The Floating Greenhouse on the Thames

Guidelines for nature based solutions

ALTERRA
WAGENINGEN UR

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Ministerie van Economische Zaken

Kingdom of the Netherlands

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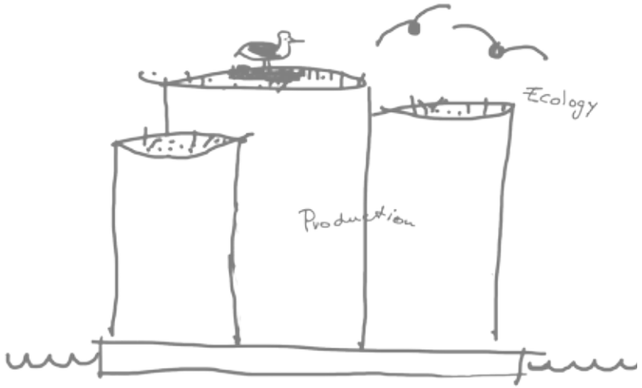
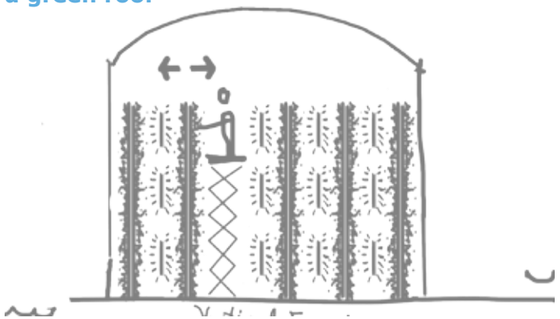


Creating conditions for birds to nest

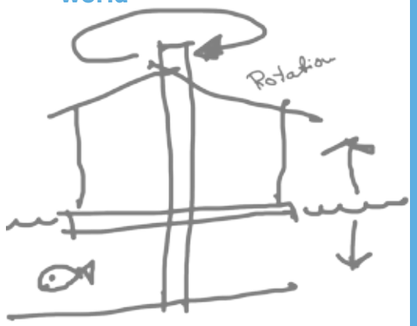
Combining maximum sun penetration with a green roof

Tidal Energy & underwater world

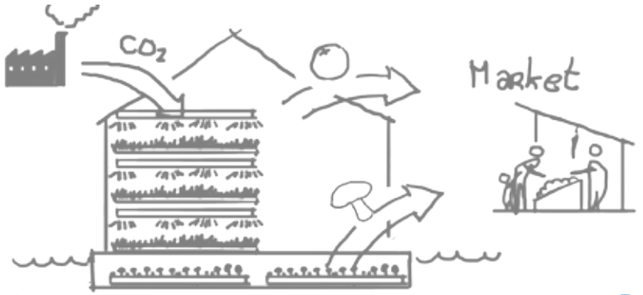
Showcasing different greenhouse architecture styles like organic shapes



Vertical farming for space use efficiency



Rotation with the sun for maximum light use



Circular food production within the greenhouse in synergy with city's metabolism

Pontoons of floating wetlands

Super hydroponic

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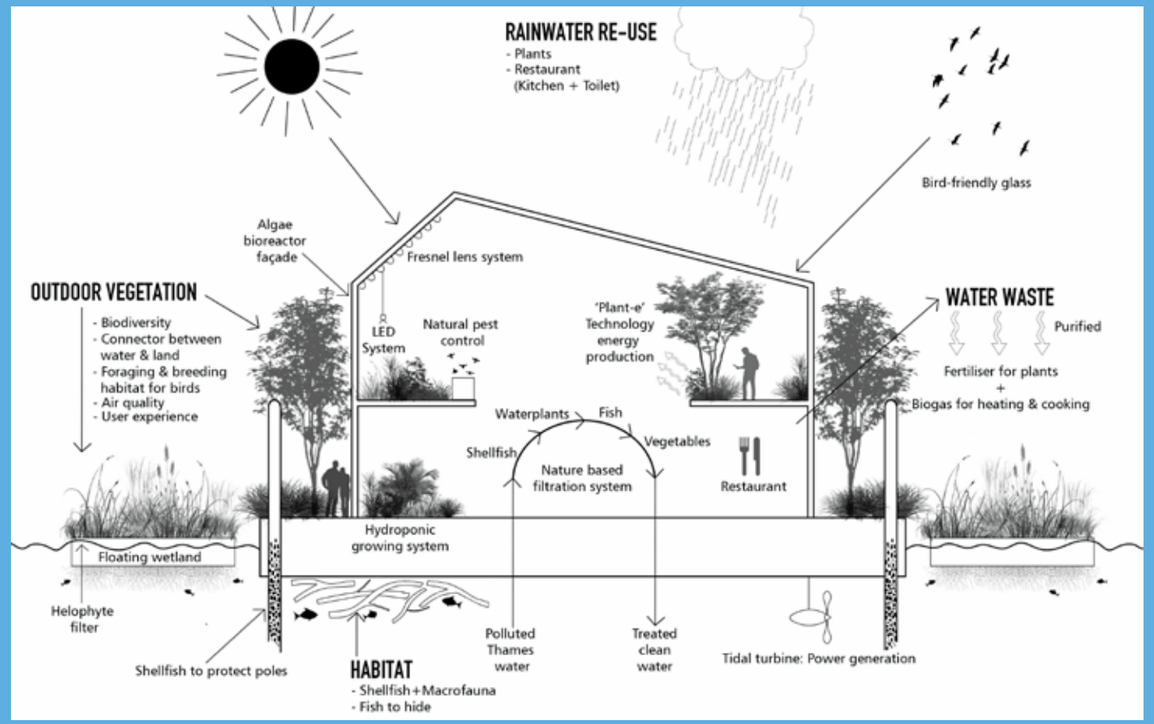
Out of the box ideas of floating greenhouses created during brainstorm session

Guidelines for nature based solutions

This booklet is creating guidelines for the realization of a floating greenhouse by integrating nature based solutions. These solutions are inspired by nature and supported by nature. Nature has gained an enormous experience in terms of efficiency, resilience, adaptivity and resource recycling. By implementing the knowledge of nature as well as using nature as a tool for urban improvement, resource efficient, greener and resilient environments can be realized.

