OFF-GRID IN CONTEXT

A design guide for sustainable and off-grid architectures in Midden-Delfland

RESEARCH REPORT
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INTRODUCTION

The problem statement:
Environmental crisis has roamed the world since the late 60s and early 70s with the 1970s first ‘Earth Day’ as clear indicator of a starting global environmental awareness. During the 21st century the environmental crisis took the stage in global discourse. The world is already on the brink of exceeding the planetary boundaries (Rees, 2009). Resource depletion, environmental degradation and rising water levels due to climate change are the main global concerns. The built environment is a tremendous contributor to these pressures. Buildings are currently responsible for 39% of global energy related carbon emissions: 28% from operational emissions, from energy needed to heat, cool and power them, and the remaining 11% from materials and construction (WorldGBC, 2019). It is therefore important to seek solutions that challenge the current way of living, and minimise impact from operational emissions and materials and construction.

Throughout history battling these environmental problems has been done by making things more ‘sustainable’. Sustainability is a rather ambiguous term, the most common definition of sustainability is found in the 1987 ‘Brundtland Report’. They define sustainability as development set within the environmental ‘limits’ of the earth (Brundtland, 1987). This concept has been incorporated in some form into many governmental and institutional reports. Development inherently builds upon the existing. This is also the reason why this definition of the World Commission on Environment and Development (WCED) has been criticised. William Rees argues that the notion of development in sustainability has only paved the way for viewing sustainability as the ‘increasing of efficiency’ in all fields. He and many others advocate for a paradigm shift, re-imagining current relations and systems of our world (Worster, 1994).

The earliest environmentalists from the 60s and 70s also focused on this first definition of sustainability. Architectural elements such as the Trombe wall in the Trombe House by Jacques Michel & Felix Trombe & the drum wall in the 88 Zome House Corrales by Steve Baer took the stage. This inspired a movement of solar-passive designs in which the sun became the main source for the operational processes in the built environment. These first designs can be seen as optimised products for more efficient architecture, for example: a wall as a storage for heat and energy.

Relating to the emissions of materials & construction, commonly discussed solutions relate to the ideas of a circular and regenerative designs (Benites, 2022). A future in which building materials either come from nature or from waste streams. Recycling, re-using and re-imagining took the stage in the late 90s. Since then an increasing number of buildings adhere to frameworks such as the British BREAAM and the American LEED (Mhatre, 2021). Albeith that these material frameworks enhance material efficiency in the built environment, they also contribute to the continuous, developmental, ‘efficiency problem’ as stated by William Rees. Rees also argues that in order for something to become sustainable **it must be detached from all unsustainable systems** (Rees, 2009).

A very interesting architectural idea that attempts to break free from all unsustainable systems, is the concept of the 'Earthship'. The earthship, a concept created in the early 70s by Michael Reynolds, is a fully passive house constructed of at least 50% re-used materials and 50% natural materials. The earthship dwellings are almost all fully off the grid, they harvest heat from the sun, gain water from rain which is filtered with plants and electricity from the sun & wind. Furthermore, according to the architect, it can be built everywhere & in each climate (Earthship Biotecture, 2023).

The Earthship forms an example in which architecture can be separated from all unsustainable systems by using waste & natural materials in order to create a house that performs passively. In a way it is a first attempt to a general contextualisation of the different architectural elements that enhance the building performance by using materials that are either considered waste in the global context of the 70s (such as rubber and glass) or natural (clay and wood). This research plan aims to put the concept of an earthship in context of the 21st century.

Research shows that Reynolds promises relating to the thermal qualities of his earthships are met whenever the houses are built in moderately hot areas such as southern parts of spain and New Mexico, yet when in the more wet and colder climates such as Brighton (England) & Zwolle (the Netherlands) the thermal perfomance tends to lack during winter months and damp issues occur more often (Miller, 2009). Furthermore, since the 70s a lot has changed regarding the re-using and recycling of resources. In 1972 the first glass collection point was placed in Rotterdam, currently (2020) there is a network of around 16.000 glass collection points. Using bottles as aesthetics in room dividers may be less environmentally friendly as it was 50 years ago. Furthermore, the biggest contributor of waste is the built environment, producing 41% waste in the Netherlands (CLO, 2020).

Around the same time that Reynolds developed his first earthship in the U.S., a same trend in utopian can be observed in Europe. Although there is some discussion online about who was first, several ecological communities started to arise. One of these was the Scottish Findhorn, created in 1962 the people involved started as, what was then called, an intentional community. The intentional community describes a group of people that bear the same ideals and values (Metcalf, 2004). Later in 1991, the term Ecovillage was introduced for the first time in a paper written by Robert and Diane Gilman. Short thereafter in 1995 the first international conference of Ecovillages was held in Findhorn and the Global Ecovillage Network (GEN) was born. The total of ecovillages is estimated to be well over 10.000 and they have been grounds for experimental architecture and systems all over the world. Several of these initiatives have also sprouted in the Netherlands and often showcase experiments that lie behind the boundaries of our construction regulations.

These Ecovillages know many shapes and forms, yet they share one definition. An Ecovillage is an intentional, traditional, or urban community using local participatory design to regenerate social and natural environments (GEN, 2023).

Rising sea levels, increasing droughts, severe storms, increasing health risks and many other problems have been presented as problems over the last few years. A response in the architectural discourse is to start to think about resilient architecture and landscape. Resilience is context dependent and is defined by the magnitude of disturbance a system can tolerate and still persist (Limnios, 2014).

The Redesigning Deltas project aims to develop a water-resilient, biodiverse, sustainable, productive landscape for the Dutch deltas. Regeneration of the natural environment of the peat landscape is one of the pillars of this project. The Peatlands currently excrete CO2 while they could be carbon storages if restored to its former state.

This research connects to this project by providing different architectural solutions that asssist in achieving a heatlhy, sustainable & resilient water system. Furthermore, the architecture should contribute to the regeneration of the natural environment of Midden-Delfland.

Therefore, this research aims to take lessons from earthships and ecovillages in the Netherlands, searching for a housing complex: free from all unsustainable systems while adapting construction methods of the 21st century and at the same time contribute to the regeneration of the natural environment of Midden-Delfland by being fully self sustaining and non-pollutive.

In this spirit the main research question this research plan investigates is the following:

How to design
a sustainable housing district
in Midden-Delfland?

This question is split into three **sub questions** and three **case studies**. The solutions to these questions are placed in frameworks and are further investigated *in context for the site of Midden-Delfland:*

How can architecture assist in the reduction of emissions relating to materials & construction?
- *What circular/recycling infrastructures relating to the built environment are in place in Midden-Delfland?*
- *What bio-based foundation materials can be produced sustainably in Midden-Delfland?*
Case study A: Dutch floriade Pavillion

How can architecture reduce the operational emissions of dwellings?
- *What present energy storage and harvesting systems relate to the built environment?*
- *What architectural elements have been built that relate to the reduction of operational emissions in dwellings?*

Is self sufficiency in water management a sustainable solution?
- *What are the spatial requirements and necessities for harvesting drinkwater in Midden-Delfland?*
- *How can feces be processed locally in Midden-Delfland?*

A Case study into sustainable systems, construction methods and materials and shared spaces of ecovillages in the Netherlands.
Case study B: Ecovillage Olst
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Research

How can architecture assist in the reduction of emissions relating to materials & construction?

It is a very easily accepted truth that for architecture to assits in the reduction of emissions relating to materials & construction, architecture has to be precise in the level of sustainability attained in each building material. Life-cycle assesment (LCA) is a tool used to asses the carbon emission that are excreted in the life cycle of a material. The lifecycle is most often split into 3 stages: the production stage, usage and end-of-life (Kotaji et al, 2003). The research of Mouton et al. (2023) acknowledges these stages and further splits the life-cycle into 11 different stages (figure 1). Furthermore, they specify the aspects of land use and particle matter.

Zabalza, et al (2011), has provided a wide overview of the different footprints of conventional building materials seen in figure 2. In their analysis they also express the amount of water needed for the construction of a material, highlighting an extra valuable resource used in the process of manufacturing building materials.

These LCA's give insights into the production of materials and points to area in the life cycle of a material that could use innovation to minimise impacts. Looking at the results of Mouton et al. it becomes clear that in almost all combined material packages the production phase emits the most carbon and is most unsustainable. Furthermore, materials like EPS or XPS require high 'waste disposal' emissions.

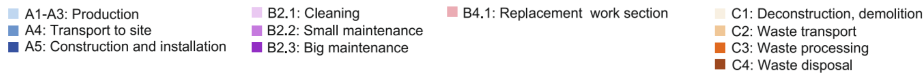


Fig. 1: Categories of a building materials life cycle as according to Mouton et al. (Mouton et al., 2023)

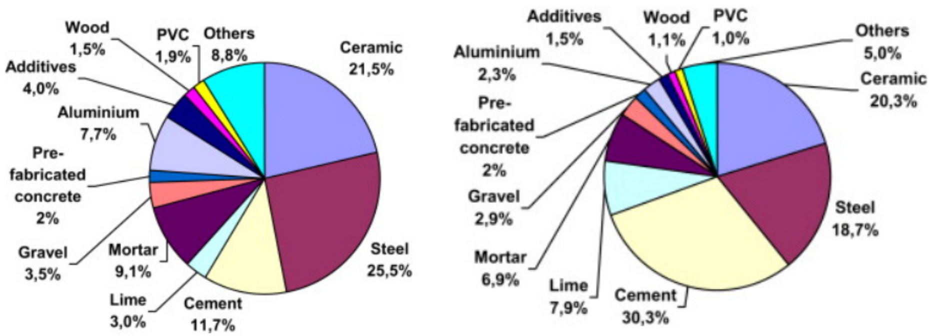


Fig. 2: Contribution of primary energy demand (left) and for the manufacture of the materials needed in the construction of 1 m2 (gross floor area) (Mouton et al., 2023)

No.	Research title	Building type	Location	Software	Conclusion	References
1	Analyze Differences in Carbon Emissions from Traditional and Prefabricated Buildings Combining the Life Cycle	Traditional and Prefabricated Buildings	China	One click LCA	Prefabricated buildings offer significant carbon emission reductions compared to cast-in-situ buildings with the highest emissions occuring during the field installation.	[52]
2	A Comparative Study on the Life Cycle Assesment of New Zealand Residential Buildings	Residential buildings	New Zealand	One click LCA	The light steel house had 12,3% more carbon emissions compared to the light timber house. However the extra carbon emitted by the light steel house can possibly be balanced out because steel is recyclable.	[53]
3	Comparative life cycle assesment of a reinforced concrete residential building with equivalent cross-laminated timber alternatives in China	Residential buildings	China	Revit, DesignBuilder 4.6, One click LCA	The use of cross-laminated (CLT) and hybrid CLT buildings leads to reduced greenhouse gas emissions throughout their life cycle, particularly in the product and construction stages, making them more sustainable compared to reinforced concrete(RC) buildings.	[54]
4	Life cycle assesment for carbon emission impact analysis for the renovation of old residential area.	Old residential buildings	China	—	When the impact of embodied carbon is not taken into account, the estimates for carbon reduction are inflated by 5.54%, Furthermore, Incorporating rooftop sola panels is the most effective measure to reduce carbon emissions, and can serve as a guide for low-carbon renovations in older residential areas, benefiting energy saving and emission reduction in cities.	[55]
5	Comparative Life Cycle Assesment of Mass Timber and-Concrete Residential Buildings: A Case Study in China	Residential buildings	China	One click LCA, Carbon Designer	The timber building highlighting its environmental benefits demonstrated an impressive decrease of 25% in the global warming potential compared to its concrete counterpart. To enhance the sustainability of timber buildins, focusing on local sourcing, improved logistics, and manufacturing optimizations is crucial.	[56]
6	Assesing the emobdied carbon reduction potential of straw bale rural houses by hybrid life cycle assesment: A four-case study	Rural houses	China	One click LCA	The materialization stage is the primary contributor to carbon emissions in building construction, indicating the need for sustainable material choices. Wood and light-steel structures ffer significant reductions in carbon emissions for rural houses, emphasizing the importance of selecting low-carbon materials.	[57]

Fig. 3: Segment of the overview on research on LCA by Dehvari et, al. (2023)

Many of these comparative studies have been performed all over the world as can be seen in the overview made by Dehvari et, al. (2023) Several of these studies compare timber, steel and concrete to each other. The outcome often crowns timber as having the lowest global warming potential (GWP). Furthermore, it accentuates the necessity in choosing the right construction material relating to context, use and re-use. Dehvari et, al. also further prove the merits that regenarative materials have over finite materials. They analyse and compare the life-cycle of a conventional house and a traditional house in iran by reviewing the material emissions as well as the consumption emissions during the average life time of the houses. In their case it also becomes clear that the consumption stage of a houses emits much more carbon than the production stage of a house. This confirms the earlier found global disparity in carbon emissions between the production stage (11%) and operational stage (28%) of a building.

Another addition to the LCA is proposed by van Stijn et al. (2021). In their research they develop a way of using LCA for the circular economy in order to assess the potentials for emission reduction. As shown in figure 4, additional cycles (C+1, C+2) in the BAU (business-as-usual) kitchen block have bigger potentials for emission reduction than in the “Reclaim!” (first cycle of direct re-use), this is due to increased life span of the materials of the BAU module that were put in the model. Additionally if the lifespans would have been the same the “Reclaim! cabinet” would have 35-60% (ranging correlates to various impact categories) more potential for impact reduction.

In this sense, it is important to note that lifespan is assessed by looking at the ‘weakest link’. The element of a composite building part with the shortest lifespan dictates the lifespan of the entire module.

“a building consists of ‘layers’ with their own lifespan which could be changed independently. Similarly, building components could be regarded as a composite of parts and materials with different lifespans. Per building component more levels (e.g., sub-components, resources) or fewer could be identified.” (van Stijn et al., 2021)

In this spirit, a variation of a kitchen cabinet with disconnectable parts is also evaluated. In this example the various parts are grouped in lifespans and are detachable accordingly. This results in the least environmental impact through the prolonged lifespan of the different parts.

	BAU						Reclaim!						
Impact category	Baseline	C+1	C+2	L7	L40	L80	Baseline	C+1	C+2	L7	L20	L40	L80
Global warming potential	0%	30%	44%	-200%	50%	75%	0%	7%	19%	-50%	50%	75%	88%
Ozone layer depletion potential	0%	32%	47%	-200%	50%	75%	0%	1%	11%	-50%	50%	75%	88%
Photochemical oxidation potential	0%	29%	42%	-200%	50%	75%	0%	1%	12%	-50%	50%	75%	88%
Acidification potential	0%	30%	45%	-200%	50%	75%	0%	3%	13%	-50%	50%	75%	88%
Eutrophication potential	0%	30%	45%	-200%	50%	75%	0%	3%	14%	-50%	50%	75%	88%
Abiotic depletion potential for elements	0%	31%	46%	-200%	50%	75%	0%	2%	10%	-50%	50%	75%	88%
Abiotic depletion potential for fossil fuels	0%	31%	46%	-200%	50%	75%	0%	3%	13%	-50%	50%	75%	88%
Fresh water aquatic ecotoxicity potential	0%	27%	40%	-200%	50%	75%	0%	10%	20%	-50%	50%	75%	88%
Human toxicity potential	0%	21%	31%	-200%	50%	75%	0%	6%	14%	-50%	50%	75%	88%
Marine aquatic ecotoxicity potential	0%	29%	43%	-200%	50%	75%	0%	7%	18%	-50%	50%	75%	88%
Terrestrial ecotoxicity potential	0%	27%	40%	-200%	50%	75%	0%	4%	12%	-50%	50%	75%	88%

Note: The colour shows a gradient between the highest percentual savings (green) and lowest percentual savings (red) for all scenarios per design variant, per impact category.

	P&P										
Impact category	Baseline	C-3	C-2	C-1	C+1	C+2	Lf=80-40-7-40, Lt=80-40-40-40	Lf=80-40-40-40, Lt=80-40-40-40	Lt=7-7-7-7, Lf=7-7-3,5-7	Lt=20-20-20-20, Lf=20-20-10-20	Lt=40-20-20-20, Lf=40-20-10-20	Lt=80-80-80-80, Lf=80-80-40-80
Global warming potential	0%	-49%	-12%	3%	18%	30%	-23%	22%	-527%	-109%	-99%	47%
Ozone layer depletion potential	0%	-71%	-24%	-4%	18%	31%	-25%	25%	-527%	-109%	-99%	46%
Photochemical oxidation potential	0%	-65%	-23%	-3%	17%	28%	-21%	21%	-532%	-111%	-100%	46%
Acidification potential	0%	-62%	-19%	-1%	18%	29%	-23%	22%	-531%	-110%	-100%	46%
Eutrophication potential	0%	-55%	-16%	2%	17%	29%	-23%	22%	-533%	-111%	-100%	46%
Abiotic depletion potential for elements	0%	61%	69%	73%	16%	27%	-37%	23%	-556%	-119%	-100%	45%
Abiotic depletion potential for fossil fuels	0%	-61%	-18%	-1%	18%	30%	-23%	23%	-528%	-109%	-99%	46%
Fresh water aquatic ecotoxicity potential	0%	-3%	16%	23%	17%	27%	-22%	18%	-540%	-113%	-100%	46%
Human toxicity potential	0%	-7%	5%	10%	14%	22%	-12%	10%	-545%	-115%	-100%	46%
Marine aquatic ecotoxicity potential	0%	-12%	13%	24%	17%	28%	-24%	20%	-538%	-113%	-100%	46%
Terrestrial ecotoxicity potential	0%	-26%	3%	16%	16%	27%	-23%	19%	-540%	-113%	-100%	46%

Note: The colour shows a gradient between the highest percentual savings (green) and lowest percentual savings (red) for all scenarios per design variant, per impact category.

