a third step micro pollutants are removed by a ozonization from the nutrient-depleted effluent. The existing sewer system allows discharging the effluent together with greywater. Another option is to discharge the urine effluent in a separated pipeline to the *Terra Preta Treatment* unit. Here, the effluent can be trickled over an exchange filter with either char coal or composted terra preta as filter substrate. Thereby residue nutrients like K, Mg or S can be recovered. With reference to the described urine treatment technologies in literature [5], [6]. the decentralized plants are designed for 200 persons, which is approximately equivalent with a standard block perimeter development or a 11-storey prefabricated residential house. The device consists of the following components: A flow-equalization tank with a volume of 300 litres and a MAP-Reactor with a batch volume of 800 litres and a treatment performance of 400-500 litres per day [4].

After the precipitation with MgO, the produced struvite pulver is first dryied in a drying box and later in a oven for several days. The stripping device consists of one or more columns, with about 5 meters height [5]. The ozone unit includes devices for ozone generation, a contact basin and the off gas destruction [8]. In prefab-residential buildings the treatment can be placed in the basement. At perimeter block houses, the unit can be placed in the courtyard. To avoid odour emissions, the treatment should be constructed as in-house device.

Semicentralized treatment centre

Terra Preta

The *Terra Preta* production is located at a central place within the settlement. Basically the area consists of a (1) delivery zone for the transport vehicles, a (2) fermentation building a (3) composting place and a (4) Pyrolysis unit. In a weekly rotation, feces drawers as well as bio waste is transported to the treatment centre. In return, empty feces drawers and charcoal pads with Effective Microorganisms (EM) are delivered back to the households. The filled toilet boxes are stored in the fermentation building together with the biowaste bins.

After 30 days, when the fermentation is finished, the toilet boxes are opened, and the fermented feces, together with the biowaste are taken to the composting building. Due to the high amount of feces drawers an automatic or half-automatic device opens the boxes and store the the faeces-coal mixture at the composting heap. A pyrolysis oven is located beside the building. Green waste from the settlement is transported to the treatment centre. At the settlement approximately 454t green cuttings per year from the two parks *Volkspark Friedrichshain* (47.2 ha) and *Volkspark Prenzlauer Allee* (28.5 ha) and about 200t green waste from the trees in the settlements and parks can be collected *(google maps)*. With a assumed output of a Pyreg-Pyrolysis facility of 0.35 t charcoal per t green waste, about 230t charcoal can be produced which is enough to cover the charcoal demand for the *Terra Preta* process [9] [10].