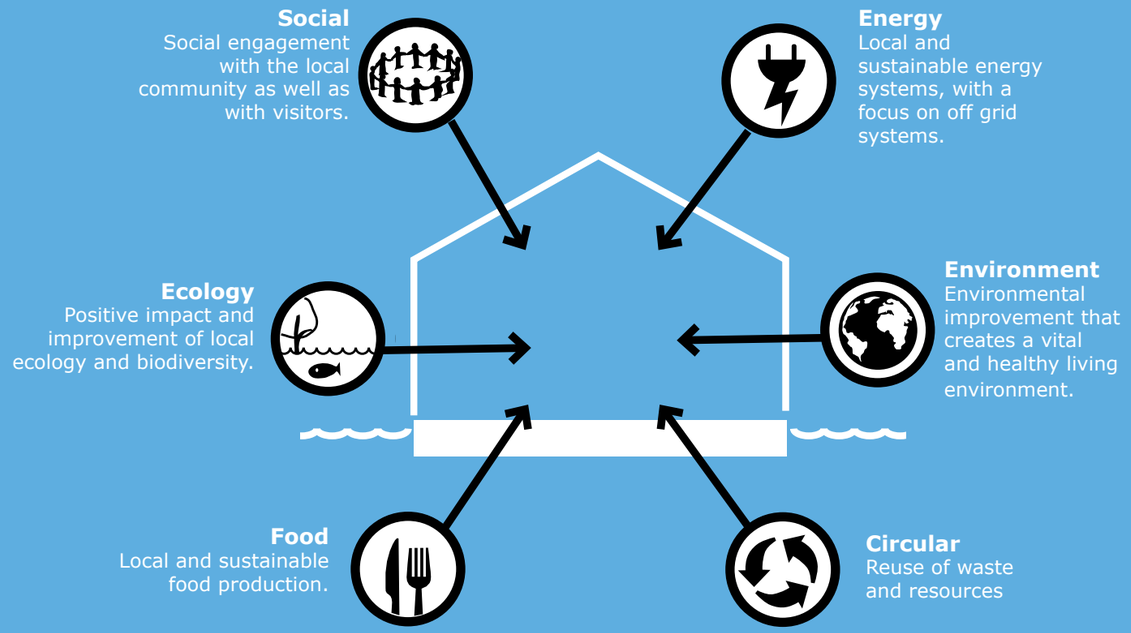
Renaturing the city enhances biodiversity, air quality, water quality, social cohesion, citizen engagement, health, climate adaptation and waste recycling. The floating greenhouse will be a hub for ecological development and environmental renewal, challenging ideas of ecosystem services as well as supporting and presenting natural technologies.

The current project will give a quick insight into the ecological impacts of ongoing innovations at Wageningen UR on sustainable intensification, nature, horticulture, greenhouses, waste management, integrated innovation, water innovation and circular and nature-inclusive design. This cross-disciplinary collaboration is crucial in order to meet technological innovations, design and nature-inclusive development.



Themes

In this booklet we present different nature based solutions that illustrate sustainable, circular and environmental perspectives for the floating greenhouse. We defined six different themes in order to indicate the focus of every perspective.



Left

Overview nature based solutions for floating greenhouse. Image Cityscapes

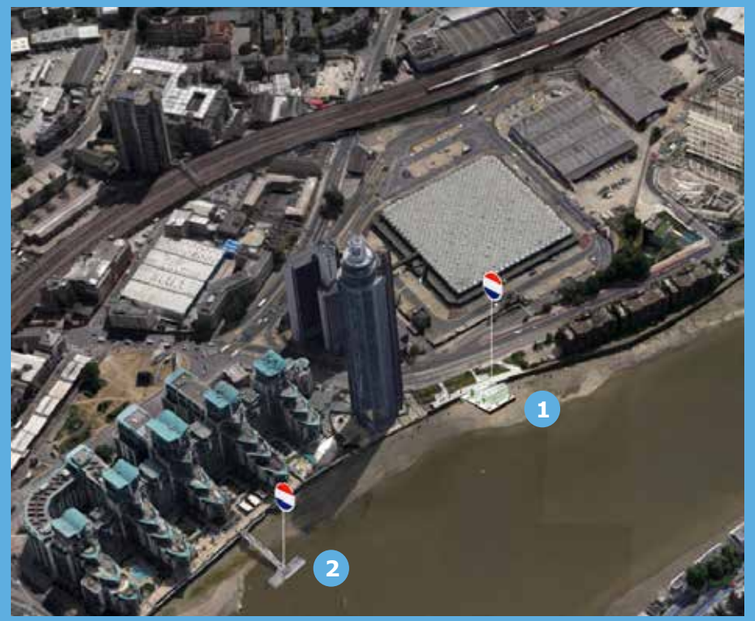
Right

Conceptual overview of the different themes

Potential greenhouse locations

The Dutch Embassy in London is relocating to regeneration area Nine Elms. This neighbourhood located along the tidal river Thames is currently a dense area of urban development. The Dutch Embassy has the ambition to contribute to the improvement of the liveability and vitality of this area. Thereby, they want to highlight innovations in Dutch horticulture, scientific advances, contemporary art, design and architecture.

In order to create a prominent landmark and illustrate Dutch expertise on water and building innovation, the Dutch Embassy would like to present the Floating Greenhouse. Two potential locations have been selected. Location 1, is facing a small park. This location experiences low tides, which indicates that the Greenhouse should be standing on poles, in order to prevent stranding. Location 2, is the floating link span, which is currently in use as a platform for water taxis. The river has been dredged at this location, thereby creating larger depths during low tides. This will enable the Greenhouse to be fully floating.



Page left:

Overview of the two locations

Page right:

(top) Location 1

(bottom) Location 2

Photos of the Nine Elms area

Bank of the river Thames, location of the greenhouse.

The Greenhouse with impact

Our goal is that the floating greenhouse will be a contribution to the natural and social environments of the Nine Elms neighbourhood and the river Thames area. We want to achieve this on three aspects:

- Social interaction with the Nine Elms neighbourhood
- Ecological improvement of the Thames
- Circular and sustainable building system of the greenhouse

Ecological improvement can lead to an increase of both social engagement and biodiversity. At the same time it can affect health and the liveability of the city. This is why we consider greening as a tool for multifunctional improvement of the urban environment. The greenhouse on the Thames is an excellent example of this vision because it can have a positive impact on its environment, whilst preserving or even improving the current ecological systems.

