



Utvikling av hallsystem for nødhjelp

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Industriell design

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CONCEPT DEVELOPMENT OF HALL SYSTEM FOR DISASTER RELIEF

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Master Thesis

Department of Product Design

NTNU 2012

PREFACE

Foreword

This project was started by the initiative of Henning Nilsen and Tov Giezendanner at W. Giertsen Hallsystem AS (WGH). The objective was to put focus on one of their hall systems to investigate new potential based on the existing design. My connection to Henning and Tov was made through Brita Fladvad Nilsen and Johannes Sigurjonsson at NTNU.

The context for this assignment has been disaster aid in sub-Saharan Africa. With the possibility to study a challenging and expanding market, I was sold.

I wish to thank Johannes Sigurjonsson and Nils Stensrud who have been my supervisors at NTNU during this project.

Many thanks to Henning Nilsen and Tov Giezendanner who have been my contacts at WGH. They are remarkably inclusive, and their colleagues at WGH Bergen met me with much enthusiasm. A special thanks to W. Giertsen Hallsystem AS for letting me work on this project.

Thank you to classmates, friends and family for a constant supply of support and the never ending good spirits.

Christoffer Sæther Sørensen, Trondheim 25 January 2013

Abstract

With changes in politics regarding refugee camps and how they should be managed enables changes in existing designs of equipment used. Along with developments in relevant technologies such as solar panels, gives incentives to think in new ways on shelters and hall systems for disaster aid.

W. Giertsen Hallsystem AS (WGH) have long traditions on delivering equipment for disaster aid, and is currently one of the suppliers to NOREPS permanent stock of equipment used in case of emergencies world wide. NOREPS is a Norwegian organization which provides relief agencies with immediate support during emergency operations.

WGH wants to investigate if there is new potential for their hall systems, based on the new developments in this market.

Background information concerning WGH and its competitors is presented. Background is also given on the context where the hall systems are used. Based on the context study, the assembly crew is chosen as the user-group to focus on. Interviews with assembly crew and designers at WGH are done. Participation on the construction of an NG3 hall in Bergen is done to get practical experience with the challenges of setting up a larger hall.

Based on these findings, several possible projects are listed. A focus on rainwater harvesting with its untapped potential is chosen for further study. The product to base a future solution on is chosen to be the NG1 system.

A literature study gives further background on rainwater harvesting. A collection of existing products gives inspiration to new ideas. Through brainstorming and idea generation using sketches, two concepts stand out as good candidates for detailing. One concept prepares the existing hall systems for rainwater harvesting. The other concept presents an option of redesigning the typical hall-structure, making it more adapted to auxiliary systems such as rainwater harvesting (RWH), solar power and ventilation.

A gutter solution is chosen as the concept to be detailed. The result is a simple yet efficient add-on for the NG1 system. The solution takes advantage of the existing supply chain of WGH and its sub-contractors. Materials are chosen so no new production technologies are needed. All the vital tools for assembly are already in place.

The RWH system that is suggested has many positive side-effects, most importantly it increases the availability of potable water in a situation where infrastructure and supplies presents a challenge that needs to be solved.



The Result

A simple add-on with many benefits. Designed to fit in the supply-chain of WGH. It presents a missing piece in the puzzle of water supply, linking rainwater harvesting with hall systems used in refugee camps and disaster aid.

The resources needed to implement this system is already present. Well suited water storage kits are available through sub-contractors for WGH, making this system realizable today.



Master thesis for student Christoffer Sæther Sørensen

Concept development of hall system for disaster relief

Utvikling av hallsystem for nødhjelp

When a humanitarian disaster occurs, international support is in place normally within 48 hours, providing the critical equipment needed to protect people temporarily. There is a great challenge to meet the needs and demands presented at a refugee camp, when it comes to providing shelter for refugees and staff. Also there is a need to provide energy to such camps in a sustainable manner. Green buildings and facilities have therefore become an important topic within UN organizations, working with refugees and IDP's

The master thesis is carried out in cooperation with WGH (W. Giertsen HallSystem). WGH is a company located in Bergen, providing hall systems to a range of market segments, with deliveries for humanitarian organizations as an important activity. An integration of sustainable technology in their products is a priority. WGH has over forty years of experience delivering products providing aid during humanitarian disasters.

The goal for the master thesis is to develop an integrated hall system based on the existing technology of the company.

The assignment will include:

- Analysis of client and user needs, including gathering of information
- Idea and concept development
- Evaluation and refinement of concept
- Detailing of chosen concept

The assignment is performed within "Retningslinjer for masteroppgaver i Industriell design".

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Supervisor: Nils H. Stensruud, NTNU
Company mentors: Henning Nilsen, Tov Giezendanner, W.Giertsen Hallsystem AS

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Trondheim, 20. august 2012

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INTRODUCTION

This chapter presents the background of this project. Relevant methods and tools are debated. An outline of the phases of this project is given along with an explanation of the structure in this report.

PROJECT BACKGROUND

With changes in politics regarding refugee camps and how they should be managed enables changes to existing designs of equipment used. Along with developments in relevant technologies such as solar panels, this gives incentives to think in new ways on shelters and hall systems provided for disaster aid.

DESIGN BRIEF & PROBLEM DEFINITION

Investigate new potential for hall systems, with regard to available technology at W.Giertsen Hallsystem AS (WGH). Focus for analysis will be hall systems NG1, NG15 and NG3. The context is aid and relief operations in sub-Saharan Africa. The steel version of NG1 is of special interest for WGH.

Improvements or re-design should aid in making the hall system more autonomous. As of today, refugee camps are dependant on diesel aggregates for power. Food is easily destroyed when stored under unsuitable conditions. Halls have a potential to be more optimized for the logistical challenges and demanding environment when being deployed in rapid response missions during disaster aid.

It is important to conserve WGH's focus on quality and durability.

Tools and Methods

Main Questions ?

How can a new generation of hall systems be used to meet the needs of the

- refugee camp organizers?
- assembly crew?
- end users (doctors, refugees, logistics crew)?
- service crew?

Sub questions ?

• What are the sheltering needs?

Problems / current use / assembly / preferences / norms / customs

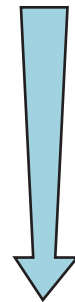
• How can a new solution fit in the selected context?

Stakeholders / local knowledge / crew capability / local value perception

• How should the solution work technically?

Materials / production / maintenance / use / repair / transportation

Top Down



The problem definition structured in layers.

The Design Process

The general design process is considered known material, but still there is a need for some debate. Design for aid and development presents challenges somewhat different when compared to traditional design projects in developed countries.

Design Methodology

A *top-down approach* ensures a wide idea-space and welcomes radically new concepts, whereas a bottom-up approach would be more effective and focused. This choice is made to motivate a solutions-space large enough not to exclude innovative suggestions, as this is an important motivator for this project, rather than making only incremental improvements.

Tim Brown's *Change by Design* (2009) presents insight on the term *Design Thinking*. The chapter on Design Activism is specially relevant for this thesis. A strength of Design Thinking is that a broad foundation is sought for when designing a new solution.

Combining a top down approach with Design Thinking involves finding out why users act the way they do. Relevant user groups must be defined and attention is put on more than just a technical solution. After identifying also the surrounding problems, a product solution can be developed.

When applying a traditional top down process, the questions would often start directly with how a hall system should perform, instead of directly involving the surrounding context and its many different user groups. It is needed to think beyond the product and the project.

According to literature and personal experience are designers excelling at:

- Creative and practical problem solving
- Analyzing situations and user needs
- Creating a link between finding a goal and the final solution
- Looking at all phases of a products "life"
- Analyzing the overall impact of a solution

Still, a designer is not able to save the world

alone, which makes a multidisciplinary team to be preferred. The challenges in a development project as this can become far too complex to be solved by a designer alone. (Hussain 2005)

Design Methods

To overcome such complex scenarios tools and methodology are needed. In the designer's toolbox there are a wide array of tools, such as personas, mood boards, story telling and more. Many of these (200 to be exact!) are explained in Design Methods 1 (Curedale 2012). In addition Managing the Industrial Design Process (Liem 2006) gives an introduction to a general design process. At the Department of Product Design (IPD) at NTNU, a focus on a user centered design process is being taught. A relevant and comprehensive process guide is available through the IDE faculty at TU Delft (<http://ocw.tudelft.nl/courses/product-design/delft-design-guide/course-home/>).

Designing for aid and development

Access to electricity, infrastructure and basic sanitary functions are often a luxury rather than something one can expect. Often a rough climate, both weather and political-wise brings even more problems to the table. Providing shelter in these circumstances demands simple yet efficient solutions, that simply works no matter what.

To create products suited for this context it is needed to get in direct contact with users in their own environment.

Disaster aid is performed in environments more or less unavailable for studies based in Trondheim where this project is done. When the original environment is inaccessible, substitutions with simulated environments and settings are used. Second-hand observations becomes a primary source of information. This results in a filtered input, and care must be taken when making decisions based on this foundation.

The difference between an aid and a development setting must not be forgotten. Where disaster aid focuses on rapid deployment with effective logistics, long term development is all about low cost and long lasting solutions. These situations demands different solutions, but much is to be gained if a link can be made between the efforts being invested during the two stages.

Participatory studies

Assembly of an NG3 hall in Bontveit, Bergen became the substitute for field experiences. The

crew at Bontveit included me as an assembly crew member, and this gave me loads of input. Bontveit was by all practical means very much isolated, when mobile signal was out thanks to mountains, and access to electricity was gone because of its remote location. Portable aggregates became precious. Weather was challenging to some extent, when the local climate presented true "Bergen-rain", and gave its effect on the work environment.

"Use what you design" is a good rule of thumb. Hidden solutions and also hidden problems often appears in his way. Ask simple questions and listen is also a good advice!

Interviews

Interviews and correspondence with aid crew at NRC or Henning at WGH became my source of experience from refugee camps. Photos taken by others, articles on the subject and the camp management tool kits from NRC and UNHCR was translated into my input from this context.

Sketching, 3D modelling and Mock-ups

Quick sketches are a valuable way of explaining ideas and to do rapid idea development. After a certain idea on where the project was headed was secured, three dimensional mock ups, even low fidelity models, becomes more and more valuable to the concept development. In this project, toilet paper cores(!) became an indispensable substitute for piping arrangements, and ordinary paper doubled as PVC sheeting.

A goal is to force the brain into unmasking all the "short-cuts" the brain easily takes when working in 2 dimensions.

Workshops

A workshop with Engineers Without Borders of the student chapter at NTNU was done early in the idea generation. After an introduction on the topic, a brain-writing session was done on RWH. Sessions like these can be valuable to spark new ideas and can provide a broad solution space early in the process. Most importantly these sessions are valuable networking events at the same time. Many connections are made, and this gave me a practical way to identify persons with interest for the subject, who can later in the process provide with valuable expert advice from own field of study.

Literature Review

A literature review was needed to provide a theoretical foundation for the choices to be made during this project. A focus is put on

articles concerning refugee camp management and rainwater harvesting. A more detailed article review debating design tools for disaster aid and RWH is done in Rethinking Rain (Sørensen 2013).

Appropriate Technology

Principles behind applying appropriate technology is important for this thesis. As discussed in Martinson (2007) the use of technology not suited for the context is often the reason for system failure. Sustainable development should be promoted.

New methodology

“The message: Your designs will break. Plan for it, and make it easy to repair the most likely reasons for failure.” (Lecture notes - Amy Smith, available in the appendix.)

“Design for Failure” is a provocative term for a design method but still relevant for the given context. Tools, spare parts and the ability to fix complex products are not available in abundance. Therefore it becomes important that key components are easily replaceable or can be fixed with minimum effort. A hall system must be easy to maintain. Maintenance-free systems are to some extent available, but relies on often more sophisticated designs than what is appropriate to apply in a refugee camp. This is clearly exemplified with RWH systems implemented in many contexts throughout the world.

Care must be taken when choosing a methodology to apply for this project. Traditional design methods aimed at development work will help to some extent, but many differences between aid and long term development work calls out for a somewhat different approach.

PROJECT STAGES

The report is divided in sections reflecting the different phases of the thesis.

Initial Analysis consists of a visit to W. Giertsen Hallsystem AS at Laksevåg in Bergen. After this visit the external and internal analysis could be completed.

During this stage the frames for this project were still wide and very much open. A large part of this project has revolved around the challenge of finding a good topic to focus on. Designing a hall system is a definition too wide to be able to result in a tangible solution within the time frame of this thesis. Compared to the original plan the extent of preparations needed before the active idea generation could be started became the biggest change during this project.

With the chapter Project Focus a debate is performed on where to go from the analysis. With the conclusion of RWH as a project topic, a new iteration of background research was needed. Idea generation is done parallel with the literature studies, and provides the foundation for the concepts.

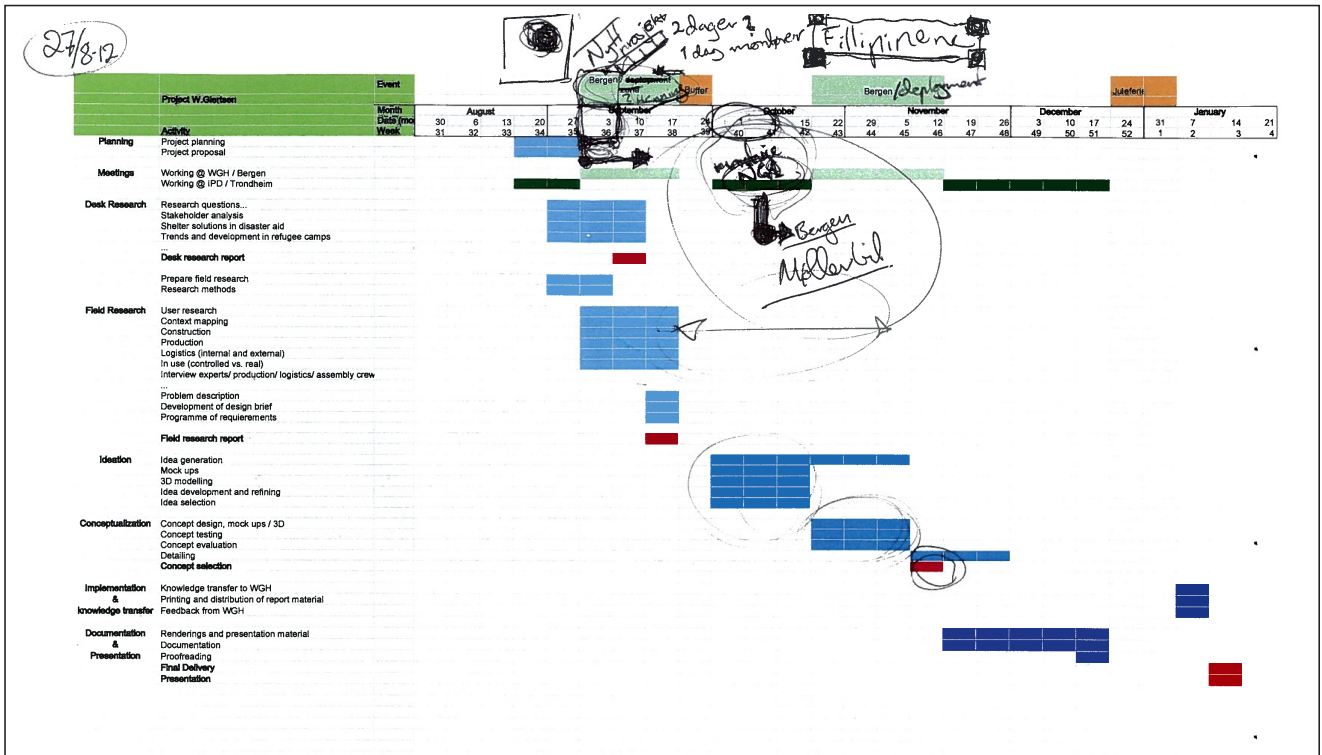
Planning

A detailed plan is made from the beginning. A Gantt chart gives a break-down of the project tasks. Time needed on each task is estimated. As lines and notes on the Gantt-chart shows, the plan changes constantly, still a detailed plan is needed from the start to be aware of the motive behind each task, and its relevance for the overall process.

Post-its placed on a grid showing each week are used to organize weekly tasks.

Milestones:

- Project start, 21st of August, week 34.
- Background research, week 38.
- Concept selection, week 46.
- Project delivery, week 3.
- Project presentation, 21st of January, week 4.



Gantt chart showing planned progression and a distribution of work-packages. Larger version is available in the appendix.

INITIAL ANALYSIS



Company Overview

Introducing WGH

W. Giertsen Hallsystem AS (WGH) delivers mobile hall systems used in the industry, consumer market and also to disaster aid and development operations, starting in 1967. The company has a domestic as well as an international focus. Core values in the company are responsibility, respect and professionalism.

WGH is part of W. Giertsen AS, a family enterprise located in Bergen, Norway, established in 1875. Other branches of the W. Giertsen enterprise is W. Giertsen Services AS and Giertsen Tunnel AS.

The Public Market Segment

Includes disaster aid, peace keeping activities, military and governmental projects. Examples includes deliveries of shelter used after the tsunami in Asia during the Christmas in '05, and projects for NOREPS (Norwegian Emergency Preparedness System).

Domestic and Private Market Segment

A sector in growth, includes recreational and sports facilities, normally financed through private or governmental funding. Several specialized solutions exists for different activities. WGH can provide cost efficient solutions compared to similar permanent installations.

The Industrial Market Segment

Business to business commerce includes situations where companies need to expand their existing storage or production capacity. WGH focus on clients within the engineering and construction industry, industrial production, on and off-shore as well as maritime industries.

Core competencies of WGH

- Unique knowledge of client needs.
- Unique competence to meet needs through WGH's product concepts.
- The brand name of WGH.
- Close collaboration with their clients.

GiertsenHall NG1

A basic hall/production tent for temporarily use, for instance on project basis. Product Advantages: Quick assembly, smart solutions, efficient logistics and optimal storage usage as a consequence of the removal of the support beam in the upgraded version. Available in both steel and aluminium.



GiertsenHall NG2

Flexible and cost effective hall. Tall, straight side walls ensures increased storage capacity. Perfect as a double garage for large vehicles.



GiertsenHall NG3

Larger hall with good storage capacity. Product Advantages: Good storage capacity and flexible logistic.



GiertsenHall NG5

Large hall with straight side walls for semi-permanent usage. Product Advantages: Efficient storage economy and environmental friendly design.



Product Portfolio

Hall Systems

WGH offers 4 main products in its portfolio. The halls can be customized to fit a large range of applications, available with a selection of additional equipment such as insulation, lighting, heating or cooling, ventilation and more.

Also WGH deliver specialized solutions for sporting arrangements, aircraft hangars, as well as providing service agreements and rental options.

Usage areas are many, including multipurpose halls, dry storage, large scale storage, aid and relief, workshop, production, exhibition events, riding centers, waste handling, hangar.

Focus areas

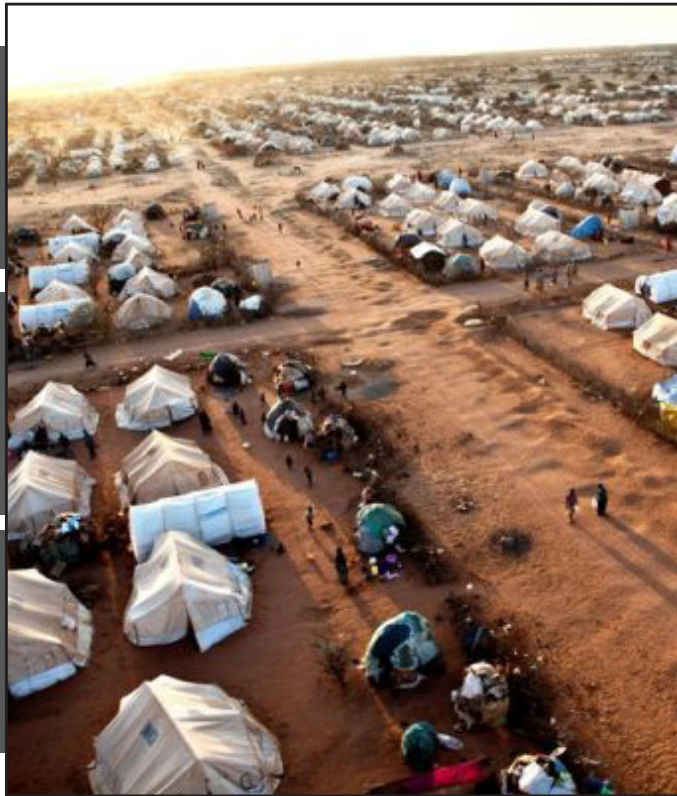
- Logistics
- Assembly
- Implementation / Use
- Service / Follow-up / Re-use
- End of Lease / Recycling / Alternative use

Stakeholders?

- NGO's
- Transportation companies
- Assembly crew
- Subcontractors

Business models

- Business <--> Business (Norwegian market)
- Business <--> NGO (Disaster relief)
- Business <--> NGO (Transitional)
- NGO <--> Local entrepreneurs (Long term)



Context Overview

Concerning Refugee and IDP Camps

Dadaab refugee camp in Somalia is the home for almost 500 000 refugees. This place was intended to be a temporary location, just as many other refugee camps. Over 20 years has gone by since its first tents were put up, and there are today no reasons not to believe there will come 20 more years where this camp is needed.

A change of politics is noticed within NGO's and several governments, where the fact that many refugee camps are often permanent solutions is now becoming an accepted reality. This calls out for sustainable solutions rather than short term quick-fixes to many of the challenges presented when setting up a camp.

Designing aid and relief equipment with this reality in mind, brings new problems as well as many new opportunities. This thesis will present a concept for one such solution.

Context Related Literature

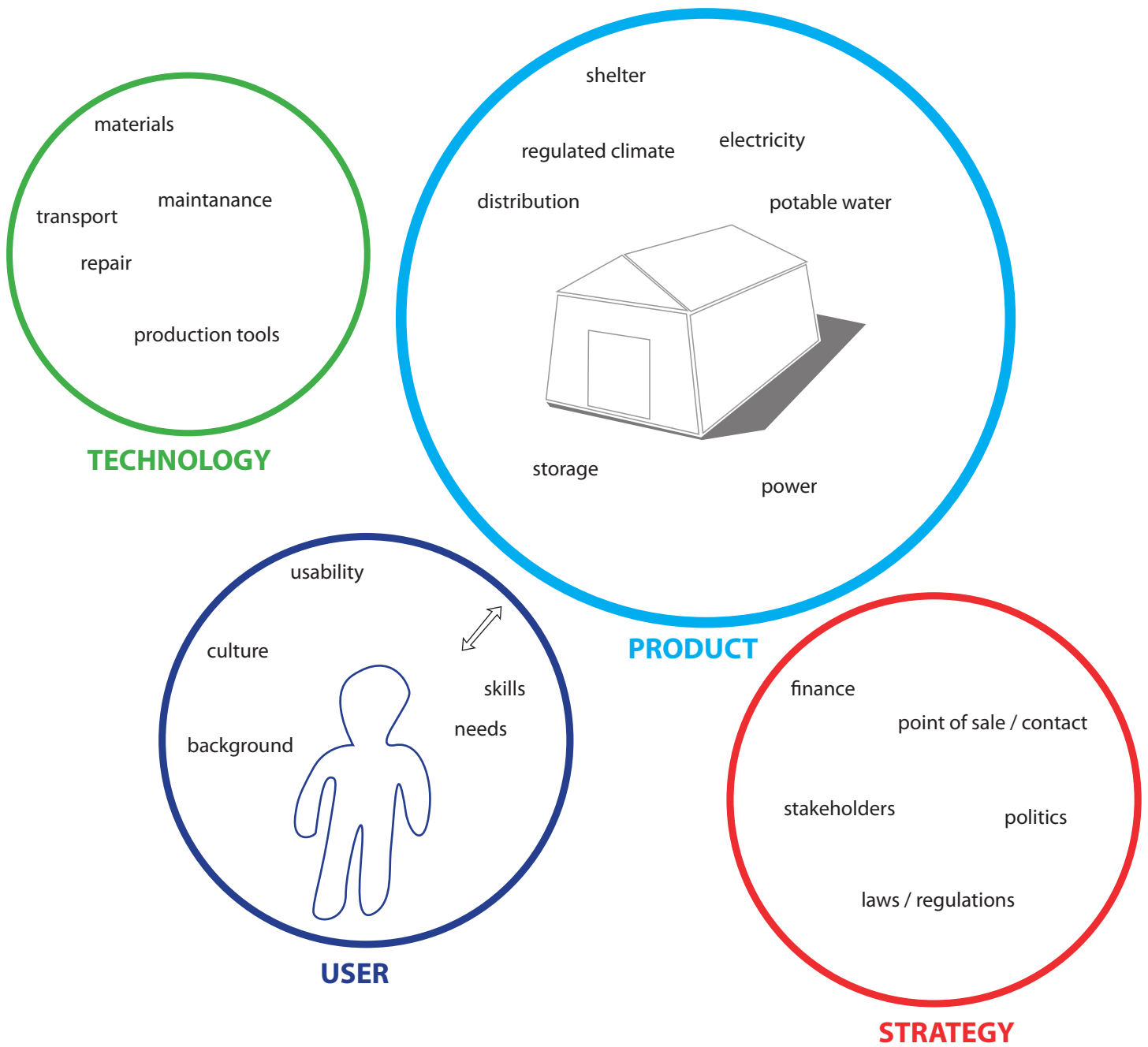
Previous of this master assignment, a review article was written on the subject of RWH in disaster-aid and the need of a holistic design approach to meet the challenge of providing enough drinking water to all, please see Sørensen (2013), Rethinking Rain.

Camp tool-kits from Sphere, UNHCR and NRC are valuable to gaining insight into how a refugee or IDP camp is managed and how they are made survivable.

Research papers, especially paper nr. 147 by Manuel Herz has given valuable insight on the daily life inside a camp from the view point of an aid worker.

IDEO as well as Design Without Borders have made available user centred design tool-kits aimed for projects done in developing countries. Many practical and constructive advice can be found in these works.

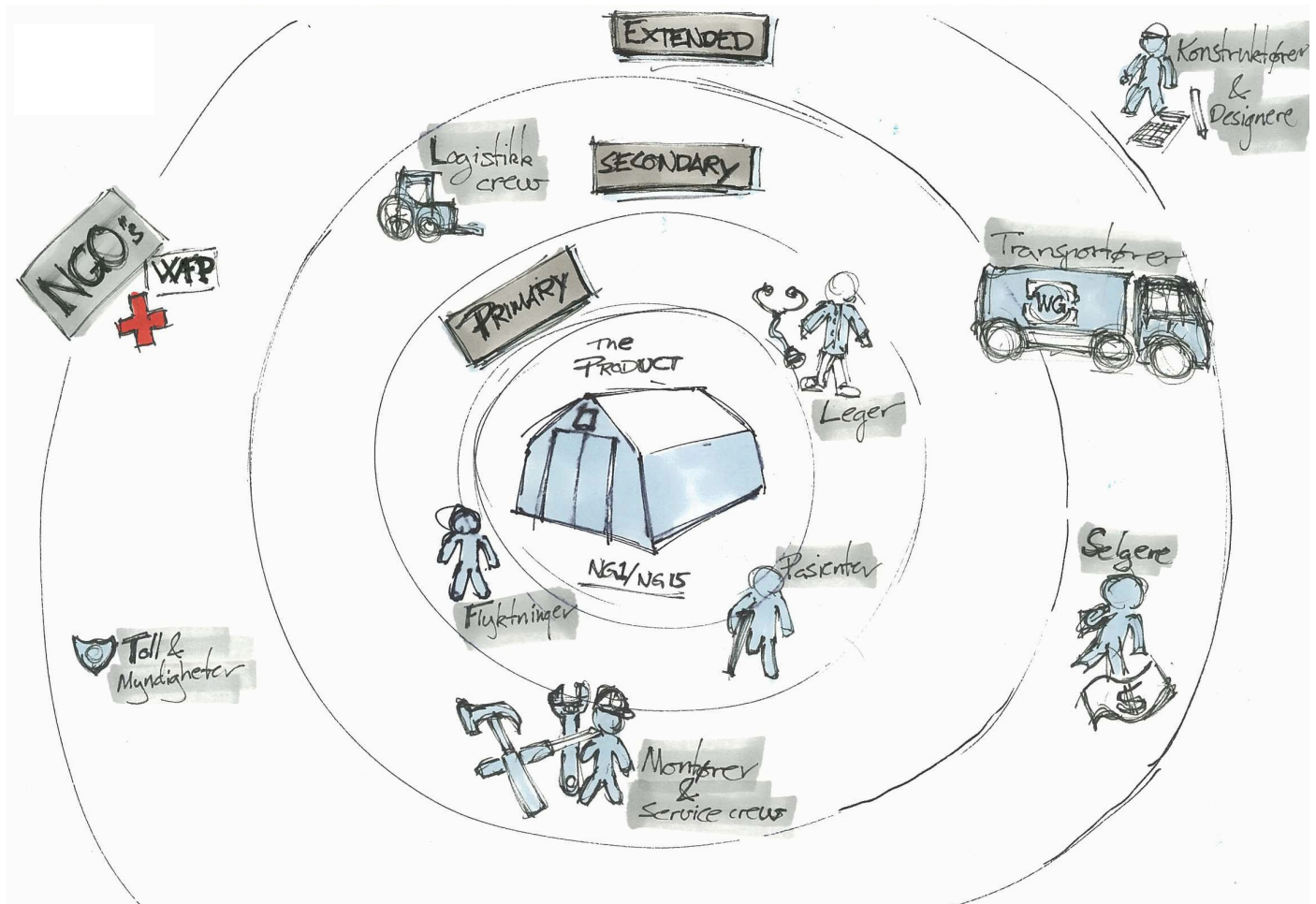
The most central advice occurring in several designer tool kits for this setting is to focus on the users. One needs to define and involve the users who are important to the solution under development. Depending on the situation, this can mean both secondary and primary users. To experience and participate in facing the challenges presented to users in this context, is vital to get a complete understanding of their environment. Participatory design is a recurring theme.