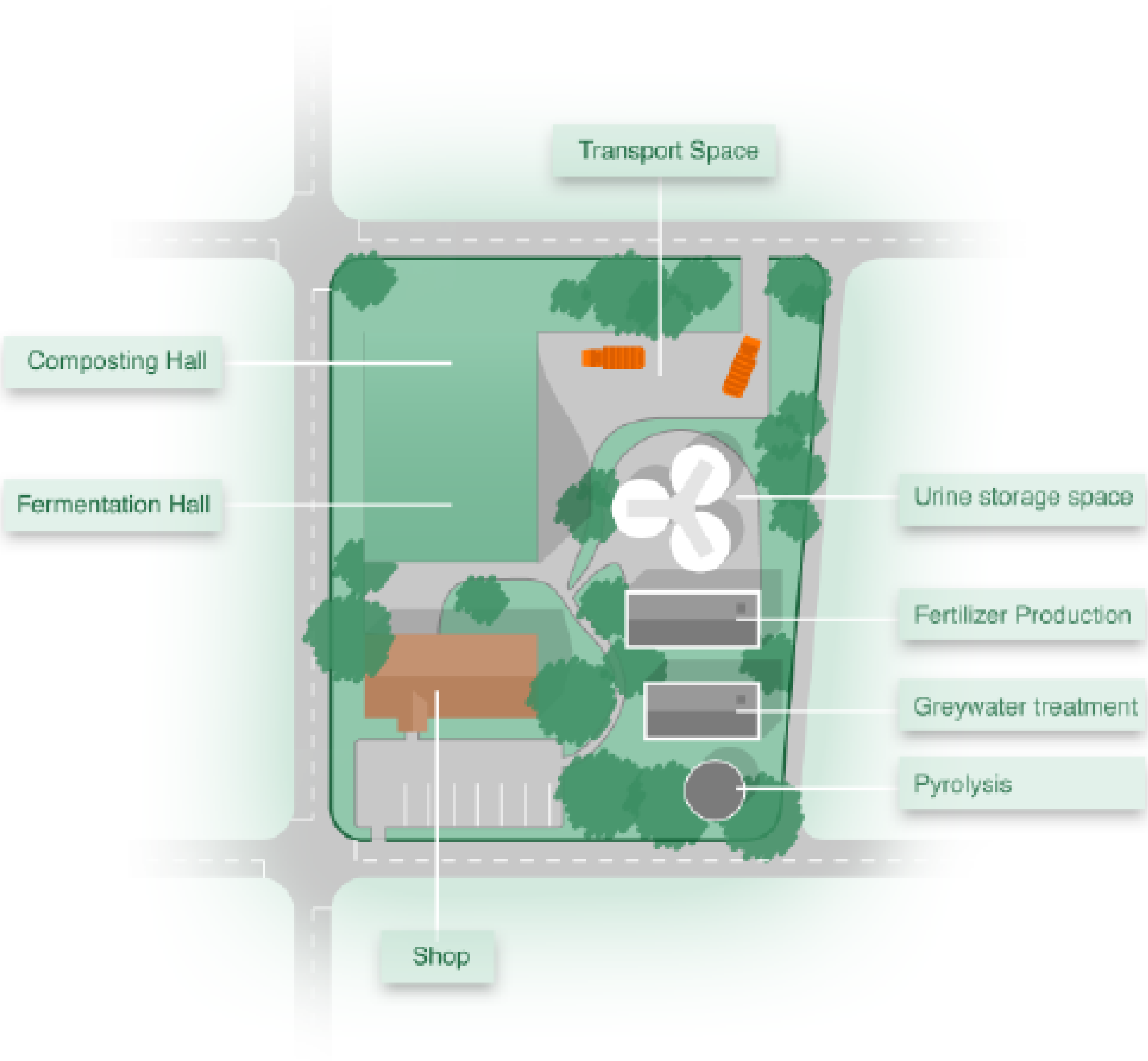
Urine Storage

One half of the settlements urine is collected in a weekly rotation from the households and transported to the treatment centre. The Urine is stored for 6 month in storage tanks. The total required storage volume is 2500 m^3.

Greywater

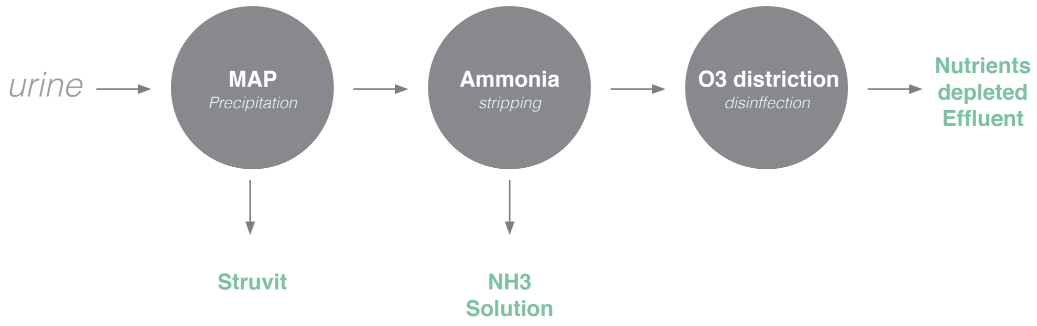
The greywater treatment plant is also located at the treatment centre. Technical treatment technologies like MBR, MBBR or SBR are all suitable for a application within the settlement. The treatment plant has to designed for a treatment capacity of 1300 m^3/d. The treated grey water can be used as servicewater in households (e.g. laundry) or for irrigation of urban farming fields and landscaping.

Treatment

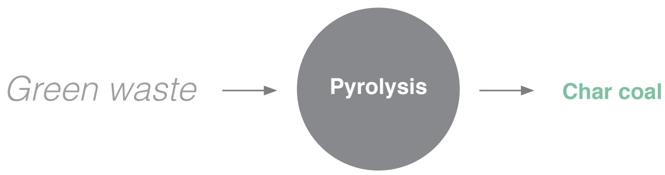

Transport Space
Composting Hall
Fermentation Hall
Urine storage space
Fertilizer Production
Greywater treatment
Pyrolysis
Shop