Fig 4: Percentual reduction per scenario compared to the baseline scenario of that design variant (van Stijn et al., 2021)

Conclusively, it is important to be mindful of the processes involved in both the production process as wel the operational process of a building or material. Local sourcing and use of regenarative materials help reducing the total carbon emissions yet when looking at the life-cycle of a house it becomes clear that the operational emissions have the potential to greatly outweigh the production emissions.

CE-LCA's show that the circular economy could also highly impact the pollution rates positively. Furthermore, replaceabililty based on the duration of lifespan could further enhance the positive impact of a circular approach especially when the initial product is also re-used (while it doesn't lower the lifespan).

Relating to architecture it becomes apparent that it is important to be aware of the lifespan of certain materials, especially of re-used materials. Furthermore, detachability relating to lifespan has the opportunity to greatly impact the total environmental impact of a dwelling. This becomes particulary more important when re-using or recycling building materials, since they could potentially lower the lifespan of a dwelling when seen as a whole.

What circular/recycling infrastructures relating to the built environment are in place locally?

In the previous chapter we have established the necessity for re-using and recycling building materials through evidence collected by performing all sorts of different LCA's. This knowledge is not new (although additional and innovating models are still being built and continue to prove the concepts of circularity and regenerative building materials), yet it is now properly comparable. The insights are of theoretical importance since they promote the creation of ventures that relate to circular economy and incentivise proper decision making relating to materials in the process.

The next step of this research is to try and develop a method that ensures a proper grouping of building elements according to their predicted lifespan and to indicate several local initiatives in South-Holland that are currently re-using and recycling building products in the vicinity of Vlietpoort, Midden-Delfland.

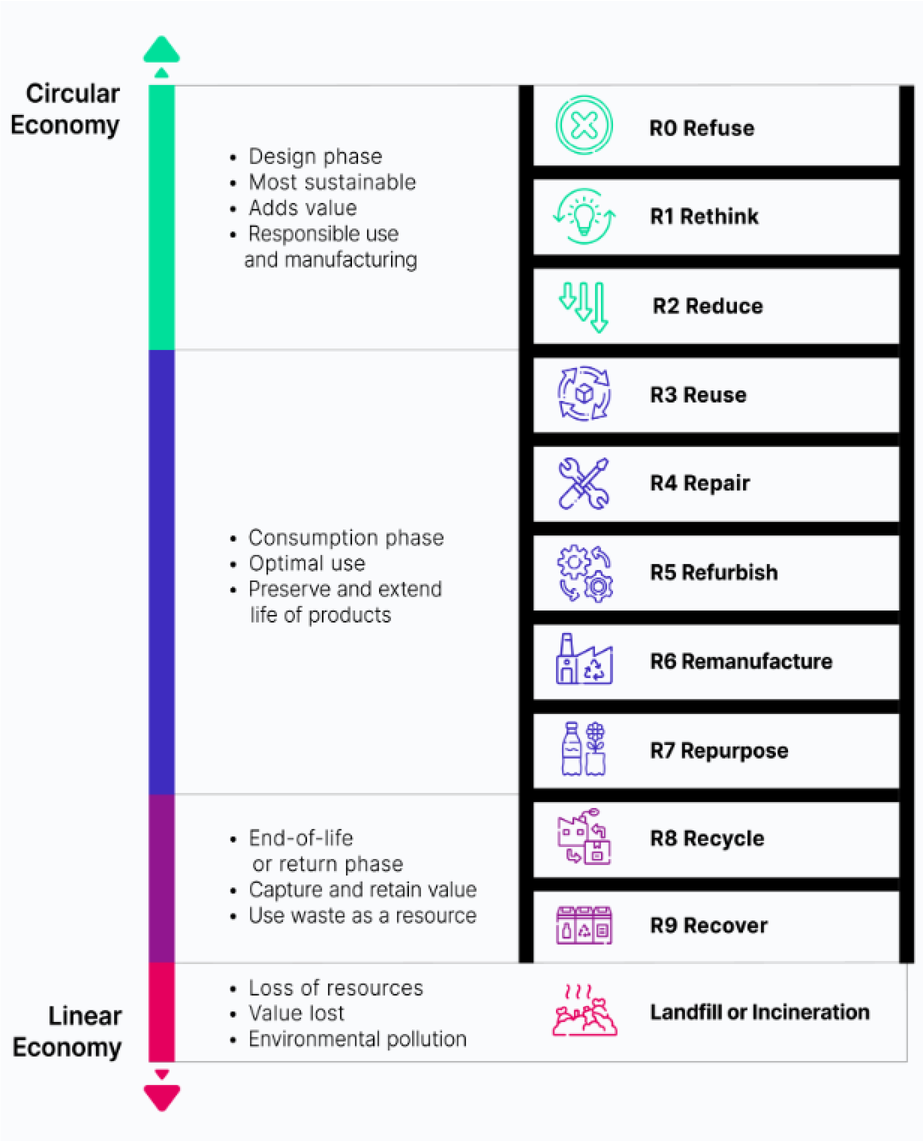


Fig 5: The different stages in which R-Strategies can be implemented (R-Strategies for a Circular Economy, 2023)

Before highlighting the different circular initiatives it is important to understand the basic circular economy principles. A circular economy tries to mitigate value loss throughout the entire cycle of materials (Rahman et al., 2021). This is commonly done along the lines of the 10R-strategy. The 10 R’s provide a hierarchy for different strategies relating to value loss, they are respectively: R0 Refuse, R1 Rethink, R2 Reduce, R3 Reuse, R4 Repair, R5 Refurbish, R6 Remanufacture, R7 Repurpose, R8 Recycle and R9 Recover. The first three R’s are the ‘short’ loops, these foucs on smarter product use and manufacture. The medium loops focus on life extension strategies while the last two loops focus on creative material application (R-Strategies for a Circular Economy, 2023).

Urban mining initiatives in the Netherlands widely vary in foucs around these 10 R’s. The following database highlights the Dutch initiatives, groupes them along the 10R’s and arranges them from close to distant from Midden-Delfland. A first initial database for Dutch, circular materials is presented on the next pages. The focus here lies on the retailers that sell either re-used or repaired goods.

collection at urban mining site

collection at urban mining site

collection at urban mining site

multiple locations nation-wide (check for circular products)

multiple locations nation-wide (check for circular products)

collection at urban mining site or delivery

digital platform with different pro-viders

digital platform with different pro-viders

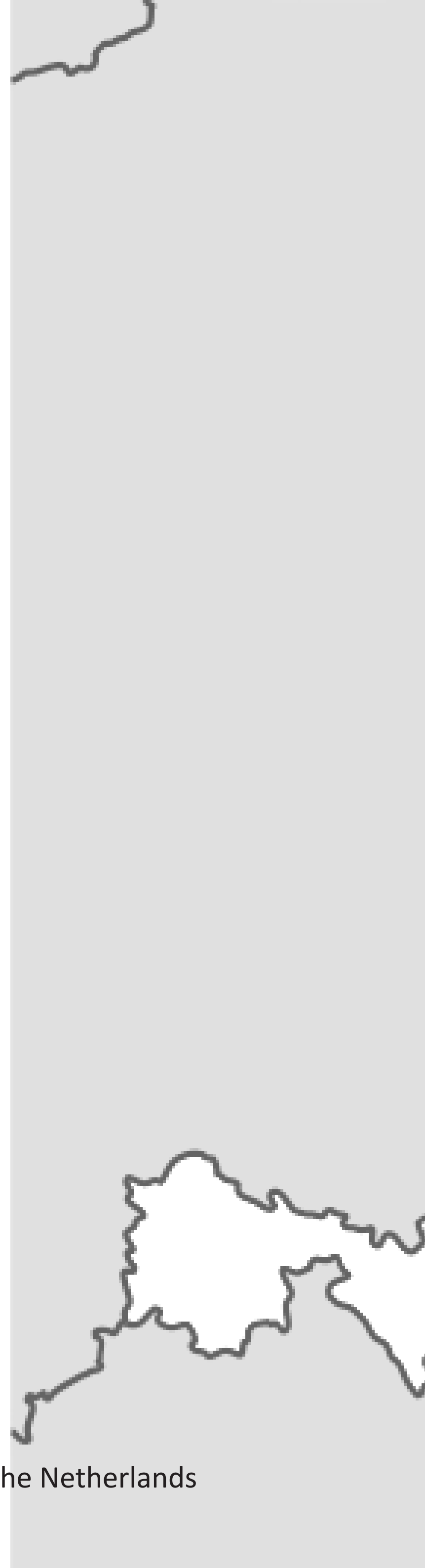
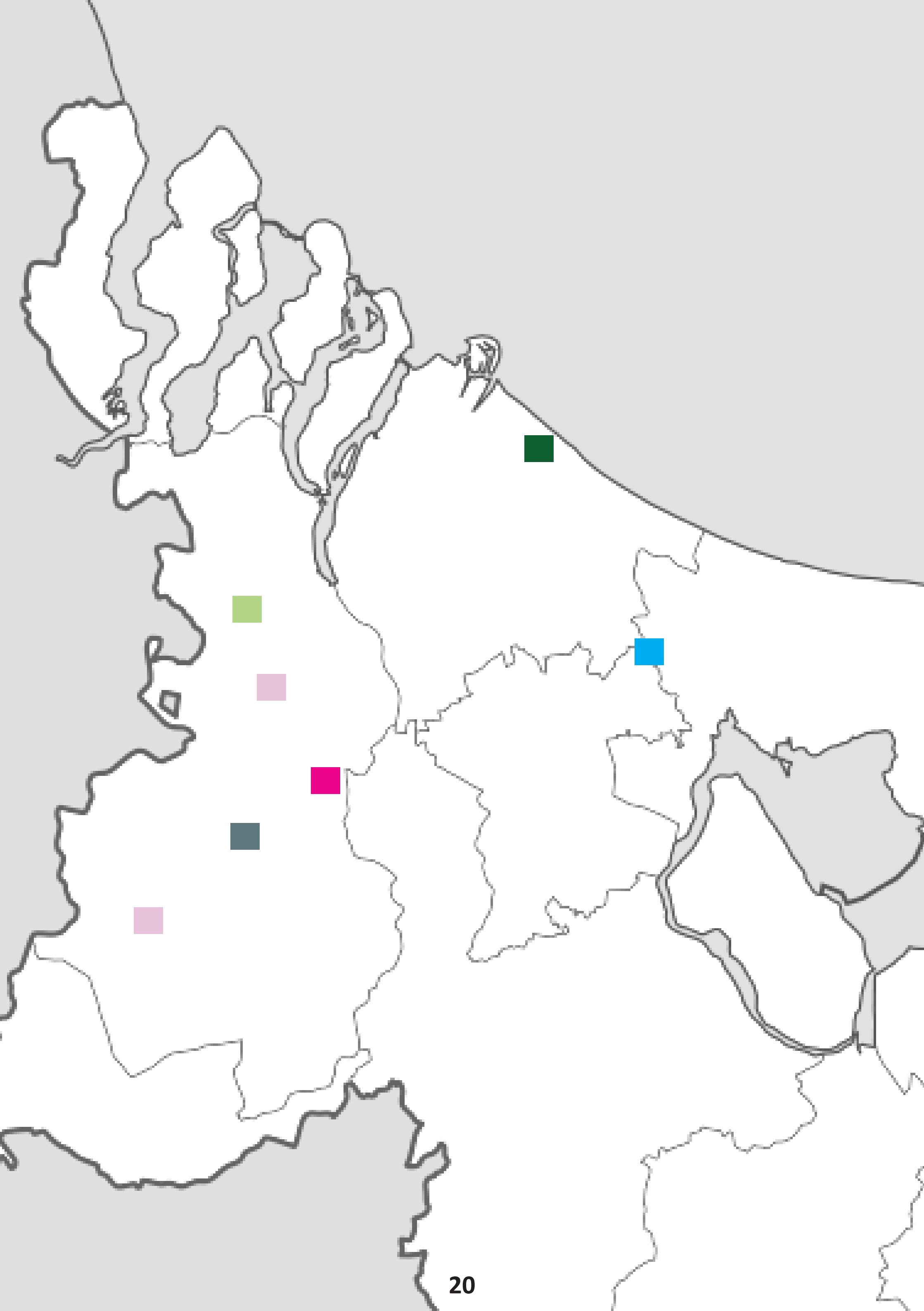


Fig 6: Map with several re-use intiatives in the Netherlands



Retailer	Type of provider	Current inventory (2024)
Materiaalbank	Retailer	Steel profiles, roof plates, appliances
Restoric	Retailer	biggest supplier of doors
CIRCULAIRE BOUWMATERIALEN	Retailer	Wide variety of materials
Van Zundert CirculairAanbod.nl	Retailer	36 total items: several painted IPE profiles, appliances, wooden staircase
insert®	Open platform	Bulk wood, appliances, interior
stiho thuis in de bouw	Retailer	Construction materials
rexel	Retailer	Electrical building components
GEBRUIKTEBOUWMATERIALEN.COM	Retailer	wide offer, variety of steel profiles
Marktplaats	Open platform	All second hand products

R-strategy	Available infrastructure	Distance [km]
re-use	Road & water	56
re-use, repair, recycle	Road & water	48
re-use	Road	65
re-use	Road	11
direct re-use	variable, mostly road	-
re-use & repair	Road & water	-
re-use & repair	Road	-
re-use & repair	Road	87
direct re-use	variable, mostly road	-

Retailer	Type of provider	Inventory
2dehands bouwmaterialen.nl	retailer	Wood, doors, insulation, stained glass
SNELLEN tweedehandsmaterialen.nl	retailer	10.000+ items, free stones
INKOOP • VERKOOP MAMMOET Oude bouwmaterialen	retailer	Vintage interior items
De circulaire bouwcatalogus	informative platform	circular initiatives
NewHorizon	Urban mining collective	circular initiatives

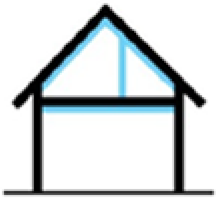
Fig 7: Different providers of re-used, recycled or remanufactured building materials in the Netherlands

R-strategy	Available infrastructure	Distance [km]
direct re-use	Road & water	51
re-use & repair	Road	52
re-use, repair, refurbish	Road	11
collection of all R-strategies	-	variable
collection of all	-	variable

Conclusive remarks
As can be seen in figure 6, the retailers already offer a wide variety of second hand products that can be used in the building envelope. However it is important to state that these items are often times of lower quality than new items and could therefore reduce the lifespan of a building. Detailing these elements properly and looking to the different functions they could fill in the envelope is therefore of extra importance.

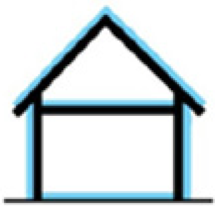
Another important aspect of proper re-use of these building elements in new constructions relates to the standards as posed in the Bouwbesluit. Doors, windows and window frames need to have a U-value of maximum 1,65 W/m2K. Re-used windows, doors and window frames can therefore not be used in the facade of the building. The interior regulations are less strict, re-used materials can therefore be used on the interior when constructed demountable. (Bouwbesluit 2012, 2023)

Another quite interesting find was that several retailers provide free cobblestones. These cobblestones are often made from high thermal mass elements such as Basalt or Granite. They could be directly re-used as street materials, or when placed on the interior function as extra thermal mass in architectures made of wood or other lightweight insulation structures.



Straw:
applicable as insulation or as stabilising panels.

Wood:
applicable in many forms througout the entire house



Cellulose:
applicable as insulation in walls, floors and roofs

Lime plaster or blocks:
applicable as construction in block form, applicable as finish in plaster form

Fig 8: comparative drawings for bio-based material categorisation used by Van Dam & Van Den Oever (Van Dam & Van Den Oever, 2019)

- What bio-based materials can be produced and manufactured sustainably in Productive Park Midden-Delfland?