The brackish water of the Thames contains enough nutrients for algae production (both macro and micro algae). When turbidity is restricting the growth of algae, the clarity can be enhanced by a settling process. Additionally, the food level (phytoplankton) is sufficient for the growth of mussels (brackish water mussels). The mussels also support a decrease of the turbidity level, and can therefore be used for the filtration of the water particles, afterwards the water can be used for growing vegetables. However, this is dependent on the nutrient level.

It is expected that the grown mussels and vegetables can be used for consumption purposes. However, it is recommended to execute further research on the quality of these products.

Water data

- Slightly brackish (ca 1 ppt (range 1-4))
- Mediate low oxygen level (75% (range 40-100))
- Turbidity level is average (100 mg/l with a maximum of 200 mg/l)
- Water depth 6.6 meter (range 0.5-9.4)
- Eutrophic: Nutrient-rich, low chlorophyll level, which can be result from turbidity that causes low light and low algae grow.
- Nitrogen, N medium (3 times higher compared to norm Dutch rivers)
- Phosphate, P medium (4 times higher compared to norm Dutch rivers)
- Chlorophyll, not very high (24 range 2-169)
- pH 7.8 (range 7.4-8.2)

Bank of the river Thames, location of the greenhouse.

Environmental impact

Potential physical and ecological damage to foreshore and river wall.

In order to prevent damage, it is important that the floating greenhouse is placed in the open water, in such a way that the side walls (quay) are not affected. Therefore, the floating greenhouse should be accessible via a link-span. Other solutions can be thought of, but the walls should remain untouched.

As the Thames is a tidal river and the slope of the river is quite shallow, the greenhouse should be placed a considerable distance from the quay in order to prevent contact with the foreshore and contact with the bottom. However, this might interfere with the waterways of transportation. It should be noted that contact with the foreshore should be prevented as this might cause a negative impact on the aquatic life. Therefore, a jacked-up method on piles can overcome this problem. The greenhouse will float on the water at high tides, but will rest on piles at low tides, creating a suspended pontoon.

The piles will have a negligible effect on the population of the flora and fauna in this section of the Thames. The shading of the greenhouse on the foreshore is also expected to have no effect on the biodiversity at this location. Additionally, the scale of the greenhouse in relation to the Thames is minimal and has therefore no consequential effect.

The greenhouse will have no waste streams running into the Thames, and will be fully focussing on circular processes of resources and purification of poor water quality.

Natural tidal scouring caused by introducing foundations.

The bottom of the pontoon will remain approximately two metres above the foreshore. This distance will create enough circulation possibilities to prevent scouring. Additionally, the piles are expected to have no effect on the tidal scouring, due to the small dimensions.

Movement of juvenile fish in the area. Looking at possible effects to negate disturbance and benefits we can introduce.

The relatively small scale of the floating greenhouse in relation to the Thames and the fact that the soil remains undisturbed (only the poles are drilled into the bottom), indicates that there will be no significant negative effect on the existing fish community and other aquatic organisms. If the amount of

floating disturbances increases, covering a large area of the river would this have a cumulative effect.

We expect that the additional complement of dead branches and scrub attached to the platform of the floating greenhouse will have a positive impact on the fish community. They form substrate on which fauna can create new habitats. For example macro fauna and shellfish can grow on them, they can attract fish for foraging and also provide shelter for juvenile fish.

However, the potential use of tidal turbines (power generation) may mean that the size (scale) of the platform is too small to combine tidal power equipment. Calculations on the effect of tidal energy generation will be required.

The river side is a main flight corridor for birds. Possible effects to negate and benefits that can be introduced.

The greenhouse will contribute as a location on the flight corridor for birds, by creating outdoor planting areas and green roof and facades. Thereby, we will advise to use permanent plants as pollinators. Bushes and small trees can contribute to expanding the living area of native small songbirds.
Additionally, the selection of the plants should be based on the required function. For example, plants with pollen will attract insects and thus attract birds.

By creating outdoor green areas, the floating greenhouse can form a little green oasis for migrating species along the banks of the Thames for foraging and resting. However, the scale of this is too small to give it the same ecological value as a real stepping stone on the bank of the Thames. So in the adjacent park on the riverbank, an increase in greenery can be complimentary, as well as helping to strengthen the urban green infrastructure and increasing the biodiversity of insects and small species.

Bank of the river Thames, location

of the greenhouse.

Natural cleaning of the Thames

Growing edible vegetables with Thames water as a showcase could educate visitors about food production and a biobased system. The production of these vegetables can be achieved by placing a natural filtration system in the water, whereby every product of the cycle can be reused as a resource in the system. When filtrated, the water can meet the standards for the consumption of the vegetables. Nature provides excellent methods for water filtration, that is why we let nature work with us for healthy water quality.

References

Urban Playground by Mediamatic, Amsterdam

This urban playground will be transformed into an eco-friendly oasis for urban agriculture. Right now the Mediamatic team is experimenting with aquaponics.
"We're sharing our knowledge by organizing workshops that enable customers to build their own system at home."

www.mediametic.com

Informal learning environment

NEMO is an interactive informal learning environment where the general public comes into contact with science and technology. Visitors see, hear and experience how scientific phenomena and technology play an important part in their lives.

www.e-nemo.nl

Aquaponic system

Aquaponics is a sustainable, recirculating ecosystem for food production made up of fish, microorganisms and vegetables. The fish feed the plants and the plants clean the water the fish swim in.

