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STUDIO
Architectural Engineering
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PROJECT TITLE
New typology of temporary recreational dune houses
Concept impression dune houses
How to design a new typology for a compact, pop-up, transportable, self-supporting beach house with a zero or positive footprint located in the dune area of the Netherlands?

How to design a new temporary, recreational beach house typology in the coastal area of the Netherlands? For this project the dune area of Kijkduin near Den Hague is chosen. The dune area is a protected area in the Netherlands because of its fauna and flora, natural water treatment and most important to protect the land from the sea. Because of this a conventional building wouldn't work. It's important to not damage the dunes. This raises the research question “How can I design a new typology for a beach houses located in the dunes area of the Netherlands?”

To answer the research question as complete and correctly as possible within the given time several case studies were done out of reference projects. Research about how other designers design a small building, think of micro dwellings, is the building off the grid and if so what kind of (sustainable) installations and systems were used and are suitable for the dune location. Other studies were done about pop-up shelters. How does the pop-up work? What kinds of materials, joints, systems, weather protection were used? How to keep the object transportable.
Rijkswaterstaat (RWS) has asked the TU Delft Architectural Engineering studio to design a new typology for temporary recreational beach houses for the beach area of the Dutch coast. TU Delft Architectural Engineering studio is based on graduation students who chose their project and design out of fascination.

RWS struggles with the problem that the beaches in the Netherlands are getting narrower and that the existing beach buildings obstruct the natural process of sand deposit for the dunes. The beach house should be appropriate to fit narrow beach-locations along the Dutch coast. Normally beach houses along narrow coasts are prohibited, because of storm risk and blockage of important sand transport to the dunes. The innovative beach house should overcome these obstacles by building on higher platforms, so sand transport won’t be blocked, or by adding sand to the system.

The research and design in this project focuses on the dune area of the Netherlands and for this project the specific location of Kijkduin, near Den Hague in the Netherlands. The dunes are chosen to avoid the existing problem on the narrow beaches and to introduce a complete new beach and dune house typology. Kijkduin is a suitable location because of its wide dunes and future plans for (dune) beach houses.

The research question for the design; “How can I design new typology for a beach house located in the dunes area of the Netherlands?”

To answer the research question the research is divided into two sub researches; The ‘environmental research’ which answers the question; “How to build on the specific location” and the ‘design research’ which answers the question; “How to build the building itself.”
2.1 Research questions

This research paper gives an answer to the 'environmental research question' and will be the startup of the 'design research'. Both research questions are divided into a couple of criteria. These criteria are developed out of the location and out of personal fascination. For the 'environmental research' these are: environmental awareness, compact, self-supporting. The 'design research' is divided in the following subjects; pop-up, fabrication and polygon shapes are mostly born out of personal fascination and the program of requirements of RWS:

The thematic research question for the project will be; “How can I design a compact, pop-up, transportable, self-supporting beach house with a zero (carbon) or positive footprint located in the dunes area of the Netherlands?”

2.1.1 Environmental awareness

Research on how the beach house should be designed to function in the dune area without disrupting the natural processes or damaging the fragile nature.

2.1.2 Compact

The compactness of the design is partly formed from fascination. The research will be on how to design a small, smart, compact (beach) house and will it be suitable for the dune location?

2.1.3 Self-supporting

This research about self-supporting focuses on the beach house being completely self-supporting in the way of electricity, water supply and heating demand and what kind of installations are usable on the dune location.

2.1.4 Pop-up

The pop-up principle is 'easy to build up, easy to take down'. Because of the temporariness the beach house could be pop-up in a certain way. Research on how to design a pop-up shelter

2.1.5 Fabrication

Research on the fabrication of the beach house is also born out of fascination and answers to the question if the fabrication could be done by CNC-milling and laser cutting.

2.1.6 Polygon shapes

Another fascination which is reflected on the design is the fascination about origami or polygon art. This fascination will be used in the transport and storage of the beach house but is also reflected on the interior of the beach house.

