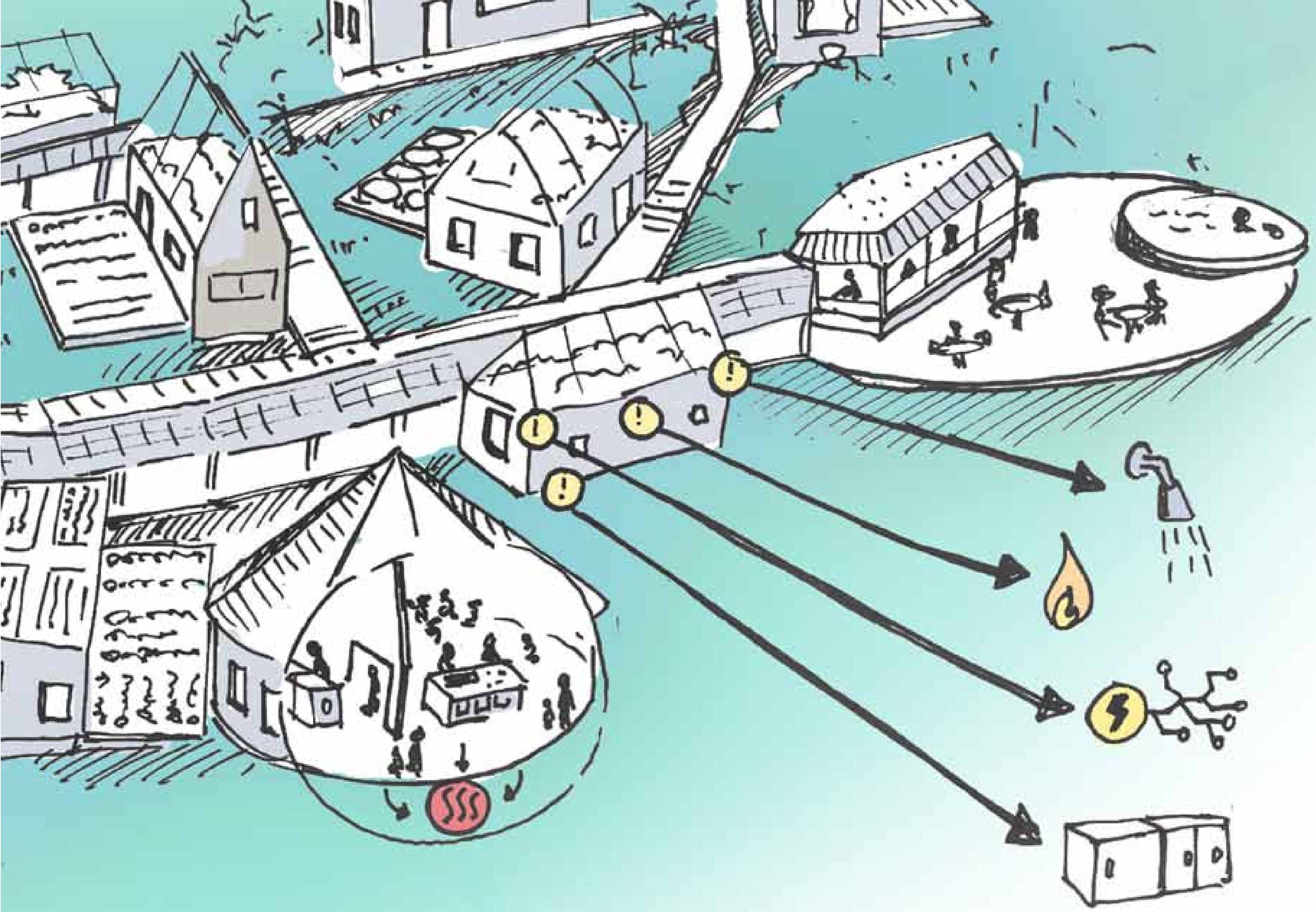

metaboliclab

InnovatieNetwerk
Grensverleggend in Agro en Groen

cleantech playground

A CLEANTECH UTILITY IN AMSTERDAM NORTH
FEBRUARY 2013

Version 2.1 - February 11, 2013

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Reading Guide

This report consists of the following main sections:

- **An Executive Summary**
- **A Process Description**
- **A Vision and Deployment Plan for each of the two urban developments (de Ceuvel and Schoonschip)**
- **Appendices with additional data**

The Executive Summary describes the main features of the modeled “test case” that we used to examine the feasibility of the technical designs for both the de Ceuvel and Schoonschip communities.

The Process Description provides a quick snapshot of the steps we took to achieve these final designs.

The Vision and Deployment Plans describe how the final system for each of the sites should work and how much it will cost. The Deployment Plans detail which steps need to be taken over three phases to achieve this end vision.

The Appendices contain additional information on the site, rules and regulations, assumptions about site resource demand, and the initial scenarios we developed as part of the design process.

Index

Voorwoord InnovatieNetwerk

Een van de grote uitdagingen op het gebied van duurzaamheid is het sluiten van kringlopen. Met name in een stedelijke context is dit een hardnekkig probleem. Gemeenten zamelen gescheiden afvalstromen in, particulieren kiezen steeds vaker voor het opwekken van eigen zonne-energie en stadslandbouwprojecten zijn er in overvloed, maar we kunnen nog lang niet spreken van gesloten nutriëntenkringlopen en onafhankelijkheid van fossiele energie. Kunnen we kringlopen beter sluitend krijgen als we de stad gaan zien als een natuurlijk ecosysteem?

Deze vraag staat centraal in het rapport 'Cleantech Playground', waarbij voor twee locaties in Amsterdam-Noord een plan is gemaakt om voedselproductie, afvalwaterzuivering en energieopwekking te combineren. De ene locatie betreft een drijvende woonwijk (Schoonschip) en de andere – naastgelegen – locatie een tijdelijk kantorenpark (De Ceuvel). Door op een slimme manier verschillende technologieën samen te voegen heeft het bedrijf Metabolic Lab een ontwerp gemaakt dat kringlopen vergaand sluitend maakt. De toekomstige gebruikers en bewoners van de twee locaties zijn vanaf het begin intensief bij het ontwerp betrokken, omdat kringlopen alleen sluitend te krijgen zijn als bewoners en gebruikers zelf willen investeren in duurzame technologie en als ze bereid zijn om hun leefstijl aan te passen. Onafhankelijkheid van fossiele energie begint immers bij het zoveel mogelijk besparen van energie, bijvoorbeeld door faciliteiten te delen, zoals wasmachines die worden gevoed met warm in plaats van koud water. Ook de verantwoordelijkheid voor de eigen voedselvoorziening vraagt om een continue inspanning van bewoners en gebruikers.

De eerste locatie in Amsterdam-Noord – kantorenpark De Ceuvel – wordt in 2013 ingericht, hopelijk snel gevolgd door de drijvende woonwijk Schoonschip. Beide locaties kunnen uitgroeien tot een 'speeltuin' voor schone technologie en kunnen gaan dienen als een blauwdruk voor nieuwe stedelijke ontwikkeling, gebaseerd op de ecosysteemgedachte. Zij kunnen daarmee een inspiratiebron vormen voor stedebouwkundigen, architecten en stadslandbouwprojecten die hun initiatief op een hoger en duurzamer plan willen tillen.

Ger Vos
InnovatieNetwerk

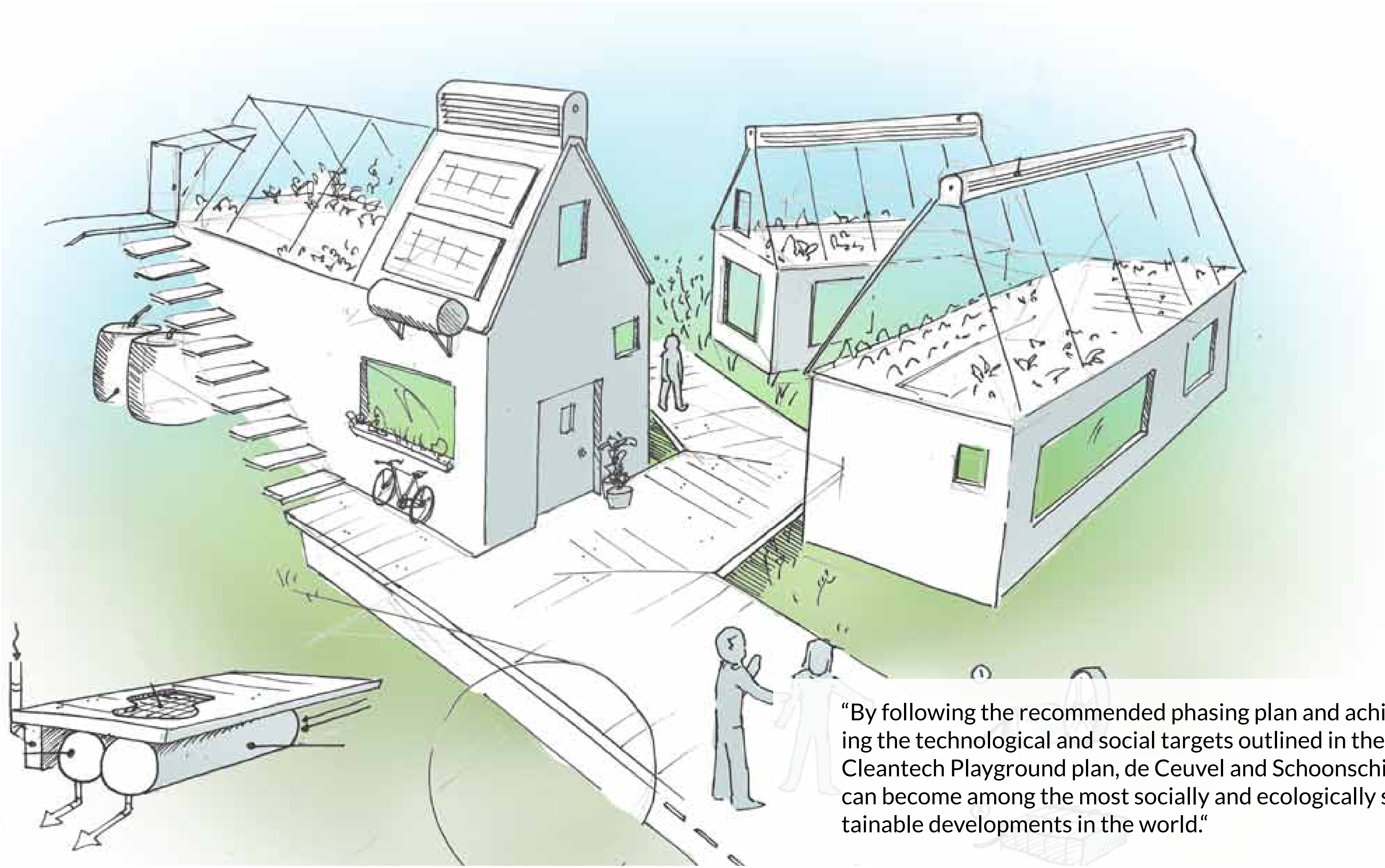
InnovationNetwork Foreword

One of the major challenges in the field of sustainable development is the closing of cycles. Especially in urban contexts, linear material flows remain a persistent problem. Municipalities collect segregated waste streams, individuals are increasingly opting to generate their own solar energy, and urban agriculture projects abound, but we still cannot point to examples of successfully closed nutrient cycles or true independence from fossil energy. Can we be more successful at closing cycles if we start to see cities as natural ecosystems?

This question is central to the ‘Cleantech Playground’ report, which describes a plan made for two locations in Amsterdam North that combines food production, sanitation, and energy systems. One of the sites is a floating residential development (Schoonschip) and the other, next door, an office park on a temporary development site (de Ceuvel). By cleverly combining different technologies, Metabolic Lab designed a system that closes material cycles on both sites. The future users and residents of both developments were intensively involved in the design process. Their involvement was essential as it is these users who will need to invest in the sustainable technologies and be willing to adjust their lifestyles. Achieving independence from fossil energy starts by achieving maximum energy savings, such as those that can be gained through the use of shared facilities, like using washing machines that can take hot instead of cold water as inputs. On-site food production will require continued effort and maintenance from both residents and users.

The first location, the office park de Ceuvel, will begin construction in 2013, hopefully soon to be followed by the floating residential community Schoonschip. Both locations can become a “playground” for clean technology and serve as a blueprint for new urban development, modeled after natural ecosystems. They can thus serve as a source of inspiration for urban planners, architects, and urban agriculture projects that wish to raise the ambition and sustainability of their initiatives.

Ger Vos
Innovation Network



“By following the recommended phasing plan and achieving the technological and social targets outlined in the Cleantech Playground plan, de Ceuvel and Schoonschip can become among the most socially and ecologically sustainable developments in the world.“

INTRODUCTION

the cleantech playground

The Cleantech Playground (CTP) is a planned cleantech utility and demonstration ground that will be integrated throughout two adjacent sites in North Amsterdam: a land-based office and commercial park, de Ceuvel, and a water-based residential community, Schoonschip. It will combine urban agriculture, small-scale renewable energy technologies, biological water purification systems, urban food production, and several other components of a healthy urban metabolism to:

- **produce food**
- **purify water**
- **generate energy**
- **treat organic waste**
- **support cleantech R&D, and**
- **provide education and inspiration for those wishing to adopt decentralized and renewable technologies**

This report presents Metabolic Lab's recommendations for how to achieve these goals in a financially, socially, and technologically feasible manner. By following the recommended phasing plan and achieving the targets outlined here, de Ceuvel and Schoonschip can become among the most socially and ecologically sustainable developments in the world.

Our recommendations also include ways to make the system measurable and transparent; a network of sensors installed throughout both sites will monitor the system's performance, display this information for the community, and provide insights for continued development. In particular, the de Ceuvel site will have many areas open for public visits where these technologies will be on display for all to see and understand.

Construction on the de Ceuvel site will begin in spring of 2013. The Schoonschip community does not yet have its site secured, but hopes to win a tender procedure held by the municipality of Amsterdam for a property directly adjacent to de Ceuvel.

PROJECT BACKGROUND

Schoonschip and de Ceuvel are two separate community development projects that were initiated by different, but overlapping groups of citizens. Sustainability has been a key objective of both projects since their inception, with both groups requiring all members to sign a manifesto committing them to sustainable living and practices.

Schoonschip was the initiative of Marjan de Blok who was inspired by the Gewoonboot, a largely autarkic houseboat docked in Amsterdam North, to imagine the possibility of a sustainable floating community in her home city. She soon found a group of citizens inspired by the same vision, and formed a foundation to oversee the process. This now close-knit community has been working towards securing a site for the execution of the plan since 2009, with many of the community's members taking leading roles in pushing the project forward (among them, board members Sjoerd Dijkstra, Thomas Sykora, and Marnix van der Pool).

The de Ceuvel project was initiated by space&matter and Smeelearchitectuur, and the concept for the site was developed by space&matter. De Ceuvel is a 10-year temporary development that will feature beatifully retrofitted houseboats placed on the land and surrounded by a "forbidden garden" of soil-cleaning plants. The architectural plan for both sites has been developed by space&matter and the phytoremediation plan for the de Ceuvel site is being developed by Delva Landscape Architects in collaboration with the University of Ghent in Belgium. The overall feasibility study for both projects was conducted by space&matter (design) and Duurzaam Drijvend Wonen (finances).

In September 2012, Metabolic Lab received financial support from InnovatieNetwerk, a program of the Dutch ministry of economic affairs, to help translate the projects' high sustainability ambitions into a concrete, implementable technical design with a workable business case. The design process involved close collaboration with the existing development team as well as regular feedback from both the Schoonschip and de Ceuvel communities and other relevant stakeholders. Metabolic Lab worked closely with these groups to develop a technological plan that was consistent with the broader vision behind both developments.

PROJECT OUTCOMES

This document summarizes the work done by the Metabolic Lab team since phase two of both projects began in September 2012. Though this was officially a conceptual design and feasibility study for the technological aspects of the plan, our goal from the start was to ensure that the design we developed would lead to a socially, technologically, and financially realistic plan within the contexts' of both Schoonschip and de Ceuvel.

From early on in the process, we knew that a single, inflexible design would not constitute a realistic solution for these sites. Both communities are diverse in terms of their financial means and desired levels of hands-on involvement. Moreover, due to the nature of both projects, there remain many unknown variables in how the development process will unfold. One of the clearest examples of this uncertainty is the fact that the de Ceuvel site will be populated with upcycled houseboats, most of which still need to be acquired. Properly retrofitting these houseboats will require a plan that is specifically adapted to the quality and typology of each boat. Meanwhile, the Schoonschip community has diverse income levels and housing preferences, which cannot be optimally served with a single design. To handle these unknown variables, we have developed an overall technological framework and toolkit that includes the following elements:

› **Performance targets:** A set of performance targets for each major aspect of site construction (on the level of individual buildings as well as the level of each neighborhood as a whole).

› **Fixed and flexible elements:** a mix of fixed technological recommendations and flexible elements that can be selected by users depending on their specific preferences and financial means (similar to buying a computer or car and being able to choose preferred options and add-ons).

› **A technology selection tool** consisting of a set of decision trees that will guide users through the suitable technological options we have identified for the site.

› **A financial modeling tool** that will allow users to see the cost and earnings profile of any selected technological mix, including upfront investment, overall costs, and payback times.

› **A phasing and deployment plan** recommending when investments should be made in order to keep the project financially feasible while still reaching the highest sustainability targets.

› **Recommendations for creating specific management structures** within both communities to handle do-it-yourself (DIY) constructions and shared oversight responsibilities, such as system maintenance, which will continue throughout the lifetime of both developments.

Taken together, these elements result in a flexible toolkit of technologies than can be selected by individual home or office owners based on their specific requirments, financial situations, and market prices for technologies at the time of construction.

TEST SCENARIOS

To make our recommendations concrete, this document presents a worked out test case for each site to demonstrate that the toolkit yields options that are feasible even for the lowest possible range of financial flexibility.

We summarize the general plan, the anticipated system performance, and estimated costs for each site. For both Schoonschip and de Ceuvel, we have described the final vision of how the communities will function and relate to the suggested technologies. We have also included a more detailed deployment plan for how new technologies can be adopted over time by the users of both areas.

At the end of all three deployment phases, both sites should be fully self-sufficient in renewable energy, water management, organic waste processing, and a large part of food production.

BLUEPRINT FOR SUSTAINABLE CITIES

Besides aiming to exceed the targets currently set by state-of-the-art ecovillages, the drive behind the CTP is to fundamentally shift the pattern of urbanization by providing a reusable blueprint for development. A large part of this is the goal of making these systems transparent and educational for visitors who wish to see the functioning of the system.

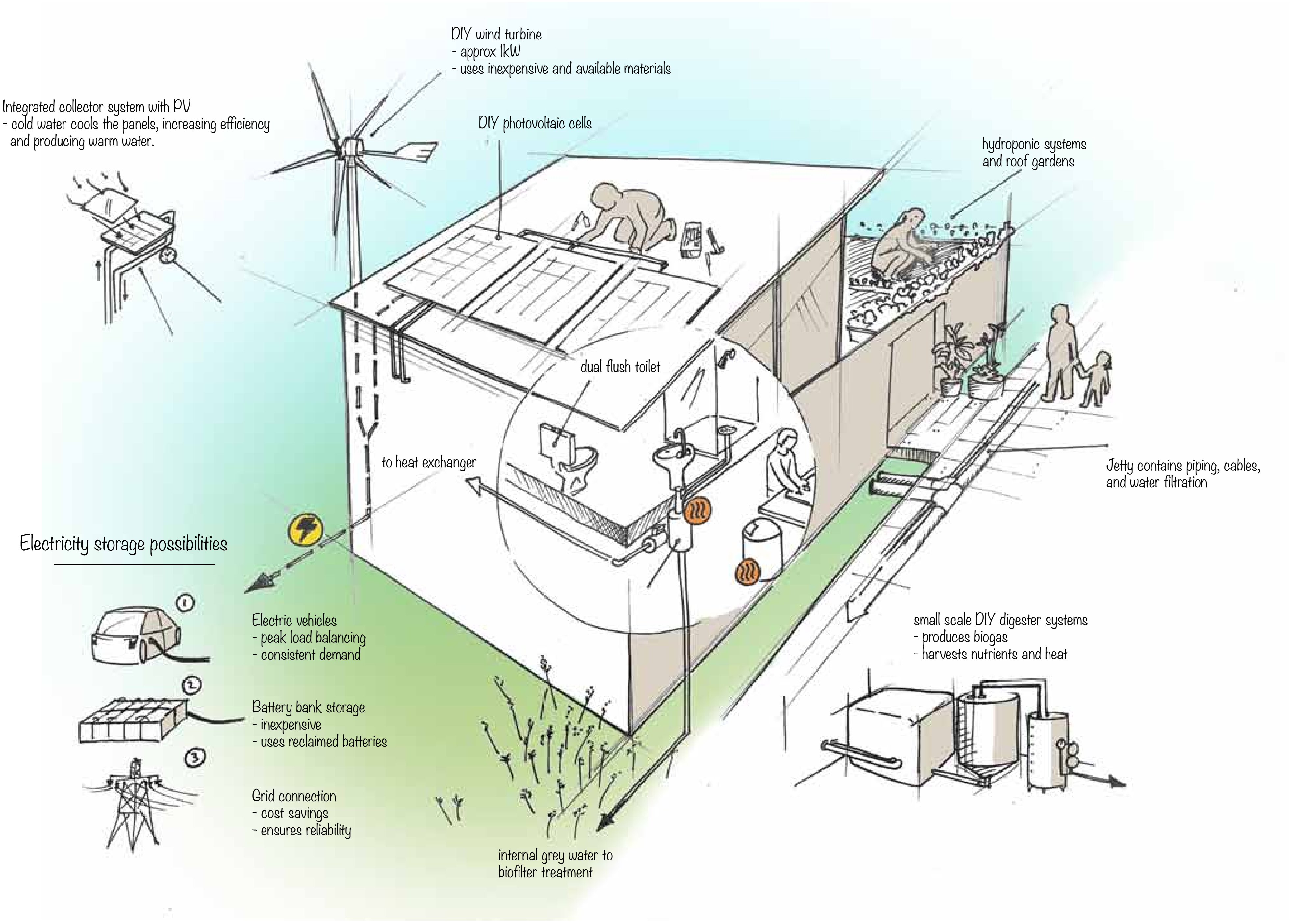
Cities are currently consumers. They are drainage points for resources; river deltas of food, fuels, metals, minerals, and other valuable materials. Despite their enormous social, cultural, and economic value, the primary physical output of cities is waste. A majority of the materials that enter are destined to become pollutants of some kind.

As urbanization continues at a fast clip, we believe it is essential to alter this pattern of lineral material flows by making cities producers in their own right. This shift requires the adoption of new technologies, new infrastructural patterns, and changes in the mindsets of individuals and communities.

URBAN ECOSYSTEM

The Cleantech Playground can be seen as an urban ecosystem embedded into the fabric of the city. All ecosystems are made up of a complex web of actors: plants that harvest sunlight as fuel, herbivores that consume the plants, carnivores and omnivores that consume each other, and detritivores that break down wastes, bringing nutrients back into a state that can be used as food by other living creatures in the system.

Natural systems are not perfect, but they are much more efficient than most current urban and industrial human systems.


DIY wind turbine
- approx 1kW
- uses inexpensive and available materials
Integrated collector system with PV
- cold water cools the panels, increasing efficiency
and producing warm water.
DIY photovoltaic cells
hydroponic systems
and roof gardens
dual flush toilet
to heat exchanger
Jetty contains piping, cables,
and water filtration
Electricity storage possibilities
Electric vehicles
- peak load balancing
- consistent demand
Battery bank storage
- inexpensive
- uses reclaimed batteries
Grid connection
- cost savings
- ensures reliability
small scale DIY digester systems
- produces biogas
- harvests nutrients and heat
internal grey water to
biofilter treatment

Above are photos of members of the Schoonschip community taken throughout the fall and winter of 2012/13 by Marnix van der Pool, one of the community members. This close-knit group is highly committed to achieving a vision of sustainable living.

Ecosystems are made up of diverse, complementary players, consuming and producing materials and energy in short cycles. They are also quite resilient to abrupt changes, like storms and modifications to the environment, because they have many different species fulfilling the same role and compensating for the decline of any individual actor or species due to disease or environmental stress.

Our goal with the Cleantech Playground was to create a system that works similarly to an ecosystem: harvesting ambient energy and water for use on site, cycling nutrients locally, and creating an environment that is supportive of natural biodiversity. Our goal is to create a new blueprint for biobased cities, rooted in the strength of human community.

COMMUNITY FOCUS

Though much of the focus of this report is on technology, the essential core of this new developmental blueprint is the power of community. Without trusting communities of individuals who hold shared values and are willing to work together to build a greater whole, the kind of urban development we describe is not possible. People make up the most important part of this cleantech ecosystem. They become essentially linked to one another in caring for their local resources, trading energy, producing shared crops of food. This is not a retrograde approach hearkening us back to pre-modern lifestyles. Rather, it is a big step forward, where technology is used to assist in making connections between people, facilitating the transfer of knowledge, easing the burden of work, and increasing the comfort and joy of living. At both sites we have designed for the preservation of modern comforts to as great an extent possible.

Fundamentally, however the willingness of individuals to cooperate with one another, work together, share, and trust one another is the cornerstone of the success of these endeavors.

PROJECT TARGETS

We believe that the Cleantech Playground will be a success if it exceeds the standards of existing eco-communities in at least the following ways:

- **Achieving the highest goals for renewable resource management** (further defined in the “goals” section on pages 24 and 25).

- **Exemplifying integrated design principles**. We recognize that sustainability goes far beyond just physical resource management. The CTP should support a healthy, enjoyable, and beautiful living environment. The technologies included should work with realistic behavioral constraints and contribute to a socially cohesive environment.

- **Providing room to experiment and to evolve over time**. Neighborhoods should not be created in a static vision of what is possible right now: they should be designed to improve and grow over time. It should be possible to upgrade to newer and better functioning technologies as they become available on the market. The site should also be a testing ground for small-scale technology pilots that can become more broadly adopted if they are successful.

- **Inspiring and educating.** The implemented technologies should be made visible and their functionalities explained. The site should be at least partly accessible to parties wishing to learn about this kind of development approach. Data on the system’s performance should be collected via an integrated IT system and used both in user feedback mechanisms as well as recommendations for policy development.

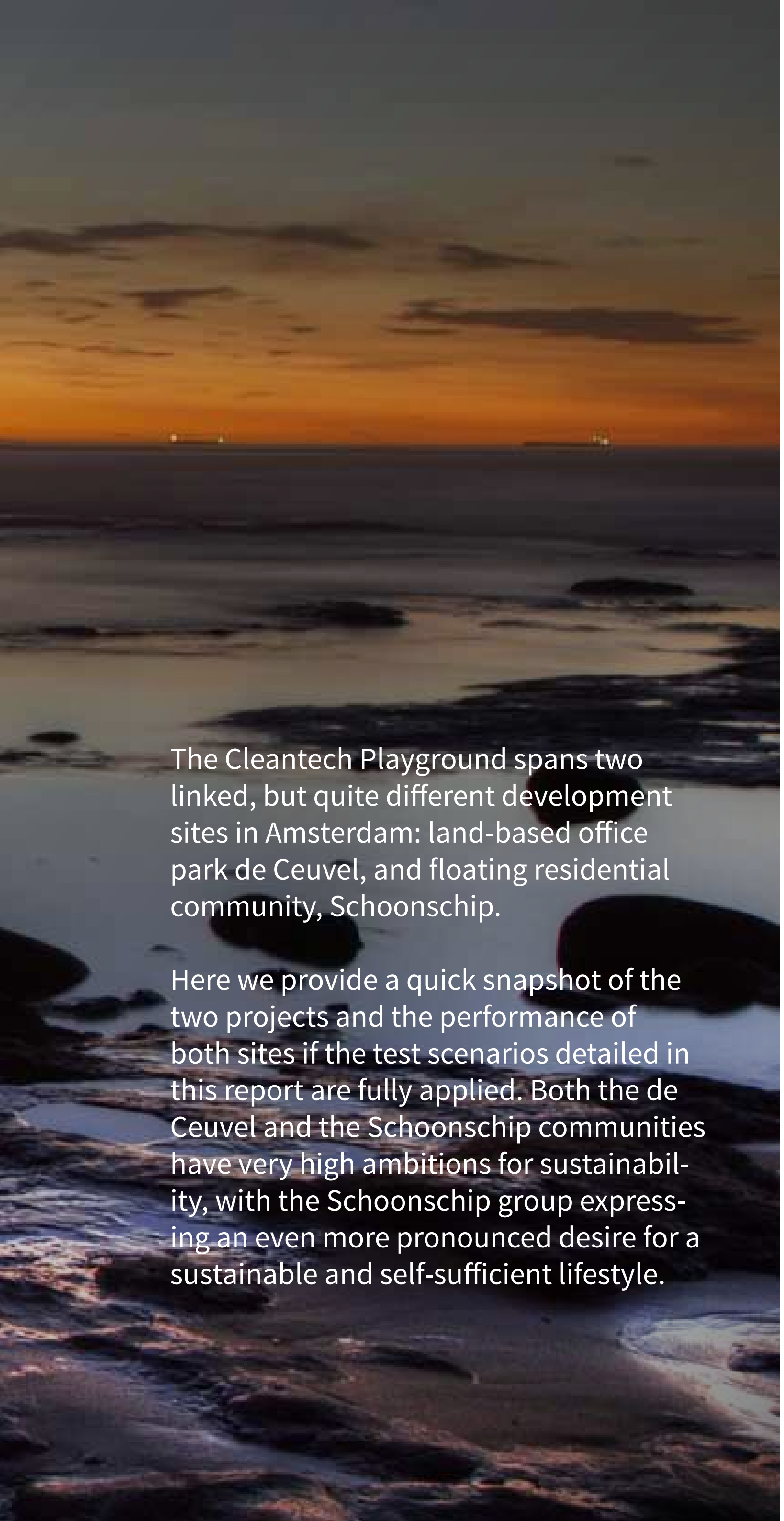
- **Replicability**. Though pioneering projects can sometimes require an extra boost to get off the ground, we want the fundamental approaches used in the CTP to be financially viable within the short- to mid-term, and to be user-friendly enough that they represent a realistic alternative to the status quo. All of the designs and calculations for our work are therefore published under a non-commercial Creative Commons License and distributed broadly to encourage widespread adoption.

PROJECT EXECUTION

Perhaps the most important measure of success, however, will be to see the Cleantech Playground actually built. As part of our commitment to its realization, Metabolic Lab has joined the de Ceuvel community as a stakeholder; we plan to retrofit a houseboat on the site to serve as our own office. This houseboat can also potentially become a focal point for educational activities, public site visits, and the integration of new technology pilots on the de Ceuvel site.

We believe this project offers an opportunity to implement a working system of environmental technologies and community practices that can inspire the rest of the world to imagine what is possible. It shows how inexpensive, beautiful, and comfortable the path of a sustainable lifestyle can be if we choose not to walk it alone.


cleantech
playground
executive summary



The Cleantech Playground spans two linked, but quite different development sites in Amsterdam: land-based office park de Ceuvel, and floating residential community, Schoonschip.

Here we provide a quick snapshot of the two projects and the performance of both sites if the test scenarios detailed in this report are fully applied. Both the de Ceuvel and the Schoonschip communities have very high ambitions for sustainability, with the Schoonschip group expressing an even more pronounced desire for a sustainable and self-sufficient lifestyle.

The test case we have worked out for both sites, summarized on the next two pages, will achieve extremely high sustainability performance on both sites with a comparatively minimal investment. One of the key challenges to overcome was the limited budget of the whole de Ceuvel project and the financial variation among the members of the Schoonschip community. To cut the costs of our proposed technological system, we have used two approaches: a focus on “do-it-yourself” (DIY) and low-tech solutions, and a phased development plan which spreads investment over time.

“DIY” FOCUS

The DIY approach requires more labor from individual house owners and higher personal risk, but can achieve the desired ambitions for self-sufficiency at around a third of the price that would otherwise be possible. We have recommended only proven technologies for essential functions on both sites, though some have been recombined in unique ways (for example, the custom-designed waste processing system we have recommended on both sites; see pages 51 - 53).

PHASED DEVELOPMENT PLAN

To reduce the total amount of up-front investment, we have recommended three phases of technological deployment for both de Ceuvel and Schoonschip. For both developments, the first phase focuses on essential infrastructure, the second phase on power generation and food production, and the third phase on the continued addition of technologies over time to keep the system up to date and evolving as technologies become less expensive and improve.

de ceuvel

executive summary

Above is an artist's impression of the de Ceuvel site once the buildings and walkways are constructed. The site design and image were made by architecture firm space&matter, one of the initiators of the de Ceuvel project and the developer of the concept.

DE CEUVEL

De Ceuvel is a planned workplace for creative and social enterprises adjacent to a canal off the river IJ in northern Amsterdam. The land was secured for a 10-year lease in 2012. The formerly industrial plot has heavily polluted soils that will be treated with a phytoremediation garden ("The Forbidden Garden") designed by Delva Landscape Architects in collaboration with the University of Ghent. Scattered throughout the plot will be reclaimed and retroffitted houseboats that will house offices, ateliers, and workshops. The de Ceuvel site will also have some public functions including a teahouse and bed and breakfast.

STRATEGY AND ACTIVITIES

The de Ceuvel development strategy we recommend takes place over three phases.

In the first phase of the de Ceuvel deployment plan, the boats will be retrofitted off-site to a very high level of eco-efficiency. The focus is primarily on basic repairs, insulation, and the installation of a solar heating system. The main goal of this phase is to achieve sufficient insulation and renewable heating capacity to eliminate the need for a gas connection. Secondary goals include installing a rainwater collection system, dry toilets for sanitation, and integrating ecological elements such as green roofs into the boat structures. We will work together with architects space&matter to ensure that the boats are retrofitted to a high level of architectural quality. The materials budget for phase one is capped at a strict limit of 5.000 € per boat. To keep to this budget, a lot of creativity will be required to scavenge free and cheap materials and adapt the plan during the retrofit process.

In phase two, the boats will be placed on the site, the phytoremediation garden will be planted, and the communal infrastructure will be built. A central feature of the technology plan in this phase is the construction of the D-SARR system, a waste treatment and resource recovery unit that will serve the entire de Ceuvel site, producing biogas and harvesting nutrients for on-site use. Additionally, urban food production and floating gardens will be deployed during this stage. Electric power generation capacity will also be installed in this phase if sufficient funding is acquired. If not, this step will be pushed to phase three. A site-wide IT system will show live feeds of all resources used and produced on site to give users feedback about their behavior and showcase the performance of these technologies for visitors to the area. This IT platform will also serve as a collection point for information on monitoring biodiversity, and sharing resources (such as cars or tools) among site users. The total estimated costs of phase two development are 10.000 € per boat.

By 2014, once the two first development phases of the de Ceuvel site have been completed, the houseboats on the de Ceuvel site should be fully self-sufficient in renewable heat and electricity supply, water collection and upgrading, and 50 - 70% lower electricity demand than a conventional office building. The buildings themselves will not only be highly eco-efficient, but also designed in a variety of architectural styles with creative exterior finishing.

In phase three of the development, which spans the remaining period of the ten year lease, the technological plan should remain flexible and continue to evolve. The site can serve as a pilot space for decentralized, renewable technologies. If the association managing the site is able to generate profits from festivals, educational activities, and other planned sources of income, these can partially be re-invested in the continued development of the plan.

FINAL SYSTEM PERFORMANCE

The de Ceuvel development plan has the following key features:

› **"Featherlight" footprint**: infrastructure on site will be minimized, with the objective of all boats only having a connection to the electric grid, but no other utility demands. As largely autarkic elements, the boats will be able to leave the site after ten years without leaving much of a trace.

› **Regenerative development:** the phytoremediation plan and biodiverisity measures will result in a cleaner and more biodiverse area than at the start of the project.

› **Fast return on investment:** using a DIY approach and recycled materials, return on investment is possible in under five years for all recommended interventions.

› **Closed material cycles:** reuse of nutrients and energy on site.

› **Evolving technology landscape:** continual improvement of system performance by adopting new technologies as they become avaiable and affordable.

FINAL TARGETS ACHIEVED (HIGHLIGHTS):

› 100% renewable heat and hot water supply
› 100% renewable electricity
› 100% wastewater and organic waste treatment
› 100% water self-sufficiency
› 60 - 80% nutrient recovery
› 50 - 70% reduction in electricity demand over conventional offices
› 10 - 30% vegetable & fruit production using locally recovered nutrients
› sensor network and real-time system performance displays

schoonschip

executive summary

Above is an artist's impression of the Schoonschip site once the full plan is completed, which will take an estimated three years from the start of the development. The site design and image were made by architecture firm space&matter.

SCHOONSCHIP

The Schoonschip project is a prospective floating residential community of 30 houseboats (a total of ~48 households) to be built over the coming two and a half years, where people with diverse incomes can live together with shared values. The group focuses on sustainable living, which is partially achieved through building a strong community. This water-based site will be built surrounding five piers, each of which will have 5 - 6 buildings, most of which will be shared by multiple households. In between these piers is space for additional program like gardens or a swimming pool. The community will determine what they would like to build and invest in over time, and jointly finance these projects in later phases of construction.

STRATEGY AND ACTIVITIES

The Schoonschip technological development strategy we have recommended takes place over three phases and must match the financial phasing and communal investment in the overall construction of the site.

To limit the risk of investment in communal infrastructure such as the piers in between the boats, the Schoonship site will be constructed one pier at a time. Because of this construction pattern, we have also recommended the centralization of certain technological functions on the level of each pier. Some of the recommended technologies in our plan, such as urine separating toilets, are fixed. Others, such as the degree of insulation for each home's building envelope, are flexible. In the test case described throughout this report, we have used the passive house standard of insulation. However, this is by no means a requirement. Home owners will be able to select other options as long as the recommended performance targets are met.

Phase one includes the construction of the passive and active heating system, water collection and ugrading, wastewater and organic waste treatment, green roofs and greenhouses, and some of the communal gardens. In this phase we also recommend the construction of the communal laundry facility, combined with greenhouse, kitchen, and play area. This facility will allow for approximately 20% reduction in domestic electricity use by employing laundry machines that can use hot water as a direct input and using this hot water to heat the community pool (to be built in phase two) via a heat exchanger.

Phase two includes the addition of solar electricity and potentially other power generation equipment such as a gassifer. In this phase, additional communal areas will also be built, some of which, such as a community managed bed and breakfast, can also generate profit for future investments. The urban food production plan comes into full development at this stage, with collective harvesting,management,and processing of various food types in a collective area.

In phase three of the development, the technological plan should remain flexible and continue to evolve. The site can serve as a pilot space for decentralized, renewable technologies.

FINAL SYSTEM PERFORMANCE

The Schoonschip development plan has the following key features:

- **Communal facilities**: shared laundry facilities, kitchens, gardens, playgrounds, pools, food processing and storage, and other elements will increase community interaction and facilitate resource sharing.

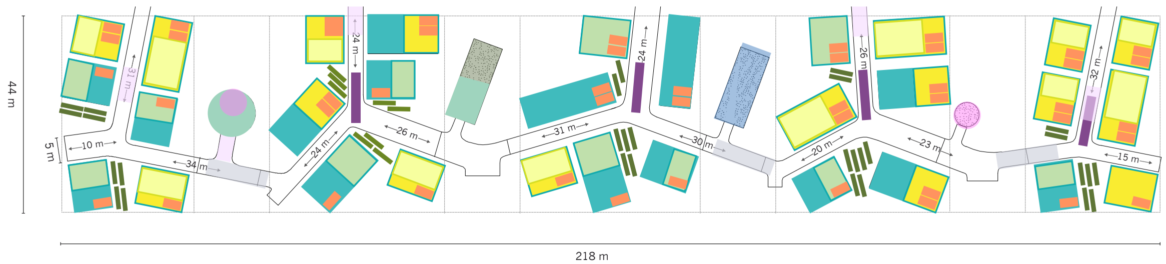
- **Demand side management:** The success of the plan will partly be achieved through strong demand-side management approaches which will limit overall resource demand.

- **Heat and nutrient cascades and closed material cycles:** reuse of nutrients and energy on site, cascading of heat from waste sources for reuse in other functions (from greenhouses to the community pool).

- **Evolving technology landscape:** continual improvement of system performance by adopting new technologies as they become avaiable and affordable.