Within the plan for Productive Park Midden-Delfland, three production landscapes are designed based on the underlying soiltypes: woodproduction on the dry claylandsapes, straw & flax on grasslands and reed & elephantgrass on wet peatlands.

At the university of Wageningen they have created a catalog for biobased building products in which they highlight the different uses relating to the different crops (Van Dam & Van Den Oever, 2019). The catalog is very expansive, therefore this chapter builds further upon this catalog by performing a case study on the Dutch, biobased pavilion of the Floriade. This chapter highlights findings from the research done by the woningbouwatelier (woningbouwatelier, 2024)

The natural pavillion at Floriade 2022 - setup

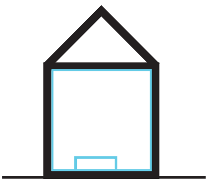
The Dutch floriade pavillion was designed by DP6 architectural office. The 95% biobased pavillion is fully deconstructible and creates a space where visitors can experience and dicover the new trends on biobased materials, produced in the Netherlands. The building is made up of several wood cubes (HoutKern system) with non-loadbearing walls that exhibit the different trends in biobased materials. Furthermore, the topic of nature-inclusive building is also touched upon by creating food gardens and green roof with native plants. For the glazing, they re-used glass from an old office building at Koningskade 4, The Hague. To be able to use this glass properly they made use of **material driven design.** This meant that the measurements of the glass are starting points for the design of the window frames, where normally the frames are designed and glass is cut accordingly.

The Natural Pavilion at Floriade 2022 - inner walls

The inner walls of the Natural Pavilion highlight some promising biobased building materials that are poduced in the Netherlands. Het Woningbouwatelier has performed a life cycle analysis on the different materials and came up with a MKI-score for each material.

Van Hier

Van Hier produces BioM (bio-multiplex), a flooring and cladding material made from biological waste streams. During the Floriade, they exhibited panels made from several materials amongst which are: elephantgrass, reed clippings and freesialeafs. The panel consists of three ingredients: natural fibres, a filler and a binder. The natual fibres are made of a variety of different agricultural waste, the filler is made from elepantgrass and the binder is 100% home-compostable and natural. Furthermore, it is available in a multitude of different colors, made with natural chalks
MKI/m2: €0,38
Carbon stored: 1,85 kg CO_2



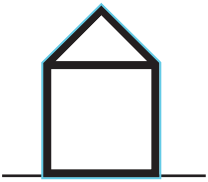
Bio-multiplex:
applicable as cladding material, furniture and flooring

Thermofloc

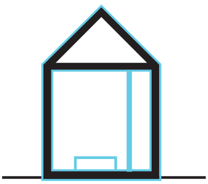
Thermofloc is a cellulose-based insulation material produced from sorted newspapers with the addition of several minerals in respect to conservation and fire-safety. This material was also decribed in the catalog yet Thermofloc differentiates itself by being 100% borate free. The resulting MKI is therefore also considerably low.
MKI/m2: €0,027
Carbon stored: 1,485 kg CO2

MYMO

MYMO is a product developed by studio Cartier and is made up of hempfibres and mycelium. Mycelium is a by product of mushrooms and can be used to make furniture, wall finishings and even insulation.
MKI/m2: €0,58
Carbon stored: 5,85 kg CO2



Thermofloc insulation: applicable as insulation in floor, roof and walls



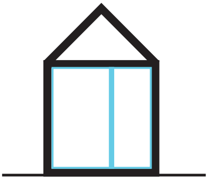
MYMO: applicable as interior cladding, insulation, partition wall or furniture

Rik Makes

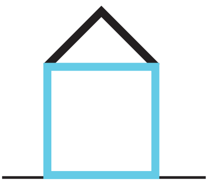
Rik makes compost boards for interiors. It is also made from agricultural waste and is 100% degradable. After its use it can be put outside, where it will slowly break down into sugars and nutritious fibres that feed the soil. The binder in this panel is potato starch, this is also the reason why the MKI is on the high side. Rik Makes is currently investigating using potato starch from rest-streams to even further increase the MKI. The range of panels vary in color and material. One of the more interesting ones is the panel made from paprika fibres. The Dutch are famous for their greenhouse produce, the paprikaplant is one of many plants that is produced in these greenhouses. The stalks are being used for for the panels, yet since the paprika's have been sold, plastics often still stick to these stalk. If the panel would not have been made these plastics will often either be incinerated or put into landfill where they will inevitably end up in nature. The paprika panel tells this story, unfortunately this also means that this panel is not 100% degradeable.
MKI: 3,30
Carbon stored: 16,02 kg CO2

ECOCOCON & STRO-TEC

Ecococon and stro-tec have developed an outer, structural wall made of timber and pressed straw. The straw functions as insulation material while the wood creates the structure while also keeping the straw compact. The prefab panels are fully damp-open and made without any chemicals and are 98% regenerative. The panels are 300-400mm in width and have a U-value of 0.12 W/m2K. The MKI of one square meter is currently 3,22. This is mainly due to the transportation of materials to Lithuania, where the panels are currently produced. Stro-tec and Ecococon are looking to open a factory in the Netherlands as well.
MKI/m2: €3,22
Carbon stored: 94,42 kg CO2



Rik Makes: applicable as interior wall cladding or partition wall



ECOCOCON: applicable as construction and insulation material in one

Lessons learned from the Floriade Expo

In a report by the buyer group, several lessons were noted relating to the floriade pavilion. These are quoted here and form a basis for the use of some of these materials in the design in Midden-Delfland (Buyer Group, 2022).

- Biobased wall panels are promising, a lot of research and design is currently focused around the manufacturing of these panels and should be watched closely

- Scalability remains an issue for most of the biobased materials. Mainly straw, flax and wood are currently in the scaling phase.

- The applicability of the panels remains a hard task since these panels are often expensive and relatively new. It is therefore applicable in interiors since margins are larger and flexibility in relation to the law is wider.


THE
NATURAL
PAVILION

How can architecture reduce the operational emissions of dwellings?

According to the Eurostat (2023), within the EU, the heating and cooling of buidings accounts for 50% of the final energy consumption.
Buildings consume energy for heating, cooling, interior ventilation, domestic hot water (DHW) production, lighting appliances, electrical equipment, people transport, and cooking (Casini, 2016).

The sustainability of this energy consumption is directly related to the energy mix that is used for buildings. Currently, 18% of the total energy demand is created with renewable energy and 75% originates from the use of fossil fuels. In colder climates space heating accounts for more than 80% of heating and cooling consumption, while in warmer climates space cooling accounts for most of the energy consumption. 45% Of this energy for heating and cooling originates from the residential sector, highlighting that proper housing and system design has the opportunity to greatly reduce energy demands in the EU.

Several frameworks have been developed to tackle this problem, an interesting research that touches on a lot of scale has been developed by Casini in 2016, this chapter continues by discussing his proposed framework.

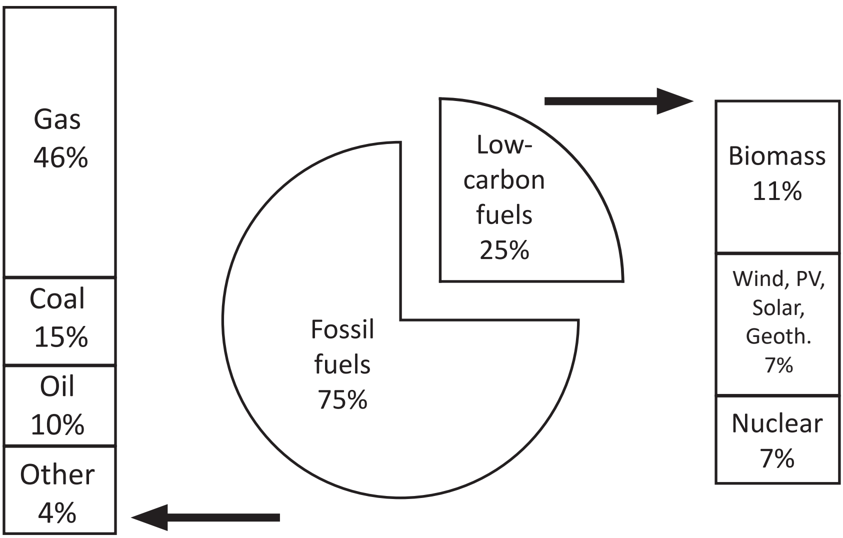


Fig 9: Total energy consumption of built environment in EU-countries (Eurostat, 2023)

In his research Casini (2016) appoints to 4 areas that could help minimise the operational emissions of a building:

AREA 1 The first area relates to the typology of a building: the buildings shape, orientation, positioning and sizing and, the distribution of inner spaces to optimise the environmental context and facilitate aspects such as solar gain, natural daylight and ventilation, acoustic comfort, and reduced consumption of resources.

AREA 2 The second area focuses on the building envelope. This is related to the thermal performance of materials within the building systems that could improve the energy and environmental performance of the buliding. This step also relates to the life cycle of materials.

AREA 3 The third area aims to achieve maximum efficiency of mechanichal systems and equipments, the integration of renewable energy sources and their relationship to the grid. Furthermore, it introduces climate regulation techniques to optimize energy management and microclimates.

AREA 4 The last research area regards the behavior of the user and the opportunities to reduce energy waste.

These four areas form the guidelines for this research on the reduction of operational emissions of dwellings and create the structure of this theoretical chapter.

AREA 1: typology

In his research Casini has created a framework with attention points that could minimise the operational emissions of a dwelling (figure 8). It provides a guideline to design principles that could minimise the operational emissions by proper use of context. This Metric is used to further develop the typology suiteable for Midden-Delfland.

His objective is “to mediate between shape, function and efficiency to achieve the highest “building quality”. In its modern meaning of formal-spatial, techological, technical, environmental, maintenance, operational and useful quality: “form follows sustainabiliy””

The design choices in his metric focus on the optimisation of ratio between dispersing surfaces and heated volumes of a building, orientation to maximise winter solar gain, the architecture should reduce heat gain during summer and enhance heat gain during winter and a choice of solutions that improve the microclimate.

Climate parameters	Monitoring parameters	Design choices	Design objectives
Air temperature	Daily and monthly average temperature Monthly average of minimum and maximum daily temperatures Degree days	Building form factor and orientation Room distribution Building envelope thermal resistance Shading systems Mechanical equipment sizing Outdoor space characterization	Thermohygrometric comfort Reduction of energy consumption
Wind	Prevailing direction sector for each month Average speed of prevailing wind (m/s) Presence in prevailing sector (%) Wind calm (%) Average monthly wind speed (m/s)	Building form factor and orientation Room distribution Size and position of openings Building envelope thermal resistance Renewable energy sources Noise and pollution barriers	Thermohygrometric, physiologic, respiratory/ smell comfort Exploitation of renewable energy sources and reduction of energy consumption Structure cost reduction
Humidity	Monthly average of minimum and maximum relative humidity	Thermohygrometric characteristics of building envelope (humidity condensation) Ventilation needs Mechanical equipment sizing Outdoor spaces	Thermohygrometric, physiologic, respiratory/ smell comfort Structure maintenance
Rain	Annual and monthly rainfall average Average distribution of rainy days, days when soil is covered by snow, thick fog days, stormy days, and dry days	Roof type and inclination, rainwater harvesting and disposal, choice of vegetation	Rainwater recovery and reduction of water consumption Correct disposal of waste water Vegetation management
Sun path	Available sun hours over course of a year for each elevation orientation and roof Radiation energy related to sunshine hours affecting building Ratios with external air temperature Sun ray penetration into interior spaces	Building ground plan and orientation Sizing, orientation, and position of glazed surfaces and shading systems Inclination of sun-collecting surfaces Room distribution Thermal inertia of building envelope	Improvement of hygienic and thermohygrometric well-being Reduction of building energy consumption Exploitation of available solar energy via passive and active systems
Sky conditions	Monthly average of fair weather, overcast, and cloudy days	Sizing, orientation, and position of glazed surfaces and shading systems Average reflecting factor of indoor surfaces	Improvement of visual comfort conditions Reduction of building energy consumption

Fig 10: Framework for minimisation of operational emissions as posed by Casini

AREA 2: building envelope

Design choices at the level of the building envelope concern the following:

“- High levels of insulation in walls, roofs, and floors to reduce heat losses in cold climates, optimised using life-cycle cost assessment

- High levels of thermal inertia and highly reflective surfaces in roofs and walls to reduce summer overheating in hot climates

- High-performance windows with low thermal transmittance and climate appropriate solar heat-gain coefficent, solar shading systems for correct solar use

- Properly sealed structures with low air infiltration rates with controlled ventilation for fresh air (air sealing alone can reduce the need for heatin by 20-30%)

- minimalisation of thermal bridges” (Casini, 2016)

In his research, he appoints to several high techonology solutions, unfortunately most of these solutions require depletable materials or unsustainable manufacturing processes. Relating the development of architecture free from all unsustainable systems Casini suggest building envelope solutions integrated with the operation of mechancial equipment such as transpired solar collectors, ventilated walls, double glazed skin facades & passive solar systems. Several of these passive systems will be mentioned in the contextualisation.

AREA 3:

The third area focuses on the different appliances that could assist in changing the primary energy source for buildings. Within this area economic viability, architectural integration possibilities and overall reduction dictate a grounded choice. Casini suggests the following attention to the solutions:

- The method of heat and electiricy production and th exploitation of renewable nergy sources.

- High energy efficiency, with a particular reference to heat pumps for space heating, cooling and hot water production.

- Thermal storage, latent storage and thermochemical storage

- Electricity storage systems

- Hybrid natural cooling systems like ventilated air through ground pits, air exchange, water and night sky radiative cooling

- Highly efficient appliances

AREA 4: behavioural

Within this chapter, Casini highlights the importance of reduction in behavioural patterns. He states that inclusion and engagement into the processes that relate to energy efficiency or demand response have the possibilities to change consumer patterns.

In this section instruction, shared responsibility and insights of energy systems are put forward as most promising methods of changing consumer patterns. The last years smart appliances and infrastructures have been the main contributor to enhancing insights on energy consumption. These appliances are less architectural and require intricate technical systems that require energy consumption in the production phase.

The main solution that is low-tech in Casini's work focuses around the sharing and managing of local energy storage systems. Several examples will be put into a framework and will be elaborated on later in this report

- *What present energy storage systems relate to the built environment?*

Energy in the built environment of cold climates mainly revolves around heat and electricity. Wind and sun are locally available, renewable energy sources in Midden Delfland (fig. 11). Unfortunately, these are variable energy sources, meaning that some times they perform well and other times they don't perform. It is therefore imperative to look for a sustainable energy storage solution to prevent cold or darkness when using the dwelling.

In the research of Walsweer (2019), represented in figure 12, 6 types of energy storage are distinguished: mechanical storage, electromagnetic storage, biological storage, elektrochemical storage, chemical storage & thermal storage. Conventional methods in the built environment often revolves around the use of thermal storage as well as chemical storage. These methods require high initial material inputs and are therefore disregarded in this research. Furthermore, biological energy storage relates to processes in plants or animals which are very intricate and not applicable to the building scale.

The more interesting storage forms are mechanical storage and thermal storage. The following pages will provide information on considerations that should be made in order to properly manage these storage systems. Finally the salt water battery is discussed.