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2 | Directorate General for Public Works and Water Management
3 | 2014 09 12 V3 Specifications for an innovative beach house 2014 JVB AS.docx
4 | Nota van Uitgangspunten Kijkduin [16-05] p.8
5 | Program of requirements given by RWS

Specs of the Building to be developed:
- A beachhouse is meant for living and sleeping for 2-4 persons during the summer season (4 april – 1 okt)
- Space ca 15 m² including facilities (kitchenette, toilet/shower), extendable to 25 m²
- Demountable, easy to (re-)erect (2 weeks), transport and store in winter season.
- Weatherproof, including shelter for sandstorms.
- Prefab.
- Use of sustainable materials, if possible recycled material.
- Use of local material (sand / grass) as much as possible.
- Based on a smart platform (low for Oerol, on stands for Zeeland). If the idea works, one can decide to build the platform for Zeeland later.
- Performance of a real beach house with reservations for installations, to be engineered later on. Installations as autarkic as possible (solar energy, compost toilet, woodstove, etc)
Research

“How to build on the specific location”

Disturb nature as less as possible → Build in protected area

Position paper

Zero/ small (carbon) footprint

Self-supportive

Small footprint

Temporary/ portable

Compact

Pop-up

Environmental research

Design research
This research paper focuses on two research questions and four main research subjects; Compact, Self-supporting, Comfort and Structure. This research doesn’t cover all the aspects of these four research subjects. The research focuses on what applies to the design for this specific location. Research about the self-supporting installations is done for electricity, water and sanitary facilities usable on small scale.

Compact focuses on, what the word already says, the compactness of the building. Fascination and location are part of the research about small compact houses and shelters, this is because the dune environment is a delicate and protected area.

Comfort can be divided in two main subjects; comfort of interior and comfort of exterior. Comfort of interior focuses on facilities and material. Comfort of exterior focuses on accessibility, configuration and weather influences on the beach house.

The structure research is originated by looking for an answer to the question how to build a demountable, prefabricated, pop-up beach house which could be delivered on site and build up by one, two or three man.
3.1 Way of working

The main research methods that were used were case studies, literature, and partly research by design. For this I collected a variety of projects which I could use for research. In the case studies the research mainly focuses on size, configuration of interior elements, and material usage. Literature was mainly used for the environmental research.

3.1.1 Case studies

The case studies are divided in three subgroups; Exterior, Pop-Up shelter and Interior. The research within each subject shows how the architect or designers designed the project. What design tools did the architect use? These studies leaded to a number of items that match that can be used as a ‘toolbox’ for the beach house design.

The exterior case studies were used to research how a small, micro, and nano houses can be designed, what kind of requirements the (small) building should have and what kind of design tools the architect has used to design the final design.

The pop-up case study used to study how a pop-up shelter works. What kind of requirements a pop-up structure or shelter should have to function as pop-up. Therefore the research was also about materials and joints, ability to be flattened, and weight.

Using the Interior case study, I could first of all show my concept idea for the interior by references, and second how I could make such a ‘foldable’ interior. Just like the previous case studies the research mainly focuses on what kind of materials and design tools are used to design a ‘foldable’ interior. What requirements a foldable (small) interior should meet.

3.1.2 Literature

The research on the environmental question self-supporting part of the design is mainly done by the use of literature because there was little case study material on the specific topic. The few amount of projects where the ‘of the grid’ principle is combined with a small ‘pop-up’ house. Based on the literature the research focuses on what techniques are possible in electricity, (water, and plumbing. The gained resources / techniques are linked back to the project site and the project site itself.

3.1.3 Research by design

The follow research, the ‘design research’, will be done by researched by design. The main part of the structure, as in construction, fabrication, connection joints, and assembly will be figured out by designing frail and error.

Case studies can be found in the attached file; ‘Case studies Compact Pop-up - Eco houses, Tiny houses, self-sufficient houses’
As described in the previous chapter, Methods, the research was divided in several research questions and subjects; Environmental research and the design research. The results of the research are described in following pages. The results will be displayed in text and in images what will together form a toolbox for a compact, pop-up like beach house.

To build in the dunes you have to keep a couple of things in mind. The dunes are a protected area and people like conservation organizations don’t want you to build there. Well, they don’t want you to build a traditional building there. You have to be aware that the dune location isn’t a suitable location for a traditional building or a traditional house. In this chapter you will find answers to the question; “How to build on the specific dune location”. In the end of this chapter there are a couple of answers to the ‘design research question’ but this paper, as said in the introduction, mainly answers to the environmental research question.

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### 4.1 Location potentials per month

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Table 01 | Climate overview (source KNMI, image FMJ Ulijn)
4.1 Location potentials for self-support
The given location, the dune area of Kijkduin, has got potentials for self-supporting building or as they are called ‘off the grid’ buildings. This means that the environment can provide for resources for the energy and water demand so the building itself doesn’t need external powersources.\textsuperscript{7,8}

The climate of Kijkduin is overall an Sea climate and common for the Netherlands.\textsuperscript{9,10} Table 01 is used to extract information from to determine the capacity of the location.