FINAL TARGETS ACHIEVED (HIGHLIGHTS):

- 100% renewable heat and hot water supply
- 100% renewable electricity
- 100% wastewater and organic waste treatment
- 100% water self-sufficiency
- 60 - 80% nutrient recovery
- 50 - 70% reduction in electricity demand over conventional households
- 60 - 80% vegetable & fruit production using locally recovered nutrients
- sensor network and real-time system performance displays



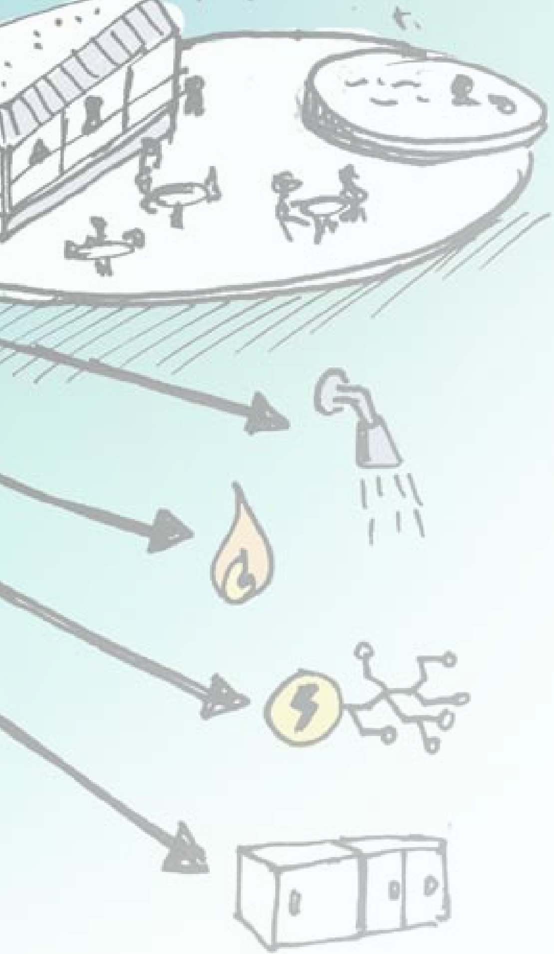
Green roof + solar infrastructure	1.155 sqm
Greenhouses	490 sqm
Green roof terraces	741 sqm
Solar heat collectors	384 sqm (8 sqm / house)
Solar PV cells	480 sqm (10 sqm / house)
Outdoor food production	180 sqm
Food processing & storage	120 sqm
DESAR organic waste treatment	110 sqm (22 sqm /pier)
Reedbed filtration	600 sqm (1,4 sqm/person)
Vertical food production	300 sqm
Vertical ecosystem	220 sqm
Pool and sauna	250 sqm
Play area	60 sqm

HOUSE BOATS: 6300 sqm (30)

JETTY: 1635 sqm

cleantech playground

process & strategy



PROCESS

Designing a complete ecosystem of technologies for the Cleantech Playground was a complex process with many iterative steps.

Here we briefly describe our design approach and how we came to the final decisions represented in this report. These solutions are not ideal or recommended for every situation, but rather, have been adapted to this particular context, the desires of the communities and stakeholders involved, and the financial constraints of both communities.

This quick snapshot gives insight into how we arrived at certain key decisions and why certain tradeoffs were made.

STRATEGY

The final result of our work is a framework for further decision making that will lead to a customized mix of technologies and practices that will make these neighborhoods largely resource self-sufficient and adaptive over time.

In this section we describe some of the tools we have developed to guide this further decision-making process. We focus specifically on the technology selection tool and the financial modeling tool. It is on the basis of these tools that we have modeled the test case scenarios detailed further in the document.

DESIGN PROCESS

Metabolic Lab is a sustainable design company that takes a systemic and iterative approach to urban and agricultural development. We work on applied projects, making it essential to integrate the users and address practical challenges throughout the process. From the start of the Cleantech Playground project in October 2012, Metabolic Lab actively engaged community stakeholders, utilities, knowledge institutes, technology partners, and other relevant groups in a high-input design process.

De Ceuvel and Schoonschip have unique contextual considerations. The entire Buiksloterham region, where both sites are located, is highly polluted with industrial wastes. For de Ceuvel this is of particular concern because no digging can be done on site. There are differing levels of commitment to sustainability between and among the De Ceuvel and Schoonschip communities. The Schoonschip community is a more cohesive, residential group with a stronger commitment to sustainable living. The de Ceuvel group formed more recently and is still evolving. These and other legal, financial, and environmental particularities of the case impacted our design objectives. More details on the site location can be found in Appendix A.

Our design process began with defining shared performance goals for both sites (these are listed on the pages 24 and 25 of this document). Once the initial set of goals was established, we followed several design process loops.

Our first step was to scan for as many technological solutions as possible by examining the latest eco-community designs and augmenting our existing database of clean technologies with the latest published breakthroughs. We used this technology database as a starting point to create a tangible pallette of options to work with. With this information in hand, set off on two parallel trajectories to help us collect the necessary information for the complete design process: a community and stakeholder engagement path, and a technical design process. These two approaches were used to clarify community preferences, receive advice from external experts, and test proposed systems against technical parameters.

COMMUNITY AND STAKEHOLDER ENGAGEMENT

De Ceuvel and Schoonschip are separate but connected communities, both of which have existed since 2009. Both communities require all members to sign a manifesto committing them to a sustainable lifestyle.

Metabolic Lab joined the De Ceuvel vereniging (association), becoming a stakeholder in the process and part of one of the communities involved in the Cleantech Playground. As a member of the association, we participated in monthly meetings and in sub-teams for the site's development. We met at least bi-montly with the Schoonschip management team as they also oversaw the development process for the Schoonschip tender. We met with both communities as a group in October, December, and January.

We worked with public utilities and government agencies to understand their potential interests in decentralized technology as pilot opportunities for research. We reached out to agencies responsible for different regulatory aspects of the sites, including the water authorities and the local government, to gain a clear understanding of the regulatory process, detailed further in Appendix B. Clean technologies providing resource self-sufficiency are innovating faster than governments' ability to regulate them. For some technologies, like solar PV, regulatory issues are clear; the technology has been available on the market for decades and is by now ubiquitously used to generate clean energy. Other technologies, such as waste digestion, gasification, and local food production, have more complicated regulatory hurdles.

Based on precedent research, Metabolic Lab catalogued regulatory concerns and what they meant for the Cleantech Playground in initial design phases. Nevertheless, new regulatory questions arose throughout the iterative process as we incorporated community interests and the contextual challenges of the sites themselves.




CTP SYSTEM GOALS

GOALS USING ELSIA FRAMEWORK

At the start of the design process for the Cleantech Playground, we established a set of performance goals that we wanted the final technological plan to uphold.

These goals were formulated using the ELSIA framework, which is most simply understood as an alternative to the traditional People, Planet, Profit division. It recognizes an implicit hierarchy in areas of concern: energy and materials, ecosystems and species, culture and economy, and health and happiness.

The functional foundation of any system is its physical performance in terms of energy and material use. Misusing resources in these category has consequences throughout the more complex ranks of the system above, beginning wtih ecosystems and species. System complexity continues to increase towards the “health and happiness” category. There is an implicit dependency between each set of goals, with all of them aiming towards high ultimate performance on human health and happiness.

Throughout the iterative design process, we continuously checked whether our recommendations would satisfy the initial performance goals outlined on this page.

ENERGY & MATERIALS

- Maximum reduction of energy and material resource demand through implementation of best practices and highest efficiency technologies
- 100% renewable electricity supply
- 100% renewable heat supply
- Smart energy systems for local load balancing and optimized day cycle uses
- Self sufficiency in food production for all food types that can be feasibly produced in the local area
- 100% recycling collection capacity for recyclable materials
- 100% sustainably sourced materials
- 100% reusable and recyclable constructions and materials
- 100% water self-sufficiency (excluding potable water for legal reasons)
- Greywater recycling
- Nutrient recovery from wastewater

ENERGY & MATERIALS

- Optimized transportation access; reduction of systemic transport demand through information sharing tools
- Feedback systems should be incorporated into the design to provide users with information on their own energy usage patterns

ECOSYSTEMS & SPECIES

- Beneficial impact on existing ecosystems: focus on not only conserving existing value, but regenerating ecological quality where possible
- Regenerative treatment of local soil and water
- High on-site biological diversity
- Preservation of existing species habitats and migration corridors
- Consider animal welfare a top priority within all agricultural production systems

CULTURE & ECONOMY

- The system design should incorporate an intelligent governance model, which insures appropriate management
- The system is financially viable within a short to mid-range time horizon
- Provides high levels of self sufficiency and fossil fuel independence for residents
- Engages the broader community beyond the immediate development site
- It provides opportunities for functions in addition to basic utility provision. These functions could include: education, tourism, social uses, product processing and sales (particularly food products), etc.

HEALTH & HAPPINESS

- A healthy safe and enjoyable environment to work and live in
- No use of toxic chemicals or materials that may pose a threat to human or ecosystem healthy
- Aesthetically pleasing in outside appearance, enriching landscape quality
- Design for social cohesion and community interation
- A highly resource efficient and comfortable living environment that achieves all performance objectives without compromising fundamental quality of life

TECHNICAL DESIGN PROCESS

On October 31st and November 1st, 2012, Metabolic Lab hosted a technical design workshop for the Cleantech Playground, which was attended by our core team and a number of domain experts.

During this workshop, we explored three conceptual approaches for how the CTP system could work. These scenarios were conceived of as thought experiments to test the range of potential technologies and edge conditions that we may encounter. They are further documented and described in Appendix D of this document.

The scenarios were:

- **Do-It-Yourself (DIY) Scenario:** explores what can be achieved with minimal funding, repurposed materials, and a high level of community participation for both construction and management of the CTP.
- **Proven Technology Scenario:** evaluates how commercially available systems can be recombined to provide the targeted needs of the CTP.
- **Fantasy Technology Scenario:** imagines how to incorporate developing and new technologies into the CTP and how to reasonably push the boundaries of current standards in cleantech.

Using and adding to a clean technology database we had developed over the summer of 2012, we created cleantech cards showing inputs, outputs, and key information about individual technologies. We used these cards and their data to visually model different technological systems. From modeling these systems with internal and external experts, we designed three test case scenarios for review. From these midterm designs, we received feedback from the communities and a selection of engineers from different backgrounds. This informed our final design decisions and our approach of creating flexible tools in addition to design recommendations.

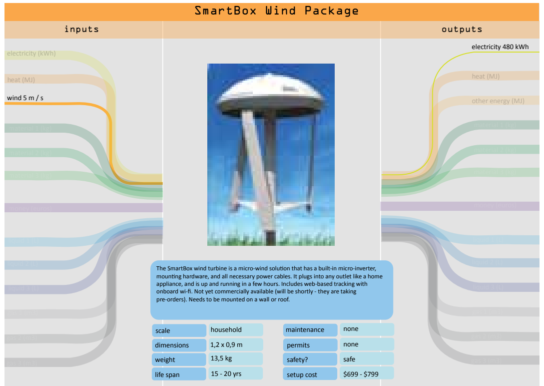
Early in the design process, we contacted hundreds of technology providers in order to understand the specifications of products offered by cleantech companies, which products at what performance were in development, and how companies would like to be involved in projects like the Cleantech Playground. Thus far, potential technology partners have been interested in the opportunities embedded in the project and have been receptive to providing technology in-kind in exchange for visibility and ongoing research.

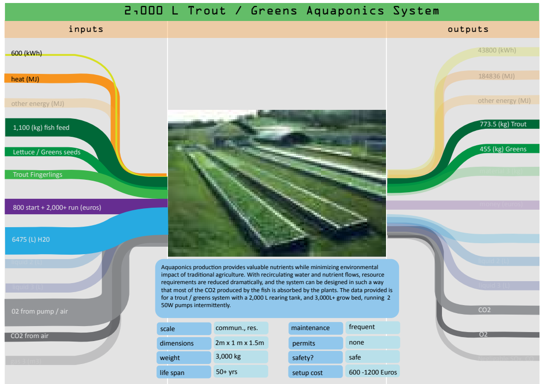
TECHNOLOGICAL SCALE

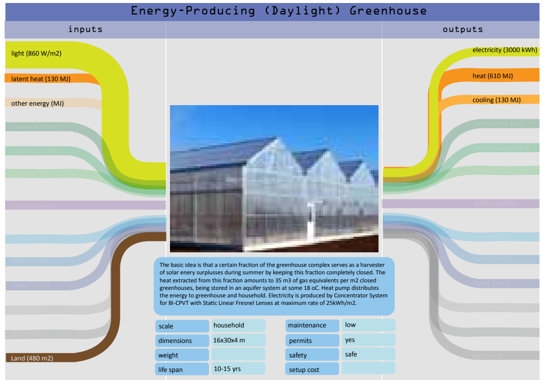
Within the sustainability field, there is a debate about the optimal scale and degree of centralization of technologies for energy generation, waste processing, and other resource management. There is a tradeoff between the costs and materials required for decentralization and the flexibility and responsiveness of the system.

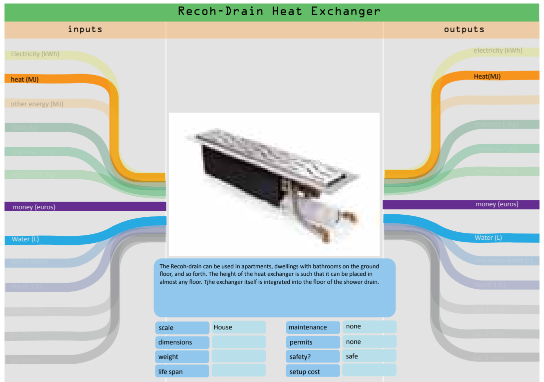
It is possible to develop an algorithm for determining the optimal level of technological decentralization by factoring in parameters such as: the occurance of a resource (spatial density and abundance), the cost of the technology required to process that resource until it is useful, the material impacts of the processing technology (represented sometimes in proxy by cost), the cost of transport, and the density of demand / consumption of that resource. These variables are constantly in flux, so the answer to how centralized or decentralized should optimally be is also contantly changing.

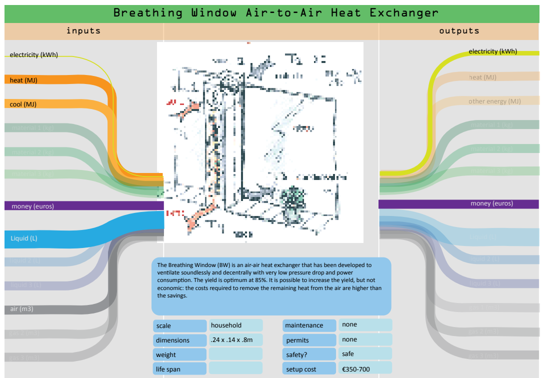
The system designs presented in this report do not reflect an optimal level of technological decentralization. Rather, because the main focus of this project is to illustrate what is possible even within severe financial constraints, our primary drivers for technological selection in this regard were the expressed desire of the community to be self sufficient and the financial investment capacity of both communities.

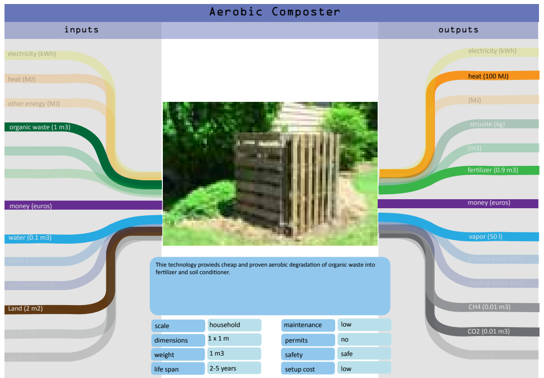










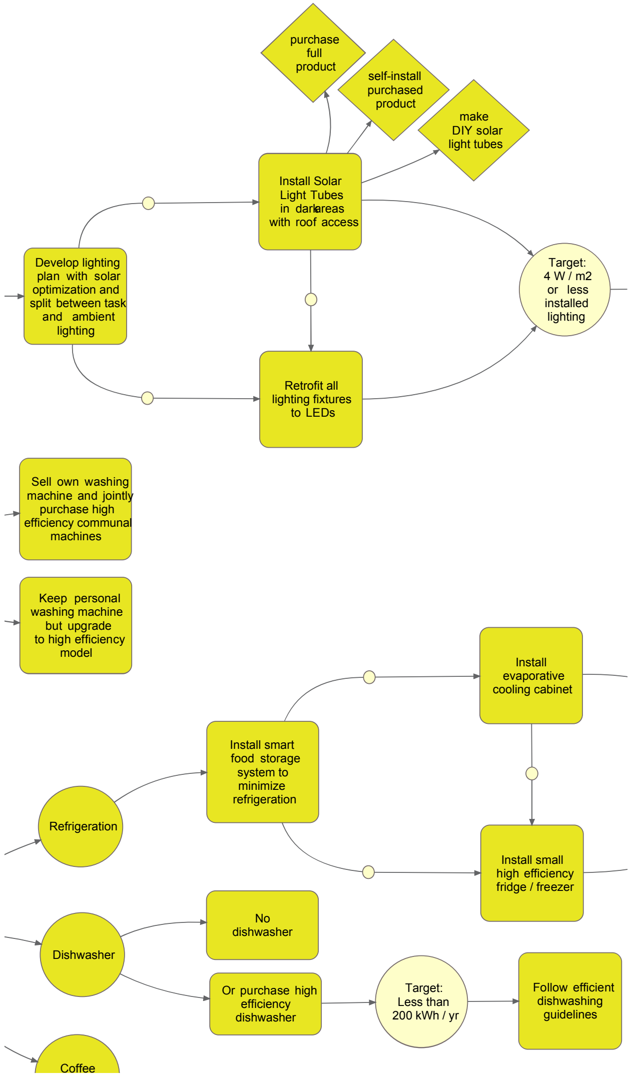


CLEANTECH PLAYING CARDS

As one of the steps in our technical design process, we created over a hundred of the technology "playing cards" shown on the left. By mixing and matching the flows, the cards were used to help build an ecosystem of appropriate technologies for the site.

CTP TOOLKIT

The Cleantech Playground and the community around it inspired us to think beyond delivering a report and becoming involved in the project as a stakeholder. Metabolic Lab produced two tools for the community to use in consultation. A technology selection tree and complimentary financial modeling tool provides community members the capacity to choose technologies unique to their preferences and financial ability. The tools are simple and straightforward, but they serve to empower the community to make informed decisions before and during the project, and allow the project's output to apply to different projects with contextual differences. Metabolic Lab will work with the de Ceuvel and Schoonschip communities and help apply these tools to inform engineering calculations and investment decisions.

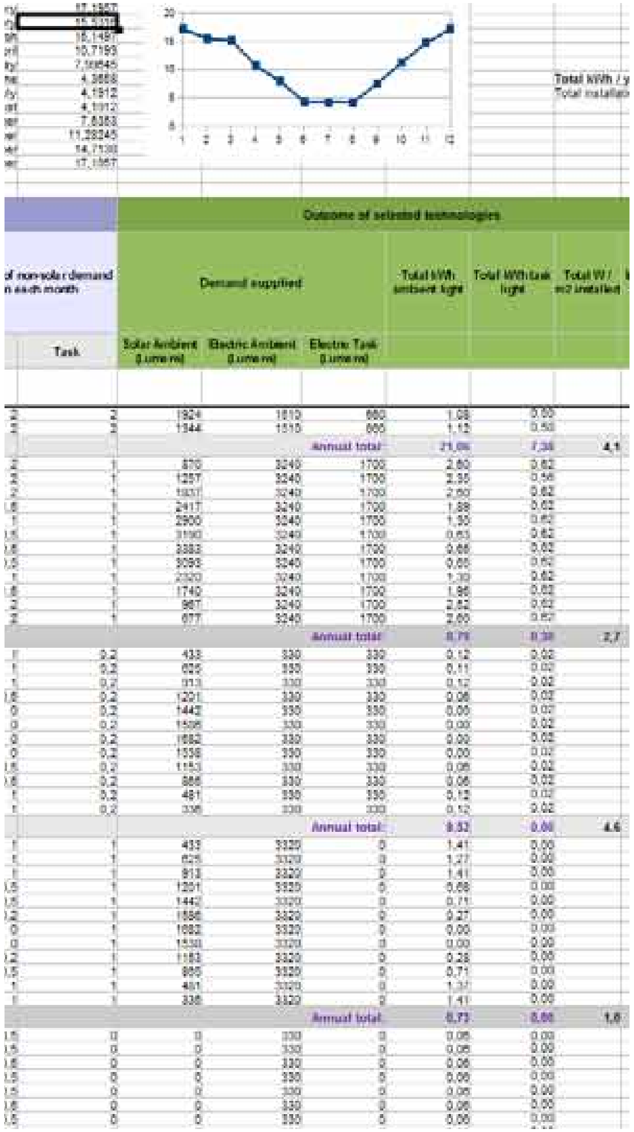


TECHNOLOGY SELECTION TOOL

The technology selection tool is a decision tree that allows people to choose technologies based on their financial and comfort preferences. Both sites have fixed infrastructure, such as the wastewater system, which are not included within the flexible elements covered by the decision tree. Other key decision a homeowner must make about their household, such as walls, insulation, and lighting, become parameters that can be worked out using this set of tools.

The selection tool works similarly to purchasing a computer. Customers choose a base model and can then include additional RAM, a faster processor, a larger screen, and a better video card. In the decision trees, community members can customize the solutions they choose to meet performance targets of the system as a whole.

As part of our report, we have worked out a decision tree for both De Ceuvel and Schoonschip as model scenarios. This provides the community with a baseline for how to achieve target performance and expresses our recommendations for constructing the average boat. Some members may opt to build more technologies themselves, while others may desire more technological luxury.



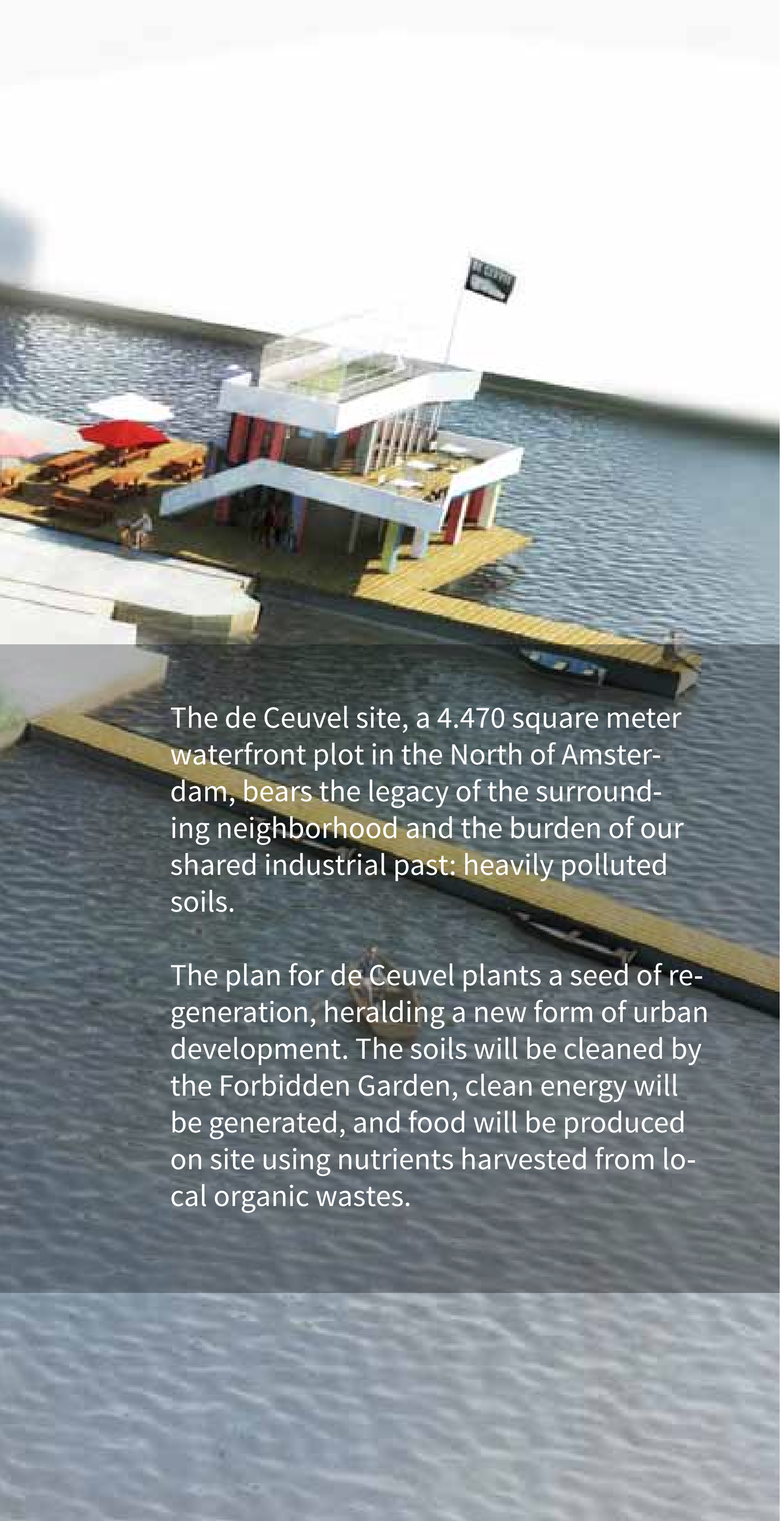
FINANCIAL MODELING TOOL

Once people select the technologies they wish to incorporate in their homes and offices, they can input those technologies in the financial modeling tool and automatically generate short and long-term financial projections. The tool allows for technologies to be turned on or off depending on user preferences. It models up-front costs, costs and savings over 10-years, break-even points, and how the technology selection compares to the baseline scenario.

With this tool, individuals can select a set of technologies that fit their initial preferences and immediately understand what it means for them financially. Together, these two tools can assist the community easily make individual and group decisions about which technologies to invest in during which phase of development.

de ceuvel

vision



The de Ceuvel site, a 4.470 square meter waterfront plot in the North of Amsterdam, bears the legacy of the surrounding neighborhood and the burden of our shared industrial past: heavily polluted soils.

The plan for de Ceuvel plants a seed of regeneration, heralding a new form of urban development. The soils will be cleaned by the Forbidden Garden, clean energy will be generated, and food will be produced on site using nutrients harvested from local organic wastes.

DE CEUVEL IN 2014

Approaching the de Ceuvel site by boat from the south, we see a slowly densifying sea of small floating islands in the water covered in flowering plants and reeds. Darting among these islands are birds and insects. Closer to shore, some of the green platforms are enclosed with bubbles of transparent plastic, serving as microgreenhouses with growing edible crops.

The edge of the land is densely planted with low growing vegetation, all of which has been carefully selected to clean the soil of pollution. A winding wooden boardwalk wraps throughout the site, guiding visitors to the various offices and alteriers placed along the path.

Each of these buildings is an upcycled houseboat, retrofitted to a very high level of ecoefficiency and designed to reflect the style and character of each office. The boats have all been salvaged and repaired by the de Ceuvel association that oversees the site. Each boat is largely autarkic, supplying its own heat, water, and most of its electricity. A centralized toilet and organic waste processing center on the eastern part of the site produces biogas and harvests nutrients from the organic wastes collected.

On the southeast corner of the site is a bustling cafe, whose kitchen is fueled entirely on this locally produced biogas. Across from the cafe is a visitor's center which showcases some of the technologies that are used with live digital displays of the material flows as tracked by the sensor network. Once a week, visitors are offered an experiential tour of the site.

After ten years have passed, the boats will be floated to another site, leaving de Ceuvel behind cleaner and more vibrant.

de ceuvel: urban plan

Greenhouses	250 sqm	DESAR organic waste treatment	110 sqm
Green roof terraces	600 sqm	Reedbed filtration	200 sqm (1.4 sqm/person)
Solar heat collectors	80 sqm (5 sqm / house)	Food production	300 sqm
Solar PV cells	160 sqm (10 sqm / house)	Ecosystem elements	1.500 sqm

The site is divided into two waterbound parcels, which will be linked by a bridge. A curved wooden walkway winding throughout the plot will guide visitors and site users through the area. The upcycled houseboats are scattered across both plots. De Ceuvel's teahouse / restaurant is situated on the eastern parcel, along with the visitor's center and the centralized sanitation and waste facility. A bed and breakfast will be located slightly offshore on a separate floating construction.
The de Ceuvel site will combine the urban and architectural plan of space&matter, the landscape design of Delva Landscape Architects, and Metabolic Lab's technological selection and urban food design.

- total site area: 4,470 sqm
- number of offices: 13
- number of restaurants: 1
- number of workshops: 1
- total walkway area: 450 sqm
- total estimated daily occupancy: 200 people

PROJECT OVERVIEW

The current site for the de Ceuvel development is in a sparsely developed portion of Amsterdam North that was formerly dedicated to industrial activities. The plot of land is now empty, save for a sparse collection of young trees and grasses. A soil report for the site reveals high levels of copper, heavy metals, and other pollutants left behind by past industrial operations. Surrounding the site are mostly low buildings with a mix of commercial activities (e.g., auto repair) and some residences. There is very little traffic at night.

Amsterdam North is a rapidly developing area because of its comparatively low real estate prices, empty tracts of land, and relative accessibility to the city center. There are free ferries that cross the river IJ, taking 5 - 15 minutes to bring passengers between the north and the south sides of the city. North has become a hub of activity for the creative sector, with a number of social and artistic initiatives taking root there among the low-income housing and light industrial activities. The de Ceuvel site follows this pattern: it will be developed as a "Broedplaats," under a 10-year land lease with the express goal of "placemaking." Placemaking is a form of urban upgrading where cultural activities are used to generate traffic and boost the social profile and real estate value of urban areas.

A "Broedplaats" or "breeding ground," is a special category of urban development in Amsterdam. These types of developments receive subsidy funding from the city government and in exchange provide very low rent offices and studios to registered "creatives." Much of the funding for the de Ceuvel project is coming directly from the Broedplaats subsidy, which amounts to a total of 250.000 €. Additional subsidy money or low interest bank loans may also be secured, but at the moment only this base amount of funding forms the project budget.

REGENERATIVE APPROACH

The proposed development for de Ceuvel is uniquely regenerative, leaving behind cleaner soils and water, producing rather than consuming resources, and enhancing existing community structure and economic activity. All buildings on the site will be placed temporarily on the surface without significant foundations. The houseboats which will make up the bulk of the built elements on the site are all existing structures rather than new buildings. After the planned ten years of occupancy, the houseboats can be floated to a new location for another round of regeneration, leaving the de Ceuvel site cleaner and mostly unscarred by construction.

To gather useful data about the effects of this plan on local ecosystem quality, we are also recommending that a community biodiversity monitoring program be established to track sitings of various species. The results of this monitoring program will be displayed in a common area on the site. Alongside this information will be live feeds from sensors placed throughout the area documenting the performance of the buildings and systems on-site (energy generation and use, water collection, waste production, etc.). This community tracking system will allow for users to adjust their resource consumption behavior and for visitors to see how the installations are performing in real-time.

DEVELOPMENT STRATEGY

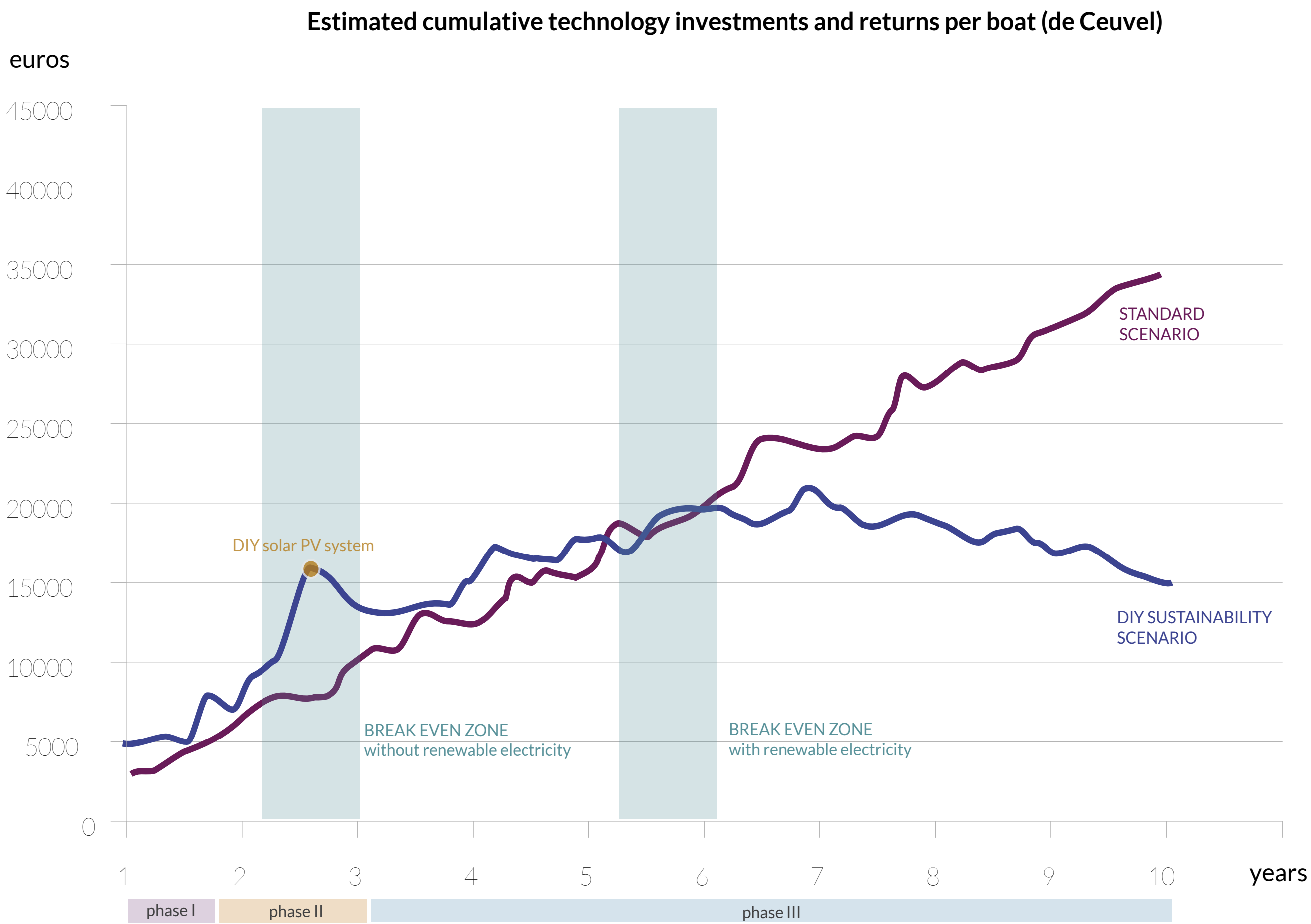
Because the current total budget of the project is relatively small for the magnitude and ambition of the plan, the development process needs to adapt to changing conditions. Most of the approaches suggested in this report focus on do-it-yourself (DIY) installations. Materials will be purchased as inexpensively as possible or sourced from waste streams. They will be acquired in unassembled form, which will also require a high input of labor from the development team.

The proposed technological plan unfolds over three phases, which are briefly described in on the next page and in more detail in the "deployment strategy" section that follows. Broadly speaking, the first phase involves basic repairs and upgrades to the boats at an offsite location. The second phase involves placing the boats on-site and continuing with interior boat upgrades. In the second phase, communal infrastructure such as walkways, gardens, and waste processing will also be installed. The third phase will include adding solar electricity generation, floating ecological platforms, and continued technological upgrades.

Completing the reconstruction of the boats off-site extends the total lease period of the land (which officially begins as soon as the boats are placed onsite), and avoids the need for acquiring additional permits.

The boat reconstruction will be overseen by a foreman experienced in houseboat renovation. Teams from both space&matter and Metabolic Lab will also be involved throughout the construction process to find materials, adjust designs, and help with the physical execution of the project. An overall goal is to document the construction process on video and host DIY workshops during the retrofitting to give outside groups an opportunity to learn more about eco-retrofitting techniques.

de ceuvel: costs and time line



This graph is indicative of the general pattern of investment and return of the base case (business as usual) in comparison with the DIY sustainability scenario we describe in this report.

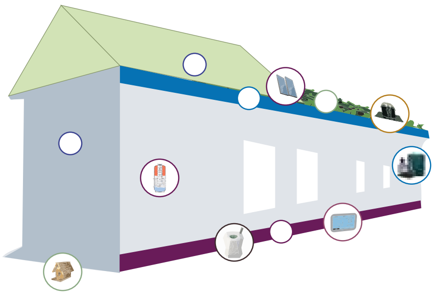
TOTAL COSTS AND LABOR

The total costs we project for the eco-upgrading of the houseboats and the construction of communal infrastructure on the de Ceuvel site range from an estimated 15.000 € to approximately 30.000 € per boat, in comparison to 8.000 - 15.000 € for the business as usual scenario. These numbers are based on sketch designs of the recommended technological systems and price estimates from various online suppliers.

A surprisingly fast return on investment of 2-3 years is possible in the best case scenarios we have calculated. Because the site is currently undeveloped, the "business as usual" costs would include the construction of standard utility infrastructure (gas, water, sewage, electricity), which would amount to a total of around 3.000 € per boat. By eliminating the need for gas, water, and sewage connections we save an estimated 1.900 € per building in up-front costs. The DIY approach also keeps the costs of new technologies very low. Even without an "eco-upgrade," basic renovations of the boats would only be marginally cheaper than with the added technologies.

After phase one, each boat renter will save an estimated 1.000 € per year on heating costs. Additional savings on electricity, food, and water will also achieved through the plan, though these all depend on what the final installation looks like. It is impossible to have a completely accurate prediction of costs and returns at this stage because the development approach is largely based on finding suitable, inexpensive materials during the construction process. The plan will be adjusted after the first pilot construction is completed in March 2013.

PHASE I : MARCH 2013 - SEPTEMBER 2013

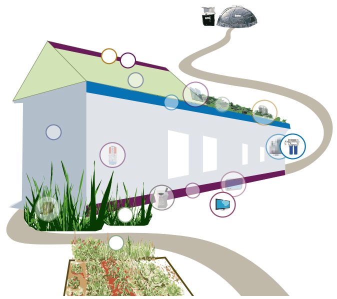


In phase one, the boats will be retrofitted off-site and the site will be prepared for the phytoremediation garden and infrastructure installations.

Efficiency targets have been defined for each boat in terms of heat and electricity demand, water use, and sewage management. Because the budget is limited, we will follow a priority list of modifications that need to be made to each boat, focusing on major changes to the building envelope (insulation and roof), and continuing as far down the list as the budget allows. After installing the insulation and heating system, we will continue with electricity-efficiency measures, green roof construction or DIY greenhouses, and the installation of dry toilets. Additional upgrades will be made over time once the boats are placed on site.

We estimate a minimum of 160 hours of labor per boat for the basic installations recommended in phase one and a conservative estimate of 240 hours. The materials budget is limited to 5.000 €.

PHASE II : SEPTEMBER 2013 - JULY 2014



In phase two, the boats will be placed on site and essential site infrastructure will be constructed, including communal sanitation and wastewater treatment facilities as well as the walkways and phytoremediation garden.

Phase two is currently scheduled to begin in September 2013. Shallow platforms will be installed on-site to stabilize the boats, prevent them from sliding, and provide additional insulation. The walkway will be constructed and used to store some infrastructural elements such as electricity cables. The interior of the boats will be further improved, with individual boat owners having the option to further reduce electricity consumption demand and upgrade water purification and heating systems.

The communal wastewater treatment and biogas plant will also be constructed at this time. The construction of this facility is partially dependent on finding an appropriate partner (wastewater utility or private company) willing to assist with the final engineering and exploitation of the plan.

In this phase, we will prepare the site for food production in raised beds. Community monitoring equipment will also be installed to record and showcase the system's performance.

We estimate around 800 hours of labor for communal installations and a total cost of around 10.000 €.

PHASE III : JULY 2014 - SEPTEMBER 2023

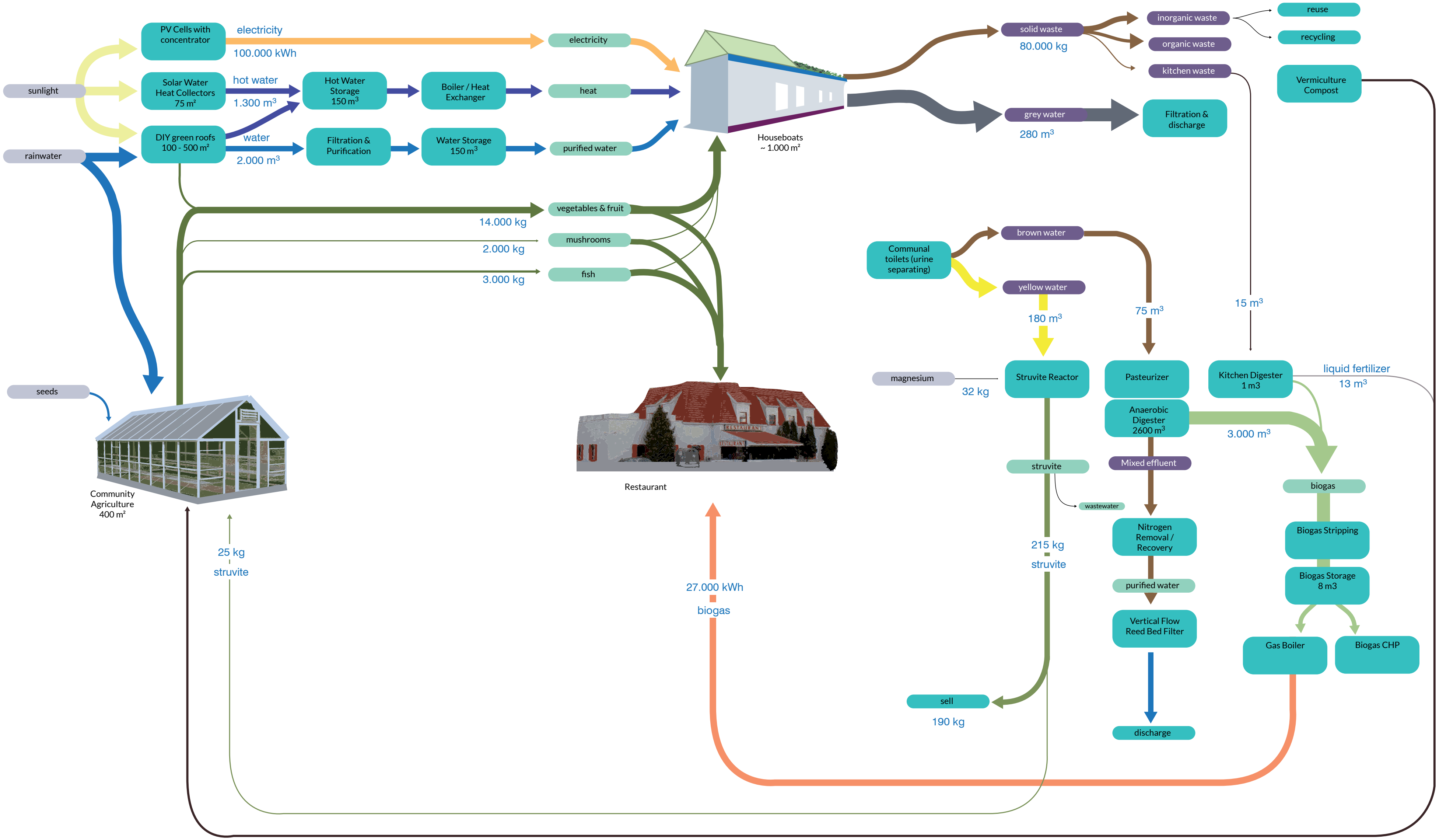
Phase three is the least defined because it is largely dependent on the progress made in the preceding two phases. Exact activities will depend on the availability of financing and community investment preferences.

