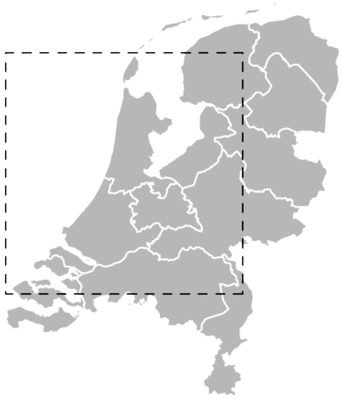
THE FORT OF THE FUTURE

REDEFINING RESILIENCE: DUTCH FORTS AS INSPIRATION FOR SELF-SUFFICIENT BUILDING DESIGN

5846072
Anne Eder



Dutch Waterlinie Forts

01 Lighthouse Island

02 Fort Island Pampus

03 Fort Honswijk

04 Fort Everdingen

05 Fort Pannerden

Contemporary Projects

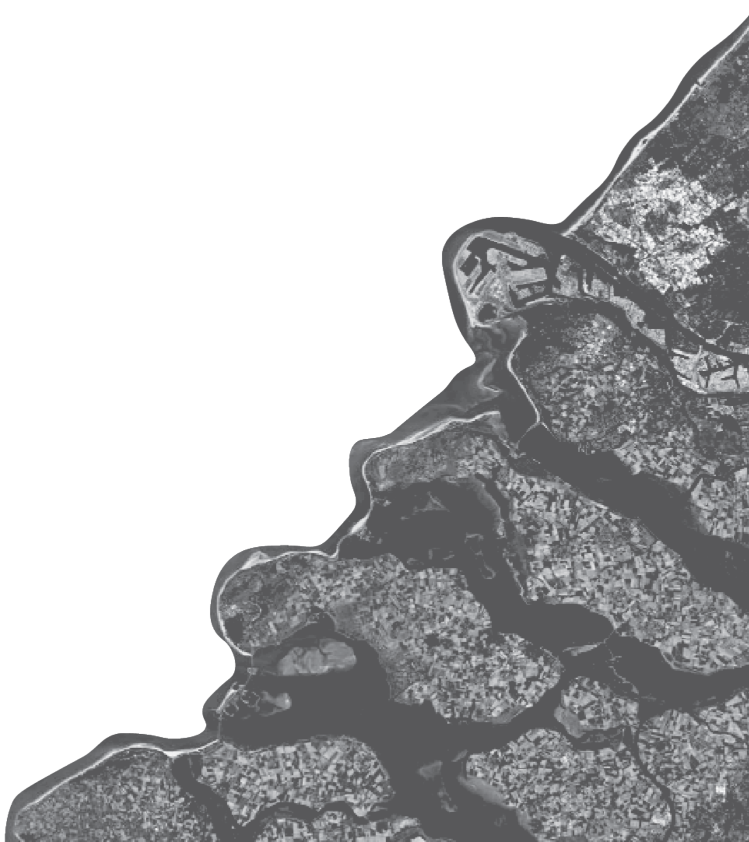
06 Schoonschip

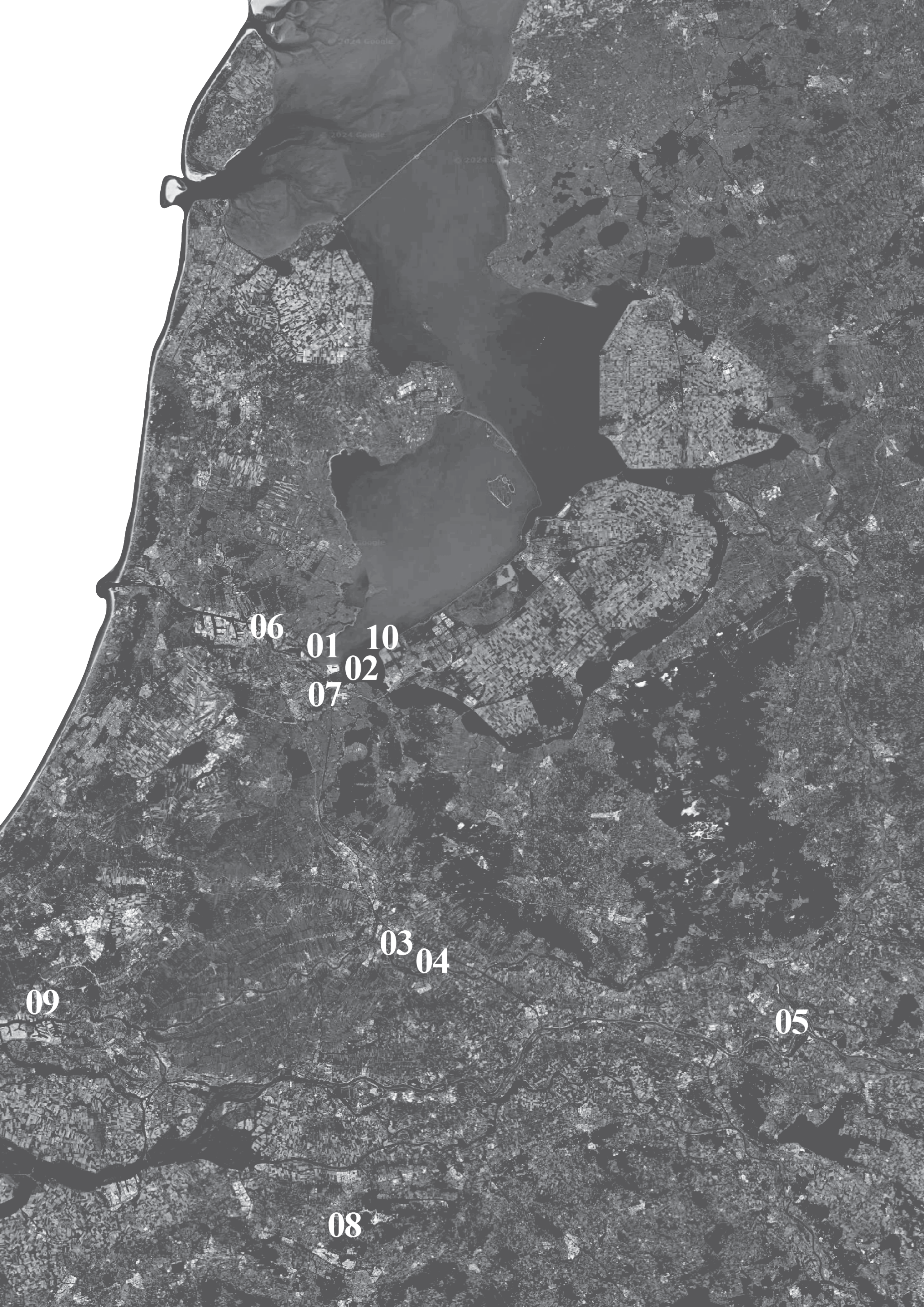
07 Four Elements Hotel

08 Proyecto Roble

09 Floating Farm

10 ReGen Village




06
01
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08

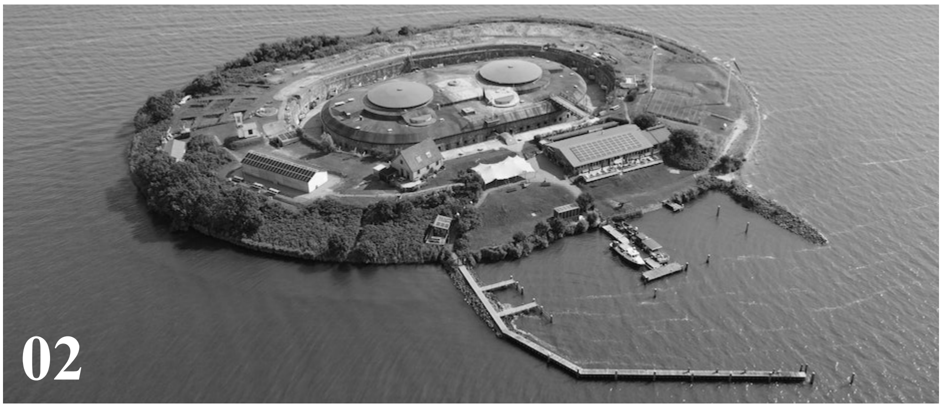
01 ANA

HISTORIC

LYSIS

FORTS

LIGHTHOUSE ISLAND
1844-1885



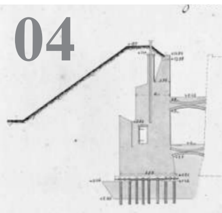
PAMPUS
1887-1895

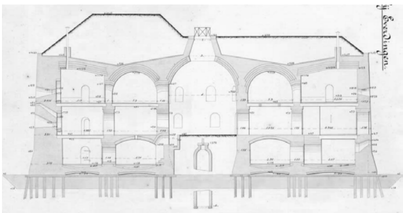
HONSWIJK
1841-1848

EVERDINGEN
1841-1864

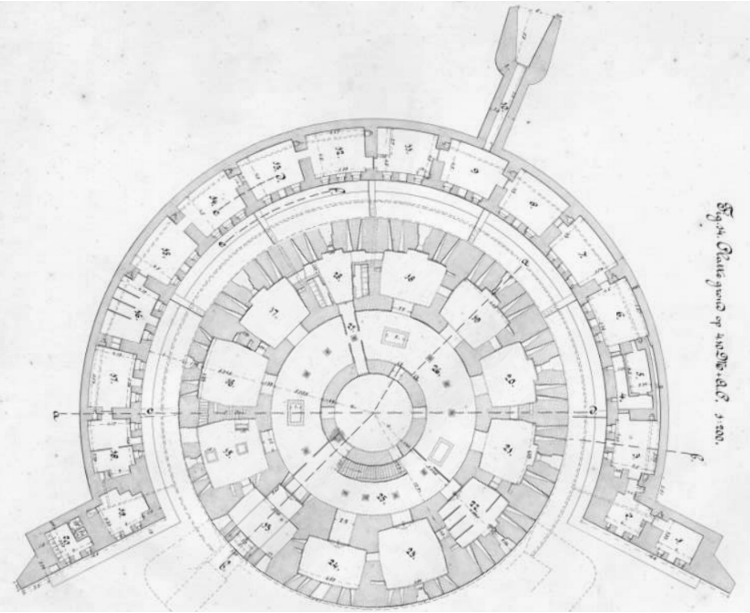
PANNERDEN
1869-1872

04



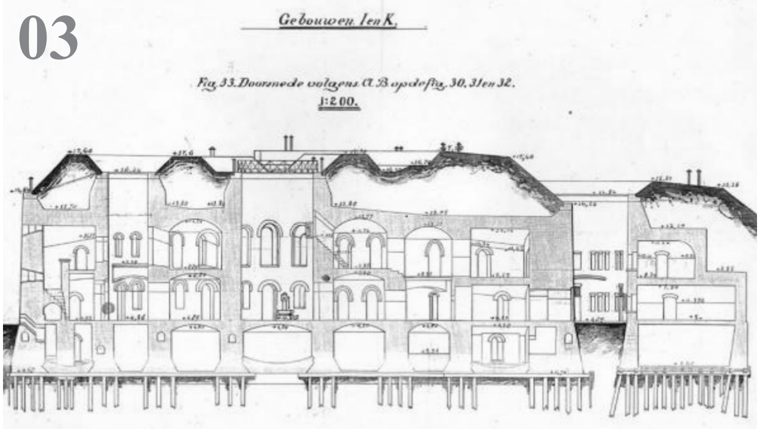


Section a (Register Vesting Gorinchem,1888)



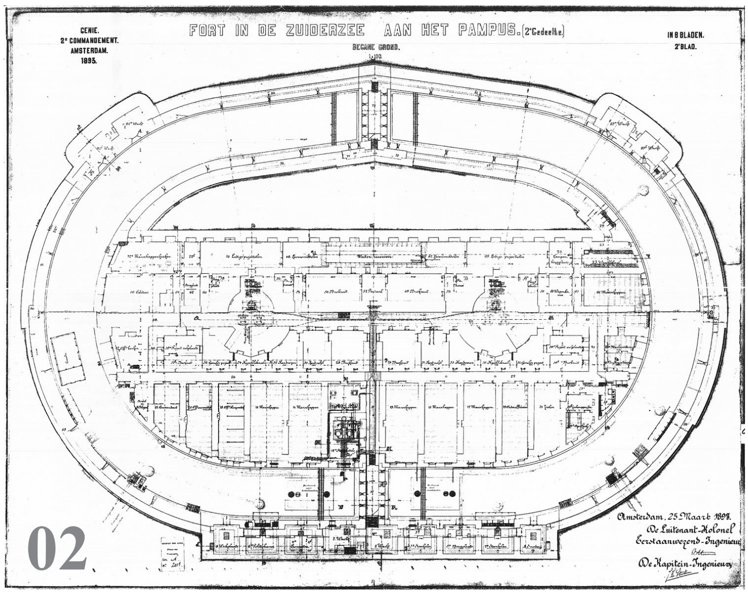
Ground floor Fort Everdingen (Register Vesting Gorinchem,1888)

03



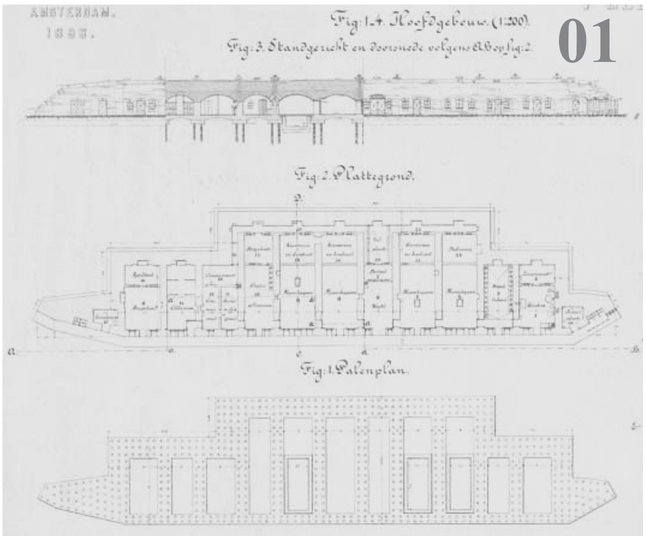
Section A & B, Towerfort Honswijk (Zaaijer and Van Der Gun, 2019)

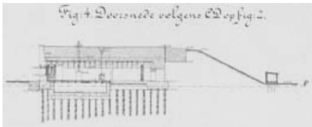
02



Floor plan Fort Pampus (Genie van het Ministerie van Oorlog, 1893)

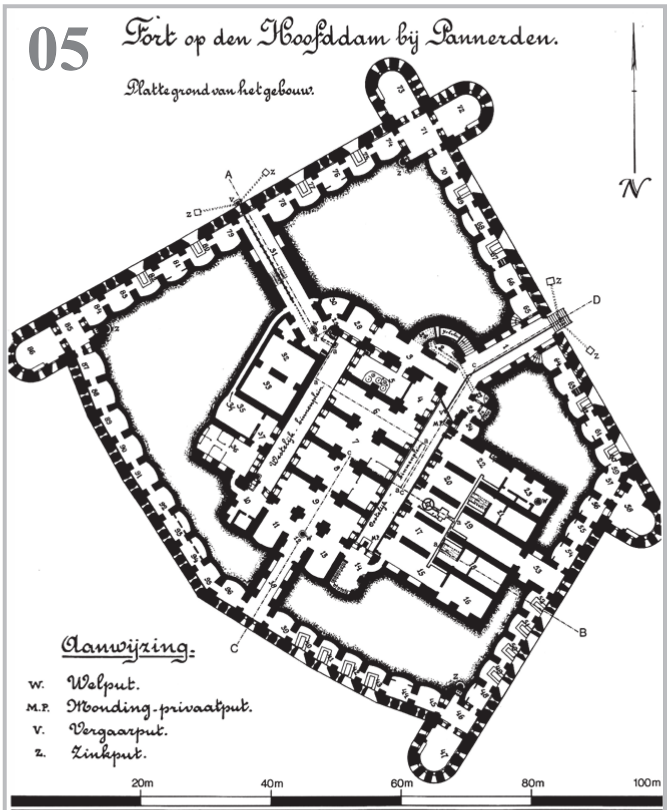
01

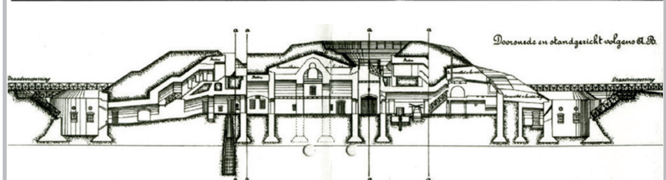




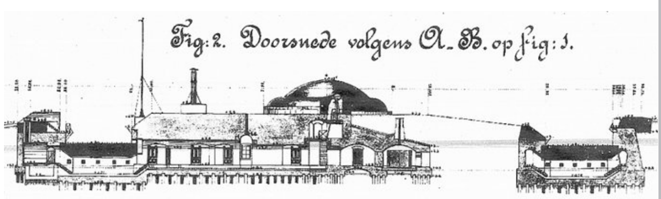
Sections and plan views
Coastal fort on lighthouse island
near Durgerdam, 1896
(kustbatterijbijdurgerdam.nl)

05





Section & Floor plan Fort Pannerden
(Stichting Menno van Coehoom, 2013)



Section Fort Pampus (Genie van het Ministerie van Oorlog, 1893)

Figure 1: (Stadsarchief Amsterdam and Vos, 2003)

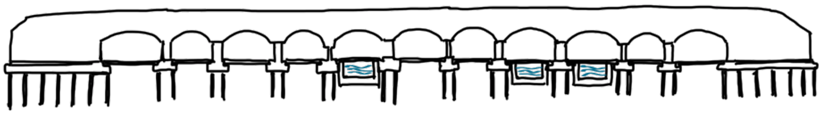


Figure 2: Section A, Coastal fort on lighthouse island near Durgerdam (own illustration)

01

Lighthouse island

NAME	Vuurtoren eiland
LOCATION	IJmeer, The Netherlands
CONSTRUCTION PERIOD	1701 construction island 1844 expansion into fortress 1883-1885 expansion for the defence line of Amsterdam
SPECIFICATIONS	- Integrated in Landscape - water self- sufficient - storage based self-sufficiency for energy and food
SIZE ISLAND	Length: ca. 158 meter Width: ca. 150 meter Area: 20.000m²
SIZE FORT	Length: ca. 75 meter Width: ca. 22 meter
PERIOD OF SELF-SUFFICIENCY	Unknown how long the island could sustain itself
LEVEL OF SELF-SUFFICIENCY	Water ●●●○ Energy ●●○○ Food ●○○○
CURRENT FUNCTION	Family residence, Restaurant, Accomodation

INTEGRATED SYSTEMS

WATER

Rainwater harvesting and purification system
Rainwater was collected by the roof under the soil package and drained via drip tubes to a water filtration tank in the basement with an overflow to a clean water tank. As a result, the fort had a considerable water supply for consumption and other uses.

ENERGY

Energy - Oil and possibly wood or coal
It is not clear what resource was used for cooking. Probably wood or coal. Wood stoves wer used for heating and petroleum lamps functioned as lightning.

FOOD

Food - Canned and stored
The main building housed a bakery, a kitchen and storage rooms that could provide the occupants with food. The whole Defence line of Amsterdam was supposed to have enough food to provide 1 million people for 6 months with food.