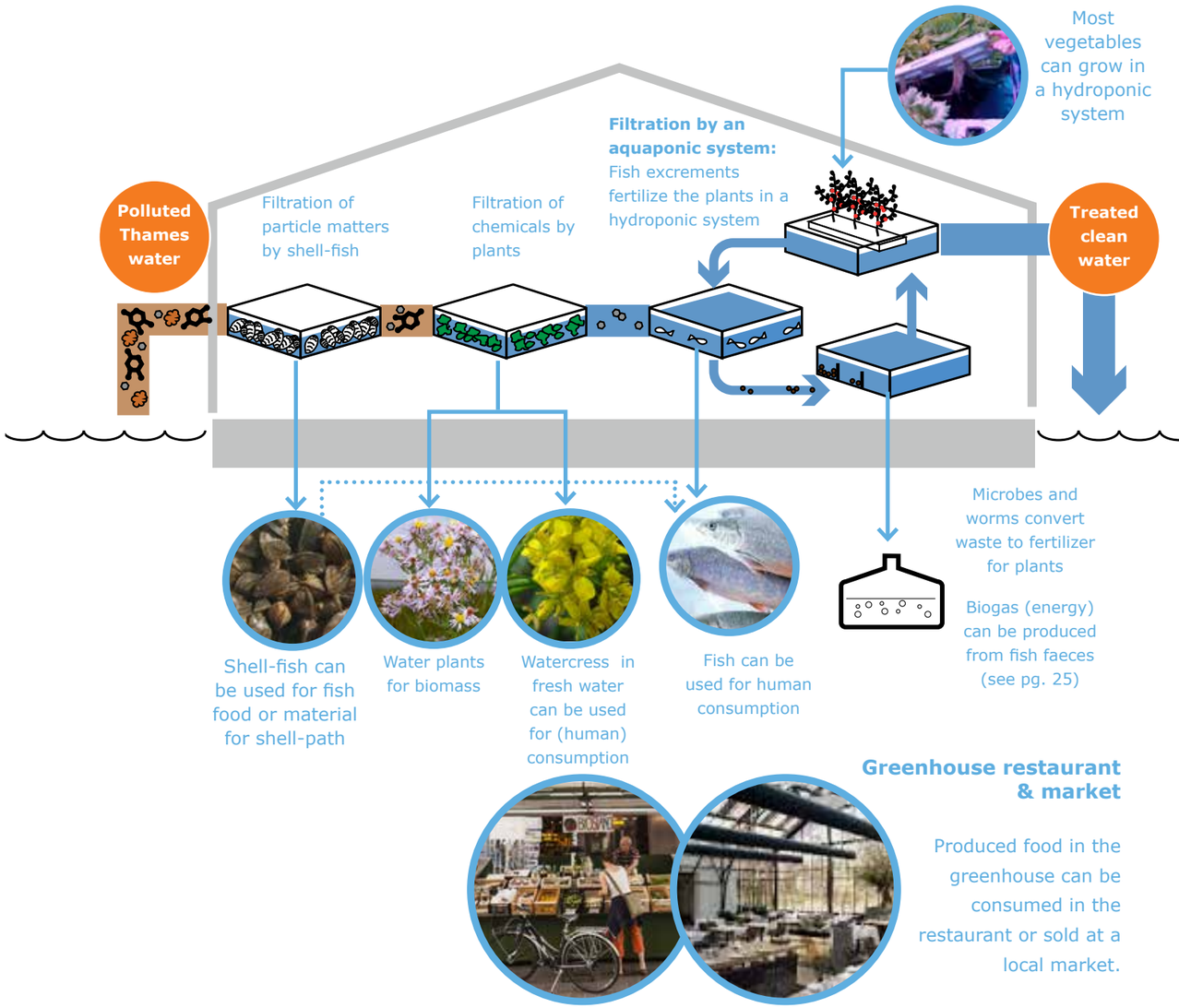
www.mediamatic.com

Hydroponic system

The system consists of a 15-cm deep water basin with v-shaped plant holders to keep the plants upright. Plants are grown directly in the water – without a rooting substrate.

www.hydroponics.com.au

Conceptual illustration filtration system



Greenhouse restaurant & market

Produced food in the greenhouse can be consumed in the restaurant or sold at a local market.

Energy producing greenhouse

With new technologies it is possible to make the greenhouse completely off grid and could function as a showcase for sustainable energy production. Just like natural systems, the greenhouse can utilise available energy sources to meet its own needs. Solar energy for example, requires a challenging solution, as we don't want the solar panels to block the incidence of light, which is crucial for growing plants. Therefore, an innovative lens system that bundles the light on a solar cell is available. This solar cell is cooled by water which increases the efficiency. Additional energy systems, such as current energy and biogas out of waste water, can be used as a showcase for alternative energy sources.

References

Producing energy from plants

Plant-e develops products in which living plants generate electricity. These products are based on technology that was developed at Wageningen UR. The technology enables us to produce electricity from living plants at practically every site.

plant-e.com/technology.html

Algae bioreactor as a façade

The world's first building with an algae bioreactor façade, finished construction in April 2013 and is part of the International Building Exhibition in Hamburg, Germany.

www.gizmag.com/algae-powered-building

Digital growing

Since growing locations are quite often at large distances from each other, the IDC digital offers growers and farmers a method to work with a control panel so they can work at a distance.

www.wageningenUR.nl/IDC

LED lightning

Research shows the following results with LED instead of traditional lighting:

- 30% energy saving
- Doubling of vitamin C value
- Red light stimulates the plants defence system
- 10% higher photosynthesis efficiency with green leaves and 30% with red leaves