At minimum, we expect that site additions in this phase will include floating garden platforms, electric power generation capacity, and a variety of potential upgrades to existing systems.

An inexpensive DIY system of solar PV panels will cost an estimated 5.000 € per boat, with additional costs for efficiency boosting elements (e.g., concentrators) and electric storage capacity. However, as technology is advancing rapidly in the solar sector, it is possible that these prices will be lower by the time a purchase needs to be made.

With the capacity to sell excess electricity back to the grid and highly energy efficient offices, we have calculated that these inexpensive solar installations could have a payback time of as little as five years. A decision about whether to invest in additional power generation or other technologies should be made by the group during phase two.

de ceuvel: final material flows



FINAL SYSTEM PERFORMANCE

At the end of the first two development phases, the house-boats on the de Ceuvel site should be fully self-sufficient in renewable heat, water collection and upgrading, and have much lower electricity demand than a conventional office building. The buildings themselves will not only be highly eco-efficient, but also designed in a variety of architectural styles with creative exterior finishing.

Communal constructions on the site will also provide shared sanitation facilities, organic waste treatment, nutrient recovery for use in on-site food production, and digital monitoring and feedback of system performance.

The targets achieved on the site will differ depending on whether or not the community opts for investment in renewable electric-ity generation in phase two.

TARGETS ACHIEVED WITHOUT RENEWABLE ELECTRICITY SUPPLY:

- 50% - 70% renewable heat and hot water supply
- 50 - 70% reduction in electricity demand over conventional
- 100% wastewater and organic waste treatment
- 80% nutrient recovery
- 100% water self-sufficiency
- 10 - 30% vegetable & fruit production using lo-cally recovered nutrients
- sensor network and real-time system perfor-mance displays

TARGETS ACHIEVED WITH RENEWABLE ELEC-TRICITY SUPPLY:

- 100% renewable heat and hot water supply
- 100% renewable electricity
- 100% wastewater and organic waste treatment
- 100% water self-sufficiency
- 80% nutrient recovery
- 70% reduction in electricity demand over con-ventional
- 10 - 30% vegetable & fruit production using lo-cally recovered nutrients
- sensor network and real-time system perfor-mance displays

de ceuvel

deployment plan

The primary challenge in the execution of the de Ceuvel CTP plan is the limited budget, which needs to be compensated for with creativity and hand labor. Most technologies installed will be of the do-it-yourself (DIY) variety. The plan needs to remain adaptable as the construction team finds cheap or free materials for use in the design.

In this section, we provide an overview of the general process for retrofitting the boats and constructing the planned communal facilities on the site.

DEPLOYMENT SUMMARY

Construction for the de Ceuvel development will begin in March of 2013. The first phase of the project involves clearing the site, securing free or inexpensive houseboats, and renovating the houseboats in an off-site location. The renovated boats will be moved to the de Ceuvel site in September 2013. Further work will take place there, including the construction of the communal wastewater treatment and biogas production facility, the walkways linking the boats, the phytoremediation garden, food production, and floating garden platforms.

The three recommended phases for the development of the de Ceuvel site are detailed on the following pages. The test case described here details one selected set of technologies, though the plan can be adopted to others as well. The final result of each boat reconstruction and the site as a whole will vary depending on the types of materials and prices that can be sourced throughout the building process.

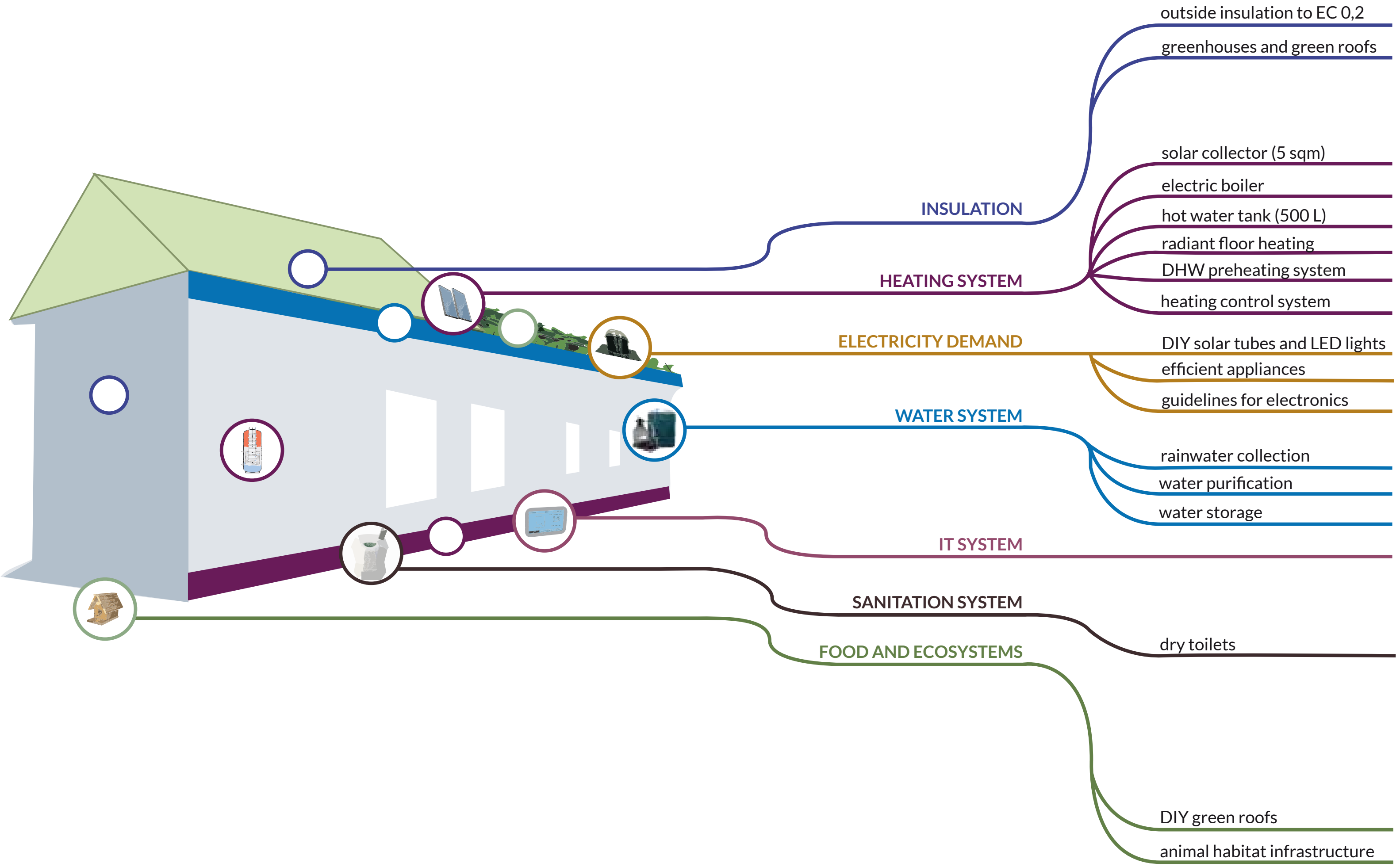
For each phase, we summarize the targets that we expect to achieve with the proposed interventions and we itemize the primary steps that need to be taken to achieve these targets. Cost and labor estimates are included, but are subject to change once the process is actually underway. The interventions described in each phase are included in order of priority.

PILOT BOAT

This deployment plan will be fully tested in March 2013 when we will renovate the first pilot boat. Based on actual costs and labor requirements, we will adjust the recommendations for the renovation of all other boats on the site.

phase I

DE CEUVEL PHASE I: ACTIVITIES



In phase I of the de Ceuvel project, the houseboats which will eventually go on the site will be purchased and retrofitted.

The primary interventions we recommend are summarized in the graphic on the left.

DE CEUVEL PHASE I: TARGETS

ENERGY & MATERIALS

- Boats retrofitted to an insulation value of at least EPC 0,2
- 50 - 75% renewable heating supply
- 30 - 50% reduction in electricity demand over conventional
- 100% water supply (conditional on permits)
- No gas or water hookup for boats
- Sensors installed to support later IT infrastructure

CULTURE & ECONOMY

- Total phase I materials cost not to exceed 5.000 €
- Organize community management for DIY construction process
- Secure financing for future technology investments
- Document the construction process
- Codify experience in educational workshops and materials

ECOSYSTEMS & SPECIES

- Install structural ecosystem support elements on roofs and building structures (green roofs, small habitat elements)

HEALTH & HAPPINESS

- Aesthetically pleasing in outside appearance: incorporate custom decorative elements in building structures and conceal technological systems like rainwater collection
- Achieve high level of comfort for users by maintaining modern standards of living
- Use only non-toxic materials

BOAT RETROFITS AND SITE PREPARATION

Phase one of the de Ceuvel development is focused on the following tasks:

- purchasing or acquiring houseboats in suitable condition (free or inexpensive)
- making essential upgrades to the houseboat building envelopes and infrastructure, and adding in as many eco-upgrades as the budget allows
- clearing the site in preparation for the phytoremediation garden

There is a strict budget of 5.000 € per boat for materials costs. To compensate for this small budget, there will be a large team of volunteers to contribute labor.

IMPROVIZATION

Because the boats will be of varying quality and uncertainty remains as to the type and cost of materials that we will be able to source for the project, this deployment plan calls for a great deal of creativity and improvization.

The highest priority in phase one is to eliminate the necessity for as many utility connections as possible, which will lead to overall savings necessary for the financial viability of the plan. The goal is for the boats to only have one utility connection: electricity. Gas, water, and sewer connections should be eliminated.

The process of retrofitting the pilot boat will be an essential step in confirming whether or not we can achieve the necessary targets to avoid these connection costs and secure the permits required. Gas connections, for example, are not required if buildings are sufficiently insulated.

PRIORITIZATION

We will complete the boat retrofit following the sequence outlined here (in order of importance):

- **basic repairs:** fixing leaks and visible gaps in building envelope and roof
- **insulation:** performance testing of scavenged materials that may be suitable for insulation; upgrading insulation to at least EC 0,2 (0,2 W/m^2.K)to eliminate the necessity of a gas connection; fitting DIY greenhouses or green roofs to add roof insulation
- **solar heat:** installing solar heating tubes and an insulated hot water storage tank in the boat crawl space
- **heating system:** installing an electric boiler and heat distribution system (either floor heating or using the existing radiators, depending on the boat); potentially adding in a small wood-burning stove for supplemental heat
- **water supply:** a rainwater collection, storage, and upgrading system will be installed as part of the roof retrofitting and can be coupled with the installation of a DIY greenhouse or green roof
- **sensors:** inexpensive sensors should be installed at this phase if the budget permits since all constructions will be exposed; these sensors can later be connected to the neighborhood IT system which will monitor and display the performance of all the installations
- **daylighting:** to reduce electricity demand, as much daylight access as possible should be included through solar tubes and skylights
- **ecosystem:** planned ecosystem and habitat elements on the boat level include small habitat constructions (for example, bird or bat nesting elements in the building roof or facade) as well as green roof structures; green roofs will be installed for insulation, water collection, and ecological value, but the type of green roof will vary depending on the bearing capacity of the structure
- **sanitation:** in order to centrally process organic wastes on site, the boats will all be equipped with dry toilets and no sewage connection; a dry toilet construction will either be added in phase one or phase two depending on what the materials budget allows

CODIFYING KNOWLEDGE

An important part of the pilot boat construction phase in particular will be the codification of our experience during the process. This will be accomplished through at least two means: video recordings and the hosting of workshops at certain key points in the construction.

1 basic repairs

The first step of the retrofit process is to perform tests to uncover any air leaks and identify the air flow patterns within each house, which can be done with a smoke test.

To evaluate the effectiveness of the retrofitting and document the process, each boat will be photographed with infrared cameras before and after construction.

On the basis of the initial tests, we will develop a plan to seal all air leaks in the building. We have a detailed process guide that will be followed depending on the circumstances and materials present in each boat. Once all the air leaks are sealed, and during the process of sealing the leaks, we will conduct an insulation scan to examine the existing insulation within the house and identify any areas where it might be damaged.

For each boat, we will be examining the possibility of increasing passive ventilation units with heat recovery to ensure sufficient air flow once the boats are made highly airtight.

COST & LABOR ESTIMATES

We estimate that sealing gaps will cost around 100 € in materials (caulking, foam strips, and other sealing elements) and require up to 10 hours of labor.

2 insulation

One of the primary retrofit activities will be the addition of insulation to the boats to a target level of 0,2 $W/m^2.K$. Insulation efforts will focus on these areas in order of importance: roof, exterior walls, windows, ducts and crawl spaces, basement and foundation, ceiling, and floor.

In timber frame structures, which will be the most common among these boats, breathability is important to prevent moisture buildup and rot. For this reason, only open cell insulation can be used coupled with appropriate vapor and radiant barriers installed on the inner wall.

Interior insulation is unlikely to be possible, so we will focus on insulating the boats from the outside by constructing a batten frame using inexpensive recycled wood and filling it with an appropriate insulation material, such as loose fill cellulose. We estimate that at least 20 centimeters of insulation will be needed to reach the target U value. The roof will additionally be insulated with a DIY green roof or greenhouse installation.

It is not within the budget of this project to replace windows, but their air tightness can be improved by replacing sliding mechanisms with spring loaded insulated sliders and installing weather stripping and window putty around the frames. The space around the windows will be beveled to allow additional light into the building, and outside storm windows can be installed for added insulation value.

The outside cladding of the frame will be finished in a customized manner for each boat with architectural design.

COST & LABOR ESTIMATES

Total costs for the insulation step is estimated at 2.500 € and 90 hours of labor. This may vary depending on the type of materials found.

3 solar heat

A central step in achieving a renewable heat supply in the de Ceuvel boats is the installation of a DIY solar space and water heating system.

Each boat should be fitted with a 5-square meter collector system and have an insulated water storage tank of 500 liters in the boat's basement or crawl space to store the heated water.

We recommend a flat plate collector with a drainback system to prevent freezing without necessitating any potentially hazardous anti-freeze agents. A differential controller will activate the pump and determine when the water needs to be moved from the collector to the storage tank.

The storage tank will provide hot water for both domestic hot water use as well as space heating, which will be self-constructed from PEX coils running underneath the flooring.

COST & LABOR ESTIMATES

The estimated costs for the DIY solar collector and water storage system are 1.600 €. Installation of the system will require approximately 40 hours of labor.

4 heating system

The heating system on each houseboat will consist of DIY radiant floor heating connected to the solar collector and topped up by an electric boiler. This system can be upgraded in phase two with additional heat collection from the greenhouse using fresnel lenses.

If possible and deemed necessary for risk management on each particular boat, we may also install wood burning stoves for supplemental heating.

Most boats will come equipped with a gas boiler, which can also be sold to recoup some of the costs of purchasing an electric boiler and the floor heating installation.

COST & LABOR ESTIMATES

Electric boilers can be purchased for as little as 300 €. The materials for the floor heating system and its associated controls are estimated at 700 €. The labor for installation is estimated at 60 hours.

5 water supply

Rainwater harvest potential on the de Ceuvel site is around 800 milimeters per square meter per year. We intend to use the roof of each houseboat as a rainwater collection system. This rainwater will be put through a sand filter prior to storage in water tanks. An upgrading system including UV filtration, water softening, mineralizers and stabilizers will purify the water to potable quality.

The collection system will consist of pipes of 5 - 10 centimeters in diameter connecting to the filtration and treatment system.

Water storage tanks will hold water of different quality levels. A 2 m^3 holding tank will be used for potable water. Filtered (but not upgraded water) will be stored in a 1 m^3 tank and can be used for garden irrigation.

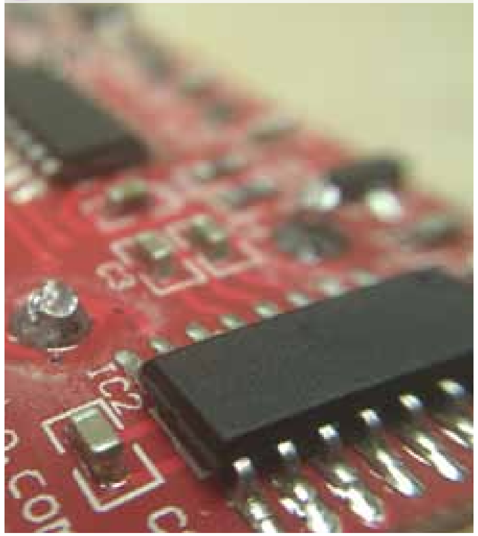
The type of material used for surface collection should be free of chemical additives to avoid contamination. Rainwater quality on the site will first need to be tested to ensure that ambient pollutant levels are low. If this is not the case, then reverse osmosis will need to be added as a purification step in addition to UV filtration.

COST & LABOR ESTIMATES

A DIY rainwater collection system will cost an estimated 800 € if all materials need to be purchased new. However, most boats will already have some form of guttering which can be re-used for this purpose amounting to a significant cut in costs. The installation of the system will require an estimated 20 hours.

Upgrading the water to drinking-level quality will cost approximately 1.500 € and 25 hours of labor. We recommend that this step be left for phase two. If the water collection system proves too expensive during the pilot boat construction, we will default to a standard municipal water connection.

6 sensors



Sensors for temperature, pH, and resource flow monitoring should be installed during the construction process whenever feasible. Placing them at this stage while many technologies are exposed will facilitate the monitoring and display system that will be installed for the community in phase two.

Recent advances in sensor technology, and the development of small plug-and-play modules such as Arduino chips makes this cost-feasible. Inexpensive microcomputers like Raspberry Pi can also be used to monitor and control distributed sensor systems.

COST & LABOR ESTIMATES

A Raspberry Pi microcomputer retails at 35 €. An arduino costs around 100 €. We estimate that the sensor system for each boat will cost an estimated 500 € and cost 10 hours to install. This installtion time does not include the design and programming of the system.

7 daylighting

To reduce electricity demand for lighting, we also recommend the installation of skylights and suntubes at this stage whenever it is feasible. Retail suntube systems can be quite expensive (500 - 1.000 € a piece). DIY systems can be quite cheap by contrast, but require very careful installation to avoid any roof leakage and cold bridge formation.

COST & LABOR ESTIMATES

It is difficult to estimate how many solar tube installations will be appropriate per boat, since some boats may already have these installed. We assume that each DIY solar tube system will cost an estimated 100 € and that an average of three will be installed per boat, totalling 300 €. We estimate the installation of these solar tube systems to total 20 hours.

8 ecosystem

For a variety of reasons, we recommend that all rooftops on the de Ceuvel site have a significant percentage of green roof cover. Green roofs bring benefits not only in terms of improved insulation, water retention, and roof durability, but also serve as an ecological habitat structure. The cost of a professionally installed green roof can be as high as 200 € per square meter. A DIY system can amount to a small fraction of the cost (e.g., 10 € per square meter). Care must be taken to ensure that the roof construction can bear the extra weight of the substrate, plants, and water.

We recommend that the roof be reinforced during the installation of insulation. The insulation frame can also be extended above the boat to create an added support structure for a green roof.

COST & LABOR ESTIMATES

We estimate that a DIY green roof will cost roughly 10 € per square meter for materials, amounting to 750 € for a roof surface of 75 square meters. A conservative labor estimate is 80 hours for the installation.

9 sanitation

To eliminate the need for a sewage connection and simplify the processing of organic wastes on site for energy production and nutrient recovery, we recommend that all boats on site be equipped with a dry toilet. In contrast to standard flush toilets, composting toilets are very simple constructions that collect waste into a compartment.

We recommend the Loowatt toilet (pictured above), which stores waste in a sealed biofilm to eliminate odor. The sealed storage compartment must be emptied once a week and can be directly taken to the on-site digester installation. This sanitation system will require some adaptation in terms of user behavior, but has the benefits of being comfortable and odorless. Alternatives to the Loowatt include standard composting toilets.

COST & LABOR ESTIMATES

Loowatt is still under development and we have requested a price quote from the UK-based company. A comparable DIY composting toilet system will cost an estimated 300 € and require five hours of de-installation (of the existing toilet) and installation of the new dry system. The old toilet can potentially also be sold for a small profit if it is not too old or damaged.

COST AND LABOR SUMMARY (PER BOAT)

component	€	hours
basic repairs	100	10
DIY insulation	2.500	90
DIY solar collector	1.600	40
DIY heating system	1.000	60
DIY rainwater collection	800	20
DIY sensor system	500	10
DIY daylighting	300	20
DIY green roof	700	80
Sanitation: dry toilet	300	5

budget limit

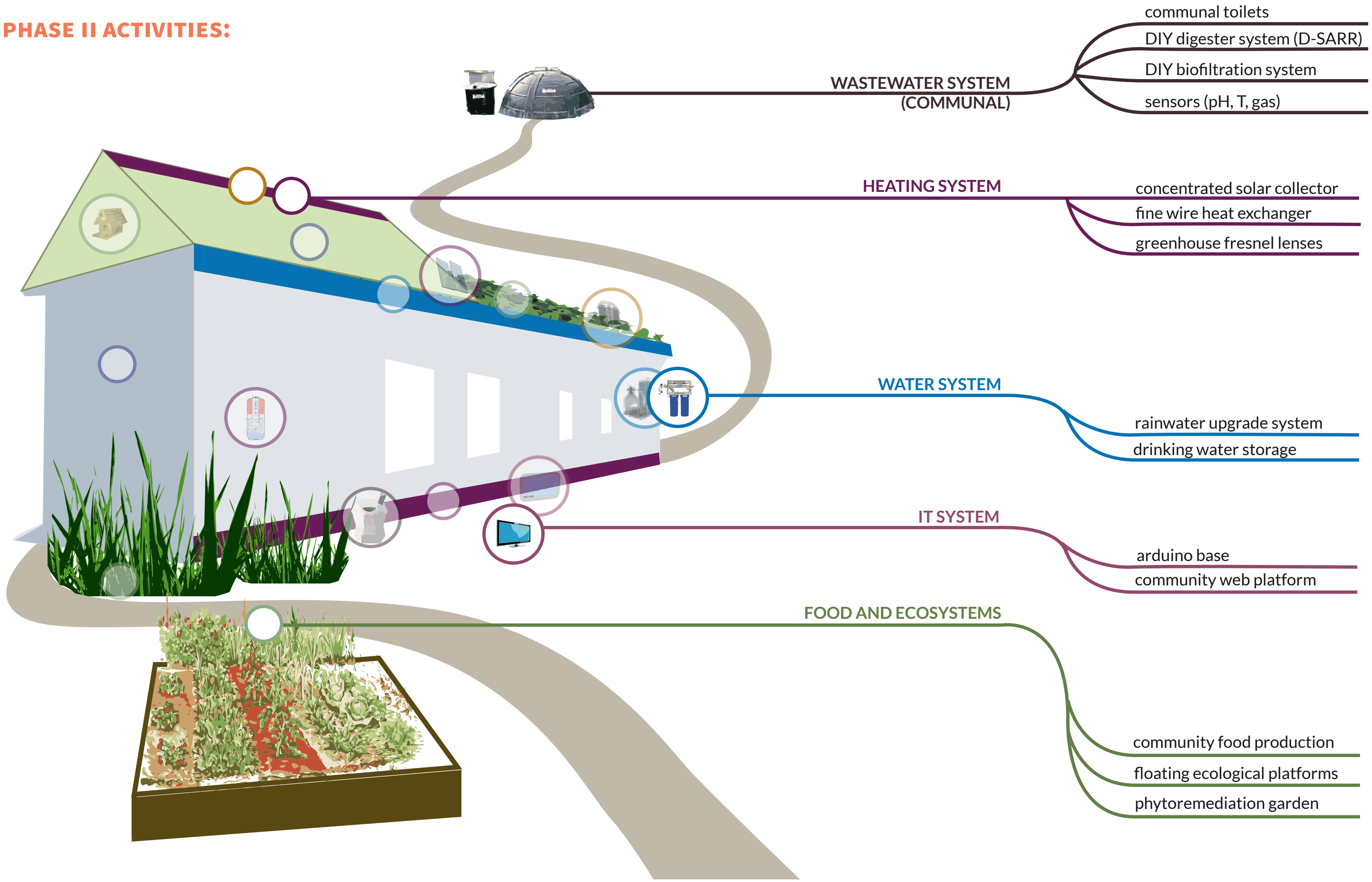
As seen in the chart to the left, our current estimates indicate that the 5.000 euro materials budget will just barely suffice for basic repairs, insulation, and the installation of the heating system. The remainder of the desired phase one activities falls beyond the current budget.

However, because these costs are based on retail material prices, we hope to achieve significant savings by sourcing waste materials. Metabolic Lab will work in close collaboration with the builders and architects to evaluate the suitability of found materials for construction as well as design purposes.

In the pilot boat construction phase, all costs and actual labor hours will be carefully recorded to improve estimates for the remaining retrofits.

phase II

PHASE II ACTIVITIES:



In phase two of the de Ceuvel project, the houseboats will be placed on the site and basic communal infrastructure will be built.

The major interventions proposed for this stage are summarized in the graphic to the left.

PHASE II GOALS:

ENERGY & MATERIALS

- 100% renewable heat and hot water supply
- 100% renewable electricity supply
- 100% wastewater and organic waste treatment
- 100% water self-sufficiency
- 80% nutrient recovery

CULTURE & ECONOMY

- Establishment of community management structure
- Installation of monitoring and feedback IT system
- Implement guidelines for efficient appliances
- 10% fruit and vegetable production
- Determine a financial structure for future investments
- Ensure financial viability

ECOSYSTEMS & SPECIES

- Installation of structural ecosystem support elements in buildings, walkway, and surrounding waterway
- Establishment of community ecological monitoring program

HEALTH & HAPPINESS

- Aesthetically pleasing in outside appearance: incorporate artistic and attractive elements in landscape quality
- Conceal technology like rainwater collection system
- Achieve high level of comfort for users by maintaining modern standards of living
- Create enjoyable communal spaces and social activities

on-site construction

ON-SITE CONSTRUCTION AND COMMUNAL INFRASTRUCTURE INSTALLATION

Phase two of the de Ceuvel development is focused on the placement of the boats and the construction of infrastructure on the site. It consists of the following steps, in approximate order of activity:

- building platforms on the site to support the boats
- placing the boats on site
- planting the phytoremediation garden
- building the walkway and installing utility infrastructure as needed (ideally only electricity hookups)
- building communal facilities for sanitation, wastewater treatment, organic waste treatment, biogas production, and food production
- finishing boat interiors
- installing electricity-generating capacity and upgrading heating systems on the boats
- reducing electricity use per boat by applying additional efficiency measures
- setting up a web platform and community digital display which will provide live feeds about resource use on site

There is currently sufficient financing in the project budget for all of the basic construction and infrastructural elements in this part of the plan, up to and through the building of the walkway and standard utility infrastructure.

The elements specific to the Cleantech Playground plan begin with the communal facility installations. The extent to which phase two of the CTP technological plan can be completed as planned will depend on our success in phase one and the group's ability to secure additional financing, partnerships, and permits where needed.

PRIORITIZATION

The technological installations of phase two will be completed in the following order of priority:

- **wastewater & organic waste:** building a centralized sanitation, wastewater and organic waste treatment facility which will consist of communal toilets, a modular digester system (D-SARR), and water filtration elements; this digester system will produce biogas and recover nutrients for reuse on site
- **biogas production:** producing biogas in the D-SARR reactor and collecting it for use in the on-site restaurant
- **nutrient recovery:** recovering phosphorus from the D-SARR reactor for use in on-site food production; removing and potentially recovering nitrates for agricultural use
- **power generation:** installing solar photovoltaic panels and fresnel lens concentrators for the generation of renewable electricity
- **heating upgrade:** using fresnel lenses for additional heating capacity for the boats' heating systems
- **food production:** constructing raised bed gardens on the eastern part of the site which will be used for some local fruit and vegetable production
- **web platform:** connecting the sensor network to an online platform that will display live feeds of resource use on site in a central communal area
- **habitat elements & floating gardens:** building and installing floating garden platforms for the water surrounding the site using ecological materials; installing additional habitat structures on buildings and walkways|
- **drinking water:** installing a drinking water upgrade for the rainwater system if the appropriate permits can be secured

In addition to these physical activities, we will also be working with the community to recommend appropriate site management protocols. The equipment on site, such as the reactor, the water collection systems, and the food production, will all require a certain level of maintenance and participation. The community will need to clearly define who is responsible for which activities and where financing will come from to pay for this anticipated maintenance.

Finally, beyond overall site maintenance activities, community members will need to follow guidelines on energy efficiency and avoiding the use of chemicals. We have drawn up simple manuals for the purchase of personal electronic equipment and office appliances. In the initial months of the use of the de Ceuvel site, the monitoring system will show exactly how much energy is used on site and where that use is primarily coming from.

1 wastewater & organic waste

There are several types of organic waste that will be generated on the de Ceuvel site, including wastes suspended in wastewater, kitchen scraps, and green wastes from food production and landscaping. Within the CTP plan, a primary objective is to recover as much of the calorific value and nutrients from these waste streams as possible.

WASTEWATER COLLECTION

To avoid the costs and impacts of the installation of unnecessary infrastructure on the de Ceuvel site, we have recommended that all the toilets in the individual houseboats be dry toilets which do not require any water for flushing (as described in the phase one section of the deployment plan).

One centralized set of flush toilets will be located on the eastern parcel of the site. These will be urine separating toilets, which have separate collection of urine and solid waste. Urine separating toilets allow for the use of much lower quantities of water in the flushing process, reducing the total required volume of the digester. They use only 2,6 liters for a solid flush and 0,2 liters for urine. These two wastewater streams are collected separately and taken through different treatment processes for optimal nutrient recovery.

On the houseboat level, all discharged grey water will be treated with a simple sand filtration and upgrade step before being safely dischared to the landscape.

KITCHEN SCRAPS AND GREEN WASTES

Kitchen scraps and green wastes will be collected mannually by users of the de Ceuvel site in organic waste collection bins. Some of this material can be composted in small scale aerobic vermiculture composters, which will produce nutrient-rich material for direct use in landscaping or on-site agriculture. The excess organic wastes can be macerated and fed into the anaerobic digester unit that will be treating the wastewater produced on site.

D-SARR SYSTEM

The whole wastewater and organic waste utilization system we have designed for the de Ceuvel site is called D-SARR.

The D-SARR system is a modular digester and resource recovery system which is designed to be low-tech and expandible if more capacity is needed (for example, if more people begin using the site). It can also all be placed in one location or its individual components can be distributed across the site as necessary. The D-SARR contains the following elements:

- vacuum collection of wastes from the centralized urine-diverting toilets
- feces pasteurizer
- organic waste macerator
- anaerobic digestion system for the recovery of biogas and fertilizer
- struvite reactor for phosphorus recovery from urine
- N-removal or recovery installation
- vertical flow reedbed filtration system
- water upgrade (UV irradiation, mineralization, softening
- control and quality management system

Because each unit is in a separate contained module, the whole system can be expanded if necessary, and quality control steps can be introduced at each valve to ensure that waste flows are sufficiently treated. A schematic of the D-SARR can be found on the following page.

The resources recovered from the D-SARR include:

- clean water effluent which can be safely dischared or upgraded to drinking water
- biogas
- liquid fertilizers
- purified chemical fertilizers

The feces will be digested anaerobically to ensure that pathogens are destroyed and that the outgoing effluent is safe and can be cascaded to the next unit of the D-SARR for better nutrient recovery. Because the safety of effluent can vary depending on inputs to the system, we advise installing monitoring equipment to analyse and showcase the effluent quality at all times.

A final sand filtration step is equipped with an overflow chamber, allowing water to be directly discharged to the ground after traveling through the entire system. It is very important to ensure that no chemicals are used in kitchens on site or thrown into the toilets, otherwise additional pre- or post- treatment steps, such as reverse osmosis, would need to be taken to avoid ground water pollution.

The D-SARR system will be equipped with its own control system. This largely DIY system will run on Arduino chips connected to sensors. To avoid system failures, any element of the D-SARR which appears to be underperforming will be flagged with an alert. The valves to the flagged unit will be safely shut down and the flows rerouted, without shutting down the whole system. The collection of data on the system's performance will also help standardize its functioning over time and provide valuable data to the academic community.

To keep the costs of this system reasonable, we have recommended that the D-SARR reactor be constructed in DIY fashion by the de Ceuvel group with the advice an oversight of an engineering firm. Some professional oversight is necessary to avoid poor mounting of the units that could lead to leaks, reactor malfunctions, or poorly executed insulation.

The D-SARR system will also require regular maintenance and monitoring to ensure that it is properly functioning. Some possible ways of managing this maintenance demand are to divide maintenance responsibilities among users of the site or to allocate some of the money that would normally be paid to utilities to hire a part-time manager for various aspects of the site.

COST & LABOR ESTIMATES

We estimate the cost of the DIY D-SARR system at 2.700 € per renter on the de Ceuvel site. The total cost of the communal D-SARR facility is 43.000 € and will require an estimated 350 hours of labor to build and install overall (22 hours per renter). A commercial version of a reactor performing the same functions would cost an estimated 10.000 € per boat, or a total of 160.000 €.

A DIY reedbed filtration system will cost an additional 1.000 € per renter and require an estimated 70 hours of labor. The management and control system is estimated to cost an additional 100 € per renter, including microcomputing equipment, sensors, and a display.

Our material cost calcuations are based on the assumption that they will be purchased from inexpensive sources in Asia or Eastern Europe.

With the lower cost of installation of a DIY system, the anticipated return on investment can be under five years. To arrive at this figure we consider that without the D-SARR system and solar heating, each boat would require around 2.000 € worth of new infrastructure connections. The biogas and valuable nutrients (such as struvite) can also be sold by the association for a small annual profit. For this return on investment to be achieved, maintenance costs will also need to be kept relatively low.

2 biogas production

The biogas produced from the digestion of organic wastes in the D-SARR system will be used to run the D-SARR itself (for heating the pasteurizer and keeping the reactor at a suitably high temperature), and for use in the restaurant on site. The link between the biogas at the restaurant and the adjacent D-SARR treatment facility should be made transparent and educational for all visitors to the area.

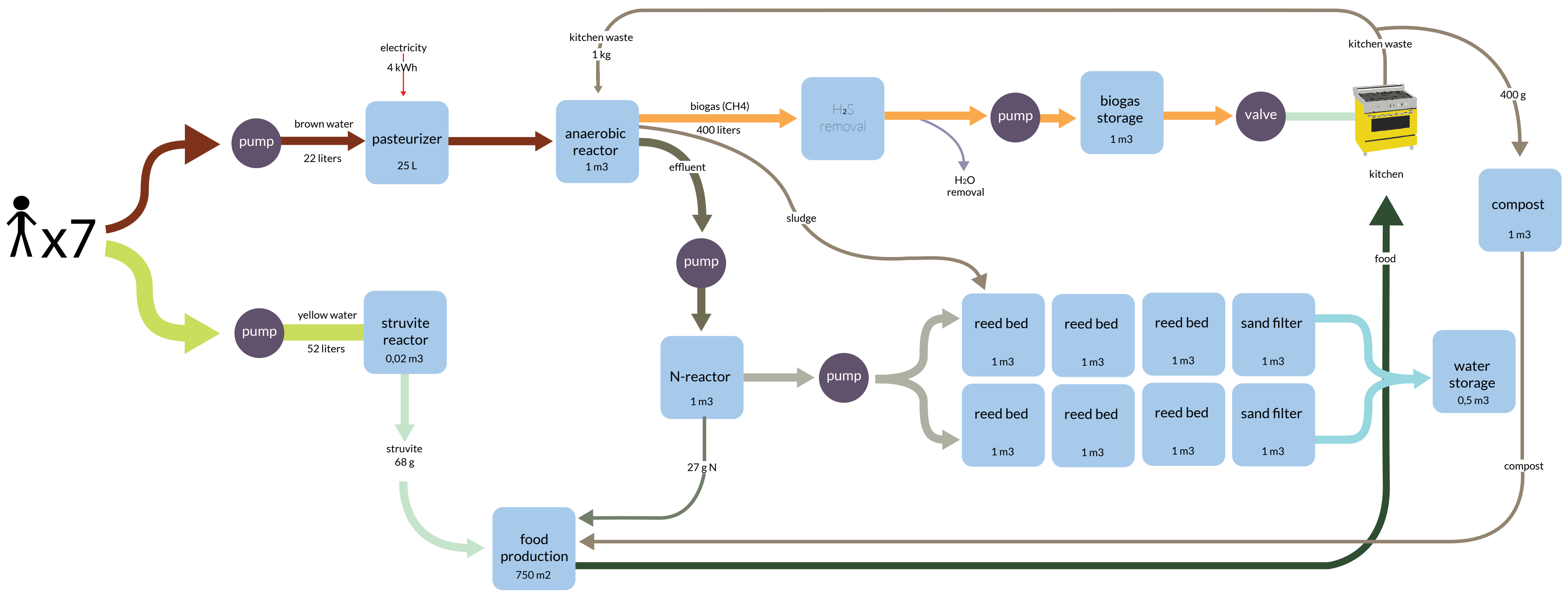
COST & LABOR ESTIMATES

The costs of biogas production and collection are included within the overall estimates for the cost of the D-SARR modular reactor. The biogas produced also has a financial value, which can be recouped by the association by selling the biogas to site users or outside parties. Using the biogas on site is highly recommended to showcase the closed material flow and avoid transportation costs.

The de Ceuvel site will produce 2.700 usable m3 of biogas per year, with an average calorific content of 54.000 MJ (assuming 20 MJ/m^3) or approximately 15.000 kWh. At a market price of 0,7 euro cents per kWh, this is valued at 10.500 € in equivalent energetic value from natural gas.

To arrive at these biogas production calculations, we have assumed that the site will be used by an average of 75 people, each of whom will produce an average of 100 grams of feces, 0,2 kg of kitchen waste, and 0,2 liters of urine per day.

D-SARR: DECENTRALIZED WASTE TREATMENT AND RESOURCE RECOVERY



The graphic above shows the daily material flows associated with the D-SARR system when handling the flows produced by 7 people. The material and nutrient exchange loop on the de Ceuvel site can become largely closed.

3 nutrient recovery

All organic wastes, from kitchen scraps to sewage, contain valuable nutrients that should be cycled back into the biological cycle. In current practice, most of these nutrients are lost into our waterways and end up causing eutrophication.

There are two forms of nutrient recovery that we will be implementing as part of the CTP plan: recovery from safe, organic waste streams such as kitchen scraps and recovery from mixed wastewater streams and garden clippings.

We recommend that a large part of kitchen wastes be used for direct aerobic composting. Fast aerobic composting can be achieved using a vermiculture compost, which makes use of earthworms for the fast digestion of wastes. A centralized vermiculture compost will be built on site where all de Ceuvel users can deposit their food scraps. This vermiculture system will produce compost and liquid fertilizer.

Excess kitchen wastes can be macerated and manually thrown into the D-SARR system described on the previous pages.

Care should be taken to ensure that no plastic, bones, citrus, or chemicals are placed in either the aerobic composter or the D-SARR. Guidelines for organic waste disposal will need to be clearly communicated to all members of the de Ceuvel community. We estimate that 0,2 kilograms of kitchen waste and 0,1 kg of other green wastes will be produced per person per day.

COST & LABOR ESTIMATES

A vermiculture compost can be built very inexpensively out of wooden slats and a plastic lining, costing a total of 50 € in materials costs and a total of 5 hours of labor. One or two of these composters should be sufficient for the entire community to use if they are built to be large.

4 power generation

If sufficient investment can be secured, either through rental income or through additional financing, the community can purchase equipment for the generation of electricity. Despite the relatively low solar irradiance, the most practical and economically feasible solution for this scale is still solar photovoltaic cells.

We recommend this investment for phase two partly to keep initial investment costs manageable, and partly to use the opportunity of phase one to measure and monitor energy use on site to come up with accurate estimates for how much electricity is required.

COST & LABOR ESTIMATES

We estimate that an inexpensive DIY solar PV system will cost around 6.000 € per boat, and require 20 hours of installation time. The exact capacity of the system will depend on how successful boat users are at reducing their electricity demand through implementing efficiency measures.

5 heating upgrade

In this phase, any greenhouses constructed on iste can be outfitted with fresnel lenses and CPVT to boost heat collection for the solar water heating system installed in phase one.

A fresnel lens system concentrates solar energy onto a small panel, which when heated creates source of heat and electricity. This increases the efficiency and warms water pumped

Electricity produced by the CPVT can be used to support heat transfer to the boat, hence, improving overall performance, and providing excess heat for storage, or covering additional needs in heat in winter. CPVT system should be well-insulated to perform at targeted rates.