Treatment

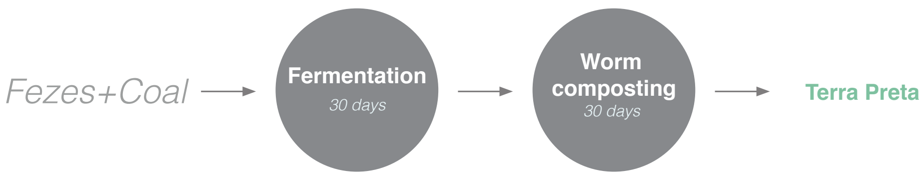
Urine Treatment



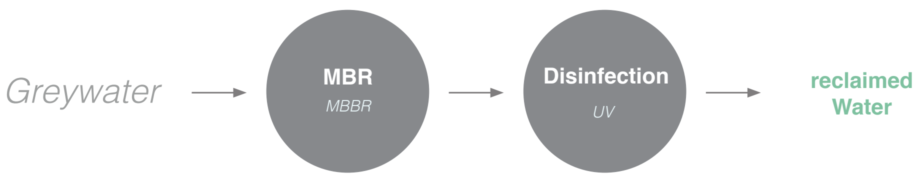
Green waste Treatment



Fezes Treatment



Greywater Treatment

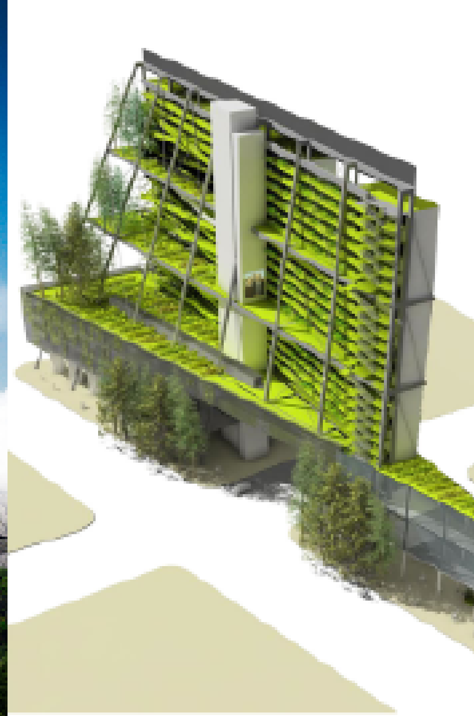


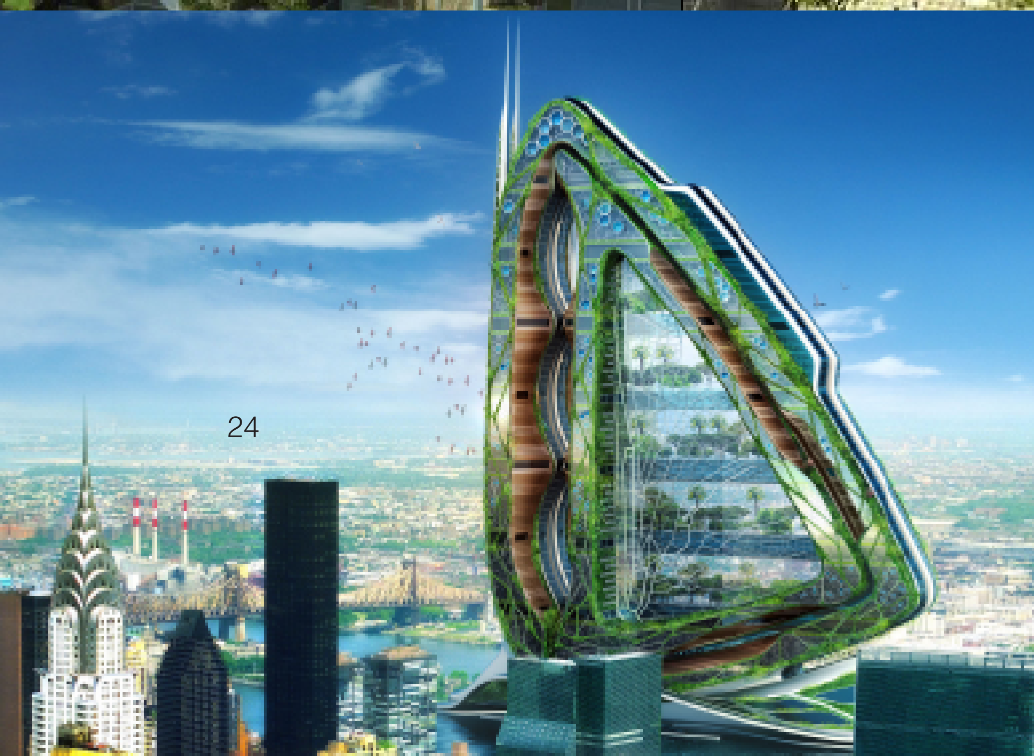
2.2.4

Reuse

An urban *Terra Preta* system gives the user many options for the reuse and be a part of the cycle. “Urban farming” and “urban gardening” are attractive options for the reuse of *Terra Preta* in the city. Thereby communities or neighborhoods can setup a local food production which is sustained only by the nutrients and substrate produced from the people living in the district. Furthermore the greening in the city could be enhanced. Grey water could mainly used for urban water surfaces to improve the urban microclimate. The following illustrations show some impressions how *Terra Preta* could be used in the urban context.

Examples for urban gardening / farming

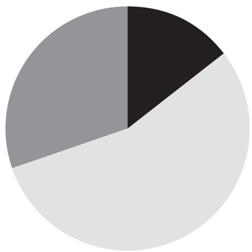




Fertilizer production per person per year

Terra Preta

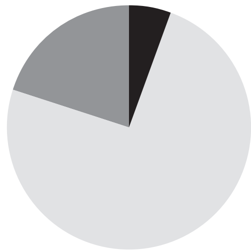
Soil	67kg



■	Phosphor	0.17kg
■	Nitrogen	0.64kg
■	Potassium	0.35kg

Urine

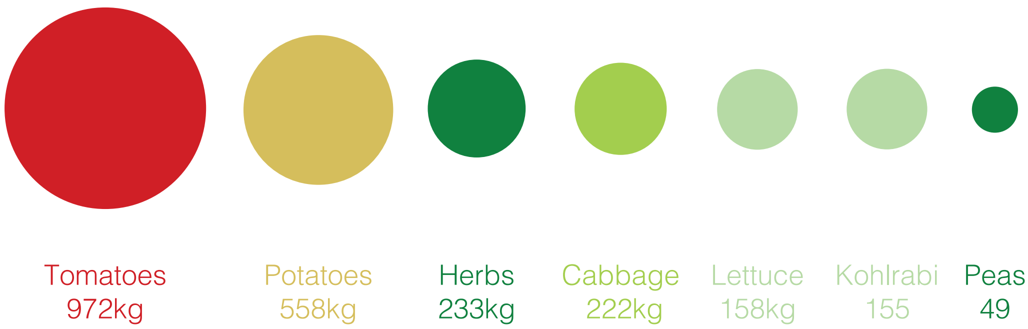
Volume	500L



■	Phosphor	260kg
■	Nitrogen	3400kg
■	Potassium	915kg

Food production per person per year