www.wageningenUR.nl/glastuinbouw

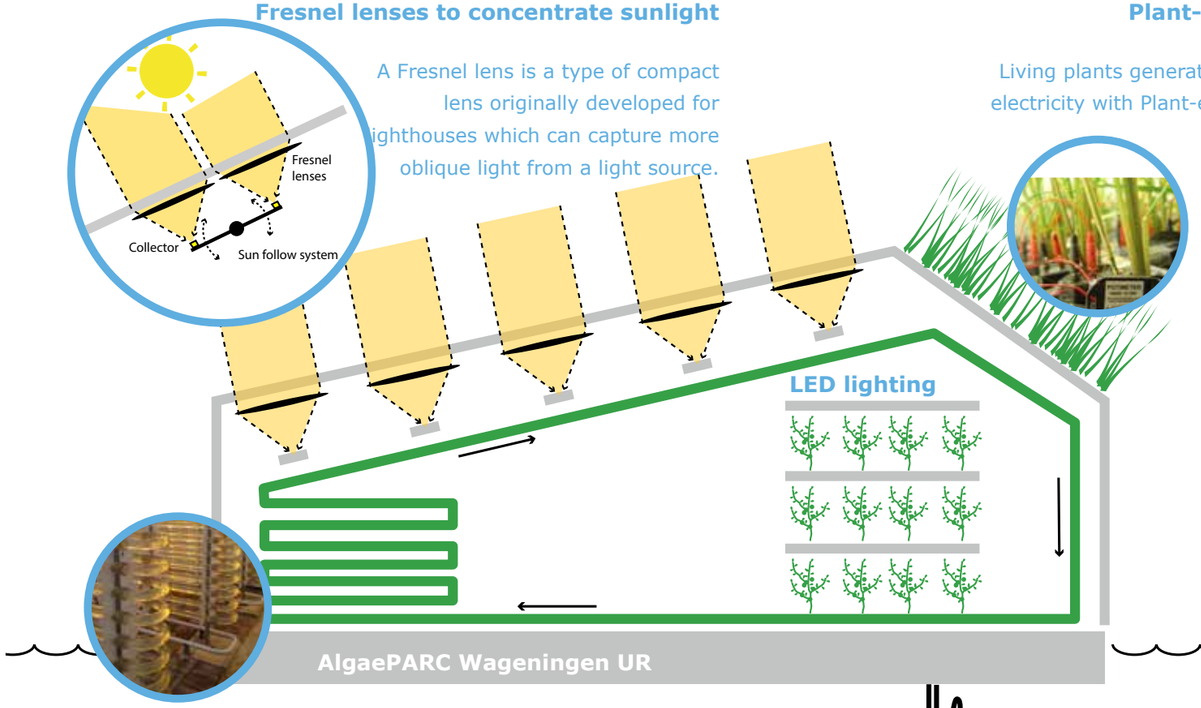
Conceptual illustration energy system

Fresnel lenses to concentrate sunlight

A Fresnel lens is a type of compact lens originally developed for lighthouses which can capture more oblique light from a light source.

Plant-e

Living plants generate electricity with Plant-e.



Developing cost-effective and sustainable micro algae production methods outdoors:

- Additive for food and animal feed (Algae contain a lot of Omega 3 fatty acids and valuable ingredients such as astaxanthin)
- Recovering phosphate from wastewater
- Energy usage

www.wageningenUR.nl/algaePARC

Energy producing greenhouse at PPO Wageningen UR in Bleiswijk

Tidal and free-flow water turbines

www.tocardo.nl

Sustainable water use

Water has different functions on various levels, so naturally the required quality of the water differs depending on the purpose of the water. Creating a water management system that enables the realization of these different quality levels allows us to reuse both waste water and rain runoff for functional purposes.

The considerable amount of rainfall in London enables the reuse of rainwater for utility use, such as toilet flush and grey water use in the greenhouse restaurant. After the rainwater is used it becomes waste water which has to be purified. This can be done by helophyte filters (see illustration).These helophyte filters have multiple functions such as purifying the waste water and increasing the natural habitat of different species. After the waste water is filtered by the helophyte filter the water is clean enough to be discharged into the Thames.

References

Cleantech Playground, De Ceuvel

The Ceuvel site, which is now heavily polluted, will feature retrofitted houseboats placed around a winding wooden walkway and surrounded by an undulating landscape of soil-cleaning plants.
The site serves as a new blueprint for urban development, where decentralized technologies and full recycling of local resources empowers urban areas to be self-sufficient.

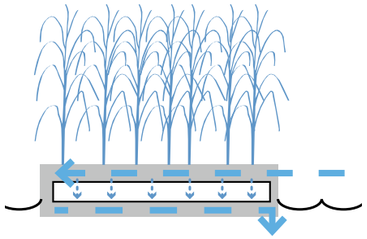
www.metabolic.nl

Helophyte filter

A helophyte filter is a natural filter that is generally planted with reeds. The reeds serve principally to aerate the roots and to capture nitrates and phosphorous.

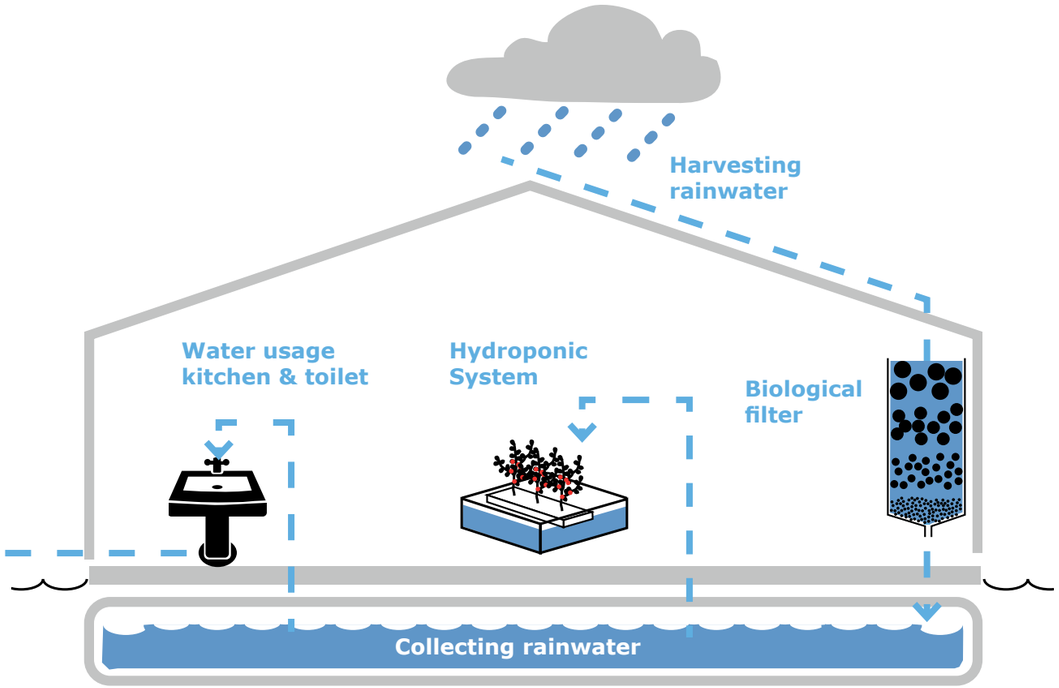
Ditch in the farmland as helophyte filter

Pontoon as helophyte filter



Helophyte filters spread the wastewater in a smooth layer several centimetres below the surface of the filter. The wastewater seeps through the layer of sand and the roots, where it undergoes biological treatment. Iron or copper particles are generally added to the sand layer to bind phosphates.

Conceptual illustration water system



Water collection of rainwater will have a sufficient quality for agricultural purposes.

Watercycle waste water

The water use of the greenhouse can be fully based on rainwater and water from the Thames. The aim of the greenhouse is to purify all the waste water for reuse and for return to the Thames. Therefore, high quality demands are required. The waste water from toilet use can be purified by the use of natural processes and reused as fertilizer for plants and biogas for heating and cooking. Grey waste water can be purified by the helophyte principle.