Project-information gathered from:
(Kustbatterij bij Durgerdam, no date; Vuurtoreneiland, 2023 & Analysis of floor plans and sections)

Stadsarchief Amsterdam:
Piet Spijker, 1946

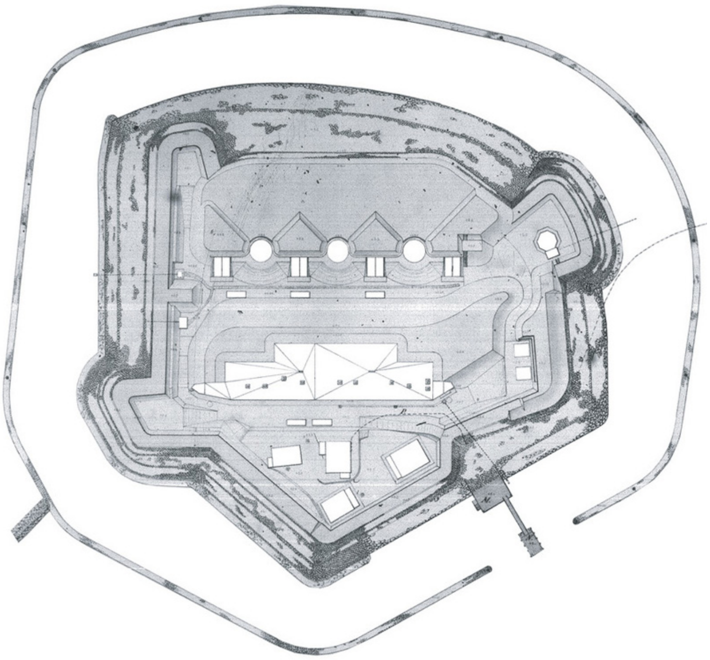


Figure 3: Top view (krft, 2017)

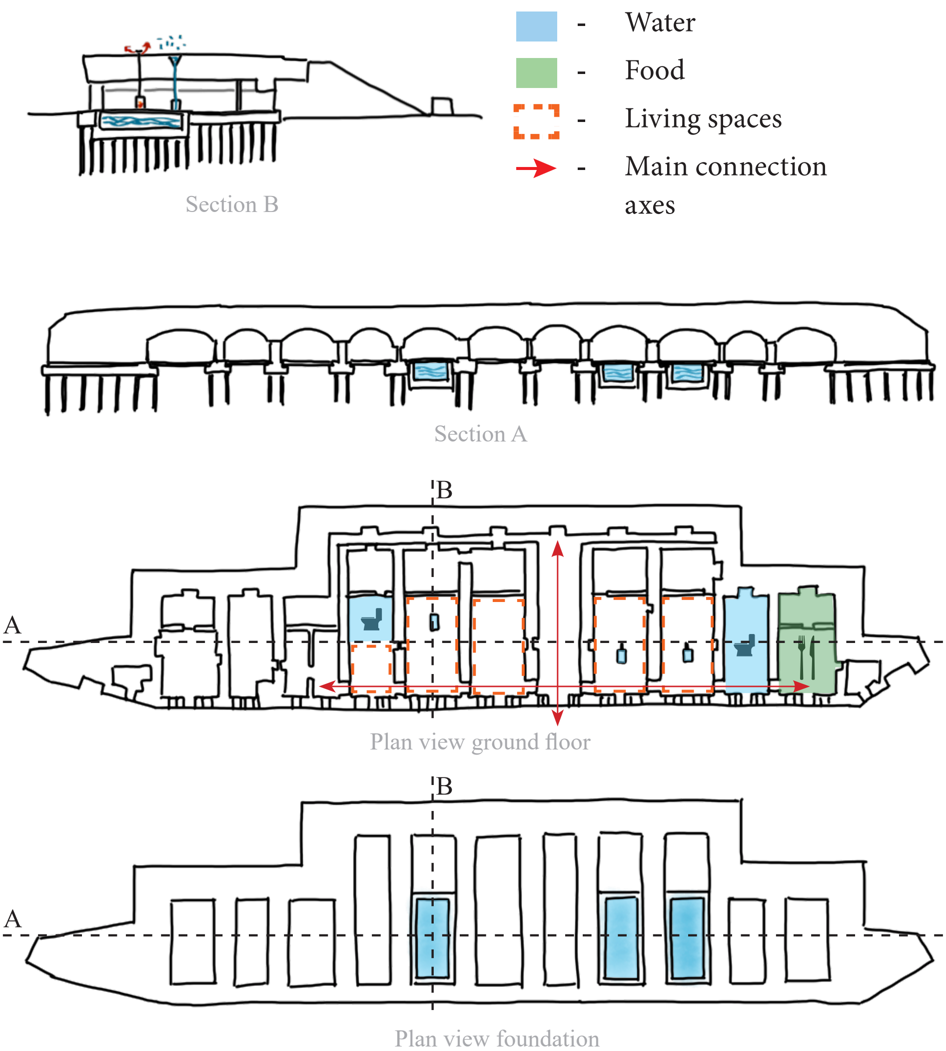


Figure 4: Plan views and Sections Lighthouse Island (own illustration)

CURRENT SYSTEMS

LESSONS LEARNED

- Energy production relies on solar panels and wind energy
- Solar collectors and a solar boiler provide warm water
- Drinking water is produced independently from Markermeer
- A reed filter treatment plant processes wastewater
- A geothermal heat pump with low-temperature heating ensures efficient heating
- Additional heating is supported by a wood stove

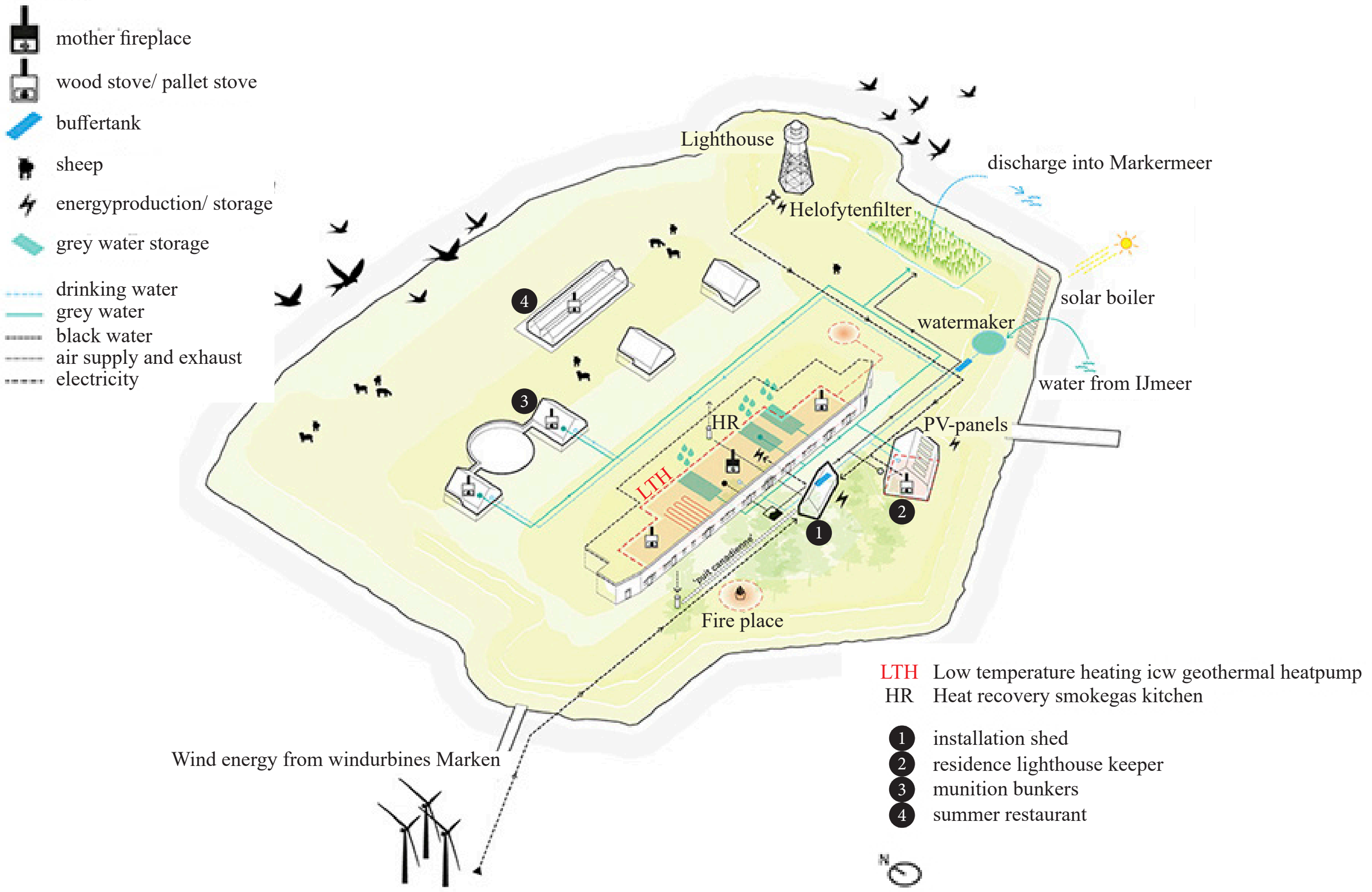


Figure 5: Sustainable infrastructure lighthouse island (krft; bunkerQ, 2017)

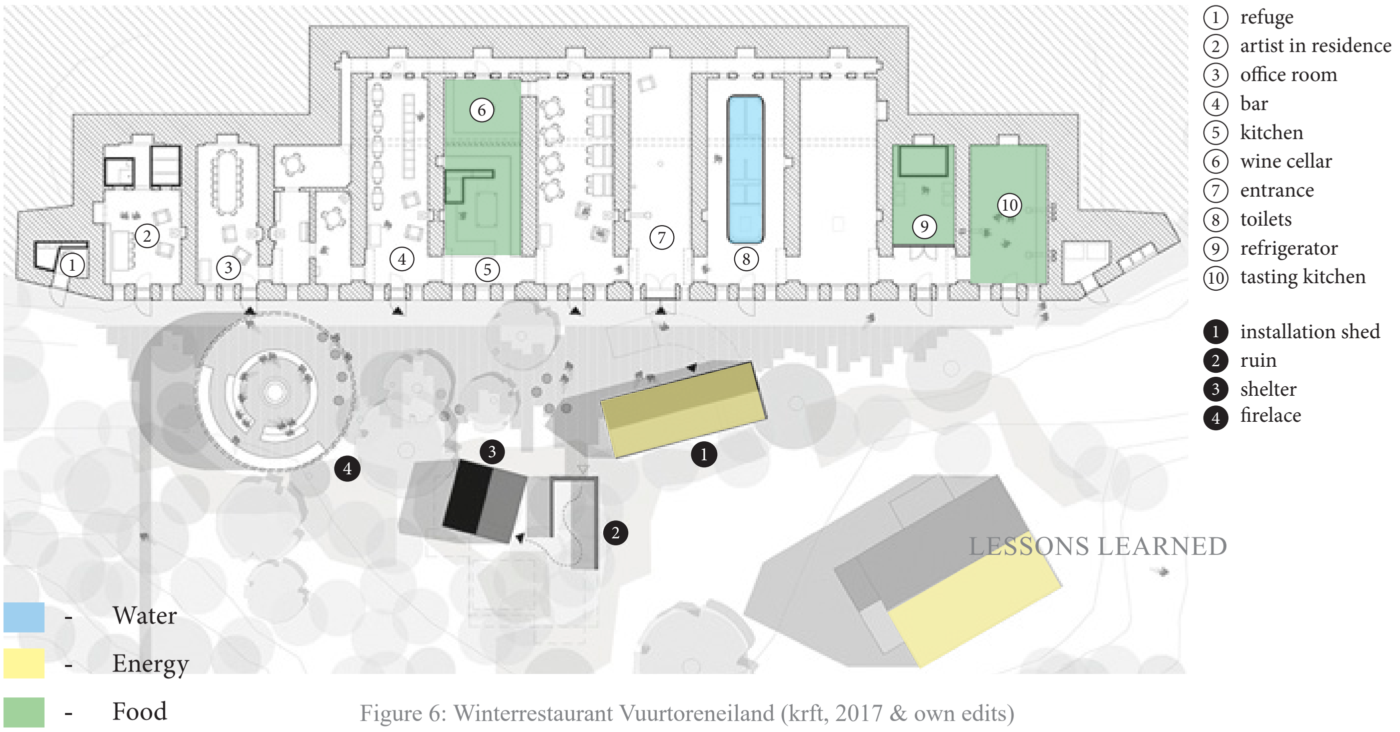


Figure 6: Winterrestaurant Vuurtoreneiland (krft, 2017 & own edits)

Grid dependent ↔ Self sufficient

		1	2	3	4		TECHNOLOGY
WATER	SUPPLY				■		Rainwater harvesting
	BUFFER/ STORAGE			■		3,3	Green roof & water storage tank
	REUSE/ TREATMENT			■			reuse of rainwater & sewage pit
ENERGY	SUPPLY		■				Oil lamps, Coal/ Wood
	STORAGE		■				Fuel stock, firewood
	INSULATION	■					
	HEATING		■			1,7	Wood stove
	COOLING	■					
	VENTILATION		■				Natural ventilation
	PASSIVE TECHNIQUES		■				Thermal mass
FOOD	SUPPLY		■			1,5	Caned & stored
	WASTE	■					Disposal at mainland

Grid dependent ↔ Self sufficient

		1	2	3	4		TECHNOLOGY
WATER	SUPPLY				■		Watermaker
	BUFFER/ STORAGE				■	3,7	Green roof, greywater storage & continious drinkingwater soruce
	REUSE/ TREATMENT			■			reuse of rainwater, drinkingwater purification & sewage pit
ENERGY	SUPPLY				■		PV panels, wind energy, solar boiler
	STORAGE			■			Firewood, battery & geothermal storage
	INSULATION		■				
	HEATING			■		2,9	LTH, geothermal heatpump + woodstove
	COOLING			■			geothermal heatpump
	VENTILATION			■			Natural supply, mechanical exhaust & Heat recovery
	PASSIVE TECHNIQUES		■				Thermal mass
FOOD	SUPPLY	■				1	
	WASTE	■					

Figure 7: Forteiland Pampus (Vrije Tijd Amsterdam, 2024)

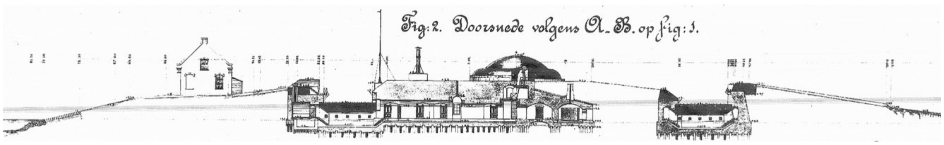


Figure 8: Section Pampus (Genie van het Ministerie van Oorlog, 1893)

02

Fort Island Pampus

NAME	Forteiland Pampus
LOCATION	IJmeer, The Netherlands
CONSTRUCTION PERIOD	1887-1895
SPECIFICATIONS	- Sunken into Landscape - Living spaces on the south, east and west side of the inner fort - storage spaces located in the middle - northside filled with earth
SIZE ISLAND	Length:205 meter Width: 164 meter
SIZE FORT	Lenght: 86 meter Width: 49 meter
PERIOD OF SELF-SUFFICIENCY	Two months
DIMENSION SYSTEM	2,60 m 14,80 m ca. 86.000 liter water
LEVEL OF SELF-SUFFICIENCY	Water ●●●○ Energy ●●●○ Food ●●●●

INTEGRATED SYSTEMS

WATER

Rainwater harvesting system

Rainwater was collected from the fort's roof and was directed through drainage pipes into underground storage tanks, each with a capacity of 27.000 liters.

Water purification

The collected rainwater was filtered by an underground filtering system of layers of sand and gravel. The filtered water was stored in a clean water reservoir, which was connected to a pump so that it could be used for consumption and other uses.

ENERGY

Energy and heating - with Coal

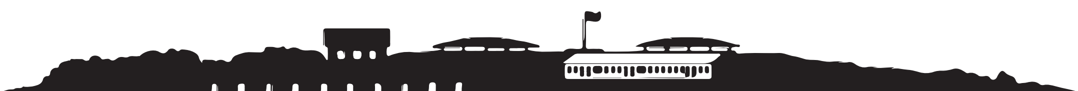
On the southeast side of the island a coalfield was located with a huge supply of coal, which was used as a source of energy for the steam kettle, blacksmith's fire, cooking kettle, bread oven and all the stoves in the fort.

FOOD

Food - Canned and stored

On Pampus, the necessary supplies of (field) rations, ship's biscuits, cans of minced meat and condensed milk were stored in the foodstorage. This enabled 200 men to provide themselves with food for a long time.

Project-information gathered from:
(Pampus, 2024; Claesen and Stichting Forteiland Pampus, 2022 & Analysis of floor plans and sections)



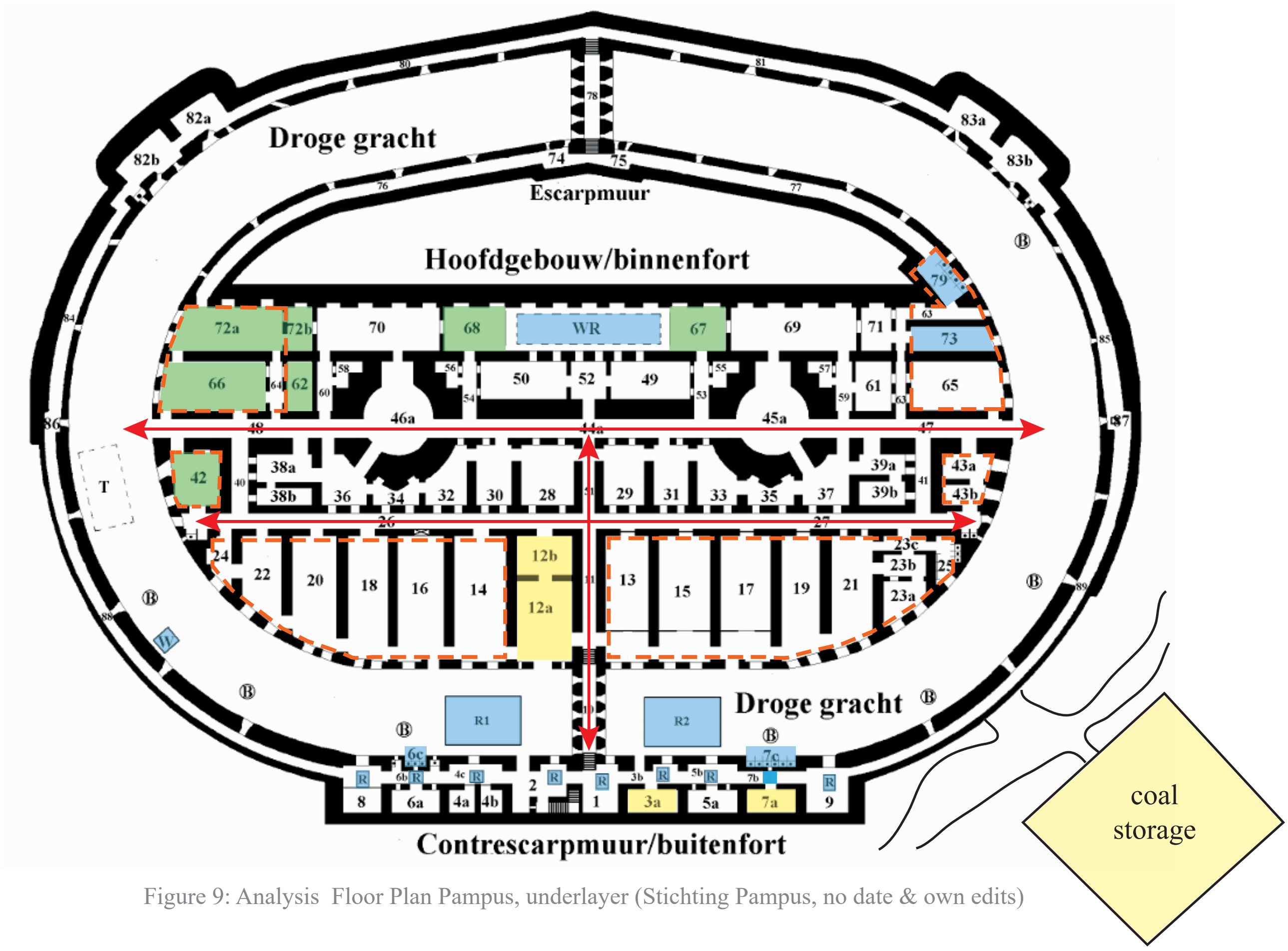


Figure 9: Analysis Floor Plan Pampus, underlayer (Stichting Pampus, no date & own edits)