(not combined – either or)



Yields Terra Preta + Urine

Potatoes		N	P	K
Possible harvest cycles		296	237	83
Total Production (t/ha/		11831	9481	3337
Total area specific mass	3337	t/ha		
Total mass potatoes	11183	t/a		
Per person mass potatoes	558	kg/p/a		

Chinese Cabbage		N	P	K
Possible harvest cycles		225	302	68
Total Production (t/ha/		13521	18100	4052
Total area specific mass	4052	t/ha		
Total mass chinese cabbage	4052	t/a		
Per person mass chinese cabbage	222	kg/p/a		

Tomatoes		N	P	K
Possible harvest cycles		135	332	89
Total Production (t/ha/		27042	66366	17729
Total area specific mass	17729	t/ha		
Total mass tomatoes	19479	t/a		
Per person mass tomatoes	972	kg/p/a		

Iceberg Lettuce		N	P	K
Possible harvest cycles		338	830	89
Total Production (t/ha/		10986	26961	2881
Total area specific mass	2881	t/ha		
Total mass lettuce	3165	t/a		
Per person mass lettuce	158	kg/p/a		

Kohlrabi		N	P	K
Possible harvest cycles		206	415	95
Total Production (t/ha/		6173	12444	2837
Total area specific mass	2837	t/ha		
Total mass kohlrabi	3117	t/a		
Per person mass kohlrabi	155	kg/p/a		

Peas		N	P	K
Possible harvest cycles		296	830	177
Total Production (t/ha/		1479	4148	886
Total area specific mass	886	t/ha		
Total mass peas	974	t/a		
Per person mass peas	49	kg/p/a		