24m^2 greenhouse with Fresnel lenses and CPVT at the southside produces around 2GJ of heat, on the top – around 6 GJ. Completely covered houseboat with greenhouse will produce around 10 GJ.

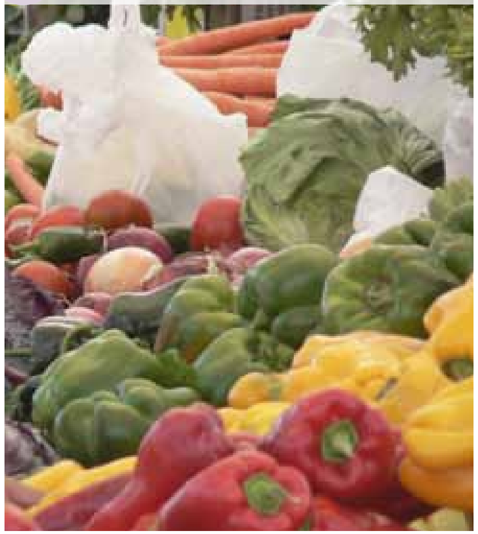
Distribution: distribution is assured through solar tubing and water-to-water heat exchangers connected to the solar water boiler and floor heating.

Assumptions: irradiation in the Netherlands is assumed to be of 800 W/m2; thermal energy harvest by the CPVT + Fresnel = 345 MJ/m2. Surface of the greenhouse covered by the Fresnel is 25%. Size of the greenhouse on southside is 24m2.

COST & LABOR ESTIMATES

Fresnel lenses can be purchased inexpensively at a material pice of around 50 € per boat. The fine wire heat exchangers will cost an additional 500 € per boat. The labor for the installation of both systems will take around 15 hours.

6 food production



The nutrients collected on site will be used to fertilize the raised-bed food gardens that will be built in phase two. A total area of approximately 400 square meters will be planted with fruit and vegetables. If well managed, this small area can potentially yield up to 12.000 kilograms of food for use on the site. This is potentially a large part of the fresh produce consumed by the residents.

COST & LABOR ESTIMATES

The initial setup cost of a raised garden system for the site is not very high, however agriculture requires continued maintenance and labor.
We estimate that recycled wood constructions with imported soil can be built for a cost of 300 € per boat. Continued maintenance and the labor required for growing the crops will need to either be outsourced to a third party or divided amongst the de Ceuvel site users. The value of the food can also provide a means for offsetting the cost of the production labor.

7 web platform

In phase two, all of the sensor systems installed in the first part of the project can be connected to an online platform and used for community wide feedback about the performance of the installed systems.

COST & LABOR ESTIMATES

The only materials costs for the implementation of a public web platform are the cost of a display that can be placed in one of the public buildings on the site. The primary cost of the web platform is its design and programming, which will take an estimated 5 hours of labor per boat. This labor will ideally be donated to the association by one of the community members with skills in this area to reduce overall costs of the project.

8 floating gardens

The landscape architecture plan for the site, developed by Delva Landscape Architects, includes floating gardens in the water surrounding the site. To incorporate this aspect into the CTP plan, we investigated options for ecological materials that could be used as floating platforms. These gardens can have multiple functions, from supporting pollinating insects and creating wetland structure to serving as growing platforms for some limited food production capacity.

The material that we found to hold the most promise for floating garden structures is an agricultural waste product: mushroom mycelium. The root structures of mushrooms capture a lot of air in their growth process and can create a material with natural buoyancy. We recommend testing this material in small quantities for the initial floating platforms, and expanding the experiment if it appears successful.

COST & LABOR ESTIMATES

Mushroom mycelium blocks can be obtained for free from commercial mushroom farms. These will need to be treated with saline solution and sealed with natural rubber to prevent them from degrading too quickly in the open water. Different treatment approaches can also be tested as an experiment to see what approach produces platforms with the longest durability.

It is difficult to accurately estimate the costs of these platforms. We have estimated 300 € per boat plus an addtional 30 hours of labor per boat.

9 drinking water

During phase one and just prior the initiation of phase two, we will determine whether it will be possible, legally and financially, or desired by the community, to install a drinking water upgrading system. This would allow all boats to have drinking-quality water without being connected to the municipal water supply.

A test of ambient water quality will first need to be performed to establish what kinds of treatment the water will need to undergo to be considered safe for drinking. The purification steps required may include UV filtration, water softening, stabilization, and mineralization. In the case of polluted water, activated carbon filters or reverse osmosis may also be required.

COST & LABOR ESTIMATES

We estimate that a drinking water upgrade system will cost 1.400 € per boat and an estimated 20 hours of labor.

This is one of the elements of the system with the least favorable return on investment. It is therefore up to the community to determine whether to invest in this system. The strongest argument in favor of this investment is the overall cohesion with the low-impact and low-infrastructure development plan.

COST AND LABOR SUMMARY (PER BOAT)

component	€	hours
DIY D-SARR reactor	2.700	22
DIY reedbed filtration	1.000	5
DIY sensors & control for D-SARR	100	10
DIY vermiculture compost	6	0,6
DIY Solar PV	6.000	20
Fresnel lenses and FiWiHex	550	12
Drinking water upgrade	1400	20
Raised gardens	300	20
Web platform	100	80
Floating gardens	300	30

As seen in the chart to the left, our current estimates indicate that the materials costs for the recommended phase two interventions come out to a total of approximately 12.500 € per boat. Not all of these interventions are necessary - the most essential are the wastewater and organic waste treatment system.

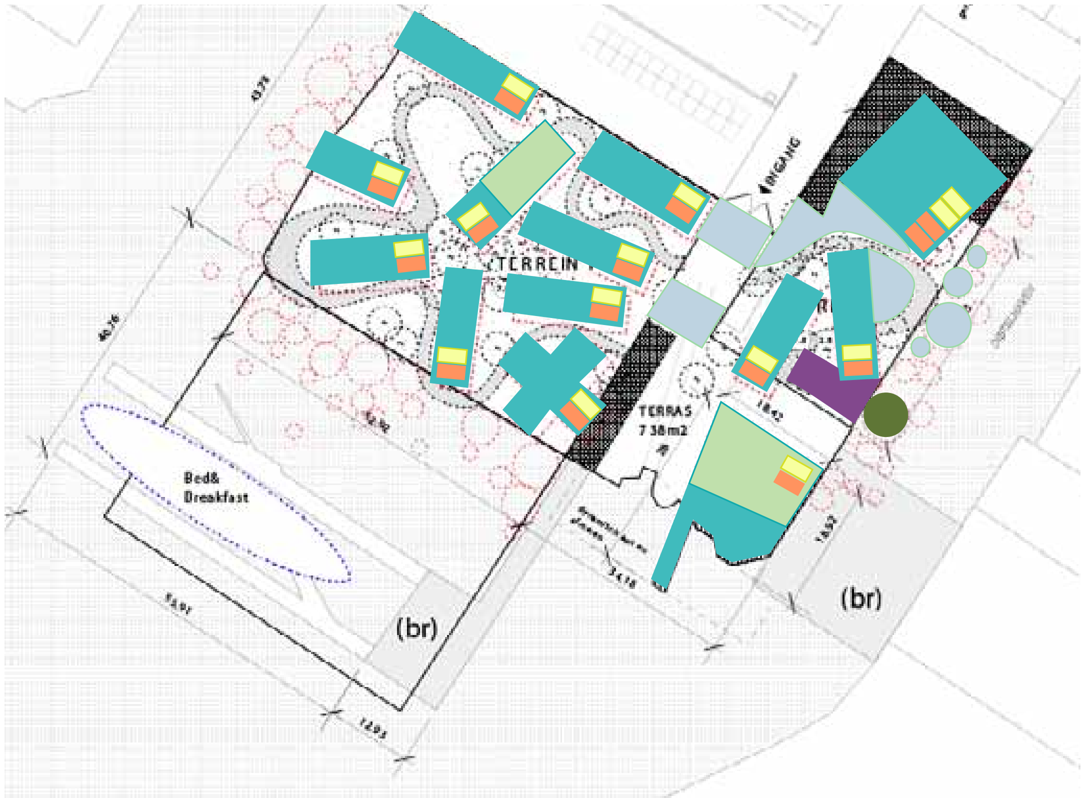
Once again, these costs are based on retail material prices for new and recycled materials, and can potentially be reduced through scavenging or donations. Technology partners and additional investment will be needed to fully realize the aspects of this plan as outlined here.

The phytoremediation garden plan has not been described in this document because it is already accounted for in the project budget and will be overseen by Delva Landscape Architects.

An important factor which is not included in these cost calculations is the continued management of these systems. The cost of maintenance will greatly depend on the community oversight structure put in place once the site is complete.

phase III

PHASE III ACTIVITIES



Greenhouses	250 sqm	DESAR organic waste treatment	110 sqm
Green roof terraces	600 sqm	Reedbed filtration	200 sqm (1,4 sqm/person)
Solar heat collectors	80 sqm (5 sqm / house)	Food production	300 sqm
Solar PV cells	160 sqm (10 sqm / house)	Ecosystem elements	1.500 sqm

Phase III of the de Ceuvel project does not include specific action points, but is rather meant to be a flexible development and maintenance phase. Technologies that are not working should be replaced and upgraded, new ideas for community investment or projects should be taken on.

The map on the left represents an aerial view of how the community will look at this stage. The centralized waste treatment facility is shown in purple on the eastern parcel of the site. Food production area is shown in light blue, and will also potentially take place on the rooftops in greenhouse structures or on the proposed green roofs. Some of the floating gardens are specifically earmarked for water filtration (dark green) and others for food production (light blue).

UPGRADES AND EXPERIMENTATION

The final phase of the de Ceuvel development plan, scheduled to last from July 2014 until the end of the 10-year land lease in September 2023, is a period of technological upgrades and experimentation.

We have not defined specific goals for this period because these will evolve with the desires of the community and are dependent on the success of the first two phases of the implementation plan. However, there are some general directions that we imagine to be interesting for the community as a whole.

ELECTRICITY GENERATION AND STORAGE

Depending on the availability of financing earlier in the development process, there may still be a need for investing in renewable electricity generation and storage on site. This sector is improving quickly, with advances in thin film solar, organic solar, integrated urban wind, battery storage, and many other relevant technologies reported daily. Phase three will present opportunities to pilot or simply invest in some of these technologies.

OUTREACH AND EDUCATION

Many opportunities will emerge around showcasing the de Ceuvel site and hosting public cultural or educational events. If appropriate business models can be worked into these efforts, then they can even potentially earn money for the de Ceuvel association and some can be invested in continued aspects of the Cleantech Playground plan.

EXPERIMENTAL TECHNOLOGY PILOTS

De Ceuvel will remain an excellent place to test experimental clean technologies and evaluate their performance. This is something which can either be done by individual boat renters or the association as a whole, but may need to be coordinated centrally.

ANALYZING COMMUNITY DATA

During phase three, it is important for the community to continue collecting and analyzing the data that is generated on site regarding resource flows and consumption. This data is potentially of great value to policymakers, research institutes, and other groups interested in decentralized, renewable technologies. Communicating this data publicly will have a great deal of practical and academic value.

schoonschip

vision

It is 2020. On the edge of a channel off of the river IJ in the Northern part of Amsterdam is a thriving and unique neighborhood. Schoonschip, a floating residential community, is largely resource self-sufficient, producing all of its energy and most of its food on site.

The neighborhood is overseen by a board that coordinates collective investments and operates a few of the local businesses. Beautiful, clean, and full of community spirit, Schoonschip is widely known as one of the best places to live in the Netherlands.

SCHOONSCHIP IN 2020

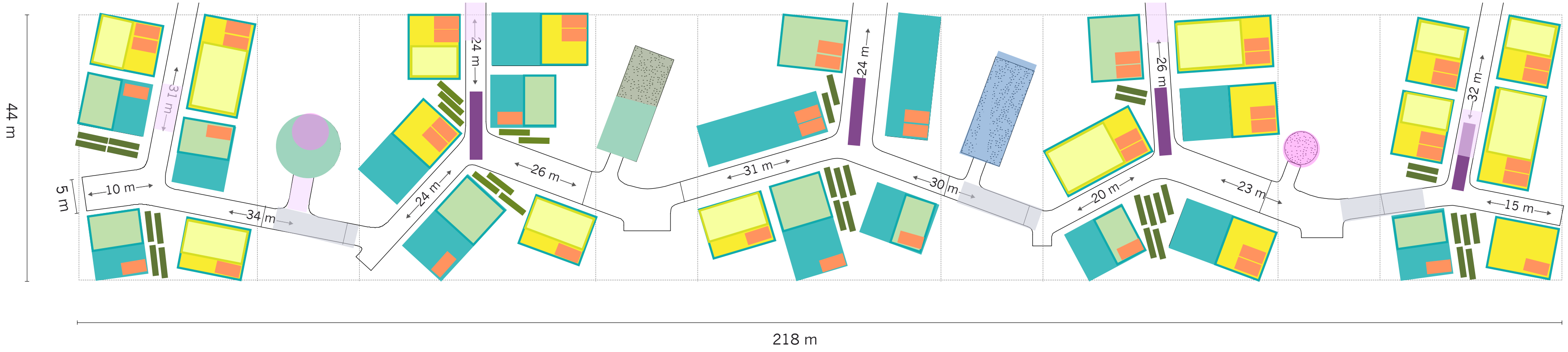
When entering the Schoonschip community, visitors step onto a jetty surrounded by floating plants and flowers. Greenhouses reflect sunlight from rooftops throughout the site, and plant walls grow up the south-facing walls of the houseboats clustered around each jetty.

It is Saturday: one of two large communal areas is busy with residents doing their laundry as they keep an eye on children climbing through an adjacent playground. As they wait for their laundry and their children play, residents enjoy a coffee from a small community managed café housed in one of the community-owned buildings, serving mostly food produced on site.

The community management system is enormously successful, showcasing the power of a group of people with busy lives to not only share a unified vision but to operate one. Depending on what the community desires to eat, the community board decides each year what will be planted in the greenhouses. Some food from the greenhouse is sold at a local market, while most is processed and stored in the community pantry. Some members have begun a successful food processing business, making locally branded jam and tomato sauce—products that are becoming known in Amsterdam North for their quality and local origin. Half of the profits are recycled back into the community.

The Schoonschip bed and breakfast has become a popular destination in the city, especially for groups coming to learn about the functioning of zero impact developments. Local urban farmers and distributors have used Schoonschip as one of the starting points for a city-wide network of locally grown produce, powering a successful urban farming exchange for city markets and home delivery.

schoonschip: urban plan



Green roof + solar infrastructure	1.155 sqm	DESAR organic waste treatment	110 sqm (22 sqm /pier)
Greenhouses	490 sqm	Reedbed filtration	600 sqm (1.4 sqm/person)
Green roof terraces	741 sqm	Vertical food production	300 sqm
Solar heat collectors	384 sqm (8 sqm / house)	Vertical ecosystem	220 sqm
Solar PV cells	480 sqm (10 sqm / house)	Pool and sauna	250 sqm
Outdoor food production	180 sqm	Play area	60 sqm
Food processing & storage	120 sqm		

HOUSE BOATS: 6300 sqm (30)

JETTY: 1635 sqm

The Schoonschip site is a water based plot that will house 48 households on 30 houseboats. As shown above, the technological plan makes use of all available rooftop space and the floating areas in between the houseboats. Two-story roofs will ideally be outfitted with a combination of greenhouses and green roof terraces. These are used for water collection, food production, biodiversity support, and recreational space for the home owners. Three-story roofs will be used primarily for solar infrastructure: solar hot water collectors and PV systems. Parts of the jetty will have vertical food production. Contained inside the jetty will be the wastewater treatment and nutrient recovery system. Surrounding the jetty are floating helophyte filters that use plants to clean the last remnants of nutrients before clean water is discharged into the surrounding area.

The urban plan for the Schoonschip site was designed by architecture firm space&matter. The technology plan has been matched to the urban design.

SCHOONSCHIP SITE

- total site area: 8.500 sqm
- number of households: 48
- number of boats: 30
- estimated number of residents: 120 - 160
- total available jetty surface area: 600 sqm
- total communal surface: 212 sqm
- total available roof area: 1.008 sqm

PROJECT OVERVIEW

In these pages we describe how Schoonschip, which is planned to begin construction by the end of 2013, can achieve the vision described with a manageable and phased investment plan. Upon executing the plan described, the performance of the community can far exceed current "eco-neighborhood" standards in terms of its comprehensive resource self-sufficiency, comfort of living, and integrated plan for community management.

In the first phase, per household investment is estimated at 5.000 € - 10.000 € above the cost of a standard construction. The second phase requires a similar investment of 5.000 € - 10.000 € and will lead to a fully renewable energy system and expanded food production capacity on site. The comparatively low costs and quick return on investment are possible because of the focus on do-it-yourself (DIY) technology and the subsitution of other standard costs associated with new construction.

Because this is a community development process, many of the decisions and the organization around the plan will need to be coordinated by the group as a whole. Key milestones include the upcoming tender procedure for the site. If all goes as planned and the site is secured, the process described here can be taken as a starting point for further activity by the community.

CLOSE-KNIT COMMUNITY

Over the years since it's formation, the Schoonschip community has become a close-knit group that share a commitment to living a sustainable lifestlye. Because of this unified vision and the community's close involvement in the design process, we believe achieving the goals outlined in this document are highly feasible--technically, financially, and socially.

One of the prerequisites for achieving the vision outlined here is the development of a comprehensive community management system. Distributed food production, collective investment in renewable energy technologies, and group decision-making in terms of which communal facilities to build are all an essential part of the plan. The site will need unique types of maintenance, which will require continued oversight.

To facilitate community management practices, we recommend establishing a clear leadership and responsibility structure from the beginning of the site's development. Various tasks will need to be split up amongst working groups, and a clear decision-making structure that everyone agrees with will need to be established. We believe technology can also be used to ease the burden of information-sharing and decision-making: monitoring systems throughout the site will provide feedback via community web platform, keeping everyone aware of the status of food production, resource flows, and maintenance tasks. A community credits system could also be used to facilitate trades in time, resources, or effort between residents so people can choose the work they do based on their interests and availability.

Shared facilities that we envision on the site include a pool and sauna, a community pantry for storing bulk purchases of eco-friendly products, an electric car sharing system, equipment for maintenance and recreation, laundry, and food production. The Schoonschip community is already far along in establishing a board and activity clusters to support the ongoing management of the site.

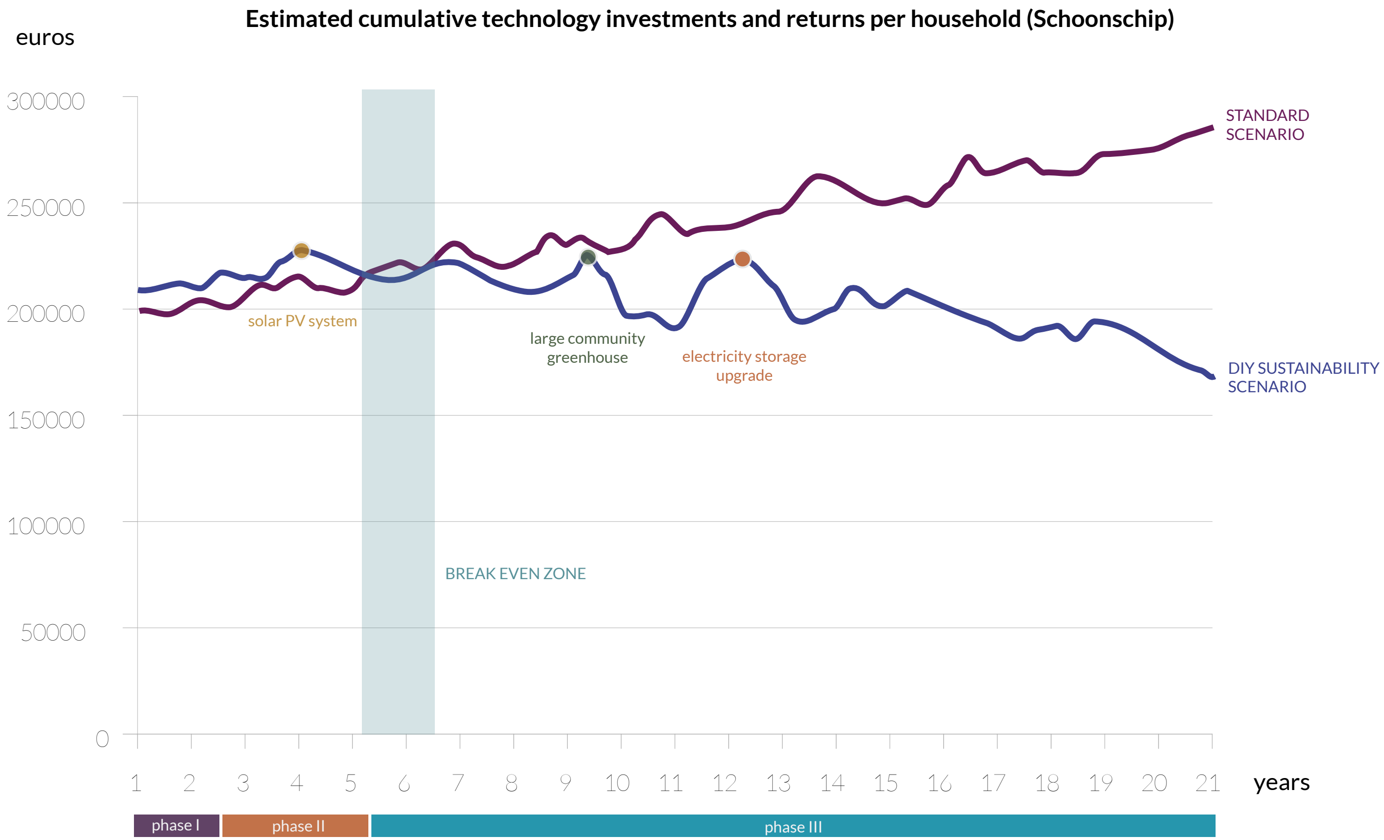
DEVELOPMENT STRATEGY

Technologies have been selected based on their appropriate scale and feasible costs of implementation. While some technologies are implemented on the scale of individual boats, others are more centralized in clusters of 4-6 boats or centralized even further for the entire community. Our technical design is based on the site's development process and integrated with the socioeconomic realities and goals of the community.

The technology selection and financial modeling tools we have developed will be used to adjust the test case described here to the desires of each home owner. The existing Schoonschip group has several sub-committees who will take on the responsibility of facilitating joint construction processes for some of the recommended technologies and working together as the project enters the stage of realization.

The technical system for Schoonschip is also designed to adapt and improve over time. The installations of energy and wastewater systems, for example, are modular, allowing the community to easily change their capacity, add a processing step, or replace the component with something more advanced in the future. As technologies become cheaper, like battery storage, the community can collectively buy new technologies that improve the performance of the site in a cost-effective way.

schoonschip: costs and time line



This graph is indicative of the general pattern of investment and return of the base case (business as usual) in comparison with the DIY sustainability scenario we describe in this report.

TOTAL COSTS AND LABOR

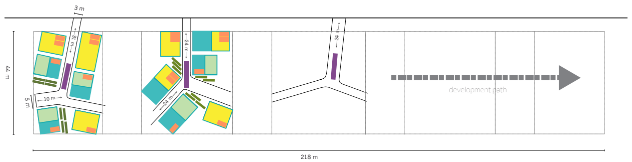
As with the scenario described for de Ceuvel, Schoonschip can receive very favorable return on investment in the "sustainable DIY" scenario we describe here because of two primary factors: the low cost of the DIY approach and the avoidance of standard costs that are part of the business as usual scenario.

The elements we have recommended in phase one cost an estimated total of 29.000 € per boat, the most expensive of which is the additional cost of building a house to Passive House standard. It is important to remember with all of these costs, however, that they replace certain costs in the standard scenario. For example, as a result of adopting the passive house standard, the individual buildings will no longer need a heating system and will continue to save money on fossil fuel costs each year.

One of the primary standard costs in the case of Schoonschip is the set of utility connections to gas, water, and sewage, which are all avoided in the plan we describe. This saves an estimated 12.000 euros per boat in phase one. Many of the other recommendations we make, such as an LED lighting plan, are of increasingly comparable price to a standard lighting alternative. Elements such as the urine separating toilet and the hybrid heat pump / electric boiler would have a similar cost if standard items were purchased.

Overall, we estimate that the net additional cost of the sustainable DIY scenario in phase one is between 5.000 € - 10.000 € more than the standard. In phase two, the investment is once again between 5.000 € - 10.000 €. In the best case scenario, the break even point comes as early as in five years, and the home continues to be an asset that avoids costs and earns money for its owners after that point.

PHASE I : MARCH 2014 - SEPTEMBER 2016



In phase one, boats will progressively be built and placed on site as individual home owners acquire their mortgages. Each of the five piers will be built once a set of houseboats is ready for construction in order to reduce the risk associated with the cost of collective investment in the pier infrastructure. In this phase, we also recommend building at least one of the communal buildings dedicated to shared laundry and kitchen space.

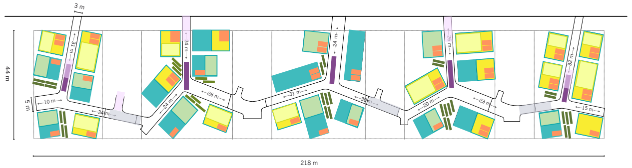
Efficiency targets have been defined for each boat in terms of heat and electricity demand, water use, and sewage management. Home owners will need to make personal decisions about what set of technologies they would like to select with these performance targets in mind.

The basic activities in this phase include the installation of renewable heating supply for space heating and hot water, the implementation of energy efficiency strategies for lowering electricity demand, and the installation of building-integrated structures for water collection and biodiversity support.

In this phase, the wastewater and organic waste treatment system will also be installed in the jetty, and sensors will be installed throughout the neighborhood to monitor key flows of energy and resources.

The communal facilities that should be installed in this phase include the shared laundry room and smaller greenhouses on top of the community buildings.

PHASE II : SEPTEMBER 2016 - 2018



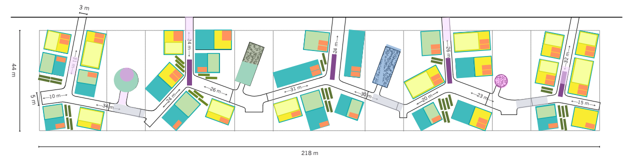
Phase two begins once all of the piers and houseboats have been constructed and further investment in additional communal infrastructure can begin.

The primary investment on a household level in phase two is the purchase of renewable energy technologies. Because of the design of the urban plan, most solar panels will be installed on the rooftops of the 3-story buildings and feed into the general grid for the neighborhood. The exact sizing of the renewable energy system will be determined based on the measured energy demand in phase one. The sizing of the system will then determine the cost of the installation per household, which we currently estimate at around 6.000 €.

In this phase, the online web platform and resource monitoring system will also be fully installed and implemented, giving all residents of Schoonschip insight into their own waste production, energy use, hot water demand, and other parameters. The web platform can also be used to coordinate childcare, carpooling, food production and sharing, and other community resources.

Community gardens in between the piers and along some sections of the jetty can also be built at this time, along with the pool and sauna, communal pantry, and the other shared facilities that residents have expressed interest in having.

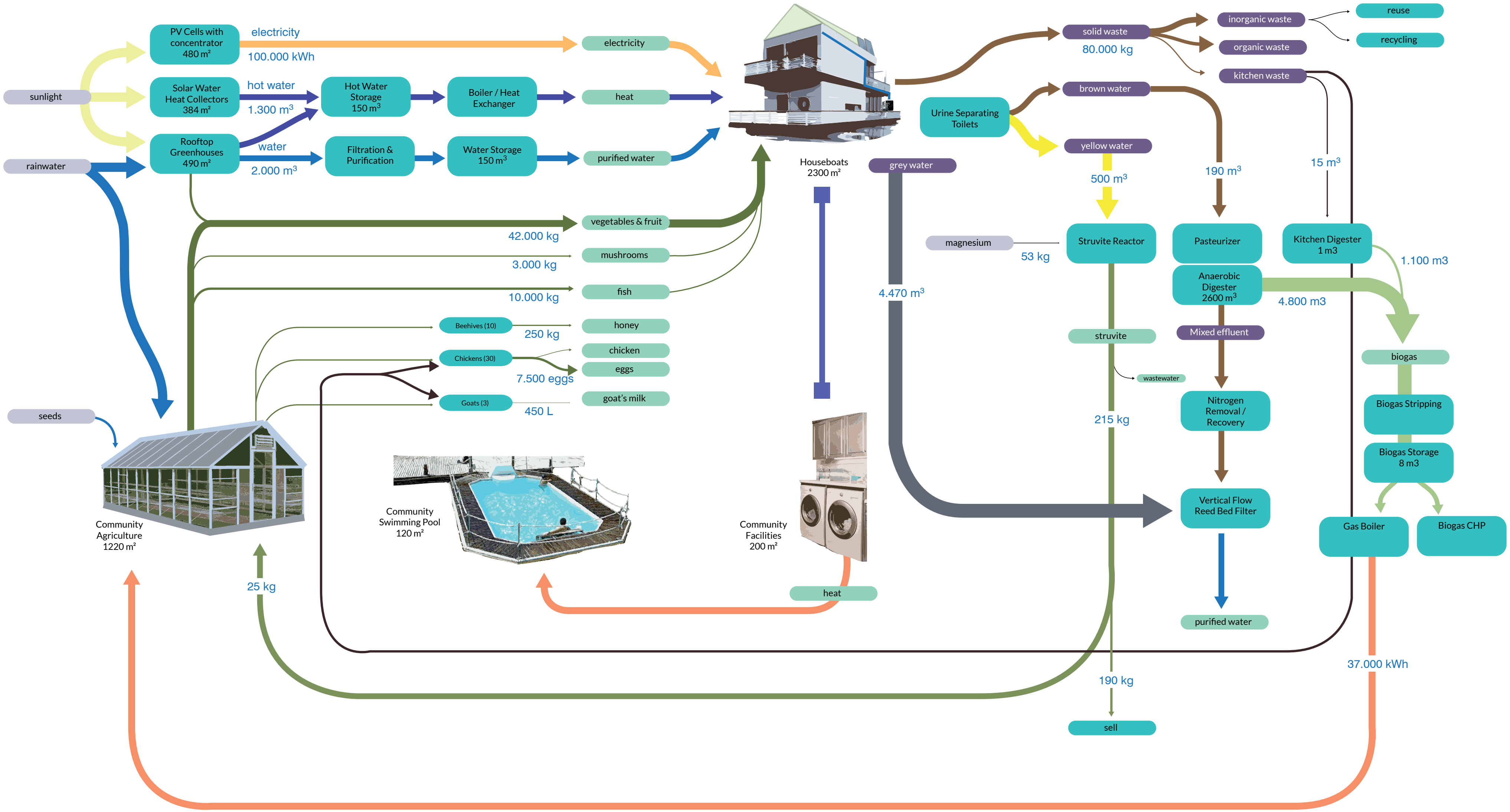
PHASE III : SEPTEMBER 2018 - 2060



Phase three is focused on upgrades and innovations. Some primary suggestions for investment in this phase include the creation of a large, floating community greenhouse, investment in a local microgrid for load balancing, expansion of power generation and storage capacity, and the further creation of new businesses and communal facilities on site.

We recommend that Schoonship fully develop business models to launch community-managed ventures between phase two and phase three. Profits from these businesses, such as a bed and breakfast in a communal building, can serve as a potential funding stream for further renewable energy technologies like a local smart grid or energy storage capacity.

schoonschip: final material flows



FINAL SYSTEM PERFORMANCE

At the end of the first two development phases, the house-boats on the Schoonschip site should be fully self-sufficient in renewable heat and electricity, water collection and upgrading, and have much lower resource demand than conventional homes. The buildings themselves will not only be highly eco-efficient, but also designed in a variety of architectural styles with creative exterior finishing.

The community will have its own wastewater treatment system that recovers all valuable nutrients from wastewater and organic waste streams for on-site food production. Individual house-holds have greenhouses in which some food is produced and heat is collected. These small greenhouses will compliment a larger greenhouse installation on site, producing the bulk of the fresh produce required for the community. Chickens, bees, and a few goats will also be raised in the floating community gardens in between the piers, adding some diversity to the local food supply.

An intelligent monitoring and management system will support the efficiency, visibility, accessibility, and capacity for improve-ment of all of the clean technologies on site. This system will showcase resource flows and ensure wastewater and nutrient delivery systems are working properly. Sensors will measure amounts of organic waste processed, biogas produced, and nu-trients recovered. The system will keep track of flows of nitrogen and phosphorus, pathogen levels in water, the pH of nutrient streams, and efficiency rates of different energy conversion pro-cesses, such as organic waste into biogas into electricity.

As each boat will have its own electricity production, a micro-grid installed in phase three will enable load balancing. The system uses demand response to indicate optimal times to do laundry and when more energy production is necessary. It sells energy back to the grid in times of excess and stores it temporar-ily when grid prices are low.

Green roofs, plant walls, flowers, and greenhouses will create an environment that showcases a new vibrant healthy, and nurtur-ing urbanism. A community biodiversity monitoring program allows individuals to report sitings of birds, amphibians, and other animals spotted on site to track how the neighborhood is impacting the surrounding ecosystem.

TARGETS ACHIEVED:

- 100% renewable heat and hot water supply
- 100% renewable electricity
- 100% wastewater and organic waste treatment
- 100% water self-sufficiency
- 60 - 80% nutrient recovery
- 50 - 70% reduction in electricity demand over conventional
- 60 - 70% vegetable & fruit production using lo-cally recovered nutrients
- sensor network and real-time system perfor-mance displays
- community facilities for resource sharing and support of group cohesion
- electric mobility capacity
- support of biodiversity

schoonschip

deployment plan

The following pages contain a basic sketch of the three phases of technological deployment that we are recommending for Schoonschip.

As with the de Ceuvel plan, the largest planned investments are split between phases one and two, with the third phase remaining largely open for experimentation and growth. Many of the same technologies are recommended here as for de Ceuvel, but often in expanded form. In the case that a technology or approach has already been mentioned in the previous section, we do not repeat the description here.

PHASING

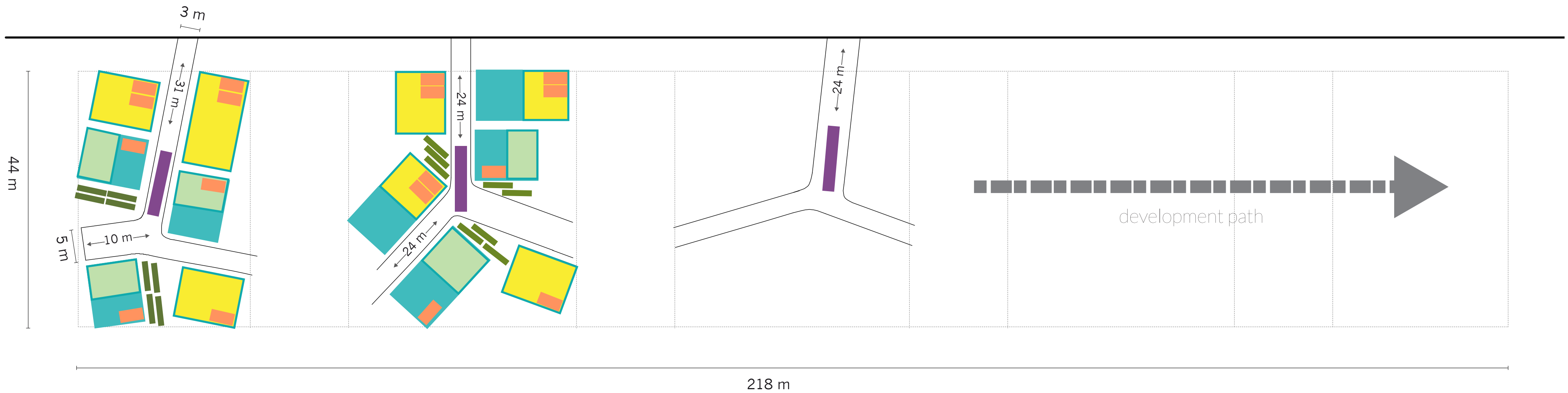
The final Schoonschip plan includes five piers connected by walkways on the water. Because the communal infrastructure like the jetty and the infrastructure inside the jetty need to be jointly financed, each section of pier can only be built once all houses attached to that section are secured. As each pier is constructed, the basic technological infrastructure for wastewater treatment, rainwater collection, and heat supply must be built in the jetties and as part of the individual boats. Each phase achieves all or part of the performance goals set for the system.

Phase one of the Schoonschip CTP deployment plan is the most intensive in terms of investment and the basic infrastructure that needs to be installed, and includes the wastewater treatment system in the jetty.

Phase two is focused on the addition of renewable energy technologies, the expansion of local food production, and the construction of additional communal facilities.

Phase three is a period of upgrades and experimentation, when additional investments can be made as technologies improve and become less expensive. A financing structure for these future investments is established in phases one and two.

phase I



Green roof + solar infrastructure

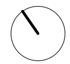
Greenhouses

Green roof terraces

DESAR organic waste treatment

Reedbed filtration

Solar heat collectors



HOUSE BOATS: 6300 sqm (30)

JETTY: 1635 sqm

In phase one, the individual sections of the jetty are built as homeownersacquire their mortgages. This construction pattern is tied to the financing structure of the project.

As seen on the above map, this phase includes the construction of the the decentralized waste treatment system inside of each pier (seen in purple), the floating helophyte filters, and the installation of some of the rooftop infrastructure including: green roofs, greenhouses, and solar heat collectors.

PHASE I: GOALS

ENERGY & MATERIALS

- 80% renewable heat and hot water supply
- 50 -70% reduction in electricity demand over conventional
- 100% wastewater and organic waste treatment
- 60 - 80% nutrient recovery
- 100% water self-sufficiency
- Installation of sensors to support subsequent IT infrastructure

CULTURE & ECONOMY

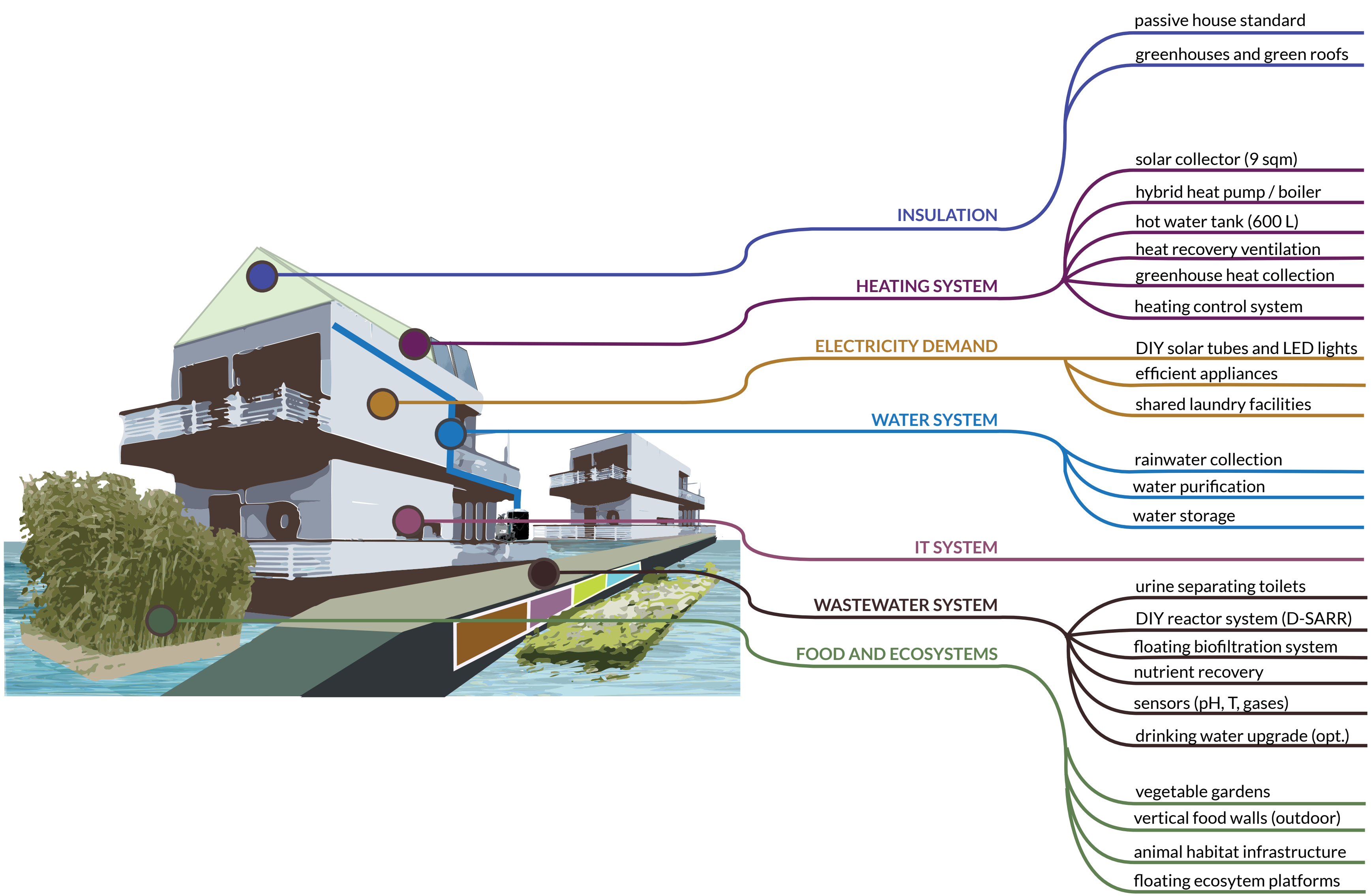
- Construction of first communal buildings and facilities
- Establishment of community governance structure
- Organization of DIY process
- 10 - 20% fruit and vegetable production
- Determine a financial structure for future investments
- Ensure financial viability

ECOSYSTEMS & SPECIES

- Installation of structural ecosystem support elements in buildings, jetty, and surrounding waterway
- Establishment of community ecological monitoring program

HEALTH & HAPPINESS

- Aesthetically pleasing in outside appearance: incorporate artistic and attractive elements in landscape quality
- Conceal technology like rainwater collection system
- Achieve high level of comfort for users by maintaining modern standards of living
- Create enjoyable communal spaces and social activities


INSULATION
passive house standard
greenhouses and green roofs
HEATING SYSTEM
solar collector (9 sqm)
hybrid heat pump / boiler
hot water tank (600 L)
heat recovery ventilation
greenhouse heat collection
heating control system
ELECTRICITY DEMAND
DIY solar tubes and LED lights
efficient appliances
shared laundry facilities
WATER SYSTEM
rainwater collection
water purification
water storage
IT SYSTEM
WASTEWATER SYSTEM
urine separating toilets
DIY reactor system (D-SARR)
floating biofiltration system
nutrient recovery
sensors (pH, T, gases)
drinking water upgrade (opt.)
FOOD AND ECOSYSTEMS
vegetable gardens
vertical food walls (outdoor)
animal habitat infrastructure
floating ecosytem platforms

1 60 - 80% renewable heat and hot water

DEMAND-SIDE MANAGEMENT

Each boat will be built to passive house standard using very high efficiency insulation and sealed air flow. There have been concerns in the past about the ventilation in homes designed to passive house standards, but technology and practice have both improved so that this is no longer an issue.