- Water
- Energy
- Food
- Living spaces
- Main connection axes

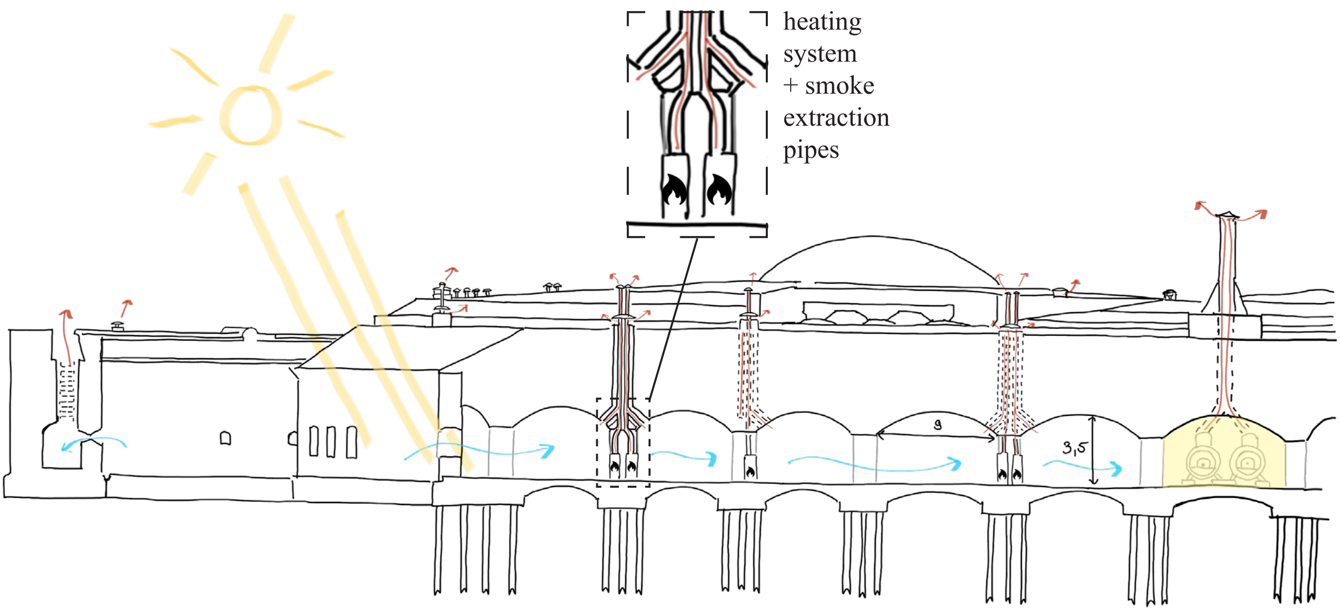


Figure 10: Section with ventilation openings and pipes (own illustration)

CURRENT SYSTEMS

CURRENT FUNCTION	Museum, Restaurant, Event location, Summer campingspot
LEVEL OF SELF-SUFFICIENCY	Water ●●●● Energy ●●●○ Food ●●●●

LESSONS LEARNED

- Rainwater harvesting tank installed in the basement
- Filtering rainwater to use for consumption and other purposes
- Drinking water production from Ijmeerwater
- Natural ventilation through window air supply and pipe exhaust
- Incorporation natural daylight reduces the need for artificial lighting
- Thermal mass regulates indoor temperatures
- Partial food supply with a vegetable garden
- Biodeigester processes bio waste and produces biogas and compost
- Old ar batteries are used as energy storage currently, with plans to transtin to hydrogen and seasalt batteries

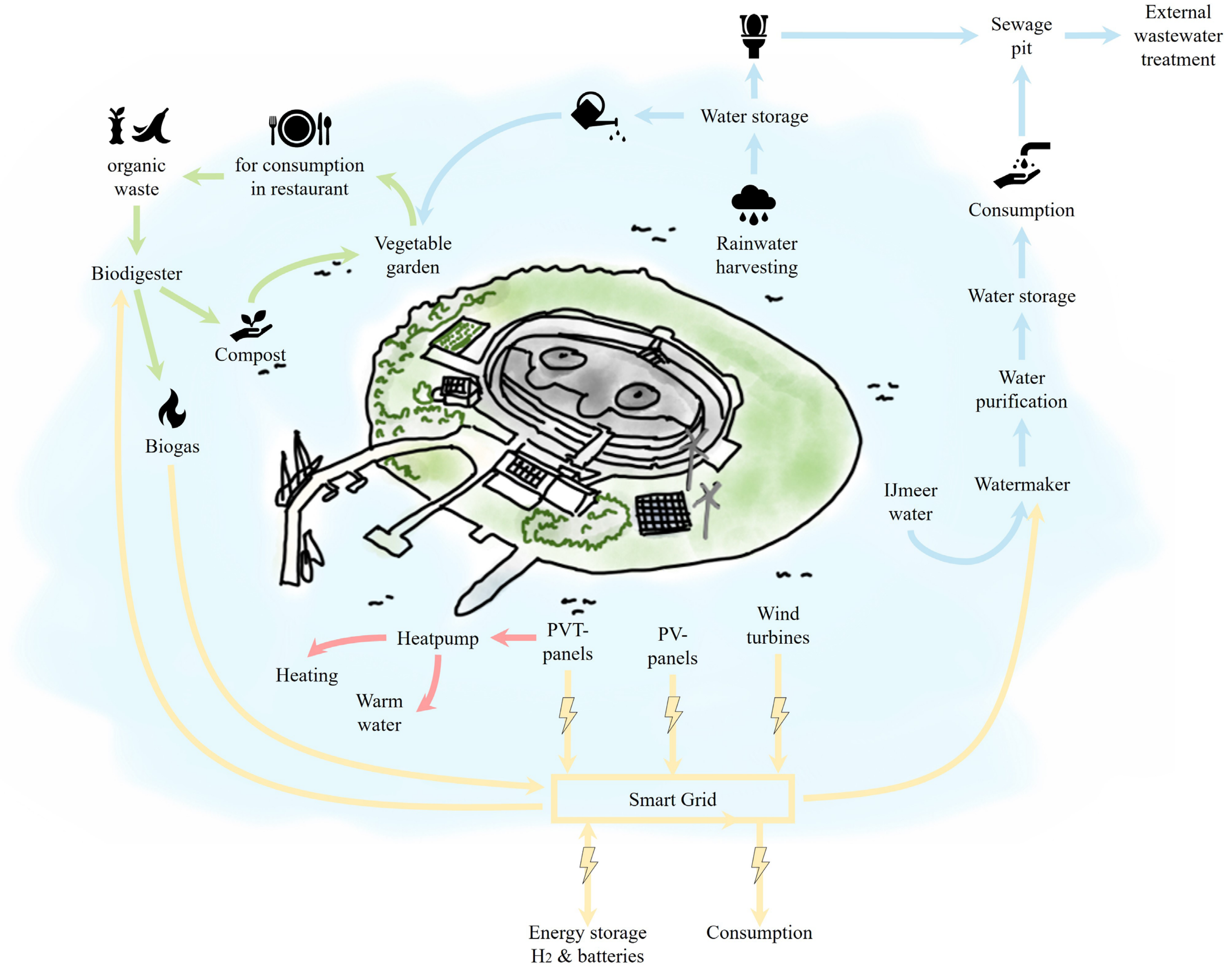


Figure 11: Currents systems that can be found on the island (own illustration)

Grid dependent ⟷ Self sufficient

		1	2	3	4		TECHNOLOGY
WATER	SUPPLY				■	3,3	Rainwater harvesting
	BUFFER/ STORAGE			■			underground water storage tank
	REUSE/ TREATMENT			■			reuse of rainwater & sewage pit on island
ENERGY	SUPPLY		■			1,7	Steam-machine on coal, Oil lamps, Wood stove
	STORAGE		■				Fuel stock, firewood
	INSULATION	■					
	HEATING		■				Wood stove
	COOLING	■					
	VENTILATION		■				Natural ventilation
	PASSIVE TECHNIQUES		■				Thermal mass
FOOD	SUPPLY		■			1,5	Caned & stored
	WASTE	■					Disposal at mainland

Grid dependent ⟷ Self sufficient

		1	2	3	4		TECHNOLOGY
WATER	SUPPLY				■	3,7	Watermaker
	BUFFER/ STORAGE				■		Continious drinking water source & rainwater storage
	REUSE/ TREATMENT			■			reuse of rainwater & sewage pit
ENERGY	SUPPLY				■	3	PV panels, wind energy, PVT panels, biogas
	STORAGE				■		now: old car batteries later: H_2, Seasalt battery
	INSULATION		■				Parts insulated, parts not insulated
	HEATING			■			Heatpump
	COOLING			■			Heatpump
	VENTILATION			■			Natural supply, mechanical exhaust
	PASSIVE TECHNIQUES		■				Thermal mass
FOOD	SUPPLY			■		3,5	Vegetable garden
	WASTE				■		Biodigester

Figure 12: Fort Honswijk (Fotodienst HUA, 2001)

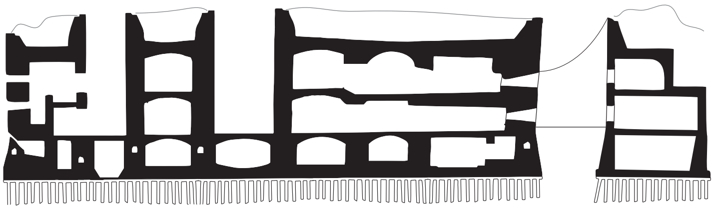


Figure 13: Section Fort Honswijk (own illustration)

03

Fort Honswijk

NAME	Fort Honswijk
LOCATION	Utrecht, The Netherlands
CONSTRUCTION PERIOD	1841-1848
SPECIFICATIONS	- Covered with soil package - two seperate water supply systems - Surrounded by water, located next to the Lek - Towerfort
SIZE AREA	Length: 390 meter Width: 225 meter Area: 135.000 m²
SIZE TOWERFORT	Diameter: 43 meter Heigth: 19 meter
PERIOD OF SELF-SUFFICIENCY	30 days clean water from rainwater collection, but also ground well
LEVEL OF SELF-SUFFICIENCY	Water ●●●● Energy ●●○○ Food ●●○○

INTEGRATED SYSTEMS

WATER

Rainwater harvesting and purification

Rainwater was collected from the roof under the ground package and drained via drip tubes to a water filtration tank in the basement with an overflow to a clean water tank in another room of the basement. In this tank a water supply for about 30 days could be stored. The surplus water was drained to outside the tower.

Ground well

The second facility was a deep well pump struck into the aquifer in the centre of the tower.

ENERGY

Energy - Wood or coal

It is not clear what resource was used for cooking and possibly heating. Probably wood or coal.

FOOD

Food - Canned and stored

The ground floor of the Fort housed a bakery and kitchen. In the basement were food storage rooms that should provide 400 people with food.

Project-information gathered from:
(Zaaijer and Van Der Gun, 2019 & Stichting Honswijk - Everdingen, 2024)

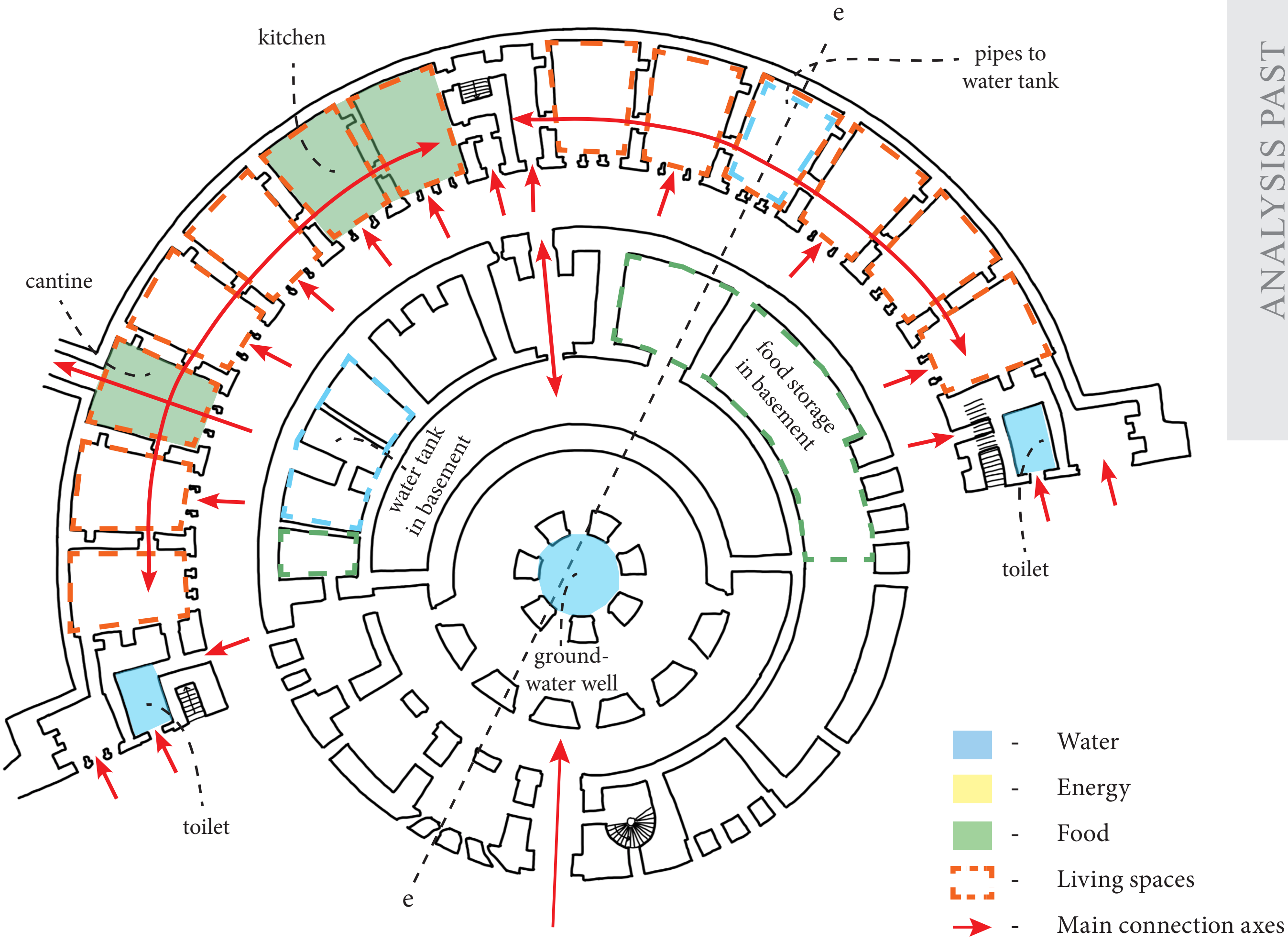


Figure 14: Ground floor, Towerfort Honswijk (own illustration)

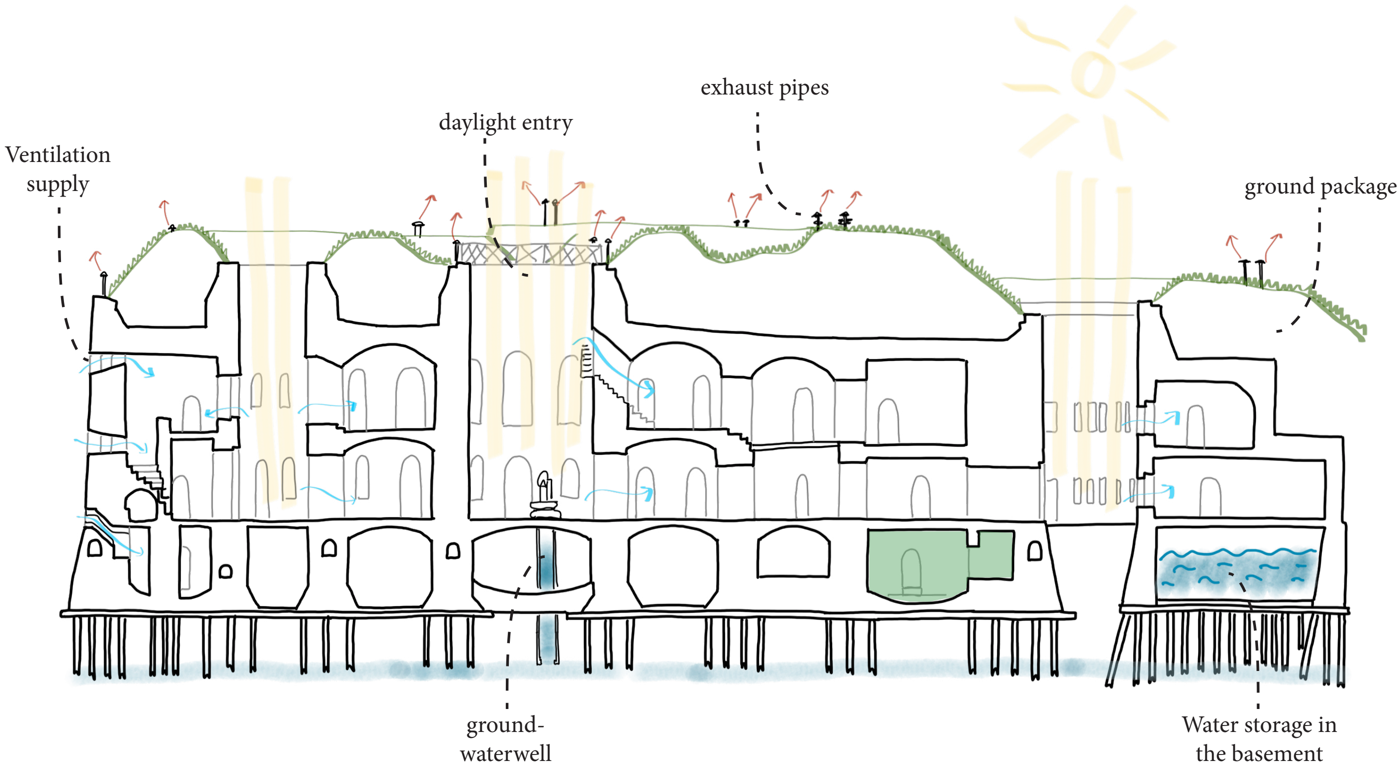


Figure 15: Section A & B, Towerfort Honswijk (own illustration)

CURRENT & FUTURE SYSTEMS

CURRENT FUNCTION	Museum, Workspace, Eventlocation, Restaurant, Accomodation, Creative venue	
LEVEL OF SELF-SUFFICIENCY	Water	●●○○
	Energy	●●○○
	Food	●●○○

LESSONS LEARNED

- Rainwater harvesting tank installed in the basement
- Filtering rainwater to use for consumption and other purposes
- Natural ventilation through window air supply and pipe exhaust
- Incorporation natural daylight reduces the need for artificial lighting
- Thermal mass regulates indoor temperatures
- Partial food supply with a vegetable garden