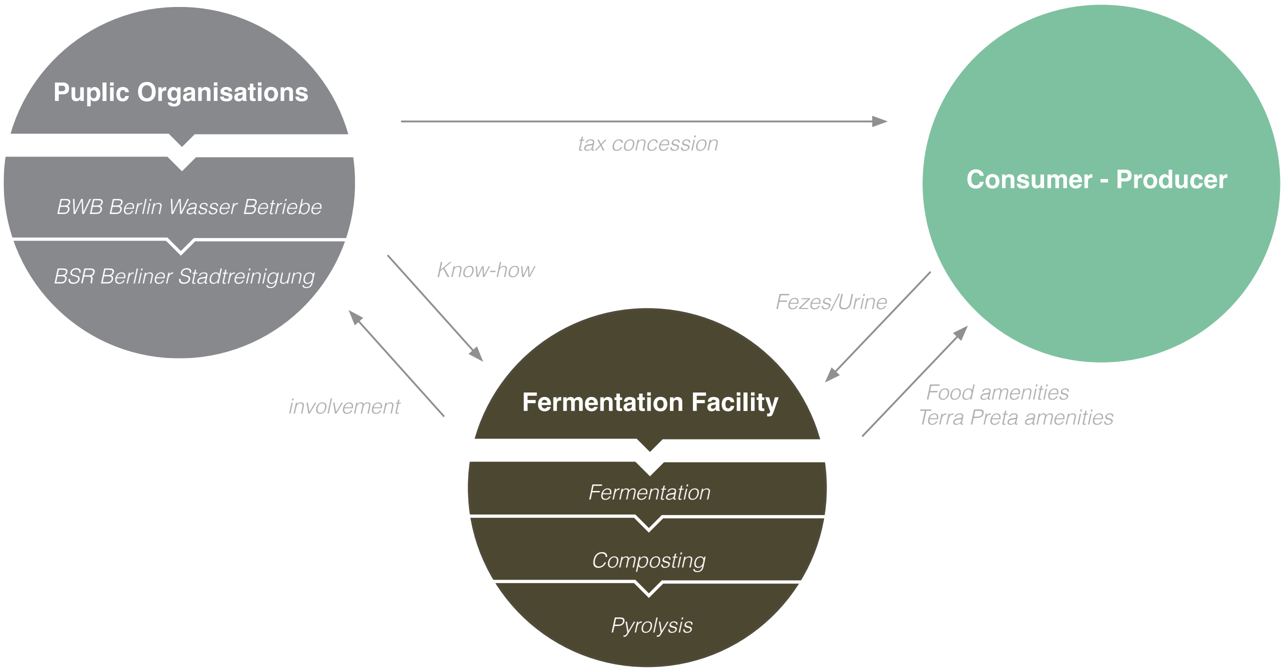
Herbs		N	P	K
Possible harvest cycles		394	830	142
Total Production (t/ha/		11831	24887	4255
Total area specific mass	4255	t/ha		
Total mass herbs	4675	t/a		
Per person mass herbs	233	kg/p/a		

3

Business model

The business model consists basically of the *Public Organisation* (1), *Fermentation Facility* (2) and *Consumer,* who are at the same time also *Producer* (3). The parts are separate subsystems, which are interconnected in a larger System. Basically our model follows the idea, that every participant donates a good to the system and in return gets a product produced or manufactured in a closed local circle. The producer/consumer contributes nutrients, and can get *Terra Preta* from the nearby production. A incentive could be a discounted access to food from urban agriculture in the neighbourhood. To set up a new infrastructure it is a key point to involve also centralized public infrastructure companies (e.g. BSR, BWB), because they have long-term experiences and qualified staff for the operation of large infrastructure systems. Regarding the maintenance and operation of technical treatment devices, it might be only a small step for municipal wastewater companies to shift from centralized plants to decentralized devices. Since a complete shift from the existing centralized wastewater infrastructure towards a *Terra Preta* system at the large scale might be not realistic in the near future, at the first step transition scenarios should be developed which enables the coexistence of centralized and decentralized treatment technologies. The most promising option to open the door for *Terra Preta* sanitation are cooperations with schools or any other educational institution In order to make young people familiar with natural circles at an early stage.

Business Model



4.1

CO_2 Assessment

Besides nutrients, *Terra Preta* can also capture CO_2 due to its high Carbon content. A 100 m^2 field with a humus content of 1% and 10% can respectively capture 300 kg CO_2 and 8000 kg CO_2 from the atmosphere [1]. Depending on the clay content, humus contents from healthy soils range between 3.5 to 6%. If we assume a humus content of 5% for the produced *Terra Preta* in our case study we could reduce the CO_2-emissions from the treatment facilities by 40% , if we only store urine and treat greywater by MBR. If we would use a natural system (e.g. constructed wetlands) we could capture far more CO_2 .