Context Brainstorming

Grouping topics

Words are grouped in topics to easier identify what is important to a new hall system, and in what way different topics influent each other.



User Groups

Selected Focus

Many different types of users are in contact with a hall system in some way.

A hall system has its primary users in the form of patients, doctors, refugees and others taking shelter, also including stored goods. These people are to a large extent unaware of the design of the hall, except its ability to isolate from outside elements. As long as a hall stands, and deliver stable conditions, their main needs are met.

The users in the secondary level are the ones most available for testing of new concepts. They are also the ones who have the most influence on the effectiveness of a hall system and to ensure optimal deployment and use. Secondary users

such as the assembly crew are in other words given the most attention in this project.

Secondary-user needs

Ideally one should study the users in their natural environment, and create scenarios based on this. Aid crew in Africa is substituted with the construction crew in Bergen, yet this will still provide valuable insight. A qualitative study of this group is performed to be able to create a programme of requirements with roots in reality.

Based on interviews and also on my own experience as a construction crew, many problems became apparent to me, where otherwise I would have easily neglected those situations without some sort of field experience.

CONSTRUCTION CREW

TEAM COMPOSITION:

- 1 senior crew chief
- 2 senior construction workers/ crane operators
- 3 - 5 junior construction workers

What tools are available when the system is being assembled? When batteries was emptied out, power tools became dependant on portable aggregates, or pure manual labour became the solution, stealing a lot of time.

4 meters is a rough estimate on what length of a component being practical to handle at the construction site. At rural locations, hoisting devices and heavy machinery are unavailable, making heavy components even more cumbersome. When working in the heights, weight becomes even more of an issue.

Standardised components such as nuts and bolts makes life easier. Simple and fool-proof technical drawings and product guides are needed. Where snap-fit solution and machine-less / toll-less assembly is possible, it's all to the best. Butterfly bolts saves plenty of time.

The assembly crew in rural Africa can run into language barriers, making intuitive assembly important.

In Europe, small and trained teams are available. In disaster aid at sites in rural Africa there will normally be present an experienced crew chief, but the rest of the work team will have as much experience as I did the first day of construction, even though plenty in numbers.

Errors made during assembly and poorly planned logistics steals as much time and effort as a bad technical solution will do. The importance of taking into account all the surrounding elements of a hall system cannot be stressed enough.



Steffen & Joar
Construction workers
20 years old
High school graduates

"When climbing 15 meters up in the air.. then it's cool!"

"Those steel structures are mad heavy to carry around"

"A cut on the finger? Meh.. No biggy, I'll just tape it and I'm good to go."



Stig & Leif
Construction workers
45 years old
Senior crew chiefs

"You have to train a bit, so you can handle the ruff environment."

"You - go there, and you, -you go over there!"

"I can't wait untill we get them new cars, hope the doors will still slide upwards or else we'll have no shelter.."

THE NECESSITIES OF LIFE

End-user Needs

Maslow's hierarchy of needs states water, food and sleep amongst our most basic needs. Next follows security of body, resources and health along other needs. In the context together with NG1's that can be interpreted as a stable power and water supply, durable shelter and a suitable food storage.

Power Supply

Diesel aggregates is by far the preferred way of providing electricity in rural camp sites. UNHCR sponsored diesel reserves makes nobody worry about saving power.* No culture for "turning off the light" when a room is empty can put RWH in a difficult position, where rationing is important.

Windmills and other ways of generating power are interesting options, if the technology can adapt to the demands coming from the logistical challenges in this setting.

The amount of power needed varies. Typical user needs range from charging mobile and sat-phones to keeping a field hospital or food storage operating continuously. Air conditioning and heating are luxuries, but are often also necessities.

**From interviews with H.N. at WGH*

Shelter

Shelter is provided by structures ranging from the more temporary tents and tarpaulins to more semi permanent brick houses. Insulation and protection against the elements are important, but also privacy

and dignity in a stressed situation factors in.

Spare parts and the opportunity for repairing one's equipment can often be more or less unavailable in a camp setting. Low quality equipment will eventually break down, and leave families vulnerable against the elements, even though they have been taken care for, according to the statistics of camp managers.*

**From interviews H.N. WGH.*

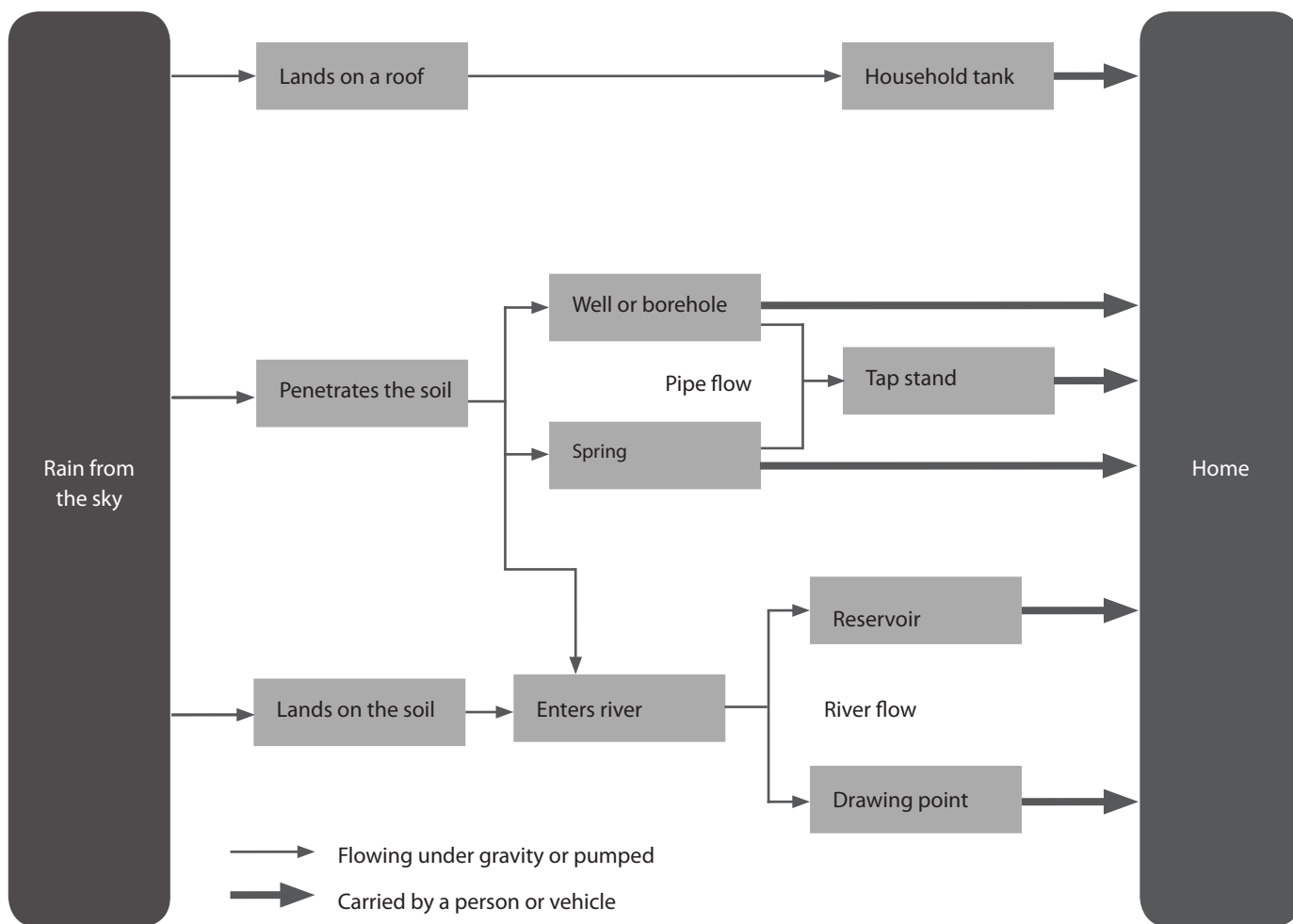
Water Supply

At most refugee camps water is often provided from bore holes or with bowsered water. Depending on local water table, having access to water is either not an issue at all or *the* source for concern in a camp.

Dadaab in Somalia is a refugee camp supporting 500 000 people. The water table have only sunk around 15 cm during the last 20 years and makes water supply an issue not receiving much attention.* In this situation, sufficient water might be easier provided with enough bore holes. Care must be taken with sanitation, as not to salinate the ground water and render it undrinkable.

High quality water is needed for drinking-water, food preparation and basic hygiene. If relevant, other tasks such as cleaning, care taking of live stock and agriculture have less demand on water quality.

**From mail correspondence with NRC crew, Eric Nyawara.*



Common rural water supply techniques. Figure from Martinson, 2007.

How to get access to water?

Groundwater, either from the surface or from bore holes, is the most common way of accessing water. In developed countries this is accessible through piped systems. When present in developing countries, water pressure and quality might be variable. RWH enables access to water at the point of use, just as with tapped water, clean and safe.

Gathering water can involve many hours each day to be able to cover the demand of a family. The time lost is often on the expense of the education of the children in the family, and mothers ability to care for their kids. An important factor of this puzzle is the gender debate which is very much linked to how a family is providing their water supply.

Excessive exploitation of ground water might lower the water table. Salinization of the groundwater

might happen and make the ground water unusable. This is a problem often related to poor sanitation coverage or flooding in coastal areas.

Both bowsered water and bottled water are effective means of distributing water, but extremely expensive. These are two of the most common ways of providing potable water during the initial stage of disaster aid.

In most camps where groundwater is available through bore holes, this provides a safe access. The groundwater table is diminishing in most parts of the world because of excessive exploitation. Please see appendix for statistics. If groundwater is available in abundance, a new tapping station will often provide a simple access point, though demand will often surpass the replenishing rate.

Getting Experience With Construction



NG3 - ASSEMBLY AT BONTVEIT, BERGEN

Supply chain

- Base of operations at Laksevåg, Bergen.
- Vans are means of transportation and contain all the necessary tools used in the field.
- Trucks, lifts and other heavy machinery are necessary when assembling NG3.
- Pallets with pre-welded modules arrive from Polen,
- ...rarly in a practical way, with regard to construction, bottom-most component is needed to begin assembly...
- Heavy modules are to a large extent carried around the site by hand, to prepare for final assembly.



Important accessories are:

- Protective shoes, helmet and reflective clothing.
- Thermos with hot beverage.
- Light diesel generator.
- Specialized drills and drill-bits.
- Nuts and bolts delivered in crates
- Heavy machinery
- Field generators



Key experiences made from Bontveit

- Packaging and even building materials is used as assembly tools. "if parts don't fit, you make them fit!"
- Internal logistics at a construction site can be a manual labour-nightmare.
- Time consuming adjustments are necessary on many parts, because of a complex network of parts that are meant to fit together.
- Time consuming manual attachment of nuts and bolts are necessary when batteries for power-tools are empty.
- Machine drawings are often not detailed enough, forcing crew to guess at certain points, risking a lot of correction-work later.
- Constructors and designers have seldom much field experience, if so only as observers, not as crew members.
- Good morale and atmosphere within the crew makes demanding manual labour less tiresome.
- Heavy machines are a blessing..!
- Experienced crew chiefs are just as important!



The crew chief hands Steffen a bolt while attaching a cross bar 15 meters up in the air. Security is always in focus.



Details of the NG1 hall system. Many practical solutions based on tried and tested principles throughout the structure.

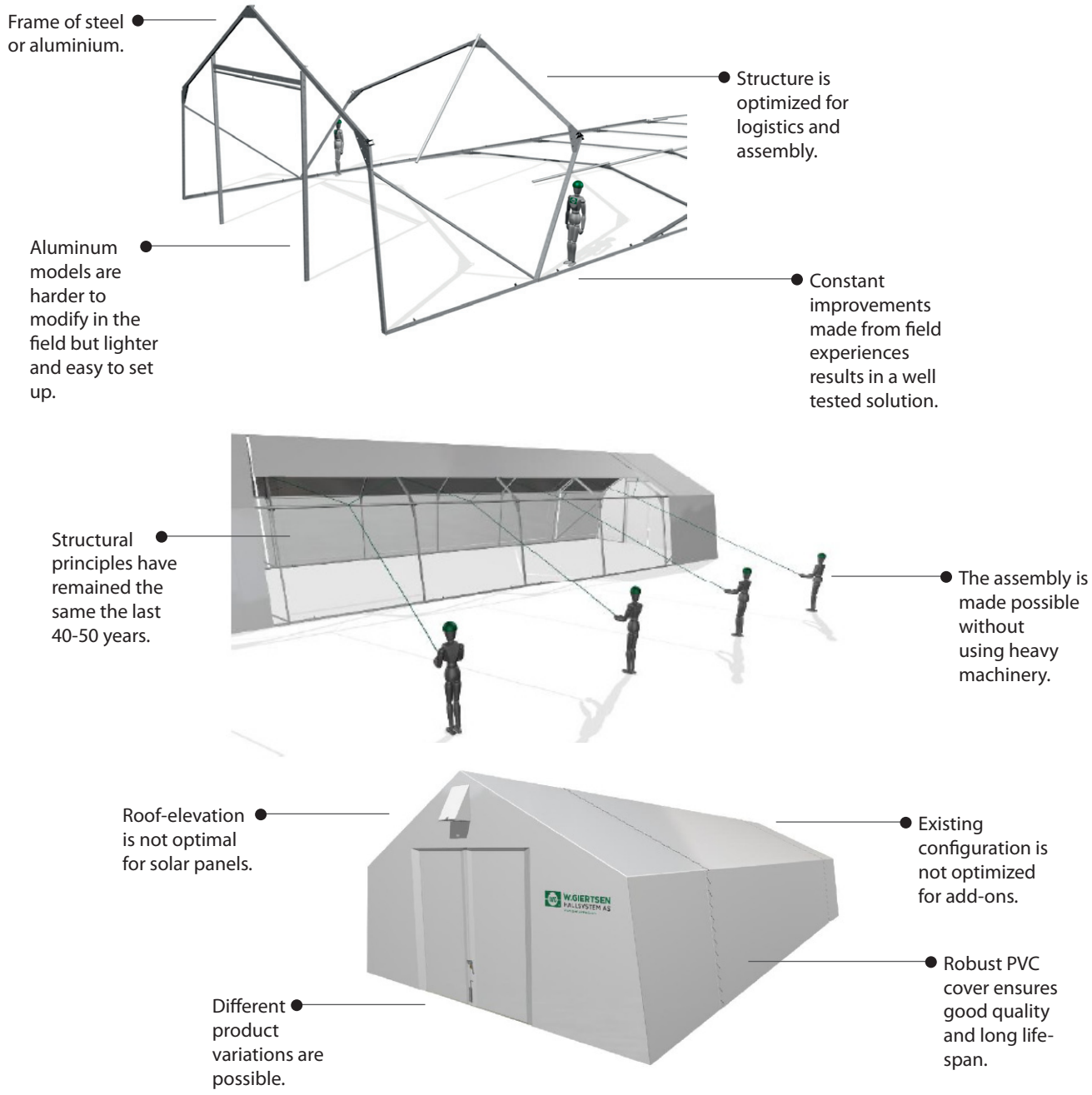
NG1 - A CLOSER LOOK

Lightweight and flexibility

NG1 can be delivered with aluminium frame, drastically dropping its weight down to under 1900kg, instead of a steel version at 2750 kg. Weight is important along with the ability to be efficiently packed in containers.

In aid and relief, response time is crucial, making transport by air a necessity. The ability of installing this hall without the aid of heavy machinery also plays a vital role for NG1's role as a practical shelter option in disaster areas, as well as remote refugee camps located in rural areas.

NG1 is designed to be easily disassembled and rapidly redeployed elsewhere at a later stage. Long-lasting quality is one of WGH's selling points.



Summary of impressions on NG1. Renderings of NG1 are gathered from the NG1 manual.

Assembly of NG1

An important difference between NG3 and NG1 is its machineless assembly. The load bearing beams are attached while on ground, by the same principle as with NG3. Where NG3's cross beams must be hoisted in place, the cross section is linked to the foundation with a rotational joint. This design eliminates the need for elevators and hoisting machines.

When deployed, NG1 is able to withstand rough climate. An optional inner tent will provide insulation.

NG1's simple construction makes it well suited in its intended environment, since a short setup time is key in a rough environment. A crew of 4-6 people can assemble one NG1 within 6-8 hours.

Stakeholder Analysis

Relations

In comparison to users, stakeholders do not necessarily have a direct contact with the product, but will still have a great influence on its level of success.

Several groups influence each other as much as they do directly towards WGH. Demands coming from camp organizers are directly affecting choices the designers can make, and political choices made at national level affect what products that can be relevant to produce. Governments, NGO's and camp organizers influence each other, so do many of the other involved stakeholders.

Cultural differences

Health and security regulations differ depending what country you work in. WGH has stated that their workers including local contract workers must adjust according to the active set of regulations within WGH. Workers not affiliated with WGH during projects are not their responsibility.

Camp planning and hall systems

Camp organizers have the power to include WGH in the strategical planning of a refugee camp. With this

option, a large saving potential could be realized with a more effective camp structure.

Political influence

Political climate and local decision makers influence what technologies that are acceptable to invest in. Important these days are the transition into more sustainable energy sources, enabling WGH to become a leading supplier of solar panel driven electricity.

Reputation amongst clients

Behavior and skill level of the deployment crew affect WGH's professional reputation outwards to clients. Experienced crew chiefs are vital during assembly of many of the hall systems, because of their complexity and more. NG3 is such an example. Poorly made construction work will directly influence how clients and end-users experience the quality of a hall system. Practical consequences can be poor isolation, unstable structure during wind loads, a rugged look of the finished product and more.

NGO's / Customers

Need pre-tested and plug-and-play solutions. Focus on cost vs. usefulness. Is new technology cost-effective? Idealistic gains such as sustainability is considered a bonus, not key.

Government

Political challenges with refugee camps being permanent.

Customs

Organic material is not popular. Might limit introduction of other materials.

Logistics partners

Weight and volume is an issue. Prefers standardized containers and pallets.

Local assembly crew

Time and effort needed for construction influent their capability to perform. Language barriers and even illiteracy might be an issue.

Union organizations

Health and security regulations.

Camp organizers

Is responsible for maintenance and daily operation of the hall systems. Desires durability, flexibility, ease of modification and simple maintenance solutions.

WGH shareholders

Turnover. Public impression of WGH through media. Market shares.

Material Suppliers

PVC from Protan, Poland. Steel and aluminium components are also prefabricated in Poland.

Production partners

Factories located in Poland, makes close collaboration necessary. Protan have an R&D departments located in Norway, enabling this collaboration with greater ease.

NOREPS

Keeps a readily available stock of aid equipment.
Long lasting contracts with both governmental agencies and NGO's are vital for WGH's position in the market.

Internal Stakeholders



Construction crew



Engineers



Management

External Stakeholders



Union regulations



Society



NGO's



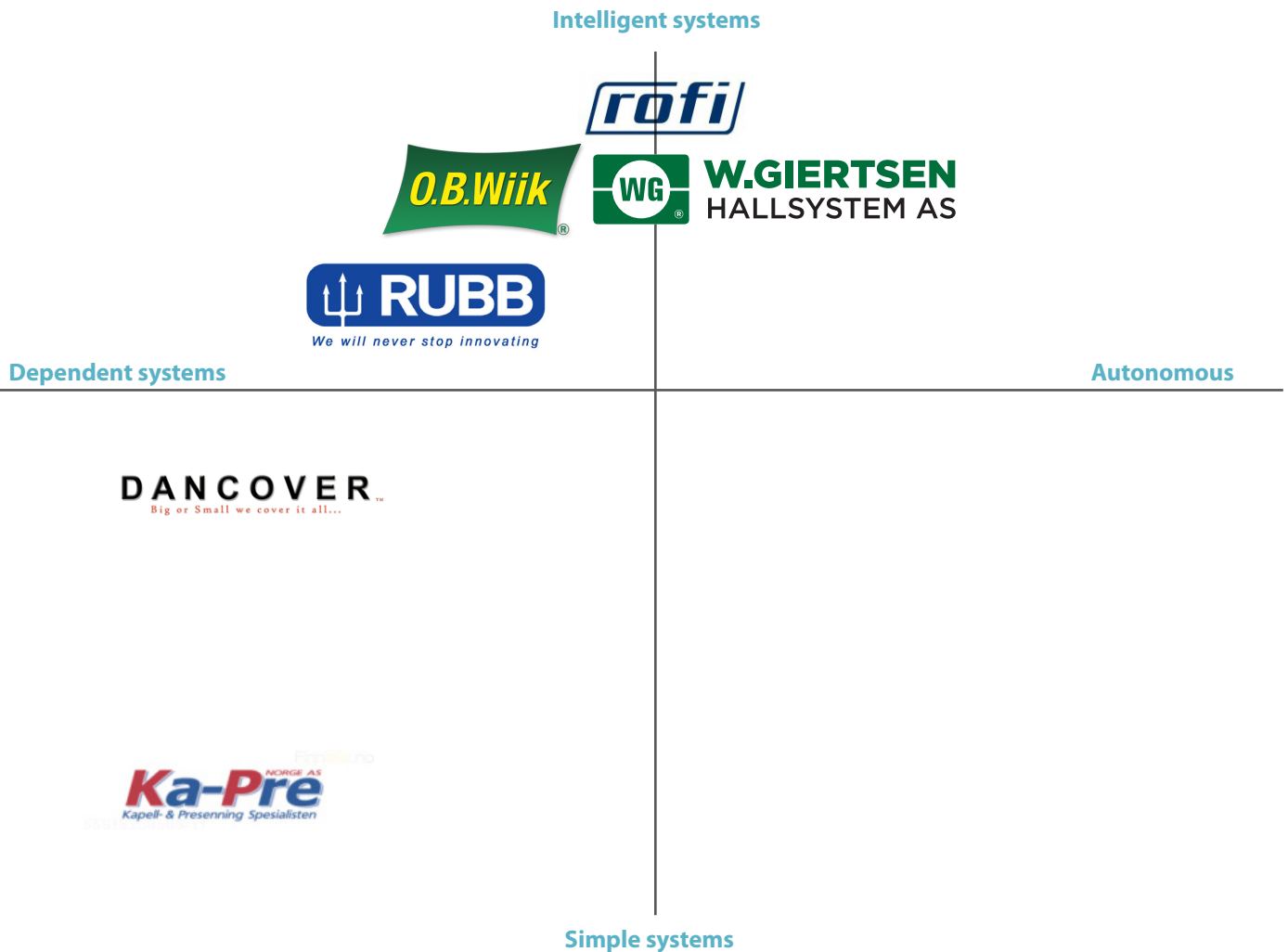
Camp organizers



WGH shareholders

A selection of stakeholders that have an influence on WGH and vice versa.

The Competition



Market segments

PVC hall systems with steel skeleton are an efficient and popular solution for temporary storage and shelter needs. Many hall systems are of a quality, lasting much longer than would be the need for anything temporary. This has made it profitable to create re-locatable systems, suited to be assembled and dis-assembled in an easy manner.

Rofi stands out as a producer of intelligent hall systems with innovative designs, where the others are holding on to conservative configurations. Rofi's portfolio consists of smaller systems compared to Rubb, O.B.Wiik, Dancover and WGH.

Products aimed for aid and relief must in most occasions be independent of heavy machinery

during setup. Weight is also an important competitive edge in this segment, when most regional transportation is done by airplane. WGH is at the frontier on saving weight through the use of aluminium.

Complex solutions, offering lighting, insulation, ventilation and more, can be ordered from several suppliers such as Rubb and O.B.Wiik. Systems not present are solutions that are autonomous. While solar panel technology has come a far way, this has yet to be a popular trend. Rainwater harvesting or wind powered solutions are not present in the market .

Both amongst complex and simple hall systems, there are room for autonomous systems in the market. WGH has the opportunity to become a leading actor within this segment.

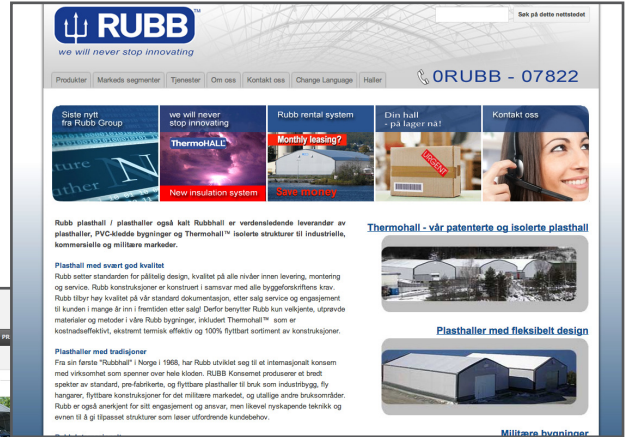


A selection of products produced by competing brands, show the span of different ways PVC and metal constructions are delivered. Small but subtle differences separate the selected companies. A domestic focus with tailor made but simple products is coming from Ka-Pre. Rubb and O.B.Wiik produce complex and functionality-packed solutions, but not self-sustainable. Modularity for simple setup and service for aid and relief products is a focus area for some of the designs.

Company Profiles

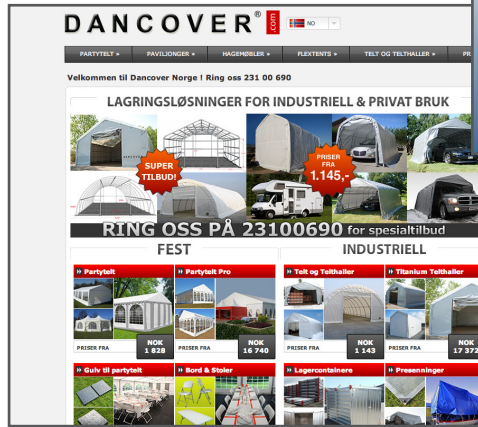
Rubb

Similar lineup of products as WGH, caters to similar market segments. Also an international supplier.



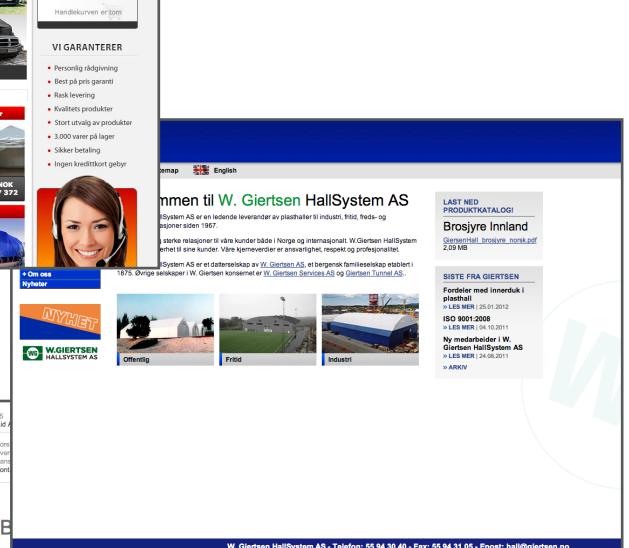
Dancover

Local or Scandinavian focus. Caters the private market.



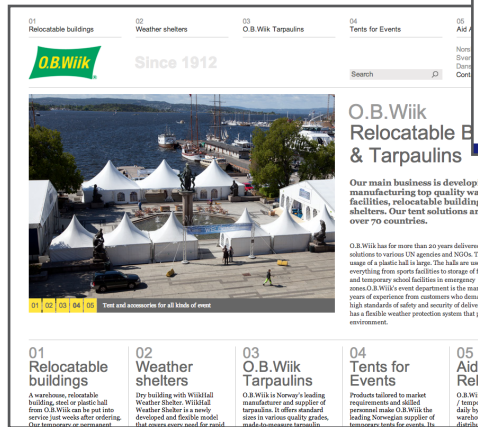
WGH

International focus with their slogan "We Cover the World". Most deliveries is business to business, not to the private market.



O.B.Wiik

International focus and similar product range as WGH. Many similar solutions as WGH.



Ka-Pre

Offers more low-key solutions. Local, Norwegian focus.



Several of the companies have a matching lineup of products and solutions. Hall systems are in general constructed similar ways amongst the competitors. Minor differences such as structural weight or improved logistics are what separates

the competitors. On a visual level, the quality of web pages and external profile is something that separates the different companies.

State of the Art of Hall Systems



Assembly
Need for power tools for big halls, smaller types requires only manual labour. No need for "air born" assembly with smaller halls.



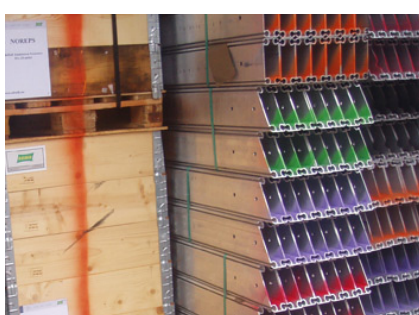
Cover-types
Top mounting, as large rolls, or deployed on one side to be pulled over as a blanket.



Structure
Similar metal foundation. Steel and aluminium. Weight on smaller halls differs from 1600 - 3000 kg.