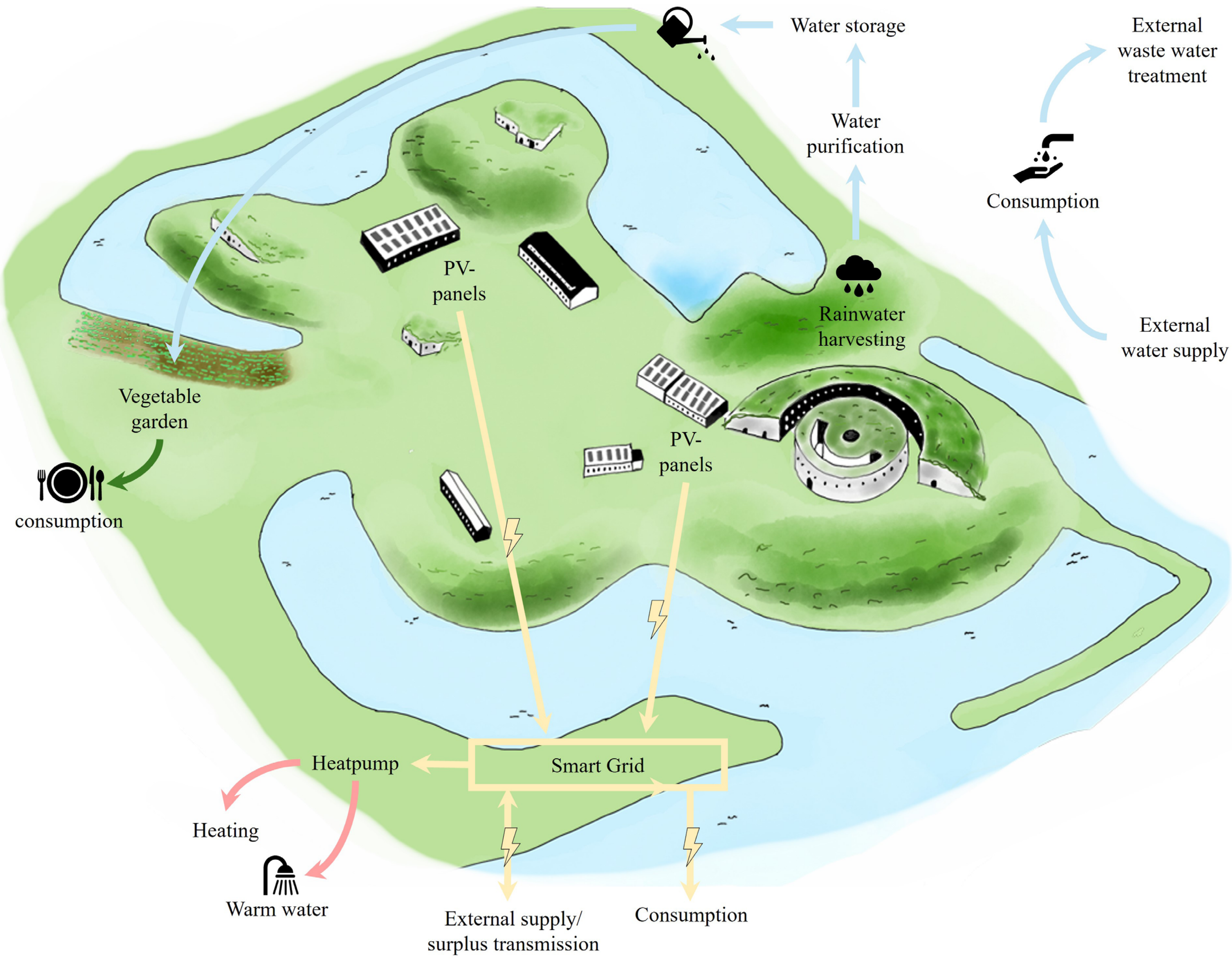
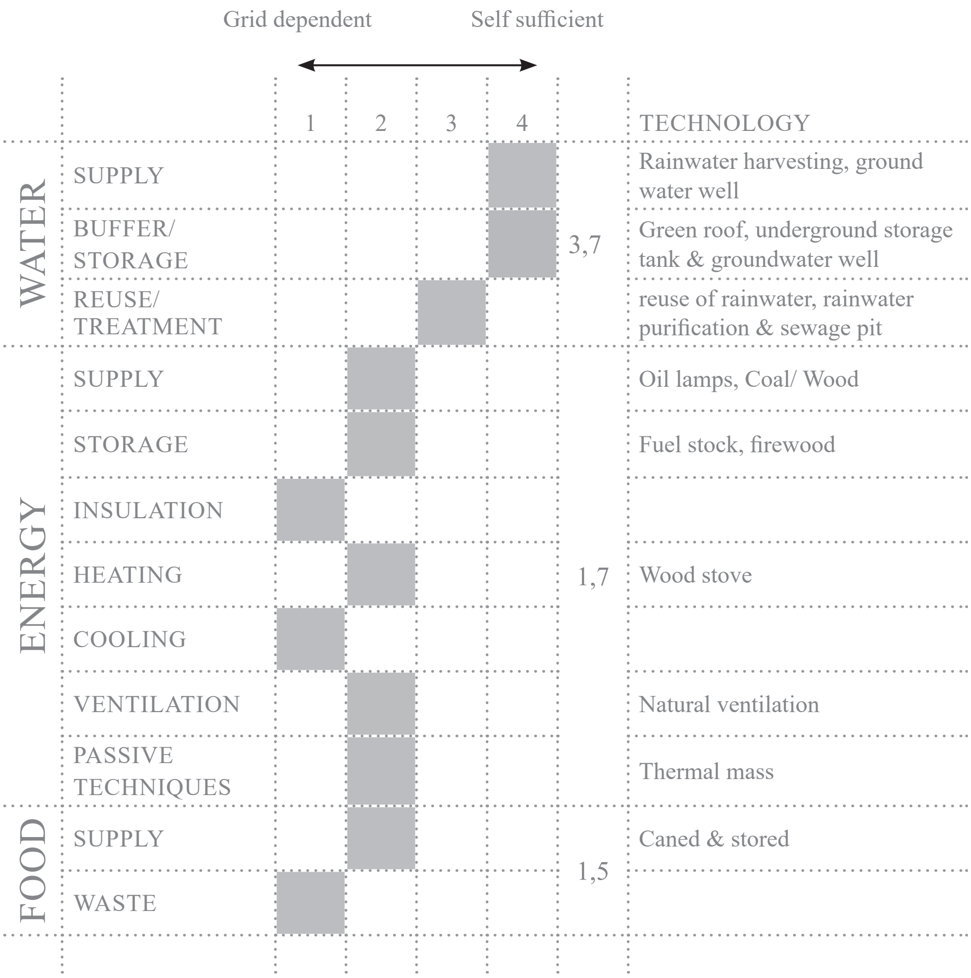


Figure 16: Current systems used at Fort Honswijk (own illustration)


Grid dependent
Self sufficient
1
2
3
4
TECHNOLOGY
WATER
SUPPLY
Rainwater harvesting, ground water well
BUFFER/ STORAGE
Green roof, underground storage tank & groundwater well
3,7
REUSE/ TREATMENT
reuse of rainwater, rainwater purification & sewage pit
ENERGY
SUPPLY
Oil lamps, Coal/ Wood
STORAGE
Fuel stock, firewood
INSULATION
HEATING
1,7
Wood stove
COOLING
VENTILATION
Natural ventilation
PASSIVE TECHNIQUES
Thermal mass
FOOD
SUPPLY
Caned & stored
1,5
WASTE

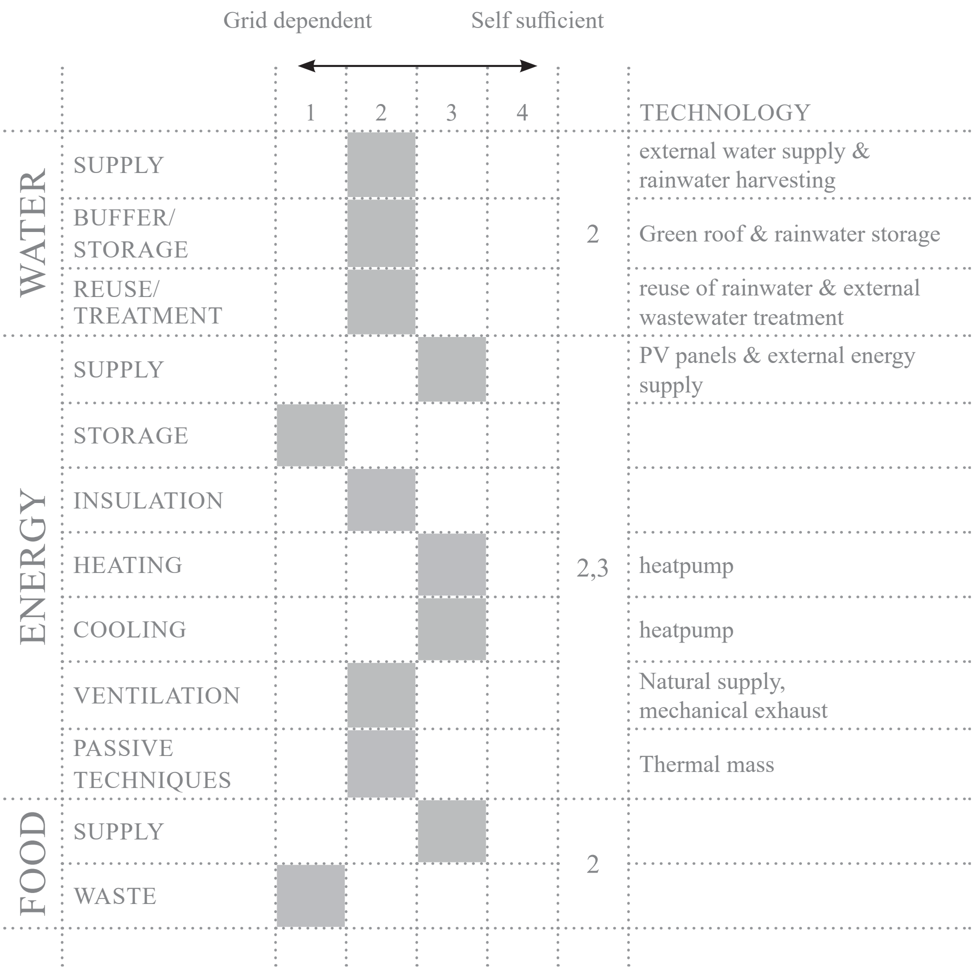

Grid dependent
Self sufficient
1
2
3
4
TECHNOLOGY
WATER
SUPPLY
external water supply & rainwater harvesting
BUFFER/ STORAGE
2
Green roof & rainwater storage
REUSE/ TREATMENT
reuse of rainwater & external wastewater treatment
ENERGY
SUPPLY
PV panels & external energy supply
STORAGE
INSULATION
HEATING
2,3
heatpump
COOLING
heatpump
VENTILATION
Natural supply, mechanical exhaust
PASSIVE TECHNIQUES
Thermal mass
FOOD
SUPPLY
2
WASTE

Figure 17: Fort Everdingen (Forten.nl 2021)

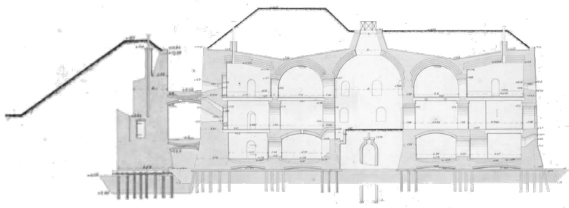


Figure 18: Section Fort Everdingen (Register Vesting Gorinchem,1888)

05

Fort Everdingen

NAME	Fort Everdingen
LOCATION	Gelderland, The Netherlands
CONSTRUCTION PERIOD	1841-1864
SPECIFICATIONS	- Covered with soil package - Surrounded by water, located next to the Lek - Towerfort - Rainwater harvesting and ground well as water supply system - open shaft in the middle of the building functioned as ventilation and lighting shaft
SIZE AREA	Length: 330 meter Width: 250 meter
SIZE TOWERFORT	Length: 92,5 meter Width: 80 meter
PERIOD OF SELF-SUFFICIENCY	6 weeks
DIMENSION SYSTEM	Clean water storage of 65m³
CURRENT FUNCTION	Museum, Beer brewery, Tasting room, Shop, Camping spot

Project-information gathered from:
(De Groot, 2013; Register Vesting Gorinchem,1888; Batist, 2023 & Analysis of floor plans and sections)

INTEGRATED SYSTEMS

WATER

Rainwater harvesting and purification

Rainwater was collected via the roof under a 5m thick soil package and drained via drip tubes to a water filtration tank in the basement. After a filtration process of 3 months, it reached the clean water tank. The drip tubes on the ground floor, were a in between station where water could be collected in a bucket. The clean water tank had a volume of 65m³ and could supply the fort's occupants with water for 6 weeks.

Ground well

The second facility was a deep well pump struck into the aquifer in the centre of the tower.

ENERGY

Energy - Wood, turf, petroleum

Section C shows the four chimney pipes that emerge above the ground layer from the kitchen. Branches and turf was used for cooking fire. Wood stoves were used for heating and petroleum lamps functioned as lighting.

FOOD

Food - Canned and stored

The ground floor of the Fort housed a bakery and kitchen. In the basement were food storage rooms that should provide the occupants with food.

Figure 19: Analysis Basement (Register Vesting Gorinchem, 1888 & own edits)

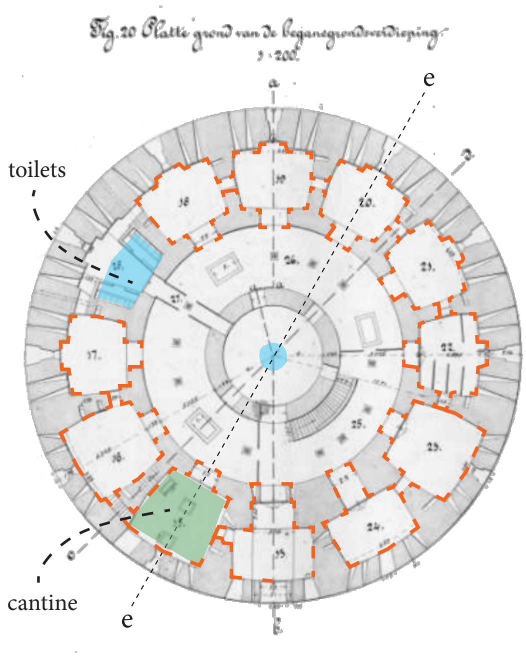


Figure 20: Analysis First floor (Register Vesting Gorinchem, 1888 & own edits)

- Water
- Energy
- Food
- Living spaces

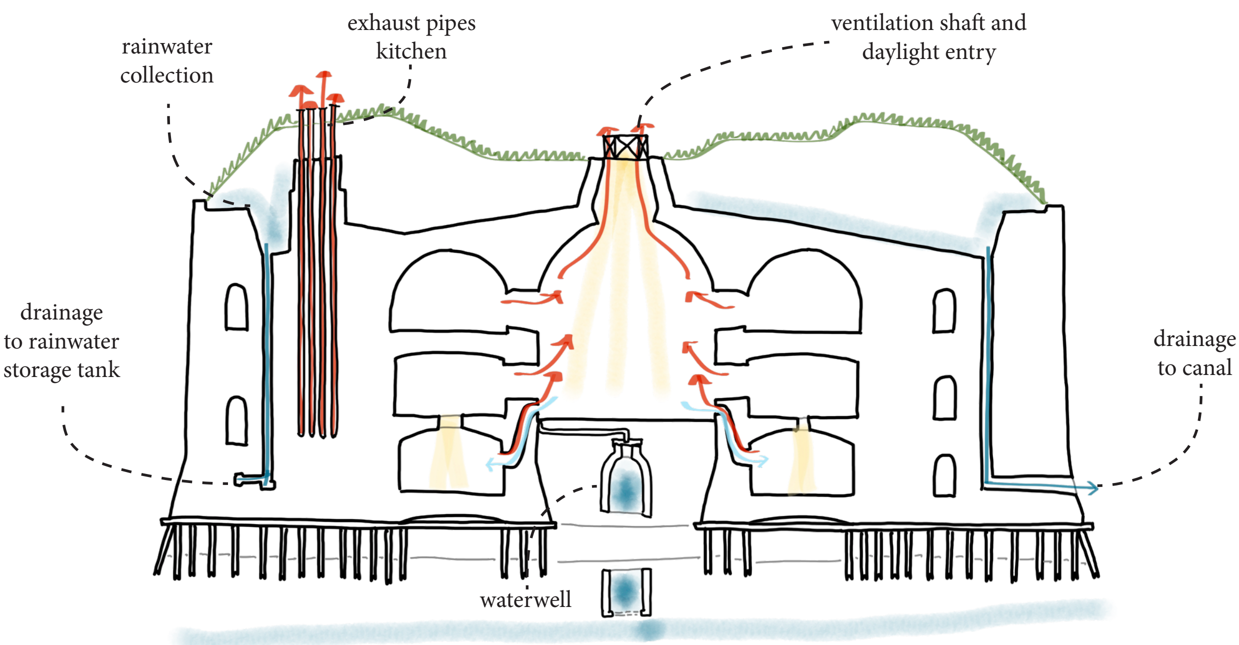


Figure 21: Analysis Section c (own illustration)

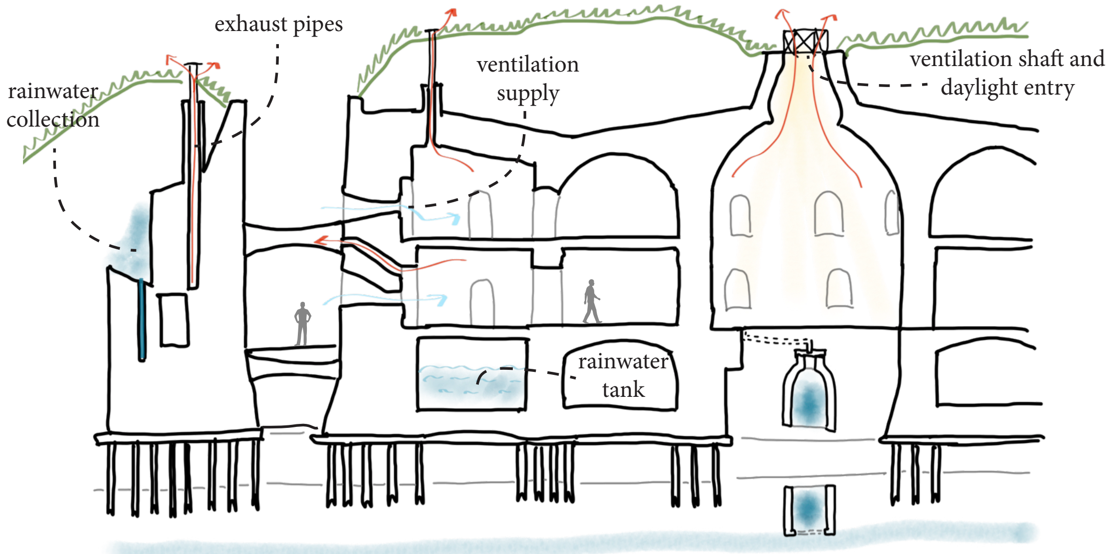


Figure 22: Analysis Section e (own illustration)

CURRENT SYSTEMS

CURRENT FUNCTION	Museum, Beer brewery, Tasting room, Shop, Camping spot	
LEVEL OF SELF-SUFFICIENCY	Water	● ● ● ○
	Energy	● ● ○ ○
	Food	● ● ○ ○

LESSONS LEARNED

- Rainwater harvesting tank installed in the basement
- Filtering rainwater to use for consumption and other purposes
- Natural ventilation through window air supply and pipe exhaust
- Incorporation natural daylight reduces the need for artificial lighting
- Thermal mass regulates indoor temperatures

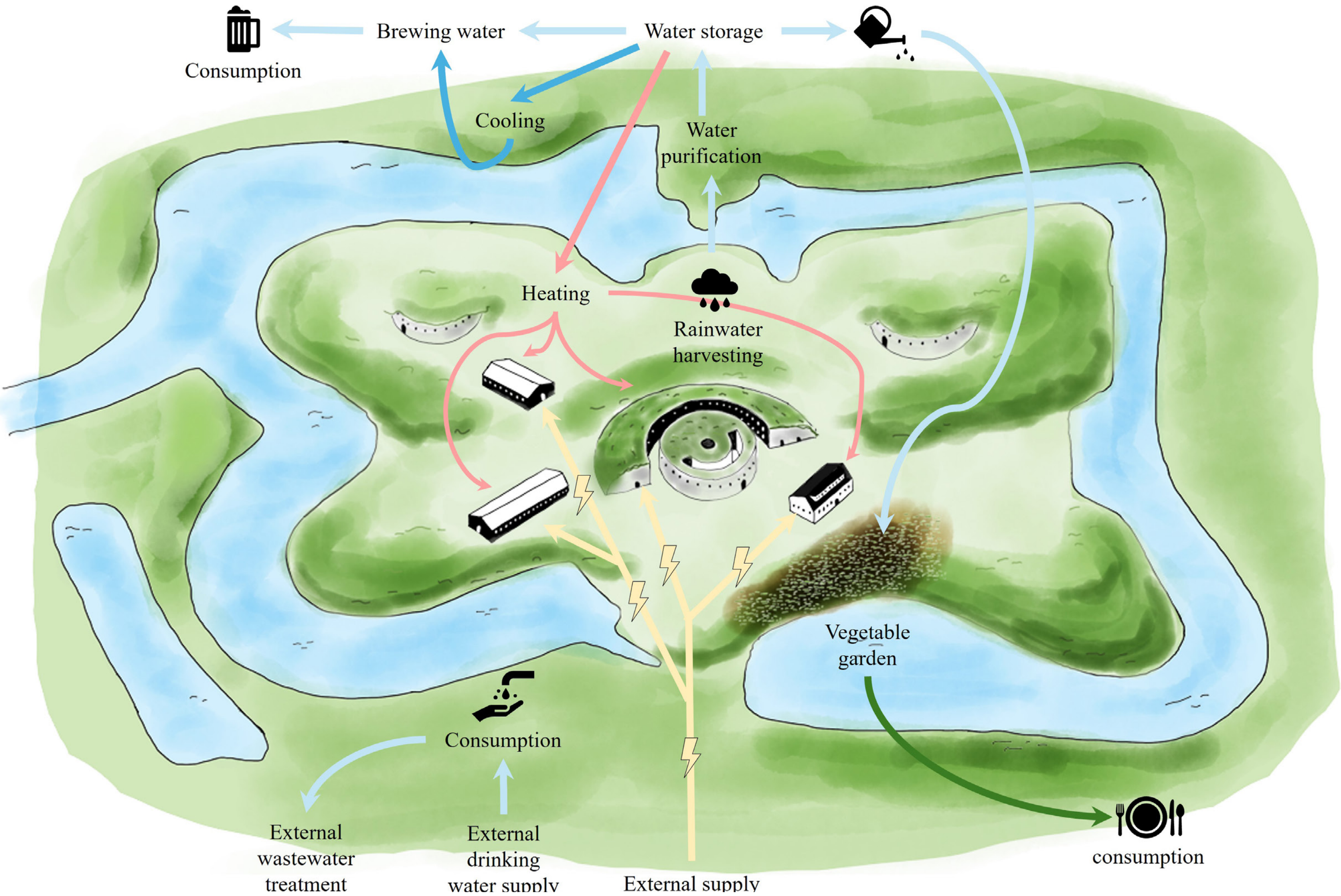


Figure 23: Current systems used at Fort Everdingen (own illustration)

Grid dependent ⟷ Self sufficient

		1	2	3	4		TECHNOLOGY
WATER	SUPPLY				■	3,7	Rainwater harvesting, ground water well
	BUFFER/ STORAGE				■		Green roof, underground storage tank & groundwater well
	REUSE/ TREATMENT			■			reuse of rainwater, rainwater purification & sewage pit
ENERGY	SUPPLY		■			1,7	Oil lamps, Coal/ Wood
	STORAGE		■				Fuel stock, firewood
	INSULATION	■					
	HEATING		■				Wood stove
	COOLING	■					
	VENTILATION		■				Natural ventilation
	PASSIVE TECHNIQUES		■				Thermal mass
FOOD	SUPPLY		■			1,5	Caned & stored
	WASTE	■					

Grid dependent ⟷ Self sufficient

		1	2	3	4		TECHNOLOGY
WATER	SUPPLY		■			2,7	external water supply & rainwater harvesting
	BUFFER/ STORAGE			■			Green roof & rainwater storage (for beer brewing)
	REUSE/ TREATMENT			■			reuse of rainwater, rainwater purification & external wastewater treatment
ENERGY	SUPPLY	■				1,7	External energy supply
	STORAGE	■					
	INSULATION		■				
	HEATING		■				conventional heating + use of harvested rainwater
	COOLING		■				Cooling with harvested rainwater
	VENTILATION		■				Natural supply, mechanical exhaust
	PASSIVE TECHNIQUES		■				Thermal mass
FOOD	SUPPLY			■		2	vegetable garden
	WASTE	■					

Figure 24: (*Fort Pannerden*, 2024)

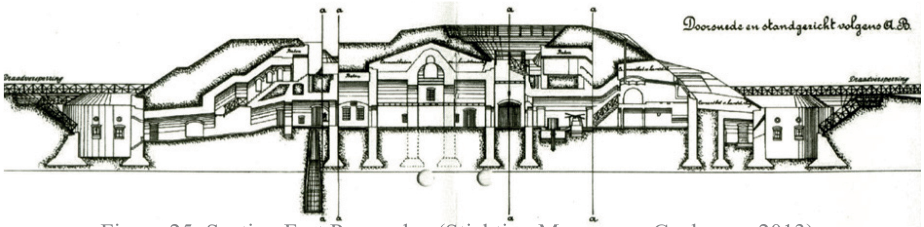


Figure 25: Section Fort Pannerden (Stichting Menno van Coehoom, 2013)

05

Fort Pannerden

NAME	Fort Pannerden
LOCATION	Gelderland, The Netherlands
CONSTRUCTION PERIOD	1869-1872
SPECIFICATIONS	- Part of the IJssel defence line - Integrated in Landscape - Living spaces and storage in the heart of the building - Inner Fort is surrounded by a defence ring
SIZE FORT	Length: 92,5 meter Width: 80 meter
PERIOD OF SELF-SUFFICIENCY	30 days
LEVEL OF SELF-SUFFICIENCY	Water ●●●○ Energy ●●○○ Food ●●○○

INTEGRATED SYSTEMS

WATER

Rainwater harvesting system
Rainwater was collected using a drainage system via drip pipes in the walls of the fort which were directed to sinkholes.