4.1.1 Sun
The sun is a direct and indirect energy source for plants, animals, and humans on earth. The energy we can harvest from the sun is radiation and can be used to generate electricity and heating.

Kijkduin receives an annual year amount of solar radiation of 1040 kWh for each square meter. This variates from 5 kWh/m\textsuperscript{2} per day in June until 0,5 kWh/m\textsuperscript{2} per day in December\textsuperscript{11}.

During the months of March until October Kijkduin gets 1382 hours of sun which got the radiation power of 922kWh/m\textsuperscript{2}.

4.1.2 Water
Ways to collect water can be done in several ways. The most obvious way and most easy way is to collect rain water. Water can also be extracted from the ground. This can be done by natural ponds or by pomps.

A method which needs more treatment is to use the sea as a (fresh)water source. This source needs more treatment because the sea contains salt water. Reverse osmosis can be used to collect fresh water (generates electricity and fresh water). A more natural way is to use evaporation (solar heat and water) or a natural filter like Helophyte- or sand filter.

Water could be a multiple source for self-sufficiency. Water could be used to generate electricity but it mostly used for drinking and showering.

To use water as a source of energy you could use evaporation (phase changing of water), kinetic energy (energy by movement), and reverse osmosis. Most of these energy generating methods need large installations to be profitable.\textsuperscript{12}

The amount of provided rain water in the period of March till October could be 439,2mm/m\textsuperscript{2} which is 439,2L of rain water with a minimum of 10L and a maximum of 153L per month.

4.1.3 Wind
Wind has big potentials for generating electricity near the coast. The potential for energy generated by wind for a large wind turbine, near the coast of the Netherlands, could be 17 kWh$/m^2$ per year.\textsuperscript{13}

\begin{equation}
\text{AEO} = 0.01328 \times D^2 \times V^3
\end{equation}

\begin{align*}
\text{AEO} &= \text{annual energy output, (kWh/yr)} \\
D &= \text{rotor diameter, ft (1ft = 0.3048m)} \\
V &= \text{wind velocity, mph (1mph = 1.609344km/h)}
\end{align*}
The location Kijkduin has an annual wind speed of 5.0 m/s at a height of 10 m above ground. The most common wind direction is mostly land inwards which South West (SW)\textsuperscript{14}

4.1.4 Waste

The dunes are a protected area. Because of this there are no electricity cables, water piping or sewers.

Waste water could also be treated and re-used. This way the waste water needs to be separated which creates ‘gray water’ and ‘black water’. Gray water can be (easily) treated to become fresh water. The black water needs a more intern treatment to become fresh water.

Household waste like paper and plastics need to be brought to a dumpster. Waste from food could be made into compost or Biogas.\textsuperscript{15}

4.2 Potentials for self-support (in the dunes)

An answer to the question “How to build on the specific location” is to build a self-supporting beach house. The dune location provides us with a couple of ways to make the beach house self-supporting, to gain its own energy (electricity and heating/cooling) and to gain its own water. This can be done by ‘sustainable installations’ or ‘passive heating and daylighting’. For these ‘sustainable installations’ we have to keep in mind that the location isn’t suitable for big buildings and large installations.

4.2.1 Sun

The sun is a useful source of energy for electricity and heating but can be an enemy to. Orientation of the beach house plays a big role in the passive sun use\textsuperscript{1}. By designing the beach house in such a way that the sun enters the beach house when needed and blocking the light and heat when not needed which could save a lot of energy otherwise used on heating or cooling.

Ways to generate energy like electricity from the sun in this design would be the use of solar cell panels\textsuperscript{11} orientated on the south under an ideal angle of 36°. The size of the panels makes them suitable to use in this project. Highest efficiency are ‘single-crystal silicon panels’ with a 19% efficiency.\textsuperscript{16}

The sun is also be used to generate energy for heating. One could use solarboiler\textsuperscript{13} to gain and store heat from the sun.

Ventilation by heating could also be done by the sun, this sun generates a so called stack effect\textsuperscript{14}. Heated air rises which causes a natural draft inside the beach house.
4.2.2 Water
The water the location provides can be used in a couple of ways. To generate electricity, and to provide water for drinking, cooking, cleaning and showering. Before one could use the collected water it’s needs to be filtered first. The filtering could be done on a natural way or with chemicals.