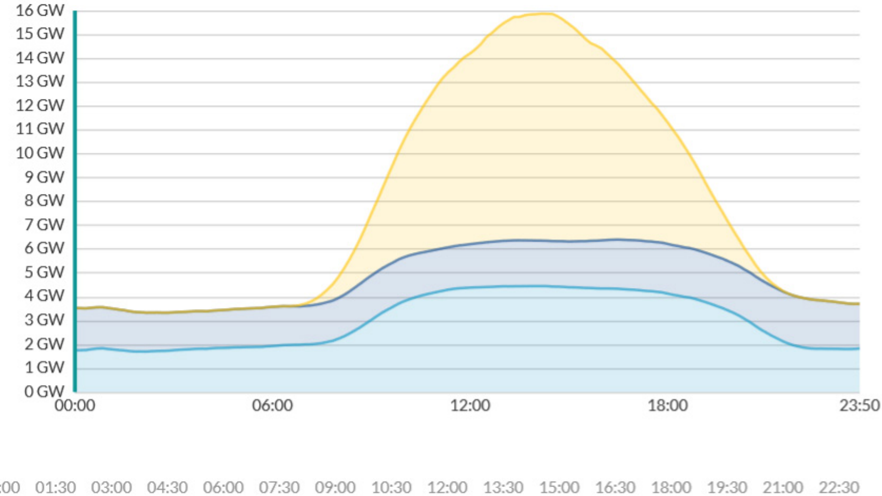


Fig 11: renewable energy income on a sunny day in the Netherlands (Energieopwek.nl, 2024)

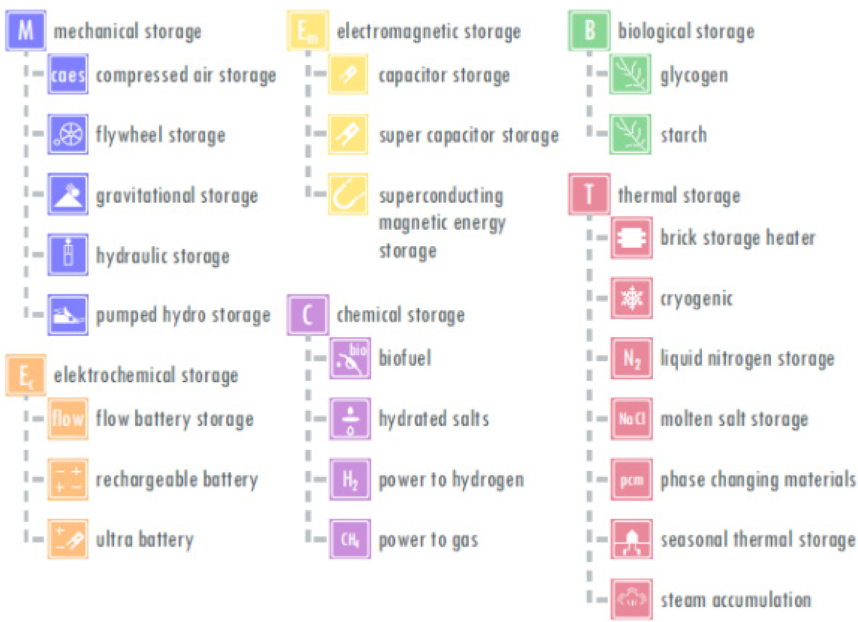


Fig 12: Energy storage systems (Walsweer, 2019)

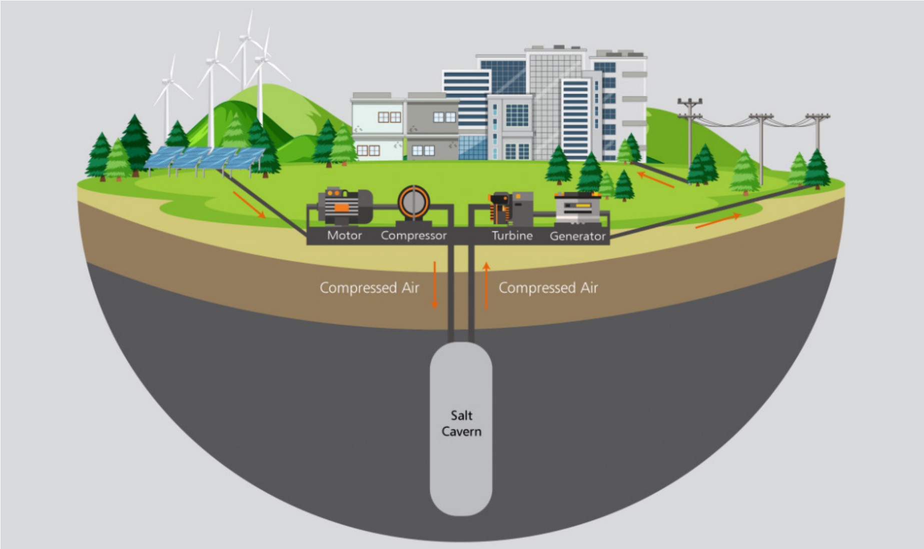


Fig 13: Large scale CAES

Fig 14: Small scale CAES

Mechanical storage systems

Within the mechanical storage systems, three systems bear potential for the built environment, compressed air storage, flywheel storage & pumped hydro storage. It is important to note that for all these energy systems new materials need to be used, resulting in less total sustainable material usage within a dwelling. They are mentioned however because thermal energy storage can't generate electricity and therefore lacks to provide a (however small in comparison to the heat demand) percentage of the energy demand. Furthermore, when these mechanical storage systems are properly used they can withstand long life-cycles and have the possibility to store energy for more than one dwelling.

Compressed air energy storage systems (CAES) are the first of the three systems with potential. CAES systems generally are regarded as large-scale energy storage solutions. The system relies on the use of a surplus of electricity to pump air to lower space (figure 13 uses a salt cavern), the air is compressed in this space and released along a turbine to generate electricity when the demand outwheighs the supply. This principle is also downscaled to a residential scale (Castellani et al., 2018). In the research of castellani et al, two simulations are performed. These simulations show that on an average summer day, the compression phase (surplus of energy) is able to absorb 32% of the PV energy excess in a vessel of 1.7 cubic meters and that the expansion phase covers 21.9% of the dwelling energy demand. The second simulation compressed air at 225 bar instead of 30 bar, this results in 96% of PV energy excess being stored in a volume of 0.25 cubic meters, with a total production of 1273 kWh yearly.

1273 kWh is around 50% of the annual electricity demand of a Dutch home (Milieucentraal, 2024). In comparison to a conventional battery, which is able to provide 100% of the energy demand of a home, the CAES system is less efficient, yet according to Castellani et al., residential batteries have a lifetime of 5 years whereas a CAES system could run for more than 20 years if properly maintained. It could therefore prove to be an interesting, future, energy storage solution.

Another mechanical storage system would be the flywheel system. A promising example is the LEFt, or Leftover Energy Flywheel Technology designed by Amstel Engineering. This system converts electricity to mechanical energy by spinning a high mass steel block. The principle of flywheel technology is to use the inertia of the high mass steel as carrier of the potential energy. This system has been compared to a Tesla Powerwall system by Stefan Lorist. Unfortunately the LCA showed less promising results due to the great amount of steel needed in the LEFt module. Although less sustainable in ecological footprint, it is important to mention that this system does not rely on rare materials such as cobalt or lithium that are often harvested in countries with political issues where the process management often lacks (Lorist, 2019).

Fig. 15: LEFt flywheel system

Fig. 16: Goudemand residence before PHES

Fig. 17: PHES system of the Goudemand residence

The final mechanical storage system would be the pumped hydro storage system. This system is also mainly used in the larger scales, mainly in mountainous areas, yet are also sometimes used for small scale energy storage on a residential scale (De Oliveira E Silva & Hendrick, 2016).
In this system the surplus of energy is used to pump water to a higher level, letting it fall down along a turbine when energy is demanded. A striking example of this is the Goudemand residence in Arras, France. The 30m building has several PV panels and windturbines on its roof, which charge a lead-acid battery, when the battery charge is insufficient the water on top of the building starts to flow along a turbine to a resevoir in the cellars. The research concludes that in its own the PHES system in buildings is technically feasible, however not economically competitive when compared to other small scale energy storage systems (De Oliveira E Silva & Hendrick, 2016). Synergies however, like a combined PHES system that also provides drinkable water, could prove to be economically competetive, yet the literature regarding this topic currently lacks.
In context of the design task in Midden-Delfand PHES is not feasible as the height according to the masterplan cannot exceed two stories. The PHES system is however mentioned as possiblity for a synergy with local water harvest. Furthermore, recent research indicates that PHES could also be done in the Netherlands, mainly in the ground by using aquifers as lower bassin.

Thermal energy storage

Thermal energy storage can be done both passively as well as actively. Passive thermal energy storage often relates to the thermal conductivity and absorptivity of materials. Relating to the design brief this issues a thorough mapping of the proposed biobased & re-used materials and their energy storage capacity in order to minimise heating and cooling demand.

Active thermal energy storage requires a grid connection as back-up. One of the most commonly used systems is the heat pump. Commonly used in net zero energy buildings (NZEB), this system stores heat in a very well insulated storage tank filled with water or air. The system is often used in combination with a heat exchanger, a device that captures leftover heat from air exhausts (Hepbali & Kalinci, 2008).

Another interesting system is underground energy storage (Fig. 19). Two storage tanks are placed at a depth of 90m, a cold water tank and a hot water tank. The demand for cooling or heating determines what is pumped up and what is pumped down. This system requires big digging operations that can’t be performed sustainably in the Productive Park Midden-Delfland, yet it is an economically viable and efficient solution to heat storage (WUR, 2024).

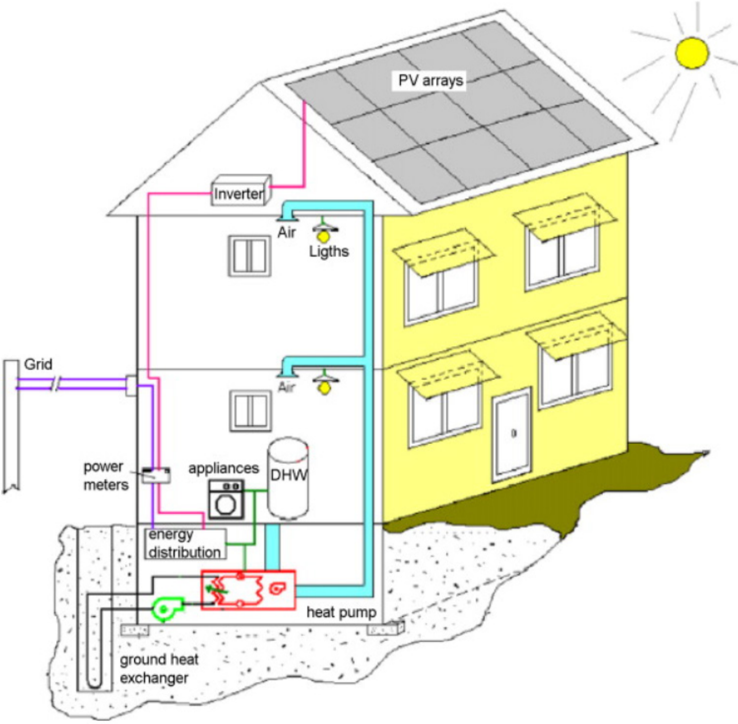


Fig. 18: Heat pump system (Hepbasli & Kalinci, 2008)

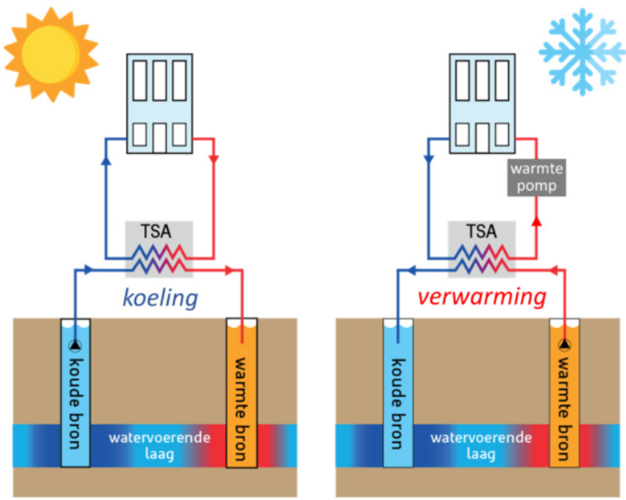


Fig. 19: Underground thermal storage system (WUR, 2024)

GreenRock salt water battery

The GreenRock salt water battery is a newly developed, modular, non-flammable, non toxic, battery solution. The system consists of a central box (90x45x90 cm) that is connected to several modules of 2.5 kWh (45x45x96 cm). The home version consists of these 2.5 kWh modules that can be linked till a maximum of 30 kWh is achieved. The greenrock salt water battery is, albeith self-proclaimed, currently the most environmental battery in the world. A downside of this battery is the size and weight of the system, a module for one dwelling quickly becomes the size of a laundry machine. Specifically, the space needed for the batteries is 2.19 m3 per 24 kWh battery stack and 0.73 m3 for the DC installation box per 24 kWh. The overall efficiency of charging and discharging the battery is 90%, while the self-discharge of the battery equals 0.01% per hour. (Brinkhof & ESRIG, 2019)

It is, therefore, hard to introduce this system in the current built environment. It does however provide potential when constructing new dwellings as the space necessary can be taken into account in early design stages.

ThuisbatterijNederland.nl

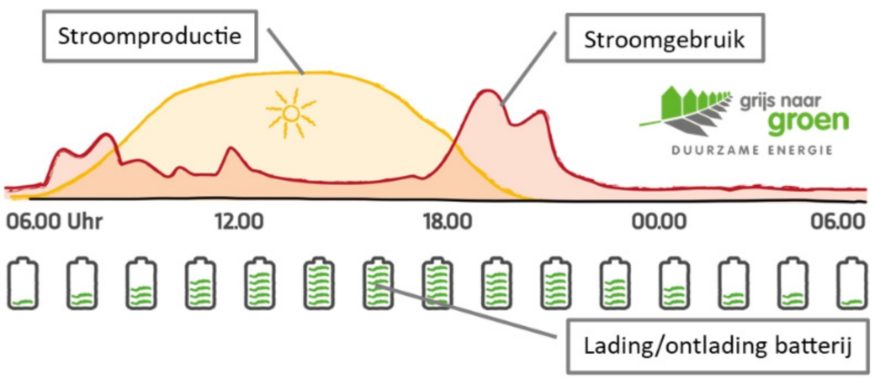


Fig. 19: Greenrock battery & electricity use/harvest + store/release diagram

- What architectural elements have been built that relate to the reduction of operational emissions in dwellings?

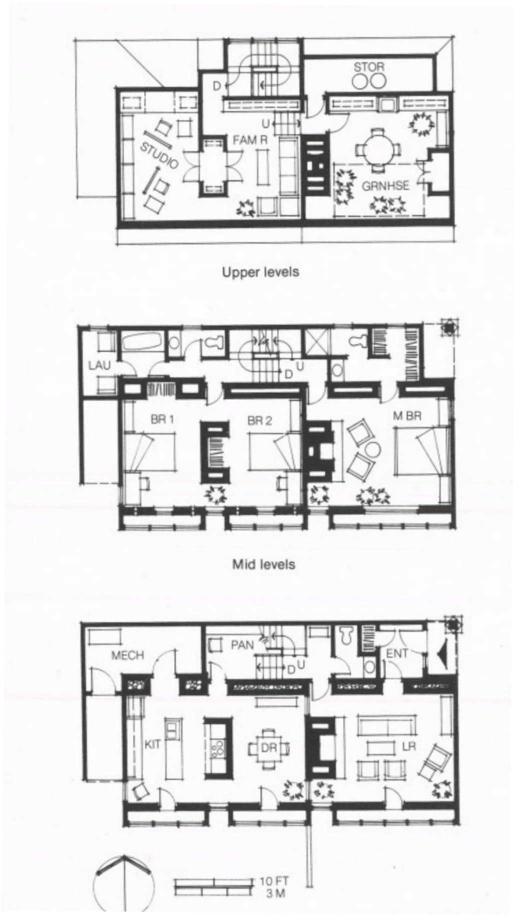
Throughout architecture many precedents have focused around minimising operational emissions. This chapter highlights several typologies that harbor low-tech, architectural solutions to energy management relating to a cold climate. It focuses therefore on principles that harvest heat since this is the main contributor to the operational emissions of a dwelling.

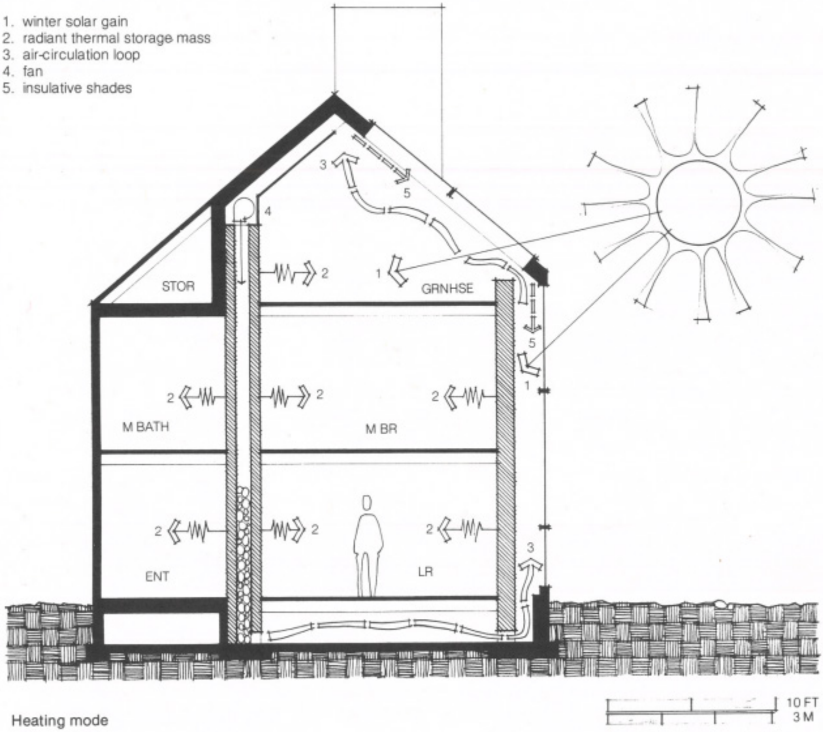
The typologies are not evaluated along their thermal performance but form a digital database of different architectural solutions relating heat gain. In 'Solar Architecture in Cool Climates' by Porteus they distinguish two solar gain systems: direct systems and indirect systems. Direct systems focus on the generation of heat through direct solar gain in living spaces, whereas indirect systems use a medium, like air, water or thermal mass, to transfer heat. Since some of the investigated typologies use both of these systems simultaneously the hybrid solar gain system is also introduced in this system.