We recommend that where possible, greenhouses should be built on top of the regular building structure in order to boost heat collection through the use of Fine Wire Heat Exchangers (Fiwihex). An important note is that the Schoonschip community will need to apply for an exemption for these greenhouses so they are not counted as part of the permitted building volume. An exemption permit is possible if the greenhouses are used primarily for food production and heat collection, as we recommend here.

Houses will contain an intelligent temperature control system in which different spaces within the house will have varying levels of comfort. For example, the living room and bedrooms will be warmer than the hallways, ensuring the heat is focused on where people are spending their time.

Each house will maximize solar gain, having mostly south-facing windows to capture heat. In the summer, window shades will block excess solar heat, keeping the house cooler in warmer months.

Low-flow fixtures will be installed on each faucet and showerhead, reducing overall hot water demand.

SUPPLY

Each household will require 9 square meters of solar heat collectors. We recommend a flat plate collector with a drainback system to prevent freezing without necessitating any potentially hazardous anti-freeze agents. A differential controller will activate the pump and determine when the water needs to be moved from the collector to the storage tank.

Solar heat collectors will be combined with fresnel lenses that heat up the water as it circulates to cool the solar panels.

We recommend installing greenhouses that cover half the roof surface of each of the low buildings on site. Houses with greenhouses, which collect heat, will require less solar heat collection.

An installed electric microwave boiler or hybrid heat pump/boiler will provide top-up heating when there is insufficient hot water. These boilers heat water extremely fast and on demand, and are significantly more energy efficient than the average electric boiler.

Heat-recovery ventilation systems will be installed in each house as part of the passive house standard. These air-to-air heat exchangers intake fresh air from outside and warm it with the stale warm air leaving the house.

STORAGE

Insulated hot water tanks of 600 liters will be placed in the basement or crawlspace of each household.

COST & LABOR ESTIMATES

Passive house standard costs an estimated 10.000 € above a typical house. The estimated costs for the DIY solar collector and water storage system are 1.600 €. Installation of the system will require approximately 40 hours of labor.

With passive house design, an active heating system is unnecessary, saving the costs of a central heating system. Households can likewise save money on a gas connection and gas use, which is similarly unnecessary for passive house standard homes. Even though a passive house costs 10.000 €, forgoing a central heating system and gas connection will save 6-7.000 € during the construction phase, which will effectively reduce the cost of the passive house to around 3.000 €. Operational savings from not having to purchase gas provides a quick payback period.

2 50 -70% reduction in electricity demand

We are recommending a number of demand side measures that will greatly reduce the overall electricity consumption of each household. These are summarized by major category below.

WASHING MACHINES

All washing machines will be centrally located in communal areas. In most households, washing machines consume 20% of the electricity, mostly to heat the water.

We recommend using high-efficiency machines that can use hot water as an input. When combined with solar collectors, which will be placed on the roof of the communal zone, water heated with renewable energy can directly power the machine, saving an immediate 20% electricity use.

LIGHTING

Lighting is a significant part of household electricity demand. Each home should have an optimized lighting plan where daylight access is maximized using solar tubes, well-placed windows, and skylights.

With daylight optimized, we recommend an LED lighting plan with a target of 2-4 watts per square meter. This is very low compared to standard households but is enough to provide recommended lighting.

REFRIGERATION

Instead of a one-size-fits all refrigerator, we recommend multiple storage units that are cooled to different levels and appropriate for different food products. The system includes several small refrigerators filled sequentially and only used when necessary. It also contains evaporative cooling units which use water from the canal to cool chambers to 9-12 degrees celsius. The system is much more energy efficient by optimizing cooling depending on the quantity and type of food. Food storage guidelines distributed to the residents will also inform them about best practices for keeping food fresh with the lowest possible demand for cooling.

HOUSEHOLD APPLIANCES AND PERSONAL ELECTRONICS

We have recommended targeted efficiencies for each household appliance, with suggested wattage ratings, water use, and other resource demands per type of equipment.

Cut-off switches will be installed throughout each household. These switches will cut power to non-vital electronic equipment when it is not being used, removing the low-level power drain that normally occurs when appliances remain plugged in.

COST & LABOR ESTIMATES

These actions will provide a 50-70% savings in electricity use for an overall household. The suggested heat recovery ventilation system requires slightly more electricity than standard households, but is insignificant compared to the electricity savings generated from other recommendations.

LED lighting costs for each household can be as low as 600 €. Solar tubes are more or less expensive depending on whether they are purchased or made by hand. A commercial solar tube costs around 1000 €, but home-made products can be very simple and inexpensive. The most important factor is to ensure that leaks are avoided by correctly sealing the tube structure to the roof.

Other recommendations do not cost much. Instead, they require a change in practice, like using a different type of food storage system. For the changes that do cost some money, like purchasing more efficient appliances, old appliances can be sold to recoup some of the costs and the efficiency gains make up for the initial costs within a few years.

3 100% wastewater & organic waste treatment

We recommend using urine separating toilets, which require very little water use. The toilets separate and collect two streams of human waste, which are pumped to the DIY modular treatment system installed in the jetty (the D-SARR system, described in more detail on pages 51 - 53). The graphic to the right shows how waste streams will flow from the houseboats to the jetty and reedbed filters.

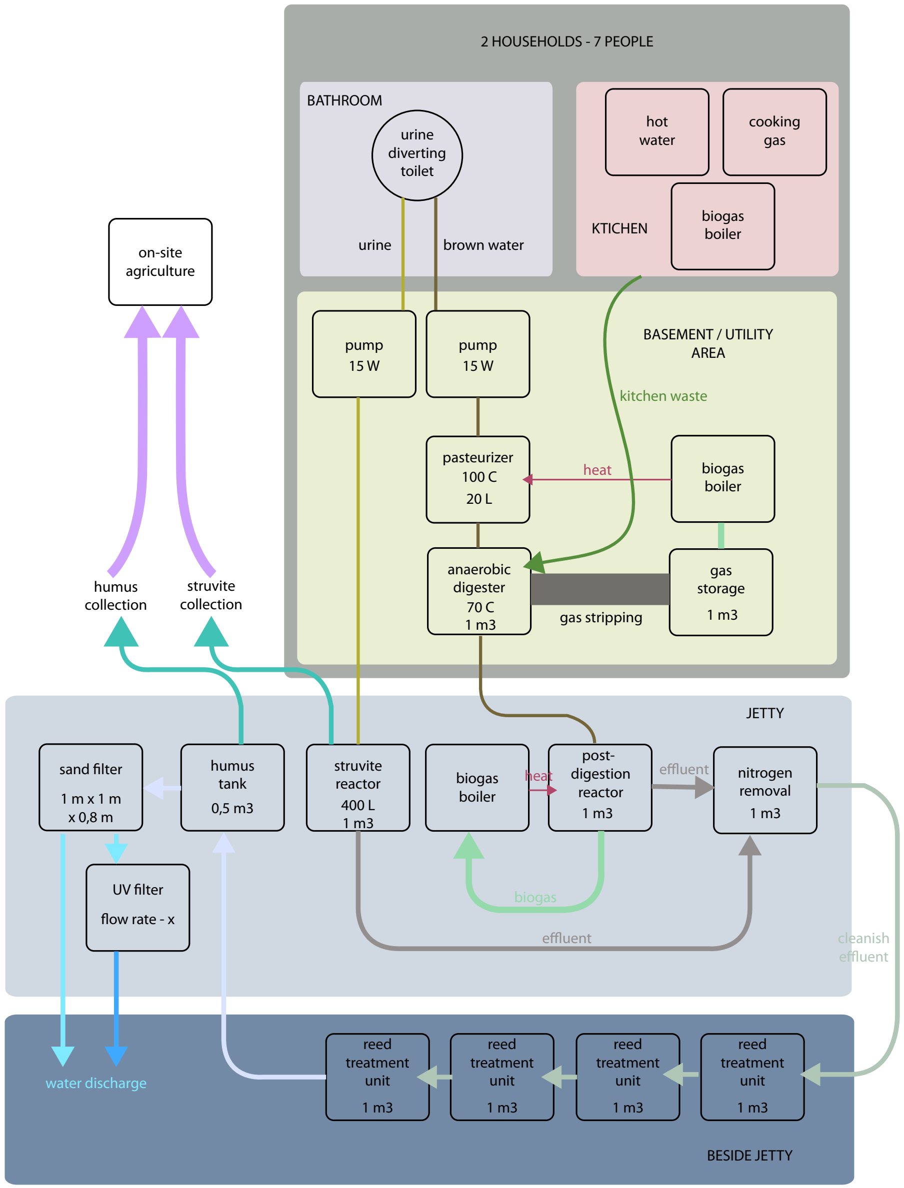
The D-SARR treatment system is modeled on the one used at the de Ceuvel site. There will need to be access hatches in the jetty so that different materials like purified nutrients can be harvested from the system for use in on-site agriculture. These hatches also allow for the system to be serviced when necesary. Each pier of 6 buildings (10-11 households) will have its own D-SARR system.

The D-SARR system will first be piloted at the de Ceuvel site. It consists of different reactors for processing the waste and producing biogas. Sensors are included to monitor flow rates and to alert the community before something goes wrong. The system will also contain water upgrading modules; helophyte filters will be placed on the side of the jetty, purifying the water before it is finally discharged.

COST & LABOR ESTIMATES

The estimated per-household cost and labor estimates for installing the D-SARR system are 4.800 € and 100 hours of labor. In addition, the water upgrading system and vertical reedbed will cost an estimated 2.000 € and 55 hours of labor per houshold.

Our materials costs are based on bulk purchases from Eastern Europe or Asia. If these purchases cannot be made collectively, the price of the system may increase. Labor costs are not included, with the assumption that the community will do a large part of the construction. However, with this element in particular, outside assistance from professionals may be required, which may increase the overall cost.



DEMAND-SIDE MANAGEMENT

Nutrients collected from the wastewater and organic waste treatment system can be used on site for food production. This creates a closed cycle between nutrient collection and food production.

Remaining nutrients can be sold for a profit by the community. The urine separating toilets will produce an estimated 250 kg of struvite per year, which is a significant amount of phosphorous. Only about 10% will be used on site for food production.

Organic waste can be processed three ways. Kitchen scraps can be fed directly to animals or be composted in an aerobic worm compost for personal garden use. They can also be fed into the D-SARR reactor and turned into biogas.

COST & LABOR ESTIMATES

Costs for vermiculture (worm compost) are minimal, amounting to less than 30 € for a small system in each household. The costs of the D-SARR system are described in the previous section on wastewater treatment.

The various rooftop gardens and greenhouses can all be used by the community to produce food on the Schoonschip site. At the end of phase one, there should be approximately 1200 square meters of greenhouse and green roof space for this purpose. At an average production output of 25 kg per square meter, which is easily achievable with well managed gardens, the site could produce approximately 30.000 kg of fruit and vegetables per year. This would be sufficient for all of the community's fruit and vegetable demand (if they were to eat only locally produced crop types).

We are assuming that not all of this space will be used for intensive food production, since there will also be recreational spaces in these areas. A very realistic target for phase one is 10 - 20% of vegetable and fruit production on site.

COST & LABOR ESTIMATES

If green roofs and greenhouses are already installed as part of the initial building structure, the added cost of cultivating these areas is not extremely high. Plants propagated from seed are less expensive that plants purchased for transplanting. Nutrients will be supplied from the on-site wastewater treatment system, and water will be collected from the rainwater system. The primary expense is in the form of labor, which can be quite high and require a great deal of regular attention. We estimate at least four hours of labor on average throughout the year for each sizable plot under cultivation.

6 100% water self-sufficiency

DEMAND-SIDE MANAGEMENT

Efficient water fixtures will be installed in each household, reducing total water demand per person.

SUPPLY SIDE

The Netherlands has enough rainfall so that each rooftop can collect more than sufficient water to meet the water demands of Schoonschip residents.

We recommend rooftop storage of the water (in EPDM bags or another suitable container) in order to make use of gravity in the water distribution process. At minimum, this locally collected water can be used for toilet flushing.

Due to the costs of installing a water upgrade to drinking-level quality and the difficulty of acquiring a permit, households might prefer to be connected to the municipal water supply. However, if individuals within the community place particularly high value on total self-sufficiency, they can begin the permitting process and make efforts to acquire the rights to upgrade their own water.

At the very least, we recommend that rainwater be used for toilet flushing and crop irrigation.

COST & LABOR ESTIMATES

A rainwater collection system will cost an estimated 700 € in materials costs plus 14 hours of labor. A DIY system to upgrade rainwater to drinking water costs 1.500 €.

7 installation of sensors

Sensors for temperature, pH, and resource flow monitoring should be installed during the construction process whenever feasible. Placing them at this stage while many technologies are exposed will facilitate the monitoring and display system that will be installed for the community in phase two.

Recent advances in sensor technology, and the development of small plug-and-play modules such as Arduino chips makes this cost-feasible. Inexpensive microcomputers like Raspberry Pi can also be used to monitor and control distributed sensor systems.

COST & LABOR ESTIMATES

A Raspberry Pi microcomputer retails at 35 €. An arduino costs around 100 €. We estimate that the sensor system for each boat will cost an estimated 500 € and cost 10 hours to install. This installtion time does not include the design and programming of the system.

8 ecosystem support elements

WATERWAY

Floating gardens will be placed around the site providing a habitats for insects and other animals. Some households have expressed a desire to keep bees. These floating areas would provide extra flowers for the bees to pollinate and offer additional aesthetic qualities to the site.

JETTY

The shading effects of a jetty have ecological impacts, but in such a shallow area with minimal plant growth, such shading does not pose a significant ecological issue. At minimum, the Jetty should be made of materials that are non-toxic to aquatic organisms. Above the jetty, we are recommending planting vertical gardens and arches. Plants would either be decorative or edible and installed as the jetties are completed.

HOUSEBOATS

We recommend integrating tiles that offer habitat for birds. For boats without greenhouses, structures like bird houses and greenroofs should be installed to support additional biodiversity.

OVERALL BIODIVERSITY

Any urban infrastructure inevitably has a footprint. By integrating ecological elements into the system, Schoonschip can be designed to provide habitats, optimize on-site food production, maintain migration corridors, and de-nutrify the river IJ. Floating platforms with flowering plants will be placed in the channels between the boats, attracting pollinating insects. Boats have roof and wall tiles that provide habitats for bats and nesting space for water fowl. Floating platforms in the water provide added habitat for fish and crustaceans. The jetty is sloped and considers light penetration, integrating it with the ecology underneath.

COST & LABOR ESTIMATES

Biodiversity elements for houses are available as retail products from companies like Vivara. To keep costs low, we recommend home made elements, which can be negligible in cost.

9 financial viability

The plan that we are recommending can be scaled down or up depending on the financial capacity of each family. It is possible, for instance, to make smaller initial investments and achieve slightly less than passive house standard. The costs will be smaller up-front but will provide less savings in energy costs month after month.

The DIY approach means that each of the technologies we are recommending will cost at least half of the commercial version of the technology, and in some cases as little as 1/10th of a commercial version.

10 community governance

Some of the technologies installed on site need to be maintained by the group. The digester systems will require routine upkeep and nutrient harvesting. Communal areas containing washing machines and kitchen equipment should be similarly governed by a managing board to ensure proper functioning.

Although we have devoted more attention to technological elements in this report, these elements of governance are equally important for the success of the system as a whole.

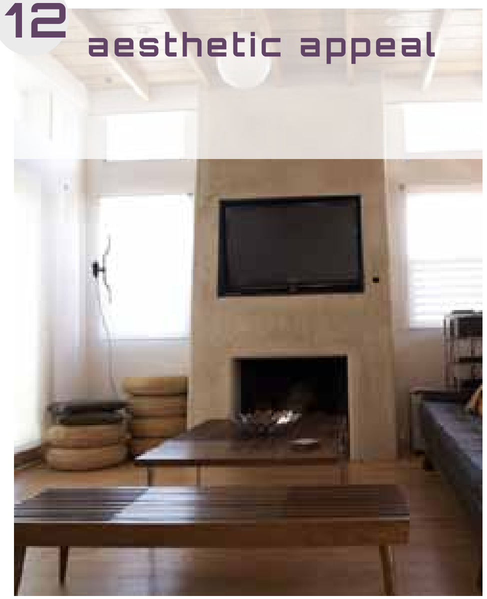
11 high levels of comfort

The plan does not sacrifice anything that is considered a modern comfort. For example, low-flow shower heads, when reduced beyond a certain point, create an unpleasant experience. The flow rate we are recommending maintains a comfortable showering experience.

The toilets installed in each household are modern fixtures that look and feel like a standard flush toilet. They just happen to have a urine separating function.

None of the behavioral changes we are suggesting alter essential quality of life. For example, the modular refrigeration system can keep food better tasting and in fresher condition than even a conventional refrigeration solution. However, it does require more care and attention from users as to where food should correctly be stored.

12 aesthetic appeal



Technologies will be designed and implemented in such a way that they are camouflaged or made into aesthetic features.

space&matter and other architects involved in the plan are taking care to ensure that the technologies are applied aesthetically.

COST AND LABOR SUMMARY PER HOUSEHOLD

component	€	hours
passive house insulation & HR ventilation	13.000	NA
DIY green roof	1.200	100
DIY solar collector & storage	2.500	40
DIY D-SARR system	4.800	100
DIY reed beds and water purification	2.000	55
DIY sensor system	500	10
DIY daylighting & LEDs	600	20
DIY ecosystem elements	200	30
Sanitation: urine separating toilet	300	5

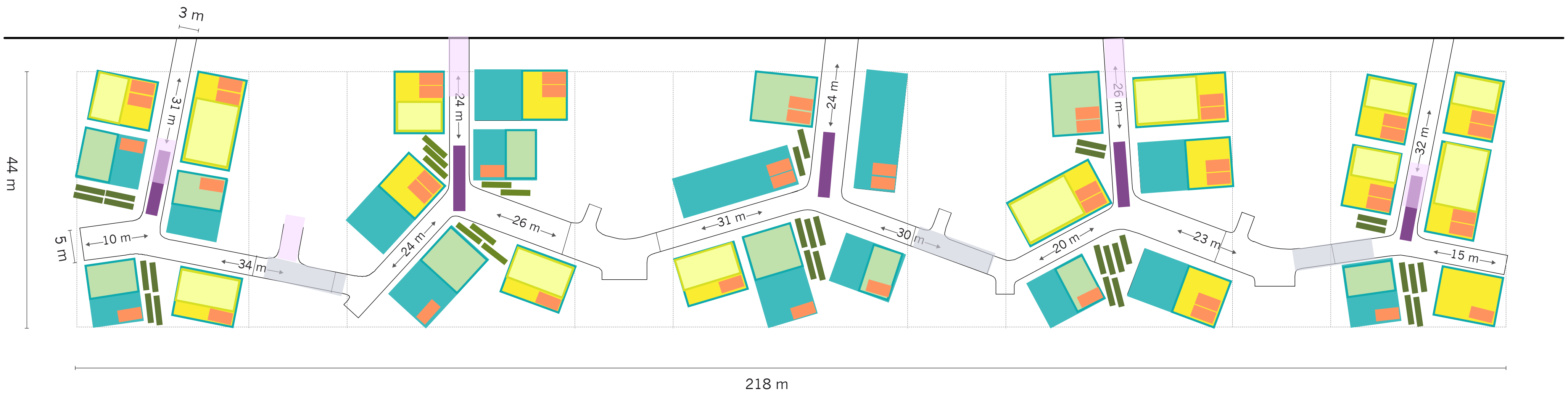
The chart to the left summarizes the primary costs per household for phase one of the Schoonschip deployment plan. These amount to roughly 25.000 euros, with some incidental costs not listed here boosting the total cost to around 30.000.

As described throughout this document, however, these costs are largely canceled out through investments that would also need to be made in the business as usual scenario.

The most significant factor, however, is the degree of DIY labor required. The elements listed here require an estimated 360 hours of labor per household, with the total estimates for phase one (including low-cost elements such as home gardening, composting, biodiversity features, etc.) amounting to well over 500 hours of labor.

Organizing cooperative construction can improve efficiency and decrease demand for labor inputs. Regardless of the strategy, it will require a significant community effort.

phase II



Green roof + solar infrastructure	1.155 sqm
Greenhouses	490 sqm
Green roof terraces	741 sqm
Solar heat collectors	384 sqm (8 sqm / house)
Solar PV cells	480 sqm (10 sqm / house)
DESAR organic waste treatment	110 sqm (22 sqm /pier)
Reedbed filtration	600 sqm (1.4 sqm/person)
Vertical food production	300 sqm
Vertical ecosystem	220 sqm

HOUSE BOATS: 6300 sqm

JETTY: 1635 sqm

During phase two, the intelligent monitoring and management system is fully activated and planned communal areas are developed. Gardens, insect hotels, and ecological support systems are implemented on site. Solar PV panels and electric charge points are installed and the community begins organized food production. In this phase, Schoonschip will begin to host the outside world. The community could host neighborhood events, tours, and workshops. The planned bed and breakfast will be operational and accepting guests. The main technical components will be installed, allowing the community to collectively assess its current and projected finances and create an investment plan for future technology improvements.

PHASE II GOALS

ENERGY & MATERIALS

- 100% renewable heat and hot water supply
- 100% renewable electricity supply
- 80 - 100% nutrient recovery
- Electric mobility capacity
- Installation of neighborhood digital monitoring system

CULTURE & ECONOMY

- Construction of additional communal facilities
- 30 - 50% fruit and vegetable production
- Financial structure for future investments
- Ensure financial viability

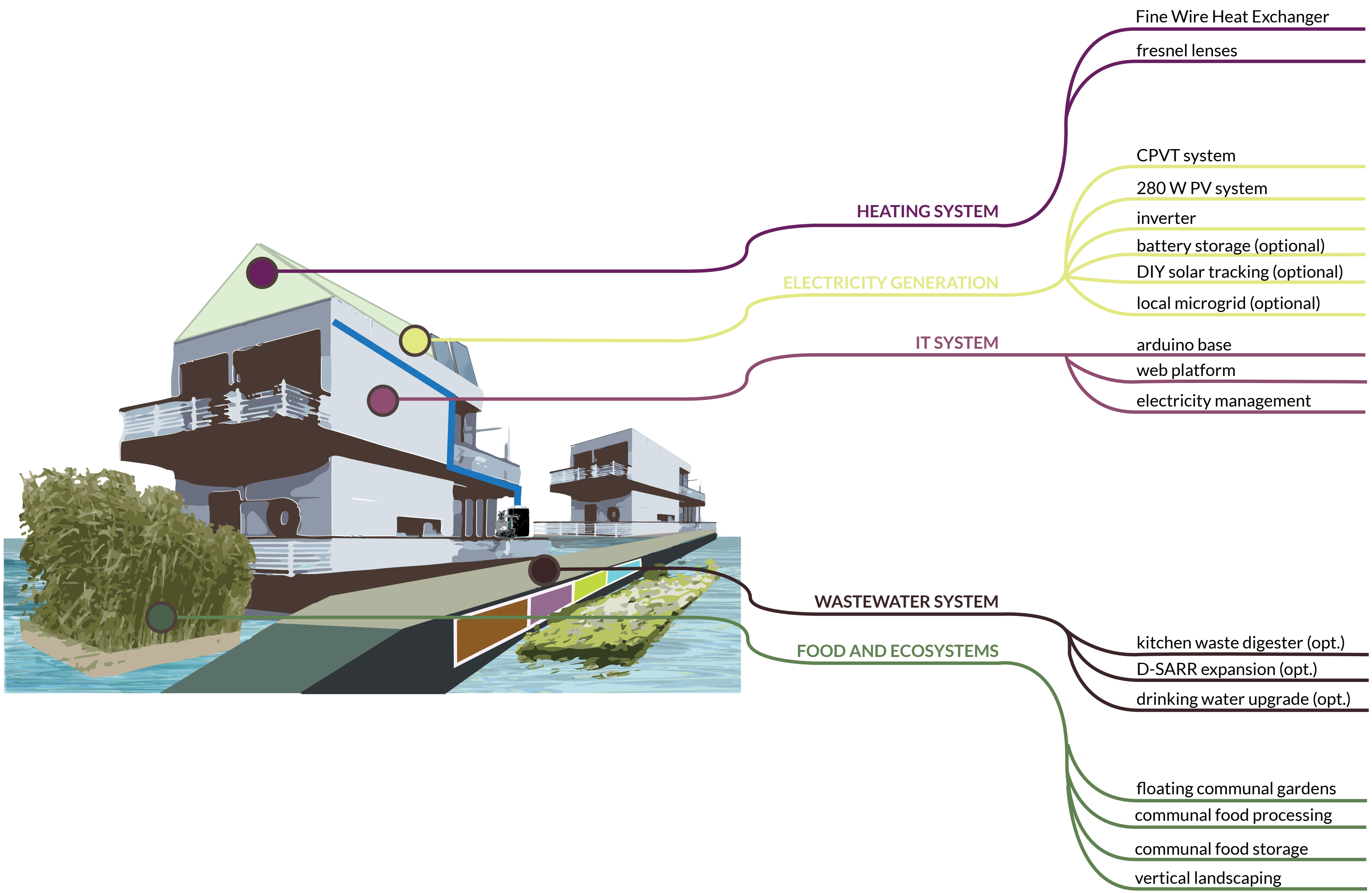
ECOSYSTEMS & SPECIES

- Floating ecosystem elements
- Vertical ecosystem elements
- Biodiversity monitoring

HEALTH & HAPPINESS

- Incorporate new artistic and attractive elements in landscape quality
- Conceal technology like solar collectors
- Create new enjoyable communal spaces and social activities

capacity expansion



1 100% renewable heat and hot water supply

In phase two, installation of electric power generation capacity and the expansion of the heat collection system will allow for each household to have a fully renewable heat and hot water supply. Electric boilers will now provide top-up heating supplied from electricity from renewable energy.

COST & LABOR ESTIMATES

The costs for upgrading to a fully renewable heat supply lie primarily in securing renewable electricity generation capacity. Additionally, renewable heat generation can be boosted directly by installing fresnel lenses and fine wire heat exchangers on any greenhouse structures. The estimated cost of the materials for this step is 550 € and 20 hours of labor.

Based on the current urban plan, not all boats will have greenhouses due to building height restrictions, therefore this will only apply to the households that do.

2 100% renewable electricity supply

In this phase, the community should invest in solar panels. During the first phase, which will stretch over a year, households can monitor their actual demand for electricity, enabling them to scale their purchase of solar panels to the right amount. Despite the relatively low solar irradiance, the most practical and economically feasible solution for this scale is still solar photovoltaic cells.

COST & LABOR ESTIMATES

We estimate that an inexpensive DIY solar PV system will cost around 6.000 € per boat, and require 20 hours of installation time. The exact capacity of the system will depend on how successful boat users are at reducing their electricity demand through implementing efficiency measures. This cost estimate also includes a DIY concentrator and tracking system and an inverter (shared by the entire community).

capacity expansion

3 80 - 100% nutrient recovery

The nutrient recovery system can be upgraded by adding an aglae bioreactor to the D-SARR digestion system. The bioreactor will harvest nitrogen from waste streams for use in on-site food production.

COST & LABOR ESTIMATES

The cost of adding a bioreactor unit to the D-SARR system that can successfully harvest nitrates for local agriculture highly depends on the type of technology that is ultimately chosen. We recommend implementing this on the Schoonschip site as a pilot by partnering with an interested research institute. This step is not critical to the overall functioning of the neighborhood, but is desireable because it will lead to a more closed material cycle overall.

4 electric mobility capacity

An electric car sharing system should be implement consistent with community demand. The system can be linked to a community management platform, allowing individuals to see when cars are not available and to block out when they plan to use one.

As a community, the group can decide if they want to purchase solar panels for charging car batteries. The electricity required for charging a vehicle with average use is equal to an entire household's domestic electricity consumption. Using an electric car sharing system will be equivalent to doubling the number of households. Without solar panels, it will not be possible for the community to self-sufficiently supply its energy needs. An investment in additional solar panels would support the community's driving habit.

COST & LABOR ESTIMATES

Installing electric charge points is currently incentivized by various government programs and subsidies. As such, we anticipate that it will be possible to install electric charging stations for free at the Schoonschip site. Producing sufficient electricity to fully power the electric vehicles owned by Schoonschip residents will approximately double the electricity demand of the neighborhood if residents drive roughly as much as average Dutch citizens do. This is an important consideration when scaling the solar system.

5 neighborhood digital monitoring system

Each household will have its performance listed on a community monitoring system. With such a monitoring system, community members can see how much waste, water, and electricity is being produced by each household. The system will show the electricity use of the communal laundry facility, the amount of electricity produced by solar panels throughout the year, and important information from the D-SARR system, like gas production and nutrient levels.

Using a digital management platform, the community can also track biodiversity by recording sightings of animals and birds over time. This allows them to see whether or not the implemented habitat elements are increasing biodiversity. This can be a casual but effective way to monitor neighborhood biodiversity. The platform can also provide information on resource sharing, such as the availability of communal tools, electric vehicles, and offer opportunities for a kind of internal market that offers details on food production, childcare support, and other data that may be interesting on a community level.

COST & LABOR ESTIMATES

The materials cost for the digital monitoring system are covered in the sensoring equipment purchased in phase one. The primary cost in establishing a neighborhood digital monitoring system is the design and implementation of an appropriate database and website. This will cost an estimated 150 hours of labor from an experienced professional, and may be done by a volunteer within the community.

6 additional communal facilities

A communal food storage and processing area will be installed where community members can make jams and cheeses. A communal pantry can support bulk purchases of eco-friendly products and the sharing of local food production. The community should create a governing system for sharing joint food production and decide whether they wish to jointly purchase commodities from outside the site.

The site plan contains space for four floating communal programs, none of which can be high and thus cannot be buildings or tall structures. We recommend that one area should consist of a swimming pool and sauna and another should include a playground and recreational area for children. The two other floating programs should be allocated as gardens used for communal food production. In these areas, barbeques and other recreational functions can be integrated into the gardens.

Two of the buildings, instead of being households, will be used as communal laundry centers with a greenhouse on top. The site's swimming pool will be heated partly by heat collectors which will harvest waste heat from the washing machines. These communal buildings can also incorporate their own business model, such as offering a bed-and-breakfast. The BnB would come online in phase two and would either be managed by the community or by some community members who would operate it as entrepreneurs. If the BnB is managed by the community, the earnings can be used for future technologies and other communal purchases, like financing the gardens or ongoing maintenance.

7 60 - 80% vegetable and fruit production

The final site plan described here has 500 square meter of greenhouses, around 740 square meters of green roof terraces, and several additional areas earmarked for vertical food production alongside the jetty. Sections of the jetty that have good access to sunlight, walls can be installed on the sides to support vertical food production for crops like vegetables and herbs. In this stage bees kept on site can begin to produce honey.

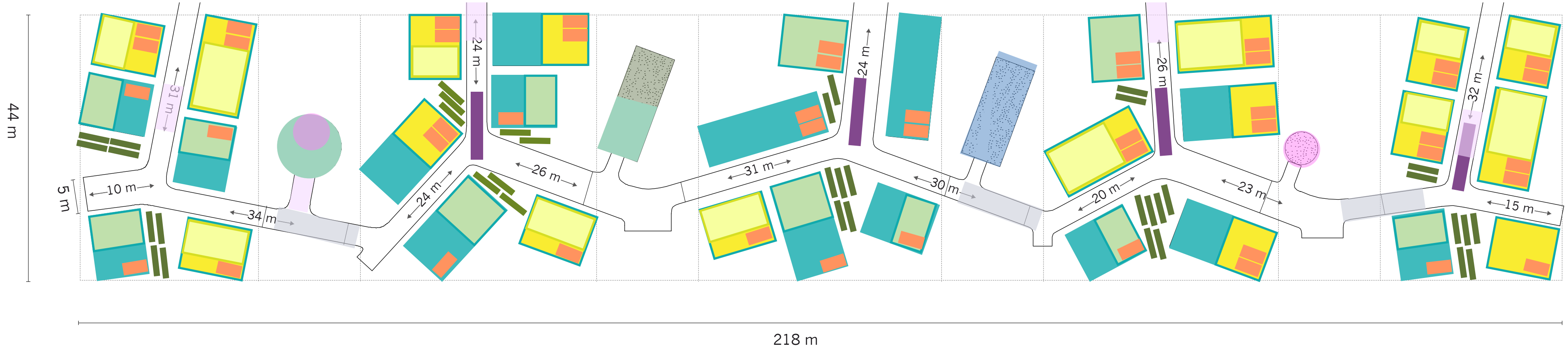
Many of the greenhouses offering opportunities for food production will effectively be private spaces. In practice this makes a community food management system challenging unless everyone is committed to co-producing and sharing food.

COST AND LABOR SUMMARY (PER HOUSEHOLD)

component	€	hours
DIY solar PV system	6.000	20
Fresnel lenses and FiWiHex	550	12
Web platform	NA	3
DIY vermiculture compost	30	3
Garden equipment	500	150

As seen in the chart to the left, our current estimates indicate that the materials costs for the recommended phase two interventions come out to a total of approximately 7.000 € per household.

phase III



Green roof + solar infrastructure	1.155 sqm
Greenhouses	490 sqm
Green roof terraces	741 sqm
Solar heat collectors	384 sqm (8 sqm / house)
Solar PV cells	480 sqm (10 sqm / house)
Outdoor food production	180 sqm
Food processing & storage	120 sqm
DESAR organic waste treatment	110 sqm (22 sqm /pier)
Reedbed filtration	600 sqm (1.4 sqm/person)
Vertical food production	300 sqm
Vertical ecosystem	220 sqm
Pool and sauna	250 sqm
Play area	60 sqm

HOUSE BOATS: 6300 sqm (30)

JETTY: 1635 sqm

In phase three, the site and most of the envisioned communal facilities will be completely developed, leaving room for future experimentation. As summarized in the map above, the community should at this point have a number of floating communal areas featuring play areas, a pool and sauna, vertical food production on the jetty, food processing and storage, and a full installation of solar photovoltaic panels.

PHASE III GOALS

ENERGY & MATERIALS

- Install larger greenhouse construction on adjacent floating site to achieve up to 80% of local food production
- Install experimental technologies and pilots
- Upgrade electricity storage

CULTURE & ECONOMY

- Education opportunities for surrounding communities
- Flexible program for experimental technology inclusion
- Encourage the development of local business and cultural activities

ECOSYSTEMS & SPECIES

- Continue evaluating ecosystem impacts of support structure installations

HEALTH & HAPPINESS

- Create enjoyable communal spaces and social activities

The Cleantech Playground is not meant to reach a static point. The community will continue to evolve alongside technological developments and changes in the surrounding environment.

MAKE ONGOING IMPROVEMENTS

The technologies implemented on site are designed to be modular so that they can be swapped out for improved systems. More DIY constructions can be installed over time, allowing for progressive improvements in quality and aesthetics. The community would benefit from a culture that constantly looks for ways to improve the site. The site should be responsive to changes and new developments. As certain technologies and materials become cheaper over time, the community can achieve even higher performance.

INSTALL LARGER GREENHOUSE STRUCTURE ON ADJACENT FLOATING SITE

In between the sites of Schoonschip and de Ceuvel is an area earmarked for special floating program. We believe this would be an ideal location to develop a multi-layered floating greenhouse. Once the community is up and running, they could petition to use this floating site their own food production. The greenhouse would include fish, livestock, mushrooms, and various fruits and vegetables. The food produced there could satisfy almost the entirety of both community's remaining food demand with the exception of red meat, exotic crops like coffee and bananas, and most grains. This greenhouse would need its own business plan and could also produce enough food for sale in the local area.

INSTALL EXPERIMENTAL TECHNOLOGIES

Experimental technologies like algae reactors, new lighting techniques, and hydrogen systems can be installed and tested on-site. The Cleantech Playground serves not just as a cleantech utility but as a demonstration site for emerging technologies, offering the community additional sources of revenue and creating visibility around promising new methods of sustainable urban development.

next steps

towards realization

This section provides a quick overview of the next steps we believe need to be taken in order to execute the Cleantech Playground. Both projects are at an advanced stage of development, but a great deal of focus and continued effort will be needed to realize the ambitious sustainability plan outlined here.

The plan and tools embedded within this document represent the conceptual phase of the design process. We have designed these tools so they are flexible and adaptable, but more specific choices need to be made by the community. Those selections will then need to be further worked out in terms of technical and financial impact.


DIY

ONGOING INVOLVEMENT

Metabolic Lab will continue working with both communities to execute the Cleantech Playground. In the case of De Ceuvel, we are a stakeholder in the project and member of the de Ceuvel association (vereniging). As a company we are committed to purchasing and retrofitting our own reclaimed houseboat, which will serve as a potential entry point for the De Ceuvel community. Our boat will host emerging technologies and act as an experiential showcase of the technical system on site, giving visitors the opportunity to explore and learn about the energy and resource flows and the technologies incorporated in both sites.

We are also committed to continuing our work with the Schoonschip community. At a minimum, we will guide community members in using the tools we have produced for selecting household technologies. As part of our work on the de Ceuvel development, we may also create educational opportunities (site visits and workshops) for members of the Schoonschip community to learn more about the technologies we have recommended here.

TECHNOLOGY PARTNERS

The Cleantech Playground has value as a showcase for technology partners who are interested in providing technologies in-kind or at-cost in return for visibility and research. We are currently in the process of talking to several technology partners about including their technology in the system. Further steps include making those relationships more concrete and establishing a structure for working with new technology partners over time. Such relationships reduce the cost burden on the communities, which are funding these investments collectively, allowing them to incorporate additional and more advanced technologies.

In particular, we will actively be seeking a partner to help implement the decentralized organic waste and wastewater treatment system we have designed (the D-SARR). Our goal will be to pilot this system on the de Ceuvel site, providing insights for how it can be implemented on the Schoonschip site as that development becomes more concrete.

DEMONSTRATION AND SHOWCASE

Part of the vision for both sites is to provide demonstration spaces in which conventional technology can replaced with demonstration technologies. This experimental side of the Cleantech Playground is works to showcase important new technologies to the market and can gather performance data in a live setting.

Embedding new technologies should be combined with designing technological implementation in such a way that the process is on constant display. There are certain areas on each site that are fitting places to make visible how these technologies work individually and together as a system. On de Ceuvel, Metabolic Lab's boat can serve part of this function by implementing an interactive exhibit that explain the function and visualize material and energy flows. The HORECA zone, which will include a restaurant, some food production, and the community's sanitation system, is another logical place. Here, urban agriculture, sanitation and water collection, and digital information about material and energy flows in real time can provide the important educational link with visitors.

SOURCING MATERIALS AND LABOR

Sourcing materials and labor will make a significant difference in the resulting costs and external impacts the Cleantech Playground has on surrounding systems. By building and installing technologies on their own, both communities will save 50 - 75% of the cost of the recommended systems.

Metabolic Lab will advise the community in constructing various DIY technologies as a group. We will continue to design and assist the construction of the sanitation system for both sites.

appendices

background data and additional information

The appendices that follow contain a summary of some additional background research and design work that we completed over the course of this project.

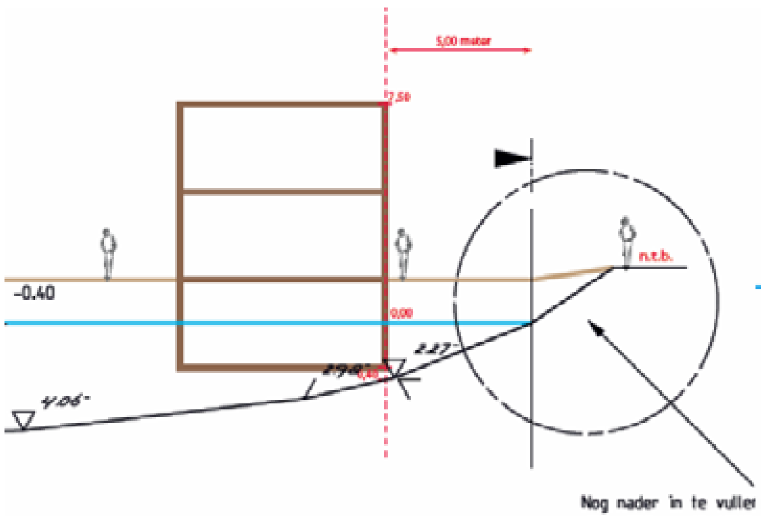
- Appendix A provides information regarding the site's spatial, physical, and ecological conditions.
- Appendix B contains a quick overview of relevant regulations and governance considerations.
- Appendix C has an overview of some of the demand side assumptions we used for modeling the clean technology designs described in this report.
- Appendix D has a description of our original "conceptual design" scenarios, which were submitted for peer commentary midway through the project.