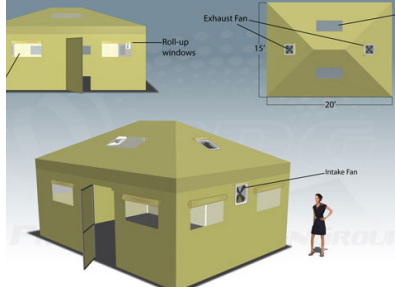
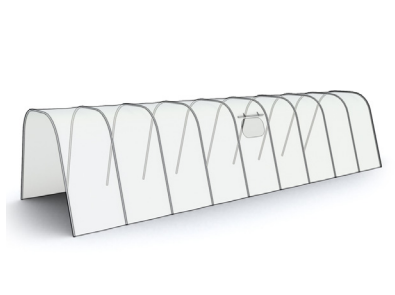
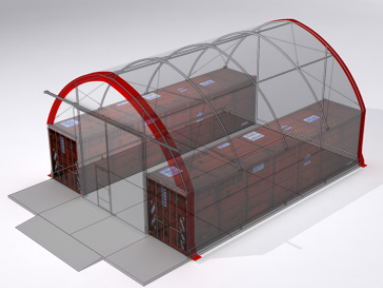


Modular halls
Expandable, thanks to PVC blankets of only 4 meter a piece. Pre-fabricated metal skeleton modules can be further expanded.



Logistics
Color-coded modules differentiates one hall from the other, but no color coded assembly within a hall is used.

Existing Products: Tents



RELIEF

Although many different shapes and structures are present, popular designs are quite similar to NG1 and NG15. A great variety of suppliers are present in the market of disaster aid equipment. NGO's will

normally dictate the properties of shelters used. As a result, new designs can be difficult to introduce into a conservative market.



CAMPING

Where a smaller range of contractors dictate the demands in disaster aid, the consumers will dictate which design will remain in the private market. A great variety of tent and shelter designs are present.

Solar panels are starting to make their presence. Glamping is a rather new trend, bringing luxury and the comfort of your home into the wild.

A CLOSER LOOK ON WGH

Technology

Solar panels are considered to be a new technology in connection with refugee camps. Both flexible and rigid frames are available. Limited access to producers with flexible solar panels is a hinder.

PVC is commonly used in temporary constructions, such as soft-wall buildings. Aluminium and steel are used for framework.

Production

PVC sheets are prepared in Polen by Protan. Steel and aluminium bars are also pre-assembled into modules on larger halls.

Logistics

Modules are shipped directly to location. Focus on space efficiency rather than packing components to make on-site assembly efficient.

Assembly

Skilled construction crew makes assembly efficient.

Research and development

Small but flexible organisation.

Improvements on the design is also performed during active field deployment.

Experience from Bontveit shows that there is a potential for improving the dialogue between the deployment crews and the design team. Knowledge transfer is a challenge.

CHALLENGES

Copycats within the industry is a recurring problem. This effect is also noticeable within camping and sports equipment.

New technology can threaten existing service providers.

Raw material costs can change, making some designs less profitable.

Competing brands can launch new designs ahead of WGH.

Most concerned with Norwegian competition. Foreign companies are not considered a threat.

MARKET TRENDS

Market is changing towards sustainable technology (*ref. camp toolkits and interviews at WGH, Bergen*). Rainwater is so far not an obvious choice for providing water to a refugee camp. Solar panels have an acceptance both from end users and camp organizers.

The politics in disaster aid are changing. When camps such as Dadaab in Somalia were created, officials would not accept that this was to be a permanent solution. A camp will rarely stay only for a short time in reality. The consequence of this is that systems and products delivered to maintain a camp is designed to last much shorter than actually needed. Solutions that are viable during a short time frame is selected.

A diesel generator will be effective in many situations, if not solar panels can operate long enough to save costs, while delivering a sustainable and reliable power supply.

Facing reality, politicians and decision makers can manage camps in a more efficient way. This development make solar panels and rainwater harvesting technology viable. A need for autonomous buildings is present. Self sustainable hall systems will make setting up a camp less dependant of a supply chain, in a setting where infrastructure is non-existing.

The longer a camp need to be present, the greater the savings. Where short term camps are needed, autonomous systems can be rapidly redeployed and will provide the sheltering needed without depending on outside support.

Autonomous hall systems are not to be seen in the market to any noticeable extent. Having a combination of efficient logistics and smart structural solutions, WGH can combine this with a new perspective on equipment delivered in disaster aid. This will give WGH a valuable advantage over their competition, and will contribute to separate them from other producers, giving a needed edge when negotiating contracts.

Convenience and most importantly cost are criteria that determines the choice of applied technology at refugee camps. More recently solar panels and other sustainable technologies are becoming cheap and available enough to make them profitable, given favorable conditions. It is the savings potential that motivates the introduction of the new tech rather than idealistic motives. This shows that if sustainable camp organization with autonomous constructions are to become successful, the savings potential needs to be made clear.

SUB-CONTRACTORS

Protan --> Water storage equipment, easy access to auxiliary items.

Noreps as client, equipment related to water storage is in place within an existing supply chain.

The availability of supporting equipment enables WGH to provide the missing piece in the rainwater puzzle --> harvesting system --> makes the NG1 more competitive, while retaining its original benefits from efficient logistics and simple assembly.

Extra components from Protan can be added to form a complete RWH system.

SWOT - Summary of an Analysis on WGH

Positives

Negatives

Internal

Strengths

- Knowledge and experience about solar panels and relevant technologies.
- Long traditions with PVC material as core knowledge.
- Small but flexible organization (WGH-department) enables fast changes to product lineup, even during deployment for an active order.

Weaknesses

- Some disconnection between production, research and development and assembly, providing challenges for effective knowledge transfer within WGH.

External

Opportunities

- Refugee camps are now more politically accepted to be lasting for longer durations than 6-18 months. This present a business opportunity for WGH, where self sustained hall systems become profitable. WGH can become leading actor within this segment.
- Rainwater harvesting is a so far untapped resource within this segment.
- Camp management/ setup can be included into WGH's portfolio, strengthening the efficiency of their solutions.
- Competing brands have a strong focus on design for manufacture, enabling WGH to gain an advantage when also using a user-centred design process while developing new systems.

Threats

- Competing companies are copying new designs.
- Political choices can be made making sustainable hall systems not fitting for refugee camps.
- Camp organizers choose less effective solutions, limiting WGH's ability to influence planning and to better utilize WGH's lineup of hall systems.
- Raw material prizes can rise, making aluminium hall systems too costly for their intended use.
- Competing brands can launch new designs, differentiating themselves ahead of WGH.
- Sub-contractors might go out of business.

From analysis to project definition

WGH has the opportunity to establish itself as a leading provider of sustainable hall systems. This market is on the rise thanks to changes within politics and a changing perception of what that is profitable.

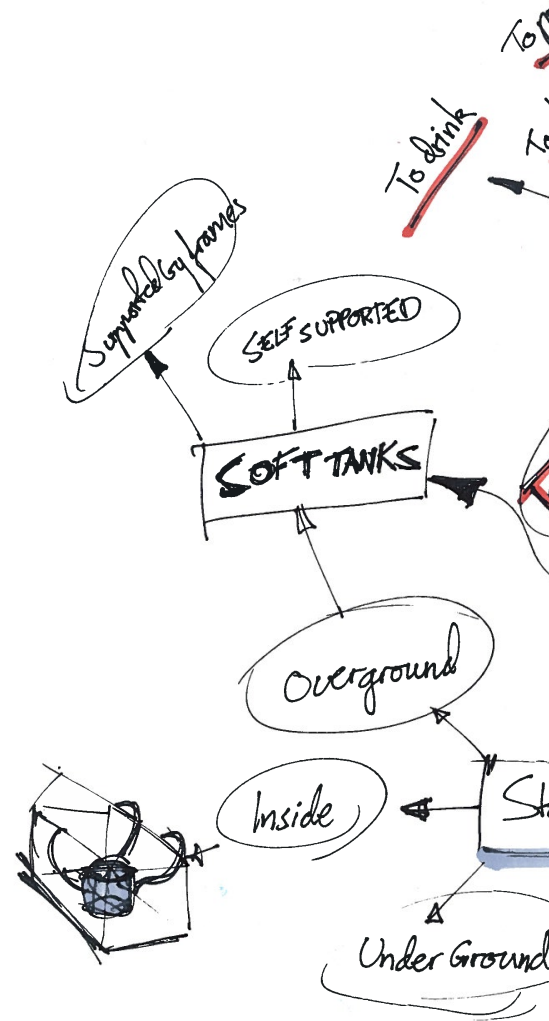
Rainwater harvesting is one of those technologies aiding in providing autonomous hall systems along with solar panel technology. Ventilation is also an important feature, making storing of goods and food a more sustainable practice.

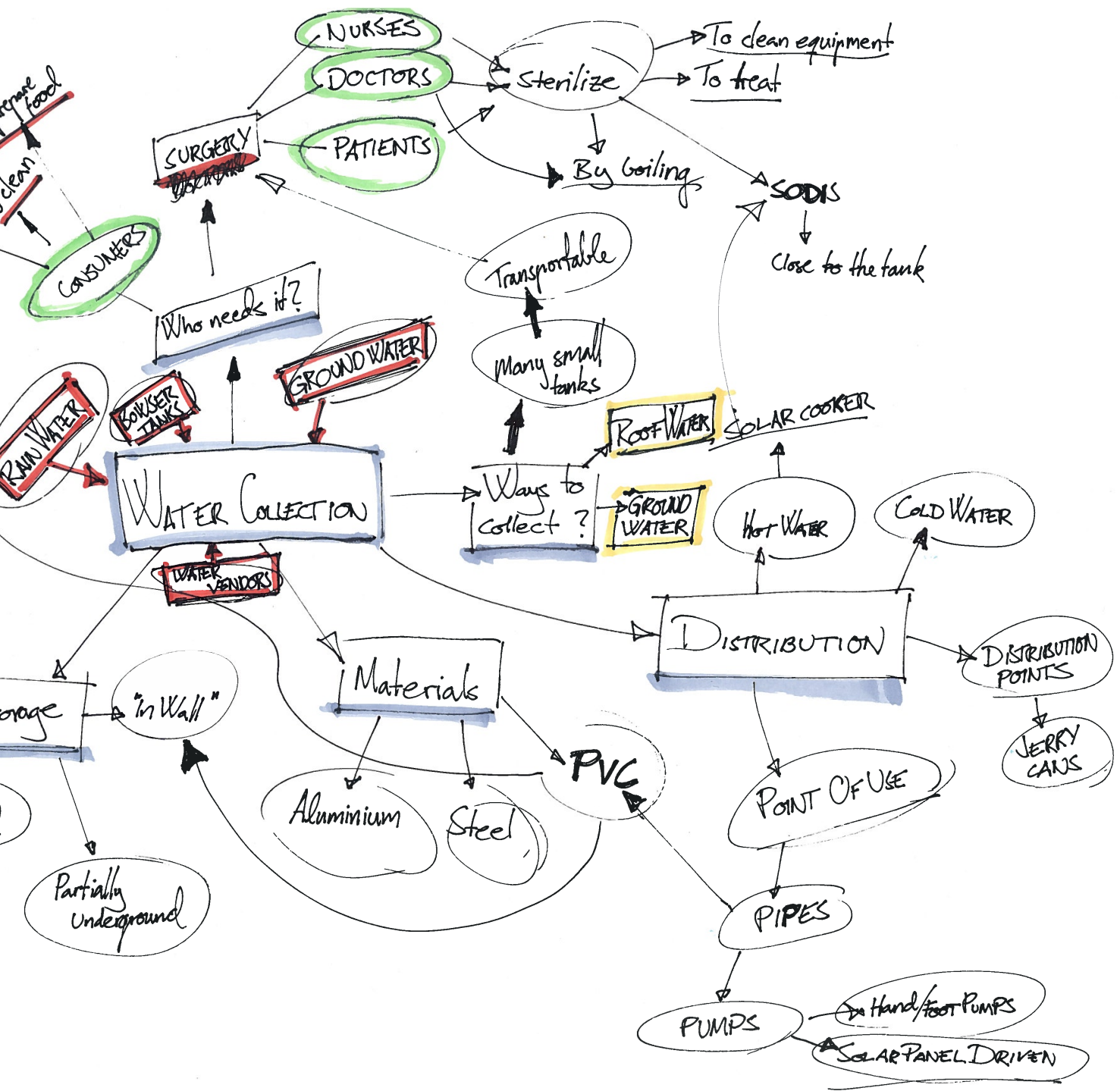
RWH is a technology that could further differentiate WGH from its competitors.

Possible project topics is listed in the following chapter, based on insight gained in these first chapters.

PROJECT FOCUS

In this chapter the direction for this project is chosen. Arguments are presented to explain this choice. A project matrix gives perspective on the different options. On this page a mind map of the selected topic is shown.





Problem Definition	Topic	Context	Goal
Only smaller halls are available.	Design for assembly	NG3 in Africa, refugee camps and cargo hubs.	No need for heavy machinery.
Manual assembly is tiresome and straining work.		NG1 in Africa, rural camp sites	Quicker assembly.
No/ unpractical access to potable water.	Adding functionality/ adding an external system.	NG1 / NG15 / (NG3) in Africa, refugee camps, small and large scale.	Integration of RWH system.
Poor access to sustainable energy sources, that are economical on long term.			Integration of solar panel system.
Batteries/ power supply can't be stored in too hot conditions.			Practical storage of batteries
Watertanks are large and heavy.			Practical storage of water
Products does not sustain re-use.	Logistics	NG1 / NG15 in Africa, temporary (6-24 months) refugee camps	Adapting hall systems for re-use and re-allocation.

A project matrix is used to decide the focus of this project. Clustered in topics, the different problems are grouped together, providing perspective.

From Problem to Goal

These problem definitions are a summary of the challenges made apparent through the analysis of WGH. By comparing these problems against each other, it becomes easier to spot which projects that can have more potential than the others. All of these problem definitions would make rewarding assignments, but to focus on hall systems as a whole becomes far too complex. A multidisciplinary team would be needed and many more hours. By narrowing down this project, it is possible to create something tangible!

In 2011 I wrote a review article concerning design for aid and development related to RWH. This gave me a good foundation to contribute on a more thorough level on this topic, compared to if I would pursue other goals. With the confidence I had on the potential for RWH combined with the other reasons mentioned here, the choice for a project focus became in the end quite clear.

When undertaking a large and undefined project, there is a lot to gain on debating its focus. It is a comprehensive and tedious process, but rewarding when done properly.

Project Outlines

Criteria for choosing project focus

- WGH have a strong knowledge about new technologies such as solar power, ventilation. They already have a good foundation of skills about structural optimization of PVC/steel halls.
- WGH has a desire to increase their competitive advantage for the aid and relief tents.
- A master thesis can either make incremental improvements for WGH, or aid in gaining new grounds for the development of their future.
- A focus on a new technology not present in their current portfolio, but still very much within WGH's core values, can have a positive and noticeable impact.

Based on these criteria, the assignment topic is chosen to be "Adding functionality/ external system" with a focus on RWH.

Debate on the project focus

Coming to this conclusion is an important contribution from this thesis. It has been taken into account the findings from the external and internal analysis.

Solar panels can have a massive impact on hall systems in the future. The choice to let this technology receive less focus in this thesis is a conscious choice. An opportunity to provide new insight by focusing on RWH outweighed the option of instead creating a more detailed system surrounding solar panels.

When a focus on autonomous hall systems is given, the following chapter will further discuss why it is viable to include RWH. To leave out this element would be to leave out a large potential. The benefits of improving the access for potable water in this context is too valuable to leave out, given how available it can be when appropriate equipment is used.

Insight used from the analysis

The external analysis showed that there is room for this technology within this market.

The internal analysis gave many insights on where the user-centred process should focus to design a best possible solution within the frames of this project. The secondary users will have certain elements of a RWH system that is important contact points. The end users have other contact points. When these points of interests are identified, it becomes much easier to create solutions that makes sense without including unnecessary features that might end up being used in the wrong way.

Generating Ideas

Workshop

With a local chapter of Engineers Without Borders based at NTNU a workshop was held. This current meet consisted of an introduction to the different problem definitions shown on the opposing page. Integrating RWH systems was chosen for the topic for a brain-writing session (Liem 2006 and Curedale 2012).

Post its

The basic elements of a RWH system is chosen as main topics to start the idea generation. As each idea is created it is put in its relevant pile. Input from the workshop is included here. This gives a good perspective on where the process is heading. To organize the ideas created at an early stage is important to be able to connect all the dots of a complex problem. (Post its with initial ideas are available in the appendix.)

Re-defined Design Brief

Design Brief

Design of a rainwater harvesting system that can be integrated on WGH's hall systems. The option of including solar panels or other auxiliary systems is relevant.

Must

- Be able to collect, filter, store, and distribute rainwater.
- Easy assembly, with regard to time needed.
- Low maintenance.
- Capacity to handle heavy rainfall.
- Water-quality with regard to potability and palatability.
- Parts that can be replaced by using available techniques.
- Fit together with existing/ future range of auxiliary systems.

Should

- Be expandable/ scalable to different hall systems.
- Take advantage of WGH's production capacities and core competencies.

Could

- Cater for different types of water sources.

Programme of Requirements

Important Factors

- Adequate amounts and just distribution amongst end-users.
- Ensuring local accept of water standard, both being potable and palatable.
- Time spent, distance covered and also safety and ease of operation are factors that determine if the solution is efficient.
- Safety connected to gathering of water, placement of water source, being culturally acceptable, also being available during the whole day, adaptable to local habits.
- Reliability, continuous operation.
- Sustainable, not affecting its surroundings in a negative way.
- Efficiency.

Criteria

Weighted on a scale of 1-5 in collaboration with WGH, these initial criteria shows important aspects for a new system.

- 5 Price
- 5 Weight
- 5 User friendliness
- 5 Logistical friendliness
- 5 Safety during installment
- 5 Safety during operation and maintenance
- 4 Capacity
- 4 Ease of assembly
- 4 Ease of maintenance
- 4 Production adaptability
- 3 Modular / Expandable
- 3 Scalable (to other hall systems)
- 3 Recyclable
- 1 Esthetics (form, presentable strong colors)

Key measurements

- Wall height needs to be at least 3 meters on larger hall systems, if lower the roof becomes an obstruction.
- 15 degrees slope on roof is preferred for using solar panels. 18-19 degrees slope is ideal for keeping panels clean with rainwater.
- 27 degrees is current design with 3.35 meter wall height.

Numbers are taken from interviews with Henning Nilsen at WGH.

RAINWATER HARVESTING

This chapter is intended to give the reader an insight on important aspects to creating a RWH system for a product such as the NG1, being deployed in a camp-environment.

This chapter includes

- Background on precipitation.
- Background on refugee camps.
- Background on water demand in camp settings.
- Social, economical and environmental aspects.
- Related existing products.
- Principal solutions of a RWH-system.

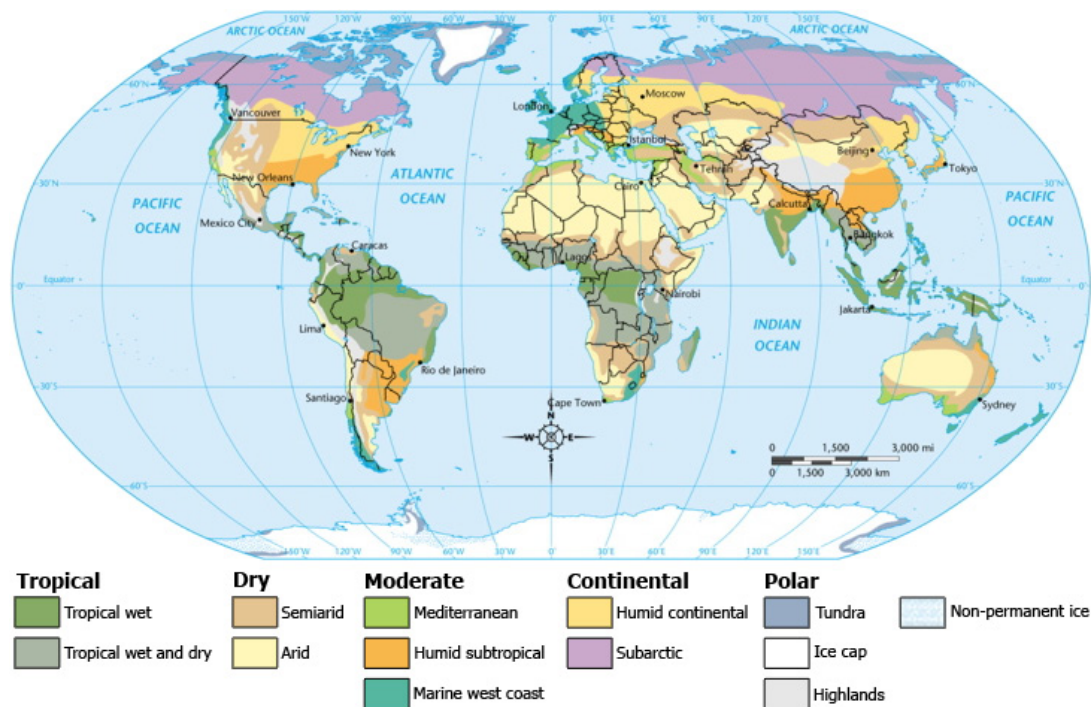
Rainwater harvesting is a large and complex topic. A technical focus alone is far from enough. Literature that describes how to implement such systems (Gould 1999) makes a point on how important it is with a holistic approach. Failure of some systems are often based on their lack of connection with the context of their use. An idea suitable in one village might not necessarily work in a second, even though similar climate and conditions are present. It is dangerous to base a design on previous experience alone (Hussain 2005).

This calls for a literature review on RWH. In addition available systems are studied. A system needs to be suited for a refugee camp setting so the demands for this context concerning water supply are debated. Interviews made with aid workers are done to give a real-life assessment about if this technology have a future in disaster aid. Interviews with suppliers of water storage systems are done to make sure the selected components of the suggested system can perform well in this setting. Interviews are available in the appendix.

A principle structure of a RWH system is given with comments on important features as a summary.

Insights from this chapter is included to further shape the programme of requirements.

Climate and Rainwater



Köppen climate classification, based on average annual precipitation, average monthly precipitation, and average monthly temperature.

When *not* to use RWH

Where cheap, sustainable, plentiful alternative supplies are already installed, or when extreme amounts or a high level of quality is demanded, RWH will be less appropriate. The climate zones each brings different intensities of rainfall and in this way also greatly influence what type of storage being necessary.

- Is current water supply considered inadequate?
- Can a RWH system be installed within a suitable time frame?
- Will sufficient catchment area be available?

In most of WGH's relief operations, these questions have answers in favor for RWH. The infrastructure of RWH will either way benefit any traditional supply chain of water. Storage tanks gives valuable capacity to obtain a supply-buffer.

Topic-related Bibliography

The works of Brett Martinson, Terry Thomas, John Gould and Erik Nissen-Petersen are famous amongst water professionals. Martinson and Thomas presents an updated work concerning roofwater harvesting in low-income communities with a focus on Sub-Saharan Africa. Gould and Petersen presents a more thorough view on rainwater catchment systems, both of them aiming at domestic supply.

UNISEF provide an extensive database on relevant statistics, please see the appendix for examples. UNHCR have available the Handbook for Emergencies, giving relevant info on water demand. The Sphere Project presents a minimum standards that should be met. NRC's Camp Toolkit brings insight on camp management and the role of rainwater in disaster aid.

Hydrological variability

Africa's climate is characterized by extremes. A humid climate can be found near equator with tropical and semi-arid zones in the middle of the region. The northern and southern parts present an arid climate.

The area with most potential for RWH is sub-Saharan Africa. It has a relatively plentiful supply of rainwater, with an annual precipitation of over 800 mm (measured in 2008). This comes on a highly seasonal basis, very unevenly distributed, making an effective storage solution important. Floods and droughts are frequent. Western and central Africa have precipitation with the extremes of variations and unpredictably, while the Sahara Desert is more or less without rain.
(UNHCR *Managing water*. p.178)

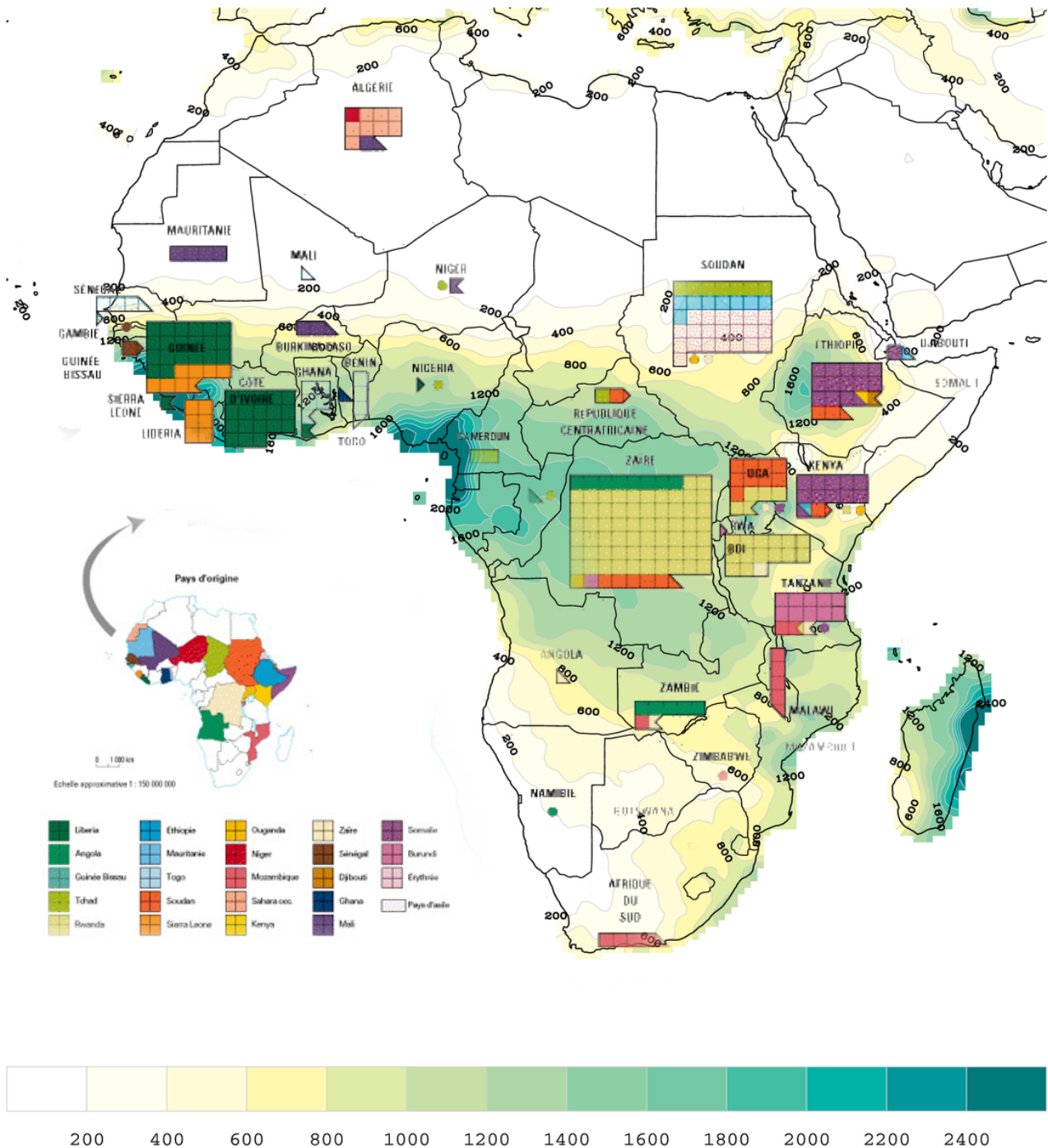
Water resources

Renewable water resources is only representing 20% of the total rainfall (2005 numbers). Renewable water resources per person fell from more than 16 500 m³ per person in 1960 to roughly 5 500 m³ in 2005.

Population growth have had a significant contribution to this change. Groundwater brings 15 % of the total renewable resources, while about 75% or more of the African population uses groundwater as their main source for drinking water. With renewable resources in short supply RWH becomes a viable option. Low access to water renewable water resources is only partially responsible for drought in some areas. Economical problems contribute as well to the problems with water supply, with large variations both within and between different regions.

With large parts of Africa being semi-arid or worse, 300 of the 800 million people in sub-Saharan Africa is struggling with water scarcity. This translates into access of less than 1 000 m³ of water per person each year.

Increase in population, heightened living standards combined with decreasing supply and poor water management results in a stressed water situation in Africa. Side-effects are amongst others food insecurity, poor health and damage to the ecosystem.
(UNHCR *Managing water*. p.179)



Location of Refugee Camps and the Availability of Water

This map is a combination of a graphical presentation of the average precipitation during a year and the distribution of refugees throughout Africa. Each colored block represent 20 000 people, and its color reflect the person's country of origin.

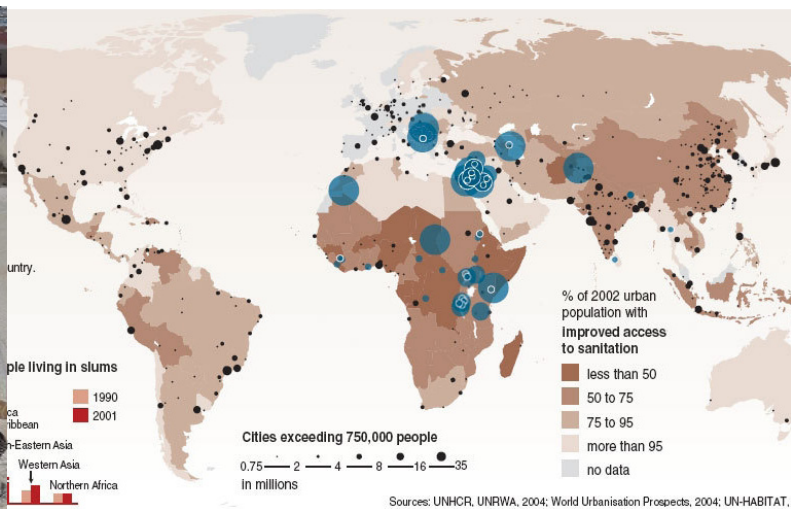
This is a very coarse comparison, yet still effective for visualizing the location of people

who lives in a camp environment, compared to how much water that is available at each area.