Roberts Residence (Sundance): Reston, Virginia

This house is described by the archtitect as “a house within a house”. This design an indirect solar gain example. The sun warms a south oriented, small space that radiates heat into the living spaces. The solar heated air is directed ,from the green house to inbetween a centered wall, by a fan. Resulting in solar radiation heat from two sides in most of the main living spaces, while providing one wall with radiant heat in the lesser heated areas. Proper positioning of living spaces in relation to orientation is also visible in this example.

example taken from the book Passive solar architecture: logic and beauty: 35 outstanding houses across the United States by D. Wright & D.A. Andrejko



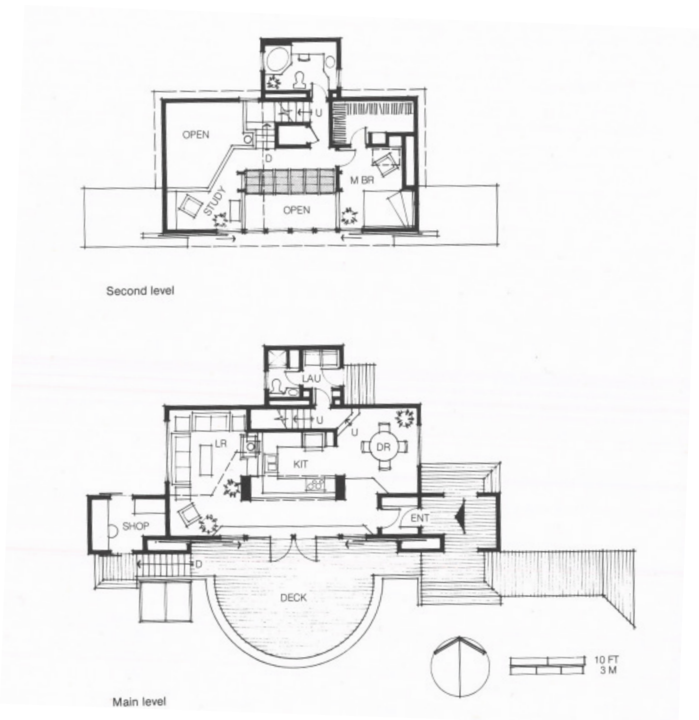


Heating mode

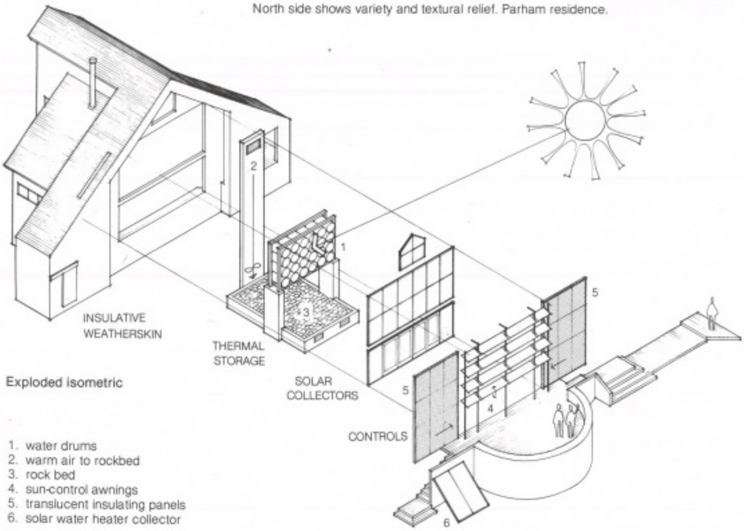
Parham Residence: Randleman, North Carolina

The Parham Residence makes use of the thermal properties of water to store heat in, what is called, a drum wall. The drums in this system are made of steel and are painted black in order to achieve the highest possible conduction of solar heat to the water. The sun only shines on one side of the drums this is the hot side of the drum wall. In the other side of the drums cold water resides, this creates a convection stream, ensuring that the water cycles and provides heat where necessary. The level of heat can be controlled through external shading systems. This system revolves around indirect solar gain

example taken from the book Passive solar architecture: logic and beauty: 35 outstanding houses across the United States by D. Wright & D.A. Andrejko



North side shows variety and textural relief. Parham residence.



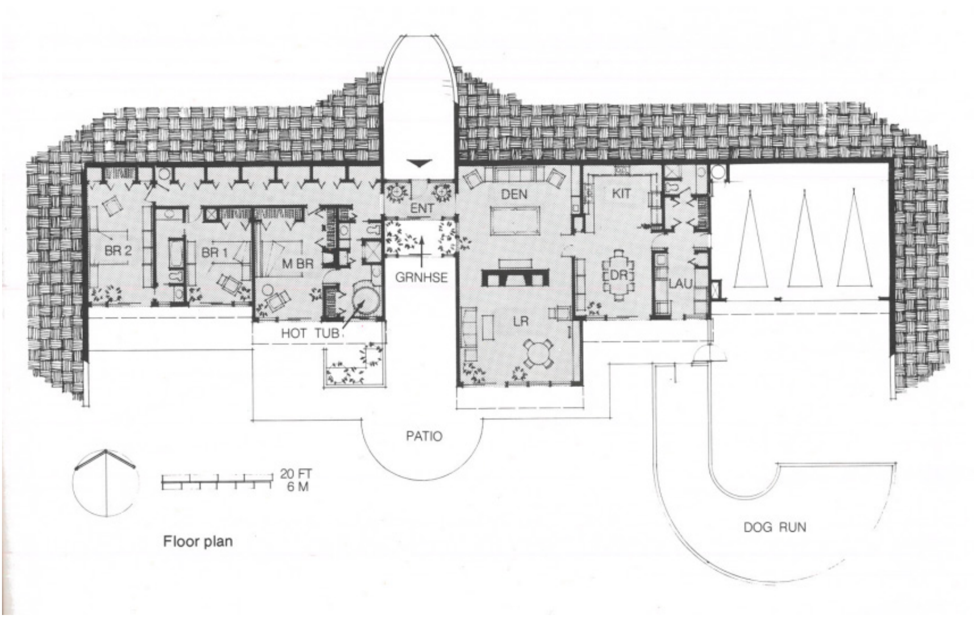
Exploded isometric

1. water drums
2. warm air to rockbed
3. rock bed
4. sun-control awnings
5. translucent insulating panels
6. solar water heater collector

Walker Residence: Springfield Missouri

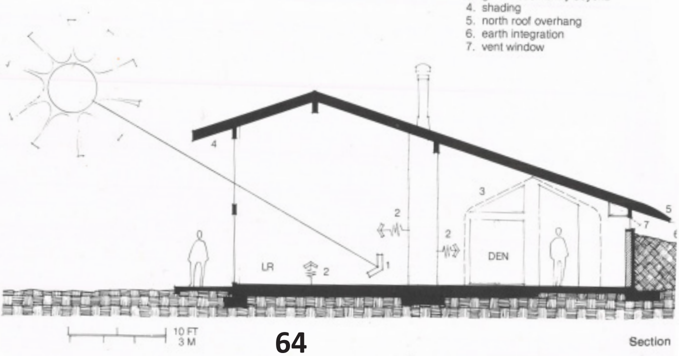
The Walker residence in Springfield Missouri harnesses the winter sun and shades the summer sun by effective use of roof shading. The solar gain in winter is enhanced by properly using material properties (the black stone slate covered fireplace stores most of the heat, while also functioning as back up heating system). This system makes use of direct solar gain.

example taken from the book Passive solar architecture: logic and beauty: 35 outstanding houses across the United States by D. Wright & D.A. Andrejko



Slate-covered fireplace stores heat and provides backup for passive solar heating. Walker residence.

1. winter solar gain
2. radiant thermal storage area
3. greenhouse entry beyond
4. shading
5. north roof overhang
6. earth integration
7. vent window

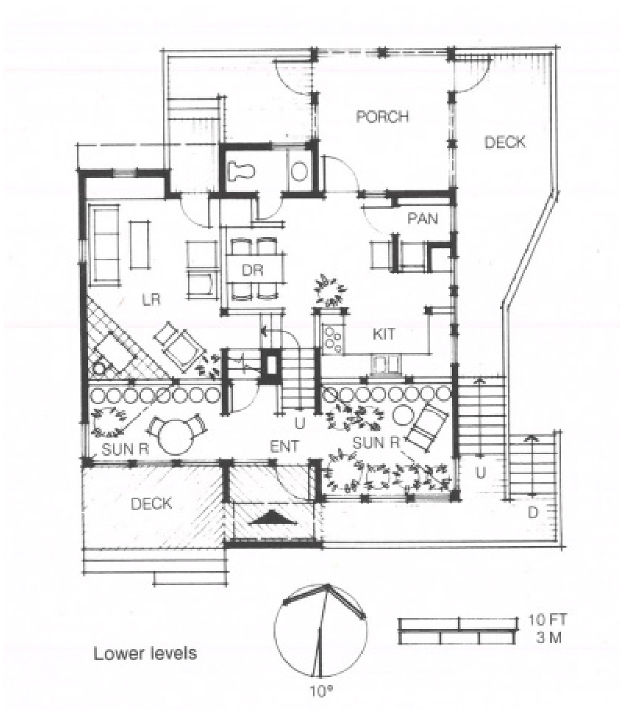


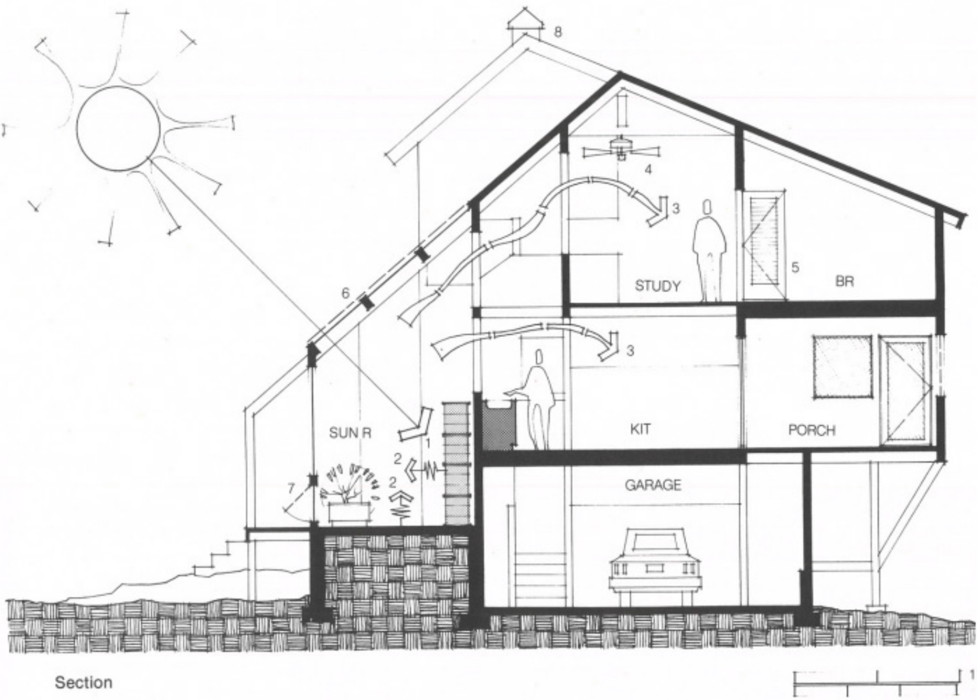
Section

Meachem Residence: Raleigh, North Carolina

The Meachem residence also makes use of indirect solar gain through the effective use of bufferzones, in this case greenhouses. Furthermore, when looking at the crossection it becomes clear that the greenhouse is connected to almost all spaces of the house ensuring proper heat dissipation.

example taken from the book Passive solar architecture: logic and beauty: 35 outstanding houses across the United States by D. Wright & D.A. Andrejko



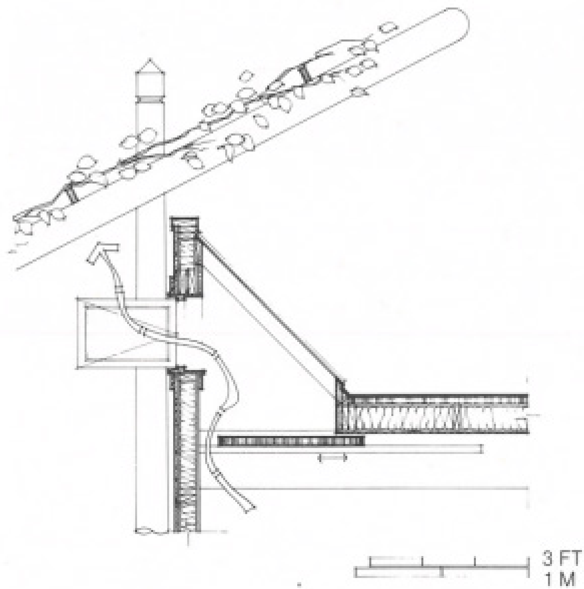


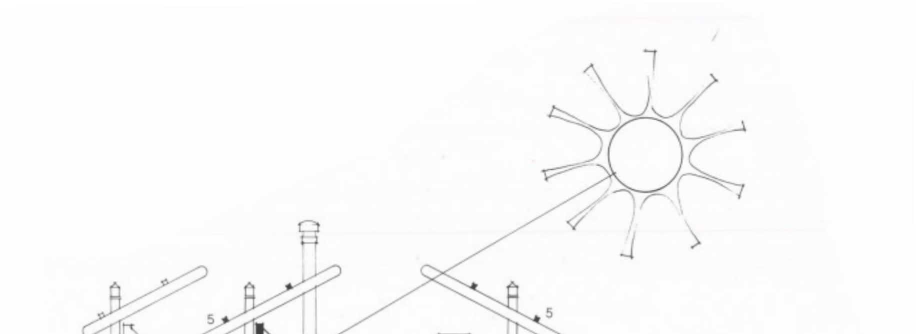
Section

Abramson Residence: Sacramento, California

The self-made Abramson Residence was built in an area that sometimes has floods. The house is therefore entirely lifted. Other than the architectural considerations such as sun paths and shape, this architect also makes smart use of biodiversity. The plants growing on the disconnected construction use their leaves to shade the windows during summer time, while the absence of their leaves makes sure that during winter time solar gain is optimalised.

example taken from the book Passive solar architecture: logic and beauty: 35 outstanding houses across the United States by D. Wright & D.A. Andrejko

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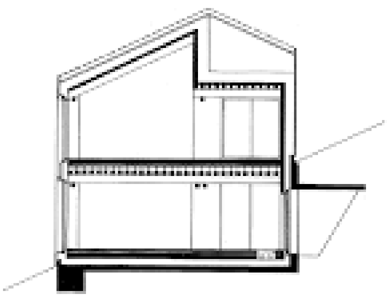
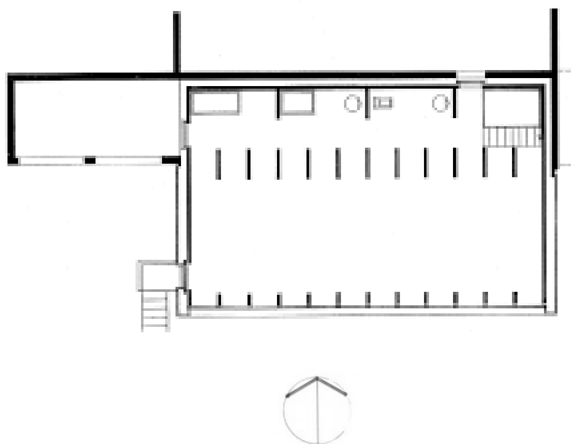
3 M

Nullheizenergie Häuser: Trin, Suisse

The Nullheizenergie häuser by Andrea Ruedi is fully powered by solar energy and uses no heating system. The house was constructed to investigate the heat absorbing qualities of materials. The result are these two reductionist houses in Suisse. Wood ensures thermal breakage while the concrete blocks create the thermal mass. Operable windows regulate the temperature during summer, yet when winter this house is bound to several restrictions. The house has no window drapes, these are prohibited, Furthermore, the floors can only be covered for 30 to 40% with furniture, tapestries or other interior pieces and, in winter ventilation can only be done short and intensively. When following these strict guidelines the interior temperature only lowers by 2 degrees in 5 days of cloudy, winter.

example taken from the book Passive solar heating in built environment by R. Hastings, 2012

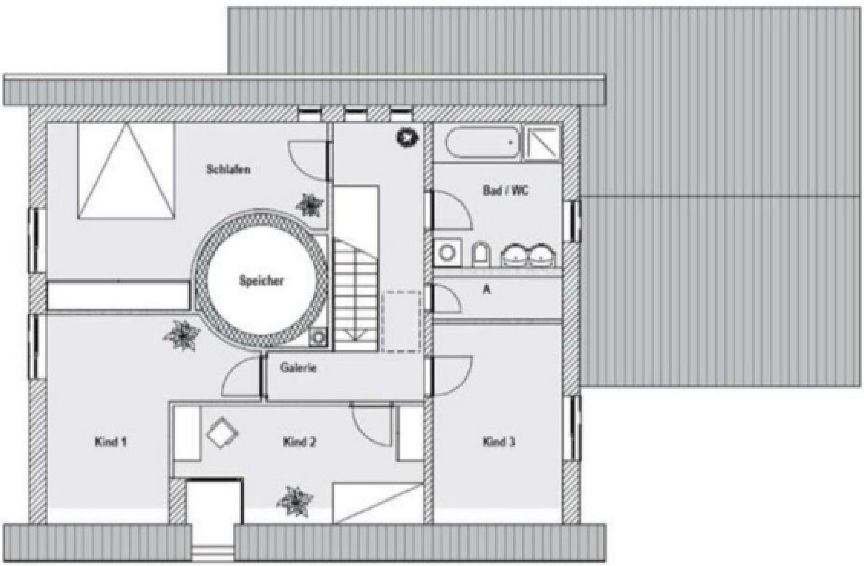




Das Aktiv-Sonnenhaus: Regensburg, Germany

Das Aktiv-Sonnenhaus in Regensburg is an example of a ZEB concept, a zero energy building concept. The 110 square meter solar thermal collectors heat up an architecturally integrated water tank in the center of the house. This 38.500L water tank provides all water and heating demands. The initial, high, environmental costs are slowly compensated by a fully sustained heating demand.

example taken from the book Overview of Building Integrated Solar Thermal Systems State of the Art, Models and Applications by L. Aelenei (2015)



Is self sufficiency in watermanagement a sustainable solution for a dwelling in Midden-Delfland, Netherlands?