APPENDIX A:

SITE DETAILS

LOCATION


Schoonschip
450 m
80 m
Buiksloterkanaal
(C)
(B)
De Ceuvel
(ca 4.470 m²)
(A)
Johan van Hasseltkanaal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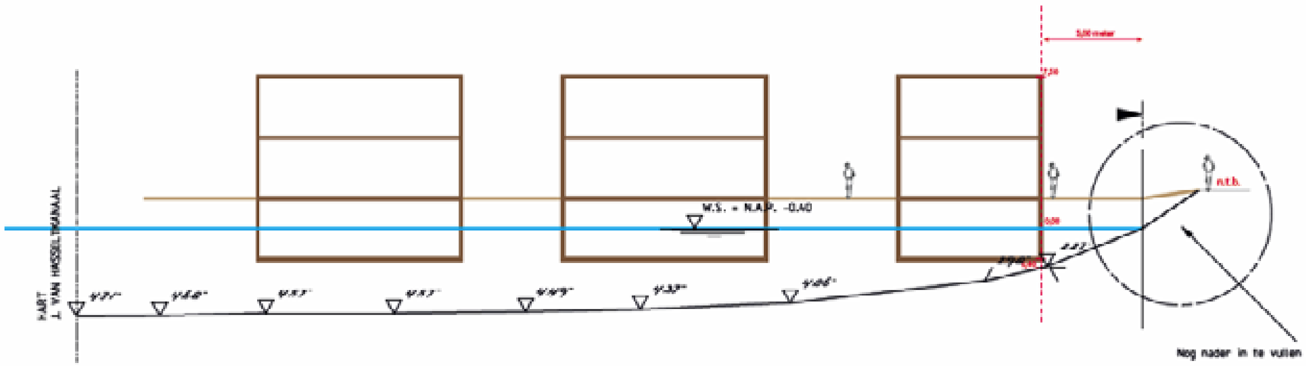
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SITE ANALYSIS > LAND USE

SUMMARY

The sites of Schoonschip and De Ceuvel carry the burden of their history of industrial activities in the 20th century, which are mainly reflected in its heavily polluted soils, water soils, poor water surface quality and other related problems such as incidental asbestos.

The sites on which the Cleantech Playground will be situated are located in the Buiksloterham area in North Amsterdam. The water depth at the Schoonschip site ranges from 4 to 4,6 meters.

The Schoonschip site is a water parcel. It comprises an area of ca. 8,500 m^2 and is located on the Johan van Hasseltkanaal-West, parallel to the bank, which is parallel to the Veldbiesstraat. The De Ceuvel site is a land parcel. It comprises an area of ca. 4,470 m^2 and is located east of the Schoonschip site, at the beginning of the Korte Papaverweg. It is subdivided into three parts:

1. A canal edge part (ca. 3080 m).
2. An eastern part (ca. 900 m^2).
3. A western part (ca. 490 m^2).

The sites are in close proximity to each other and are surrounded by open space and only few buildings. They are separated from each other by water and can be reached over land (distance ca. 450 m). This will be improved in the future, since the zoning plan of the area has plans for building a bridge over the Buiksloterkanaal which would reduce the distance to ca. 80 m.

HISTORICAL LAND USE

The Buiksloterham area has a history of being a landfill for sludge in the 19th century, and an industrial harbor area in the 20th century that is now leaving vacant and abandoned plots waiting for new developments. The Johan van Hasseltkanaal in which the Schoonschip site is situated was dug in 1908 with the goal to disburden the water traffic of the IJ at the level of the Central Station (Projectbureau Noordwaarts, 2012a). However, it was never completed. The De Ceuvel site was formerly used to repair ships for inland waterways. The buildings of the site were mostly demolished in 2002 (Projectbureau Noordwaarts, 2011).

CURRENT LAND USE

The Schoonschip site has no current land use or function. De Ceuvel site is an abandoned site with some leftovers of its former use: a number of foundations, pavements and concrete docks are on the site.

FUTURE LAND USE

In the last years, the municipality has set ambitious goals for Buiksloterham in their program ‘Noordwaarts’, which was the goal of transforming the industrial area in the coming years into a sustainable area where people can both work and live (Projectbureau Noordwaarts, 2009a).

1660

Buiksloterham is part of the IJ and located between two tongues of land

1850

Buiksloterham is used as a landfill for polluted dredge and reclaimed for agricultural use

1900

Industrialisation, harbour industries settled in Buiksloterham and the canals where dug

2009

Decrease of industrial activities leaving vacant polluted and abandonned parcels, waiting for new developments

SITE ANALYSIS > NEIGHBORHOOD

RESIDENTS

The number of residents of the area is low (646 on 1 January 2010) and mainly comprised of students (63%). However, this number is increasing and expected to grow to 11,000 people in 2030 (Stadsdeel Noord, 2010). These residents live in only 32 official housings, with student housings not counted because of their temporary nature.

BUSINESS ACTIVITIES

The sites are predominantly surrounded by office buildings and businesses. In the last decade there has been a major rise in business activities, with the number of business establishments rising 31% from 691 in 2000 to 904 in 2010 and the number of jobs rising 27% with 7,433 in 2000 to 9,471 in 2010. In these activities, consultancy and research are the largest sectors (see employment breakdown graphic at right).

INFRASTRUCTURE

The area of Buiksloterham has relatively weak accessibility to other parts of the city. Part of the plans for the area are thus improving the infrastructural network, which is expected to increase substantially with the projected completion of the North-South line subway system. Parking is possible in the public domain.

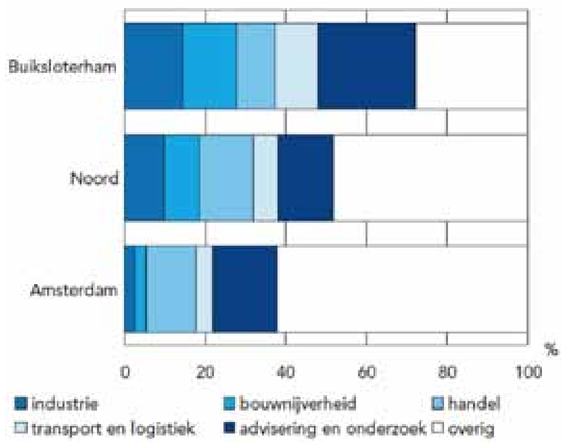
UTILITIES

Electricity and gas are available for both sites. The grid is under control of grid operator company Liander (Liander N.V., 2012). A map of the area with all the cables and pipes and possible connection points was not acquired but such a map (max 500 m x 500m) can be acquired at a cost of €21.50 at the Dutch Land Registry Office Kadaster (Kadaster, 2012).

The water system is under control of water company Waternet. Drinking water systems as well as sewage water systems are available for both sites. Possible points for connection to the system are found for Schoonschip along the Vieldbesstraat and for De Ceuvel along the Korte Papaverweg. Five water outlets are situated nearby (<100 m), one in the Buiksloterkanaal, one in the Distelhaven and three in the Johan van Hasseltkanaal.

COMMUNICATION

The standard package for communication (no fiberglass) is available via KPN at both the Veldbiesstraat (Schoonschip) and the Korte Papaverweg (De Ceuvel). This standard package comprises television, telephone and Internet (download/upload-speed up to 40/4 Mb/s) is available.



SITE ANALYSIS > PHYSICAL & ECOLOGICAL

SOILS

The geological basis of Buiksloterham is formed by a 15 to 20 meter alternation of Holocene sand, clay and peat on top of a thick layer of Pleistocene riverbed sand and gravel. On top of the sediments originating from the Holocene is a man-made layer of 2-3 meters of clay and sludge, coming out of the city centre canals. To overcome the high groundwater level, a layer of sand was put on top of this dredge layer. This has raised the ground level to between +0.6m and +1.1m NAP. Due to industrial activities this layer of sand has become polluted with mobile and immobile pollutants.

SOIL QUALITY

De Ceuvel site is highly contaminated with immobile substances (several heavy metals, polycyclic aromatic hydrocarbons (PAK) and incidentally asbestos). Current plans for De Ceuvel site with phytoremediation through a mix of various grasses that absorb mercury, arsenic, lead, zinc, manganese and aluminum.

WATER SOIL QUALITY

The sludge of the Schoonschip site is highly contaminated with heavy metals, in particular mercury, copper, zinc, lead and arsenic and moderately contaminated with other substances under examination. There is no obligation to remediate the sludge.

GROUNDWATER

The polluted dredge layer has formed an impervious layer, causing high groundwater levels, which is a major problem to the area.

SURFACE WATER

The surface water of the IJ, the canals and the harbors meet the general standards for pH (acidity), transparency, oxygen, temperatures and heavy metals. The yearly average concentrations of phosphate, nitrogen and copper are, however, above the MTR level (maximum allowed risk), which is mainly caused by the several water outlets. Therefore, the current mixed sewage system will be replaced by an improved separated system, improving the surface water quality substantially.

BIOLOGICAL WILDLIFE

The area is characterized in the Ecological Atlas of Amsterdam (2012) as the biotope 'bebouwing' (buildings). The animals of these biotopes in Amsterdam are characterized by either actively or passively using the food made available by humans. Thus, mainly 'urban' birds can be found (Swift, Urban Dove, (House) Sparrow, Brown Rat, Little Bat, Tongue Fern, Wall Fern). For the selected area, the protected species are the 'Gierzwaluw'(Swift) and the 'Huismus '(Sparrow).

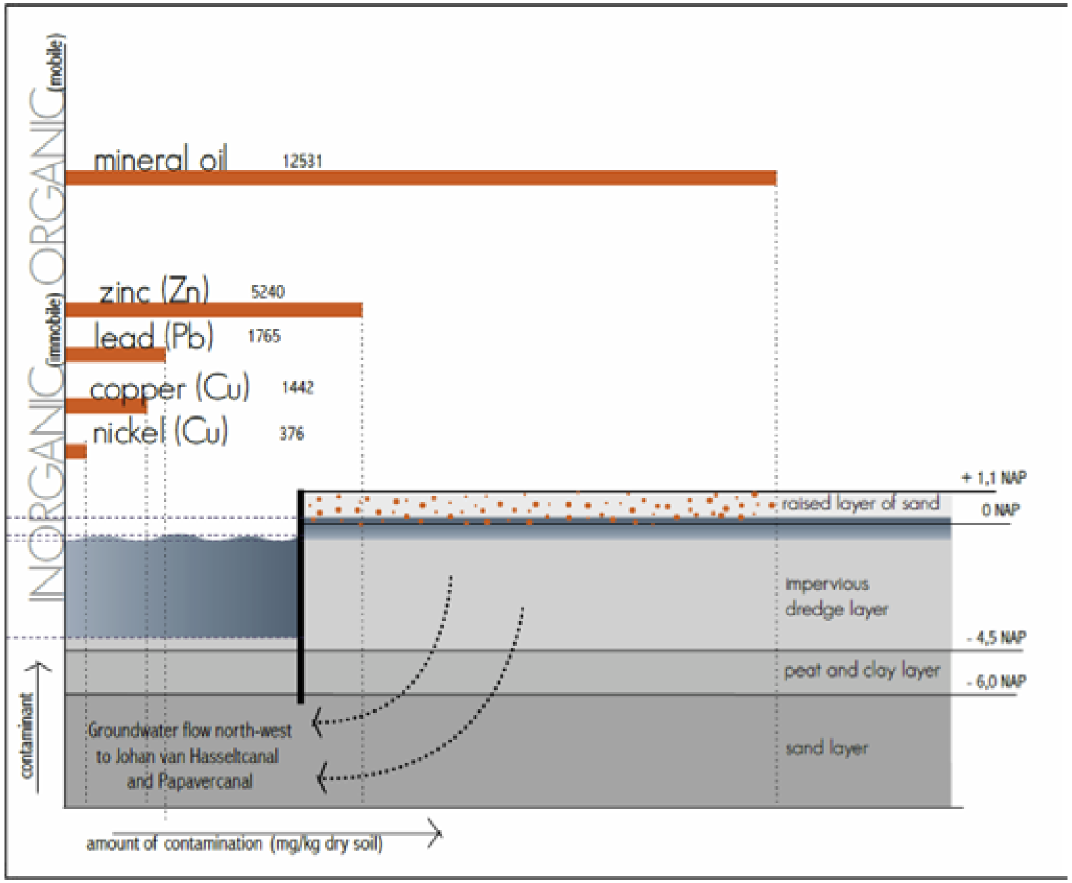
These protections make that some considerations need to be taken into account when building, especially in the months of March – June; sufficient nesting possibilities and providing some urban wilderness for food is required. The remainder of the possible present species for this area is Starling, Jackdaw, Treecreeper, Collared Dove.

VEGETATION

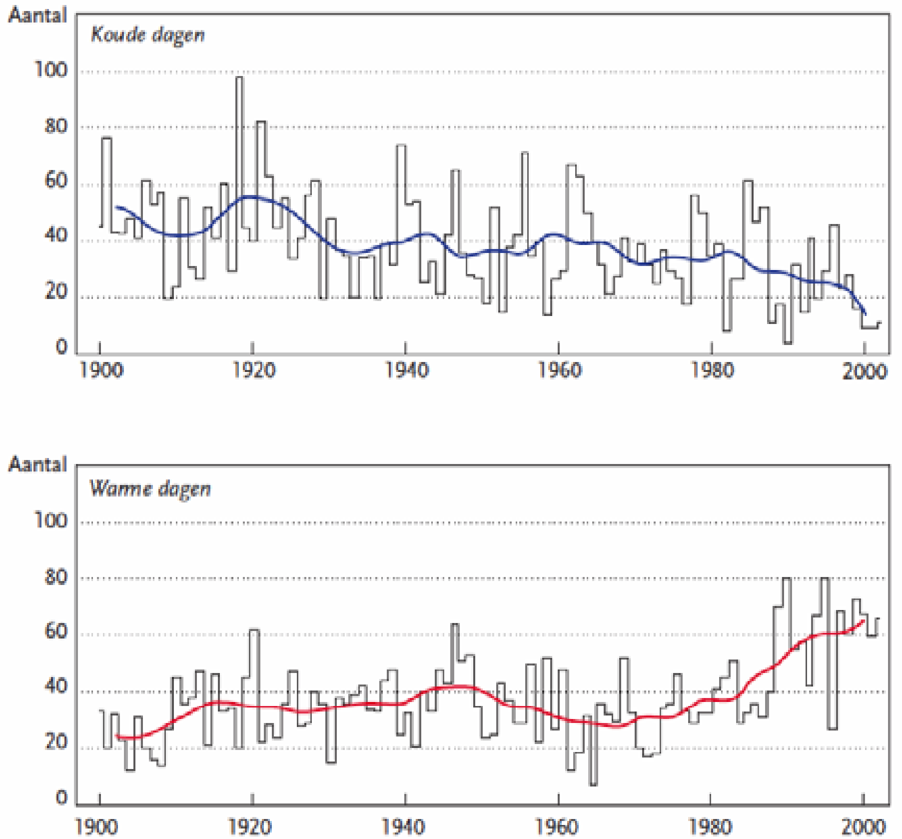
Regarding vegetation for the Schoonschip site, there are around 23 trees situated on the edge in combination with some bushes and shreds on the bank of the canal (see Appendix E, Figure 2). None of these trees or vegetation are of any threatened species or have any protected status in the form of monumental green. De Ceuvel site has more abundant vegetation and habituates 42 trees, of which 4 trees are protected with a monumental status. Next to the trees, there is an abundance of bushes and weeds and related species situated on the site, but with no special protected status. Possible species are Limestone Oak Fern, Henbane, Belladonna, Wild Lettuce, Halsbloem (Trachelium caeruleum), Trailing Bellflower, Latin American fleabane, Flattened Meadowgrass, Valerian and Common Fig.

AQUATIC ECOLOGY

No specific measurements or assessment of the aquatic ecosystem of the Johan van Hasseltkanaal have ever been performed. The water in the Johan van Hasseltkanaal comes from the Noordzeekanaal and its aquatic ecology is thus mainly determined by the state of the systems in this canal. In the report of Rijkswaterstaat (2009) on the Noordzeekanaal of 2009, the ecological quality of the water is mainly determined by the quality of the following elements: phytoplankton, macrophytes, macrofauna and fish. A table of the last studied situation is given in Appendix E, Table 1. In this report, several bottlenecks for the Noordzeekanaal were identified, but none of specific consequences or effects for the Johan van Hasseltkanaal.



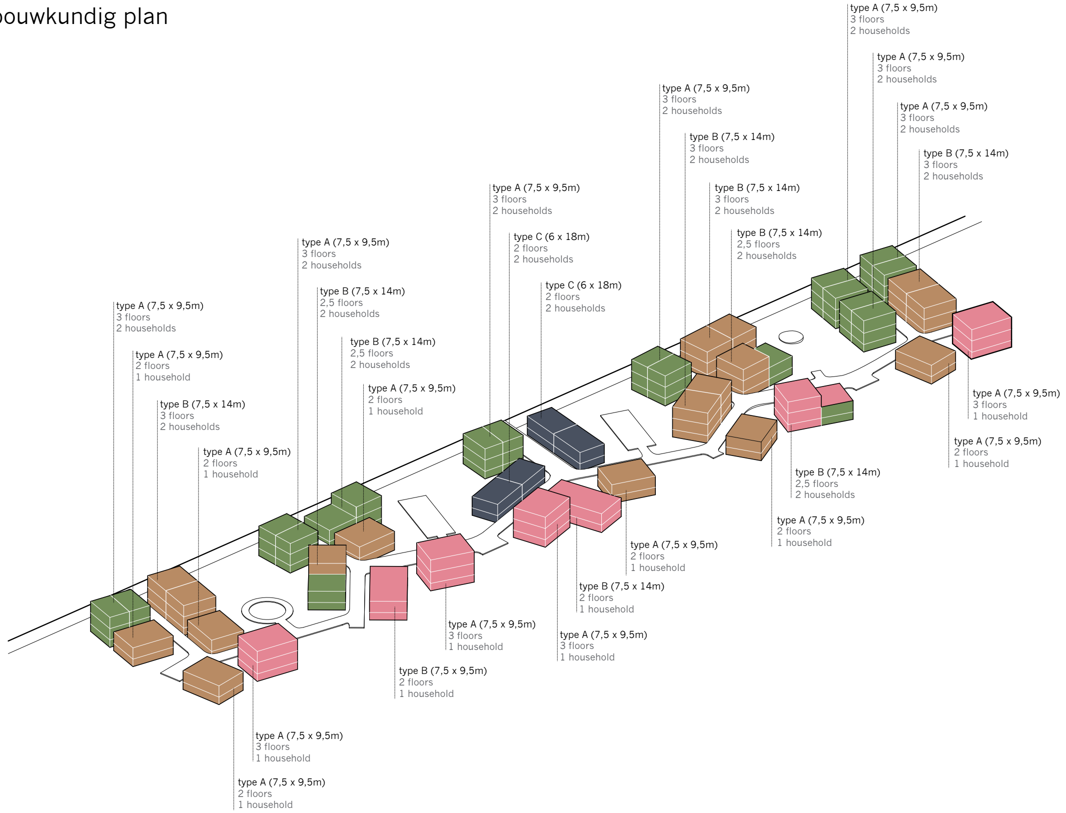
ORGANIC (mobile)
INORGANIC (immobile)
mineral oil
12531
zinc (Zn)
5240
lead (Pb)
1765
copper (Cu)
1442
nickel (Cu)
376
+ 1,1 NAP
raised layer of sand
0 NAP
impervious
dredge layer
- 4,5 NAP
peat and clay layer
- 6,0 NAP
Groundwater flow north-west
to Johan van Hasseltcanal
and Papavercanal
sand layer
contaminant
amount of contamination (mg/kg dry soil)



Aantal
Koude dagen
100
80
60
40
20
0
1900
1920
1940
1960
1980
2000
Aantal
Warme dagen
100
80
60
40
20
0
1900
1920
1940
1960
1980
2000

SCHOONSCHIP URBAN PLAN

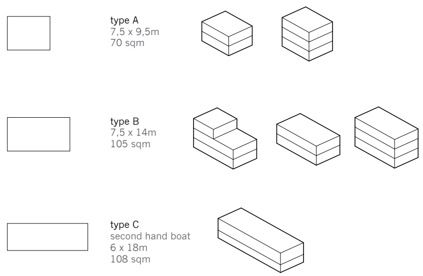
OPTION 1
Stedenbouwkundig plan

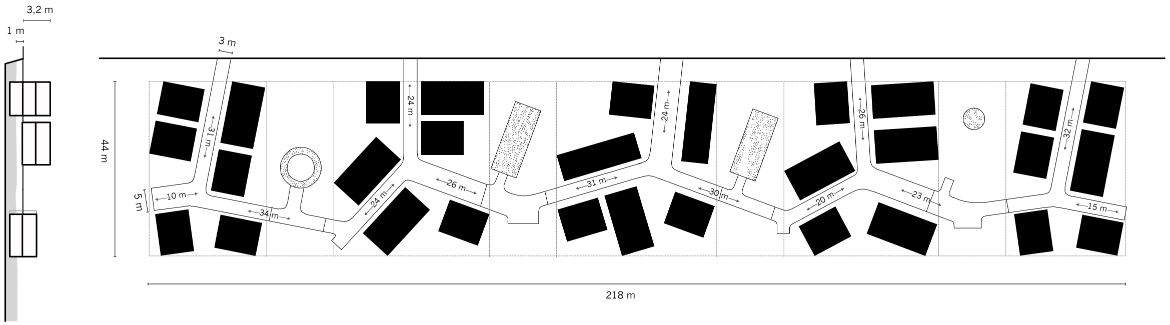


DATA

income	%	amount	BVO	GVO
25.000	10 %	5	70 m2	60 m2
50.000	40 %	19	105 m2	90 m2
75.000	35 %	17	140 mq	120 mq
100.000	15 %	7	210 mq	190 mq

TYPES





HOUSE BOATS: 6300 sqm (30)

JETTY: 1635 sqm

SCHOONSCHIP

ARCHITECT: SPACE&MATTER

- total site area: 8.500 m^2
- number of households: 48
- number of boats: 30
- estimated number of residents: 120 - 160
- total available jetty surface area: 600 m^2
- total communal surface: 212 m^2
- total available roof area: 1.008 m^2

DE CEUVEL URBAN PLAN

DE CEUVEL

ARCHITECT: SPACE&MATTER

- total site area: 4,470 m^2
- number of offices: 13
- number of restaurants: 2
- number of workshops: 1
- total walkway area: 450 m^2
- total estimated daily occupancy: 250 people

POTENTIAL FOR ADDITIONAL SHARED INFRASTRUCTURE

Between the Schoonschip and de Ceuvel sites, there is room for two so-called "special program" sites, which are not part of the main Schoonschip tender. These are also being offered up for tender. We are also considering including them in the design for additional relevant program, such as a floating greenhouses for food production.

APPENDIX B: REGULATIONS

SUMMARY OF TECH REGULATIONS

At right is a summary of the basic regulations that come into play in the selection of clean technologies.

WIND ENERGY	A building-permit is required for construction of wind turbines. This is usually a municipal decision, but in the case that the municipality rejects the project it can also be requested on the provincial level.
SOLAR COLLECTORS AND BOILERS	Larger scale projects need to comply with zoning laws (bestemmingsplan) and may need a permit (omgevingsvergunning). For roof installation, a building-permit may be required, available on the municipal level.
HYDROPOWER	A municipal building permit is generally needed for hydropower projects, sometimes exemption permit are required. These are provided by the local Waterboard or Ministry of Economic Affairs.
BIOGAS	A Wabo-permit (for management of the surroundings), building permit and environmental-permit (bouw en milieu vergunning) are needed for the construction and operation of a bio-gasifier.
GEOTHERMAL ENERGY	For installation at a depth of more than 500 meters, a permit from the ministry of Economic Affairs is needed. For any drilling a Wabo-permit is needed.
HEAT EXCHANGERS	o No permits are required for ventilation heat exchangers. o Air-heat-exchanger outside homes require a municipal building permit. o No permits are required for house-hold scale closed-loop systems o Larger community level systems require attention to provincial groundwater regulations
WATER PURIFICATION	Water is regulated on a national scale. Permits are required for waste water-discharge. Water quality is regulated by the local water utility, and any decentralized systems need to get authorization through Waternet.
RAINWATER COLLECTION	For household water-collectors, no specific permits are required. Depending on the size of the construction, a building permit may be required.

RULES AND REGULATIONS

For both the Schoonschip site and the De Ceuvel site, several spatial and environmental building restrictions are posed on the site.

The Cleantech Playground must navigate rules and regulations for two different building types and from varying sources of decision-making bodies. The broad scope of this project including businesses (De Ceuvel), housing (Schoonschip), and decentralized utility provisions. This makes the identification and understanding of relevant laws a complex task.

The pioneering work on green technology means that many of the usual laws for construction may be ill-equipped to regulate these aspects envisioned by this project. For the benefit of the project, we look at the rules and regulations in separate blocks; building regulations for floating houses and regulations on the application of green technologies.

The first difficulty when it comes to the juridical status of floating structures in their ambiguous position in the law, where they could be considered as either boats or houses. All floating structures which hold more than one house are considered as separate non-building construction entities, while if there is only one house it could be considered a building. This should be taken into consideration as part of the Schoonschip group will have shared pontoons while others will have a individual pontoon. There are specific regulations for building multiple houses on one pontoon, theses are in the construction laws and are similar to the regulations for constructing on land.

A jetty is generally classified as a non-building construction (bouwwerk geen gebouw zijnde). A jetty should function as a communal traffic space; escape route for the households connected to it. However they can be put in by the municipality, making it a public space, or by the private developers, making it a private space, in this case as part of the tendering process, and in light of the plans for the Utility system the Jetty's will be part of the private infrastructure.

The vast majority of rules affecting Schoonschip has the character of a barrier, however due to its piloting nature Schoonschip can take advantage of a) opportunities for subsidies and b) imprecise laws that can be circumvented and c) inexistent regulation due to reactive law-making.

The majority of rules affecting Schoonschip is set at a decentralized level and these rules a) better reflect local peculiarities, and b) are considered by experts as more modifiable due to a higher approachability of the rule-making institution.

MAIN SITE REQUIREMENTS

- Construction border: buildings should be built within the building boundary.
- Lines of sight: between the buildings there should be at least four lines of sight of a width of each at least 15 m to be achieved as far as possible with a uniform distribution. Sight lines are clear of obstructions and buildings, except scaffolding for access to the homes.
- Water surface: within the area built upon, at least 35% of the surface is free from any building, obstacles or scaffolding.
- Water Housings; Must comply with the building regulations.
- Connection to the edge: a maximum of 5 connections of quays to the main land.
- Quays: minimum width is 3 meters and the cables and lines are taken within this. The quays are not closed.
- Construction height: the maximum height of the housings is 7.5 meters from the water surface.
- Building is 'welstandsvrij', meaning that the municipality doesn't test the building plans on test for reasonable demands of 'welstand', but leaves it over to the initiator of the building plans.
- Environment: No leachable materials may be applied.
- Minimum distance between the bottom of the houses and the water soil is 40 cm.

BUILDING CODE AND SAFETY

Construction law does not consider using the water as an escape route either through a boat or by swimming as an acceptable escape route (VROM, 2010). Construction law indicates that any separate fire/smoke unit (house) must have at least 2 smoke-free escape routes (VROM, 2010).

- The law states that the escape route should lead to a safe adjacent plot and from there towards a public road.

- In this case the jetty could be considered one escape route as it does not form part of the unit.

- (article 2.92-2.94 of use of materials) If the project developer does not register the jetty as an adjacent plot then it's considered a construction non-building (bouwwerk geen gebouw zijnde) with a communal traffic space/ escape-route for the community. In that case the same demands count as those set for protecting smoke-free escape-routes. Furthermore it's not clear how such jettys with dead-ends would have to deal with the regulations, optional solutions can be implemented Article 2.156 demands that there be two separate smoke-free escape routes for every housing unit. In the case of floating houses the two escape routes can be on the same jetty but they have to be separated by 30 minute from each other (article 2.58 lid. 1) or by a fireproof wall, or a mixture of both.

The municipality has the duty to offer emergency services (such as fire-department) within reach of the community. Article 2.5.3 of the model guidelines for building (model bouwverordening) states a maximum distance of 10 meters between the access point to the jetty and the public road. The fire-department has the capacity to deal with a maximum distance of 40 meters. In case of longer distance arrangements can be made with the municipality and fire fighting department to set some firefighting instruments on the jetty or within the community.

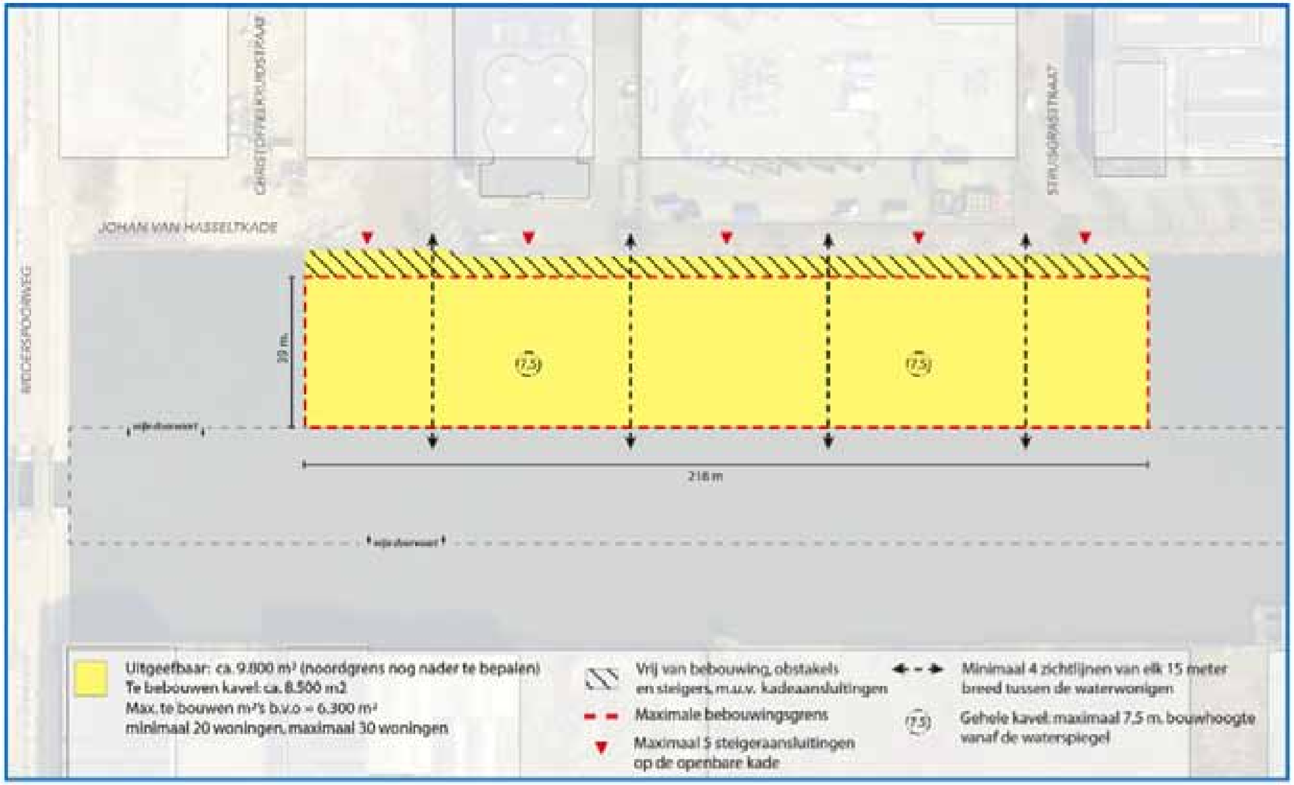
The building-code does not ask for a fence around the jetty or houses if the distance from the water is less than 1 meter or at access points to the water. The building-code asks for at least one access point for wheelchairs in each house. The model guidelines for building demand the route from the public road to also be accessible by wheelchair. In practice the steepness of the jetty or the gangway often make the implementation of this regulation impossible. The design of the hallway to the houses from the wharf, or the connection between the jetty and the entrance can be fixed or flexible (moving with the water-level).

According to the building code the owner of the floating house may choose to set meter inside the house or on the wharf. The owner has to take care of the lines and pipes from 2cm outside of the external separating construct up to the meter, to enable the grid operator to make the connection. NEN2768 regulates where pipes and lines can be laid, however this law is not applicable to the context of living on water, thus the law is not clear on this aspect and creative solutions are necessary.

SUSTAINABLE TECHNOLOGIES

The laws on national level are based on the assumption of a status quo, legally represented as bouwbesluit 2012 and drinkwaterwet, elektriciteitswet 1998. However, these laws are not final, in the sense that many applicable to sustainable development indicate situations in which permits might be lifted. These are described in other regulations such as: regeling groen projecten 2010. There are also subsidy system to promote implementation of projects deemed sustainable and desirable on either national or municipal level such as: subsidie regeleing energie en innovatie.

A bottom-up research of the applicable laws and regulations for the technologies researched in the technology scan has resulted in an exhaustive list of of laws. Not all may be relevant to the program, although they all deal in some way with the technologies that may be used in the final design of the Cleantech Playground. In the interest pragmatism, we looked at the permits required for the implementation of the most likely-used technologies indicated in the technology scan. These include: wind-energy, solar-energy, hydropower, biogas, geothermal-energy, heat-exchangers, bio-gas, composting, water purification, and rain water collection. These vary from general regulations to very specific rules. Regulations for most technologies depend on the scale of the implementation.



APPENDIX C: RESOURCE DEMAND

BASELINE DEMAND

TYPICAL RESOURCE USAGE

A central strategy for achieving all of the scenarios described in this document is to realize very high levels of resource use efficiency and demand-side reduction. As a starting point, we sketched the current consumption baseline to understand where the greatest opportunities for targeted intervention lie. Below are basic resource demand summaries for Dutch households, offices, public lighting infrastructure, personal transportation, and food consumption. These are the primary end demand scenarios that we are dealing with on the Schoonschip and de Ceuvel sites.

Dutch households

In Dutch households energy demand in 2010 broke down as follows[1]:

- 1.617 m^3 of gas, used primarily for space heating (80 - 85%), followed by hot water (10 - 15%), and finally around 2 - 5% for cooking.
- 3.480 kWh of electricity, primarily used for cleaning i.e.., laundry and clothes drying (~20%), refrigeration (~15%), lighting (~15%), followed by heating (electric heating systems), ICT, cooking, ventilation, kitchen appliances, other appliances, recreation, and personal care.

Dutch domestic water use is around 127,5 liters per person per day.[2] The majority of this water, around 50 liters, is used for showering, followed by 37 liters for toilet flushing, 23 liters for clothes washing, and the remainder used in sinks, dish washing, and food preparation. An estimated 60 liters of this water is consumed hot.

Typical per capita waste production in the Netherlands amounts to an estimated total of 549 kg per year. This includes

1 Energie in Nederland 2011 Report
2 Central Bureau of Statistics, 2010 data

Dutch offices

In Dutch offices energy demand in 2008 broke down as follows[3]:

- 15 m^3 of gas per m^2 of office space, used primarily for space heating
- 205 kWh of energy per m^2, primarily used for lighting (21%), equipment like computers and printers (12%), followed by 7% for servers and decentralized ICT, and the remainder for transport, ventilation, and other functions.

Public lighting infrastructure

In the Netherlands there are around 3.000.000 lighting masts and around 3.500.000 lighting points for public lighting. These have an average power consumption of 50 W and 4,100 operating hours per year, leading to around 800.000.000 kWh of electricity consumption per year, or around 1,2% of national electricity use. Most of these lights are sodium light points.

Personal transportation

Car ownership in the Netherlands is at around 400 cars per 1.000 people. The average travel distance by car is 37 km per day[4].

Food consumption

We have a very detailed dataset on typical Dutch food consumption based on a 2011 study conducted by research institute RIVM. A summary of average adult daily food consumption by food type is shown in the pie chart to the right. Based on these consumption rates, we can estimate local capacity for food production.

REDUCTION TARGETS

It is clear that some of these demands result from suboptimal technologies and systemic inefficiencies (household heating and lighting systems), some stem from behavioral patterns (lighting and personal transportation), and others are rather inelastic (food demand). In our demand-side design, we have begun by targeting those areas of demand that are most sub-optimized, either technologically or behaviorally.

3 Energie in Nederland 2011
4 Senter Novem Databank, SWING

Based on our initial modeling, we have concluded the following:

- Natural gas demand for space heating can be entirely eliminated in new constructions and mostly eliminated in retrofit constructions by adhering to Passive House standards. This will be replaced by a relatively small increase in electricity demand for heat recovery ventilation systems.

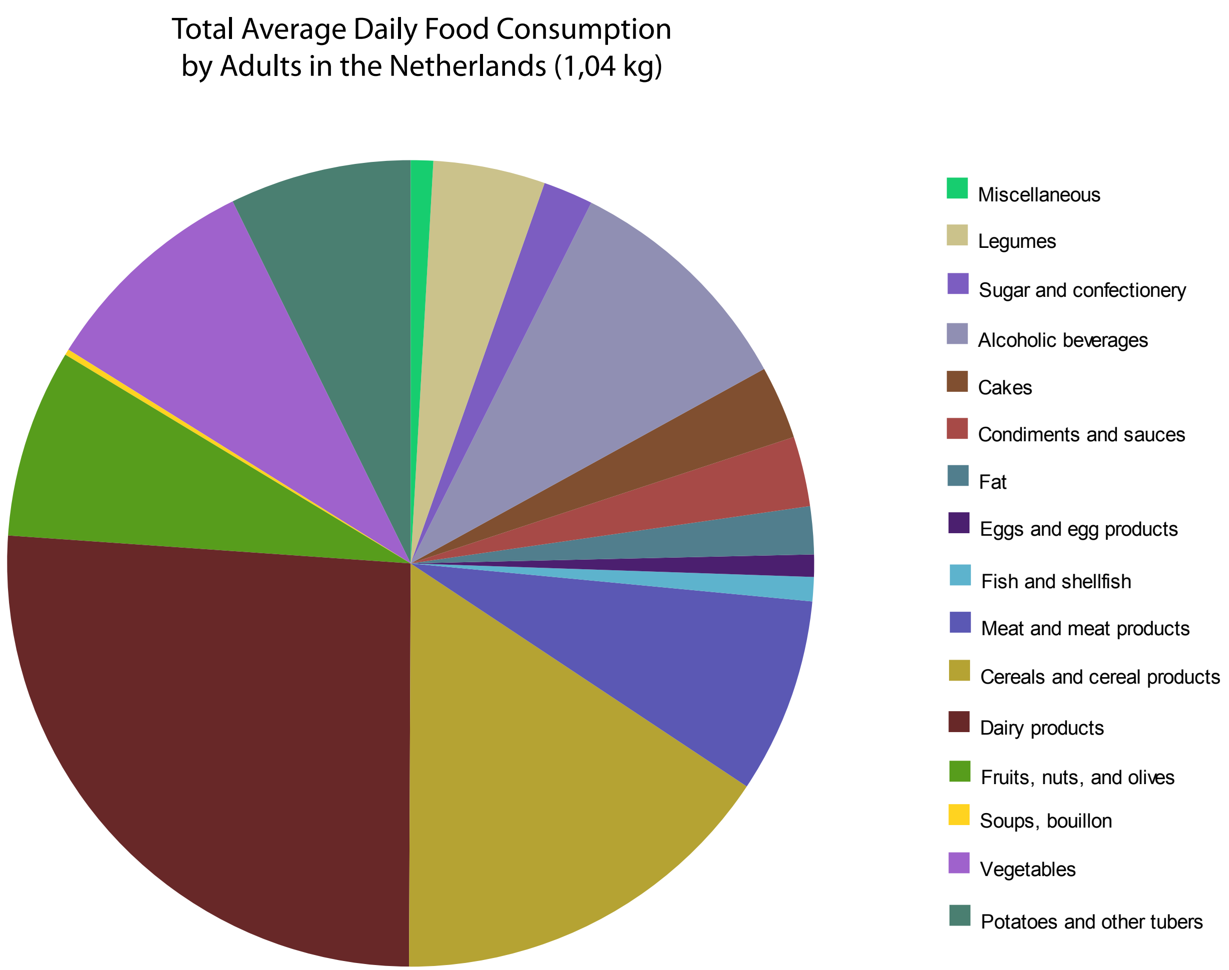
- Natural gas demand for water heating and cooking can be entirely replaced either with locally supplied biogas or locally produced renewable electricity.

- Electricity demand can be reduced 50 - 70 % by optimizing: clothes washing, refrigeration, lighting, and the type and usage pattern of personal electronic devices. Some of this demand remains inelastic due to the efficiency limits of certain technologies and the existing stock of devices owned by the incoming population. With community purchasing guidelines for new electricity-using-products, this electricity demand is projected to further decrease over time.