Even with as little as 600 mm of rain during a year, one can make a considerable contribution of the water supply, given a reasonably large catchment surface. The NG1 enables this opportunity!



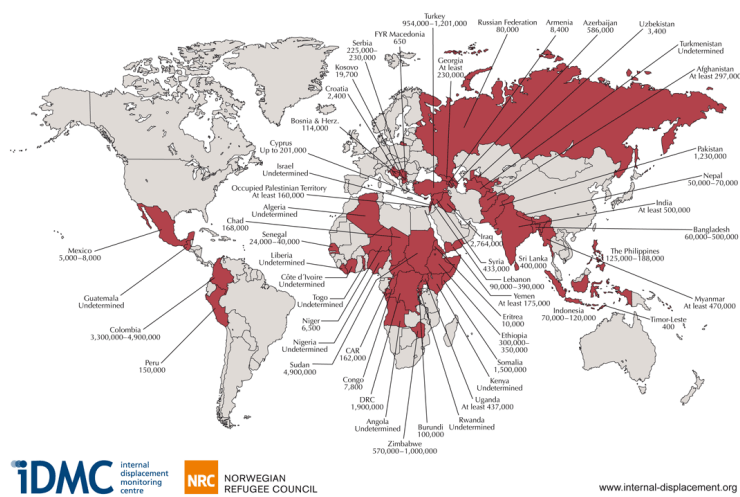
Syrian refugee camp in Turkey.



Locations of refugee camps worldwide and access to improved sanitation, 2002. Not including IDP's.



Darfur refugee camp, Chad



Internally displaced people, 2009.

Size and location

The circles in the top-right map indicate the size of each refugee camp ranging from 20,000 to 50,000 people, 50,000 to 100,000 people, and over 100,000 people. Also noted on the map is the correlation between cities with population exceeding 750,000 people and their improved access to sanitation for the year 2002. The picture below shows internally displaced people, with numbers and countries listed, the year is 2009.

There are "status-refugees" who try to obtain better rights, when IDP's often fall outside the security blanket of aid-operations. These definitions have important effects on the statistics and their real-life consequences. The two maps on this page illustrates the importance of looking at different sources to gain a realistic perspective.

Camps can be mapped out, but the number of people living in camp-like situations are high, and many of these people fall outside the aid-grid. (research paper UNHCR)

RWH and Politics

As we traverse villages with little water or sanitation we pass beneath new high-tension power lines that

deliver electricity to the boomtown of Gurgaon. In India, governments have long tended to prioritise large-scale infrastructure projects over small community-based solutions or inexpensive rural developments. For rainwater harvesting to work, it needs widespread government adoption, but the cheapness of such initiatives is, ironically, one aspect that makes them unappealing to governments, explains Saiphy.

"[Big] infrastructure projects have a lot of interests. They get commissions and everything. And all these small things like toilets, drinking-water wells, and all these things, they don't get you anything," he says. *

A short story like this shows that water supply is a challenge needed to be met at both local, communal level as well as on national, governmental level.

Problems related to water supply reach beyond just the task of gathering enough water. This means that only looking at where rainwater and camps exists is far from enough, but a good start.

* Retrieved at 18.12.12 from: <http://www.theglobalmail.org/feature/can-thirsty-india-bottle-the-monsoon/301/>

Guidelines for Water Supply in Refugee Camps

The Purpose

"...The main purposes of emergency water supply and sanitation programmes are to provide a minimum quantity of clean drinking water, and to reduce the transmission of faecal-oral diseases and disease bearing vectors.

A further important objective is to help establish the conditions that allow people to live and perform daily tasks, such as going to the toilet, and washing with dignity, comfort and security..."

(Humanitarian Charter and Minimum Standards in Disaster Response, The Sphere Project, 2000, P. 19)

In Real Life

All the numbers within the different guidelines are often a challenge to meet in real life. The tool kits for camp management both from UNHCR and NRC advises on taking use of RWH in water stressed situations along with water rationing and other measures.

In these guidelines, groundwater, surfacewater, bowsered water and water bottles are the preferred options. When surface water is used, water purifying tablets is the normal cleansing solution.

Guidelines instructs that a minimum of 20 liters of water per person should be available each day. This should cover personal hygiene and water for drinking as well as preparing food. This water is the vital amount RWH can be suited to supply. When viewed upon as a supplement, RWH becomes more viable than if it should provide the total demand.

Guidelines

Guidelines on water and sanitation in a refugee camp given in a brochure from UNHCR:

- 1 hygiene facilitator per 500 refugees
- Well located > 30 m from latrines and other contaminant sources
- Required water at feeding centres : 20-30 liters per person
- Minimum of 1 water quality test per 5000 beneficiaries per month and sanitary survey indicates low risk
- Water containers per household of 5 : 1 x 20 liters, 2 x 10 liters, 2 x 5 liters
- Required water at schools : 3 liters per student
- Primary schools < 100 m from water sources
- Required water at out-patient health centres : 5 liters per visitor
- Required water at camp administration : 5 liters per visitor
- Water quantity required for domestic use : > 20 liters per person
- Ensure gender balance in water committees
- One communal well or hand pump per 200 refugees
- Water points < 200 m walking distance from dwellings in a safe/secure location
- Required water at in-patient health centres : > 40-60 liters per patient
- Permissible faecal coliform content : 0 / 100 ml treated water
- Residual chlorine in disinfected water = 0.2 to 0.5 mg/liter
- 1 water tap per 80 to 100 refugees

Retrieved at 5/11/2012 from:

https://www.un.org/arabic/waterforlifedecade/unhcr_water_brochure.pdf

The Potential of RWH in Disaster Aid

Opinions from related literature

According to Martinson (2007), roofwater harvesting has a possible role both in disaster preparedness and in disaster relief:

- Typhoons/ hurricanes that knock out piped systems and pumping stations floods that pollute, silt-up or prevent access to wells.
- Earthquakes that damage all infrastructure and start fires needing water to extinguish (some tanks will survive a quake, whereas a centralised water system will probably fail entirely).
- War or civil unrest which damages pumping stations and reservoirs and may remove operating staff
- Oil-spills, river pollution and toxins that render surface sources unusable and sometimes also poison groundwater.

Martinson further says that there is no single RWH design that best fits disaster preparedness, although some designs do not match some emergencies. Underground tanks are inappropriate in the context of flooding and in some flood plains where houses are built on stilts, tethered floating jars have been recommended.

Domestic RWH on the other hand is not encouraged by Martinson because of the bulkiness and costly start-up expenses connected with storage. These opinions are made at a time (2007) when several flexible and cheap tank designs weren't available. An interesting question would be how this statement would change if introduced to for example *Bob -the Rainwater bag*.

Martinson continue to talk warmly about the opportunities for applying domestic RWH to supplement bowsered water in refugee camps. Here it also is suggested that it tarpaulin roofs could be hemmed up to form pseudo-guttering to direct run-off into tanks.



Bob - the rainwater bag, solves many logistical challenges connected to RWH.

The NRC Camp Toolkit encourage the use of basic RWH and states that it is an often overlooked practice. Several suggestions are made:

- Harvesting rainwater from roofs where solid surfaces like clean plastic or metal can reduce contamination from leaves and grasses, and animal droppings
- Trapping water flowing on the ground, gradually directing this towards storage units such as tanks or containers
- Encouraging local innovation to design appropriate systems of harvesting.

Social and Economical Aspects

Gender roles

What family structures means with regard to water gathering. Consequences for family when the mothers and children spend many hours each day either in waiting lines or by transporting water either a great distance or by altitude or both. The distance travelled is often exposed for violent assaults or just a harsh environment (Interview with David Okello at Rethink Relief conference, Delft 2011).

In a family the other members are often required to tend for their loved ones at local hospitals, resulting in even fewer members of the family available to raise an income. Kids can loose schooling when mothers are unavailable to tend for them and send them to school.

In a camp setting the time lost by waiting and transporting water has a negative spiral effect on the whole family, often the kids are the ones who suffer the consequences.

Time needed for water gathering

An analysis of data from 25 countries in sub-Saharan Africa, representing 48 per cent of the region's population, reveals that women and girls bear primary responsibility for water collection, at considerable cost in terms of their time.

Only a quarter of the population in these countries had water on their premises in 2010, meaning that in 75 per cent of households, water had to be collected from a source some distance from the dwelling. In 71 per cent of all households without water on the premises, women or girls are mainly responsible for water collection. In 29 per cent of households, men or boys assume this task.

Further analysis shows that the mean time of one round-trip to collect water is approximately 30 minutes for both women and men, and is only slightly lower for children (28 minutes).

Each household requires at least one trip per day, but may, in fact, require several trips. The time and energy devoted to water collection is considerable, even based on a one trip per day minimum.

In these 25 countries, it is estimated that women spend a combined total of at least 16 million hours each day collecting drinking water; men spend 6 million hours; and children, 4 million hours.

Retrieved from UNISEF Progress on Drinking Water and Sanitation 2012, p. 31

Economical

Taken from a camp manager's perspective, RWH will present a good savings potential.

Investment in safe drinking water and sanitation contributes to economic health

For every US dollar invested in safe drinking water and sanitation, the World Health Organization estimates returns of 3-4 US dollars

The overall economic loss in Africa alone due to lack of access to safe water and basic sanitation is estimated at USD 28.4 billion a year, or around 5% of GDP.

Retrieved during November 2012 from <http://www.unesco.org/new/en/natural-sciences/environment/water/wwap/facts-and-figures/all-facts-wwdr3/fact-38-investments-economic-health/>

SIZE ISN'T EVERYTHING WHEN ASSESSING IMPACT

Robin Pendoley looks at the challenge when assessing impact of social ventures.

Scale is sexy. In social ventures, it is the “mine is bigger than yours” metric. But, if your goal is to do well by doing good, it is critical to consider the “scope” of a venture, not just its scale. Failure to do so could mean that your venture enriches you while impoverishing those it was supposed to help.

...

1.) *Does the intervention affect the system that created the problem?*

Consider the economic, political, social, and cultural factors that create and sustain the problem. If the intervention reduces the causes, it has a significant impact. In the case of the water tablets, distribution may reduce concern for developing and maintaining water and solid waste systems. Public health could get worse as untreated water supplies used for washing and irrigation degrade.

2.) *Is the intervention proactive?*

Solving one problem by creating another does not improve lives. If the intervention is sustainable and doesn't draw resources from other areas, it has a significant impact. While the water treatment tablets are targeted at a population for which every penny counts. They might be affordable in the short-term, but if the tablets reduce investments in a long-term, more cost-efficient water solution (or other investments like education or business investments), the livelihood of customers could get worse.

3.) *Why this intervention for these consumers?*

One-size-fits-all solutions are easy to scale but less likely to meet each consumer's specific challenges. If the intervention is aligned with the needs of the consumer, it has a significant impact. The water tablets may result in clean water, but they won't address local realities. Clean water issues can result from low quantity, distribution, or political divisions. The tablets may not solve the specific local problem.

Clearly, the water treatment tablets have a limited scope of impact. It could do well without doing any real good.

*Article retrieved in January 2013 from:
<http://www.forbes.com/sites/ashoka/2013/01/03/size-isnt-everything-when-assessing-impact/>*



Waiting lines at a water point in Gulu, rural Uganda. Photo by David Okello.



People waiting in a water-line in Bangladesh. Up to 8 hours is normal to spend on gathering water at rural locations. Even though water stations are close enough, be it urban or rural settings, the demand is often much higher than the supply.

Inspiration From Existing Products

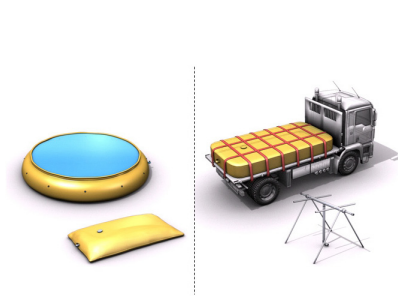
From 100 - 500 000 L there is a pillow tank for every capacity need. A typical pillow of 5000 L measures 6 x 8 x 0.6 meters when filled, and # x # x # meters when folded.



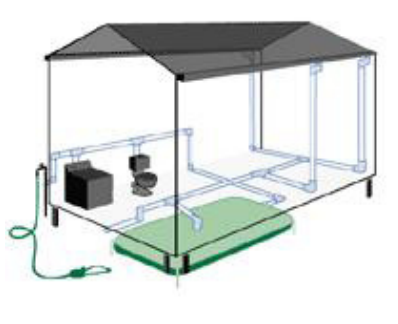
Distribution from the pillow tank is done by gravity, pump or pressure.



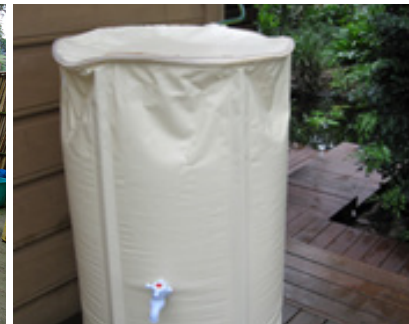
Collapsible tanks brings water storage into disaster aid. On the bike it is transported 15 units of 1400 L tanks. Effective logistics is key in disaster aid!



From complex and technology intensive systems to the basic tarpaulin with sticks and a bucket. Common factor is relatively clean water at the point of use.

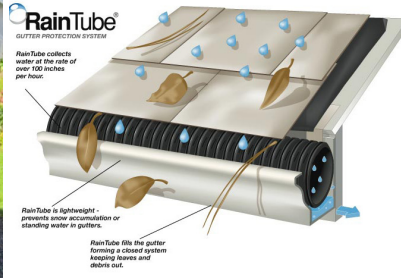


Compact storage solutions gives systems which can be easily expanded. Cumbersome storage units, has long been the "Achilles heel" of RWH.

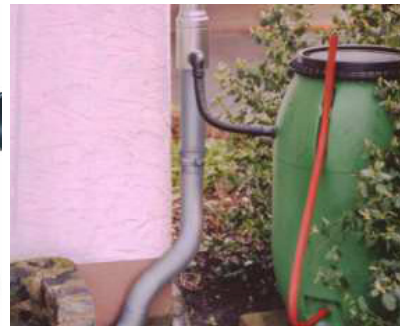
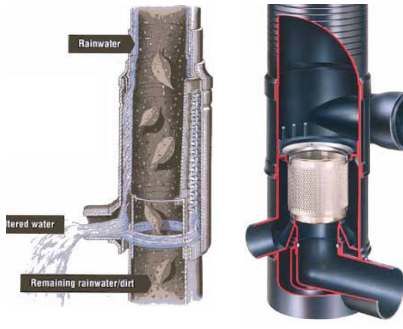


QUANTITY

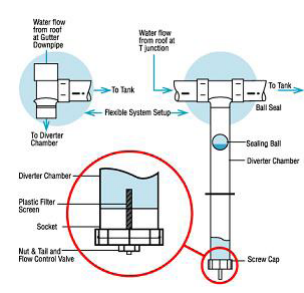
A strategy of supply must be made when designing a RWH system. Either a focus on meeting the potential of the catchment surface or dimensioning storage for a certain demand can be an option. Smaller units gives flexibility and simple logistics, larger units can result in high capacity and practical storage if space allows. Connecting for a certain demand can be an small units is often to prefer.



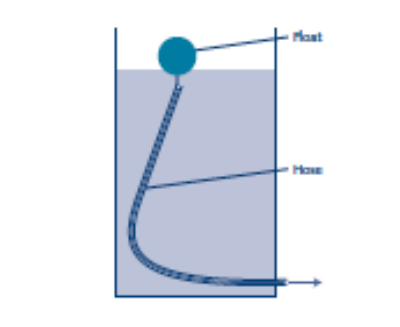
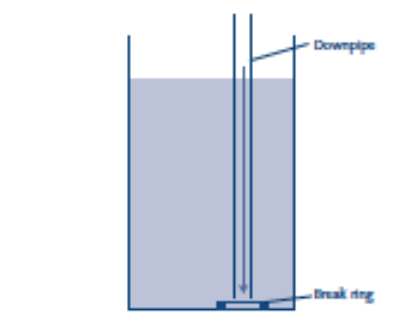
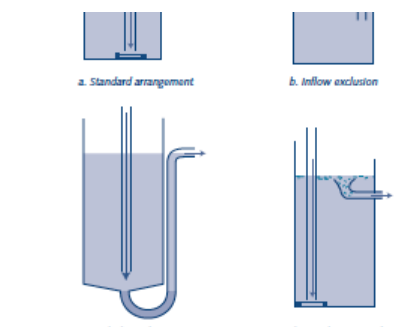
Techniques for filtering out debris can be effective for preventing fire in the gutters, and put a smaller pressure on down pipe filtering.



Filters that combines a first flush mechanism with fine filtering, can be effective also for high capacities. Units like this work well on roof sizes from 100 - 500 m².



First flush or a diverting mechanism is a vital component. This is done by either leaving out the "first flush" of a rainfall or by diverting it using other manners.



Pureness of rainwater increases with storage time if allowed to settle. Inflow is best at the bottom, when shielded, and outflow is best taken from just below the surface.

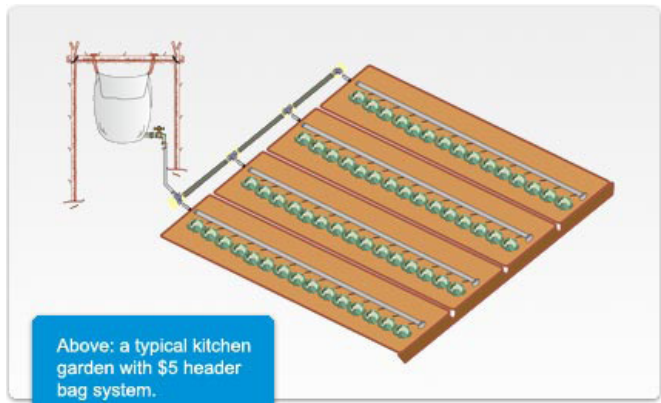


After-storage treatment work miracles on both elevating the potable and palatable standard. Biosand filtering is a promising technique.

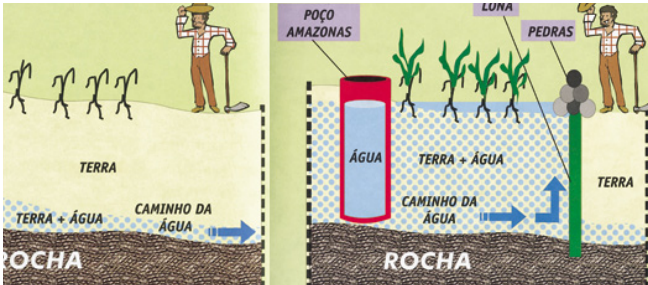
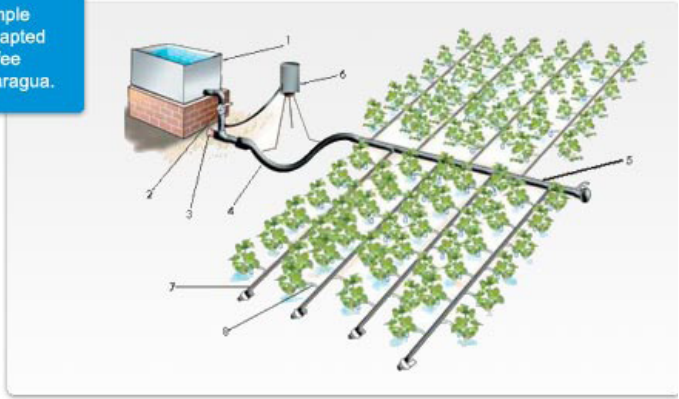
If a system is well designed, a high level of water quality is within reach. Simple but effective biosand filtering gives the option of storing water from other sources. To be able to ensure

a certain level of potability, other water sources should not be mixed with rainwater. Chlorine tablets are normally used in disaster aid for water purification.

QUALITY



Above: a typical kitchen garden with \$5 header bag system.
Below: IDE's simple drip irrigation adapted for premium coffee plantings in Nicaragua.



RWH has been done in several cultures world wide in many thousands of years. Today RWH is mandatory in for example New Zealand, where groundwater is hard to come by. In urban Europe RWH is used for watering gardens and flushing of toilets. A pilot project by Kirkens Nødhjelp focus on replenishing groundwater for

agriculture. The drip-irrigation project of IDE, India is famous for their 2\$ (!) solution. Thai jars are common in Asia for domestic supply of potable water, while ferrocement tanks are more common in Sub-Saharan Africa. Ostrich eggs have been used for storage in the South African Kalahari dessert.

CULTURAL DIFFERENCES

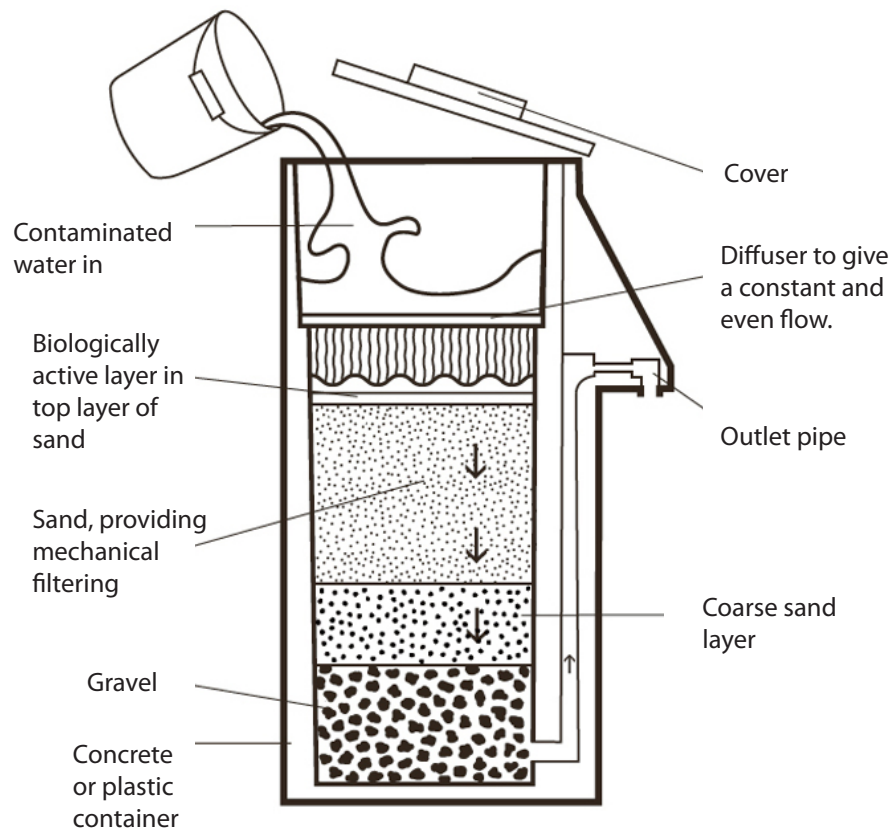


EVA tarpaulins are used together with flexible solar panels. The panels are often welded directly on. Gluing of flexible panels can be done on hard surfaces. Solar panels in rigid frames are most widespread. The use of zippers to attach panels to the tarpaulin is also used. When welded on a solar panel will add weight to a tarpaulin

making assembly cumbersome. On-site welding is often preferred.

SOLAR PANELS

Summary About RWH



Biosand filtering provides neutral taste and pure water.

Problems concerning the system:

- Overflow protection.
- Material choice for reservoir.
- Ultraviolet Resistance (UV-Resistance)
- Oxygen supply for stored water.
- Stabilizing incoming water, to prevent settlements to stir and mix with old water.
- Accessing the clear water from just below the surface when distributing.
- Temperature.
- Mosquito and animal protection.
- Cost calculations.
- Performance and capacity calculations.
- System scaling and principal layout.

Wet vs. dry systems

Gravity can force the water to flow through the system, leaving the pipes "dry". This is beneficial to combat mosquito breeding. When pipes are filled more or less constantly because a gravity flow can't be obtained the system becomes "wet".

Especially care must then be taken to prevent insects to enter. The weight of the pipes will also be an issue.

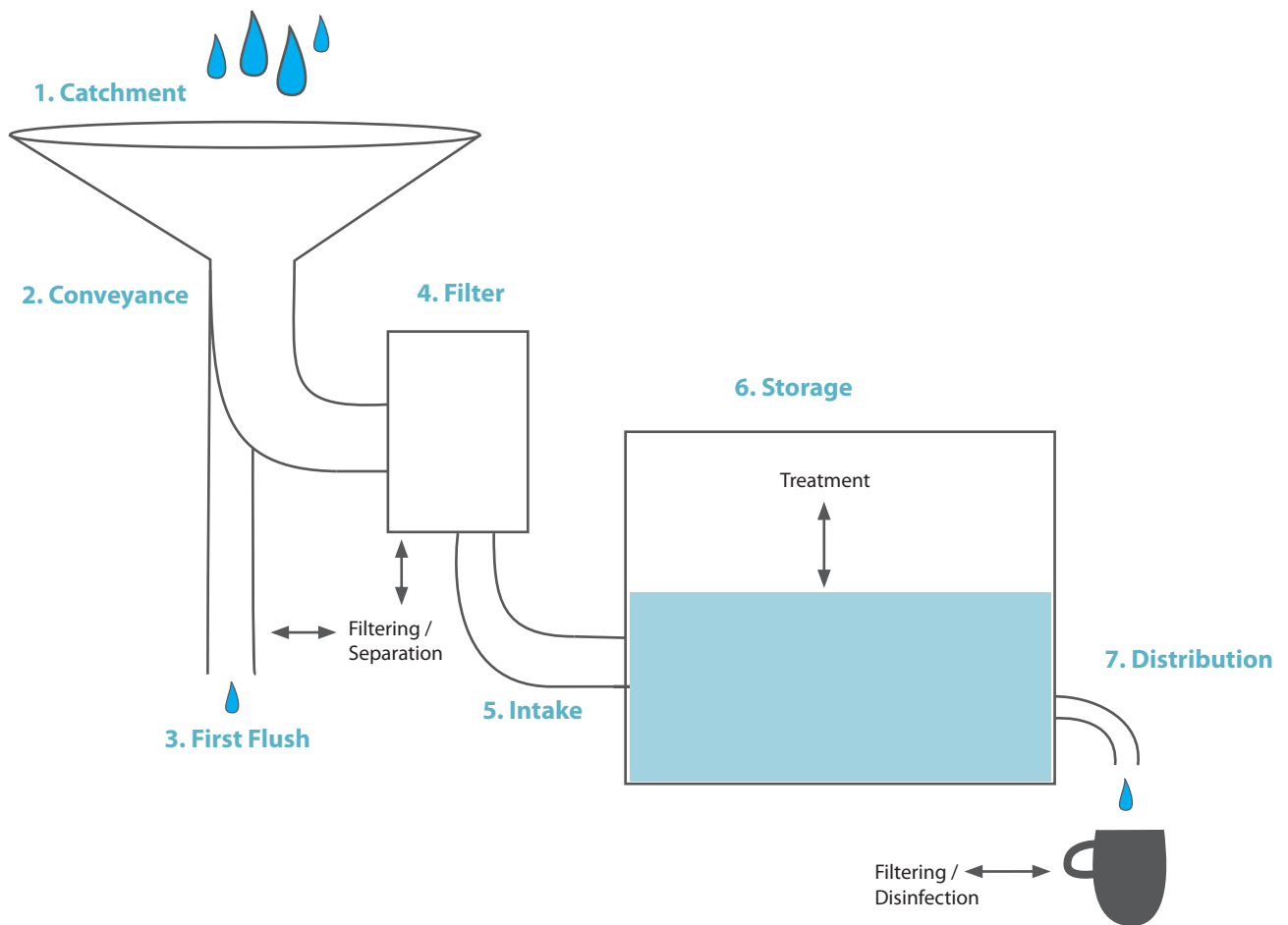
Pump vs. gravity

Mostly used for distribution, or to enable temporarily storage at an altitude, so in this way gaining access to a constant gravity driven pressure.

Post Storage Treatment

Purification pills are widely adopted as the most common treatment to purify stored drinking water. Given a well designed storage device, rainwater can be potable even without chemical disinfection.

If needed, filtering and treatment with for example biosand filtering will help with any palatability issues as well as providing chemically pure water!



Schematic overview of a standard RWH system.

Components of a RWH system

A rainwater harvesting system is in principle nothing more complex than a surface to collect, and a volume to store water. A system grows more complex when adding elements such as filters and first flush mechanisms, creating a demand for maintenance and service. A more advanced system is on the other hand able to deliver well tasting potable water, safely and reliable.

To ensure a certain quality, a filter is applied. The initial amount of water coming from a rainfall is the most dirty. With a first flush mechanism, this dirty water is guided away from the water reservoir.

A storage container is ideally suited to keep insects away, it provides some movement in the air to prevent anaerobic bacteria to form, it also enables the user to withdraw the

clean water that lies just below the surface, and it leaves the sediments at the bottom. It protects the water from direct sunlight, and it ensures a suitable temperature.

CONCEPT GENERATION

Ideas are gathered into relevant topics. Two concepts are chosen as a potential direction for further development.

This chapter includes

- Selected ideas arranged in topics.
- Idea selection.
- Two Concepts.
- Feedback from WGH.

Sketches on RWH



Gravity driven distribution system brings piped water to a rural setting!