Water purification
In these sinkholes the largest pollutions were filtered out of the water. From there the water was then led further to three clean water wells.

ENERGY

Energy - Oil and possibly wood or coal
It is not clear what resource was used for cooking and possibly heating. Probably wood or coal. In any case, there was also an oil pump and accumulator, which was used for the artillery.

FOOD

Food - Canned and stored
As a 30-day defence was assumed, food was stored at the fort for 200 people for at least 30 days. But as long as the fort was still connected to its own hinterland, every two days additional supplies of food were delivered from Nijmegen.

Project-information gathered from:
(van der Heijden and Ruissen, 2012 & Analysis of floor plans and sections)

Figure 26: Analysis Floor Plan Fort Pannerden, underlayer (Stichting Menno van Coehoom, 2013)

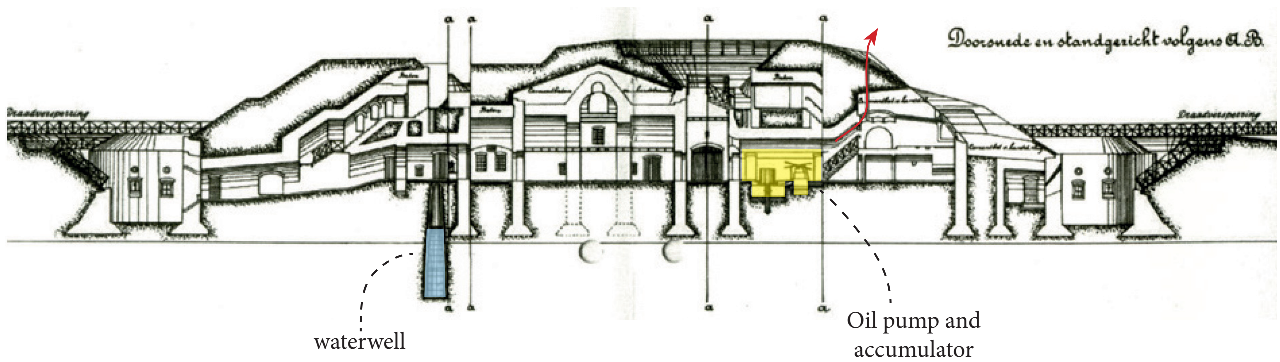


Figure 27: Section Fort Pannerden, underlayer drawing from 1869 (Stichting Menno van Coehoom, 2013)

FUTURE SYSTEMS

CURRENT FUNCTION	Museum	
LEVEL OF SELF-SUFFICIENCY	Water	●●●●
	Energy	●●●●
	Food	●●●●

LESSONS LEARNED

- Rainwater harvesting through a smart pipe network directs water to sinkholes for purification before storing it in a well
- Filtered rainwater can be utilized for consumption and various other purposes
- Natural ventilation achieved through windows for air supply and pipes for exhaust
- Hydropower serves as an efficient source of energy production

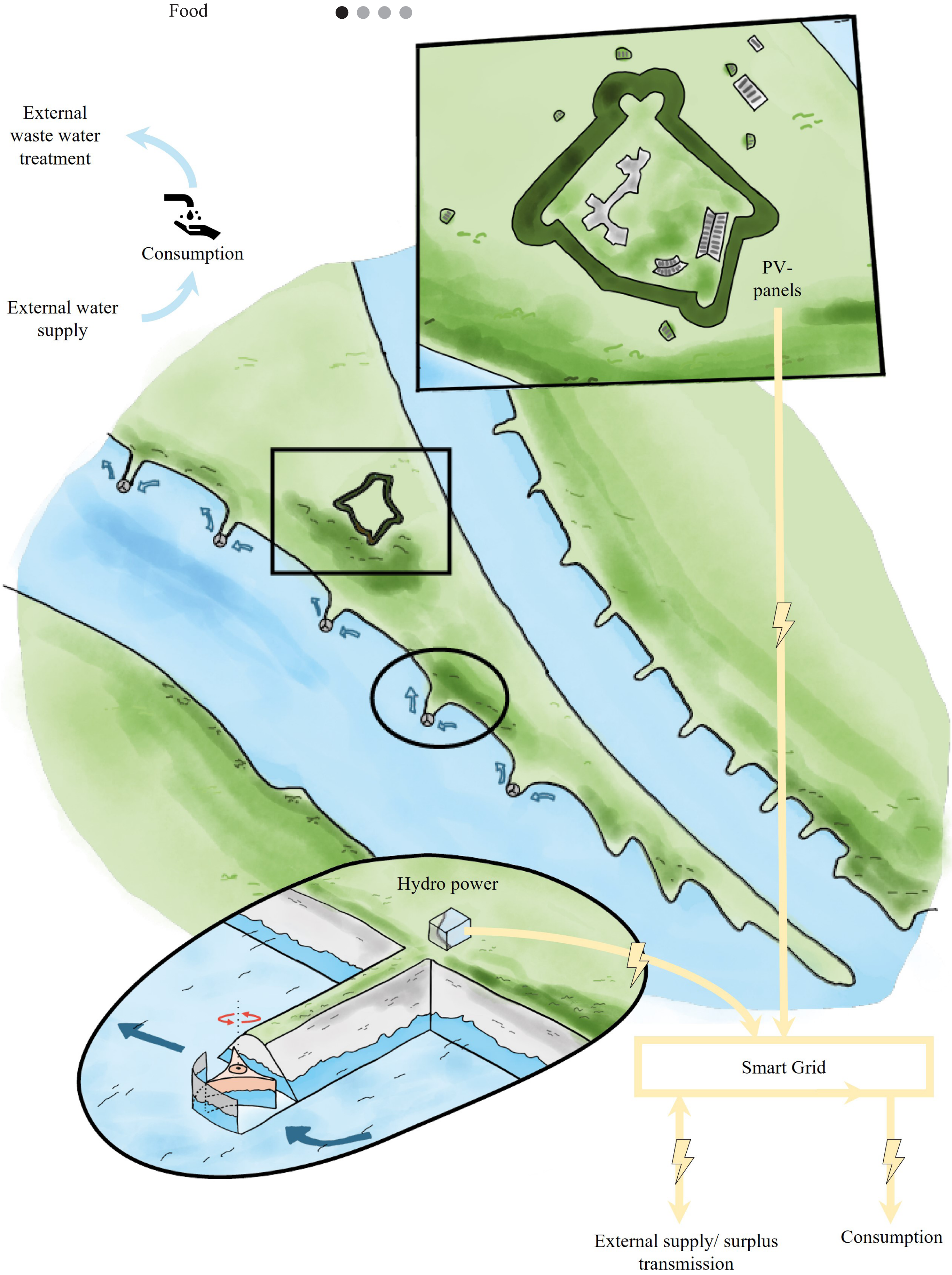


Figure 28: Current systems used at Fort Pannerden (own illustration)

Grid dependent ⟵⟶ Self sufficient

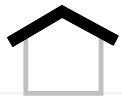
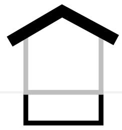
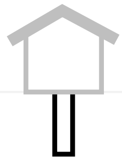
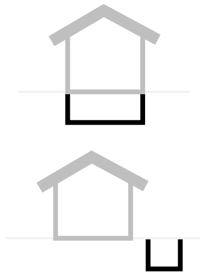
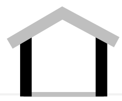
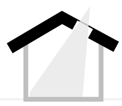
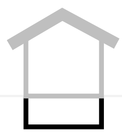
		1	2	3	4		TECHNOLOGY
WATER	SUPPLY				■	3,7	Rainwater harvesting, ground water well
	BUFFER/ STORAGE				■		Green roof, underground storage tank & water well
	REUSE/ TREATMENT			■			reuse of rainwater, rainwater purification & sewage pit
ENERGY	SUPPLY		■			1,7	Oil lamps, Coal/ Wood
	STORAGE		■				Fuel stock, firewood
	INSULATION	■					
	HEATING		■				Wood stove
	COOLING	■					
	VENTILATION		■				Natural ventilation
	PASSIVE TECHNIQUES		■				Thermal mass
FOOD	SUPPLY		■			1,5	Caned & stored
	WASTE	■					

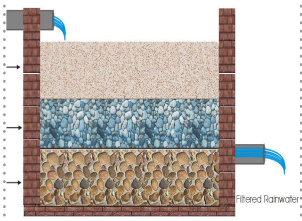
Grid dependent ⟵⟶ Self sufficient

		1	2	3	4		TECHNOLOGY
WATER	SUPPLY		■			2	external water supply & rainwater harvesting
	BUFFER/ STORAGE		■				Green roof & rain water storage
	REUSE/ TREATMENT		■				reuse of rainwater & external wastewater treatment
ENERGY	SUPPLY				■	2	PV panels, hydro power
	STORAGE	■					
	INSULATION		■				
	HEATING		■				conventiona heating system
	COOLING	■					
	VENTILATION		■				Natural supply, mechanical exhaust, HR
	PASSIVE TECHNIQUES		■				Thermal mass
FOOD	SUPPLY	■				1	
	WASTE	■					

OVERVIEW INTERESTING SYSTEMS

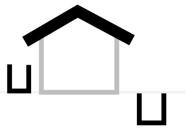
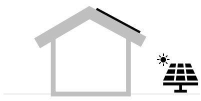
Traditional Techniques

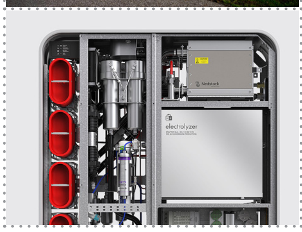
		USED IN	WATER, ENERGY, FOOD Grid dependent ↔ Self sufficient 1	2	3	4	TECHNOLOGY	LOCATION	FUNCTION
Past	WATER	01 03 04 05				■	Extensive Green roof		WATER BUFFER/ TREAT-MENT 1. Temporary water buffer 2. Purifing filter
		01 02 03 04 05				■	Rainwater harvesting & purification		WATER SUPPLY Drinking water production
		04 05				■	Groundwater well		WATER SUPPLY Drinking water
		01 02 03 04 05				■	Water storage		WATER BUFFER/ STORAGE Internal water supply
	ENERGY	01 02 03 04 05				■	Thermal mass		PASSIVE TECHNIQUES Passive temperature regulation
		03 04				■	Natural lighting		PASSIVE TECHNIQUES Optimizing light entry
		01 02 03 04 05		■			Wood stove		HEATING
	FOOD	01 02 03 04 05		■			Food storage		FOOD SUPPLY Food storage and preservation

SPECIFICATIONS	PROS AND CONS	NEEDED SPACE	APPEARANCE
A green roof captures rainwater, provides cooling in summer, and supports insect habitats. It contributes to a healthier, more pleasant environment for both people and wildlife in the neighborhood.	+ Buffering rainwater + better stormwater management + Cooling effect + contributes to biodiversity + subsrate partly cleans the water − higher investment costs − a green roof is heavy and not all constructions can bear it weight	Forts: >2 m groundlayer Today: 5-15 cm ground-layer	
Rainwater was collected from the fort's roofs and channeled through drainage pipes into underground storage tanks. The water was pre-filtered by the sand and gravel layer of the green roof and further purified by a sand-gravel filter basin located underground, which the water passed through before reaching the clean water reservoir.	+ independent source of water + can be used for watering the plants or flushing the toilets − the system requires space − The water quality of the system, without additional treatment, is insufficient for consumption or household use	Forts: >2 m groundlayer for filtering + storage tank	
A groundwater well provides a reliable water source. Historically seen, it was used as drinking water. It still remains a naturally filtered water source, but restrictions in the Netherlands now require additional treatment for consumption.	+ independent and continious source of water − the water quality, without additional treatment, is now insufficient for consumption	>6 m deep	
A water storage tank stores water for later use. These tanks are often located in basements or underground but can also be above ground, such as rain barrels.	+ independent source of water + can be used for watering the plants or flushing the toilets − the system requires space − The water quality of the system, without additional treatment, is nowadays insufficient for consumption or household use	Pampus: 14,80 m x 2,60 m ca. 86.000 l Everdingen: 65.000 l	
Thermal mass refers to a material's ability to absorb, store, and release heat. Materials such as water, concrete and bricks known as 'high thermal mass' materials, excel at storing heat from a heat-source or solar gains efficiently.	+ releases stored daytime heat in the evening − keeps the house cooler during hot summer days − heating takes longer as the thermal mass absorbs heat first − takes longer to cool once fully heated in summer	Forts: The walls and roofs were 2-4 m thick. Today: 100-150 mm thick	
Adding openings in roofs and floors increases daylight, reducing the need for artificial lighting and therefore saving energy	+ less energy demand + more natural daylight improves quality of life − glass has poor insulation, causing faster heat loss		
The wood stoves can supply heating and can enhanced natural airflow by amplifying draught.	+ simple way of heating and enhancing airflow − produces particulate matter and CO_2 when burning wood − often not very efficient (you lose alot of heat		
Proper food storage and preservation extend the shelf life of food, providing an additional food source when needed	+ additional source of food in case of need + the lifespan of food can be expanded − the food is less fresh		

OVERVIEW INTERESTING SYSTEMS

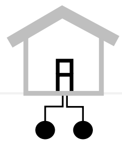
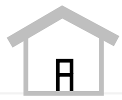
Modern Techniques

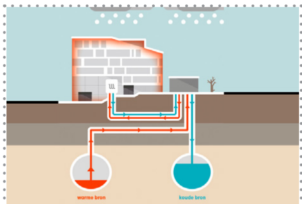
		USED IN	WATER, ENERGY, FOOD (Grid dependent ↔ Self sufficient) 1	2	3	4	TECHNOLOGY	LOCATION	FUNCTION
Present	WATER	01 02				■	Drinkingwater installation from Jotem, Van Remmen and NX Filtration as in the example of Pampus		WATER SUPPLY Drinking water production
		01 02 03 04 05				■	Helophyte filter		WATER TREATMENT Waste water purification system
		04 05				■	Rainwater collection		WATER SUPPLY AND REUSE Buffering and reusing rainwater
	ENERGY	01 02				■	Wind turbines		ENERGY SUPPLY Energy production
		01 02 03 05				■	Solar panels		ENERGY SUPPLY Energy production
		02			■		Biogas		ENERGY SUPPLY Energy production
		05				■	Oryon Watermill		ENERGY SUPPLY Energy production
		02				■	Salt-water battery		ENERGY STORAGE
		02				■	Hydrogen battery		ENERGY STORAGE

SPECIFICATIONS	PROS AND CONS	NEEDED SPACE	APPEARANCE
Water purification with a Sandfilter, Nanofiltration and UV-disinfection. Water from the IJmeer is purified using a built-in sand filter and nanofilter to remove pollutants, followed by UV disinfection to eliminate remaining residues, such as bacteria. The concentrate from the membrane filtration step is discharged back into the IJmeer (Jotem Water solutions, no date).	+ Off-grid production of drinking water + produces 20.000 l per day − High investment costs	20FT container Lengte: 6058 mm Hoogte: 2591 mm Breedte: 2438 mm	
A helophyte filter is a sand-based filtration system that uses marsh plants (helophytes) to purify water. In the Netherlands, the vertical helophyte filter is the most commonly used type. In this system, greywater first passes through a septic tank or grease trap before entering the helophyte filter. The water then infiltrates vertically through soil layers before being discharged into surface water.	+ makes use of natural processes + little maintence needed + long lifespan: ca. 30 years + treated water can be discharged into surface water − Decreased performance at low temperatures − Sufficient space required − septic tank needs cleaning	On average, around 9 m² for a house.	
Reuse of their old systems or new rainwater harvesting tanks, to water plants, vegetable garden and some even use it to flush toilets.	+ reduces drinking water demand + water can be used for plants or flushing the toilet − requires space	In new constructions or renovations: min. 60 l/m²	
A wind turbine is a device that harnesses wind energy and converts it into electricity using a generator.	+ green energy production + independet energy source − fluctuating energy output − high investment costs − the use of critical materials	Depends on needed demand	
A solar panel converts solar energy into electricity through photovoltaic solar cells.	+ green energy production + independet energy source − fluctuating energy output − high investment costs − the use of critical materials	depends on application and needed energy demand	
Biogas is a renewable energy source, which can be generated from organic materials such as agricultural waste, manure, municipal waste, plant matter, sewage, green waste, wastewater, and food waste.	+ reuse of bio-waste + independet energy source + can be used for cars or cooking − contaminated biogas can harm the environment		
A fish friendly hydro power system that works with a low head hydro power input, like rivers, small dams or tidal energy. It is sutable for a water current from 1-10 m/s (Oryon Watermill, no date).	+ fish friendly + for low head hydropower + 24/7 electricity generation + off grid solution − lower turbine efficiency than high head output		
The salt-water battery provides large-scale and long-term energy storage by storing energy in ordinary table salt and water (Aquabattery, 2025).	+ off-grid solution + easily scalable + low environmantal impact + local and non-critical materials + long lifespan: ca. 20 years − still in development		
A hydrogen battery stores sustainably generated surplus of energy by converting it into hydrogen, which can later be transformed back into electricity. This process is entirely CO2-free, making it a clean energy solution.	+ can store large amounts of energy + off grid solution − a lot of energy loss during hydrogen conversion − the installation of hydrogen infrastructure is challenging		

OVERVIEW INTERESTING SYSTEMS

Modern Techniques

	USED IN	WATER, ENERGY, FOOD (Grid dependent ← → Self sufficient) 1	2	3	4	TECHNOLOGY	LOCATION	FUNCTION
ENERGY	01				■	Thermal energy storage		ENERGY STORAGE Stores heat or cold in the underground
	01 02 03				■	Heatpump		HEATING/ COOLING
FOOD	02 03 04			■		Vegetable garden		FOOD SUPPLY Production of food
	02				■	Biodigester		FOOD WASTE Organic waste treatment

SPECIFICATIONS	PROS AND CONS	NEEDED SPACE	APPEARANCE
Aquifer Thermal Energy Storage (ATES) stores heat or cold for later use, enabling efficient heating and cooling of homes and buildings via subsurface storage.	+ not visible as it is in the underground + efficient way of storing thermal energy + very little electricity is needed for the processing − high investment costs	depth ranges from less than 100m to 500 m below ground level	
A heat pump works like a refrigerator or air conditioner, extracting heat from sources such as air, ground, water, or waste heat. It amplifies and transfers heat using a compressor and heat exchangers. In buildings, heat is distributed via forced air or hydronic systems like radiators or underfloor heating.	+ more efficient than conventional heating technologies + gas-free system + can also be used for cooling − high investment costs − needs more space than a conventinal system	ca. 60x 180x 62cm	
A vegetable garden provides an independent food source.	+ independent food supply + contact with co gardeners + physical exersise and outdoor activity − time consuming	Self-providing with a size between 41 - 62 m^2	
The biodigester converts the island's organic waste into biogas and fertiliser(circ, no date). Their machines range from a processing capacity of 30 to 600 kg of bio-waste. About 30 kilos of organic waste per day is enough to generate 9 cubic metres of biogas (Pampus, 2024).	+ bio-waste processing + production of biogas and fertiliser + energy from waste	BioTransformer50: 150x 170x 240cm 3,6 m^2 can process 50kg waste per day	

02 ANA

CONTEMPORA

LYSIS

RY PROJECTS

SCHOONSCHIP
2008 - 2021

FOUR ELEMENTS HOTEL
2019

PROYECTO ROBLE
2011 - 2012

FLOATING FARM
2018 - 2019

REGEN VILLAGE
2016 - present

Figure 29: neighbourhood Schoonschip (image by © Isabel Nabuurs)

06

Schoonschip

NAME	Schoonschip
LOCATION	Amsterdam, The Netherlands
CONSTRUCTION PERIOD	2008-2021
FUNCTION	A sustainable floating neighbourhood
SPECIFICATIONS	- ecologically and socially sustainable community - decentralised and innovative approach to water, energy, and waste systems - 46 households, on 30 arks - 144 residents - 516 solar panels, 30 heat pumps, 60 solar collectors
SIZE PROJECT	Length: 220 meter Width: 49 meter
LEVEL OF SELF-SUFFICIENCY	Water ●●○○ Energy ●●●○ Food ●○○○

Project-information gathered from:
(Schoonschip, no date & Greenprint Schoonschip, no date)

INTEGRATED SYSTEMS

WATER

Rainwater buffer - green roof
A green roof can delay the drainage of rainwater and has a cooling effect in summer.