A dutch person uses an average of 129L of water on a daily basis with most of the water from which we drink only 2.6L while more than half is being used for the toilet and shower (fig. 20). The water in the toilet and shower is initially blue, fresh, drinkable water, yet when we are done it is contaminated and reduced to what we call grey (shower) water and black (toilet) water. Taking a closer look at the graph of CBS (Bakker et al.,2022) it becomes clear that an average dwelling uses water for two purposes: as consumption, either for plants, animals or humans and as a carrier of dirty goods for transportation to centralised sewage treatment plants. The dirt-carrying character of water in a dwelling greatly outweighs the nutritional character in terms of proportion. The relation between water and the inhabitant of a dwelling is experienced as a linear relationship. The inhabitant opens a valve, drinks or contaminates the water and the water flows away, to be treated out of sight of the inhabitant.

The treatment of this contaminated water is done in the Dutch Sewage Treatment Plants, which also tend to have numerous problems (Bijleveld, 2003). A first issue is the costs of the national sewage system. Maintenance of the sewer systems is a high expenditure and costs municipalities in the netherlands 1.8 Billion euro's on a total budget of 68 billion euro, this is especially a problem in the areas of the Netherlands with softer soil conditions, because of saggin of the system. Furthermore, the costs for proper infrastructure aren't taken into account in this percentage. A second issue occurs during heavy rainfall. The sewage system is not able to handle the surplus of wastewater. This has to be bypassed into surface waters and, as rainwater, grey water & black water are all transported through the same system, this overflow causes surface water pollution.

	P (%)	F (x per dag)	Duur (in min)	C (l per minuut)	C (l per keer)	Hoeveelheid (liter/dag)
Bad totaal						5,3
Bad	42	0,09	10,3	13,9	142,4	5,2
Kinderbadje	5	0,12			20,2	0,1
Douche totaal	99	0,82	7,4	7,7	56,9	46,2
Gewoon	49	0,73	7,8	7,8	60,7	21,6
Waterbesparend	39	0,75	7,1	6,3	44,6	13,1
Regendouche	24	0,6	7	10,3	72,5	10,4
Massagedouche	2	0,3	5,9	13,6	79,6	0,5
Combinatie	12	0,06	8,6	8,7	74,8	0,5
Anders	0	0,44	6,2	10,3	63,2	0,1
Toilet	100					30,2
Volledig	100	2,93			6,7	19,7
Gedeeltelijk	78	3,65			3,7	10,5
Afwas						3,9
Vaatwasser	76	0,33			11,7	2,9
Afwas met hand		0,21			5	1,0
Was						17,5
Wasmachine	98	0,35			48,9	16,9
Handwas		0,02			32,3	0,6
Consumptie						2,6
Kopje		4,62			0,2	1,1
Kleine pan		0,59			1	0,6
Middelgrote pan		0,24			2,5	0,6
Grote pan		0,06			4,6	0,3
Buitengebruik						0,9
Kleine emmer	87	0,07			1,5	0,1
Middelgrote	87	0,03			5,1	0,1
Grote emmer	87	0,04			11,7	0,4
Kraan buitengebruik	75	0,00	49,5	5,9	289,3	0,4
Wastafel		1,89			4,6	8,7
Overig watergebruik						12,8
Schoonmaken binnenshuis		0,41			4,1	1,7
Planten binnenshuis		0,17			4,6	0,8
Huisdieren		0,17			3,6	0,6
Handen wassen		4,37			2,1	9,2
Andere activiteit		0,36			1,4	0,5

Fig. 20: Water use per person, per component, in the Netherlands, (Bakker et al., 2022)

- *What are the spatial requirements and necessities for harvesting drink-water in Midden-Delfland?*

In order to disconnect from the dutch watersystem it is important to first develop knowledge on the requirements and possibilites for the local harvest of drinkwater in Midden-Delfland. Water is harvestable from three ‘layers’ of the earth, the sky, the surface and beneith the surface. The University of Wageningen has recently discovered that the quality of the surface water of the Netherlands is the worst of all Europe (2023). This is therefore not researched in this chapter as it requires very proper treatment. Several possibilities for harvest in the other two ‘layers’ will be discussed in this chapter.

The sky

When looking at the sky for rainwater harvesting possiblities the first obvious source is rainwater. A second source of water is the humidity in the air. An important side note here is that both of these sources fluctuate in supply. During winter times the air is often much drier than in the summer and rain does not always fall. Storagetanks are therefore a necessity when harvesting drinkwater from the sky.

A rainwater harvesting systems consists of several elements, a surface area for harvesting, a gutter, pipes, a first flush, and a storage tank (fig 22). The first-flush system ensures that the first two milimeter of rainfall is disconnected from the waterharvesting system to minimise pollution from the roof. Its size is therefore directly related to the surface area of the roof. In order to first flush a roof of one square meter, a bottle of 2L is required to flush away the first rainfall. This water can be directly flushed away into the soil. The remaining rainfall is stored in the waterstorage tank where it is possibly purified and sent to the demand locations of the house.

The literature highlights that the quality of rainwater is in all cases highly dependend on the origin of the water. African rainwater often times contains higher pollutants than water from the European regions (Farreny et al., 2011). Furthermore, research indicates that the roofmaterial also influences the level of pollution in the water storage tank, not specifically due to material pollutants but more from the level of roughness of the roof as bacterias and mosses grow in the crevices that the roughness creates (Lee et al., 2012). The research of Farreny et al., concludes that after a first flush all water is suitable to drink. In the netherlands legislation prohibits the use of rainwater for anything else than drinking, so for architecural systems this is currently not possible in the Netherlands.

Nevertheless off-grid sanitation systems are plentiful (Helmreich & Horn, 2009). The most common and easy solution is chlorination, with either tablets or liquids. An acceptable amount is 0.4-0.5 mg/L. Another, low-tech and cheap solution is slow sand filtration. This relies on biological treatment rather than physical filtration processes. The filter consists of several carefully graded layers of sand, going from coarsest at the top to finest at the base. This system requires a constant flow of water through the filters. Another solution would be to pasteurise the water with heat of the sun (Fig. 21), this kills most of the infectants, yet when the solids in the water exceed 10 mg/L, extra filtration is necessary. The final solution is to use a variety of filters to extract all the bacteria and organic matter from the water. These filter systems, however, don't filter virusses and therefore often requires pasturisation.

Another consideration would be the capacity of rainwater harvesting in relation to the water usage. The roof catching system accounts for a small level of loss in shape of run off. In calculations runoffcoefficients vary between 0.7 and 0.95. Furthermore, the first flush also accounts for water losses (Bertelkamp et al., 2017). In his research Bertelkamp uses a runoff-coefficient of 0.8 and calculates that on a roof of 60 m2, 25 m3 of water is harvestable on a yearly basis, or 1.14L per square meter on a daily basis.

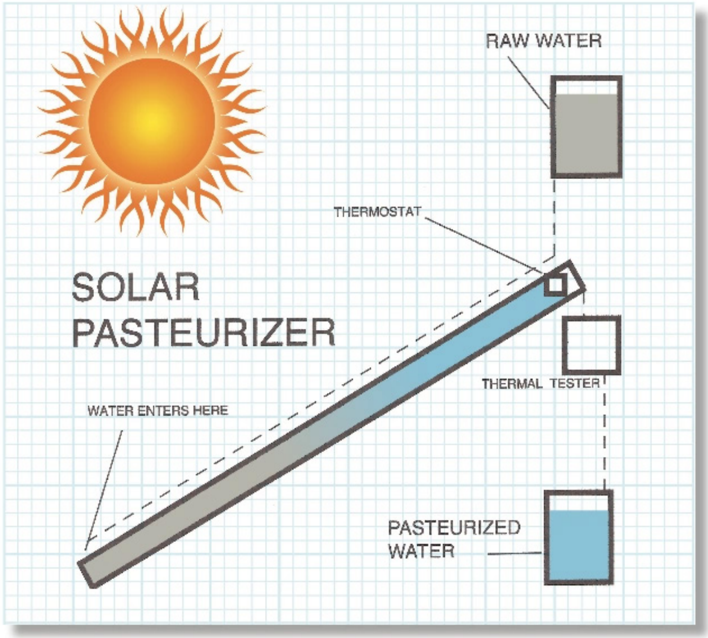


Fig. 21: Solar pasteurisation of water

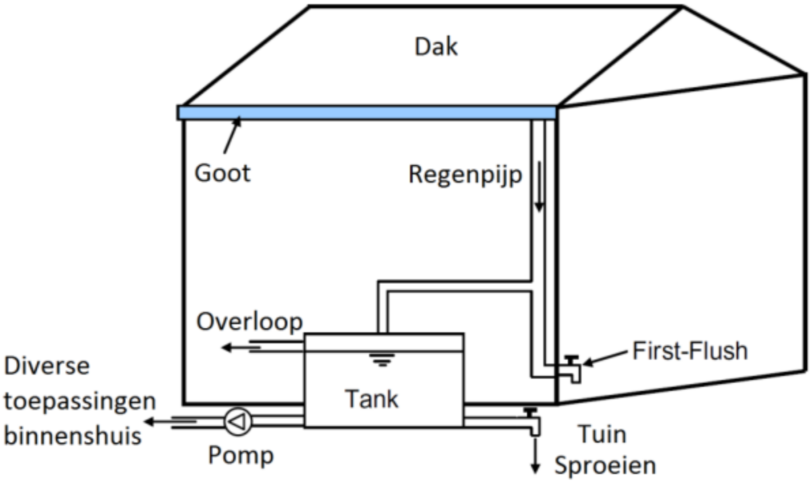


Fig. 22: Schematic representation of rainwater catching- and storage-system (Bertelkamp et al., 2017)

For an average person this would mean that they would need a total of 147 m2 of roof surface per person. The consumption of water should therefore be thoroughly assessed and minimised where possible when using rainwater. When looking at a different, more strict consumer pattern with: a watersaving shower, a dry toilet system, handwashing (both clothing as well as dishes) & no bath, the water consumption can be reduced to 60L p.p./day. This would require a total surface area of 68 square meter per person.

The second method for water harvesting would be to harvest from humidity. An interesting example that catches morning dew is the Warka Water catching system (fig 23.). This system relies on catching dew through a system of ropes that catch and trickle down the morning dew in humid climates. The caught water is directly drinkable and therefore could provide an interesting water harvesting sytem. The main constraint in this example is space and the possibilities of pollution of the structure by birds or other animals.

The ground

Decentralised groundwater harvesting is a viable and economical solution to the water demand of a dwelling. Two types of groundwater harvesting are found in the netherlands, surface water pump systems (15-30m), which and deeper groundwater pump systems (>100m). These connect to the different water bodies in the Dutch soil. To be able to asses wether decentralised groundwater harvesting is an option, it is important to know the groundwater quality of the area. In the case of Vlietpoort Midden-Delfland it becomes clear that groundwater harvesting is not an option due to saline groundwater. In other locations in South-Holland this could provide interesting solutions.

Fig. 23: Warka Water Tower (warkawater.org, 2023)

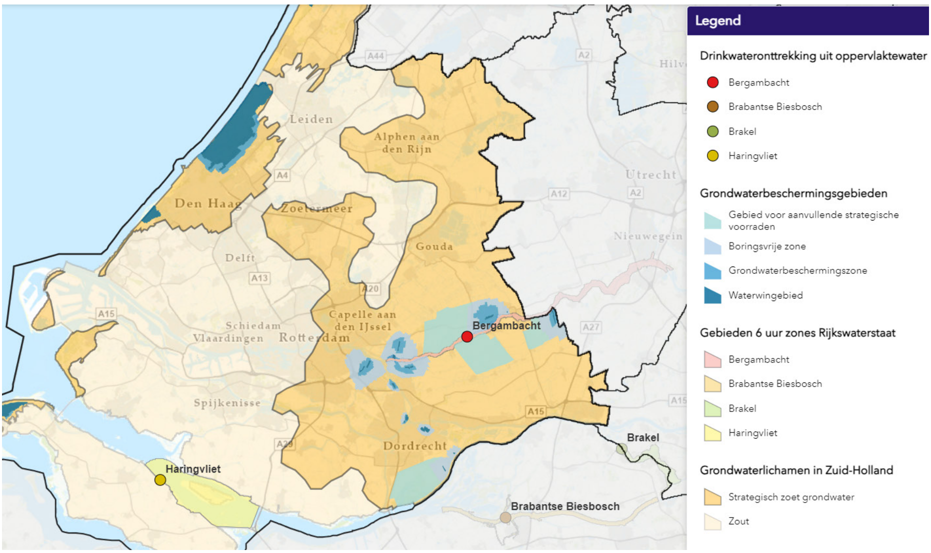


Fig. 24: Fresh water aquifers in South-Holland (Province of Zuid-Holland, 2023)

- How can feces be processed locally in Midden-Delfland?

The previous chapter indicates several issues relating to the processing of feces:

- Blue rainwater, grey shower water & black toilet water are collectively transported to water treatment plants, the quality of all water is therefore degraded to black water.
- The sewage system can overflow and contaminate surface waters.
- Toilets require 1/4th of the daily water use.
- high investment costs of infrastructure and maintenance of the current system

3 out of 4 issues are directly related to the amount of contamination that comes from the toilet system. Therefore, taking these issues into account, this chapter focuses on the different alternatives for sanitation.

Martin Bijleveld has developed a framework for comparison of different eco-toilet systems as shown in Figure 26. Looking at the table we can find two systems that do not use water and do not rely on incineration: composting sytem and the dry urine diverting system. These two systems were compared to a conventional system and to the low flush urine diverting system. From this analysis the dry urine diverting system shows the most promising results, yet a composting toilet system is a close second.