Communicating Ideas

During this phase of the project I was staying at IPD in Tromsheim. A continuous dialogue with Henning and Tov at WGH during this time has been important. Skype sessions with screen sharing became an efficient way to communicate ideas towards the WGH office at Bergen.

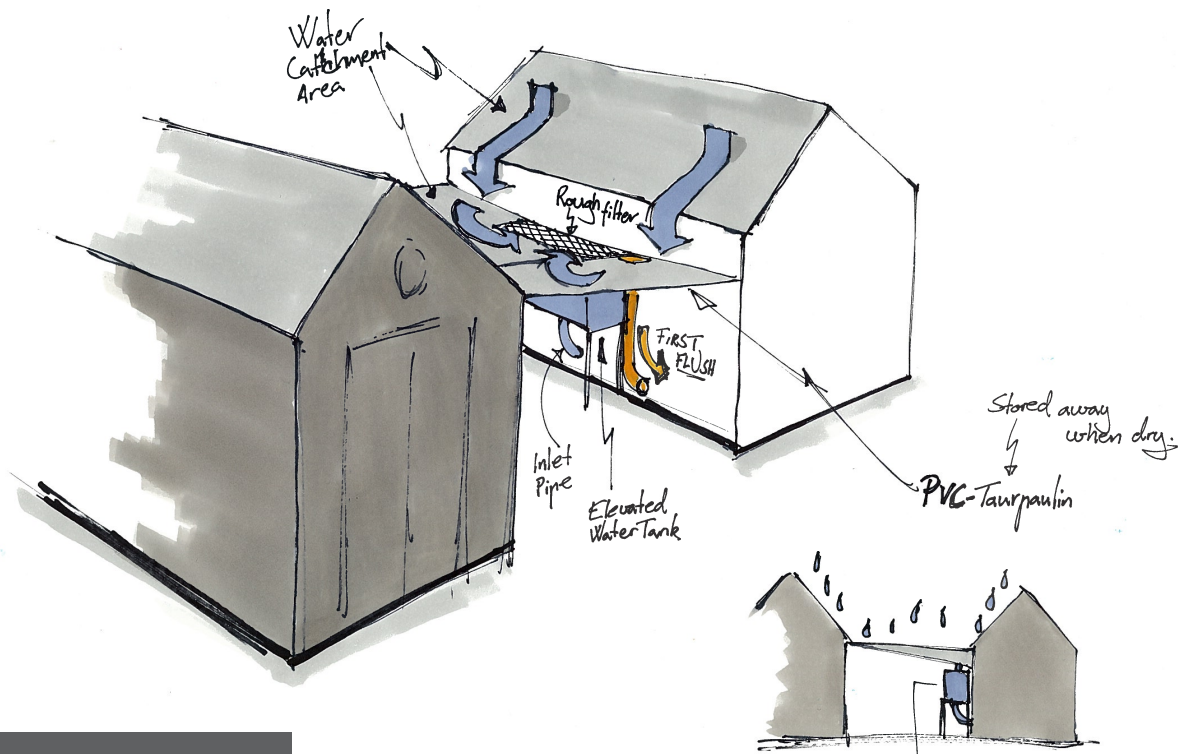
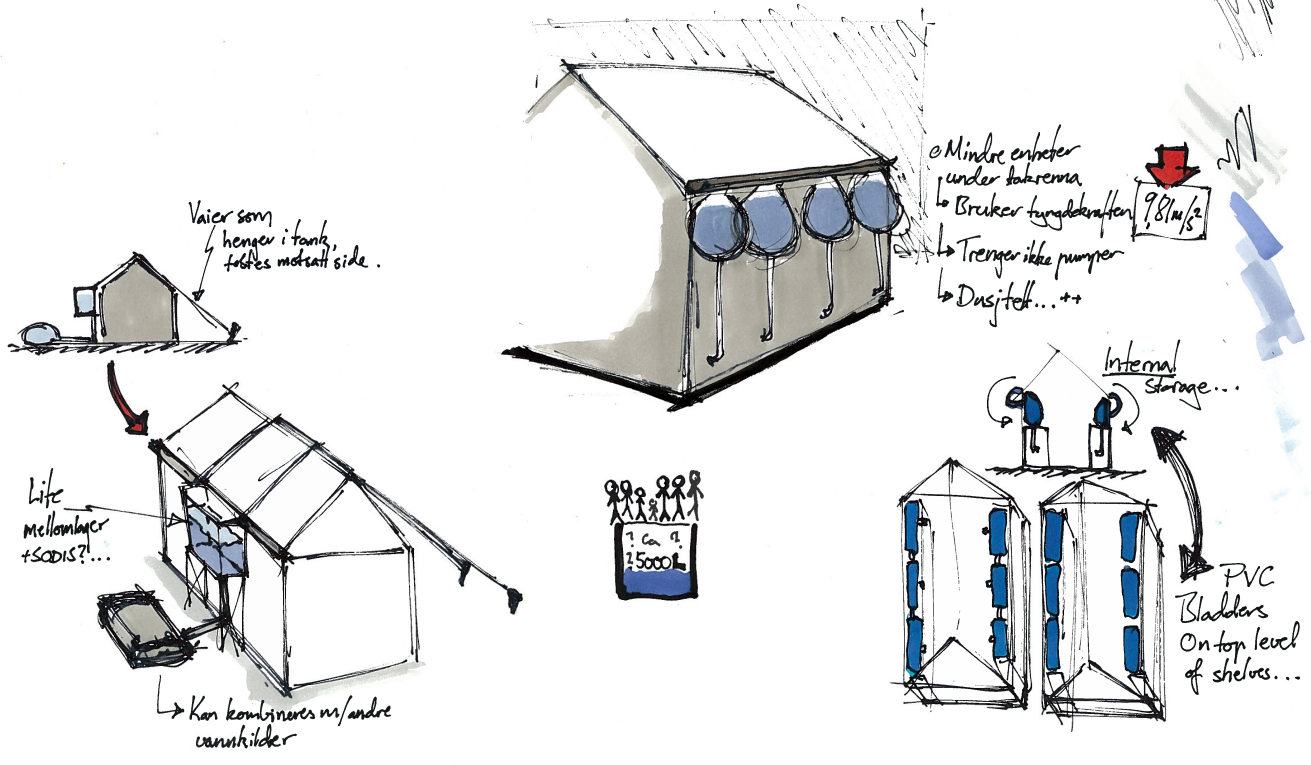
Sketching is a quick way of clearing up or identify misunderstandings. When an agreement has been made on an idea it is vital to make sure that all parties

are in fact talking about the same. Both quick sketches during a meeting or more elaborate renderings have their uses. The usefulness of "napkin design" should not be underestimated.

By taking ideas from a post-it level to more detailed drawings, the potential of an idea is a lot easier to identify.

The chapter concerning project focus acts as inspiration and framework for the following topics.

Loaring

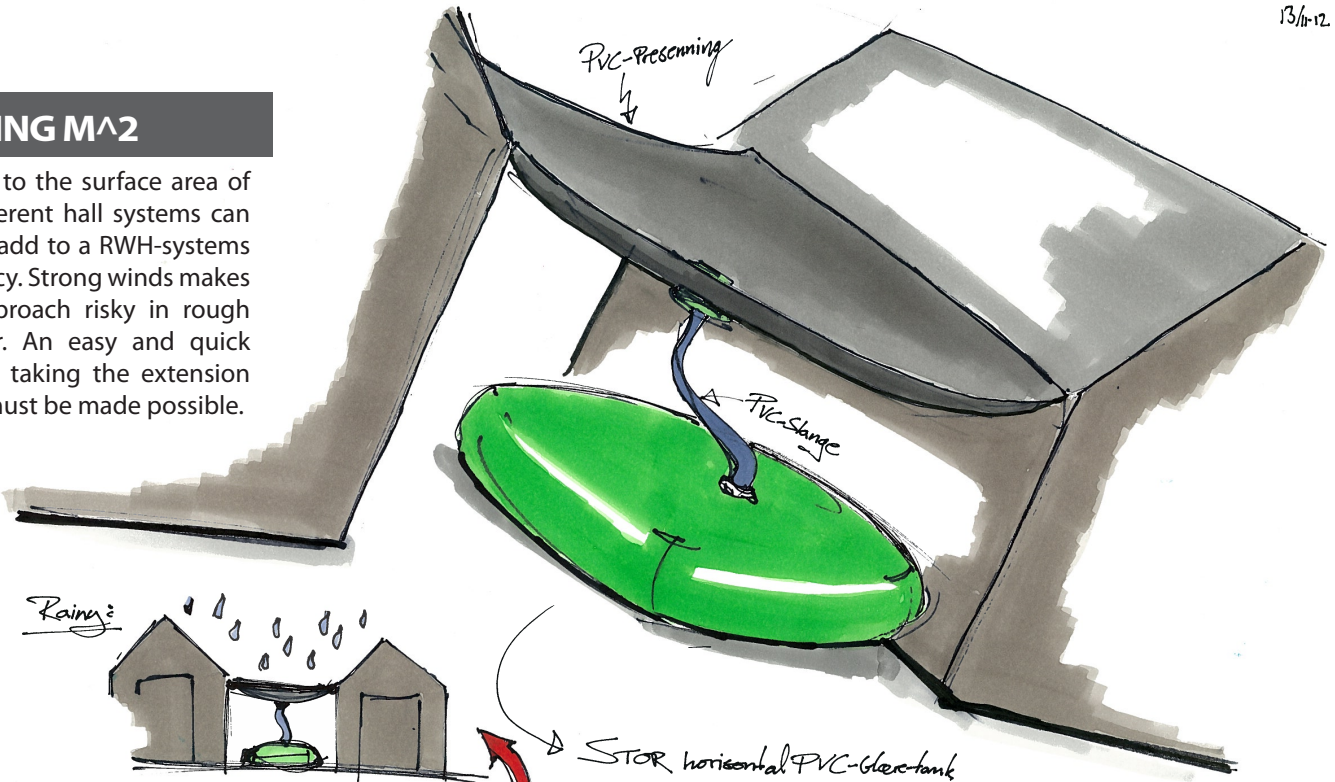


UTILIZING GRAVITY

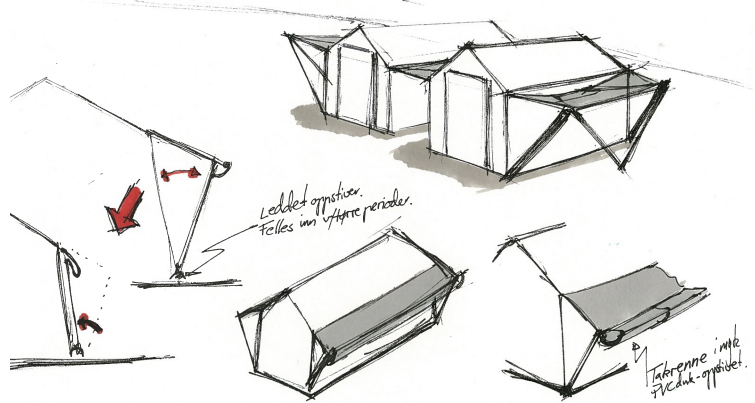
A dry system is used depending if a gravity driven piping layout is possible. While storing water at a height, water pressure is given without the use of a pump. In a wet system, water will remain in the pipes, making support for the pipes an important issue.

ADDING M^2

Adding to the surface area of the different hall systems can greatly add to a RWH-systems efficiency. Strong winds makes this approach risky in rough weather. An easy and quick way for taking the extension down must be made possible.



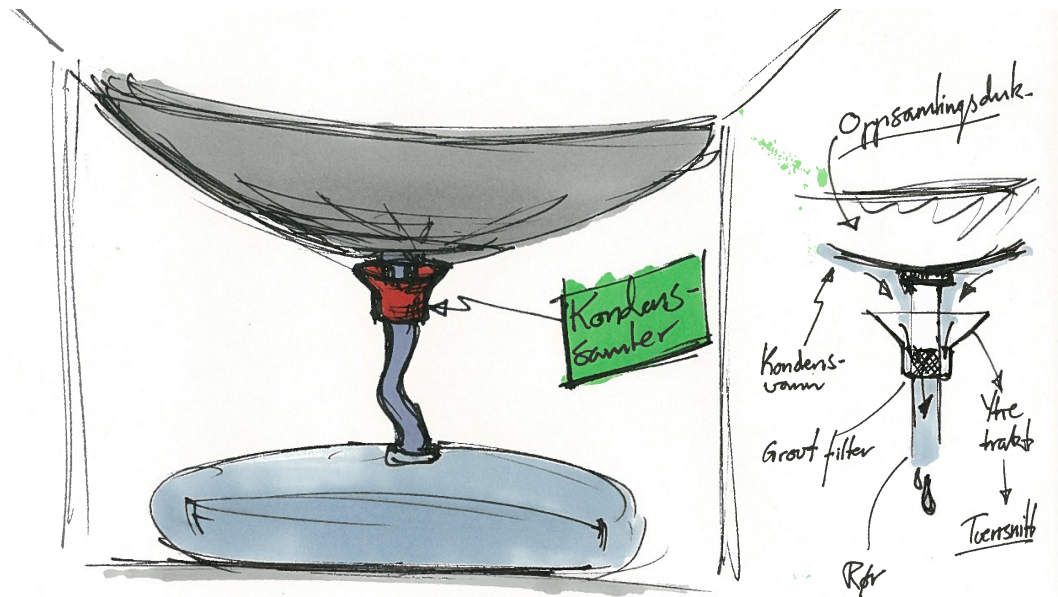
STOR horizontal PVC-Glas-tank



WATER FROM AIR

Condense can be harvested on surfaces where there is a noticeable difference in temperature between the two sides. The container protecting battery equipment for solar panels is one location where this is valid.

On some occasions, local assembly crew for WGH during assignments in Africa, have gathered potable water in this manner. (interview with Henning Nilsen, October 2012)



SHAPES AND STYLES

Pillow tanks of PVC brings many benefits used in the context of disaster-aid.

With their low profile but large surface, its weight is evenly distributed over a large area, making a heavy load storable even though the ground underneath is less stable. More compact tanks can be made. Capacity ranges from 100L to as much as is needed (500 000 L and more)!

Flexible water tanks fall into two distinct types.

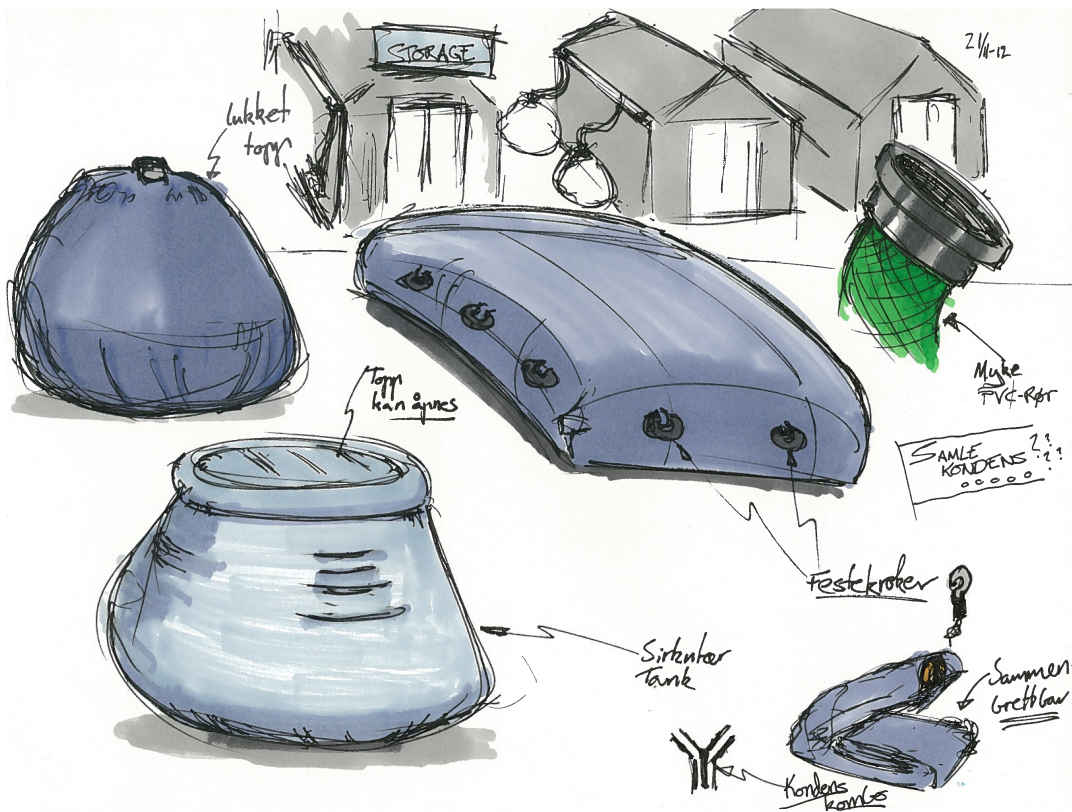
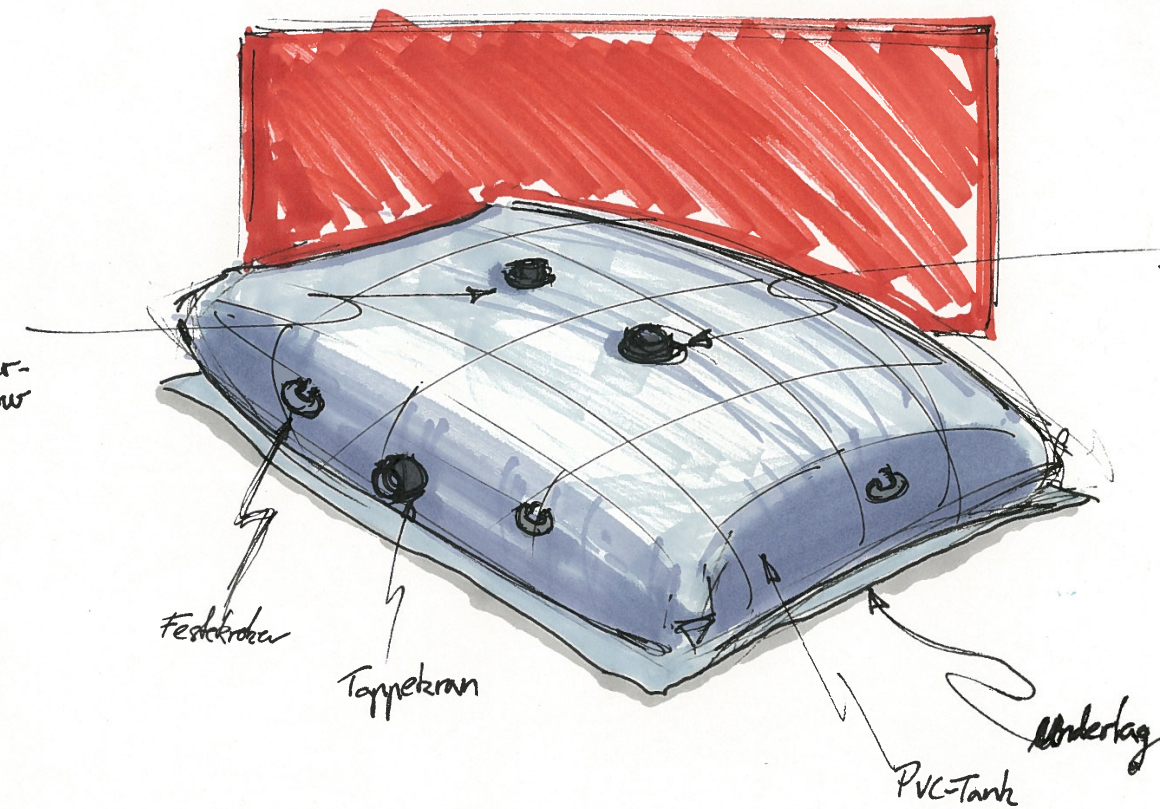
Pillow tanks

Designed like a pillow and intended to go flat as they empty. Input and overflow is normally located on top, with a tap placed at the side. An air release valve will be helpful to let air out, as water flows in, depending on inlet-design. Simplest solution is to create small holes at the inlet.

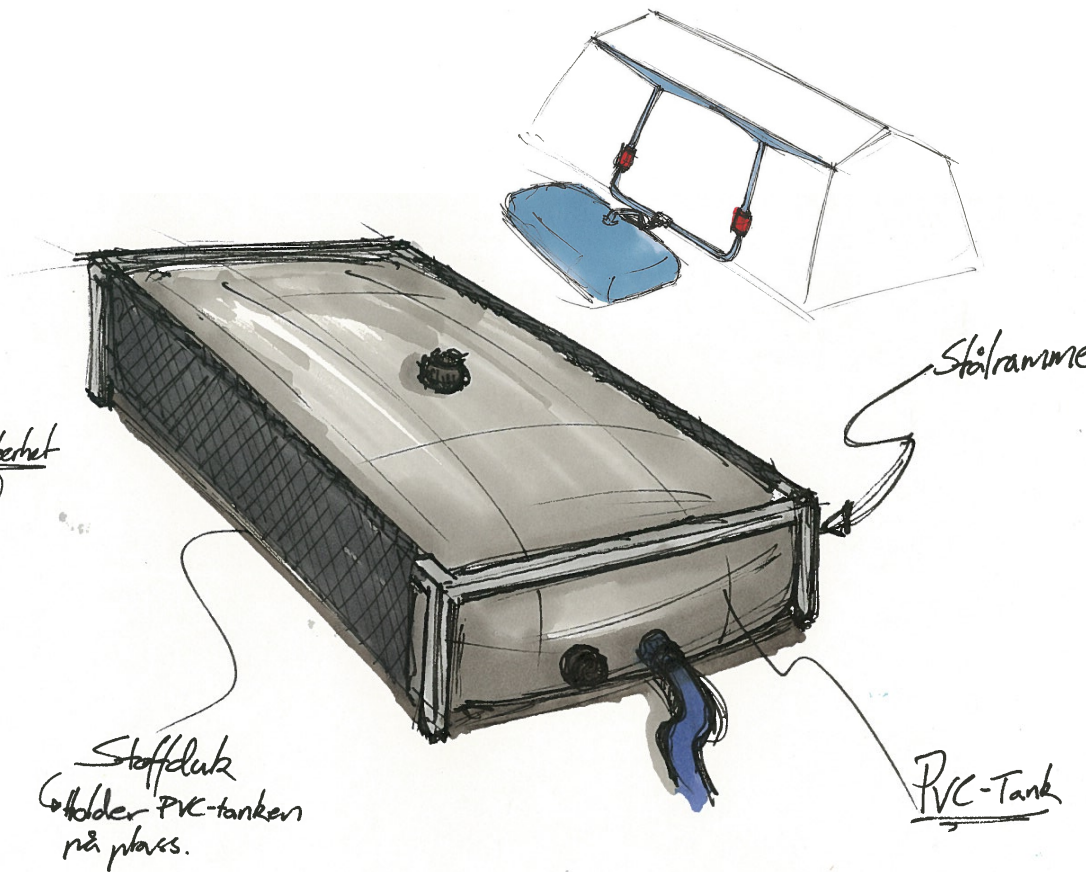
Shaped tanks

Three-dimensional tanks with top, bottom and sides. These are not intended to go flat as they empty. They must be vented in the same way as a rigid tank.

A smaller tank (1000 - 1500 liters) will be placable on one or two europallets, supported by metal pipes as frame. Self-supporting shaped tanks are also available (Bob the Rainwater Tank).



◦ Forankring → Sikkerhet
 ◦ Stabilitet → vind

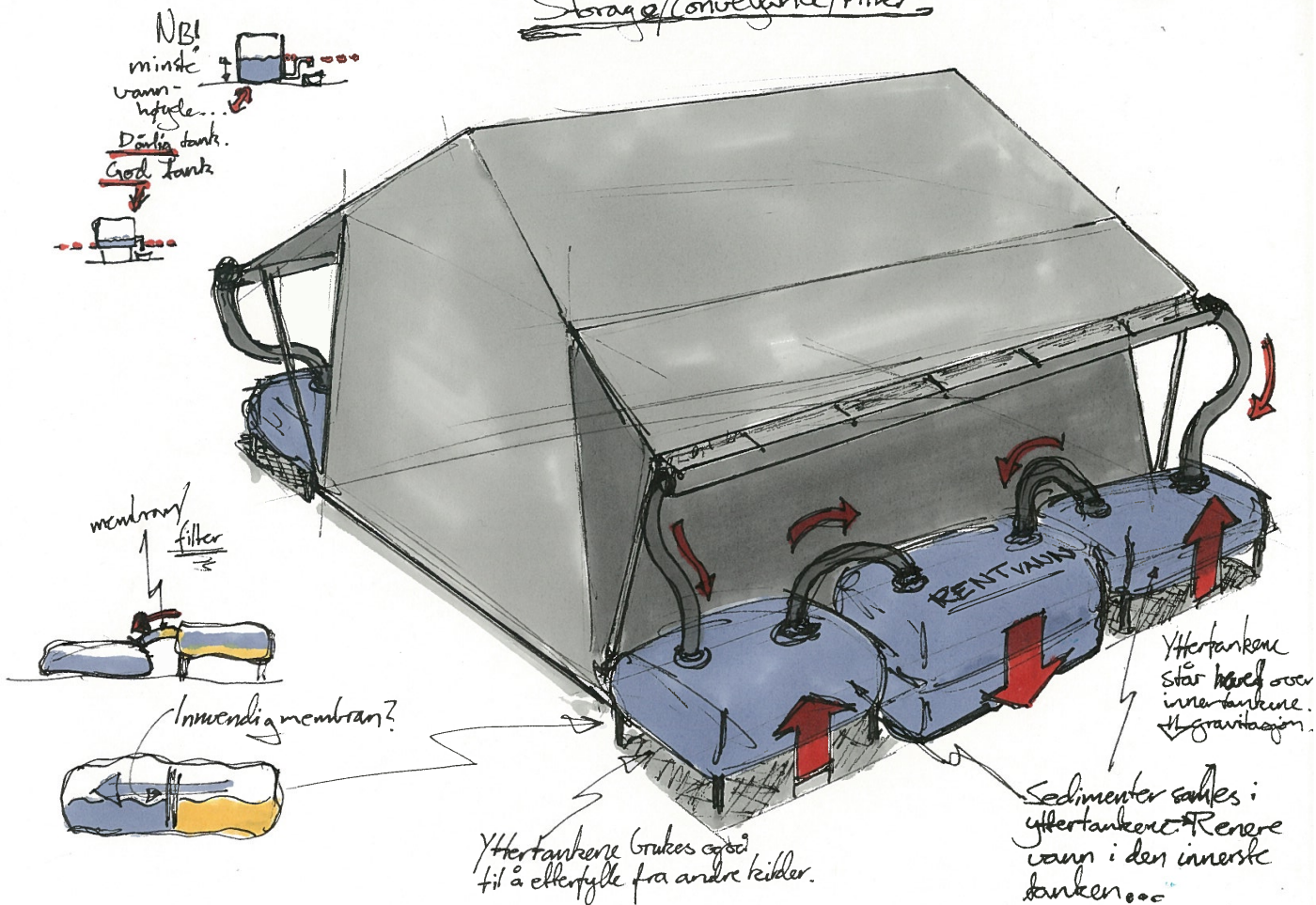


TANK ARRANGEMENT

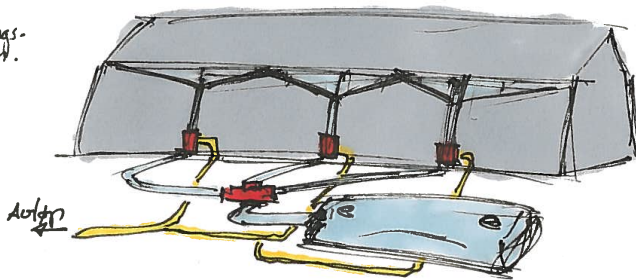
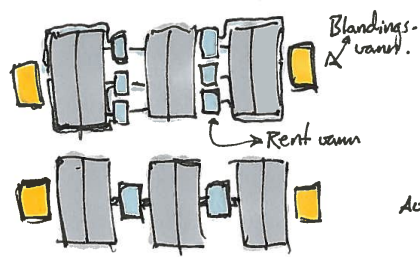
When rainwater is stored in multiple containers, the water quality will enhance by each container the water passes, by letting sediments settle as well as other material will be allowed to float to the surface.

Storage/Convergence/Filter

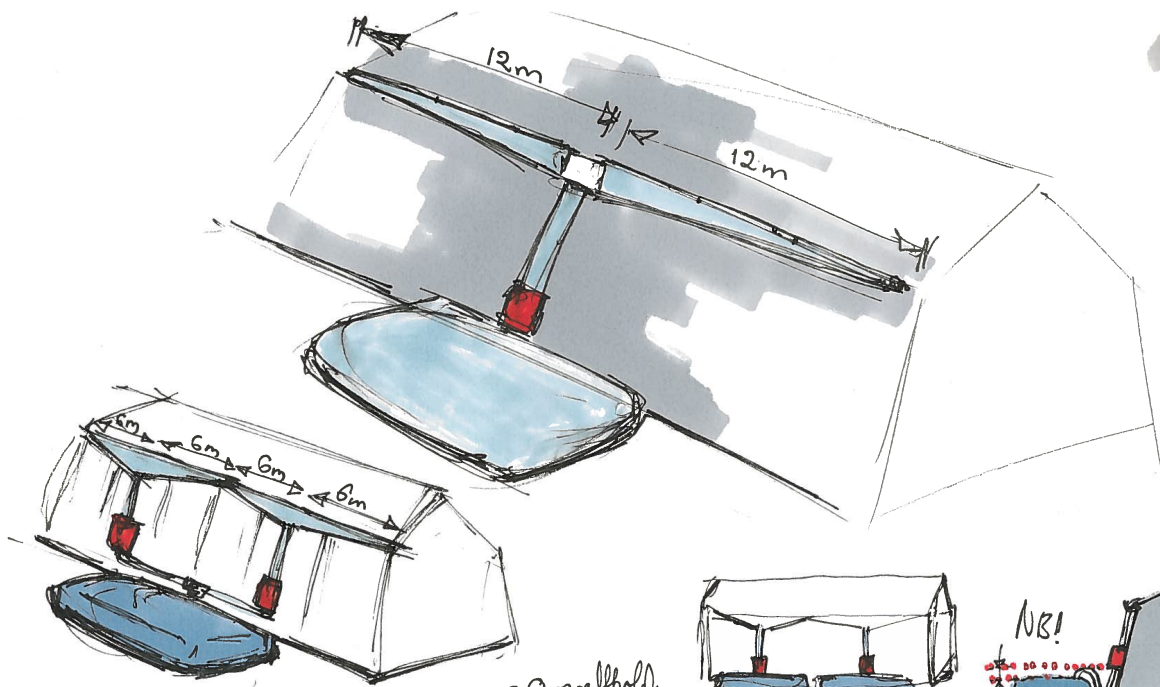
25/11



Layout av Rør & Tanker



Pumpe?
 ↳ Bilbatteri
 ↳ Solpanel
 60\$90\$
 ↳ 300L/h



○ Opprettholde trykk.
 ○ En tank ved hvert nedløp evnt. flere innløp i hver tank.