For this project it’s probably the best to keep the filtering low tech like a sand$^\text{V}$ or hylopytefilter$^\text{VI}$ because of the amount of available electricity. Further research should show if reverse osmosis$^\text{VII}$ or UV filtering$^\text{VIII}$ is profitable.

Ways to collect water can be done in several ways. The most obvious way and most easy way is to collect rain water$^\text{IX}$ and a solar water still$^\text{X}$, vaporization of seawater, could be used to collect fresh water.

Water heating/cooling can be done by heating of solar power of cooling by wind or ground. Installations like a solar boilers and heat exchanging$^\text{XI}$ would be the most energy neutral way. In case systems like Biogas heating$^\text{XII}$ and even electric heating$^\text{XIII}$ could be used.

Because of the possibility of a limited amount of water per month the use of water saving devices would be necessary. Devices could be water saving taps$^\text{XIV}$, shower heads$^\text{XV}$, and no water toilets$^\text{XVI}$.

4.2.3 Wind
The wind on the location could be a good source of energy gaining. The use of small ‘urban windturbines’. Urban windturbines’ with a rotor diameter of 3.7 meters can generate annually 3,2 kWh/m² per year (2.200 kWh/yr). Further research should tell which model would be the best choice to use.

The venturi effect$^\text{XVIII}$ of the wind can be used for natural cooling and ventilation. Air flows trough a flowtube. Because of the shape of the flow the wind creates a vacuum which sucks out the air out of the building. This way a natural ventilation emerges which also could be used for cooling.

4.2.4 Waste
A traditional flushing toilet wouldn’t be a proper solution because of it water usage and waste disposal. For the dune location a water saving toilet, a no water toilet, or a compost toilet could be used. The use of a compost toilet$^\text{XIX}$ is the best option in the beach house.

The compost from the compost toilet in combination with kitchen waste can be used to produce Biogas. This could be done with a personal Biogas plant or a shared Biogas facility.

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6 | Natura 2000
7 | AR0531 - Alexandros Christodoulou; BioClimatic Architecture Without Architects
8 | AE Studion - Jettie Vernee Research Thesis; Winddriven Archiventure TU Delft
9 | http://KNMI.nl
10 | http://klimaatinfor.nl/netland/
11 | Gommans, L., Gebiedsgerichte; Energetische Systeemoptimalisatie (Delft 2012) p.79
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13 | Gommans, L., Gebiedsgerichte; Energetische Systeemoptimalisatie (Delft 2012) p.95
14 | http://www.windfinder.com/windstatistics/hoek_van_holland
15 | AR0531 - David J. Polli; Biogas, not a waste of time TU Delft
16 | Gommans, L., Gebiedsgerichte; Energetische Systeemoptimalisatie (Delft 2012) p.85
4.3 Compact
4.3.1 Exterior
The results of the exterior case studies state that in case you design a compact house you have to keep a couple of regulations, ‘design tools’, in mind. These design tools are; designing space with multifunctional purpose, spaciousness of the house, enough light (plays a role in the spaciousness), and go back to basics.

4.3.1.1 Multi functionality
A lot of object can have a multifunctional purpose. In the case studies you can see that in a lot of compact buildings are fitted in with multifunctional furniture. Because of space saving.

You can ‘hide’ a lot of storage in the floor, clean fitted cabinets, or in furniture (the common known sofa-bed) and the shower and toilet in the same (small) room. Hiding functions is important to keep a spacious feeling in the beach house. It is necessary you don’t have the feeling of being in a very small space which could be claustrophobic.

4.3.1.2 Spaciousness
Spaciousness plays a big role in the design. As you can imagine you don’t want to be in a small oppressive space which gives a claustrophobic feeling. To keep the space spacious the design;
- Flexible interior
- One open space, no small booths but one ‘large’ space.
- ‘Sight lines’, give to user the freedom of seeing. Use of windows or openings.
- Clean design, minimalistic design (low amount or ornaments and non-useful things)
- Multiple usage of material or colour.

4.3.1.3 Basic luxury
In case of a small design ask yourself what the owner needs in the building. In this case, in combination with the provided comfort level, the owner needs a place to sit/ lounge, a bed, a toilet, a place to cook and a place to clean him/her self. Therefore it’s not necessary to design a big hot tub or a gigantic dinner table but a simple still comfortable object will do. This way you can save space and material.