		Conven-tional	Com-posting	Vacuum	Dry urine diverting	Low flush urine diverting	Vacuum urine diverting	Inci-neration toilet
Generation & separation	Water use	X	-	X	-	X	X	-
	Separation	-	-	-	X	X	X	X
Collection	Central	X	-	(X)	-	(X)	(X)	-
	Semi-central	-	-	X	-	X	X	(X)
	Decentralised	-	X	-	X	(X)	-	X
Transfer & transport	Sewer	X	-	X	-	X	X	-
	Truck	-	(X)	-	X	X	X	X
Treatment	WWTP	X	-	(X)	-	X	(X)	(X)
	Composting	-	X	-	X	-	-	-
	Anaerobic digestion	-	-	X	-	(X)	X	-
	Incineration	-	-	-	-	-	-	X
	Separate Grey water treatment	-	X	(X)	X	(X)	(X)	X
Reuse or recycling	Urine	-	X	(X)	X	X	X	X
	Faeces	-	X	(X)	X	X	X	-
Disposal	Residual Waste	X	(X)	X	-	(X)	X	X
- = No X = Yes (X) = Possible								

Fig. 25: Summary of sanitation systems and characteristics (Bijleveld, 2003)

+ +	= Much better than the conventional scenario
+	= Better than the conventional scenario
0	= Equal to the conventional scenario
-	= Worse than the conventional scenario
- -	= Much worse than the conventional scenario

		Compost-ing	Dry urine diverting	Low flush urine diverting
Economic	Investment costs	-	-	-
	Replacement costs	+	+	- / 0
	Operational costs	+	-	-
	User costs	-	- / 0	- / 0
Environmental	Energy used	+	0 / +	-
	Materials used	+	+	-
	Water used	+ +	+ +	+
	Reuse potential	+ / + +	+ +	+
	Emissions	+ / + +	+ +	+
Functional	Flexibility	+	+ +	0 / +
	Reliability	--	-	- / 0
Socio-cultural	Social acceptance	--	-	- / 0
	Experience	--	-	- / 0
Legal	Legislation	--	-	- / 0

Fig. 26: Summary of effects compared to conventional sanitation (Bijleveld, 2003)

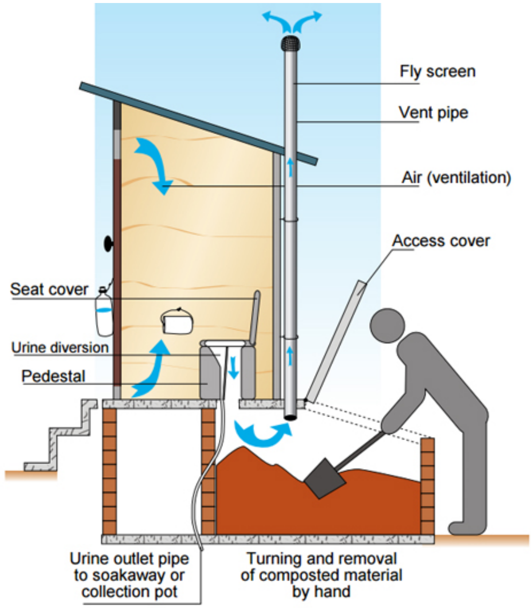


Fig. 27: Urine diverting toilet system

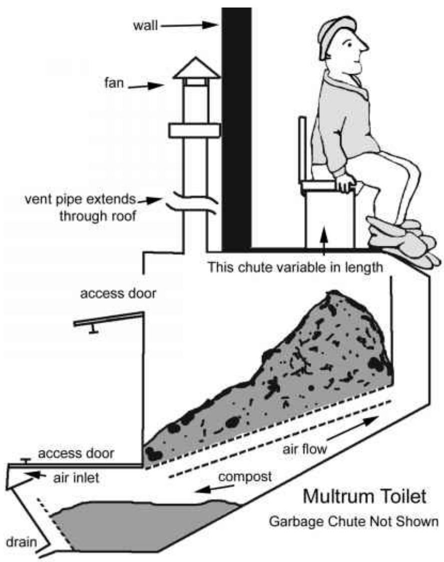


Fig. 28: Composting toilet system

Composting toilet system & Urine diverting toilet system

The composting toilet system and urine diverting toilet system are much alike as can be seen in figure 27 & 28. Both systems store the excrements in a lower tank the tanks are aerated to enhance the compostation process. The excrements dry over time and are manually taken out of the tank. This drying process requires time, therefore often two toilets are placed adjacent to each other, one empty and ready for the next user & one full and drying. The dried excrements can function as compost in both cases.

The main difference in these two systems is the separation of urine. In a urine diverting toilet system, the user separates the urine from the poop by utilising a different hole for defacation. This results in a sceptic tank that dries much faster and therefore has less problems relating to odour (Bijleveld, 2003).

A urine diverting toilet system is currently the most sustainable option for feces and urine treatment, yet it requires a heavy behavioural shift.

Helophyte filter

Another very viable ecological solution is the helophytefilter. This filter uses plants (Helophytes) that grow in anaerobic bog-like soils. These helophyte filters require a higher initial investment as well as more space than dry toilets, yet they provide the owner with a possibility of recycling their grey and black water. The helophytefilter systems come in many forms. In a sewage flowfield (vloeiveld, in Dutch), the contaminated water streams horizontally through a water body, often a ditch or a shallow pond, with helofytes, these helofytes filter the contaminated water, after which the water can be released in the surface water. Another system is the root-zone system, this system requires less space than the flow field and can be flowed through either horizontally or vertically. The vertical system performs much better, yet the horizontal variant has a much easier and cheaper set-up. This is because the vertical system need a pump that intermittently disperses the contaminated water over the plants instead of letting gravity do the work.

The processes within such filters is very much alike with processes that occur in sewage plants. Simplified, specific bacteria nest within the roots of these helophytes and react with the organic materials in the contaminated water.

Within the Netherlands, many of these helophyte filters can be observed. On the 17th of April I visited the Klimaat Expo Houten where Wetlantec stood to promote the adaptation of helophyte filters in housing projects throughout the Netherlands. Currently they have already installed more than 3000 natural filters throughout the Netherlands. Recently they have installed a 110 m2 filter for 10 households in Almere.

Type helofytenfilter	Sterk	Zwak
Horizontale doorstroming	- Eenvoudige constructie	- Verstopping leidend tot oppervlaktestroming en rendementsverlies
	- Eenvoudige bedrijfsvoering	
	- In tweetraps systeem geschikt voor denitrificatie	- Relatief groot oppervlak nodig
		- Relatief lage zuiveringsprestatie m.n. van NH_4-N.
Verticale doorstroming	- Betere zuurstofinbreng ⇒ nitrificatie	- Relatief duur (o.a. verdeel en drainage systeem)
	- Relatief hoge belasting mogelijk	- Pomp (energie) en/of influentschakeling nodig i.v.m. intermitterende belasting

fig 29. comparison of two different types of helophyte filters(Van Buuren et al., 1998)

fig 30. Helophytefilter in Almere, constructed by Wetlantec

Another dutch company that makes these filters is Ecofyt. In 1995, together with Witteveen & Bos, they have designed a helophyte filter system for 8 persons in Wapserveen that is still in use till this date and maintained by the inhabitants themselves (Knol, 2013). While most helofyte filters only filter grey water, this system also filters black water. In order to do this the grey and black water exits the building separately, the grey water from kitchen and shower goes into a preliminary sedimentation tank while the black water enters a sceptic tank. The preliminary sedimentation tank is a three champer system: in the first champer the solids sink and break down anaerobically, in the second chamber the fats are separated, due to the fact that they float to the surface while the water can only escape through the bottom. The sceptic tank often consist of only two champers, the contaminated water reacts with anaerobic bacteria creating a sludge as a by product. The sludge sinks to the bottom and slowly breaks down while the water flows up into the second chamber, out of the sceptic tank. After these first two tanks the water is combined into one tank from which it is intermittently pumped over the vertical helophyte filter. The water then flows through three layers of gravel with different stone sizes that filter out the organic materials and provide attachment points for the roots of the helophytes. The water flows through the system in 24- 72 hours and comes out clean. This water can either be re-used for the toilet and laundry or sent to the surface waters. Since the water can be re-usedm, a closed loop is created in which no additional water is needed after the system has filled up once.

The size of the helophyte filter is calulated by measuring the i.e.'s (a dutch abbreviation for the amount of contaminated water produced by one person) of the wastewater. The size of a filter should be around 3-4 m2 per i.e. A downside of this system is that it is very fragile since the bacteria can be killed by cleaning agents such as chlorine. It is therefore important to only use eco-friendly detergents.

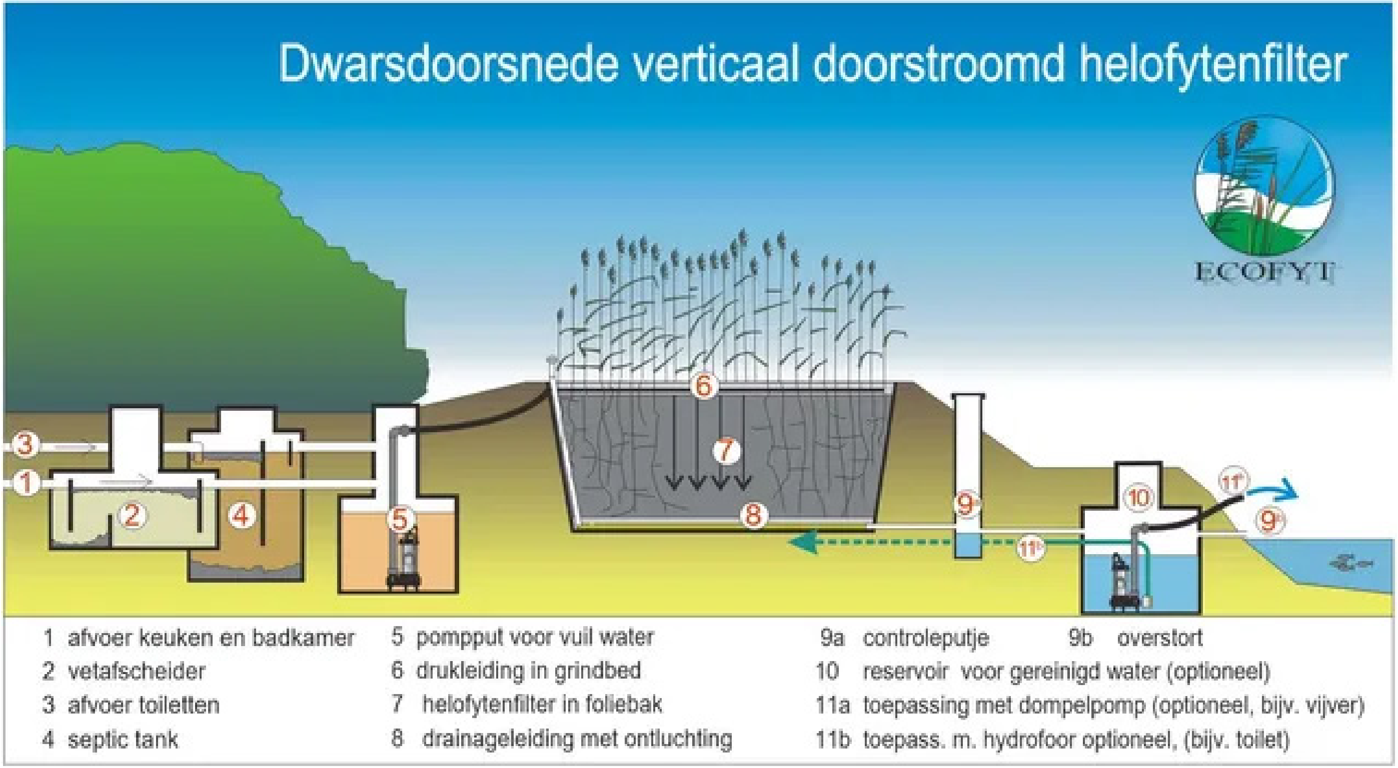


fig 31. Schematic representation of helophyte filter in Wapserveen

CASE STUDIES

This chapter highlights two case-studies into ecovillages in the Netherlands. These ecovillages have been visited by the author, the rest of the information is either coming from the inhabitants first hand or from the websites of the corresponding ecovillages. First an overview of the complex is given, after which the ecological way of living is investigated by answering the following questions:

- How does the ecovillage generate and manage its electricity demand?
- How does the ecovillage generate and manage its heat demand?
- Where does the ecovillage get its fresh water from?
- How does the ecovillage manage its waste water?
- What contributes to the creation of a community in the ecovillage?

CASE STUDIE A: Ecovillage Olst

Overview

The first case study is into the Ecovillage Olst. This community of 23 families built 24 building within the timespan of 4 years. All houses are oriented to the south with a roof angle of 9 degrees and an overhang of 1.2 meters on a 3.5m high wall. The roof angle assures that the northern walls bathe in the sun in the winter while the overhang assures that the sun does not enter through the glass in summer conditions. The center of the community gives space to a community house with a collective space with a kitchen. Several houses have a second floor that harbours a bedroom. between the houses a natural environment is created in which the inhabitants grow their own herbs and food.

Electricity

The electricity in Ecovillage Olst comes from 274 PV-panels, during the excursion I had there they told me that they investigated possibilties for going of grid, yet the battery technology of the time was expensive and often still relied on Lithium or other rare metals from far away countries. They describe their solution as the following they use the electricity net as a battery, sending all their green energy to the net and using the electricity from net to power their homes. This is of course true, unfortunately the electricity from the net is not entirely ecofriendly and therefore it devalues their sustainability.

Heat
The heat in these houses comes almost entirely from the sun. By properly designing their building envelope they are able to block the hot summer sun while taking in all of the winter sun's termal energy. This thermal energy is then stored in the materials of the house, specifically in the northern wall where extra thermal mass is created in the form of rubber tires and rammed earth. The first 11 houses where built with such tires, unfortunately the construction was very time intensive and they found that they could replace these tires for a strawbale-timber construction.
Furthermore, the house does not have any openings at the northern facade and minimal openings on the east and west facade.
During the first year that inhabitants came in the homes, there was a harsh winter in the Netherlands and temperatures would drop to below 15 degrees celsius in the Dutch Earthships, to overcome this issue some families started with burning wood in stoves. In 2021 a comparative LCA was performed by CE Delft (factsheet on the next page), from this LCA it can be concluded that the earthships secrete much less total CO2 per kg/m2. This is due to the fact that the solar panels make up for a lot of the excreted CO2. This LCA also indicates that the burning of wood in stoves is creates much more energy useage in comparison to a 2021 BENG building. Due to this discovery some of the homes switched to ground floor heating with a heat pump system. This adaptive nature also characterises ecovillages as they are never complete and often times experiment different ways of living.

Fresh water
In Olst they got the opportunity to harvest their own water. The village lies on top of a groundwater lake that is also used by several companies in the area. The municipality granted them access to this groundwater lake, the water in this lake is drinkable and does not need to be filtered.

waste water
The waste water of Olst is processed separately, the grey water flows through a helophyte filter, while the excrement and urine is either handled in composting toilets or by the dutch sewage system.

Creating Community
The ecovillage Olst takes pride in its self-built nature. People from all over the world came to assist in the building process resulting in a wide network of friends of the community, several of these people are still in contact with the community. Learning about and the sharing of ideas has developed a sense of community in this complex.

Furthermore, they have created a central space for the community. In this house celebrations such as christmas are done collectively. The collective kitchen also creates the opportunity to share a meal and discuss life. Projects improving the lifestyle of the inhabitants are often undertaken by inhabitants and create an environment in which learning and development go hand in hand with the community life.

Gemiddeld aardehuis

Afbeelding: Vereniging Aardehuis

Kenmerken:

Type	Twee-onder-een-kap woning
Woonoppervlak	119 m^2
Bouwmaterialen	Gerecycled materiaal, autobanden, leem, stro etc.
Energievoorziening	Elektriciteit, houtstook, zon-PV en zonneboiler
Bouwjaar	2015
Opmerking	Zelfbouwwoningen, opgebouwd uit duurzame (rest)materialen Cijfers inclusief energiegebruik apparaten en koken.
Referentie	Inventarisatie energie- en gebouwgegevens Aardehuizen

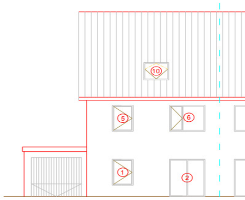
Energiegebruik en -productie

Elektriciteitsverbruik [1)]	13.573	MJ
Gasverbruik	0	MJ
Bodemwarmte	0	MJ
Zonneboilerwarmte [2)]	5.151	MJ
Hout- of houtpellets [3)]	25.500	MJ
Totaal verbruik	**44.224**	**MJ**
	373	**MJ/m^2 woonoppervlak**
Elektriciteitsproductie	12.169	MJ
Bodemwarmtewinning	0	MJ
Zonneboilerwarmte	5.151	MJ
Totaal productie	**17.320**	**MJ**
	146	**MJ/m^2 woonoppervlak**
Netto verbruik	**26.904**	**MJ**
	227	**MJ/m^2 woonoppervlak**

CO_2 voetafdruk

Elektriciteit afgenomen	1.431	kg
Gasverbruik	0	kg
Bodemwarmte	0	kg
Hout- of houtpellets [4)]	91	kg
Totale CO_2-uitstoot	**1.522**	**kg**
	13	**kg/m^2 woonoppervlak**

Typische nieuwbouwwo



Afbeelding: zie

Kenmerken:

Type	Twee-onder-een-kap wo
Woonoppervlak	148 m^2
Bouwmaterialen	Standaard bouwmateria
Energievoorziening	Elektriciteit, aardgas, zo
Bouwjaar	2015
Opmerking	Nieuwbouwwoning uit 2 Cijfers inclusief energiegeb
Referentie	RVO (2015) Referentiew

Energiegebruik en -productie [5)]

Elektriciteitsverbruik	11.344	MJ
Gasverbruik	27.547	MJ
Bodemwarmte	0	MJ
Zonneboilerwarmte [2)]	8.682	MJ
Hout- of houtpellets	0	MJ
Totaal verbruik	**47.573**	**MJ**
	322	**MJ/m^2 woono**
Elektriciteitsproductie [6)]	2.698	MJ
Bodemwarmtewinning	0	MJ
Zonneboilerwarmte	8.682	MJ
Totaal productie	**11.380**	**MJ**
	77	**MJ/m^2 woono**
Netto verbruik	**36.193**	**MJ**
	245	**MJ/m^2 woono**

CO_2 voetafdruk

Elektriciteit afgenomen	1.333	kg
Gasverbruik	1.645	kg
Bodemwarmte	0	kg
Hout- of houtpellets	0	kg
Totale CO_2-uitstoot	**2.978**	**kg**
	20	**kg/m^2 woono**

Opmerking:

Bovenstaande vergelijking heeft alleen betrekking op het gebouw en niet-gebouwgebonden energiegebruik excl. voertuigen. Het gaat om het finale eindverbruik van energie en CO_2-equivale
De cijfers waarmee het gemiddelde Aardehuis is opgesteld zijn geïnventariseerd bij de Aardehuisbewoners voor het jaar 2018. De cijfers reflecteren daarom het klimaat van dat jaar, dit was
van de RVO-factsheets en zijn meer gemiddelde waarden die niet noodzakelijk gelijk hoeven te zijn aan 2018.