NB!
 Evnt. høydeforskjell vil påvirke som vannløp

Layout of Storage and Piping

A RWH system must be designed with a holistic approach (Gould and Petersen, 1999). All aspects must be taken into consideration, all the way from the rain that falls on the catchment surface to when the water is put to use. Storm-water and overflow should as well be considered to be used for ground water recharge.

Disaster Aid vs. Development Work

Sizing and the arrangement of tanks greatly influences the capacity and effectivity of a system. Disaster aid greatly appreciates effective logistics and mobility, while long-lasting development projects appreciate lower cost combined with long-lasting durability.

Rapid response setups will be most effective with a modular storage setup, scalable and easily manageable even though space and transportation options are limited.

Large Tank + Large Filter

- Practical with fewer components.
- Easier to administrate chlorine disinfection of the water.
- Can become cumbersome where mobility is important.
- Will put a bigger strain on all components.
- Wet system, where water will stay in pipes.

Smaller Tanks + Several Filters

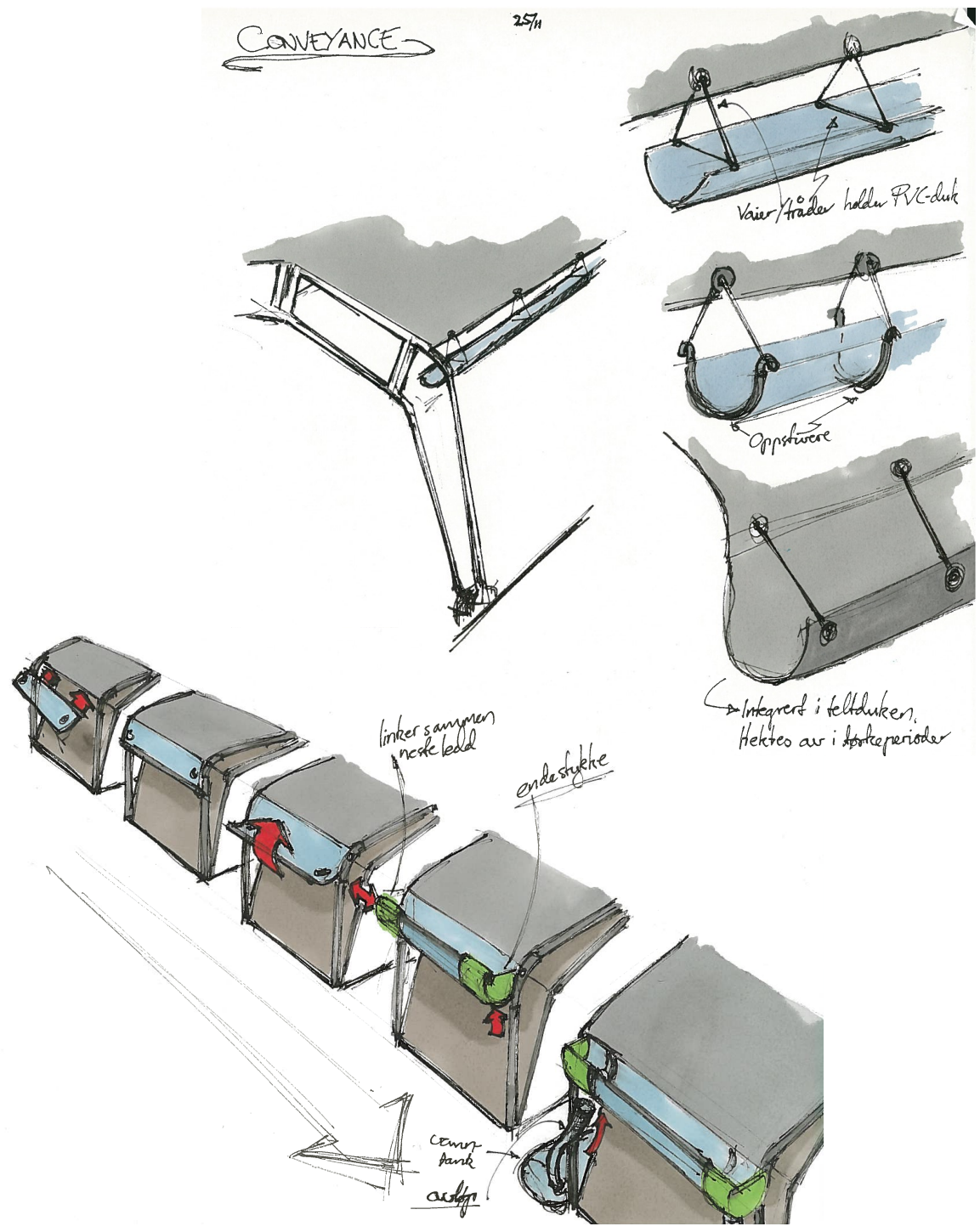
- More components equals more maintenance.
- Fewer components equals less strain.
- Smaller tanks can be placed on Euro pallets, bringing many benefits to logistics.
- Less strain on components gives longer durability.
- Dry system is possible.

Large Tank + Many Filters

- Less strain on conveyance and hall structure.
- Many downpipes involves intricate piping.
- Pipes must be supported while the water they contain will result in added weight.

CONVEYANCE

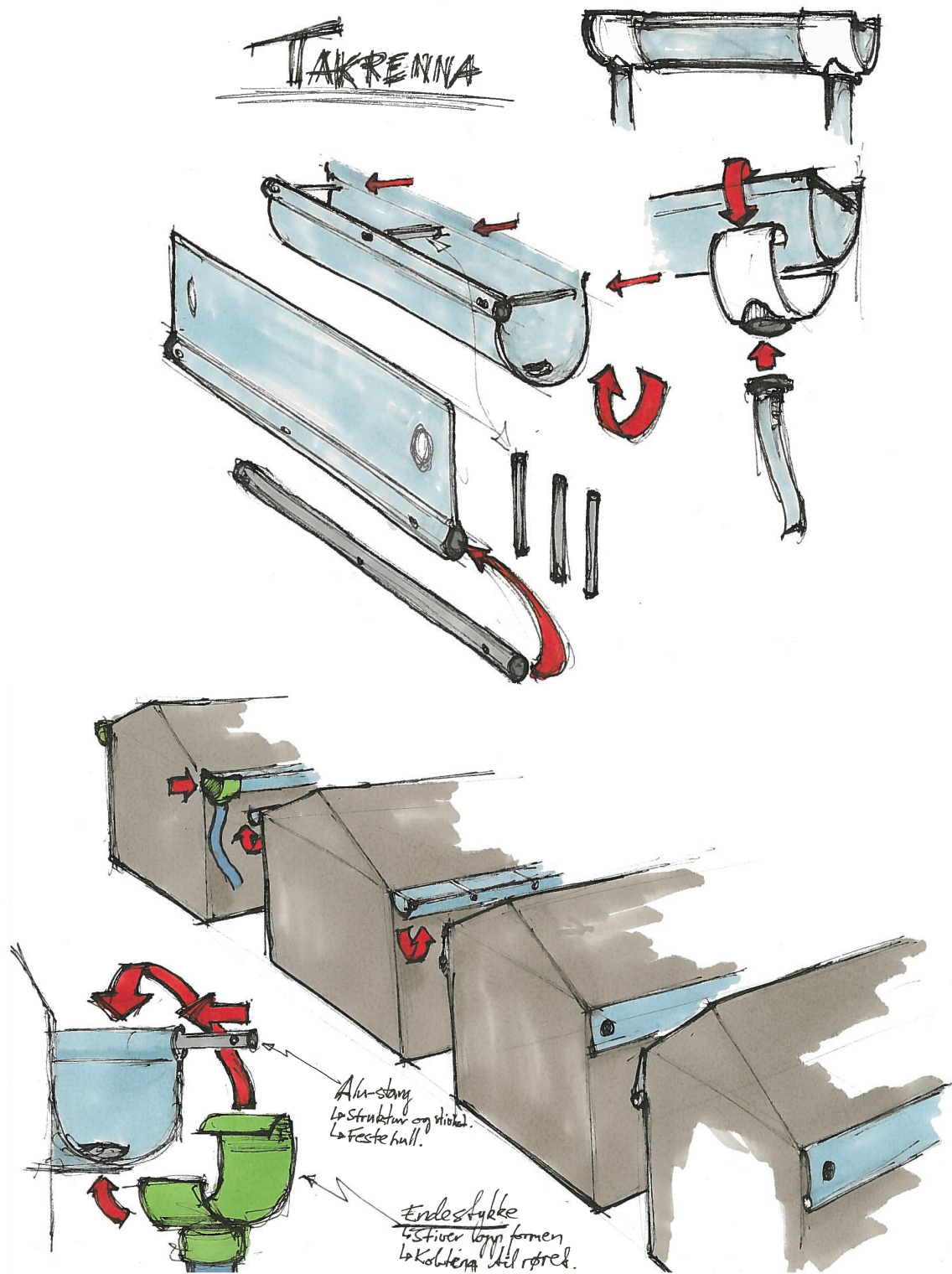
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INTEGRATING GUTTERS

A V-shaped gutter will be in risk of clogging by branches and leaves, compared to a more semicircular or square cross-section. A gutter must be shaped so its surface is used in an efficient manner. Hemming up the roof edge of a hall is a sensible way of integrating gutters on tent-like structures.

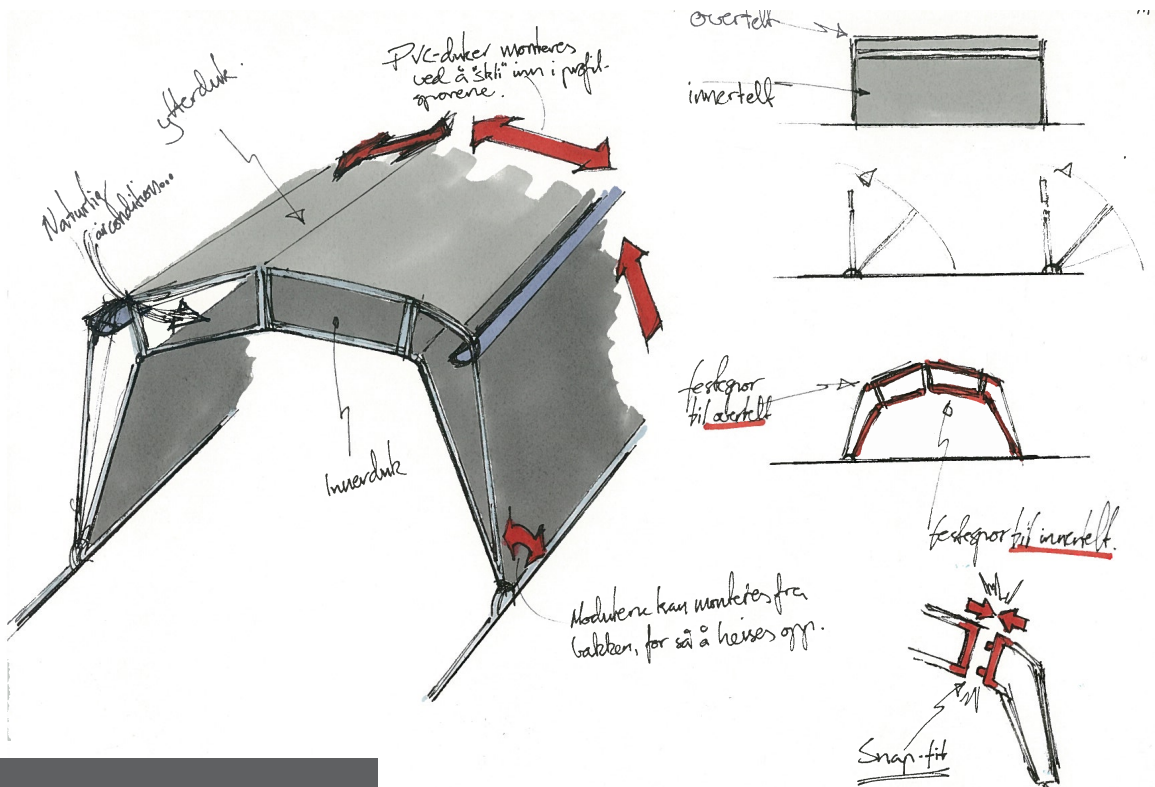
If the roof-edge allows it, gutters can be suspended from its edge. Soft PVC can easily be made into pseudo-guttering by hemming it up at the edges. Small cylinders can provide the width of the gutter, while its shape can be supported by inserting a metal pipe into a pocket along its edge.



The guttering is often becoming the forgotten "Achilles heel" to a RWH system. Domestic RWH systems provided by NGO's will contain professional storage, while guttering and conveyance is left to local innovations and customs. By securing an efficient guttering, the premises for a successful system are secured. (Martinson 2007)

A flexible gutter of PVC-cloth will be easy to integrate with the existing PVC surface.

The strength of a pseudo-guttering based on a PVC solution compared to normal roof guttering is by large connected to logistical advantages. Size and weight matters when large amounts of material is transported to rural areas!

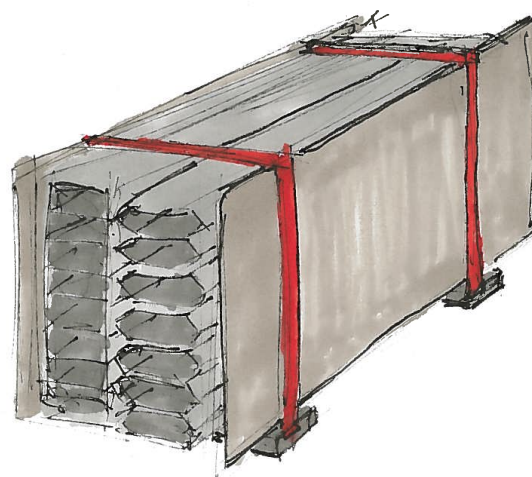


NEXT GENERATION

To integrate a gutter without putting pressure on its supporting structure involves a big challenge. The NG1 benefits from only small additional loads. A redesigned frame would easier cater for external add-ons, be it solar power panels, RWH system or ventilation equipment.

There is minimal space left for additional equipment in the otherwise filled up storage containers delivering the NG1. This puts a RWH system to a logistical challenge.

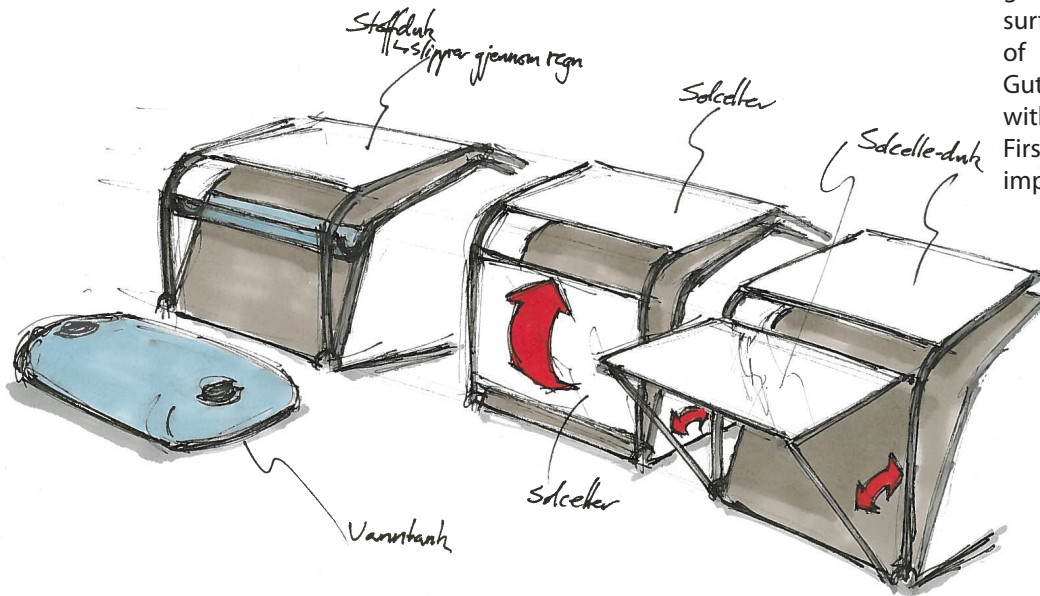
Filters and leaf removing components will be easy to attach if a rigid frame is exposed and available. The NG1 is completely covered in PVC sheets. By facilitating the attachment of auxiliary equipment many opportunities become available.



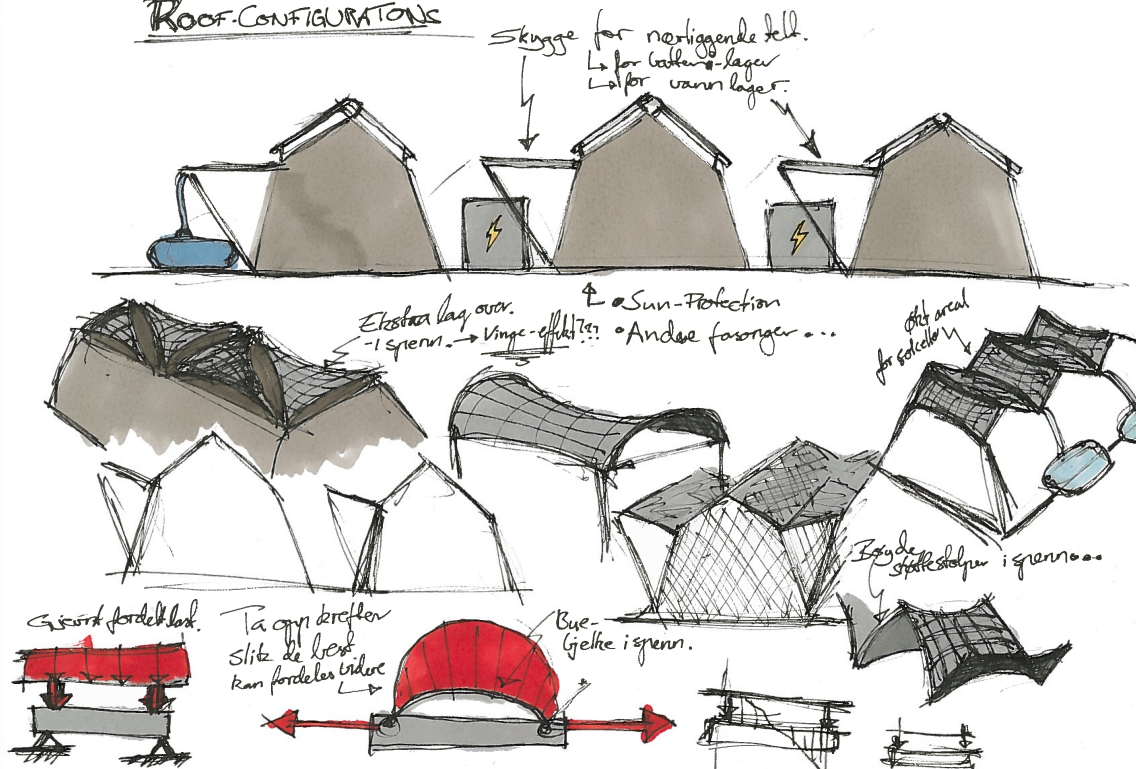
1/11

TENT CONFIGURATIONS

By maximizing existing roof surface, solar panels are given their full potential. This will also benefit RWH, as its effectiveness greatly increases with available surface area, if small amounts of precipitation is available. Guttering becomes redundant with some roof configurations. First flush systems is still important to solve.



ROOF CONFIGURATIONS



IDEAS GROUPED INTO TWO CONCEPTS

Many of the ideas are combined in two concepts.

A third concept using family sized shelters was quickly abandoned. By using PVC material and metal framework, a foundation for a home can be made. With the load bearing structure given, the rest of the house is built using local materials and customs. Equipment for a basic RWH system would be provided, along with a solar panel system. This would become a transitional shelter and eases the process of rebuilding homes after a disaster.

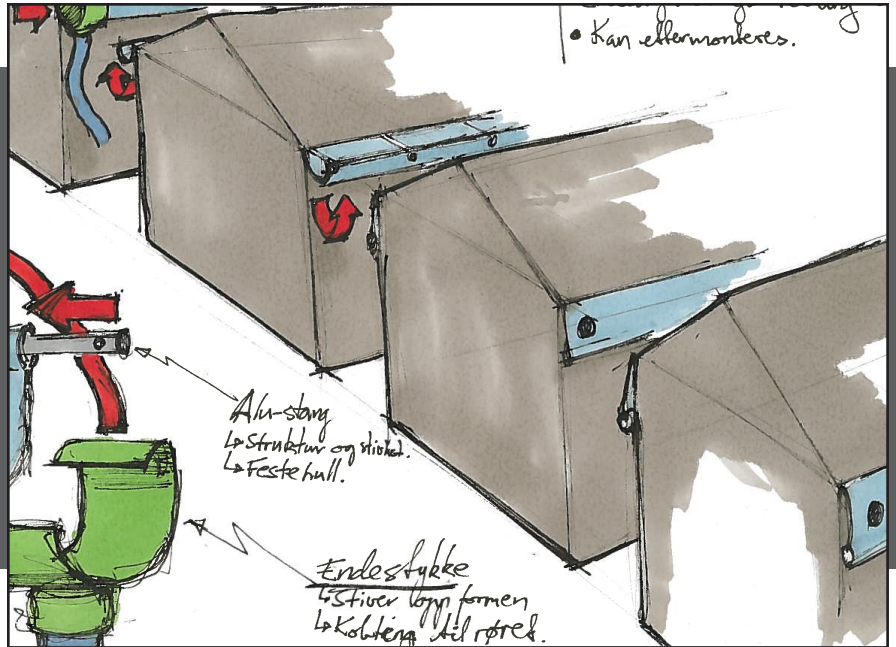
Even though it can be gained much with a concept directly focusing on the importance of combining efforts in disaster aid with long term development, the other two concepts had more potential for the existing portfolio of WGH. Transitional shelters is a large topic on its own, beyond the grasp of this assignment at this stage. Still it is an idea worth mentioning in the context of hall systems for disaster aid.

The two remaining concepts have much to offer for WGH's existing products. One is focusing on adapting the NG1 to the new technology while the other enables RWH on the current design.

CONCEPT 1

Attachable Conveyance

- RWH-system designed to added on to the existing structure of NG1
- Can be up-scaled to fit NG3. Soft PVC gutter and PVC bladder tank with simple filtration unit integrated in down-pipes.
- Simple but reliable.
- Will require minor modification on existing NG1 design.



CONCEPT 2

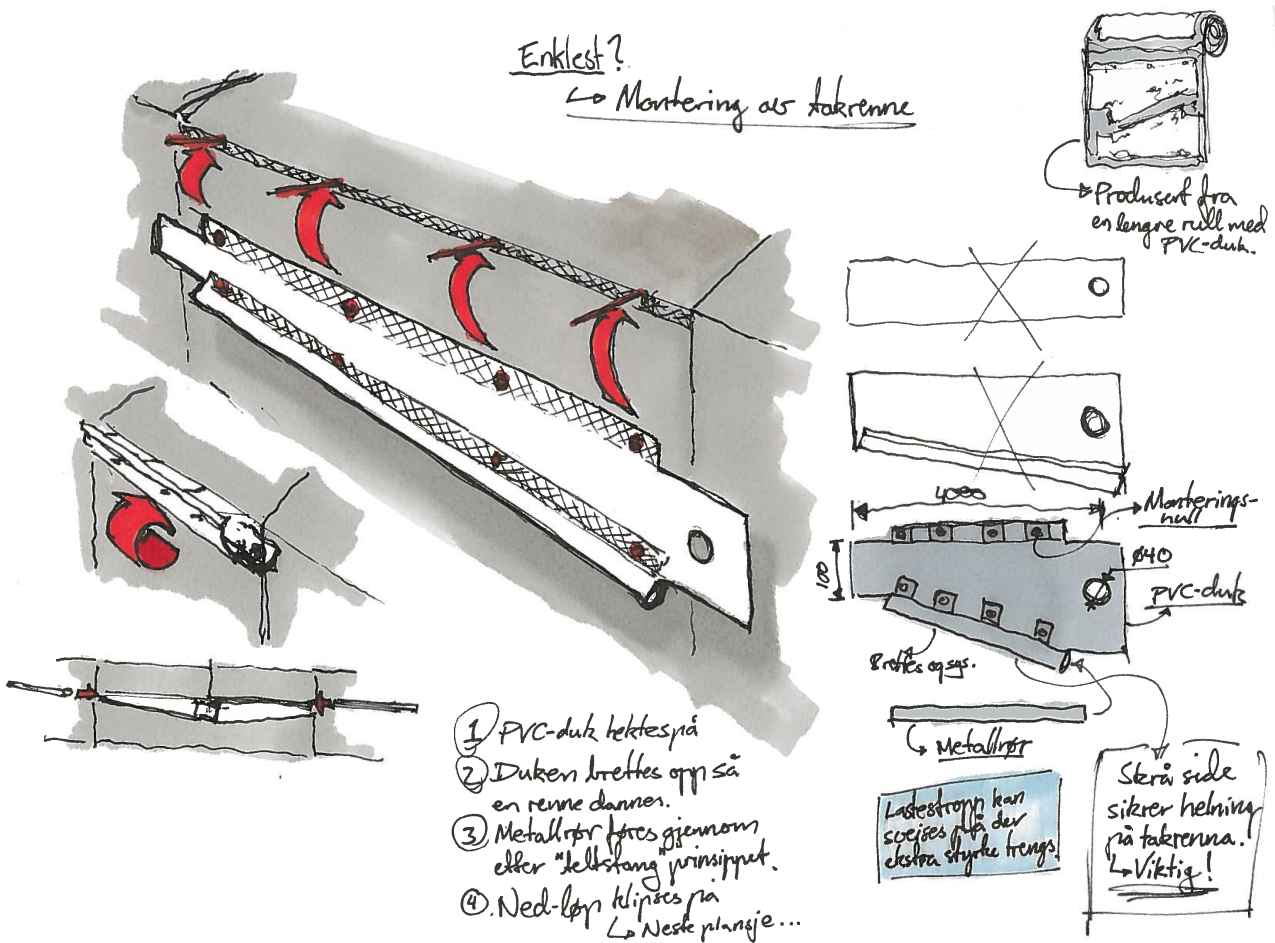
Next Generation Hall System

- Compact hall system optimized for new add-ons and functions, including solar panels, RWH-system and ventilation.
- New framework. New fabric arrangement.
- NG15-based. Small and modular.
- Optional surface expansion. Add-ons does not require on-site modifications to be attached.



THE ADD-ON CONCEPT

DETAILS



- Conveyance: PVC sheets are used along with existing material in the NG1 kit. This ensures good access to spare parts, and tools needed.
- Downpipes every 4th meter, ensures efficient drainage and minimizes strain on existing structure coming from the water.
- Connection: Downpipes and gutters are connected using custom made connector. Can easily be replaced with ad-hoc solutions if needed.
- Gutter can be unhooked in case of drought, maintenance or extreme rain. Inserted cross-beams support the weight and gives structure. Bolts inserted into main structure of NG1 are attachment points.
- Filter and first-flush: Low-maintenance, low tech, but high performance filter with integrated first-flush. Needs to be easy to replace.
- Storage: Soft tanks of PVC. Large pillow tank on blanket or smaller units on Euro pallets.
- Piping: Soft pipes of PVC.
- Distribution: Pumps or gravity-driven.
- Water rationing is needed to bring awareness on water consumption.

Dimensioning the gutters

The length of the gutter is chosen to be around 4 meters. Many of the other components of NG1 share the same length and this provides effective logistics. When supporting the weight of each gutter close to the vertical beams of NG1, efficient distribution of forces is ensured. Too much weight, inconvenient height differences and more becomes an issue with longer gutters.

The down pipes will follow the vertical arc of NG1, to best use the supporting structure. This means 4, 6 or 12 meter long gutters are optional, yet 4 meters is chosen for its convenience.

Down pipes should have the roughly the same cross-section as the pipes, making wide PVC hoses suitable.