References

Energy from human waste

It is technically possible to purify toilet water of the Netherlands Institute of Ecology (NIOO building on the Wageningen UR campus) with algae. The algae produce clean wastewater and can be used as fertilizer, this was shown in research of the NIOO together with the research groups of Environmental and Bioprocess Technology.
They have now shown that with the wastewater that is treated in this way – the effluent – you can cultivate algae. 'We have a proof of principle that you can cultivate algae on concentrated toilet water'.

resource.wageningenur.nl/en/show/Algae-can-purify-poo-and-pee-of-NIOO-.htm

Canal of the future

A multi-functional canal has been realized in Zoeterwoude at the Heineken Campus. The waterway purifies the residual waste flow of the milk installation by natural vegetation. The residue can be used for nutrient purposes.

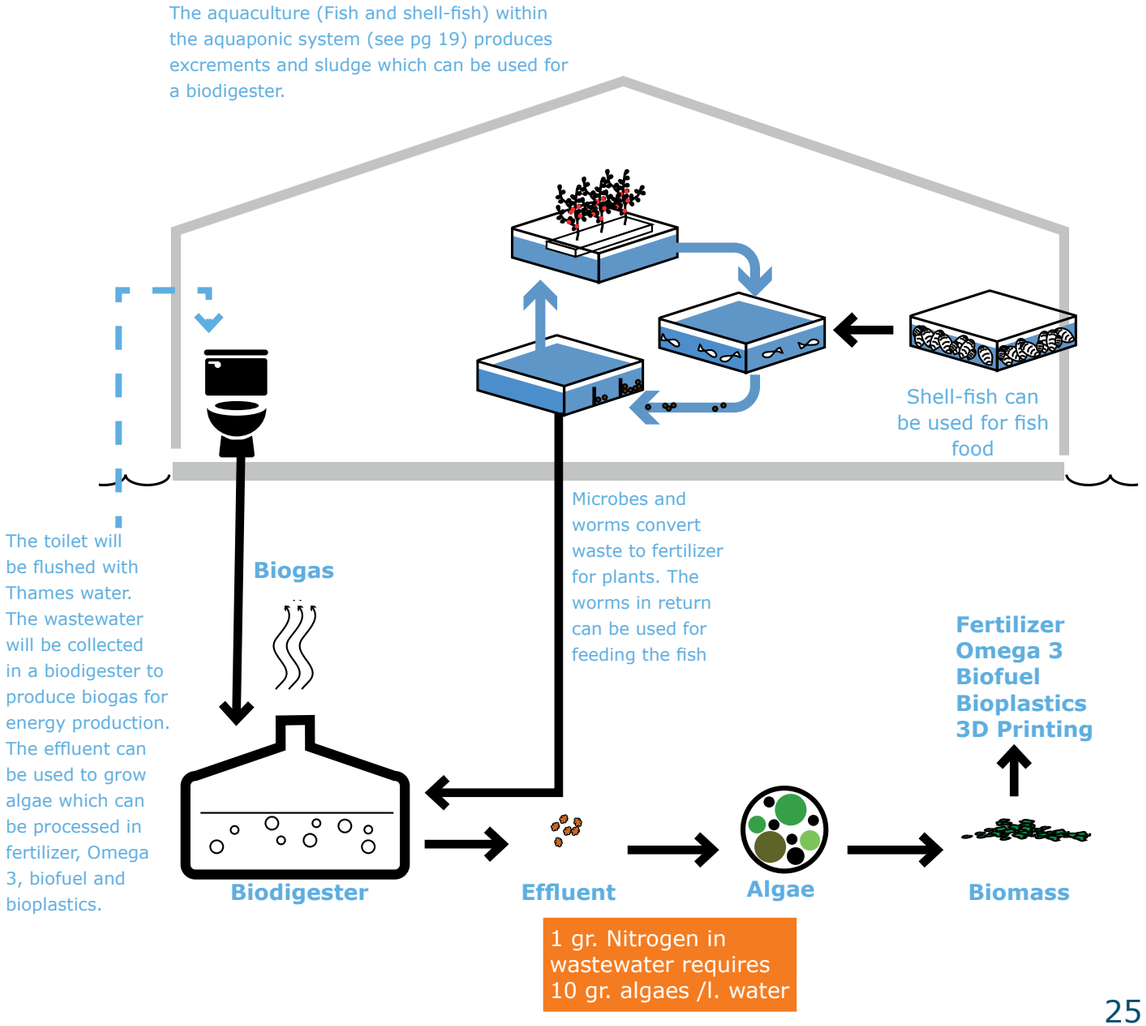
www.groenecirkels.nl

OMEGA Project

Offshore Membrane Enclosures for Growing Algae is an innovative method to grow algae, clean wastewater, capture carbon dioxide and to ultimately produce biofuel.

www.nasa.gov/centers/ames/

Conceptual illustration recycling system



Citizen science & social interaction

The greenhouse will be a visitor centre where people can watch the showcases and use the restaurant facilities. The visitors can be actively involved in the monitoring of the ecological impact and nature inclusive development.

By using the input of the visitors, large amounts of data can be harvested for analysis purposes. This way the citizens will not only be engaged in the ongoing activities, but will also be an important source of information. They can help in various ways, with the monitoring of air quality, the counting of bees and birds, the monitoring of the water quality and the control of the greenhouse conditions in order to optimise the growing of vegetables. There is no science without input, and the input comes from the visitors!

References

Counting eels on the Thames

An example of a British citizen science project is counting of eels in the Thames. A team of the Zoological Society of London (ZSL) have been monitoring the upstream migration of eels in the Thames catchment since 2005. Over 500 citizen scientists were involved in this project. Problems that eels have to deal with, like habitat loss, loss of connectivity, harvesting of glass eel, are the same as in other countries like the Netherlands. This could be a good showcase for both countries.

Juvenile Eel

Eel in net for monitoring purposes

Aquatic farming

Large scale cultivation of vegetables (such as Sea weed, Sea Aster) on sea can double the organic production worldwide. These aquatic farms are based on sea farming principles.

www.wageningenur.nl/en/show/Zeeboerderijen-voor-hoge-productie-van-eiwitten.htm

Climate research on your smart phone

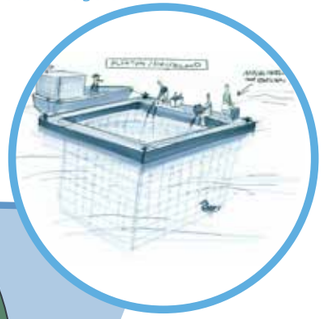
The aim of the project is to stimulate the critical reflection of students and rising awareness on the current urban climate, its causes and consequences, and be inspired to positively influence these process within its community.