4.3.1.4 Light and air
In case of a summer setting in nature it’s nice to have enough light, air (ventilation) and contact with the surrounding environment when wanted. In case of a hostile and stormy environment it’s nice to feel protected like you are in a shell of cocoon but in a summer like setting you would like to open up for maximum contact with the environment. The possibility to open and close the building to the weather- and location type.
4.3.2 Pop-up shelters
The results of the pop-up shelter case studies state that in case you design a pop-up shelter you have to keep a couple of regulations, ‘design tools’, in mind. The overall theme is ‘transportation’. To keep the pop-up shelter transportable you can divide it in these design tools;
- Lightweight materials
- Strong materials
- Intergraded construction
- Easy assembly
- Easy handling

4.3.2.1 Lightweight
One of the main design tools for a pop-up shelter is to keep it lightweight. The principle of a pop-up shelter is that you can bring it with you and pop-it-up when you need the shelter. To keep it lightweight materials like carbon, strong fabrics like polyester or, as seen in the case studies, cardboard.

The beach house needs to be transported to the location by manpower so the beach house needs to be light enough to be carried by two or three man to its location in the dunes.

4.3.2.3 Assembly
The assembly of the pop-up shelter needs to be an easy and non-permanent assembly. The pop-up shelter needs to be transportable and been build and taken away. As seen in the case studies the fixed joints are permanent, moving parts are mainly permanent but joints between connections of pre-fab elements are temporary.

4.3.2.4 Handling
Adjacent to the assembly is the foldable design tool. There are two types of ‘foldable’ structures; Origami foldable, as in the urban homeless cocoon or the Quechua Pop-up tent, or foldable as in separate elements that can be stacked together to make a small package for transport and storage. when ‘folding’ the structure the handling and transport comfort can be approved which is a valuable asset for a pop-up shelter.

4.3.2.5 Intergrade
To keep the pop-up shelter easy to assemble most of the joints, hinges, connection tools are interested in the shelter. For example the hinges are a flexible material so you don't have to add a hinge pin. The 'best' pop-up shelters have their construction integrate so the pop-up shelter can be built up in one easy way without small loose parts that can be lost or forgotten.
4.4 Comfort
Comfort can be seen in two separate ways. The comfort inside the beach house (interior comfort) and the comfort of use the beach house (exterior comfort). These two together form the level of comfort.

4.4.1 Interior comfort
As seen in the case studies the beach house needs to be lightweight and portable. The interior of the beach house needs to be simple and comfortable so the beach house design will be lightweight and portable. Comfortable in this case means the interior one needs.

4.4.2 Exterior comfort
The exterior is how the user can access the beach house. The existing roads on the location can be used to bring the beach house to its location in the dunes. These roads can also be used in need of fire safety or ambulances. Temporary roads like the ‘Dynamisch pad’ by Astrid Bennink can be used if necessary to create better accessibility.\(^{17}\)

4.4.2 Adaptability
The adaptability has to do with the weather influence on the beach house.
This conclusion is an answer for the ‘environment research stage’ of the environmental research question. It is not an answer about how to build ‘the’ building, but how to build a building on that specific location.

To answer to question “How can I design a new typology for beach houses located in the dune area of the Netherlands” I could say the following.

If you want to build a beach house in the dune area of the Netherlands you have to take a couple of things in mind. The dune area is a protected area and a delicate place. Therefore it is necessary to disturb or damage the environment as less as possible. This you can do by keeping the carbon footprint of the building as minimal as possible. By building a compact beach house the literal footprint of the building is as minimal as possible.

Self-sufficiency plays a big role in the design. Because of the fact that the dunes are a protected area there are no facilities like water pipes and electricity lines, and in case of adding them to the locations a big chance of damaging the environment is there.

The Pop-up way of building and pre-fabrication. Both are possible ‘tools’ to reduce the footprint of the beach house. Pop-up so the building can be easily be assembled and removed and the pre-fabrication is so the beach house isn’t built in situ which means no building site and again as little as possible damage to the dunes. The same is for the pre-fabrication of elements. Increase the ‘building speed’ and keep the building easily to build, without machinery. The less time it takes to build the beach house on site the less damage to the dunes.

A next logic step for research is to answer the question “how to build the building on the dunes of the Netherlands?” will be answered in the ‘design research stage’. This research will be about how to make the building pop-up and how the pre-fabricated elements are made and connected together.
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