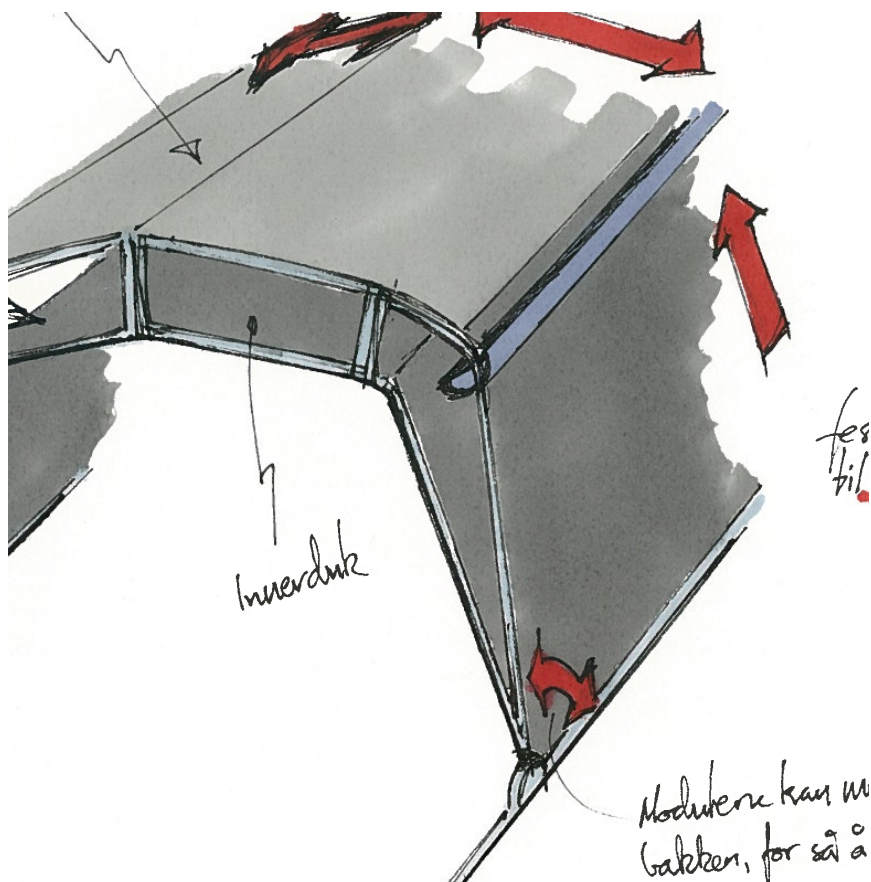
System arrangement

Filters and the number of storage tanks will be chosen according to the required capacity. Filters are provided at each down pipe for maximum security.

A smaller tank at each down pipe gives the least complex piping arrangement. Larger tanks can be connected to several down-pipes. Two halls placed adjacent to each other can share tanks.

THE NEXT GEN. CONCEPT

DETAILS



Next-generation Benefits

While a basic add-on might be readily available, there is much to gain by developing a new series of hall systems better suited for the new functionality of solar panels and RWH. By optimizing the structure for future add-ons, much more efficient assembly is made possible. This will require some redesign of the basic structure of a typical hall.

Passive ventilation with a second roof layer, which can easily be replaced with sheets with solar panels is more than only convenient.

Both with regard to assembly and daily operations including maintenance, much effort can be spared. This can then result in more rapid response times when setting up camp including many other positive side effects.

- New framework, making optional attachments more easy to attach at will.
- Sun protection with light fabric, Not water-resistant to ensure light weight.
- Soft solar panel sheets.
- Filters integrated in down-pipes, placed at each vertical frame.
- Soft PVC bladder tanks.
- Soft solar panels to be integrated in optional top-cover.
- Soft PVC gutter supported by rigid frame-bar easily attached to next gen framework.
- Option for increased area for RWH.
- Option for shower tent setup, with smaller bladder tanks stored inside, providing water pressure with elevated tanks.
- Bio-sand filters for point of use. Enables other water sources.
- Distribution into tent with simple foot-pumps/ electrical pumps if solar panel.

Feedback From WGH

SUMMARY OF KEY POINTS

Summarizing knowledge from previous chapters, results in the following criteria which are considered important for the selected concept. Conversations with Henning and Tov at WGH have been important to select where the focus needs to be.

Experienced quality vs. perceived quality

Rainwater harvesting meets skepticism even by water professional, the perceived quality is in other words important as well as its performance related qualities.

Logistics

To be successful, a system must be able to fit within the existing supply chain. PVC, steel pipes, nuts and bolts are in plenty in the well established co-operation with Protan. The gutter section is chosen to be designed with parts and material already available in abundance. Size and weight are key-factors. Must fit within NG1-limits. Most components are maximum 4 meters long. The flatter, the better, and if components are hollow, there is much to save with delivering "pipes within pipes".

Fixability

Work tools available to the construction crew from the containers with NG1 should be enough to fix, and even create spare-parts for the system.

Ease of assembly

The same principles applied during assembly should be chosen for adding gutters and auxiliary equipment. Nuts, bolts and simple modifications on steel elements as well as PVC sheets. If possible pre-attached or pre-welded gutter modules will save

assembly time on-site. A logical setup is important to avoid faulty assembly and a the potential of lost time for re-assembly or even system failure.

Kit-structure

Self containing kits are of great ease. Practical with systems that come delivered in units not depending on supporting elements to be functional.

Materials and production

PVC sheets and steel pipes are readily available. Cutting and drilling of steel pipes and columns are of small effort. Welding with hot-air gun and cutting of PVC sheets are all practical construction methods.

Concept Selection

CONCEPT 1: THE ADD-ON

Both concepts are able to cater most of the criteria from the design brief. Concept 1 stands out as having a large potential which can be realized already today. The Add-on concept is therefore chosen for further development. Other important reasons are:

- Potential for having a good impact on making NG1 more autonomous.
- Gives an opportunity to get feedback on RWH from clients while still using existing products.
- Will work as a stepping stone for new designs. This makes it easier to investigate the effect of RWH in the field.
- Production of a RWH kit in this manner is possible while making only minor alterations to a selected few parts on the NG1.

REFINED DESIGN BRIEF

Further development shall prepare the gutter add-on to cater for the needs of both the construction crew, but also those who will operate and maintain the system. Principles learned from the literature study on RWH needs to be incorporated into the design, and will provide additional guidelines.

A focus is put on the gutter and its integration on NG1. Suitable components for filtering and storage is available, making conveyance the part of the system needing further development.

REFINED PROGRAMME OF REQUIREMENTS

Following criteria needs to be followed in addition to earlier stated demands for a RWH system.

- A flow rate sufficient to cater for heavy rainfall is necessary.
- Sufficient drainage must be present to prevent that too much pressure is put on the NG1 structure.
- Easy maintenance must to be possible to ensure that no mosquito breeding or fire hazard is present.
- The system must be protected against clogging and overflow.

CONCEPT DETAILING

This chapter gives an explanation on how the detailing is done. Development of form of the gutter system is done using mock-ups as well as CAD. Measurements, sizes and capacity is chosen, along with suitable auxiliary items. The layout of the piping and storage is selected to maximise the potential of the NG1's RWH system, while keeping in mind the demands when performing rapid deployment during disaster aid.

Gutter Alternatives

Gutter options

Numerous options are available when adding gutters to a structure. When the NG1 is made up of PVC rubber over a metal skeleton, this complicates the choice. While also different user demands needs to be considered, what makes or brakes a RWH system is if it is able to be transported into action or not. For a long time, cumbersome logistics has prevented RWH of being used in disaster aid.

Hemming up a PVC tarpaulin becomes a sensible option when compared to other alternatives. The availability of spare parts, simple attachment options and its light weight and space needed when folded makes it ideal. Neither of the other realistic options can compete with its logistical benefits.

Choosing Support for the Gutters

The supporting bolt

A bolt can easily be put through the cross-beams of NG1's supporting frame. Getting a hole through the PVC sheet is also done without complications. If desired, a more rugged hole is made by clamping on metal rings to support the edges of a hole.

Numerous other options for attaching components can be made, while few alternatives includes no special components already available in the structure and spare parts of NG1.

12 mm bolts are chosen thanks to their abundance. When placed at the far ends of the cross beams, torque added from water in the gutter will be distributed in an efficient manner.

When attaching structural elements directly on the PVC canvas, it will be difficult to ensure similar stability and ruggedness, which is needed during heavy rainfall. This is an important reason to go through the canvas and into the supporting metal structure.

To add an extra hole at the ends of the cross-beams will add little effort to the manufacturing of the NG1. To put a bolt through a hole is not complicated at

all. Bolts will be held in place using locking-pins or butterfly-nuts for easy assembly. This enables crew to un-hook the gutters in case of draught, extreme storms or just for simple maintenance and cleaning.

It is important that a system gains trust and looks like it can perform as well as it does. Different support options should be tested, and the option that fulfills user demands as well as maintaining looks and sufficient strength must be chosen. Considering the theory behind "Design for Failure" is viable to apply specially on this component, as the part used for attachment will receive the hardest punishment while in use.

The supporting pipe

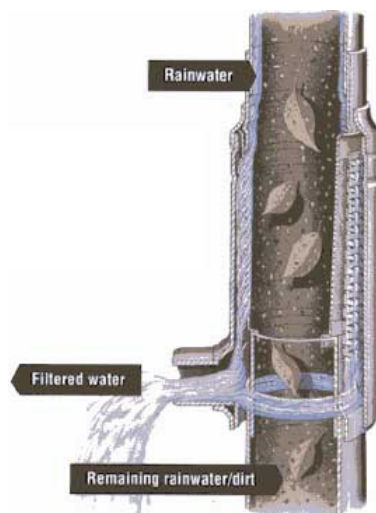
The pipe giving shape to the gutter is preferably realized in aluminium, since a combination of low weight and stiffness is preferred for this part. Steel can quickly become too heavy. PP and hard PVC can shatter under strain, while metal pipes only bends. Metal pipes is easily available in standard sizes, and 4 meter length is convenient both thanks to the structure of the NG1, but also the logistical benefits. Much longer elements can also quickly become cumbersome during assembly.

Auxiliary Components

CONVEYANCE

Down-Pipe and integration of Filter

A filter-design from Wisy in Germany fulfills many of the criteria for using it in a disaster aid setting. It has high capacity, needs little maintenance and will never allow overflow, instead it will pass through excess water. A diverting first flush effect is also obtained with this design. The filter is placed above the inlet of the tank, and integrated directly into the down pipe. Placement of the filter makes it easily available for maintenance.



Filter solution from Wisy

Piping

Pipes of soft PVC hose is used for pipes, commonly known from firefighter equipment. Great advantages with logistics and cost makes this pipe solution ideal. Longer lengths are possible. If protection is needed, these hoses can be placed in a down in a ditch. Other piping alternatives become less suited when considering space needed during transport.



PVC hose.

STORAGE

Types of flexible tanks

Optimal shape and size of a tank for a RWH system for NG1 is either several interconnected 1000- 1500 L shaped tanks placable on Euro pallets, a few larger pillow tanks of about 10 000 L or a combination of both.

Flexible water tanks fall into two distinct types. Pillow tanks, designed like a pillow and intended to go flat as they empty. Inlet is usually placed on the top surface. Shaped tanks are three dimensional tanks with top, bottom and sides. These are not intended to go flat as they empty, and will often have some sort of supporting frame. Shaped tanks have many benefits, and can easily be connected to increase capacity.

Storage capacity is a difficult topic, and each camp would benefit of making calculations to maximise the efficiency. If however more storage capacity is provided than rain can fill, these tanks will be suited for storing water from other sources, as long as they are kept separate from the rainwater.



Shaped water tank, 1400 L

Treatment during storage

With shaped tanks, more sophisticated inlet and outlet options becomes available. Low and shielded inlet, and the pipe to the outlet laying just below the water surface supported by a floating device. This is important measures to obtain greater water quality.

Treatment after storage

Biosand filtering is the preferred option for the long run, while chlorine tablets will be easier to distribute during the most early stages of deployment.



Pillow tank, 10 000 L

LOGISTICS

Different components will be delivered in crates, keeping related parts stored together in each container. A kit-structure is important to maintain, when an often chaotic logistic situation in disaster aid can introduce confusion an place important parts where they can't be reached.

Many Euro pallets where equipment are stored on becomes available during deployment of a camp. These wooden structures provide an ideal foundation for storing smaller vertically shaped PVC tanks. Wherever possible, every resource available should be exploited in a disaster setting.

PROTAN AND WATER STORAGE

Pillow tanks in sizes from 500 - 500 000 L can be ordered from Protan. A common kit for disaster aid would be their 10 000 L kit, including piping and a distribution station with six taps. With the pillow tank comes the necessary in- and outlets and tools needed for assembly.

The 10 000 L kit is delivered in two wooden crates measuring 1200 x 800 x 200 mm, containing parts for the tank in one and piping components in the other.

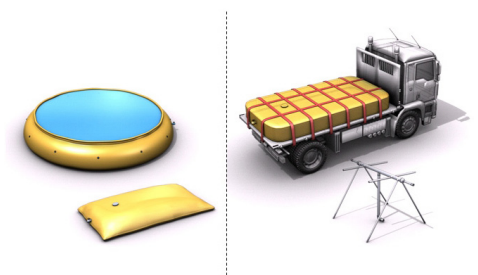
PVC is a flexible material enabling many structures for water tanks, making it possible to tailor a tank setup for any demand an situation.

PVC PRODUCTION TECHNIQUES

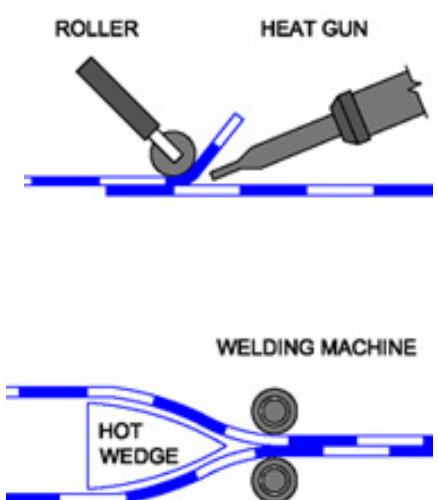
The PVC sheets are welded together in a first pass using heat from hand-held hot air device, together with pressure from a hand-held roller. The weld is reinforced by a second run over the mid portion of the overlap. The weld is sealed by applying heat with a third pass along with applied pressure from the roller.

Where hot air devices are unavailable, glue can be used. Customs prevent many types of glue being transported over borders, making certain types of tape to become the preferred option for field-repairs.

Holes can easily be made in the durable PVC sheets if needed. Loading straps of nylon can be welded on, and leather straps can be attached by using metal studs. PVC sheets provides many options.



Water storage system available from Protan as a Kit. An overview of the content is available in the appendix



Two common ways to weld PVC sheets



THE SMALL COMPONENTS

Pipe clamps

Metal pipe clamps are available throughout the world. A design suited for tightening by hand is preferred, to avoid hassle if maintenance crew by any chance should be missing the correct tool. Enables a watertight connection.

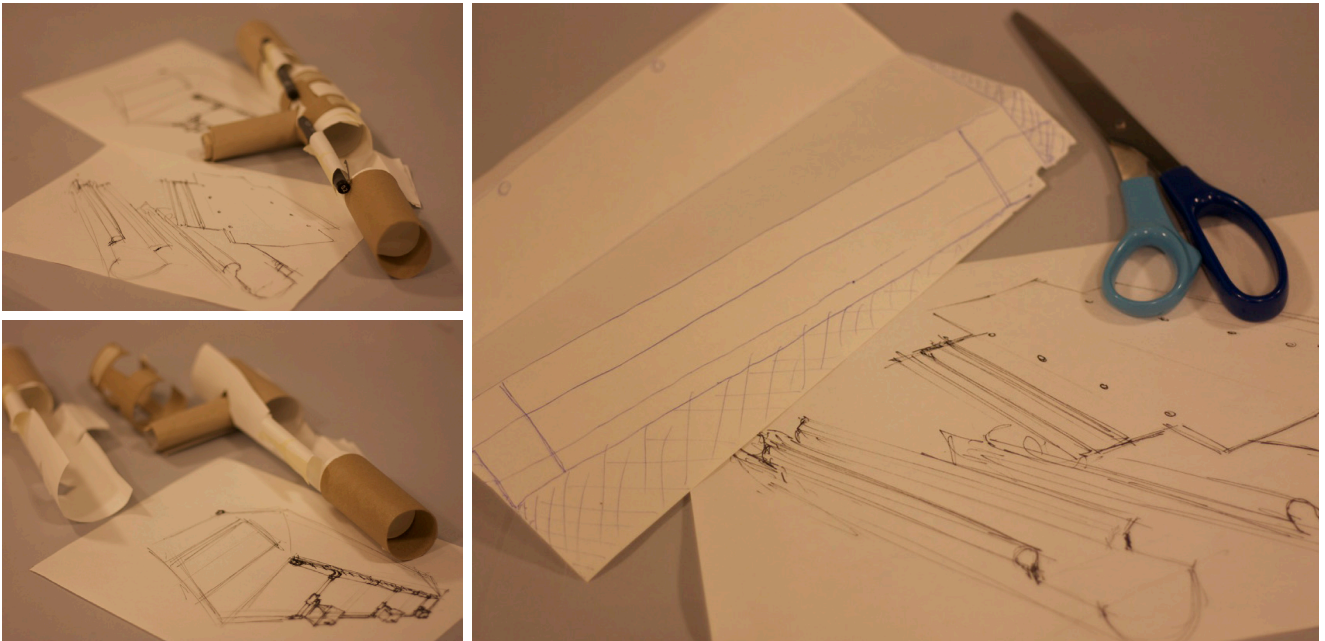
Spacers

The spacers placed on the support bolts secures correct distance from the gutter lip to the NG1 wall. Rubber is used to save the PVC canvas from unneeded stress.

T-pipes

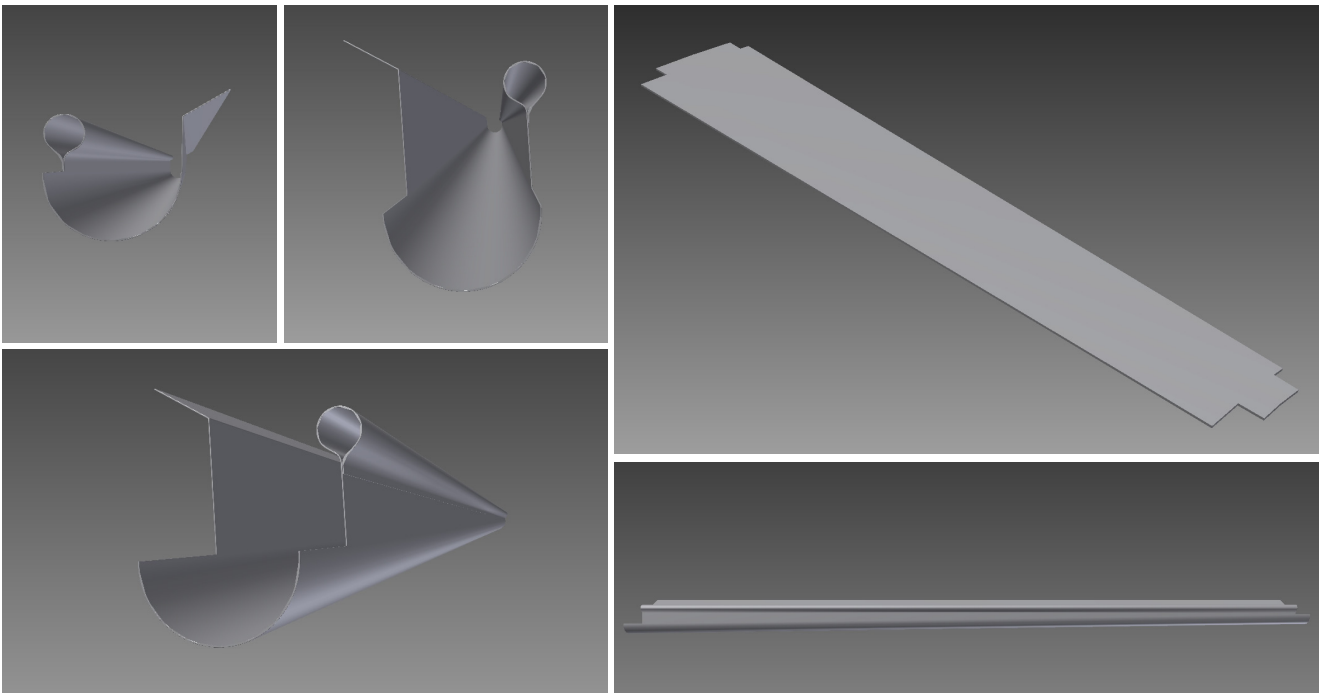
Rigid PVC pipes is chosen for central connection points, where durability and a rigid structure is needed.

Developing Form



Different attachment solutions were tried out through low-fi mock-ups. Paper and cardboard tubes are excellent replacements for PVC sheets and piping. When folding and unfolding shapes in 3D it becomes easier to see possibilities for the gutter shape. The three suggestions presented on the following pages turned out as the most promising candidates.

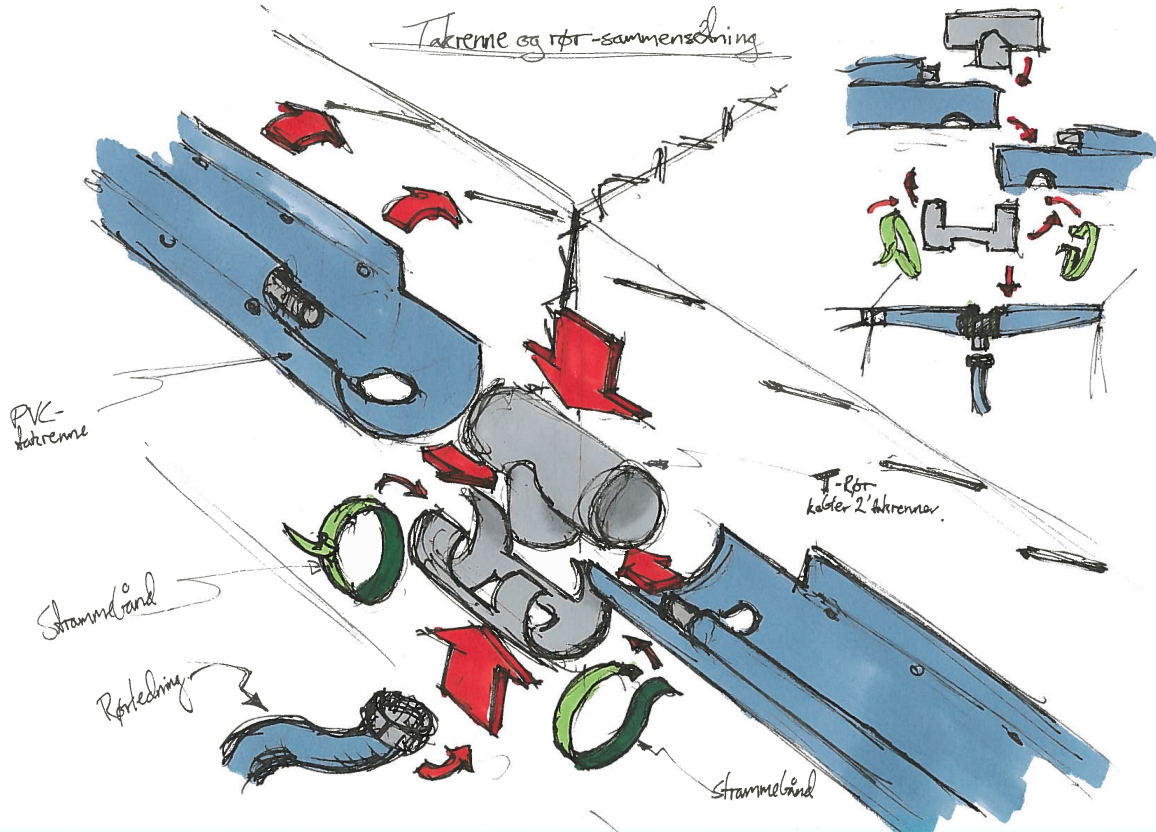
EXPLORING FORM WITH LOW-FI MOCK-UPS



Different views of the gutter, both in its final shape and when folded out. To get a realistic feel of proportions, size and placement, 3D models have a large advantage over sketches. A shape is selected that enables uncomplicated cutting patterns while in production.

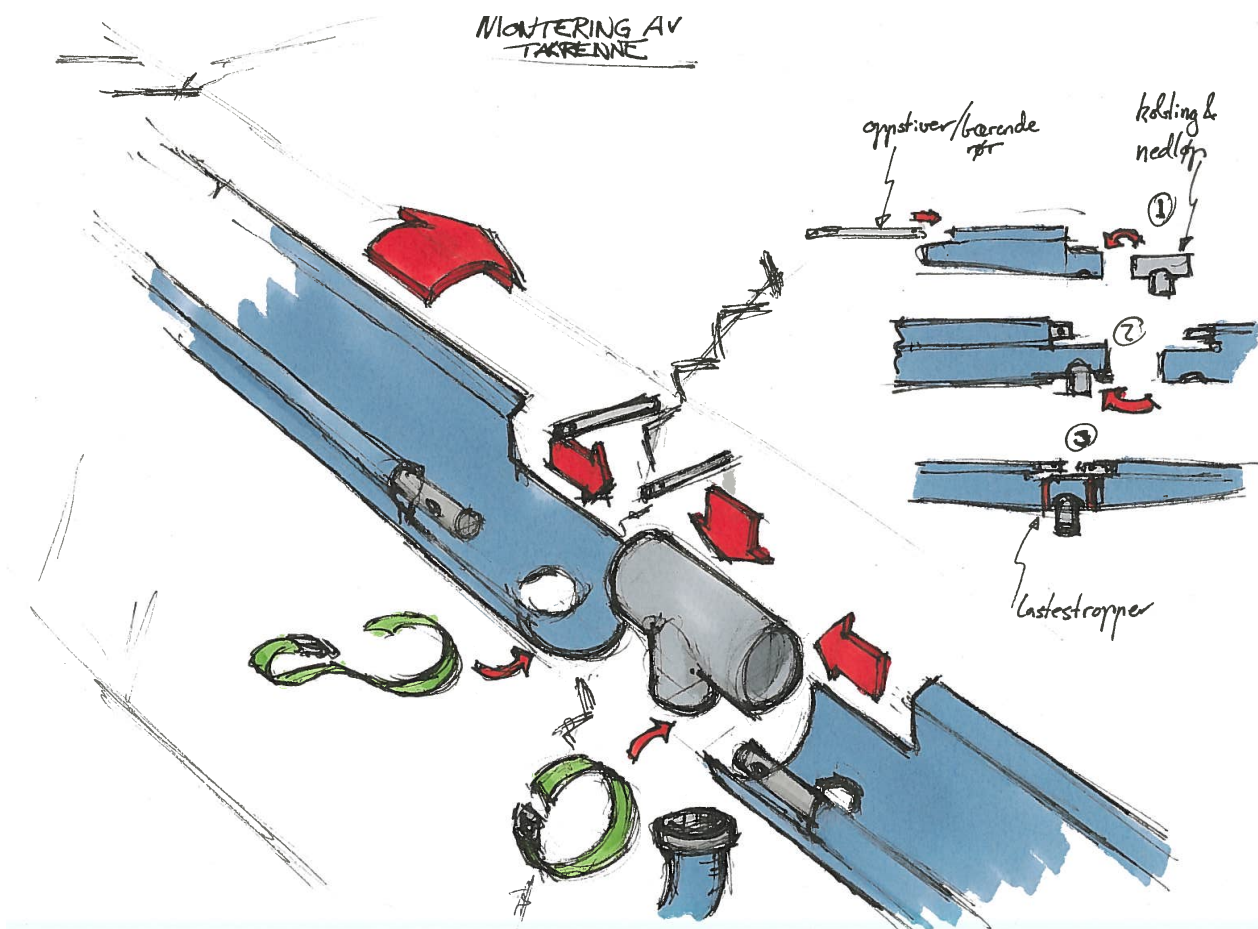
EXPLORING FORM WITH CAD

Three variations



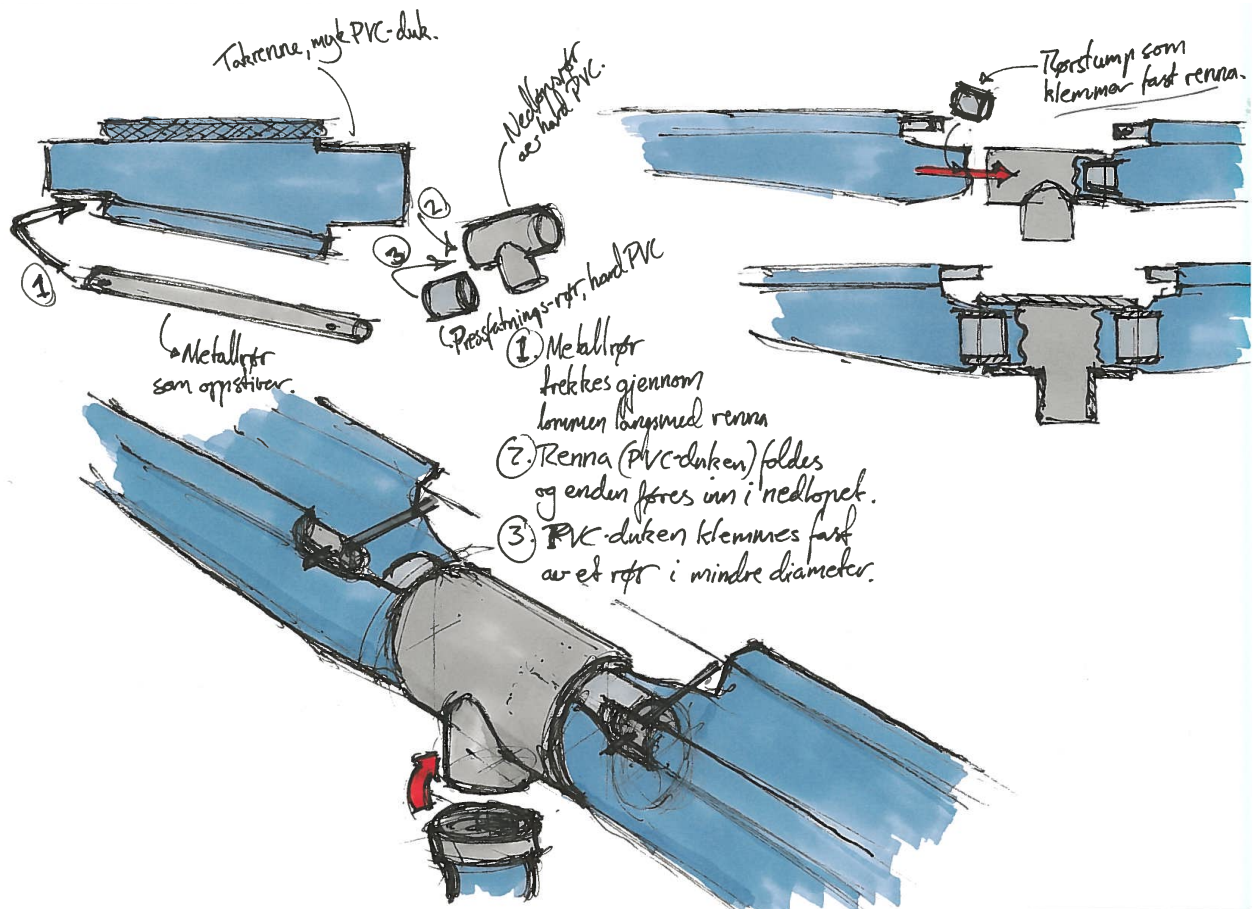
1: HOOKED ON: EASY ON-SITE ASSEMBLY

- The PVC is hooked on the NG1 by attaching it on the four bolts pointing directly out from the wall. The metal pipe going through the length of the gutter will rest on top of the bolts, which is beneficial regarding production and assembly. This makes the gutter also easy to unhook if needed.
- The T-shaped connecting pipe is placed through the holes in the PVC sheet. A shell is attached from the bottom, locking the PVC in place.
- Luggage straps can be added for extra strength.
- This option is best suited for assembly where unskilled assembly crew is used, because welding PVC is a technique best performed by skilled crew. On the down-side more holes in both the internal structure and PVC canvas is needed compared to the other two options.