Rainwater harvesting and reuse
Some boats have a watertank or barrel to collect rainwater, to use it for flushing the toilets and watering the plants.

Water efficient showers + vacuum toilets
Recirculation showers and vacuum toilets were installed to reduce the water demand.

Blackwater treatment
A digester extracts biogases and phosphate (fertilser) from the black waste water.

ENERGY

Insulation & passive techniques
Well insulated houses that make use of passive solar heat to reduce energy needs.

Energy production, storage & heating
PV panels, solar collectors and a water heat pump are used for the production of energy hot water and low temperature heating. Produced energy gets stored in an lithium-ion battery.

Smart grid
The locally generated energy in the neighbourhood is distributed through a central smart grid. If there is a shortage, additonal energy is bought from a sustainable provider.

FOOD

Food awareness
There is no food production at Schoonschip; however, residents are encouraged to purchase seasonal and local food.

Shared Food Purchase
Part of the food is bought together as a neighbourhood from local farms to reduce

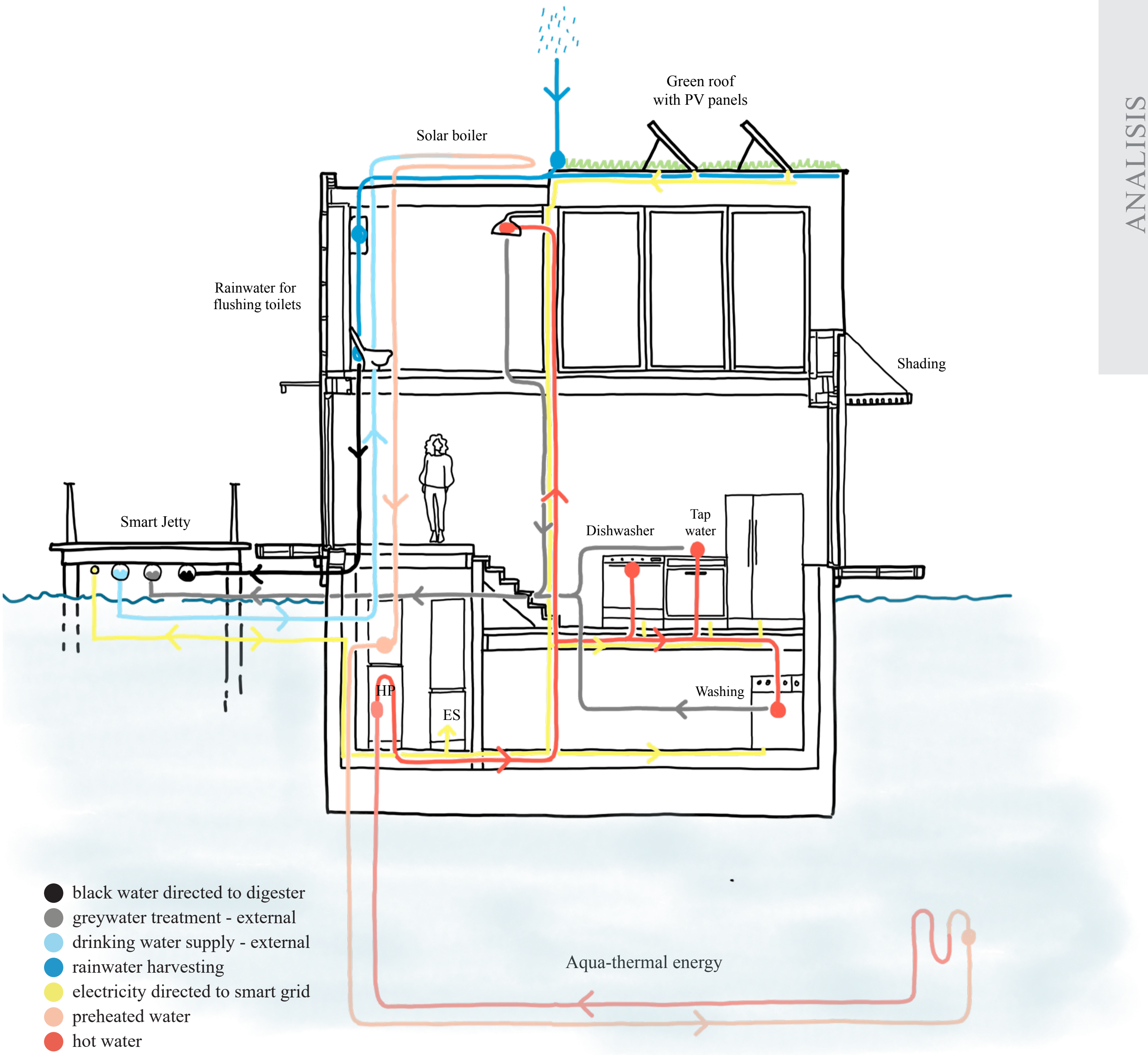


Figure 30: Integrated systems at Schoonschip (own illustration)

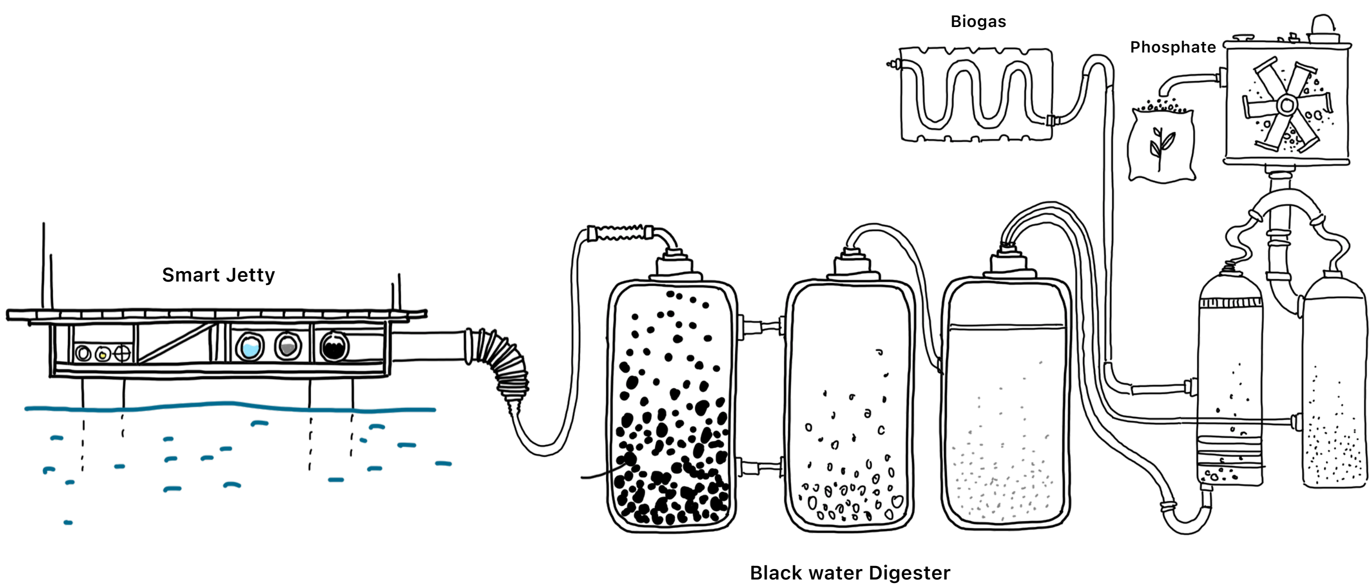


Figure 31: Black water digester used at Schoonschip (own illustration)

Grid dependent ⟷ Self sufficient

		1	2	3	4		TECHNOLOGY
WATER	SUPPLY		X			2,3	external drinking water supply & rainwater harvesting
	BUFFER/ STORAGE		X				Green roof & partly rainwater storage with tanks
	REUSE/ TREATMENT			X			rainwater reuse for plants and toilet flushing, blackwater digester, external greywater treatment
ENERGY	SUPPLY				X	3,4	PV panels, solar collectors, smart grid, biogas & additional external energy supply
	STORAGE		X				Lithium-ion battery
	INSULATION				X		well insulated
	HEATING				X		solar boiler, water heatpump with low temperature underfloor heating, shower heat recovery
	COOLING				X		water heatpump with low temperature underfloor heating
	VENTILATION			X			Mechanical supply, mechanical exhaust & heat recovery
	PASSIVE TECHNIQUES			X			Passive solar heating, adjustable shading
FOOD	SUPPLY	X				1	shared purchase from local farms
	WASTE	X					external waste treatment

Figure 32: Four Elements Hotel in IJburg (image by © Egbert de Boer)

07

Four Elements Hotel

NAME
Four Elements Hotel
(previously Hotel Breeze)

LOCATION
Amsterdam, The Netherlands

CONSTRUCTION COMPLETED
2019

FUNCTION
Zero Energy Hotel

SPECIFICATIONS
- Based on the *Earth, wind and fire concept* of Dr Ben Bronsema
- inspired by the natural ventilation system of termite mounds
- the building functions as one big natural air-conditioning system
- provides fresh air, heating, cooling, and energy, with surplus thermal energy stored underground.

SIZE PROJECT
Length: 37 meter
Width: 21 meter
Height: 11 floors
Program: 9.343 m²

LEVEL OF SELF-SUFFICIENCY

Water	●○○○
Energy	●●●●
Food	●○○○

INTEGRATED SYSTEMS

ENERGY

Insulation
The building is well insulated.

Passive techniques (Climate Cascade, Solar chimney and Ventec roof)
By integrating a solar chimney ad ventec roof the needed amout of energy is reduced as ventilation, cooling and partly heating is provided by making use of passive techniques using the elements sun, wind and water.

Energy production
PV panels are used for the production of energy. If there is a surplus of energy this is fed back to the grid.

Heating & Cooling
In summer the air is cooled by the water (constant temperature of 13°C) and in winter it is heated and humidified by the cascade in combination with a heater battery. Additional heating in the rooms in winter is done with a heatpump connected to a thermal energy storage in the underground.

Thermal energy storage icw heatpump
The surplus of warmth and cold which is extracted from the air and the water are being stored in the underground as thermal energy.

Waste water heat recovery
Thermal energy recovery from hot shower water with a heat exchanger.

Project-information gathered from:
(OZ Architect, 2019; Smith, 2019 & De Ingenieur, 2019)

1. air inlet
2. climate cascade (with water of 13°C)
3. water tank and pump
4. cooled/ preheated air
5. solar chimney
6. air extraction
7. heat exchanger
8. air outlet
9. thermal storage in underground
10. PV panels
11. external supply/ transmission

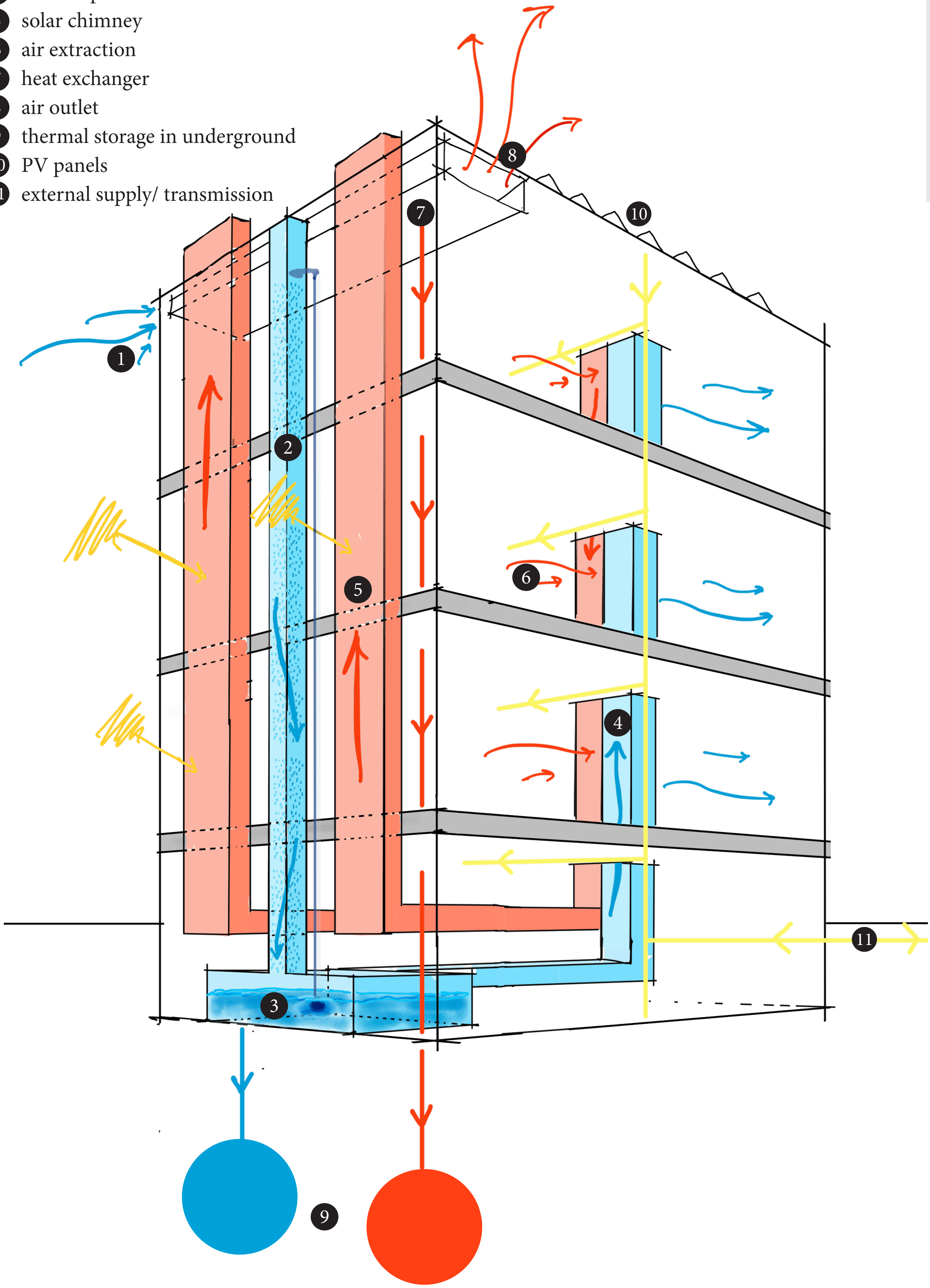


Figure 33: Earth wind and Fire concept integrated at Four Elements Hotel (own illustration)

		Grid dependent ← 1	2	3	→ Self sufficient 4		TECHNOLOGY
WATER	SUPPLY	■					external (drinking) water supply
	BUFFER/ STORAGE	■				1	no storage
	REUSE/ TREATMENT	■					no reuse & external wastewater treatment
ENERGY	SUPPLY				■		PV panels & additional external energy supply
	STORAGE			■			Underground thermal storage & surplus of electricity fed back into the grid
	INSULATION				■		well insulated
	HEATING				■	3,9	Earth, wind and fire concept & additional heating with thermal heatpump and LTH
	COOLING				■		Earth, wind and fire concept
	VENTILATION				■		Earth, wind and fire concept & heat recovery
	PASSIVE TECHNIQUES				■		Ventec roof, climate cascade, solar chimney
FOOD	SUPPLY	■				1	external
	WASTE	■					external waste treatment

EXPLANATION SYSTEM

EARTH, WIND AND FIRE CONCEPT

This system relies on three interconnected climate-control components: a climate cascade that uses falling water, a ventec roof that harnesses wind to create suction, and a solar chimney that converts solar radiation into an upward air draft (Wassink, 2013).

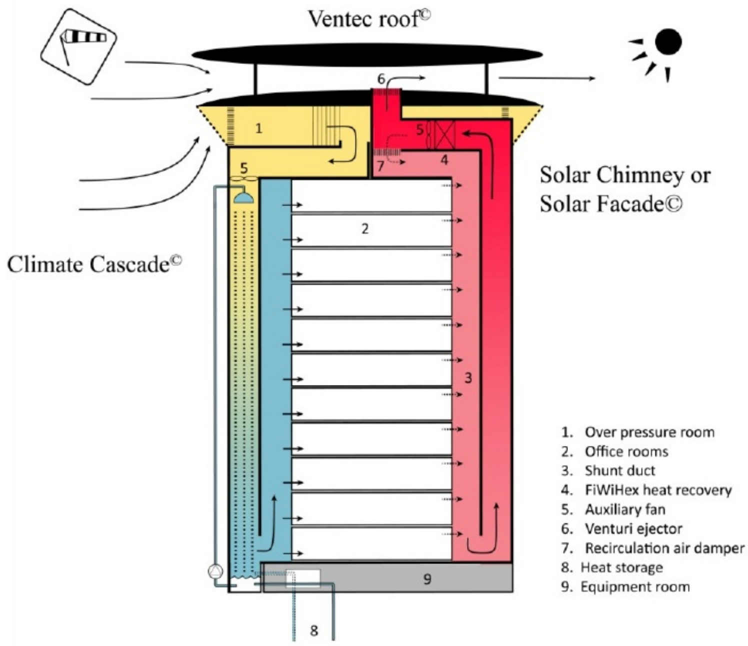


Figure 34: Earth, wind and fire concept by Dr Bronsema (Wassink, 2013)

Ventec Roof: The roof uses the Venturi effect to manage airflow, with wind pressure driving fresh air into the building while extracting used air through an underpressure system.

Climate Cascade: Incoming air flows through a shaft where falling 13°C water cools and dehumidifies hot summer air or warms cold winter air. Additional heating is provided by underground heat storage or solar energy.

Solar Chimney: Located on the south side, it generates an upward draft to expel used air while capturing solar heat. This heat is stored in an underground thermal storage for winter use.