	Urine Treatment
Scenario 1	Storage (20050p)
Scenario 2	Storage(10050P) MAP+Stripping (10025p)
Scenario 3	MAP+Stripping (20025)

Process	specific Energy consumption	Energy consumption per year		CO2-Emission factor (German Electricity mix) *	CO2-Emissions	
		(10025p)	(20050p)		(10025p)	(20050p)
	kWh/m^3	kWh/a	kWh/a	kg CO_2/kWh	kg CO_2/a	kg CO_2/a
MAP	8	76293	152586	0.559	42648	85295
Stripping	12	109134	218268	0.559	61006	122012
Ozone	35	386955	773909	0.559	216308	432615
Greywater	1.75	-	832451	0.559	-	465340

	CO_2 source				CO2 sink				
	Transport	MAP+Stripping+ Ozone	Greywater	sum sources	Terra Preta CO_2 storage capacity (Humus 5%)	Terra Preta area (layer 0.3m)	Terra Preta CO_2 storage capacity (Humus 5%)	CO_2-Balance	CO_2-reduction
	tCO_2/a	tCO_2/a	tCO_2/a	tCO_2/a	kgCO_2/m^2	m^2/a	tCO2/a	kgCO2/a	%
Scenario 1	35		465	501	43	4713	203	298	40%
Scenario 2	9	320	465	795			203	592	26%
Scenario 3	1	640	465	1106			203	903	18%

*www.statista.com

5

Summary and Vision

With a user friendly design of a source separating toilet it is possible to realise *Terra Preta* systems in urban areas. Regarding Transport, existing infrastructure can be used or combined. The advantage of a semicentralized treatment centre is reduced transport distances. With measures against odour emissions and an attractive design a composting site also can be integrated into settlements. Furthermore the use of *Terra Preta* in the settlement can improve a sence of community identity – *"We produce food from our own nutrients"*. A change to a *Terra Preta* system in urban areas is possible. Since we are still organized in very rigid centralized infrastructures, the shift towards a cycle-based, decentralized *Terra Preta* infrastructure should be implemented in different transition steps. To get the system changed a slighty transition starting with single *Terra Preta* implementations which exsist beside a centralized system might be the best strategy to get *Terra Preta* at the large scale.

6

List of sources

Text:

[1] StBA, “Bevölkerung, Familien, Lebensformen,” in Statistisches Bundesamt, Statistisches Jahrbuch 2013, 2013, pp. 23–72.
[2] DWA, Neuartige Sanitärsysteme. Hennef: DWA, 2008, p. 326.
[3] A. Wriege-Bechtold, B. Heinzmann, A. Peter-Fröhlich, and M. Barjenbruch, “Biogasgewinnung aus Braunwasser - ein Baustein für eine nachhaltige Siedlungswasserwirtschaft,” in 3. Internationales Symposium “Re-Water Braunschweig” - Implementierung und Realisierung, 2011, pp. 1–15.
[4] N. Hestermann, “Herstellung von Terra Preta,” TUHH, 2010.
[5] F. Tettenborn, Aspects of systems for separate urine collection and treatment - Selected techniques and potential implementation in an urban context. 2012.
[6] M. Maurer, “Aufbereitung von Urin – Flexibilität pur,” EAWAG News, vol. 63b, pp. 14–16, 2007.
[7] J. Peng, “MAP crystallization from urine – assessment of the international adaptability,” 2012.
[8] EPA, “Wastewater Technology Fact Sheet Ozone Disinfection,” 1999.
[9] U. Scheub, Haiko Pieplow, and H.-P. Schmidt, Terra Preta. Die schwarze Revolution aus dem Regenwald. Oekom, 2012.
[10] Wiegel and F. Riesbeck, “Hochwertige und klimaschonende Verwertung von Mähgut und Laub,” Berlin, 2011.

Images:

http://www.ecogeek.org/content/view/976/
http://www.theneweconomy.com/wp-content/uploads/2014/03/Vertical-farming.jpg
http://www.theneweconomy.com/wp-content/uploads/2014/04/Vertical-farming.jpg
http://thehort.org/blog/wp-content/uploads/2013/05/P1290139.jpg
http://dezeitdotcom.files.wordpress.com/2014/03/y3.jpg

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