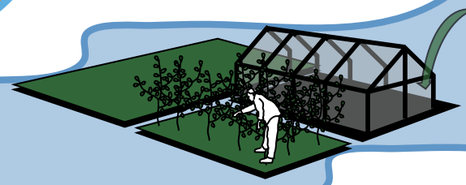
www.wageningenur.nl/en/newsarticle/Climate-research-on-your-own-smartphone.htm

Conceptual illustration citizen science

Floating community garden
Grow your own tomatoes, but also sea aster and watercress.

Project nature inclusive building at sea. Image Studio Rotor





Produced vegetables and tea can be sold at the market and restaurant

Produced vegetables and tea can be sold at the market and restaurant

Underwater Camera

Project nature inclusive building at sea. Image Studio Rotor

Dive deep, but keep dry feet!

With sensors and cameras, the visitors of the greenhouse will be able to monitor the life forms which live under the floating greenhouse. An application will make it possible to check the amount of fish that visited the greenhouse and water quality both in the Thames and in our helophyte filers.

Greenhouse as ecological stepping stone

The floating greenhouse should be more than a closed system. By integrating outdoor vegetation, the greenhouse can function as an ecological stepping stone for neighbouring green facilities. Green infrastructures within the urban fabric are crucial for biodiversity and the increase of species. In addition the greenhouse can also function as a connector between land and water life. The hard shore of the Thames is currently acting as a strict border between water and land. By creating floating, open green islands and nature-inclusive riverbanks much can be gained.

References

Floating park Rotterdam

Water purification by use of floating mini-parks of 300 square metres. These floating parks will also contribute to the wellbeing of the citizens as well as providing improved water quality. This will effectively lead to a healthy living environment for fish and other species and vegetation.

www.dearchitect.nl

Hanging gardens under water

By attaching ropes and natural substrate, shell fish can grow vertically. Additionally, these ropes will also create safe breeding ground for juvenile fish.

www.schmidtzeevis.nl

Biological pest control

Biological pest control by using natural enemies, such as wasps. This will enhance a healthy breeding environment.

Photograph by: Dick Belgers, Wageningen UR

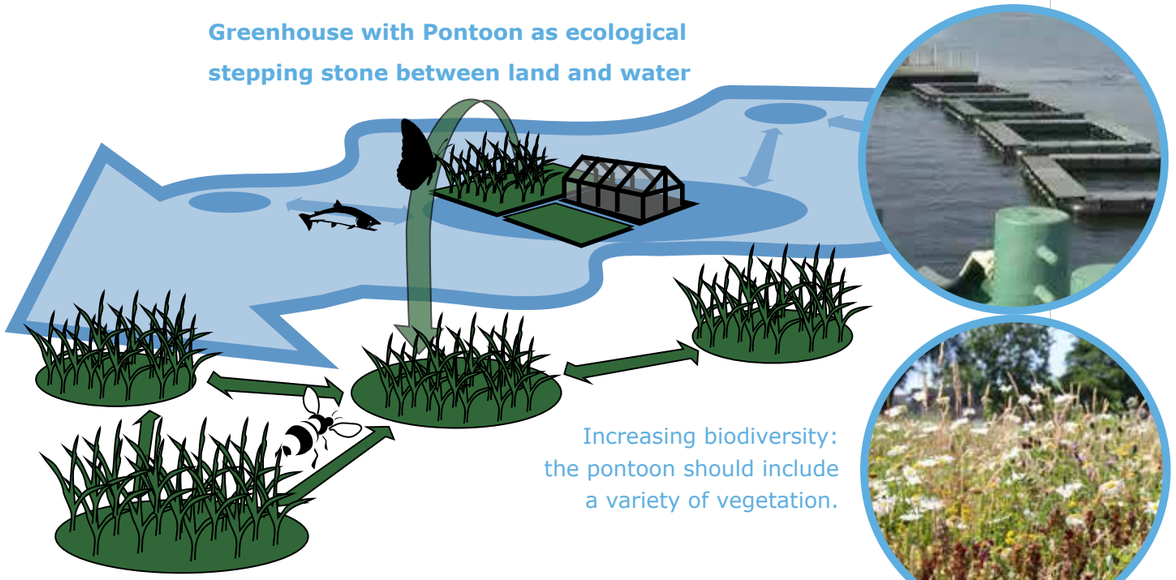
Ecology along the most busiest canal in the world

Construction of ecological zone along the Amsterdam-Rijnkanaal, the most busiest canal worldwide.

www.facebook.com/VriendenVanHetFlevopark/

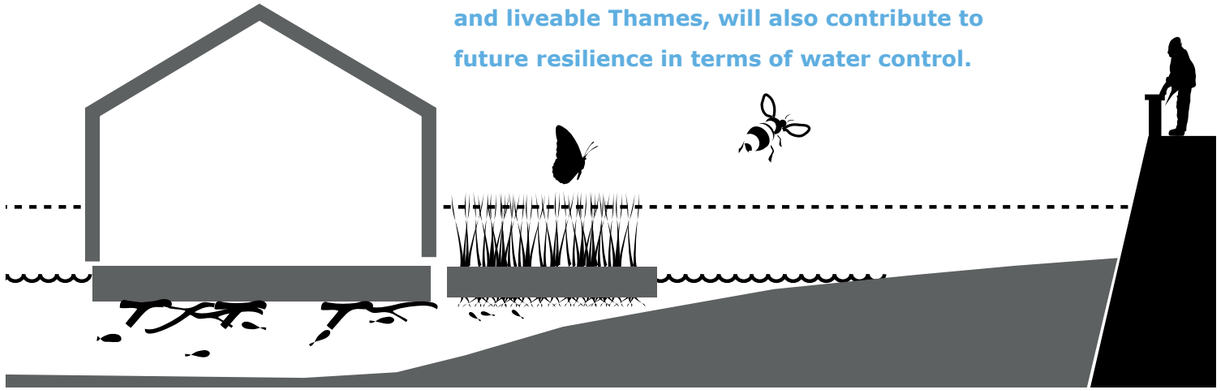
Conceptual illustration of stepping stone

Greenhouse with Pontoon as ecological stepping stone between land and water



Increasing biodiversity: the pontoon should include a variety of vegetation.

Nature inclusive river banks for a healthy and liveable Thames, will also contribute to future resilience in terms of water control.