Pros and Cons

+ reduces the needed amount of energy
+ less space needed for air circulation units
+ passive cooling, heating and ventilation
+ humidifies/ hehumidifies the incomming air
+ has a longer system lifespan: ca. 40 years

– biggest energy consume the pump needed for the climate cascade
– larger dimensions of air ducts (as the climate cascade and solar chimney only generate a modest pressure difference)
– cost are higher than a conventional system

(Smith, 2019)

Figure 35: Proyecto Roble (image by © Egbert de Boer)

08

Proyecto Roble

NAME	Proyecto Roble
LOCATION	Tilburg, The Netherlands
CONSTRUCTION PERIOD	2011-2012
FUNCTION	Eco office from Van Helvoirt Groenprojecten
SPECIFICATIONS	- biobased materials, like CLT were used - wastewater is purified and reused with a helofyten roof - uses as much as possible natural lighting - produces heating with an air heatpump and wood stove - produces energy with PV panels
SIZE PROJECT	Net floor area: 650 m²
LEVEL OF SELF-SUFFICIENCY	Water ●●●○ Energy ●●●○ Food ●○○○

INTEGRATED SYSTEMS

WATER

Rainwater harvesting & reuse
Rainwater is collected via the green roof, cleaned with the helophyte filter and finally reused for the toilets.

Water purifing roof
The grey water is purified by a helofyten roof. This is a combination of a helofytenfilter and a greenroof, which saves space and pursuits the goal for functional greenery. The waste water herby gets filtered o a quality that is harmless to the environment. In this case, even toilet wastewater is treated in this reed filter, which is reused as again toiletwater after treatment (*Kantoorpand Helvoirt Groenprojecten*, no date).

ENERGY

Energy production
PV panels are used for the production of energy. If there is a surplus of energy this is fed back to the grid.

Heating
The building makes use of an air heatpump with low-temperature floor heating. Next to that, a loam stove can be used for additional heating, as the company has a lot of left over branches from trimming.

Water refelction
To reduce the need for lighting the pond located next to the glazed wall was used to reflect the sunlight inside. In this way in winter, more sunlight gets into the building and the water gets refelcted on the ceiling of the building.

Project-information gathered from:
(Équipe, no date & Van Helvoirt Groenprojecten, no date)

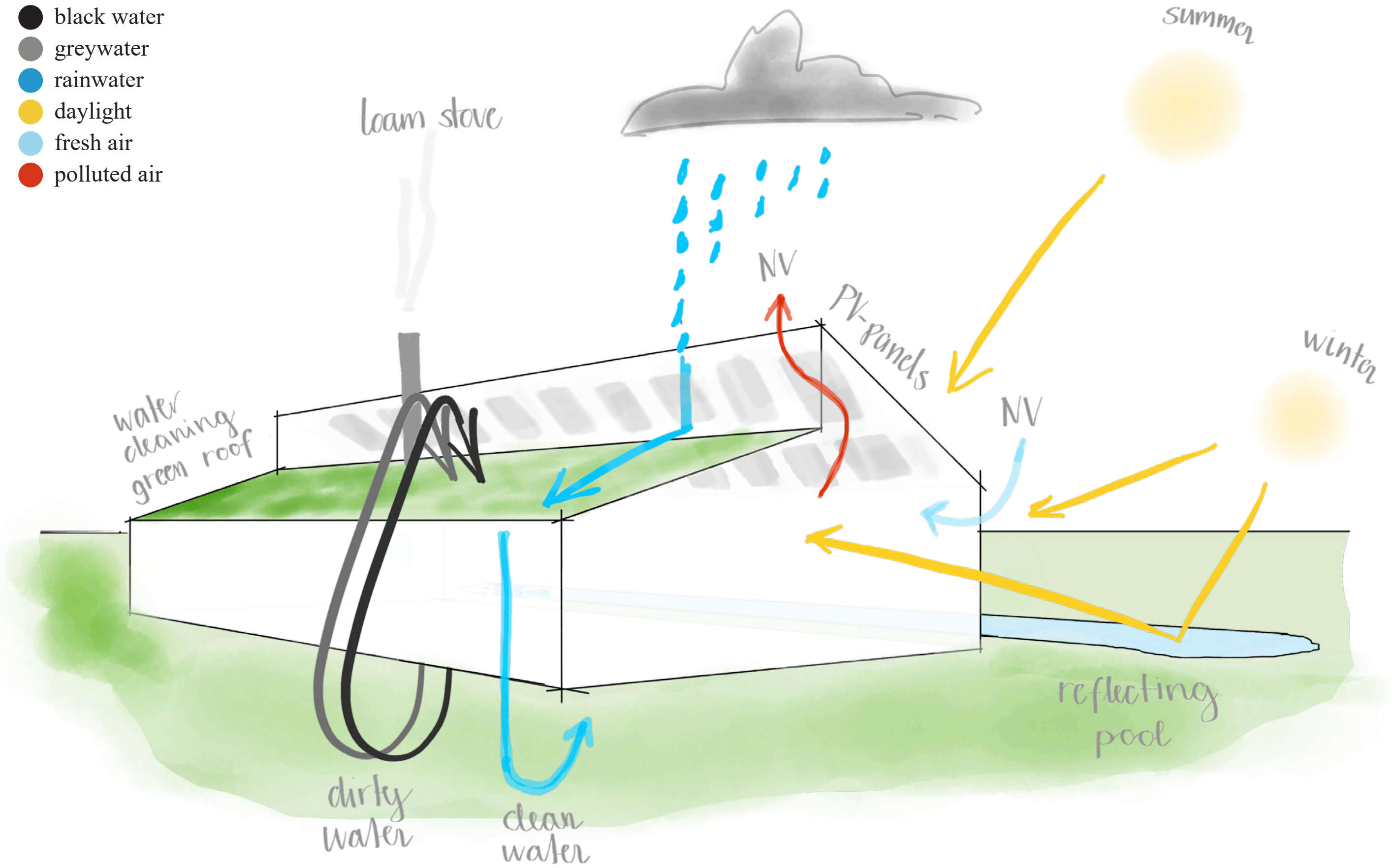


Figure 36: Integrated systems at Proyecto Roble (own illustration)

Grid dependent ⟷ Self sufficient

		1	2	3	4		TECHNOLOGY
WATER	SUPPLY		■				external drinking water supply & rainwater collection
	BUFFER/ STORAGE		■			2,7	Green roof & short term rainwater buffer
	REUSE/ TREATMENT				■		rainwater reuse for toilet flushing & helophyte green roof that purifies grey/ black water
ENERGY	SUPPLY				■		PV panels & additional external energy supply
	STORAGE		■				thermal heat storage in loam stove & no electricity storage
	INSULATION				■		well insulated
	HEATING				■	3,4	air heatpump with low temperature floor heating, loam stove, solar heating
	COOLING			■			air heatpump with low temperature floor heating
	VENTILATION			■			Natural ventilation with additional mechanical exhaust
	PASSIVE TECHNIQUES				■		Passive solar heating, shading, water reflection pool
FOOD	SUPPLY	■				1	external
	WASTE	■					external waste treatment

Figure 37: Floating farm Rotterdam (image by © Ruben Dario Kleimeer)

09

Floating Farm

NAME	Floating Fram
LOCATION	Rotterdam, The Netherlands
CONSTRUCTION PERIOD	2018-2019
FUNCTION	Farm, Educational spaces
SPECIFICATIONS	- opened in April 2020 - food production on water dairy products - climate proof and self-sustaining farm that is resistant to sea level rise - has a minimal environmental impact - features a barge housing a stable for 40 cows, with a dairy processing unit, a cheese factory, a shop, and a restaurant
SIZE PROJECT	Floor area: 1.200 m²
LEVEL OF SELF-SUFFICIENCY	Water ●●●● Energy ●●○○ Food ●●●●

INTEGRATED SYSTEMS

WATER

Rainwater collection & purification
Rainwater is collected via the roof and stored and filtered in the basement to provide for the need of fresh water.

Waste water
Urine together with manure is processed and purified with as outcome clean water which is discharged in the surface water.

ENERGY

Energy production - Floating PV panels
Floating solar panels are used for the production of electricity. If there is a surplus of energy this is fed back to the grid.

FOOD

Food for Cows
Grass from playing fields and golf courses in the city, plus food waste products like potato scraps, bran and brewers grains are fed to the cows.

Cows for Diary products
Milk is extracted from the cows and processed for consumption.

Waste recycling
The manure of the cows is collected and processed too dry fertiliser, minerals and clean water. This water is discharged in the surface water.

Food cultivation
Fruits and vegetables can be cultivated in the basement of the building. The collected and cleaned rainwater is the source for the aquaponics.

Project-information gathered from:
(Frearson, 2019, Goldsmith, 2023 & Dogan, 2024)

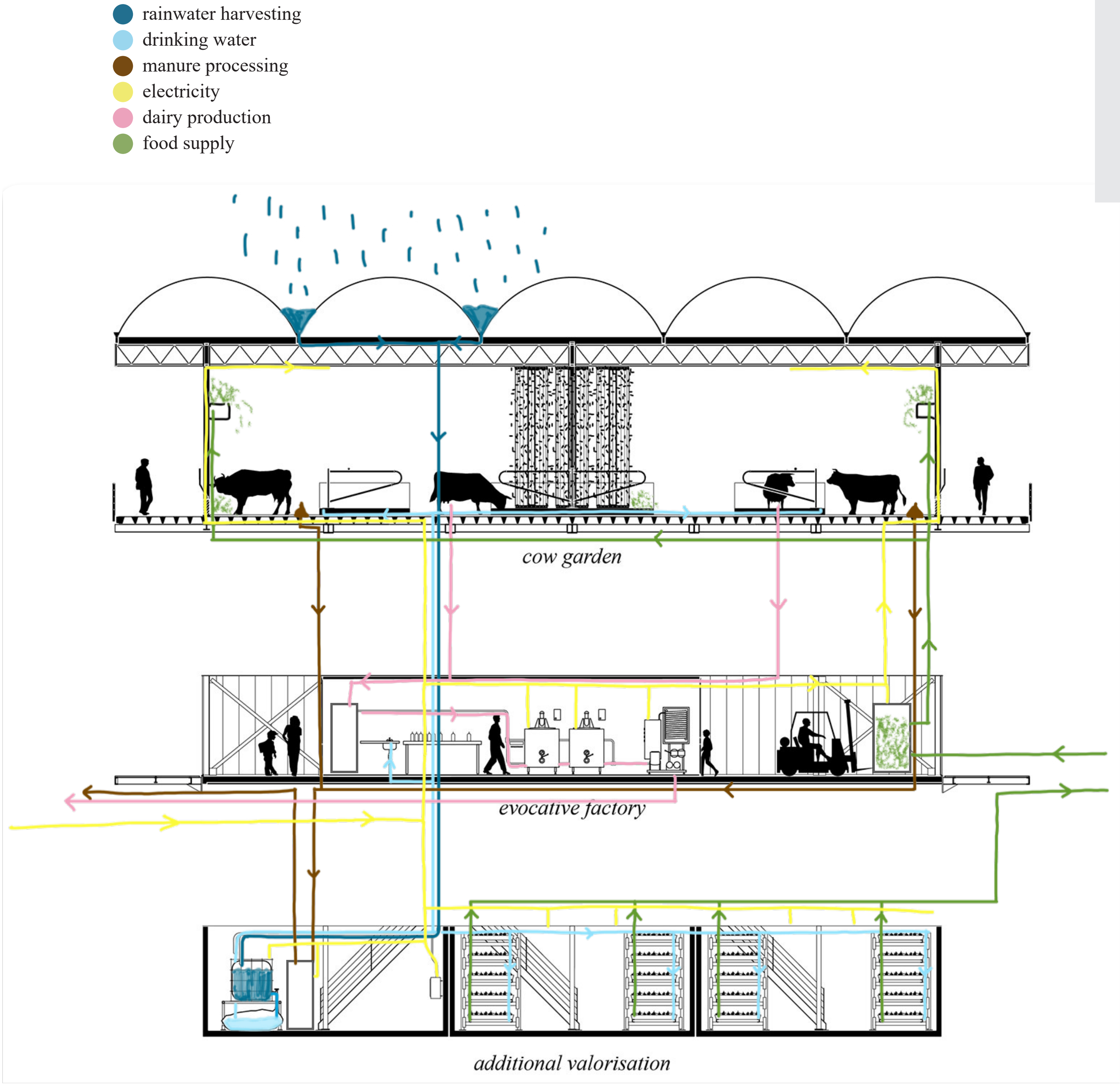


Figure 38: Functioning floating farm (Goldsmith, 2023 & own edits)

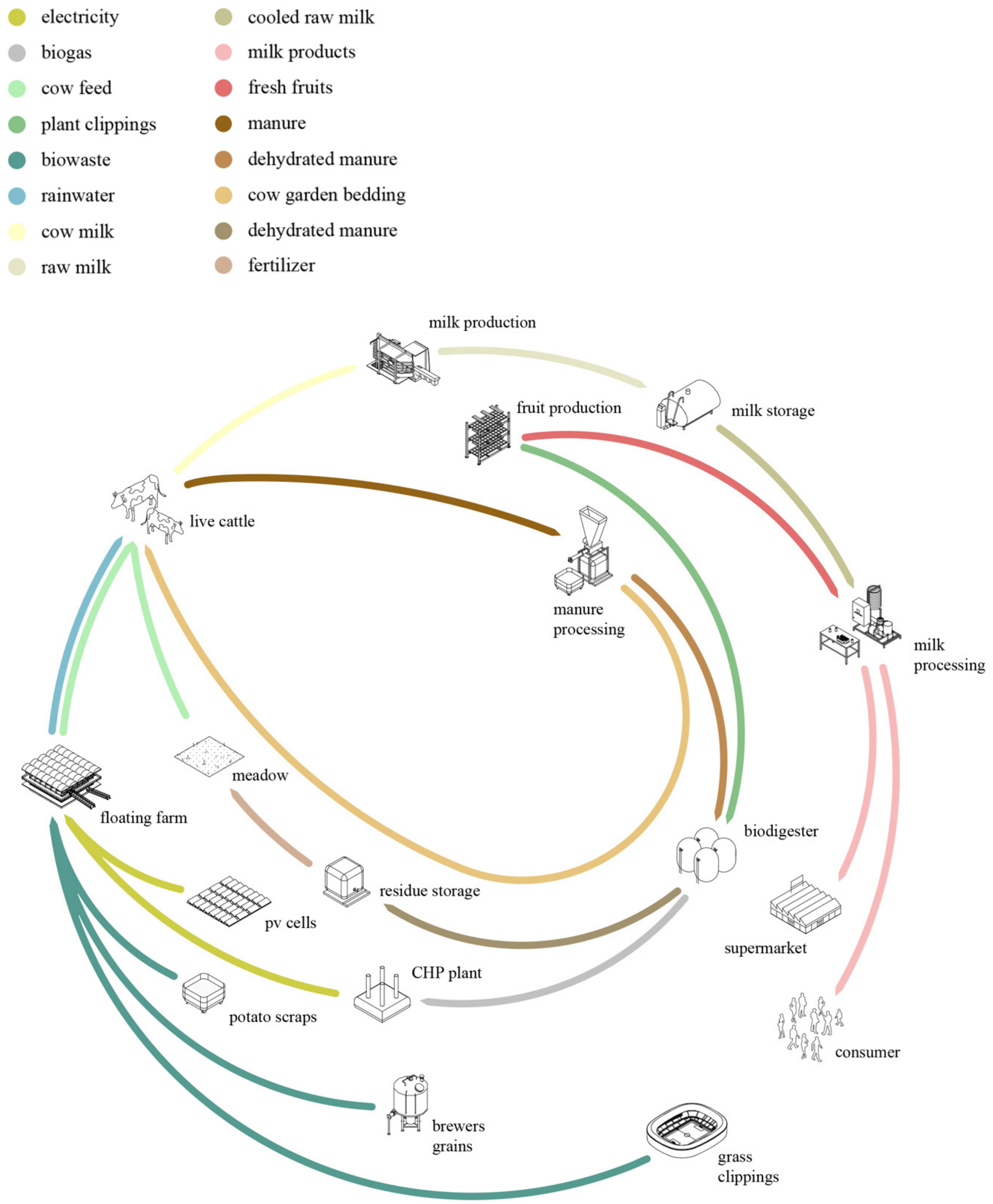


Figure 39: Circularity scheme Floating farm (Goldsmith, 2023)

Grid dependent ⟷ Self sufficient

		1	2	3	4		TECHNOLOGY
WATER	SUPPLY				■		rainwater collection
	BUFFER/ STORAGE				■	4	water storage in basement
	REUSE/ TREATMENT				■		rainwater reuse, rainwater purification & urine and manure processing and treatment
ENERGY	SUPPLY				■		floating PV panel park & additional external energy supply
	STORAGE	■					surplus of electricity fed back into the grid
	INSULATION		■				mostly no insulation needed
	HEATING		■			2	no heating needed, and if with conventional systems
	COOLING						nvt
	VENTILATION		■				natural ventilation
	PASSIVE TECHNIQUES	■					
FOOD	SUPPLY			■		3,5	vegetable/fruit production & foodwaste products, like potato scraps, bran and brewers grains
	WASTE				■		manure processing

Figure 40: Impression of ReGen Village (Effekt, 2016)

10

ReGen Village

NAME	ReGen Village
LOCATION	Almere, The Netherlands
MASTER PLAN	2016 - present
FUNCTION	Residential, Agricultural
SPECIFICATIONS	- off-grid eco village - consisting of 203 houses - able to power and feed self-reliant families - the neighbourhood is self-sufficient in energy, drinking water, food production and wastewater management - houses are connected to their own greenhouse
SIZE PROJECT	Area: 15.500 m²
LEVEL OF SELF-SUFFICIENCY	Water ●●●● Energy ●●●○ Food ●●●●

Project-information gathered from:
(Effekt, 2016, Boddchaert, 2022)

INTEGRATED SYSTEMS

WATER

Rainwater harvesting & reuse
Rainwater is collected via the roof of the buildings, purified by a filtering system, so that it can be stored and reused when needed. It is later used for vertical farming.

Waste water reuse & treatment
Grey water and black water are filtered by a helophythe filtration and reused for the seasonal gardens or discharged in the surface water.

ENERGY

Energy production
PV panels and biogas are used for the production of electricity which is distributed through a smart grid.

Energy storage
The surpus of electricity will be used for the electric-car charging station.

Active & Passive Heating + Natural Ventilation
The building makes use of an air heatpump with low-temperature heating and greenhouses in combination with natural ventilation are used to pre-heat the incoming air in winter.

FOOD

Vertical Farming - Aquaponics
For the production of vegetables and fruits for the residents.

Seasonal Garden
For additional production of food products.

Livestock and fish
For the production of the Protein Food source.

Bio-waste and Compost
Non compostable bio-waste is used for the production of biogas. Compost is used as food for soldier flies and the livestock.