Voetnoten:

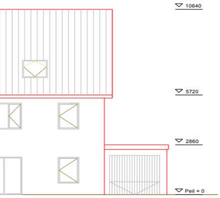
1) Voor het gemiddelde Aardehuis is niet gecorrigeerd voor het elektriciteitsverbruik van de woningen met een warmtepomp. Er zijn 6 à 7 woningen met een warmtepomp, maar het elektricite
Indien alle woningen met een warmtepomp weg worden gelaten, daalt het gemiddelde met elektriciteitsgebruik 8%. Het is echter de vraag of dit volledig is toe te schrijven aan de warmtepo
2) Hier is uitgegaan van de gemiddelde opbrengst per m^2 collectoroppervlak zoals voor 2018 door het CBS gerapporteerd.
3) Hier is uitgegaan van de stookwaarde en dichtheid van typisch stookhout zoals dat ook in de CBS-statistieken wordt gebruikt.
4) Hout (biomassa) kent methodologisch gezien geen directe CO_2-emissies, maar heeft deze in de praktijk wel. Het draagt ook bij aan luchtvervuiling. Ook zijn er indirecte emissies tijdens kap e
5) Het gaat hier om een schatting van het energiegebruik gebaseerd op de informatie verstrekt in de factsheets van RVO omgerekend naar finale energie, aangevuld met het typisch energiegeb
6) Hier is gecorrigeerd voor het hoge aantal zonuren dat in 2018 werd behaald in Olst, zodat het vergelijkbaar is met de waarden van het gemiddelde Aardehuis.

Colofon:

CE Delft, 31 januari 2020. Auteurs: Thijs scholten en Sjoerd van der Niet. Publicatienummer: 20.3K84.022
Deze factsheet is opgesteld door CE Delft voor Vereniging Aardehuis in het kader van het PROSEU-project binnen het EU Horizon 2020-programma. Dit onderzoek werd gefinancierd door de
In het PROSEU-project wordt onderzoek gedaan naar prosumers in de Europese Unie. Het project voor het Aardehuis wordt uitgevoerd als onderdeel van het werken met 'living labs' van het
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°764056.

Research received from inhabitants of ecovillage OLST (2023).

oning (2015)



referentie

oning, RVO voorbeeldwoning type A

len
n-PV en zonneboiler

2015 die voldoet aan de EPC-0.4 bouweisen
ruik apparaten en gasfornuis.
oning EPC 0,4 Twee-onder-een-kapwoning

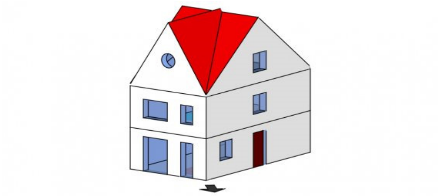
ppervlak

ppervlak

ppervlak

ppervlak

Typische nieuwbouwwoning (2021)



Afbeelding: zie referentie

Kenmerken:

Type	Twee-onder-een-kap woning, all-electric BENG voorbeeldwoning type M
Woonoppervlak	133 m^2
Bouwmaterialen	Standaard bouwmaterialen
Energievoorziening	Elektriciteit, zon-PV, bodemwarmte
Bouwjaar	2021
Opmerking	Nieuwbouwwoning voor 2021 die voldoet aan de BENG bouweisen Cijfers inclusief energiegebruik apparaten en inductiekookplaat.
Referentie	RVO (2017) Referentiewoning BENG Twee-onder-een-kapwoning

Energiegebruik en -productie [5)]

Elektriciteitsverbruik	20.830	MJ
Gasverbruik	0	MJ
Bodemwarmte	9.031	MJ
Zonneboilerwarmte	0	MJ
Hout- of houtpellets	0	MJ
Totaal verbruik	**29.861**	**MJ**
	225	**MJ/m^2 woonoppervlak**
Elektriciteitsproductie [6)]	3.754	MJ
Bodemwarmtewinning	9.031	MJ
Zonneboilerwarmte	0	MJ
Totaal productie	**12.785**	**MJ**
	96	**MJ/m^2 woonoppervlak**
Netto verbruik	**17.077**	**MJ**
	128	**MJ/m^2 woonoppervlak**

CO_2 voetafdruk

Elektriciteit afgenomen	2.588	kg
Gasverbruik	0	kg
Bodemwarmte	0	kg
Hout- of houtpellets	0	kg
Totale CO_2-uitstoot	**2.588**	**kg**
	19	**kg/m^2 woonoppervlak**

ente emissies (indirecte en directe emissies).
een relatief warm jaar met weinig stookdagen. De cijfers van de typische nieuwbouwwoningen zijn gebaseerd op de cijfers

itsverbruik van deze woningen is niet bijzonder hoog en het verbruik van de warmtepomp is lastig in te schatten.
mp.

n transport, deze zijn wel meegerekend.
ruik van huishoudelijke apparaten en verlichting en schattingen van de energieproductie van zonneboilers en zonnepanelen.

Europese Unie.
PROSEU-project. Meer informatie over PROSEU is te vinden op www.proseu.eu.

CASE STUDIE B: Ecovillage Boekel

Overview

The ecovillage Boekel consists of four circular housing complexes three of which consist of 12 homes each while the fourth functions as an educatinal center as well as an external heat storage location. A very important element of this ecovillage is the foundation on which the houses are built: due to the sandy soil, ecovillage Boekel had the opportunity to build on steel, this construction method makes the use of piles obsolete. Furthermore, the foundation is almost entirely circular and cement free. From the ground up it is made of: a geotextile, 60cm of foam glass; a residual material that is able to withstand high pressure forces while at the same time being able to insulate, a double PE-foil ensuring that water does not permeate into the foam glass while also creating the base for an airtight construction, on top of which a fly ash-based geopolymer concrete floor is placed, this geopolymer saves 90% of CO2 emissions in relation to regular concrete slabs and is finished off with an ecological pressure layer with ground floor heating. The walls are 100% bioabased and are made up of prefab hempcrete panels that create an insulation layer. Finally they have developed a new heat storage system that will be discussed later in this chapter.

Electricity

Since the complex is still under construction, specific details relating to the harvesting of electricity for indoor use can not be found online. A visit to the location (planned on the 2nd of juni, unfortunately they didn't have any ealier meeting date available) could provide more specific information on this topic. Furthermore, they aim to use 100% circular batteries, what type is also not specified.

Heat

The ecovillage Boekel makes use of a very new concept of heat storage: the CESAR-battery. Developed by electrotechnician Cees van Nimwegen, this system makes use of the thermal storage capacity of basalt. A very illustrative video about this battery sytem can be found on Youtube, yet to quickly summarise: a 11m wideand 4m high tube is filled with 400 cubic metres of residual steel slag from TATA-Steel, this steel slag is heated by the internal network of steel pipes that are put under high voltage, these steel pipes heat up in the summer and radiate the heat into the steel slag. The heat is stored in this tube due to the 2m thick insulation layer made of rockwool to withstand the high temperatures. When winter comes, air is blown through the steel pipes, taking heat in the form of air, this air gives off its heat trhough an air-water heat exchanger that heats up the water in a central boiler. This boiler sends the water to three separate boilers that each heat another 'housing-circle' through floor heating. The final result is a fully self sustaining heating system that enables the inhabitants to be completely independent in relation to their heating demands.

www.cesar-energystorage.com

Fresh water & waste water

The Ecovillage Boekel fresh water and waste water can not be discussed separately as they are inherently bound in their system. First of all thy harvest rainwater in 9 tanks of 10.000L for flushing toilets and doing laundry, the wastewater is sent to sceptic tanks and a helophyte filter after which it infiltrates in the soil. Accoring to their own research: “9,000 liters of treated wastewater will infiltrate into the soil every day, even in persistent drought!”. This is also the reason why the municipality allows them to tap into the groundwater system for their fresh water, since their reasoning was: “You have built up an entire reservoir of water under your residential area, which you can pump in the event of a prolonged drought”. Although the system is very promising, regulations on the quality of fresh water for consumption still prohibits them from being completely self sustaining in their water demand, therefore Brabant-water supplies the water for showers and consumption.

Creating community

In order to create a community in ecodorp Boekel, they have collectively created a set of guidelines to live by in order to be able to live in harmony with each other. These guidelines can be perceived as ‘spiritual’ to the outside yet they provide peaceful interactions within the community.

The Ecovillage Boekel is also trying to contribute to the bigger “community” through several ways. First of all the community is part of VrijCoop, an association that helps with financing living communites. The association loans money for the construction of the ecovillage, after which the ecovillage pays rent to pay off that loan, after this loan is repayed the inhabitants keep on paying rent, with this money VrijCoop is able to fund new Eco villages promoting a sustainable way of living. A system in which one ecovillages cares for the other.

Secondly Ecovillage Boekel gives room to one artist-in-residence who receives free housing for half a year to create art with the theme of the SDG’s, aiming to inspire people all over the world to work towards an ecofriendly environment.


omgang met het leven
- met de stroom meegaan
- bewust kiezen voor vertrouwen
- leven in het nu
- genieten van wat je doet
- verhalen vertellen, zingen, dansen en muziek maken
en humor


omgang met jezelf
communicatie met elkaar
zorgen voor onze groep
omgang met omgeving
omgang met het leven


omgang met omgeving
- bewust zijn dat we elkaar nodig hebben
- deel de weelde
- vertroetel de aarde
- gastvrijheid
- balans creëren met omgeving door samenwerking


zorgen voor onze groep
- zaaien, wieden, oogsten
-aandacht voor gevoelsniveau, zoals in het forum
- onze visie actueel houden en concreter maken
- 1+1=3 (synergie)
- evenementen/ceremonies organiseren


communicatie met elkaar
- blijf naar elkaar luisteren
- wachten met (ver)oordelen
- doorvragen tot en met begrip
- dialoog i.p.v. discussie
- leren van elkaar


omgang met jezelf
- verbinding met jezelf/ zelfreflectie
- verantwoordelijkheid voor jezelf nemen
- je eigen grenzen kennen en beschermen/ hulp vragen
- je kwaliteiten te ontplooien vanuit je hart
- persoonlijk commitment; b.v. 'oude' levenspatronen loslaten en elkaar daarin ondersteunen

CONCLUSION & REFLECTION

How to design a sustainable housing district in Midden-Delfland?

During my research I have come to the conclusion that there is not one solution to the question “how to design a sustainable housing district in Midden-Delfland?”. Sustainability in the harsh sense of William Rees is definitely still out of reach, biobased building and construction provide a solid first step, yet transportation and use of rare materials are inevitable. Therefore, much in line with earlier mentioned mantra’s as “form follows sustainability” and “material driven design”, I would like to propose a new mantra: “form follows efficiency” in which the design is first and foremost influenced by the set of appliances that enable the inhabitant to live in harmony with nature, while leaving a low carbon footprint. Adapting optimal roof angles for solar energy, creating roof area’s big enough to harvest rainwater for domestic use and dimensioning helophyte filters, basalt and salt batteries in advance of the design stage can indicate and shape a form that contributes most to the compensation of the initial input of carbon, setting the basis for ecofriendly living.

This report was an attempt at an interdisciplinary research on off-grid dwelling related topics. It tried to tackle various problems at the same time. This all-entailing approach has led to me drowning in the sea of information on several occasions, however it also showed me all elements that a housing brief requires in a new age of material and resource scarcity. A home is not only four walls and a roof, a home is conncected to a system of living, an exchange of resources and energy is inextricably linked to sustainable dwelling. My approach might be a very wide one yet it highlights a methodology for developing decentralised systems in unbuilt areas. Which could assist in overcoming housing shortages by building in remote locations.

The methodology first investigates what sustainable material systems are in place locally, biobased or re-used. Next it investigates if a sustainable watersystem is already in place and how a sustainable waterchain can be can be setup if the in-place system is unsustainable or unreachable.

Finally it highlights how to go about heating and cooling needs in a chosen site, can you achieve self-sustainability in your climate or do you need active systems for support? The architectural language, form follows efficiency, is a language dependent of all these site-specific factors, in which the architecture assists in attaining the highest efficiency of these site-specific elements that make up a system.

The case studies have helped me tremendously with defininig my scope. In hindsight I would advise to start with a case study with much relation to the site in order to develop a first frame of reference for the location. This can narrow down the research to much more ‘location and typology specific’ issues. My research has shown that systems and solutions come in many forms while tackling the same issues. It is the designers task to find a suitable synergy of the vairous applicable systems that could improve life on a specific site. Regarding my personal site (Midden-Delfland), I have listed several strategies and potentials for systems and architectures on the next page.

Finally a list with strategies and potential synergies in relation to the design phase is provided on the next page.

Materiality

- First of all, relating to material choice, regenerative materials provide a more environmentally friendly solution to construction, yet they often times remain expensive, straw, wood, flax and cellulose already prove to be affordable options.
- Secondly, when re-using building components it is important to be aware of the life-cycle prospects, the lowest-life-cycle element determines the entire life cycle prospects of the component. Design for dissambly is therefore required when using re-used building parts.
- For the area of Midden-Delfland, many second hand stores provide building materials, furthermore flax, straw, wood and cellulose can be harvested in the area and could provide a site-specific character.

Water

- The water of dwellers in the Netherlands is mainly used to wash away organic waste with valueable nutrients and minerals for soil
- Wastewater types are mixed in the sewage system, which instantly downgrades grey water and rain water to black water. Also, the system is overloaded & bypassed during heavy rainfall, which pollutes the surface water
- The most environmentally friendly toilet is the Urine diverting system
- Helophyte filters could, when designed properly, also filter black water
- Rainwater harvesting has the possibilities to provide all needs of a person living under a 68m2 roof, when consumer patterns are changed. Water can also be recycled with the use of helophyte filters, allowing to maintain the consumer patterns related to water.
- The area of Midden-Delfland requires an off grid water system, since the Dutch water system is unsustainable and overloaded, a helophyte filer and water catchment systems should be taken in consideration in early design stages

Solar Energy

- There are many approaches and principles to manage heat gain from the sun, what is most important is to be aware of the required assistance from the sun (heating, cooling, generate energy etc.) and to properly harness the sun for this particular purpose.
- When designing a passive solar heating system, mass, absorptivity and reflectivity of a material determine the level of solar energy gain in a material.
- Thermal mass has high energy demand in its production phase, mass items, like stone walls, should therefore be sourced from re-use initiatives as much as possible.
- Low tech battery systems often require more initial resources and thus often more space.

Case Study

- Sharing responsibilty for systems and gardens enhances social cohesion while at the same time reducing environmental impact of consumer pattern.
- Collective construction and learning experiences enhance a sense of community.
- When reducing emissions the strategical framework provided by Casini can be adopted.
- The earthship model reduces process costs by using raw or almost entirely unhandled materials
- If the soil is sandy, a cement-free foundation, like the one in Boekel, can be build, highly reducing environmental impact of the foundation.
- Earthships provide a passive solution to space heating, yet it does not fully suffice the heat demand in the harsh Dutch winters.
- Salt batteries, although large in size, provide an ecological solution to bridge the gap between demand and generation of electricity
- An active energy harvest and storage system that is independent of daily weather influences, like the one in Ecodorp Boekel, is warrented in the Netherlands since the climate is too cold and the sun too irregular in its daily strength.

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