Tree stumps under the greenhouse will function as foraging, breeding and resting habitat for fish

Designing with nature

By smartly collaborating with nature, human interventions can produce positive results. For example using mussels as a protection shield for piles, and using a pivoting greenhouse for optimum use of the sun. Using mussels as a protection shield for poles. Using pivoting greenhouse for optimum use of sun. But also designing in such a way that nature will not suffer from the interference by humans. Therefore solving challenges, such as the negative effect of glass on birds. There is no risk of collision with coated glass.

References

Heliotrope Rotating House

This environmentally friendly house was designed by the German architect Rolf Disch to follow the sun–like having a southern exposure from every room. The house uses solar power to rotate on a central axle. The railing system contains solar vacuum tubes to heat water and send it through the house. The house is completely energy self-sufficient.

The 18-sided spiral staircased home is constructed mainly of wood (spruce) and triple pane glass. There is a roof garden with a sun terrace.

condo-user.pamjundy.com/?p=15866

Bird friendly glass with UV-reflecting coating

Researchers estimate that hundreds of millions of birds are killed each year in North America due to collisions with glass on human-built structures, making bird collisions one of the most significant causes of avian mortality globally.

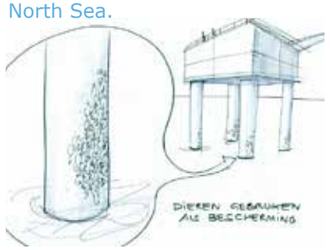
Left: how humans experience the glass

Right: how birds experience the glass

www.ornilux.com

Ecological materials

Nature-inclusive building on the North Sea.



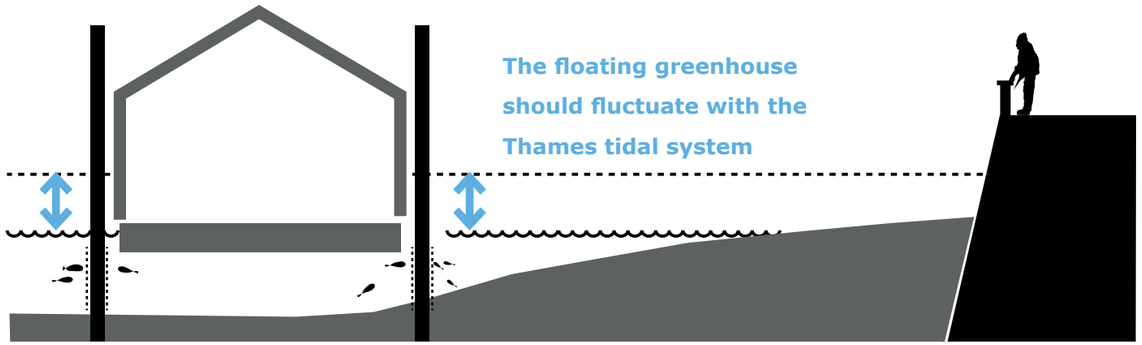
Project nature inclusive building at sea. Image Studio Rotor

Conceptual illustration of nature design

Gravity Base Foundation

Prefab base foundation will be filled with water and lowered on gravel bed, after which it will be filled with sand and ready to be used as windmill base. The GBF is self-buoyant, which prevents the use of expensive jack-up or heavy lift vessels. This method does not cause vibration in contrast to the conventional method.

www.baminnovation.eu/en/innovations/gravity-base-foundation



Eco-Xbloc

The rough surface of the blocks will perform as artificial reefs creating new habitats for marine life. This will stimulate natural development for fish, shells and vegetation, thereby increasing biodiversity.

www.xbloc.com

The steak of the future does not come from a cow, but straight from plants.

The evolution of a plant-based alternative to meat

One of the ways to make our foodstuff more sustainable is to replace the animal proteins with vegetable proteins.

resource.wageningenur.nl/en/science/show/Sniffing-the-vegetable-steak.htm

In the past beer and jenever was brewed to clean the water for human consumption. So lets brew some Thames beer!

Beer design!

A view from above Henriette van Waal's Buitenbrouwerij being used to brew beer.

Vegetable sprinkles as a healthy start of the day!

A healthy alternative for sweet cornflakes and chocolate sprinkles. Two companies from Groningen developed: vegetable sprinkles as sandwich spread.

www.dvhn.nl/groningen/Groentehagel-als-gezond-begin-van-de-dag

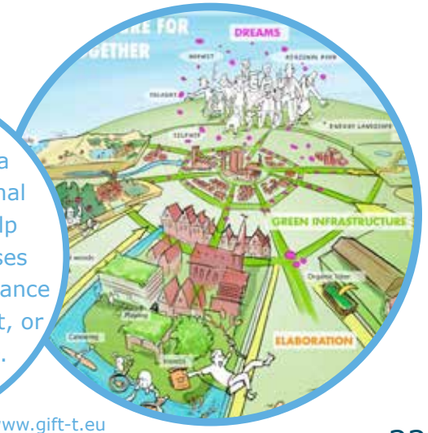
3D printing from maize!

A 3D printer that creates spare keys or Lego blocks from printer threads made of maize or potato. "Within five years, you'll be doing this yourself".

www.wageningenur.nl/en/show/Exhibition-brings-biobased-economy-to-life.htm

Green infrastructure

GIFT-T! developed a toolkit, a manual and inspirational examples that will help communities, businesses and governments to enhance their green environment, or Green Infrastructure.



www.gift-t.eu

Greenhouse references

Floating vegetable garden on ship crane
- Urban vegetable garden for community

www.timecircus.be

Floating greenhouse in Amsterdam
- Temporary greenhouse as community initiative

www.facebook.com/dedrijvendekas

International Space Station
- NASA experiment to produce food in space

www.nasa.gov

New York's floating organic urban farm
- Organic farming with educational purposes

www.nysunworks.org

Nemos garden
- Research project for farming under water

www.nemosgarden.com

Greenhouse at the Dutch Design Week
- Event location and showcase for innovations

www.naturemeetsdesign.nl

Exhibition hall at Flora Holland
- Dutch horticulture promotion

www.floraholland.com

Floating pavilion Rotterdam
- Event location and restaurant

www.drijvendpaviljoen.nl

Urban Algae Canopy Pavilion at Milan expo
- Floating pavilion with integrated algae system

www.ecologicstudio.com

Jellyfish Barge
- Autarctic module for crop cultivation

www.pnat.net

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CITY SCAPES

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