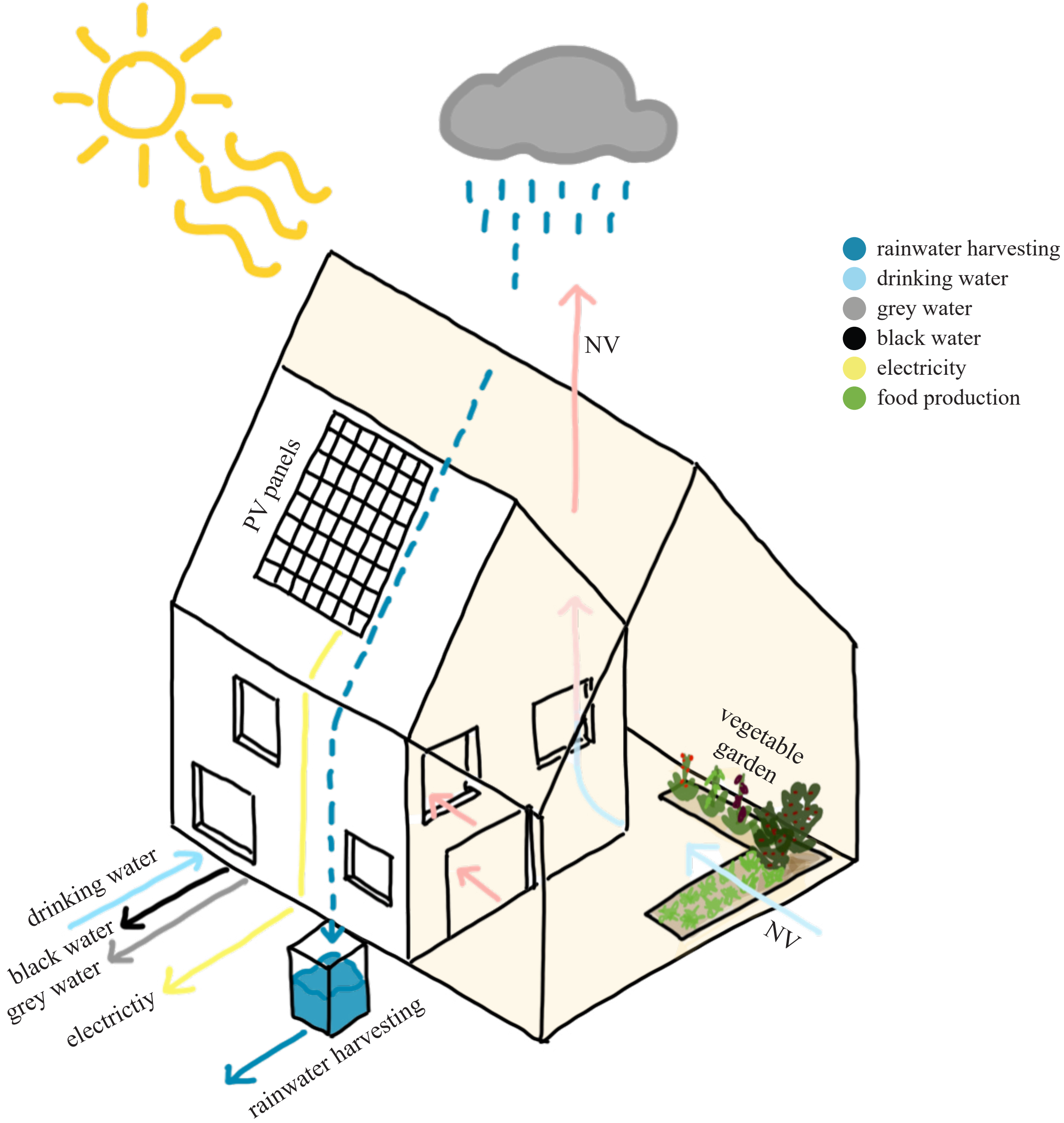


Figure 41: Housing features ReGen houses (own drawing)

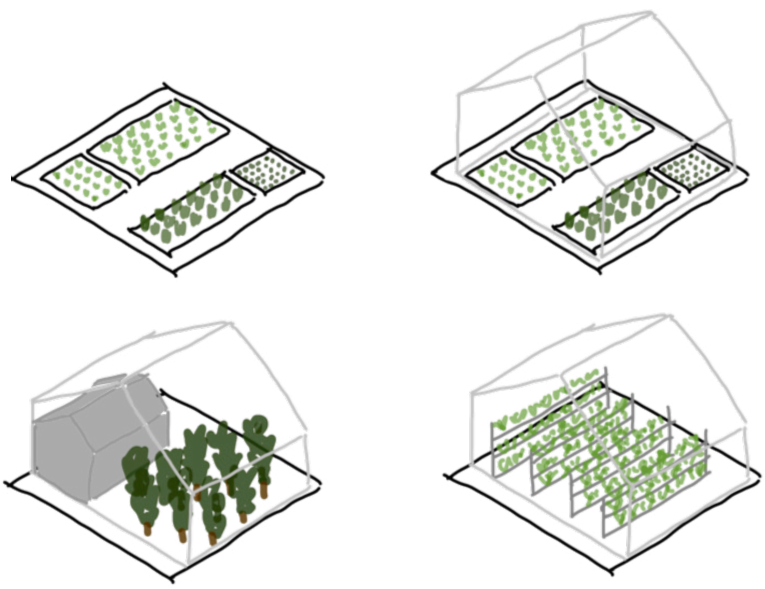
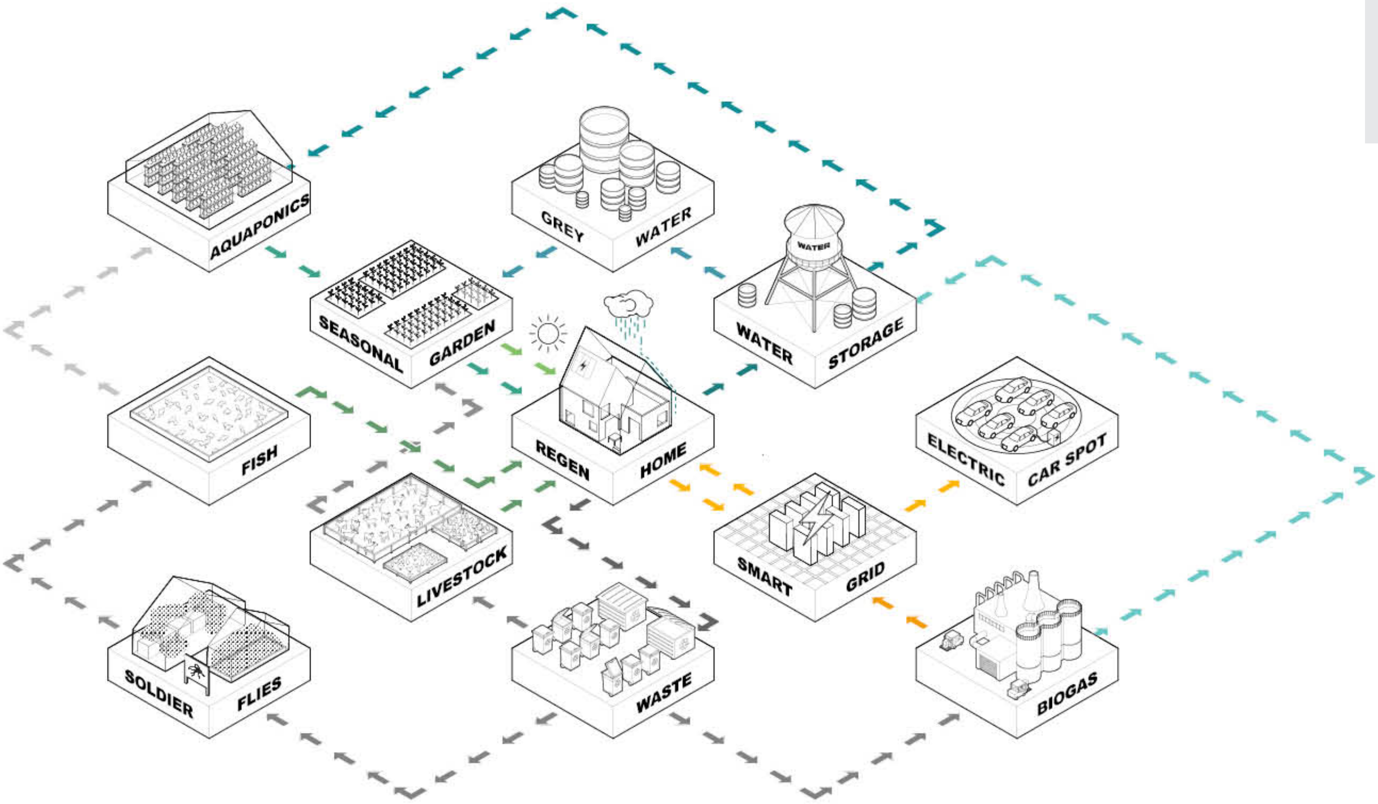


Figure 42: Methods used for food production (own drawing)



WASTE

01 HOUSEHOLD WASTE
IS SORTED, INTO DIFFERENT CATEGORIES, SO IT CAN BE RE-USED FOR MULTIPLE PURPOSES

02 BIO-WASTE
THAT IS NON COMPOSTABLE IS USED IN THE BIOGAS FACILITY

03 COMPOST
BECOMES FOOD FOR SOLIDER FLIES AND LIVESTOCK

04 SOLDER FLIES AND LIVESTOCK MANURE
SOLDIER FLIES ARE FED TO THE FISH AND MANURE FROM LIVESTOCK IS USED TO FERTILIZE THE SEASONAL GARDENS.

05 FISH FECES
BECOMES FERTILIZER FOR THE PLANT IN THE AQUAPONIC SYSTEM

FOOD

06 AQUAPONICS
THE AQUAPONICS SYSTEM PRODUCE VEGETABLES AND FRUIT FOR THE REGEN HOME

07 SEASONAL GARDENS
PRODUCE A WIDE VARIETY OF PRODUCES FOR HOME COMSUMPTION

08 LIVESTOCK AND FISH
AS THE PRIMARY PROETIN, FOOD SOURCE

WATER

09 RAINWATER COLLECTION AND STORAGE
THE SETTLEMENT IS DESIGNED TO COLLECT AND RE-USE RAINWATER

10 BIOGAS FACILITY
BURNING THE BURNING OF BIOWASTE, THE BIO GAS FACILITY EXTRACT WATER, THAT IS THEN STORED

11 GREY WATER
IS SEPARATED TO BE RE-USED

12 GREY WATER
IS USED TO IRRIGATE THE SEASONAL GARDENS.

13 AQUAPONICS
CLEAN WATER FROM THE WATER STORAGE IS DISTRIBUTED TO THE AQUAPONICS SYSTEM WHEN NEEDED

ENERGY

14 SOLAR CELLS AND SMART GRID
ON THE SETTELMENT PROVIDES ENERGY FOR THE HOME AND DISTRIBUTES THE SURPLUS OF ENERGY TO THE SMART GRID.

15 BIOGAS FACILITY
THE ENERGY PRODUCES IN THE BIOGAS IS ADDED TO THE SMART GRID

16 EL-CAR CHARGING STATION
THE SURPLUS ENERGY IN THE SMART GRID, WILL BE USED FOR THE EL-CAR CHARGING STATIONS

Figure 43: Circularity scheme village (Effekt, 2016)

Grid dependent ⟷ Self sufficient

		1	2	3	4		TECHNOLOGY
WATER	SUPPLY			■		3,7	rainwater collection & external drinking water supply
	BUFFER/ STORAGE				■		water storage in houses and for neighbourhood
	REUSE/ TREATMENT				■		rainwater/ greywater reuse, water purification & grey/ black water treatment with helophyte filter
ENERGY	SUPPLY				■	3,2	PV panels, biogas & smart grid
	STORAGE			■			energy storage & smart grid
	INSULATION				■		well insulated
	HEATING				■		passive solar heating, heatpump with low temperature floor heatng
	COOLING			■			heatpump with low temperature floor heatng, cross & night ventilation
	VENTILATION			■			natural ventilation, with preheated air because of greenhouse
	PASSIVE TECHNIQUES		■				passive heating through solar space & natural ventilation
FOOD	SUPPLY				■	4	vegetable/fruit production, livestock & fish
	WASTE				■		biowaste digester, compost

EXPLANATION SYSTEM

HELOFYTENFILTER

A helophyte filter is a sand-based filtration system that uses marsh plants (helophytes) to purify water. In the Netherlands, the vertical helophyte filter is the most commonly used type.

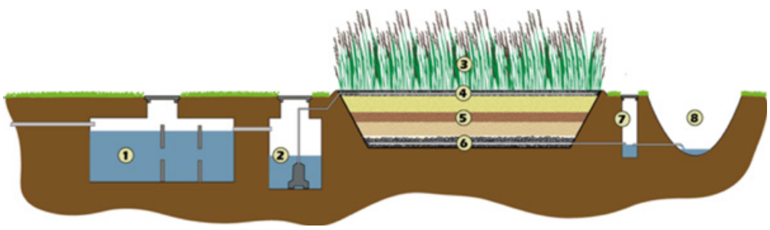


Figure 44: Vertical helophyte filter (Wetlantec BV, 2024)

According to Wetlantec BV (2024) in this system, the greywater is collected in a septic tank (1) where it can settle and where the biological treatment process begins. From the pump pit (2), the water is pumped several times a day through distribution pipes (4) over the helophyte filter. Here it flows past the roots of the reeds (3) and through the various layers of filter substrate (5). The treated wastewater (effluent) flows via drainage network (6) into a monitoring well (7) after which it can be discharged into surface water (8) (Wetlantec BV, 2024).

Pros and Cons

+ makes use of natural processes
+ low energy use
+ little maintence needed
+ long lifespan: ca. 30 years
+ treated water can be discharged into surface water

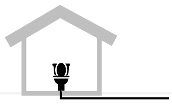
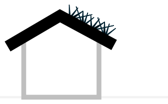
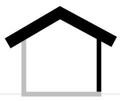
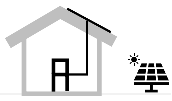
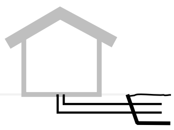
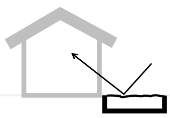
– Decreased performance at low temperatures
– Sufficient space required
– the septic tank needs to be cleaned every 2-5 years

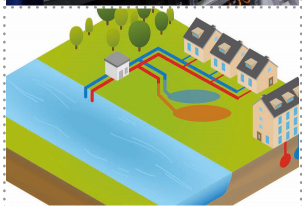
(Wetlantec BV, 2024)

OVERVIEW INTERESTING SYSTEMS

Modern Techniques

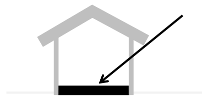
Grid dependent ⟷ Self sufficient

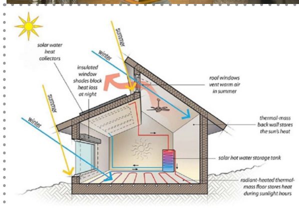
		USED IN	WATER, ENERGY, FOOD 1	2	3	4	TECHNOLOGY	LOCATION	FUNCTION
Present	WATER	06					Black water digester After the principle "Nieuwe sanitatie" from Waternet (2019)		WATER TREATMENT Black water treatment
		06					Vacuumtoilets + vacuum sewage system		WATER CONSERVATION
		08					Helophyte filter green roof		WATER TREATMENT Waste water purification system
	ENERGY	07					Earth-wind and fire concept (Climate Cascade, Solar chimney, ventec roof)		ENERGY REDUCTION By making use of passive techniques
		06					Lithium-ion battery		ENERGY STORAGE with Lithium-ion batteries
		06					Water heatpump (Aquathermy)		HEATING/ COOLING
		08					Water reflection pool		ENERGY REDUCTION

SPECIFICATIONS	PROS AND CONS	NEEDED SPACE	APPEARANCE
Phosphate and biogas are extracted from black water using a digester. The biogas can be used to produce heat, electricity, or biofuel for vehicles, while the extracted phosphate serves as a fertilizer. This system is designed to work in combination with vacuum toilets.	− extraction of biogas − extraction of phosphate (finite resources) − higher investment costs − higher management and maintenance costs − functioning relies on the residents proper use of facilities		
The vacuum toilet is designed to minimize water consumption while maintaining comfort and hygiene. By using air pressure, the system requires only a fraction of the water used by traditional toilet systems use. When using a vacuum toilet and vacuum sewage system Waternet (2019) states that saves ca. 12.000 liter drinking water per person per year.	+ saves a lot of water − higher purchase and maintenance costs	same size as regular toilet	
A helophyte filter is a sand-based filtration system that uses marsh plants (helophytes) to purify water. In this case it was combined with a sloping green roof.	+ makes use of natural processes + little maintence needed + long lifespan: ca. 30 years + as its integrated in the roof less additional space is needed (the roof gets a double function) + improved biodiverity − Decreased performance at low temperatures		
This system relies on three interconnected climate-control components: a climate cascade that uses falling water, a ventec roof that harnesses wind to create suction, and a solar chimney that converts solar radiation into an upward air draft. The sun and wind ensure the air circulation of the building and falling water humidifies or dehumidifies,and heats or cools the incomming air.	+ reduces the needed amount of energy + passive Cooling and Heating + Humidifies/ Dehumidifies the incomming air − the pump needed is the systems biggest energy consumer − larger dimensions of air ducts		
A lithium-ion battery or Li-ion battery is a rechargeable battery often used in consumer electronics and electric cars, mainly because of its high energy density and long life in comparison to other conventional batteries.	+ short-term energy storage − the uses a lot of critical materials − pose a fire hazard when overloaded − can cause a short circuit when coming in contact with water	depends on application and needed energy demand	
Aquathermy is the heating and cooling of buildings by using heat and cold from surface water, wastewater or drinking water. If necessary, the heat from the water is stored in the ground and then further heated with a collective heat pump, or with a heat pump per building.	+ sustainable source for heating or cooling − less efficient in winter due to colder temperature of water − less effixient than geothermal heat source		
By using water as a reflective body, natural day-light entering is optimized. Therefore less energy is needed for artificial lighting.	+ reduces energy demand + makes use of natual element + has technical and aesthetic benefits for a project		

OVERVIEW INTERESTING SYSTEMS

Modern Techniques

	USED IN	WATER, ENERGY, FOOD Grid dependent ↔ Self sufficient 1	2	3	4	TECHNOLOGY	LOCATION	FUNCTION
ENERGY	08		■			Loam stove		HEATING/ COOLING Wood stove with surroundig thermal mass
	06 07 08 10				■	Passive solar heating		ENERGY REDUCTION/ Heating
FOOD	09 10			■		Hydroponics		FOOD SUPPLY Vertical farming
	10			■		Aquaponics		FOOD SUPPLY Vertical farming in combination with raising aquatic animals

SPECIFICATIONS	PROS AND CONS	NEEDED SPACE	APPEARANCE
A loam stove operates by burning wood. The loam material absorbs heat and gradually releases it, maintaining a consistent, comfortable temperature in the surrounding room. Additionally, loam regulates humidity, promoting a healthy indoor environment.	+ absorbs the heat and therefore radiates heat for a long time + loam regulates humidity − when burning wood CO_2 is released	Depth:60-90cm width: 90-120cm height: >160cm	
A passive solar home captures heat through south-facing windows and stores it in thermal mass. It should be combined with fixed or adjustable shading that blocks the summer sun, to prevent overheating.	+ reduces heating demand + makes use of natural environment − glass has poor insulation, causing faster heat loss with big window openings	depends on situation	
Hydroponics is the technique of growing plants using a water-based nutrient solution rather than soil.	+ efficient water use + faster growth rates + ability to grow crops in limited spaces − reliance on artificial lighting and climate control − higher initial setup costs	Depends on needed demand	
Aquaponics combines raising aquatic animals like fish with growing plants in water, using nutrient-rich water from the animals to nourish the plants.	+ requires little water and little power + it is a closed system, so there is no waste and no water pollution − the growing of vegetables is limited to water-heavy crops, like cucumbers and lettuce.	Depends on needed demand	

WATER, ENERGY, FOOD DEMAND

The table below illustrates the average water, energy, and food demands per household in the Netherlands. An average Dutch household consists of 2.12 people (CBS, 2023).

	WATER	ENERGY	FOOD
Per day	1 person 186 l 2 persons 130 l 3 persons 112 l 4 persons 112 l 5 persons or more 96 l Source: (CBS *et al.*, 2022)	Apartment with gas — Gas — Electricity Small (<100m^2) — 570m^3 — 1560kWh Medium (100-150m^2) — 970m^3 — 3040kWh	1 person — 2.000-2.500 kcal per av. household — approx. 4,950 kcal (or 2 kg) Source: (EFSA, 2013)
Per year	1 person 67.890 l 68 m^3 Source: (CBS *et al.*, 2022)	Apartment with gas — Gas — Electricity Small (<100m^2) — 570m^3 — 1560kWh Medium (100-150m^2) — 970m^3 — 3040kWh Gas-free apartment Light & applications — 2.640kWh Heating & hot water — 2.870kWh Cooking — 220kWh 5.730kWh Source: (CBS, 2024)	1.8 million kcal per household (or 723 kg of food). Mixed diet: • Grains: 278,2 m^2 • Vegetables & fruits: 41,3 m^2 • Meat, fish, & dairy: 25.300 m^2 • Oils, fats, & others: 96,4 m^2 = **25.716 m^2** per household Plant-based diet: • Grains: 389,2 m^2 • Vegetables and fruits: 62 m^2 • Legumes and nuts: 57,8 m^2 • Oils, fats, and others: 72,3 m^2 = **581 m^2** per household Source: (FAO, 2019; FAO, 2020; WUR, 2021; Gerbens-Leenes, Nonhebel and Ivens, 2002)

Water Demand

Water consumption varies greatly depending on individual habits. For instance, a person who showers for 20 minutes daily will use significantly more water than someone who limits their shower time to 5 minutes. Similarly, water usage for tasks like dishwashing can differ depending on whether a dishwasher or manual washing is used.

Energy Demand

Energy consumption—covering gas and electricity—depends heavily on factors such as the type of dwelling, insulation quality, and the number of occupants. For example, a small, modern, well-insulated apartment occupied by one person will consume far less energy than a poorly insulated, detached house with a large family. As this research focuses on the design of new buildings, the table considers average energy use specific to newly constructed, energy-efficient homes. However, building size, function, and usage patterns remain critical factors influencing energy demand. For instance, the energy requirements of an office building differ significantly from those of a residential home.

Food Demand

Food production and consumption significantly impact resource use, with meat and dairy products being particularly resource-intensive, demanding significantly more land, water, and energy than plant-based alternatives such as grains, vegetables, and fruits. Shifting to a predominantly plant-based diet can dramatically lower the environmental footprint of food production. Moreover, plant-based diets, combined with innovative farming techniques like vertical farming, are well-suited for urban settings where space is limited, enhancing the feasibility of local and sustainable food production.

SOURCES ILLUSTRATIONS

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