- Public lighting infrastructure can be made much more efficient by switching to highly efficient and / or renewable sources of lighting. Public lighting demand reduction can range from 50 - 100% of energy demand depending on the technologies selected.

- Providing energy for personal transportation in a renewable manner from the site itself is a challenge. Electric cars typically use 10 - 23 kWh of electricity per 100 km.[5] Assuming 15 kWh of electricity per 100 km and 100 adults on site, with a car ownership rate of 40% and an average travel distance of 37 km, this would translate to an additional 81.030 kWh of electricity supply needed on site. A 50% reduction of household electricity demand over Dutch averages would result in an annual demand of 83.520 kWh for the households on the Schoonschip site. Supplying electricity for electric cars will practically double that demand. We are still evaluating to what extent this is possible to supply locally.

› A large percentage of commonly consumed foods can be produced on-site: most fruits, vegetables, tubers, legumes, and fish, as well as some alcoholic beverages, eggs, dairy products, and sugars. The actual percentage of what can be supplied will be determined by the management of on-site production systems and by the flexibility of residents' diets. Meat production, most dairy, cereal crops, and commodities such as coffee will not be included in the scope of this design.



5 *"Full Size Electric Vehicles". Idaho National Laboratory. 30 May 2006.*

DEMAND SIDE MANAGEMENT STRATEGY

PUBLIC INFRASTRUCTURE

Public lighting
To reduce public lighting demand on-site, some options include fully solar-powered street lights (as proposed through Philips' Simplicity design), or highly efficient LED lighting with lunar resonance control (reducing lighting demand based on ambient lighting from moonlight). Some on-demand public lighting systems also exist, which increase lumen output only when requested by users (via cell phone remote control or motion sensor).

A final exploratory area is the possibility of bioluminescent lighting technology. There are currently no commercial otpions for bioluminescent lighting, however there are many research advances in this area, as well as a number of DIY solutions. These options would most likely involve installing tubing or containers with bioluminscent algae or bacteria and fueling them with residual sludge from biomass digesters.

COMMUNAL SPACES

Personal versus communal technologies
There are three planned "common space" areas in the urban plan for the Schoonschip site, each of which has a surface area of around 40 m^2.

In our final design, we plan to co-locate clusters of domestic and social functions in these communal zones with the following objectives in mind:

- Reducing resource demand by installing highly efficient shared appliances (that in many cases may be too expensive or impractical for single families to own).
- Creating opportunities for time saving by co-locating domestic tasks that have intermittent time commitments (for example, by co-locating laundry facilities and household garden plots, residents can put in a load of laundry and use the time in between to tend to their greenhouse garden plot, while watching their children play in the co-located play area).
- Creating usable concentrations of waste heat for cascading (e.g., both the greenhouse and laundry equipment will create waste heat that can be collected and stored in insulated water tanks or phase change materials on site. This heat can be used, for example, to warm the adjacent swimming pool).
- Increasing social cohesion among residents by creating opportunities for casual interaction at the site of these communal activities.

In particular, clothes washing and drying, which typically use up to 20% of a household's energy demand, can be placed on one of the communal sites already planned in the Schoonschip master plan. If residents already own their own washing machine and dryer, they can sell this equipment before relocating to Schoonschip and invest a fraction of that money in the communal equipment.

For the offices on the de Ceuvel site, shared equipment such as high efficiency printers and cooking areas can similarly reduce energy demand, increase the quality of equipment, and encourage increased social interaction.

DOMESTIC TECHNOLOGY

Building envelope
Our objective is to achieve the Passive House standard for building performance. Passive House technology was once notorious for also resulting in poor indoor air quality and not allowing residents to open windows; with new approaches this is no longer the case. Achieving the Passive House standard primarily involves installing very high levels of insulation for walls, floors, roofs, and windows; the elimination of thermal bridges; and the optimization of passive solar orientation (maximizing south-facing glazing).

By following these guidelines, in new constructions (Schoonschip), natural gas demand for space heating can be completely eliminated and replaced with a small amount of electricity demand needed for heat recovering air ventilation systems. In retrofit constructions (de Ceuvel), gas demand for space heating can be mostly eliminated through retrofit insulation and some additional heating can be supplied through air-to-water heat exchangers (suited to the waterfront context of the site) or low-temperature heating systems through floor heating using seasonal heat storage in insulated water tanks (or other thermal storage options).

HVAC
When Passive House standards are adopted, ventilation performance has to be of very high quality and coupled with heat recovery to eliminate heat losses outside the building. This ventilation presents an additional electricity demand per household (of 36 - 88 watts per ventilation system per household, or 2,3 kWh per year per m^2).

Thermal comfort zones
Certain zones within the house are zoned for increased thermal comfort (living rooms, home offices), and waste heat flows within the house are directed towards these areas. Secondary thermal comfort zones include bathrooms, bedrooms, and kitchen. Lowest thermal comfort areas include hallways and storage areas. A target

of at least 60% humidity is maintained within the house year-round to increase thermal comfort. Air to air heat exchanger for heat recovery ventilation. Heat exchanger is placed in rooftop greenhouse area to avoid winter freezing concern.

Lighting
Several strategies exist for reducing the electricity demand of lighting. a primary strategy is to maximize solar lighting through solar tubes, windows, and daylight panels (easiest in new build). On the technological side, highly efficient technologies like LEDs and fiber optic cables can achieve the highest efficiencies and technological longevity of available market technologies. On the behavioral side, intelligent home control systems can be used to create targeted lighting for specific activities to reduce demand.

Clothes washing & drying
One of the largest sources of household electricity demand (~20%) is for the washing and drying of clothing. In all three scenarios we propose to address this demand by installing highly efficient clothes washers that have a third of the electricity demand of current conventional systems. New technologies that use ionic streams or charged polymers instead of water (e.g., Xeros washing machine) are also scheduled to become commercially available in the near term and could be installed in the communal areas if avialble in time.

Bathroom fixtures
Toilet technology is a key determinant of household water use and household wastewater generation. In all three scenarios we propose alternative toilet technologies: affordable low-flow retrofits for the de Ceuvel site and advanced urine-separating toilet systems for the Schoonschip site (e.g, the Ecoflush toilet). Other options, such as the freestanding Loowatt toilet and vacuum toilet technologies are also under investigation and may be selected depending on further consultation with the community.

All bathrooms will be equipped with low-flow shower heads (less than 6 liters per minute) with heat recovery systems that conserve around 60% of the heat required for water heating. Low-flow faucets or faucets retrofitted with aeration equipment will also be standard features on both the Schoonschip and de Ceuvel sites.

Kitchen appliances & fixtures
Refrigeration is another major source of electricity consumption in typical households. The way in which we propose to reduce this demand is through a custom food storage system installed in each household that will segment different units for different food types. The size of the actual refrigerator will be kept to a minimum and additional cooling will be provided through evaporative cooling units. Other appliances include high-efficiency dishwashers and biogas boilers for water heating and kitchen stove tops.

Personal & household electronics
Electricity savings on the use of electronics can primarily be achieved through two measures:

› Upgrading to more efficient technologies over time (and offering residents purchasing guidelines on new technologies as they replace their current stock).
› Including household cut-off switches for electric equipment on standby, which is a significant source of energy loss.

Water management
Even though in the Netherlands water scarcity is not an issue, we aim to develop an exemplary system that could potentially be applied to areas where water is scarce, which is the case for many parts of the world.

In most households, high quality drinking water is used for flushing toilets. This is a design issue which should be resolved in future urban development & sustainable architecture. It can be addressed in two ways. One is to use lower-quality rainwater or recycled grey water for toilet flushing. Another is reducing the total amount of water used per flush. Urine separating toilets use only a full flush for solid waste, and a small rinse flush of roughly 0,5 liters for liquid waste.

Toilet technology is a key determinant of household water use and household wastewater generation. In all three scenarios we propose alternative toilet technologies: affordable low-flow retrofits for the de Ceuvel site and advanced urine-separating toilet systems for the Schoonschip site.

Water demand can be further reduced through low-flow fixtures installed throughout each building for showers and sinks. Intelligent on-site water management also reduces the load-demand on municipal wastewater treatment. To reduce the total amount of water entering municipal stormwater run-off systems, the total amount of permeable surface area on the site will be maximized (through green roofs and water catchment technologies).

Organic waste management
Organic waste generation is relatively inflexible since a majority is food waste and sanitation waste. Our focus is on appropriate waste handling rather than reduction. A primary objective is to use all organic waste on site for both nutrient recovery and energy generation. There are several relevant organic waste streams that need to be treated separately, including feces, urine, grey water, food waste, and biomass produced on site. Because the de Ceuvel site is contaminated, biomass produced from phytoremediation may also require a separate processing and harvesting steam from uncontaminated greenhouse biomass.

Non-organic solid waste
There are special sorting bins distributed throughout the site for the collection of non-organic solid wastes, with special containers dedicated to hazardous waste like electronic waste and batteries. The objective is for the community to take responsibility and special care for its more hazardous materials. The remaining recyclables will be monitored for their volume, providing quantitative feedback to the community as part of a larger behavoral information system.

Food production
Food production creates a highly efficient sink for circulating nutrients and heat recaptured on the Schoonschip and de Ceuvel sites. The vegetables, fruits, fish, and other products grown on site will reduce residents' overall indirect environmental impacts by reducing food miles to zero, ensuring that the food is grown sustainably, and providing opportunities for education and interaction.

Food processing & storage
Across the industrial food supply chain, very large percentages of food products spoil prior to consumption. By processing and storing fresh food on-site, these spoilage losses can be minimzed. Systems for canning, smoking, pickling, pressing, bottling, and other functions will be present in all three scenarios.

Personal transportation
Personal transportation demand can be slightly reduced through the implementation of local ride-share systems. Fossil energy demand for personal transportation can be eliminated by switching to an electric vehicle fleet powered by locally generated renewable electricity. Another option, explored in the "future/fantasy" tech scenario is to have a mixed energy supply vehicle fleet with some vehicles running on electricity and others on hydrogen fuel cells. This becomes feasible if a local hydrogen infrastructure can successfully be created. Electric vehicles have a range of 60-200 km per charge, with battery packs ranging from 16 kWh - 50 kWh.

Solar tube lighting

Urine diverting toilet

APPENDIX D:
INITIAL DESIGNS

In the following pages, we describe the three conceptual scenarios that we developed as a result of our technical design workshop on October 31st, 2012.

The Do-It-Yourself (DIY) scenario images what can be achieved with minimal funding and a higher level of participation. The Proven Technology scenario uses only commercially available systems. The Fantasy scenario showcases the "playground" aspect of the Cleantech Playground, incorporating many technologies that are still in development.

For each scenario, we have made a sketch that provides an artist's impression of how aspects of the environment might look and feel. We have included the an overview of the primary technologies in each scenario, and, where possible initial estimates related to flows, size, placement, cost, and operational implications.

These scenarios served as three conceptual lenses for exploring the edge conditions of how a cleantech system on the site could work, provided us with a point of feedback, and informed our final design.

DESIGN OVERVIEW: PROVEN TECHNOLOGY

DESIGN SUMMARY

The proven technology scenario combines existing, commercially available technologies. In developing this scenario, cost was not considered a primary limiting factor (though technologies that are known to be exorbitantly expensive were also intentionally avoided).

In this design, some resource flows are handled in a highly distributed way (on the household level), and others are dealt with more centrally. The jetty and walkways on both sites are used to house many of the core community-level technologies, such as the wastewater purification system, heat storage, and waste digestion units.

KEY FEATURES

- Communal infrastructure is centralized in the jetty, with flexible hook-ups for adjacent houseboats.
- Greenhouses are placed over each houseboat for food production, water collection, heat capture, and energy generation. This significantly reduces heat demand.
- Smart Home IT systems and visual feedback of resource use plays an important role in managing resource use and reducing the demand for energy.

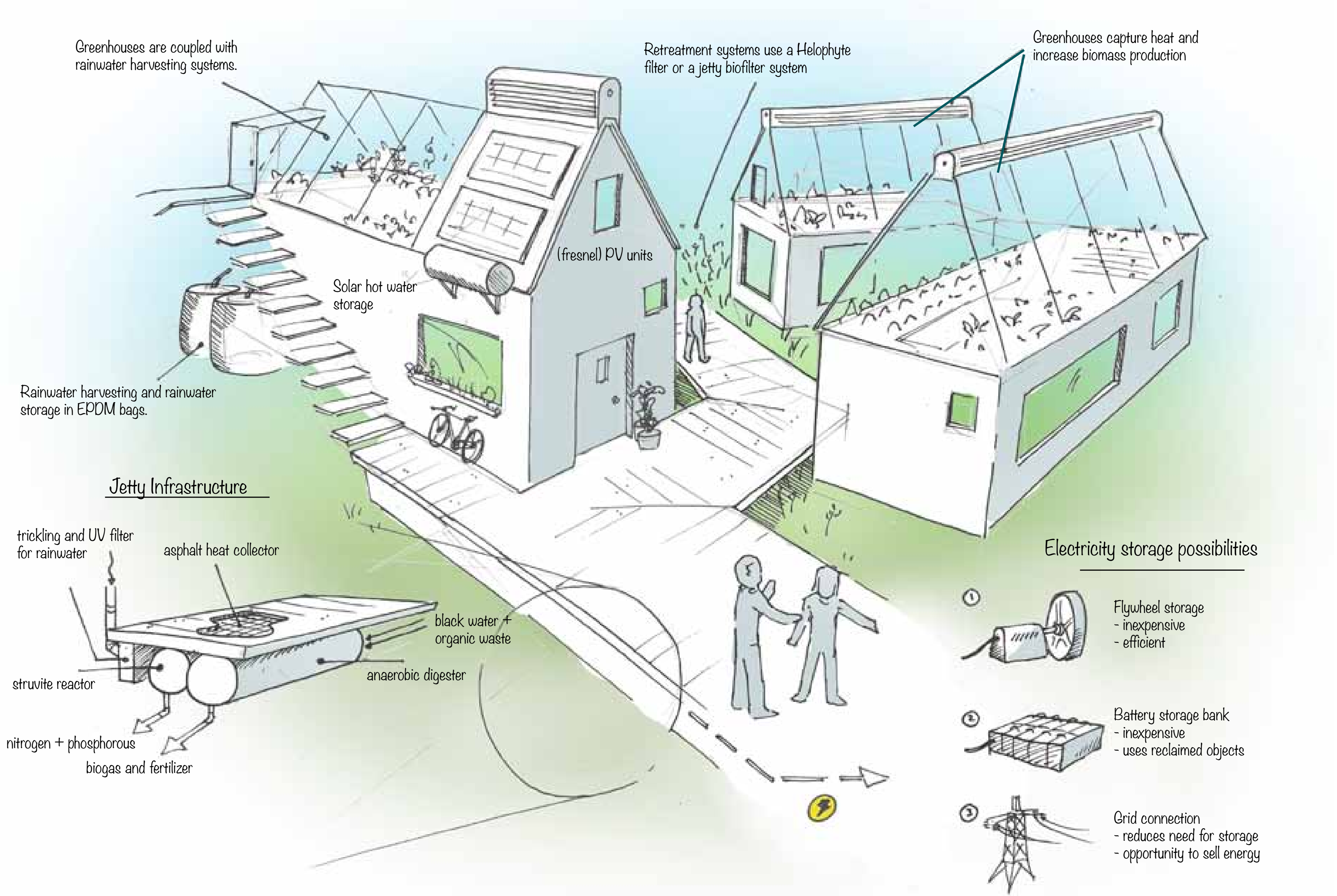
FINANCIAL AND OPERATIONAL FEASIBILITY

In this scenario, many of the suggested technologies are automated, reducing user involvement and increasing operational feasibility.

Some of the suggested technologies are not cheap. High quality solar panels and batteries can be expensive. However, all of the recommended technologies are very stable.

Technologies included in the design are available from EU, US, and Chinese suppliers. Chinese technologies are typically less expensive. European alternatives are often more durable.

DESIGN 1 : PROVEN TECHNOLOGY



TECHNOLOGY SELECTION

Electricity

Generation

- ZEM photovoltaic cells with fresnel lens concentrators.
- GEK 20KW Power Pallet

Storage

- 25 kW Samsung Community Energy Storage
- Electric Vehicles

Storage

- AEG Solar inverters of 1-4.7 kWh

Heat

Generation

- Zen Thermal Collector and heat pump
- Additional heat pumps recovering heat from showers, greenhouses, and asphalt heat collection system
- Water-to-water heat exchangers for cooling.

Storage

- A 180 liter ZEN SDB Combi Tank and a 200 liter solar boile

Transmission

- Sunmaxx heat exchangers
- V4E-Fiwihex Heat Exchanger for floor heating

Water & Waste

- D-SARR system (composed of various subelements).

Food

Production

- Hydroponic greenhouse
- Trout and tilapia aquaculture
- Mushroom production

Storage

- Sure Chill technology

PUBLIC INFRASTRUCTURE

Jetty / Walkways

The jetty on the Schoonschip site and the walkway on the De Ceuvel site serve as the infrastructure spines, functioning both as a pedestrian walkway and technological hub. Below the walkway surface, the jetty will contain a Decentralized Sanitation and Resource Recovery System (D-SARR), which will house a combination of black, grey and yellow water treatment facilities. As an output, the D-SARR will produce struvite, fertilizer, biogas, electricity, heat, and safe water effluent (a schematic of the D-SARR can be found on page 35).

Public Lighting

Lighting in communal areas is activated by proximity and light sensors, switching on lights at the appropriate time of day and in response to human movement. These methods are estimated to save 80% in lighting hours. Philips has interesting lighting options which combine solar radiation collectors with high-efficiency LEDs. Lighting after 20:00 or 24:00 can be supplied by lower lumen lights, providing glowing luminescence that uses significantly less energy and is more comfortable to surrounding households.

DOMESTIC TECHNOLOGIES

Kitchen waste can be collected in micro-scale 200 liter anaerobic digesters (commercially available from Methanogen). The technology recycles kitchen waste into biogas and liquid fertilizer. The product has few moving parts and requires almost no storage. Fertilizer produced in these systems can be used by individual households for their gardens. The digesters can be integrated into the design of the kitchen (under counters) or located in household basements. For refrigeration, cooling is provided by two mechanisms.

Two refrigeration options under investigation include a water-to-air heat exchanger and a solar charging unit created by a company called Sure Chill that uses electricity available in peak production times (e.g., daytime solar) to charge a cooling mechanism.

COMMUNAL AREAS

In the common spaces, asphalt-integrated heat collectors harvest heat from the sun, producing an estimated 900 kWh/m2 annually. Collectors can also be installed into the jetties and walkways, generating additional heat for restaurants, water appliances, and public spaces. They can also serve as a balancing and buffering systems for heat on a neighborhood scale.

ELECTRICITY

Generation

Household electricity needs are primarily generated ZEN photovoltaic cells with attached fresnel lenses. At a quantity of three per household and 30 for the entire community, output varies from a minimum of 450 kWh in the winter to 4.500+ kWh during the summer.

Additional electricity is provided by GEKs 20 kW Power Pallet System, which can act as a complimentary buffer for solar generation. One Power Pallet is needed for every ten houseboats. 0.9 tons of dry organic waste per month is needed for an annual power output of 5.421 kWh. The technology requires a 1,5 cubic meter tank for dehydrating and storing organic waste. Retention time of dehydration is normally 30 days, although ventilation improves speed of drying.

Our research suggests that commercial small-scale wind is not cost-effective on this small scale, although it can be used for testing purposes, particularly some emerging technologies (further detailed in the fantasy scenario).

Transmission

Transmission is enabled through technologies like the AEG Protect PV P8 Solar Inverter. The technology has available power outputs of 8, 10, and 12.5 kVA, translating to 1-4.7 kW.

A microgrid controller, such as AEG's ACM1000, inputs DC/AC current from a variety of sources and outputs stabilized DC/AC current to the microgrid. An Arduino computer combined with sensors and display monitors can showcase how demand shifts during the day and throughout the week. The microgrid is thus as much of an education tool as it is a load balancing and demand response technology.

Storage

For this scenario we propose a 25 kW Samsung Community Energy Storage. Each battery system is connected to residential photovoltaic system and serves the needs of 4-6 households. These storage systems can be placed in communal spaces and are convenient for displaying the current battery charge.

The Honda Smart Home System (HSHS) is a means of using electric vehicles for household electricity storage, and can also be utilized on this site if a sufficient number of electric cars are purchased by residents.

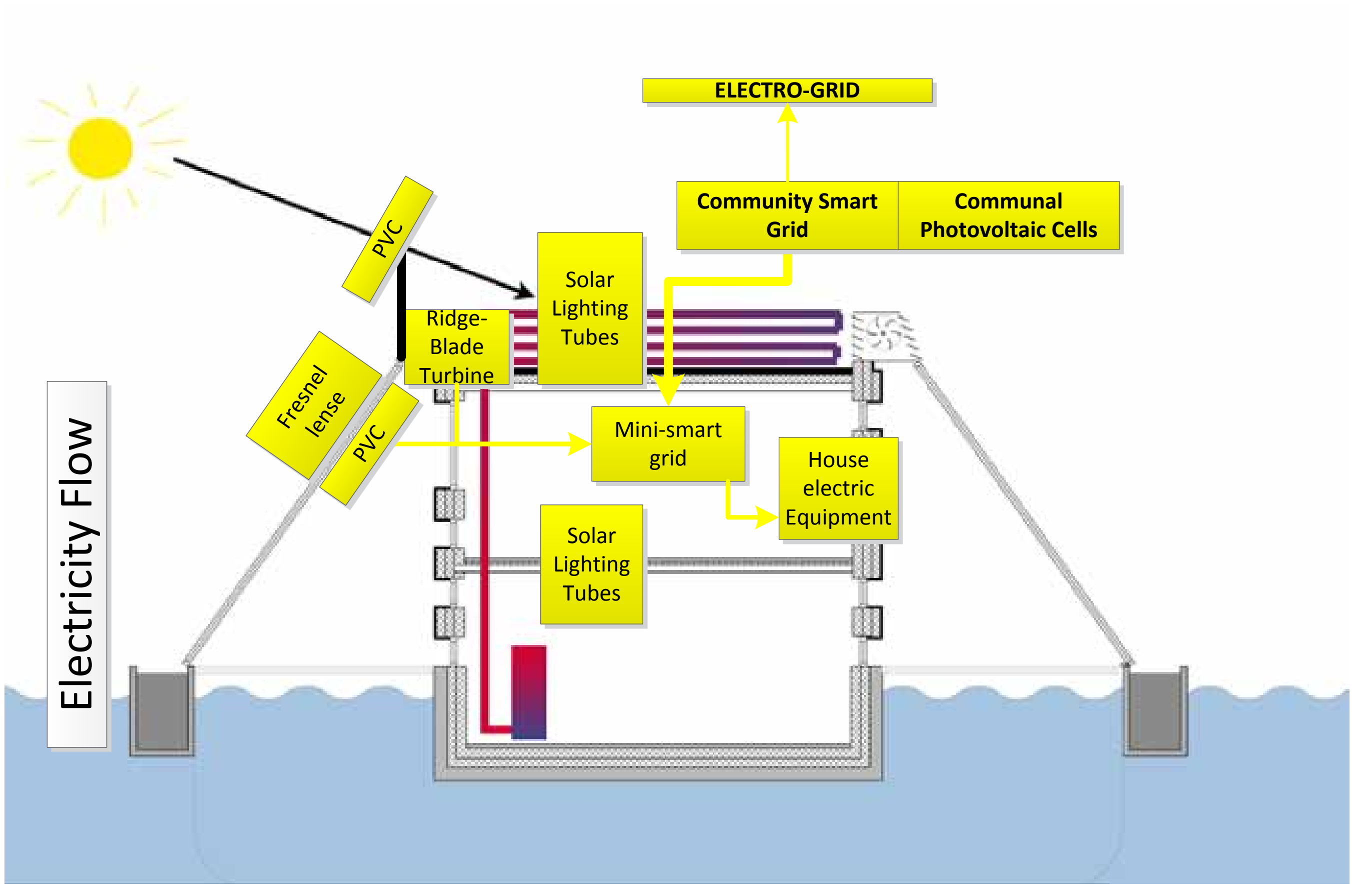
HEAT

Heating and cooling is primarily provided at the scale of the household. Together with greenhouse combined with various heat exchangers, heat is captured, cascaded, and stored in tanks.

On a neighborhood scale, the jetty is used for additional heat generation through an asphalt-integrated a heat collection system

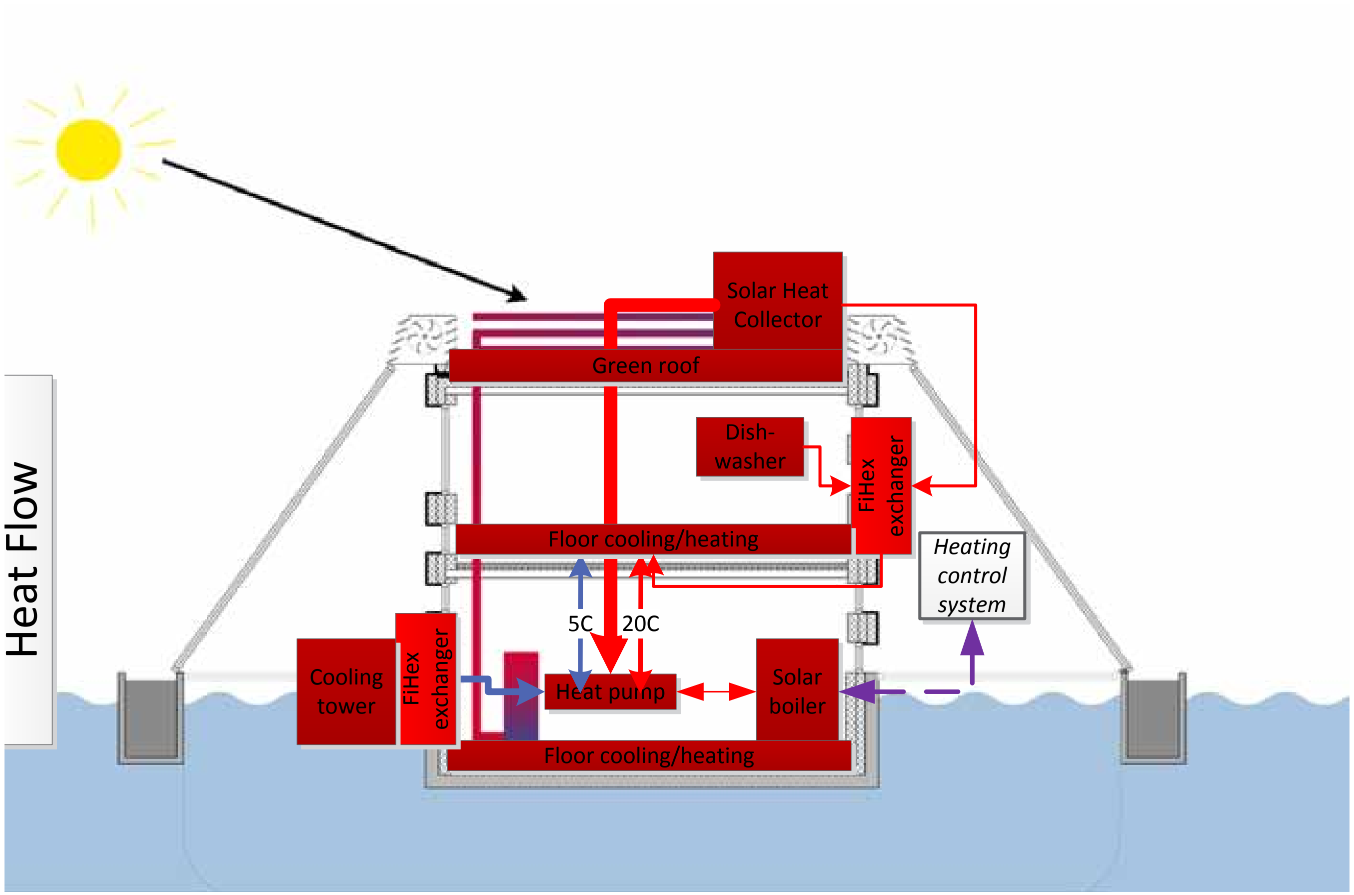
ELECTRICITY SUPPLY

The flow diagram below represents the electricity supply for the Schoonschip site.



HOUSEHOLD HEATING SYSTEM

The flow diagram below represents a household heating system for a houseboat on the Schoonschip site.



and stored in tanks below the walkway. This heat is used for communal spaces like greenhouses, restaurants, kitchens, and laundry facilities.

Generation

The primary method of heat generation at the household level is the ZEN Solar Thermal Collector. Connected to a heat pump, it produces on average 5.300 MJ (1.472 kWh) of heat. The system is mounted on each household, and connected to the water boiler and heat storage.

Sanitair heat pumps recover heat from showers and other heat producers such as greenhouses, the asphalt heat collection system, and the ZEN solar collectors. The pumps can be used for floor heating with latent heat (20C) during the winter, and also serves as distributor of cold water (5C) during the summer.

Cold water will primarily be generated by pumping river water through a number of water-to-water heat exchangers.

Transmission

SunMaxx heat exchangers are used to transmit solar heat from solar collectors to the household. Aqualogic Water-to-water heat exchangers can be used for collection and recirculation of cold water from the river or a cool water reservoir. Floor heating and cooling is highly efficient. The V4E-Fiwihex Heat Exchanger is used to both collect and transmit heat or cold streams to a household floor heating system. Heat exchangers for the shower, such as the Recoh-Drain can be used to collect further heat. If passive house standards are achieved, supplemental heating is not required. However, these technologies may still need to be applied in retro-fitted houseboats on the de Ceuvel site.

Storage

Household heat will be stored in a combination of solar boilers and storage tanks. A 180 liter ZEN SDB Combi Tank and a 200 liter solar boiler should be fitted in each home. Double-glazed energy-producing greenhouses create an average heat output of 610 MJ per square meter. Greenhouses are positioned on the sides of the household at 30 degrees to the sun. Green roofs serve as household insulation, further capturing heat.

Secondary systems will be installed in communal areas. Insulated EPDM bags will be placed under the jetties. There will be common cold water storage, serving as buffer for cool water exchange. Cold water storage can integrated directly into the water as a tank or non-insulated EPDM bags measuring 10m^3.

WATER

Collection & purification

Rainwater collected from household and communal surfaces can completely cover the water needs for laundry, dishwashers, and toilets.

Theoretically, this water can also be purified and supplied as drinking water. However, Dutch law requires proof of quality, creating an opportunity for waterboards to investigate providing clean water services using decentralized infrastructure. A testing system on the household level can include a water pump, water storage, activated carbon filtration or UV, water softener and mineralization, and an EPDM storage bag. On the household level, a greenroof reed treatment system can collect rainwater and create clean effluent of drinking-quality water.

Grey water can be stored in a water tower at the neighborhood scale or EPDM bags on a household scale. It can be pre-treated by reed treatment, sand, or trickling filtration prior to reuse for toilet flushing or irrigation.

Storage

Stormwater is collected in tanks with overflow discharged to the river. Tanks can be embedded into jetty and serve as a buffer for water.

WASTE

Liquid

Urine-diverting toilets are installed in each houseboat. When collected, urine flows to a to struvite reactor, while feces goes to a UASB. Water from the kitchen sink, dishwashers and laundry are connected to one water treatment system in the Jetty.

High density wastewater streams are treated in a D-SARR system, which is integrated into the jetty. It supports its own energy demand and treats brown water, grey water, and urine from 10 households. It produces struvite (crystallized phosphorus), fertilizer, heat, electricity and safe effluent of water.

Only organic detergents and soaps should be used on both sites. This will simplify the water purification process by removing chemical compounds that are difficult to remove through biological treatment.

FOOD

Production

Because the total site area is limited, the most viable option for food production is high-yield hydroponic greenhouse production. A variety of common vegetable crops such as greens, tomatoes, eggplants, peppers, and certain fruit types such as strawberries and raspberries can be produced almost year-round at high yields in such systems. Fish aquaculture and mushroom production can be integrated with greenhouse vegetable production, optimizing flows of nutrients and CO_2.

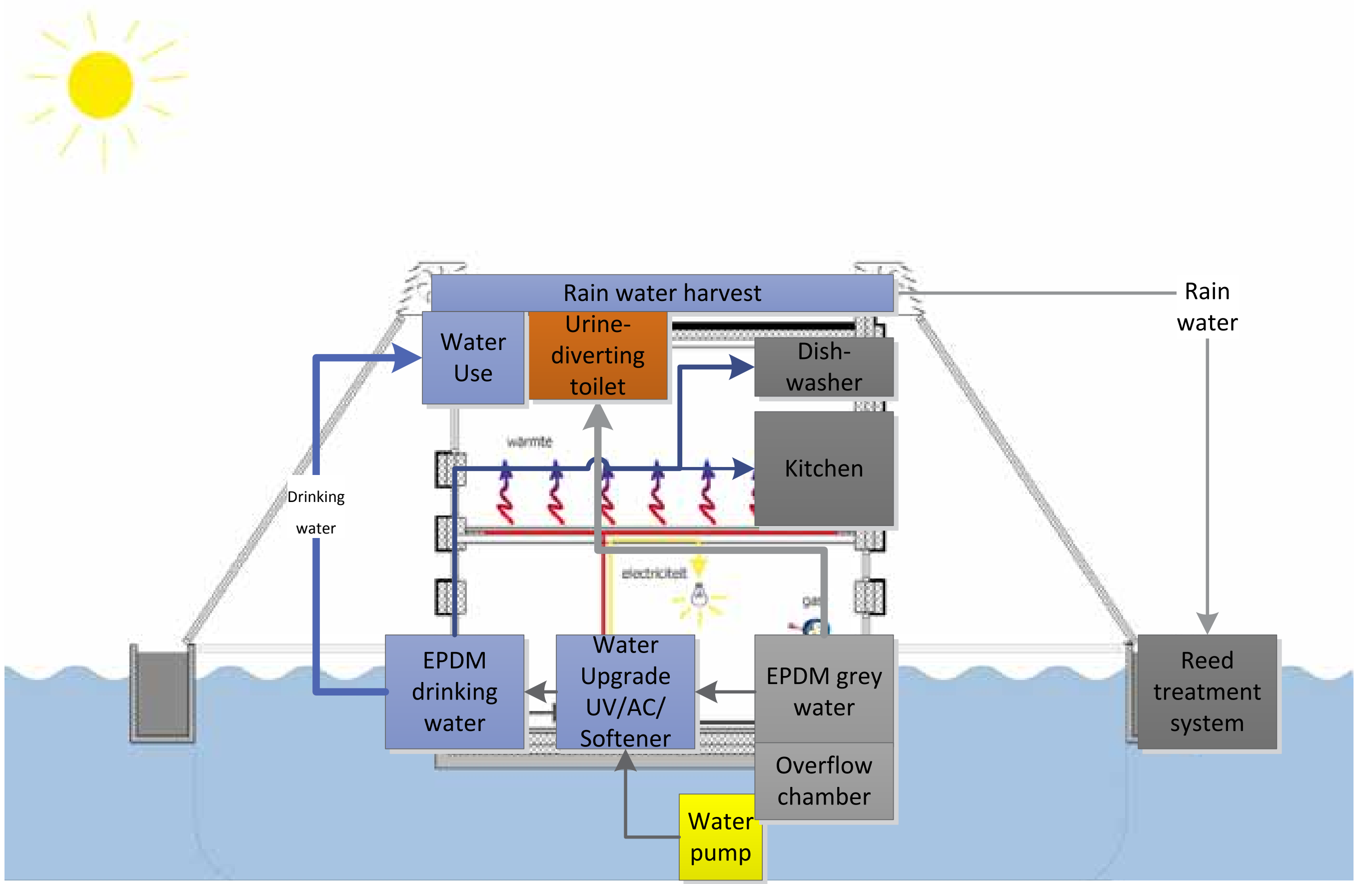
Small greenhouses will be placed throughout the site for individual garden plot use. Individual families can supplement the larger scale production with their own choice of products. For larger scale food production, a more commercially-scaled greenhouse would ideally be installed in the special area marked for floating infrastructure, which is located between the Schoonschip and de Ceuvel sites.

To coordinate food production between the various small-scale and larger-scale facilities, there should be a community board for the oversight and management of food production. In this way, it is reasonable to aim for supplying the community with a majority of its vegetables, a large part of its fruits, and a constant supply of fish and mushrooms. A few beehives can be located on-site for the production of local honey. One concern we are still investigating is whether plants on the phytoremediation site may produce contaminated pollen, which could in turn contaminate the honey supply.

A significant percentage of the Schoonschip community has also expressed interest in community ownership of some livestock, such a some goats and chickens. We are still investigating the spatial and legal constraints surrounding livestock ownership on site.

Processing & storage

Communal stores of food will be processed on site area and can be stored in large quantities in a shared pantry. Residents could have subscriptions for a certain quantities of food per week. Having this shared storage will ensure that the products that are closest to spoiling will be distributed first to minimize overall food losses. Food not produced not produced on site can be purchased at bulk prices by the community, creating of a simple local food cooperative and allows for cost savings.

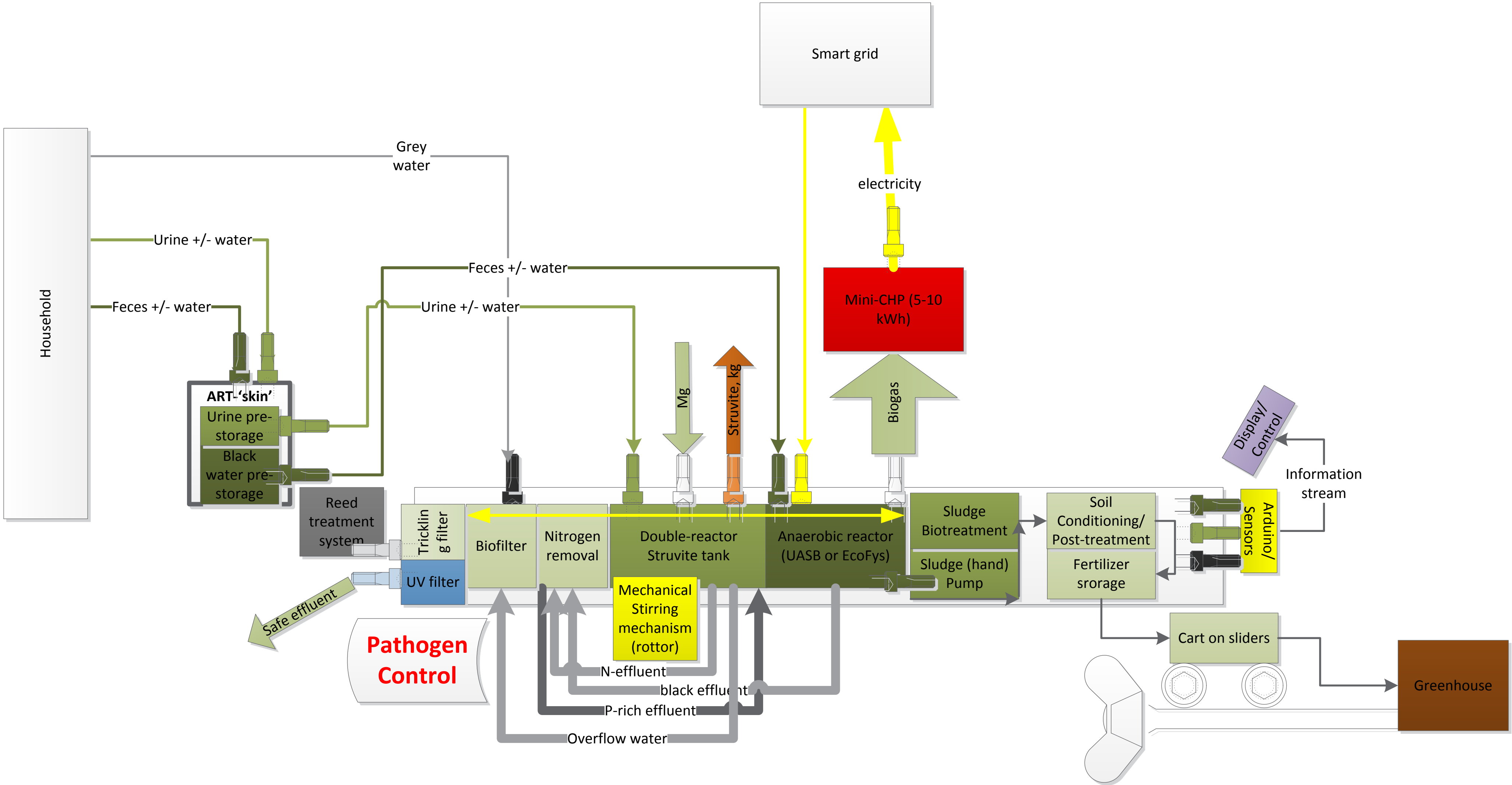


HOUSEHOLD WATER CYCLE

The flow diagram on the left represents a household water cycle for a houseboat on the Schoonschip site.

D-SARR AND WASTE TREATMENT

The flow diagram below represents the process of waste treatment on a neighborhood scale.



DESIGN OVERVIEW: DIY SCENARIO

DESIGN SUMMARY

A lack of resources can sometimes be just the push we need to help us think creatively. The low budget / DIY scenario combines a range of technological possibilities that replace high cost with community effort.

Similar to other scenarios, the DIY design minimizes resource demand by incorporating effective insulation, passive technologies, high-efficiency fixtures and appliances, and intelligent control mechanisms, while maximizing efficiency through retention, recapture, recirculation, and reuse of various energy and material flows used and produced on-site. The primary difference between this scenario and the previous one was the exploration of which technologies could feasibly be built using low-cost or recycled materials and operated by the community itself.