2: WELDED ON: FEWER COMPONENTS

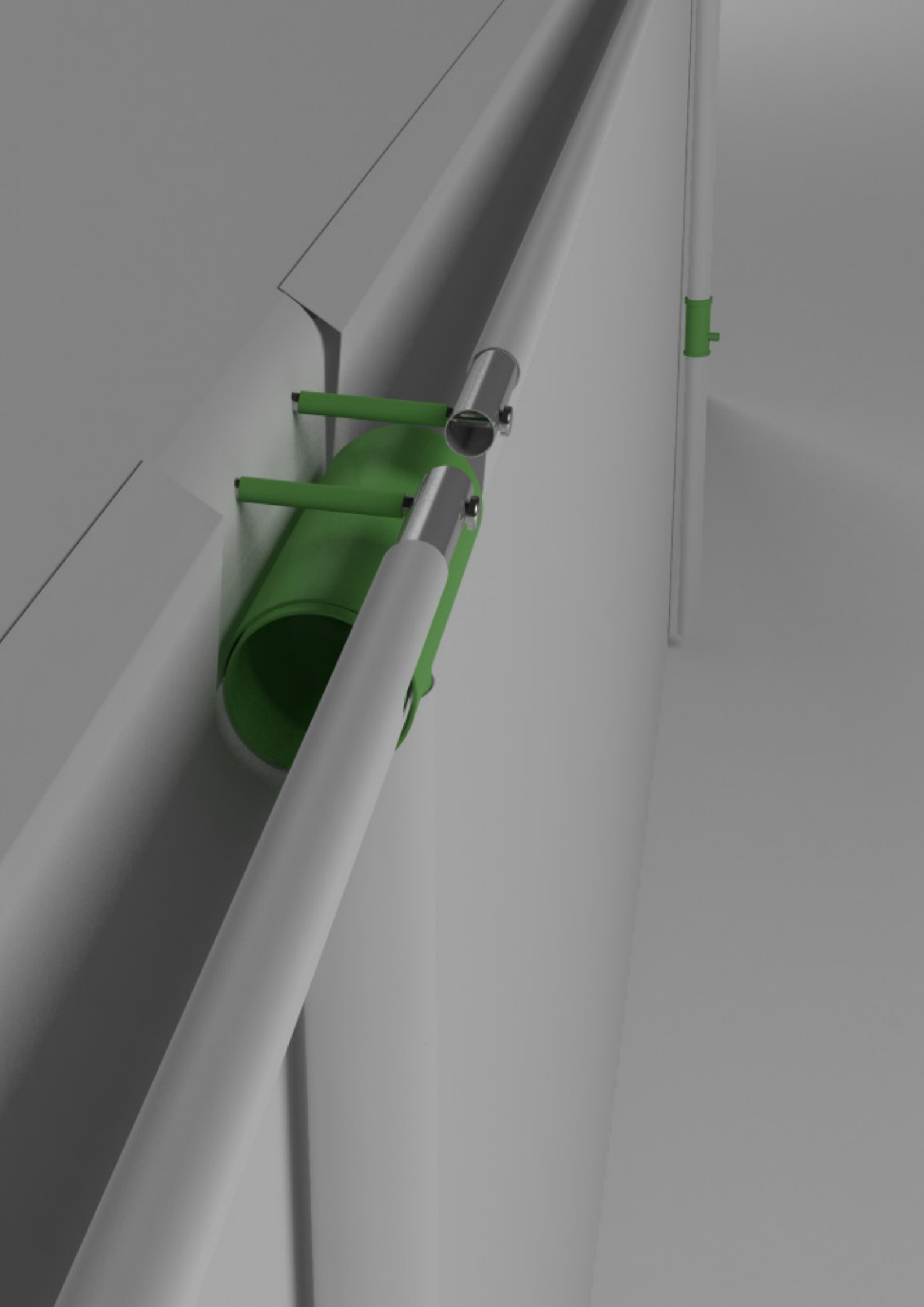
- The PVC lip is welded to the edge of the roof. This provides a water tight solution.
- Only two bolts are needed, but here they are placed through the metal pipe along the gutter. Clips or butterfly nuts are used to hold the pipes in place.
- Rubber spacers provide the distance from the wall.
- Down-pipe is assembled as with alternative 1, but the outer shell is dropped in favour for only two luggage straps.
- Main advantage is few components and thus providing easy maintenance.



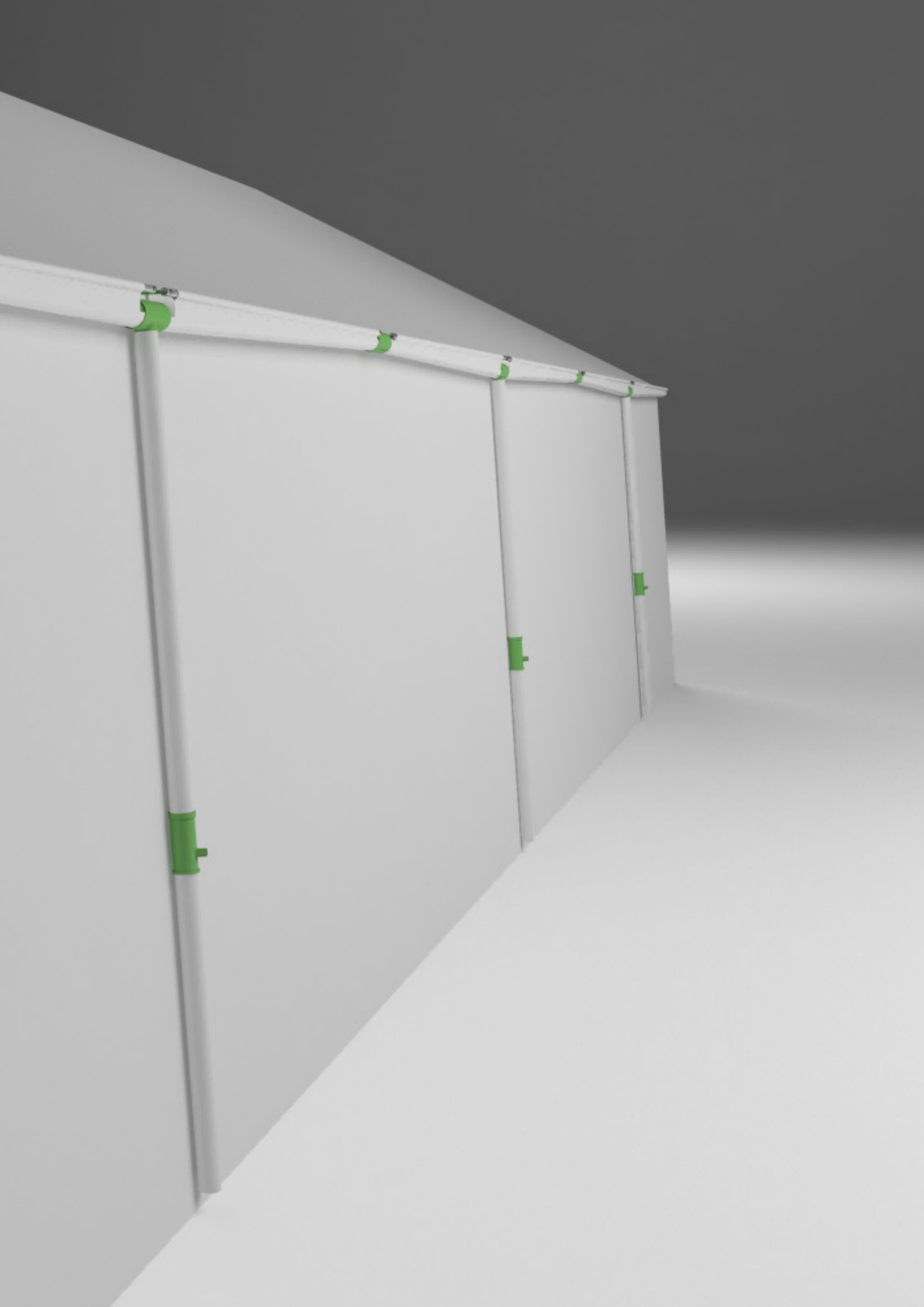
3: WELDED ON: NEW CONNECTION TYPE

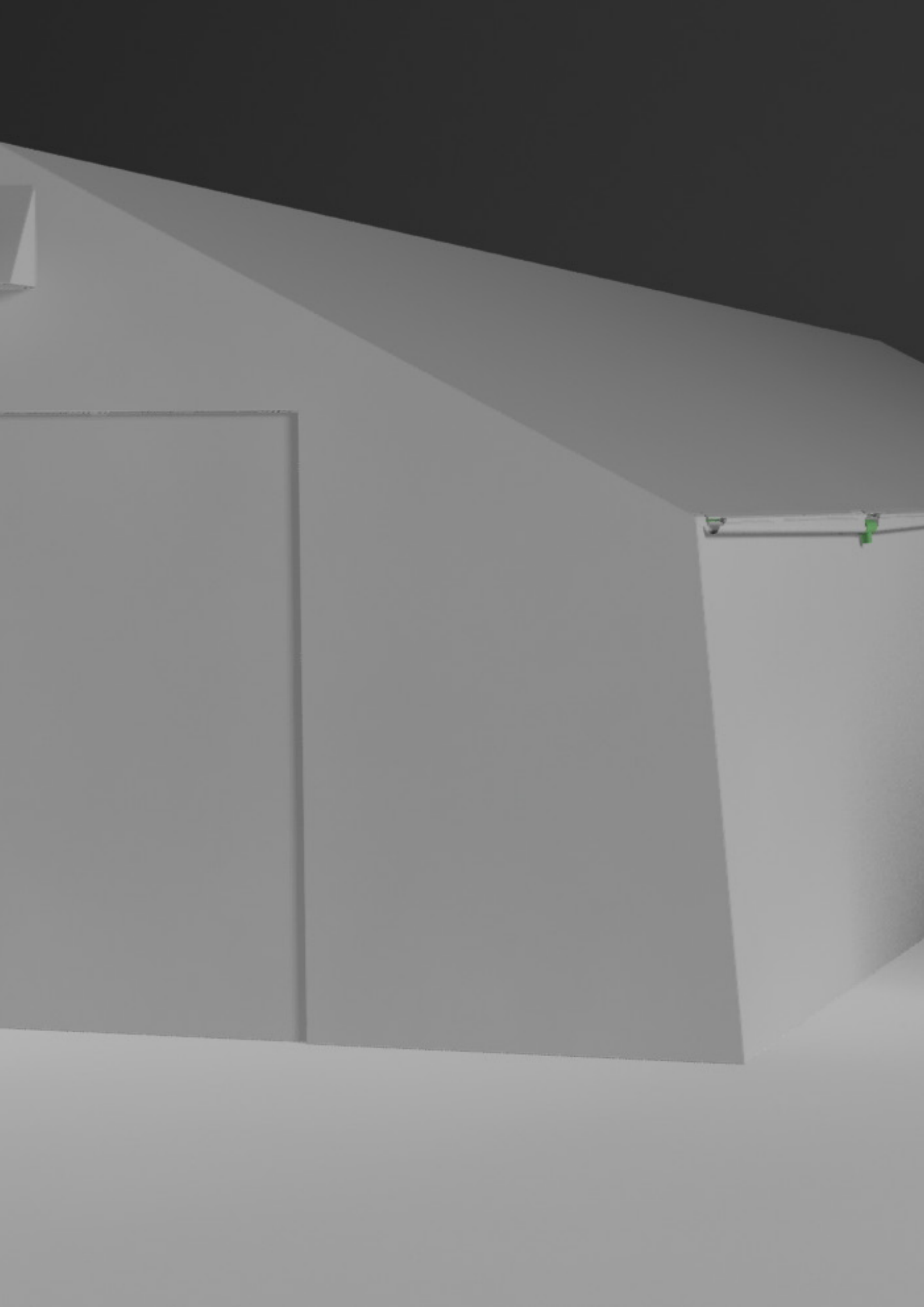
- The PVC lip is also here welded to the edge of the roof.
- Same pipe arrangement as alternative nr. 2.
- The down pipe is here secured by using two smaller pipes which are pressured into the ends of the T-pipe along with the PVC in the middle for a secure fit.
- Benefit for this design is extremely simple construction. Easy maintenance possibilities and durable construction with easily replaceable components. PVC sheets are more basic. Water tight construction is beneficial.
- This option is chosen for further detailing and future testing.

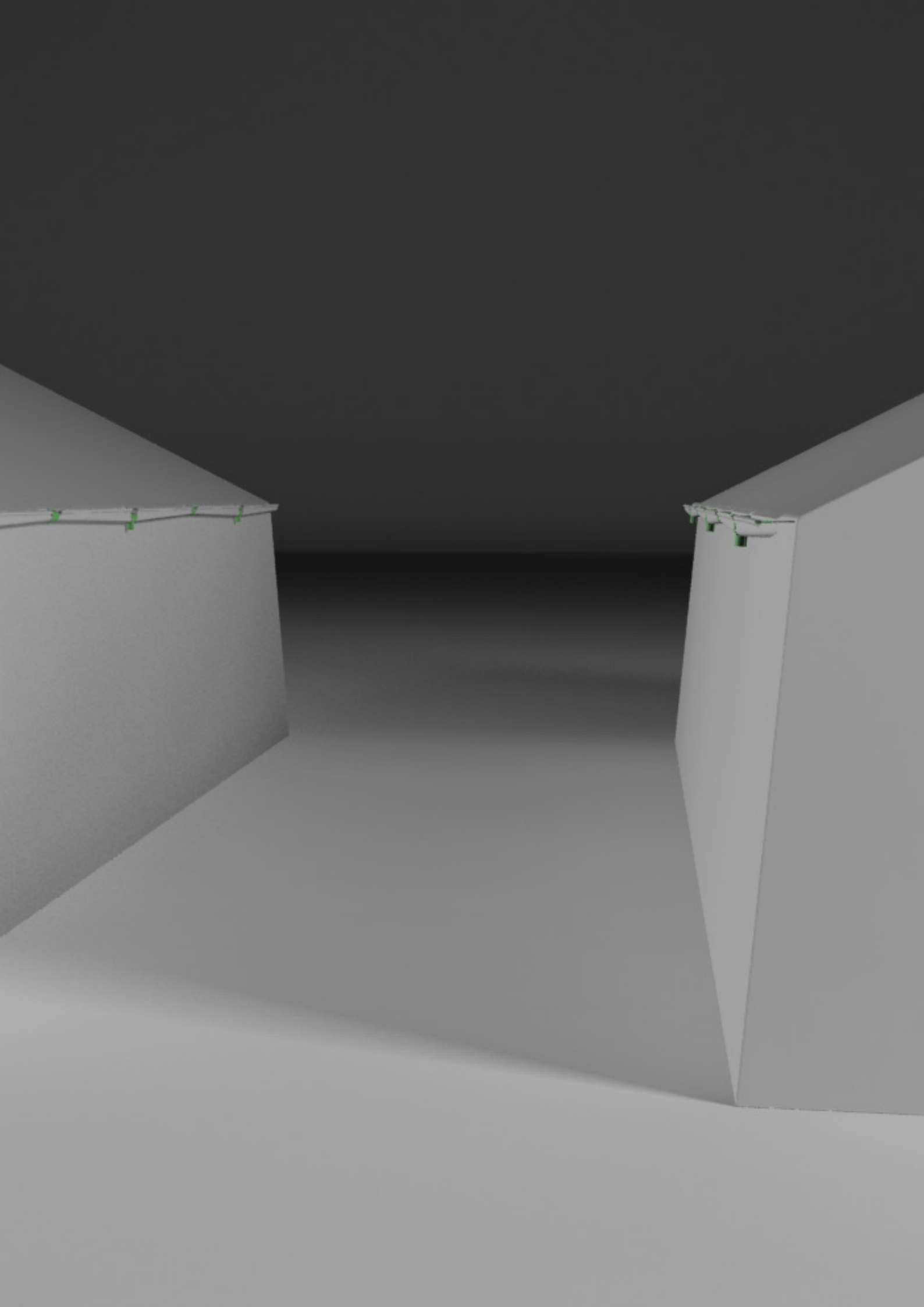
RESULT











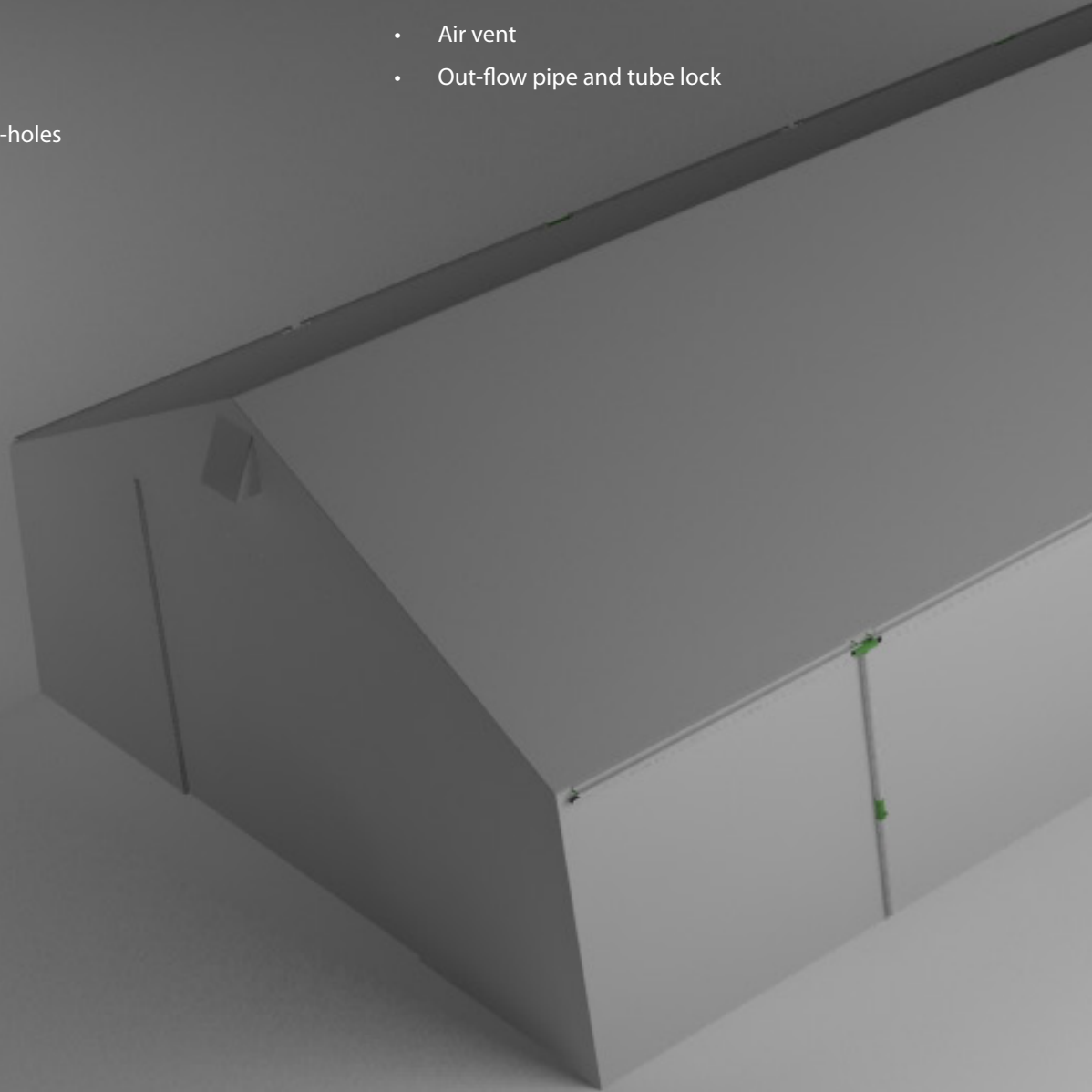
Component Overview

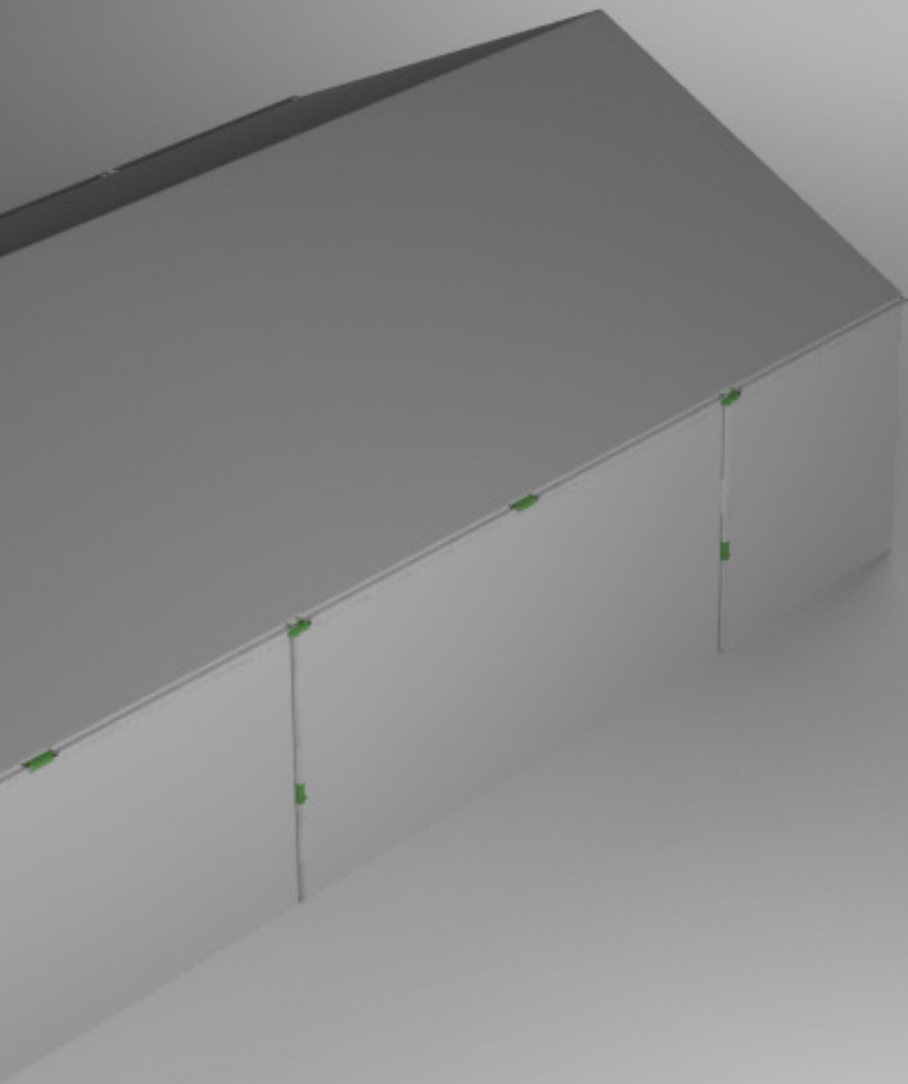
THE GUTTER

- PVC fabric
- T-pipe
- Small pipe
- Connector pipe
- Supporting metal pipe
- Bolt suspenders
- Clips
- Spacer
- Metal ring for PVC-holes
- Tube lock

DRAINAGE, FILTER AND STORAGE

- Tube / water pipes
- Filter combined with first flush, or storage-free first flush
- Water tank
- Inlet
- Outlet
- Air vent
- Out-flow pipe and tube lock





EVALUATION & FURTHER WORK

Concept Evaluation

The components which were needed to connect RWH technology with the NG1 was something as simple as a gutter and a conveyance system.

The concept is developed to cater the needs for the relevant user groups. Considerations towards production, logistics, assembly and maintenance has proven as important as optimization for daily use.

The ideas behind using appropriate technology and also “designing for failure” was used as a backbone to make decisions on which direction the concept development should go. This resulted in a product that is well suited to its intended context.

Applicability for this RWH system with other building foundations must be investigated. Regarding the other hall systems of WGH, the gutter design can easily be adapted to fit especially NG15 and NG3. Filter and tank capacity must be chosen to match the catchment surface of each hall.

An analysis on the different user groups revealed many needs that has been taken into consideration. This can be summarized in many features.

- All the components is possible to lift by hand.
- No part is depending on special tools for assembly and maintenance. A hot air device will increase the efficiency of the gutter when attaching it
- Creating a system so intuitive and simple so it is easy to use in a correct way when even large cultural differences and language barriers may apply.

The starting point of this project was to develop a hall system for disaster relief. It became clear during the concept development that much could be accomplished only by an add-on attached to the existing structure. This discovery is an important part of this thesis.

Designing a RWH system is as complex as the required technology is simple. Questions regarding tank sizing, choice of filters and the general system layout have no simple answers. Most setups require planning and previous experiences can't be made as a foundation without taking into consideration the limitations and possibilities within each individual context.

A RWH system has many potential pitfalls which must be avoided. Maintenance is a weak link of this system. It will

perform well if a good connection between the service crew and the system is made. If implementation goes well, it will continue to perform even after deployment crew from WGH has left site. It is in other words vital that the relevant user groups are identified and included in the project implementation at a refugee camp.

The structure of the conveyance setup is simple yet effective. With the correct match of filters and storage units, this system has a good potential.

Project Evaluation

Throughout the project a challenge has been to remember to move forward with an iteration even though not all elements of a concept would be covered. With several iterations things have a tendency to uncover them selves in a logical manner. The opposite scenario happens when you get stuck with a solution, trying to perfection the design without pushing it towards a more realistic level.

The analysis phase proved to be comprehensive but also very educational. Two iterations of analysis was done. The focusing on internal and external elements of WGH, the second provided insight on the combination of RWH and disaster aid. With these studies it became much easier to create criteria and to perform evaluations of the different ideas.

Workshops are useful as an idea generating tool. Most useful to the process was beyond all doubt to get experience with the actual hall system. If this project is to be continued, continuous testing with either form or functional mock-ups in different scales is recommended.

An assumption was made when choosing Bontveit in Bergen as the foundation of the field studies. If the natural environment of the product is unavailable, some sort of substitute should be made. While staying conscious on the many differences between assembly in Bergen of an NG3 and setting up a refugee camp in sub-Saharan Africa, the “field experiences” provided a lot of input valuable to the process.

An even more deliberate mixing of media at an even earlier stage in the concept development process would have proven useful. The value of doing parallel work in different media is high.

Further Work

At this stage, the concept is documented to the level where real life testing becomes natural. At WGH there is an NG1 available for assembly. Different attachment solutions should be tested. Water can often behave in unpredictable ways. The fluid mechanics related to this system must be evaluated.

Calculations on roof size vs. capacity are made, but they need to be continued. What storage solutions that are beneficial in different environments greatly varies with the distribution of precipitation.

How the system will perform is not only depending on its user friendliness, if it's adapted well to the logistical challenges and so on. How it is received by potential buyers is an important topic. RWH has from before been met with many preconceived opinions. Even amongst water professionals opinions are many and different. To create a system which gains confidence is in other words a goal to reach for.

If the reception amongst professional are positive and initial testing prove successful, a logical second step is to prepare the system for the other hall systems from WGH that are used in disaster aid.

To work towards a new generation of hall systems with modified framework is recommended. Experience has proven that small (but important) steps in the right direction is a way that yields results. In this way, the add-on designed for NG1 can make the hall system get closer to reach its full potential.

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Master Thesis

Department of Product Design

NTNU 2012