Reed bed filtration and other self-built mechanical and bio-filters will provide on-site water and waste processing, allowing recirculation of rain and grey water, and significantly reducing the demand for potable water. Furthermore, water filtration and anaerobic / vermiculture composts will enable the extraction of valuable nutrients to use for fertilizer and biomass production.

Solar radiation will be used for lighting lighting, heat and electricity. Cost-effective DIY small-scale wind kits can harness wind energy to provide extra electricity during peak and during the night.

Due to the challenge presented by electrical storage, and the additional cost of battery terminals and load distributors, it will most likely be limited to the batteries contained in personal and domestic appliances or any electric vehicles that may be on site. Instead, all the electricity produced throughout the day will be either used immediately or sold to the grid. Using the grid simplifies peak-load balancing issues, eliminating the need for additional costly infrastructure and enabling users to access current from the grid when needed. Furthermore, to facilitate on-site load balancing issues and reduce the need for each building to have its own inverter, several central inverters will be dispersed throughout the community, allowing for sharing of electrical energy between interconnected segments. Recommendations for optimal times to perform certain tasks like laundry, as well as guidelines for appliance and fixture purchases will be provided.

The boats on the de Ceuvel site can also potentially be retrofitted with greenhouses angled against each houseboat, collecting and storing heat and providing year-round food cultivation. The greenhouse food production will use self-assembled hydroponics and aquaponics systems that are partially automated and require little maintenance. Community scaled and community-operated greenhouses will provide additional food production and resource accumulation.

The water surrounding the site will be used for evaporative cooling and refrigeration. Rainwater will be collected for use in domestic, public and irrigation applications. Shared community washing and kitchen spaces might provide for an opportunity to experiment with DIY gasifiers, which could be used for cooking or energy generating purposes, and potentially useful for on demand / backup energy needs, like charging electric vehicles. The jetty between the houseboats will contain the piping and other infrastructure, potentially also acting as the site for water filtration activities.

KEY FEATURES

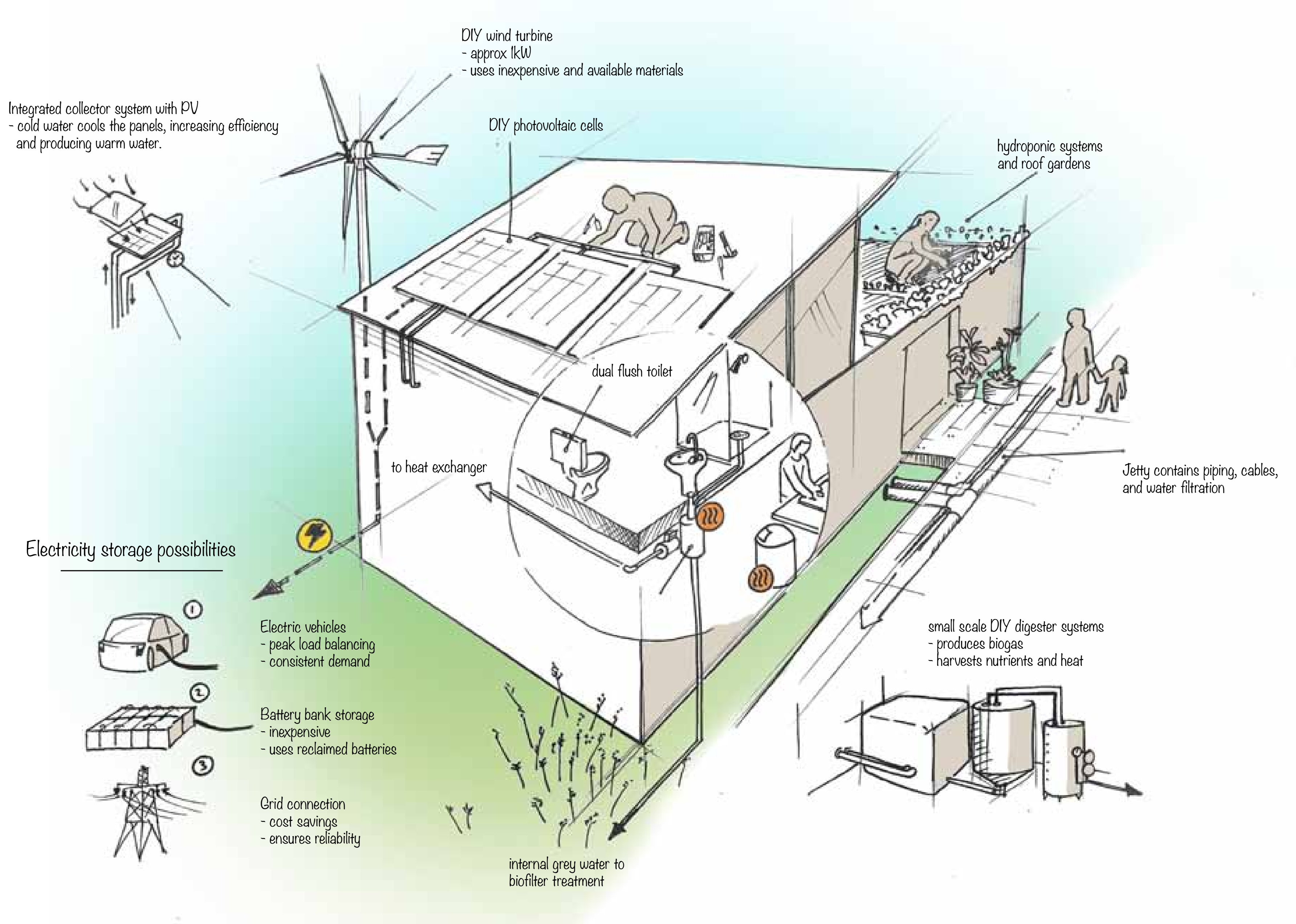
- Solar collectors include a home-made solar tracking device.
- Less efficient reclaimed boats will be modified with solar rooms and greenhouse attachments.

FINANCIAL AND OPERATIONAL FEASIBILITY

The DIY scenario creates significant cost-savings by eliminating the need for external labor for installation and internalizing various production processes. The key to success lies in the ability of the community and its members to organize and execute both the acquisition of the necessary tools and materials and the construction of the required system components. The features that are selected must have high functionality but low complexity to allow for technically untrained individuals to effectively assemble and operate them.

The best process for building each item should be well documented and easily replicated to allow for the ability to teach others the procedure, and recreate the system in other locations. During the construction phase members would attend periodic workshops on how to build, operate, and maintain various system technologies. Lessons could also be opened to people outside of the community, serving as an additional source of income. Purchasing all the materials in bulk will provide significant savings. Significant gains in efficiency will provide for greater returns on initial investment, offsetting the added materials costs.

DESIGN 2 : DIY TECHNOLOGY



TECHNOLOGY SELECTION

Electricity

Generation
- DIY Solar PV panels
- Solar concentrator with solar tracking
- Small-scale DIY wind turbine
- Smart use of mirrors and reflective surfaces

Storage
- Grid connection

Transmission
- Homegrown micro-grid system w/ sensors, feedback and electrical load control

Lighting
- Solar Tubes
- LEDs
- movable task lighting

Heat

Generation
- DIY Solar collector & water heating system
- Wood Gasifier
- Biogas boiler for cooking and water heating

Storage
- Water storage tanks

Food

Production
- DIY hydroponics
- DIY aquaponics

Storage
- Bulk communal storage and distribution
- Customized evaporative cooling cabinets

Water and Waste

Collection
- Rainwater collection on all building and jetty surfaces

Purification
- Greywater treatment using self-built mechanical, bio and reed filtration systems

PUBLIC INFRASTRUCTURE

Lighting
DIY solar tubes, solar lanterns, reflectors, and efficient LED spot lighting will be used to provide lighting for walkways and public facilities. Reflectors and low output lighting (approximately. 100 Lux) will be used to illuminate the jetty and other walkways, while solar tubes and flexible LED spot lighting will provide between 300-600 Lux for task lighting in communal spaces.

Transportation
Electric vehicle charging stations could potentially use DIY wood gasification systems to generate electricity on demand. The GEK Power Pallet system provides up to 20 kW of electricity generating capability, converting a wide range of biomass fuels (such as wood chips, nut shells, etc.) into electrical current. The system could also be used as a backup energy source, and help provide additional energy during peak usage times. The system converts 1 kg of woody biomass into 0,75 kW of electrical current, while also producing heat which can be harvested as well. Wood gasifiers typically release roughly 10 times less harmful emissions than traditional combustion engines.

Jetty/walkways
The Jetty and walkways serve to contain infrastructure such as plumbing and wiring, and could also contain system features such as water treatment as well as solar energy collection. The jetty will be equipped with rainwater harvesting capabilities to provide water for public facilities and irrigation needs. Infrastructure attached to the jetty should make use of flexible, floating supports, preventing damage during changing tide conditions.

DOMESTIC TECHNOLOGIES

Household lighting technologies will be similar to those described for the communal areas. Self built and installed heat collection, solar energy generation, air ventilation, rain water and grey water treatment and circulation, as well as small scale kitchen waste and composting will be implemented on the household scale. High-efficiency appliances, fixtures, control mechanisms and effective insulation are critical to the overall operation of the system.

Homes will be equipped with a customized DIY evaporative cooling cabinet, including different compartments with a range of varying atmospheric conditions best suited for storage of specific food types.

COMMUNAL AREAS

Communal areas will not only serve as a gathering / meeting point for social activities, but also provide access to shared washing and drying machines, as well as kitchen spaces. Heat capture from the appliances, as well as an attached community greenhouse could serve to provide any heating needs for the facilities. Additionally bulk food storage, DIY solar food dehydrators, solar pasteurization, pickling, and canning equipment will be made available to help prevent food spoilage and increase the range of food produced on site. These features will be built as a collective community effort, and will reduce overall system costs and improve efficiencies through increased scale and shared use.

ELECTRICITY

Generation
There are numerous PV panel manufacturers, who could potentially supply the necessary Solar technology to provide for a large portion of the CTP electricity demand. When determining the required number of Solar panels, factors such as Dutch weather / solar radiance conditions, as well as site features such as insulation

(passive house standards) and number of people / appliances need to be examined. The target energy demand for the CTP lies between 1,200 and 1,500 kWh per household annually, which equates to 3.28 – 4.1 kWh per day. The peak demand per household will ideally remain below 1 kW of on demand energy at any given time.

A minimum of six 240 Watt panels need to be installed per household, depending on how effectively households can manage their electricity demand. If purchased wholesale, prices as low as approximately $0.90 - $1.00 (or less) per Wp can be negotiated (e.g. Sharp ND-Q402CJ [240 Watt, $269 per panel). In order to maximize efficiency and production potential, developing a solar tracking system, integrated with a solar concentrator, would be highly beneficial. Even without concentration, solar tracking of the PV cells could improve output by 20% in winter, and up to 50% during summer months.

Although self-installation would achieve cost-savings, the cost of various necessary construction materials and system components is likely to raise overall PV system costs by 15 - 30 % (mainly due to the anticipated cost of items such as solar inverters, wiring, and potentially sensors / microgrid controls).

Based on preliminary findings, it would likely be most effective to have either one or several dispersed central inverters to manage the solar electricity conversion and distribution. This would greatly facilitate load / peak balancing, reduce individual costs by eliminating the need for each household to have an inverter, and limit the complexity of managing and servicing so many individual technology components. A more centralized infrastructure implies increased amounts of electrical wiring and transmission infrastructure

Transmission

Due to the relatively high expense of solar inverters and transmission control infrastructure, several central inverters dispersed throughout the community will control the distribution of electricity generated within, determining whether it will be used immediately or sold back to the grid. The AEG Protect PV offers 22 built in European country grid codes (including the Netherlands), with easy installation. The 3-phase string inverters are available at power outputs of 8, 10, 12.5 and 15 kVA. Designed with functions to stabilize the grid with power level adjustment, controlled reactive power input and fault-ride-through function. Multiple MPP trackers optimize the operating point for a 250-to-800 V connected string, while offering an average 98% efficiency. One of these inverters could service from 8 – 20 homes depending on the model.

HEAT

Collection

One of the most essential features of the CTP system, and the “backbone” of the DIY scenario, is the solar collector and hot water circulation system. Given our ability to customize the system to our target parameters, it is sensible to integrate technological components to increase overall system effectiveness. We would combine the solar PV panel system with a solar heat collector, while adding a solar concentration component.

Research indicates that there is potential for large efficiency gains through integration. Not only will the collector capture more heat through contact with the PV cells, but the panels themselves will function more efficiently due to the lower operating temperatures. Furthermore, by incorporating a concentrator that targets light onto both components, the potential value created by the solar concentration is increased, offsetting its’ construction costs over time. This could potentially justify the costs of including a solar tracking feature and to create an opportunity to design a truly integrated solar system for further applications outside of the CTP.

Based on the solar radiation in the Netherlands and assuming passive house standards, a DIY solar collector with roughly 4 square meters surface area could provide up to 30% of the hot water needs for one household (roughly 4 people) during the winter, and up to 80% during the summer. When combined with a concentrator, and coupled with hot water storage / collection from the greenhouse, these values could be up to 60% in the winter, and nearly 100% in the summer. This is assuming that all of the heat is used for hot water (for showers, etc), and not conventional space heating, which is not required for passive house standards. By further expanding the system to include heat recapture from water drainage, composting, and other potential heat sources from the building, system efficiencies would be even greater. Typical costs for a self-built system range from 500 - 1500 € depending on the scope and complexity.

Additional energy will come from a woody biomass gasifier for cooking and water heating and small-scale self-built wind turbines.

Storage

A hot water storage system can be constructed from insulated, reinforced plywood, lined with EPDM, with a recommended capacity of 300 L for a system of this size (and assuming 50L of 45 degree C water per person daily). The average water temperature in the tank is estimated to be at roughly 50 C during winter months, and up to 90 C in the summer. Another option is to interconnect several smaller heat resistant, well-insulated drums for heat storage abilities. Placing the hot water storage within attached greenhouse constructions can also improve system effectiveness. Temperature sensors on the collector and in the storage tank could provide feedback and assist in controlling heat distribution, and indicating optimal times for using hot water supply.

Transmission

Each building would ideally be designed with a storage room below containing the technologies and enable a central heat collection and distribution and service point.

The water-to-water heat exchangers will be self-made using either insulated PEX or copper coils, depending on the application. Due to the high degree of insulation and controlled airflow in passive houses, an excess of 80% efficiency in recapturing waste heat is possible.

The central direct air/water postheater elements are located on the building services floor and heat up the supply air after the ventilation unit, when necessary. The element used is a “hot water postheater radiator WHR 125“ from the Helios, built directly into the ventilation duct and with an output of 1.100 Watt (specifications at 0°C supply air temperature, supply/return water temperatures of 60/40 °C). The system is designed so that the maximum air temperature at the postheater does not exceed 55 °C, in order to avoid dust pyrolysis. The control for the postheater occurs over a vent with battery operated drive mechanism. A central room thermostat, located on the ground floor, controls the motorized vent. The room thermostat controls the room temperature centrally for the entire house (one zone).

The solar thermal system consists of a ca. 4 m² flat collector field on the southern roof, a control unit, the expansion vessel as well as the heat exchanger in the lower part of the hot water tank. It functions as an independent system with an anti-freeze liquid filled closed circuit. Under sufficient solar radiation, the control unit activates the pump. Due to the placement of the heat exchanger in the lower part of the water tank, it can be completely heated from below.

WATER

Collection & storage
Rainwater collection systems will be installed on roofs of buildings and the jetty. Rainwater can be used for flushes and fed into plant irrigation systems.

Water efficiency
Aerators are be installed on all faucets and shower, and toilets retrofitted with flapper valves for dual-flush, or with a container in water tank for low-flush modification. All water fixtures equipped with sensitive control valves and flow-volume options. Showers and faucets should not exceed a flow rate of 6 Lpm, while toilets should use no more than 3.6 Lpf.

Purification
Greywater from showers and sinks can be used for flushing. Greywater treatment will be implemented using self-built mechanical, bio and reed filtration systems. Reed filtration at the household scale would range between 5 – 10 square meters.
Secondary treatment through charcoal and bio filtration is possible, allowing greywater to be used for showering and washing, decreasing water use by over 70%. Self-built filtration systems may not meet regulation standards, and a commercial water treatment system might be required for this purpose.

WASTE

Solid
Kitchen waste dispensed into self-built vermiculture or anaerobic composting system.

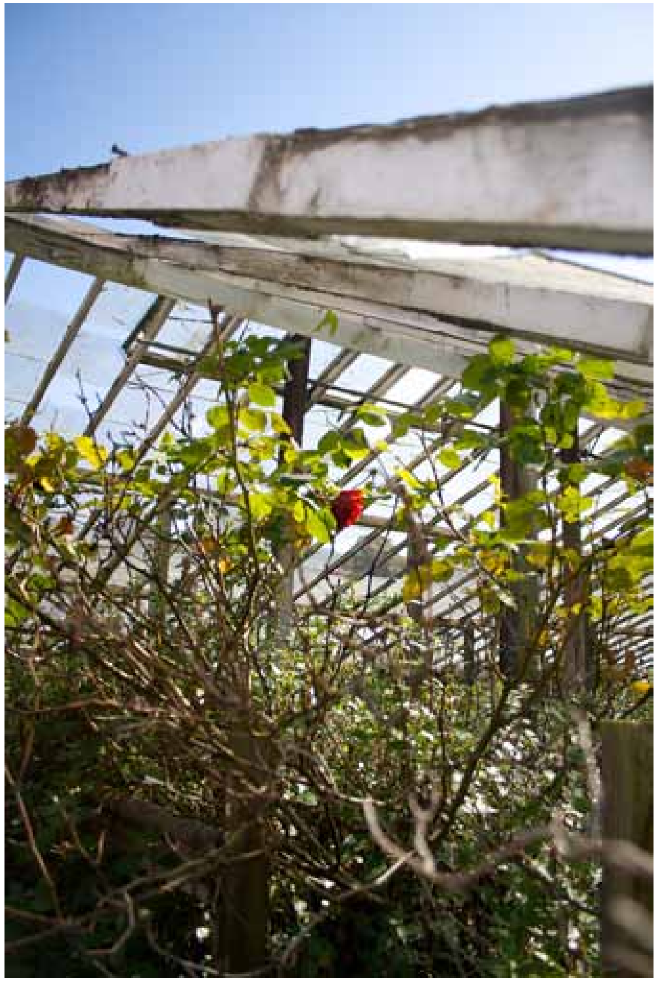
Liquid
It is possible to install a self-built urine separating toilet by retrofitting standard toilets. This is still under investigation.

FOOD

Production
Self built hydroponics / aquaponics systems utilizing rainwater irrigation and nutrient re-use from compost systems, as well as on-site algae fertilizer production.

Processing
A bulk cold storage system will be designed either in one centrally located site, or several dispersed locations, for residents to share food storage space, and thereby enabling bulk / shared purchasing to reduce overall food costs.

DESIGN 2 : DIY TECHNOLOGY



Greenhouse built from reclaimed materials

GEK Gasifier (left) and GEK construction kit (below).

Window farms

Solar water heater (left)

Community farming

DESIGN OVERVIEW: FANTASY SCENARIO

DESIGN SUMMARY

This scenario is where the outer edge of cleantech development intersects with more conventional technologies. Though most of the technologies explored here are in R&D phase or early pilot phase, many could potentially be tested out on smaller scales to complement the conventional technologies described earlier.

Here we also begin to envision how the CTP might transition over time from currently available technologies to emerging options. For example, within the planned infrastructure of the CTP, we can imagine how a battery energy storage technology may eventually be replaced by small-scall adiabatic compressed air storage, metal-air batteries, or hydrogen, as these options become affordable. Part of our challenge is to design a system where these technological shifts are possible without a total reconstruction of the system or its infrastructure.

Rather than repeating the core elements already described in the two previous scenarios, here we focus purely on those aspects which can provide added value in combination with the standard set of technologies.

KEY FEATURES

Some of the broader topic areas that we explore in this scenario are: materials innovation, biological systems integration, and the establishment of a local hydrogen cycle.

Materials Innovation
Advances in materials science are providing new pathways for clean technologies with promising study results reported in the news almost daily.

Some technologies that are potentially interesting to include in the CTP are a variety of Phase Change Materials (PCMs), many of which are already commercially available for building materials and thermal storage enhancement. Generally speaking, these can reduce the volume needed for heat energy storage (both for insulation and seasonal storage).

Other areas of exploration in advanced materials include: new battery technologies, nano-coatings for self-cleaning surfaces, nano-particles for waste treatment, improved solar photovoltaic technologies, and a variety of others.

There are also many new material options for building construction: advanced composites for floating pontoons, biological building materials such as mycelium or kenaf bricks, self-healing concrete, and a variety of nano-materials.

Biological Integration
Biologal systems can do things much faster and using less energy than almost any human technology. We are increasingly harnessing biological organisms to: purify contaminants out of water or soil, produce electricity, mine valuable compounds out of waste water, produce chemicals of interest, and produce light. We are exploring which of these biobased technologies may be possible to integrate into the scenario.

On a more macro-scale, this scenario envisions how we can integrate nature into the design of the environment at Schoonschip and de Ceuvel, by including growing plants as part of the infrastructure, for example, terrace covers that are made of trellised, perennial flowering plants, and intensive green roofs with larger growing plant structures.

Local Hydrogen Cycle
Hydrogen is broadly recognized as one of the ideal fuel sources for the sustainable economy of the future. Hydrogen is one of the most ubiquitous substances on our planet, since it is part of every water molecule. In its pure form, it is highly combustible, and its combustion results only in the release of water vapor.

There are several technological challenges to overcome before a widescale hydrogen economy becomes a reality. The large scale production of hydrogen needs to become economically viable, technologies for the safe storage of hydrogen need to be realized, and a hydrogen-supporting infrastructure needs to be developed. Most of these technologies are already in various stages of advancement and key barriers involve efficiency and cost.

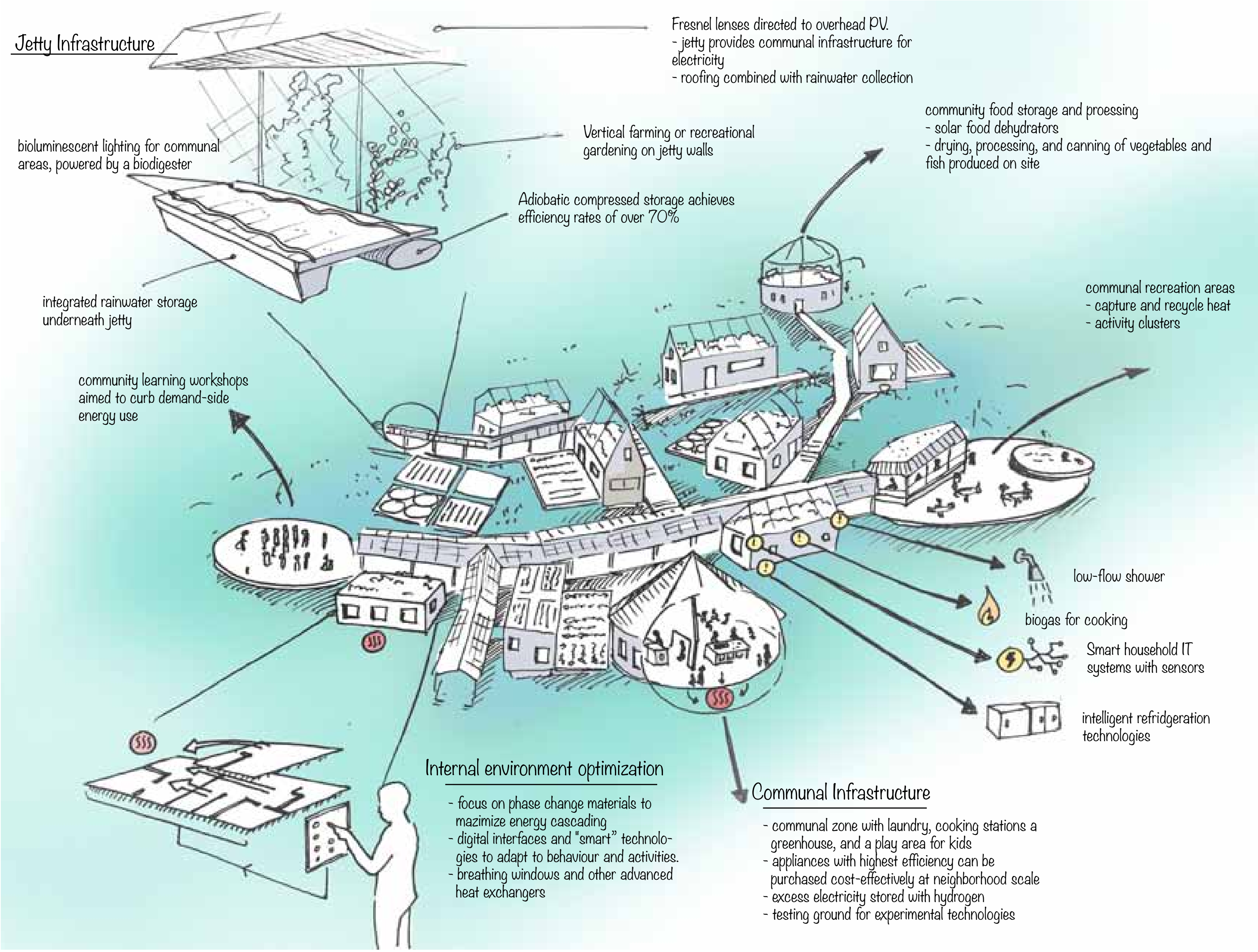
The idea of a neighborhood where hydrogen is the primary energy currency may seem far-fetched, but there are already many commercially available hydrogen technologies, both for generation as well as storage. An added benefit of hydrogen is that it is a useful common denominator for the diverse sources of energy that we anticipate having on the site.

FINANCIAL AND OPERATIONAL FEASIBILITY

Though most of these technologies are not financially or operationally feasible on a broad scale, there are many opportunities to install pilot scale technologies on a site of this relatively small size. It might be possible to do this at low cost if technology providers are still looking for sources of data and usability studies.

The operational management of these technologies may also be complex, but this is something that needs to be evaluated on a per technology basis.

DESIGN 3 : FANTASY SCENARIO



Electricity

Generation
- Advanced solar PV options
- Hydrogen Fuel Cells
- Microbial Fuel Cells
- IRWES building-integrated wind technology

Storage
- Compressed air storage
- Metal-air batteries
- Hydrogen

Heat

Generation
- Solar heat collection
- Fine-Wire Heat Exchangers in greenhouses

Storage
- Phase change materials in buildings and liquid storage tanks
- Thermal concrete storage
- Combined heat and electricity storage with adiabatic compressed air

Water and Waste
- Vacuum waste collection systems
- Microbial Fuel Cells
- Algae wastewater treatment
- Biological wastewater treatment for the removal of chemical compounds

Food

Production
- Decentralized home hydroponics technology
- Floating biomass production: algae bags, floating platforms with food production, kenaf production

Processing
- Local cheese and beer production

PUBLIC INFRASTRUCTURE

Jetty / Walkways
As in the proven technology scenario, the jetty is partly used as an infrastructural spine in this vision. Ideally, the technologies placed within the jetty can be easily removed and upgraded as time goes on. For example, the blackwater treatment unit can be lifted out and replaced with an alternative technology, but still fit into all of the piping originally designed to enter the jetty.

The jetty can also be used for aesthetic and biodiversity support purposes, if it can successfully be covered with trained flowering plants that do not interfere with other technologies that are placed on the jetty roofing (e.g., solar panels).

Public lighting
In this scenario we explore the possibility of experimental alternatives for lighting: photoluminescent pigments, bioluminescent organisms, solar lighting options. Certain types of algae and bacteria give off significant quantities of light and can be powered with sludge waste streams from biomass digesters. This may be particularly interesting for contaminated sludge streams from the digestion of plants from the phytoremediation garden on the de Ceuvel site.

Several research teams are also working on the development of modified luciferase enzymes (from fireflies) on nanostructures that produce very bright light for minimal energy output (20 - 30 times more efficient than electric lighting). It may be possible to try out some bioluminescent lighting strips in some areas of the site (e.g., low luminescence jetty tracklighting, that can be supplemented with brighter light activated by motion sensors).

Communal areas
The communal areas of the CTP are a particularly promising place to pilot new and emerging technologies. Ideally, certain kinds of technologies can be placed there on short-term lease or for showcasing purposes, in order to be annually replaced by more advanced models. In this way the communal areas can serve as a technology showroom. Less reliable technologies can also be placed here with less concern for disruption of daily activities.

Some possible technologies to pilot here include: advanced solar cookers, the latest washing machines, experimental lighting technologies, new heat storage options, and others. The Xeros waterless washing machine is an interesting option to pilot here if it is commercially released in time.

Transportation Infrastructure
Because this scenario explores the possibility of a local hydrogen cycle, the transport infrastructure is designed to support both hydrogen-fueled vehicles and electric vehicles. Initially, only electric charge points are available, but as hydrogen production technologies improve, hydrogen fueling stations can be added on site.

DOMESTIC TECHNOLOGIES

Building envelope
For the newly built boats on the Schoonschip site, passive house standards for insulation are achieved through phase change materials integrated into walls and roofing. Phase change materials use absorbed energy to change from solid to liquid. At cooler temperatures, PCMs convert back to a liquid, releasing the excess heat into the building. This evens out temperature fluxes, creating both passive cooling and decreasing heating demands. In Northern European climates, return on investment times of five years are relatively easy to achieve.

Many commercial PCM options exist, from DELTA-Cool28 (a PCM for windows that can absorb 1,2 kWh per m^2 of thermal energy during phase change), to wall insulation PCMs provided by Fabral Architectural Systems.

Boat retrofits

As in all scenarios, the de Ceuvel houseboats are retrofitted with improved insulation and windows, to achieve a standard as close to passive house as possible. They are placed on the site to maximize south-facing window area. To achieve multi-purpose insulation, they can be retrofitted with greenhouses with fresnel daylighting systems on one or more sides of each boat. These greenhouses have a U value of 0,21, which is slightly higher than the 0,1 – 0,15 range recommended for passive houses. But this is, of course, a second outside layer of insulation acting as a thermal coat on the building, which has its own inner envelope and windows. The greenhouses would also collect heat and solar energy.

For some of the communal areas, new building materials are used for experimental purposes: mycelium bricks, hemp fiber, or kenaf bricks. For example, the de Ceuvel workshop space could be built out of some experimental wall materials, which could even be grown on-site (in the case of the mushroom mycelium bricks).

Roofing

Houseboat roofs can be used for multiple functions:

- solar heaters
- solar PV
- integrated wind
- water collection
- gardens & food production
- greenhouses
- ecosystems

An ideal green roof design for the houseboats will integrate all of these functions in a multifaceted combination.

ELECTRICITY

Generation

Electricity generation in all of the scenarios is largely focused on solar photovoltaic systems. This will very likely be the primary technology of choice for its current cost effectiveness. It is interesting to explore different emerging solar PV options, such as organic solar PV, non-semiconductor technologies, silicon nanostructure PV, PV cells that use the infrared spectrum to produce electricity at night, DIY printed solar PV, solar PV integrated into shingles and walls, and emerging flexible PV options.

Wind power is generally not considered feasible on this site, however, emerging technologies such as IRWES (an integrated roof technology that does not have a visible turbine), are anticipated to be much more efficient than conventional turbines, and could be tested on one of the communal sites. The IRWES team, based in Eindhoven, is currently looking for urban pilot sites.

Another option for electricity generation is microbial fuel cells (energy producing bacteria). A team at Oregon State University recently developed a microbial fuel cell that can extract two kW per cubic meter of organic waste, which is tens of times higher than previously reported technologies. The OSU team, led by PI Hong Liu, is currently looking for a pilot site, ideally a food processing facility that produces a steady supply of certain types of wastewater. Such a pilot could potentially be placed on the Schoonschip site when coupled with the greenhouse and food processing area. It could be interesting to try this technology on a domestic site: we are exploring connections with this and other similar research groups.

Finally, hydrogen fuel cells are an option for electricity generation if sufficient hydrogen can be produced on site.

Excess electricity in peak periods can be used by a hydrogen generator to electrolyze water. It can then be converted back to electricity using a fuel cell power system. (Hydrogenics has recently developed such a system commercially for Herten, a city in Germany. Their HySTAT 30 hydrogen generator completes the electrolysis step, and their HyPM 50-KW fuel cell power system converts the hydrogen back to electricity.) Hydrogen can also be generated from excess heat from the various heat capture technologies on site to power electrolysis.

Hydrogen can also be produced photobiologically from water through green algae. When algae are blocked from performing photosynthesis (by being exposed to anaerobic conditions, which can be simulated by copper exposure), they switch to hydrogen production. The site could feature test algae bioreactors that are tooled to different purposes: some focusing on hydrogen production and others focusing on wastewater treatment coupled with fertilizer production.

Hydrogen can be produced directly from microbial electrolysis cells using seawater, river water, wastewater, and organic byproducts. The research group of Bruce E. Logan at Penn State University in the United States recently published findings that their cells were between 58 and 64 percent efficient in producing between 0,8 and 1,6 cubic meters of hydrogen for every cubic meter of liquid through their cells each day. Only 1 percent of the system's energy was needed for the pumping of water through the system.

Finally, excess biogas produced on the site can also be converted to hydrogen using more conventional processes.If all of these production technologies can be used on site, hydrogen can become a useful common "energy currency" for the CTP, though it remains to be seen to what extent this is economically feasible.

Storage
Excess electricity can be stored in a high-efficiency fly-wheel for short term load balancing (PowerTHRU offers a suitable model for the site that costs 85.000 USD).

Longer term technologies for on-site electricity storage include:

- Metal-air batteries
- Compressed air storage
- Hydrogen

Metal-air battery technology is rapidly advancing and represents high efficiency and longevity gains over existing battery technologies. We are investigating around a dozen emerging metal-air battery technologies.

Recent years have also seen many advances in compressed air storage for electricity. Adiabatic storage stores the heat generated during air compression for reuse during expansion, achieving a theoretical 100% efficiency (70% in practice). New pilot projects are underway, such as the German ADELE project (2013). SustainX has commercial isothermal CAES, and LightSail offers a 70% efficiency system that has proprietary storage tanks that can handle very high pressures and don't need to be buried underground.

If hydrogen is generated, it must also be stored. Storage in the form of hydrogen has, in particular, advantages in terms of space. Though it is less efficient than compressed air energy storage (40 - 50% efficient, as opposed to 75 - 90% efficient), it can be stored at much smaller capacities. It is therefore economically best suited to scenarios where the total amount of energy stored is a more important factor than the overall efficiency, which is usually the case when energy is stored for longer than 1 - 2 days. A 250-liter pressure vessel designed to store 10 - 20 kWh of compressed air could store enough H_2 to provide 150 - 300 kWh of electricity, reducing the cost of storage capacity by more than a factor of 10. H_2 may also be stored cheaply without high pressure at a very low temperature (-453 F) liquid (LH_2) or by absorption in powders of abundant metals (e.g. iron, titanium, aluminum, and sodium) that release H_2 upon moderate heating (less than 200 F).

There are many emerging technologies for safe hydrogen storage. Some of the more promising ones involve storing hydrogen bound in a solid alloy, which increases its volumetric energy density and removes the risk of explosion. This or a similar approach would need to be worked out for a safe hydrogen cycle to exist on site.

HEAT

Generation
There are many potential sources of heat capture and generation throughout the CTP site, mostly detailed in the other scenarios:

- solar heat collection from rooftop collectors and greenhouses
- heat exchangers (air-to-air, air-to-water)
- fuel combustion (biogas or biomass)
- waste heat from household equipment

A key design challenge will be to define a smart heat cascade through the neighborhood to use high to low quality heat in the area and store any large excesses.

Storage
Short-term heat storage can be performed in insulated water storage tanks or insulated concrete blocks. Water has one of the highest thermal capacities (4.2 J per cubic cm). Concrete has around a third of this thermal capacity. However, it can be heated to a much higher temperature (around 1200 C by electrical heating and thus has a much higher overall volumetric capacity. An insulated cube of about 2,8 meters would have sufficient heat storage for a household (calculate). The Wiggenhausen-Sud solar development has used this approach to great effect.

An alternative for short-term heat energy storage is to use high density ceramic bricks heated to a high temperature with electricity (at peak hours) and well insulated to release heat over a number of hours. Converting electricity to heat is unlikely to be a recommended option for this site, however, since electricity will be in shorter supply than heat.

For seasonal heat storage, Phase Change Materials are once again an interesting option. Molten salts retain a high temperature in thermal storage systems in conjunction with concentrated solar power. Options for molten salts include: potassium nitrate, calcium nitrate, sodium nitrate, lithium nitrate. These absorb heat and then re-release it into the water to transfer energy as needed. The salt must be mixed in a eutectic mixture.

WATER

Collection & storage
Rainwater harvesting is a standard and straightforward technology: runoff surfaces are coupled with gutters that collect water into tanks for purification and use. One option to explore in this scenario is how to integrate the water storage into the architecture of the CTP site in such a way that it is hidden from view and makes maximum use of gravity flows.

Purification

Purification of rainwater, greywater, and wastewater will be distributed throughout the site and completed through various technologies depending on the type of waste stream.

Floating helophyte filters (beds of floating wetlands) are potentially a good option for house-scale greywater purification, and can also potentially satisfy some of our biodiversity objectives. A Living Machine or Solar Aquatics system are both interesting to consider for full cycle water purification for certain organic streams.

Using algae for wastewater treatment is an interesting option, since the algae can be converted into a uniform fertilizer for food production on site. More advanced water purification technologies can also be piloted on the site. A persistent problem in wastewater treatment is the presence of estrogen disrupters and pharmaceuticals. Advanced biological treatment systems are currently being developed to deal with these problems, though none have been deployed on a large scale. We are investigating options for microbial water treatment technologies that could be tested on site.

Another potential organism for bioremediation is Geobacter, a genus of protobacteria that can oxidize organic compounds and metals, including iron, radioactive metals, and petroleum compounds into CO_2 while using iron oxide as an electron acceptor. It would be interesting to explore ways to remove contaminants from phytoremediation using Geobactor.

WASTE

Solid

One option for household solid waste collection is to explore house-scale vacuum waste collection. Vacuum waste collection

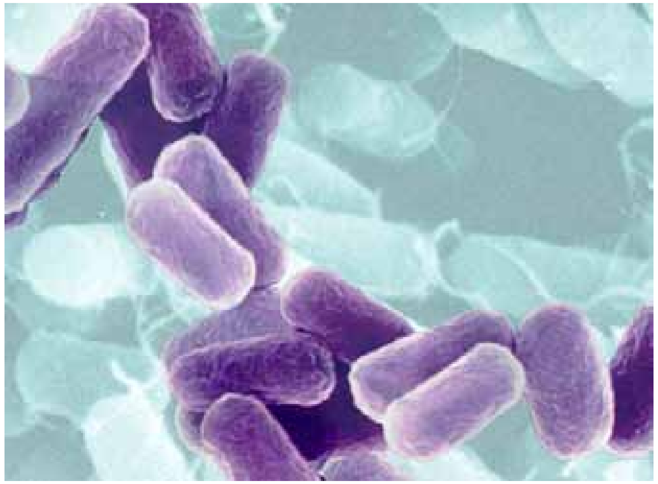
“Biolight” by Philips Netherlands Design and Lighting: a bioluminescent lamp powered by digester sludge.

Algae production by AlgaeParc, Wageningen UR.

Wisteria Tunnels: inspiration for the jetty / walkways

Mycelium Building Materials

Floating wetlands in Sengkang



Energy Producing Bacteria

3D printed reef balls

systems are offered commercially by several companies, including Veolia Environmental Services and Envac. Envac Group has completed several residential scale projects comparable in size to the planned Cleantech Playground area. Some benefits of such a vacuum collection system is that it can be hooked up to smart metering / monitoring of waste quantities and potentially assist in the timely and automated feeding of waste to the biogasifier.

All of the various organic waste streams will be reused on site for either energy production, nutrient recovery, or both. The various digestion and gasification options are described in the previous sections.

FOOD

Production
As discussed previously, food will be produced in various locations on-site. In addition to their own allotment gardens, households can be equipped with small scale window hydroponic units which can supply them with their own supply of herbs and leafy greens. These can be installed in south-facing windows, ideally in or near kitchens.

The site also offers opportunities to explore alternative food products and strains. For example, super-dwarf wheat, also known as USU Apogee Wheat was bred for compact food production necessary in applications such as space travel. In 2002 it was grown in a greenhouse on the International Space Station. It stands only 25 centimeters tall and has an extremely rapid development rate, can withstand constant grow lights, and is mature after sixty days (Bugbee, 1996). It has been considered by Columbia University as suitable for urban production in New York City because it can be tightly stacked in trays due to the short height of the breed.

Floating Food Production Facility
A stacked food production facility with many layers of production is also something we are investigating for the additional floating site earmarked by the municipality. This is a separate design, which there isn't room to detail here, but will involve layering of water treatment, aquaponics, mushroom production, and hydroponics, in a stacked floating structure. It can also potentially be done on a recovered barge or boat to save on material costs.

Floating biomass production
Because both sites are tied closely to the water, some interesting opportunities exist for creating floating biomass production systems. Bags of floating algae that purify wastewater and are harvested for fertilizer are one idea we are exploring. Floating platforms producing high yield fibrous crops such as kenaf are also a possibility for increasing biomass production on site.

Processing
We are investigating the feasibility of installing small scale beer and cheese production facilities on site, which is something that the residents have also expressed interest in having.

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