Vertical Farming Prototype

- Outdoor -

Helmut Schmidt Universität
Universität der Bundeswehr Hamburg

agya
ARAB-GERMAN YOUNG ACADEMY OF SCIENCES AND HUMANITIES

Hamburger Klimaschutzstiftung
für Bildung und Nachhaltigkeit

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This documentation has been created by

Gaia Di Martino,

Svenja Zadow,

Juan Manuel Grados Luyando,

Sebastian Graber.

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DOCUMENTATION

Introduction

The purpose of this document is to document and explain the steps and materials behind making a vertical farming prototype in a DIY style for home application.

The prototype was developed by the team Value Creation of the Laboratory of Production Engineering (LaFT) at the Helmut-Schmidt-University / University of Federal Armed Forces Hamburg for a workshop of the Arab-German Young Academy (AGYA) about Vertical Farming (July 2022). The aim was to create two prototypes (one outdoor version and one indoor version) that can easily be replicated with the help of this documentation.

The journey for both versions started with idea-hunting online: A simple research on the web gave us inspiration for what we wanted to do. The web is full of ideas, so we brought together different styles and adjusted them to our specific conditions. A site inspection was performed to understand some parameters, such as the size limitations of the outdoor prototype[1].

[1] Both versions are scalable by reducing or increasing the size. The scalability also influences the size of the used materials: e.g., for a smaller outdoor version, smaller beams should be used.

Outdoor version

The outdoor version concept is an easy, low-tech DIY project. Easy-to-find materials, such as wood beams and rain gutters, were used. The design and layout were chosen based on the planned location on a brick wall and the requirements of the plants that were considered for growing. The size of the prototype was also chosen as a compromise between the number of levels and the ease of maintenance without a ladder or other aids.

Materials and costs

This paragraph illustrates the Bill of Materials (BOM) for the outdoor version (Table 1).

Note: Costs may vary according to region, shop, and period. The links may be used as a reference to find the same or a similar item for your conditions. The prices do not include the costs for plants, seeds, seedlings, and water.

Table 1: Bill of Material (BOM) for the outdoor prototype.

Item	Description	Quantity	Size	Link	Price per Unit	Price	Note
Rain Gutters	Marley Dachrinne Kunststoff halbrund Schokoladenbraun RAL 8017 NW	4	150 x 2000 mm	Link	15,95 €	63,80 €	
Rain Gutters' End Pieces	Marley Rinnenendstück Kunststoff halbrund Schokoladenbraun RAL 8017 NW	8	150 mm	Link	5,45 €	43,60 €	
Coconut Mat	Natursache Coconut erosion protection mat, coconut 225 g/m² on jute fabric, 300 g/m²	1	1,1 x 10 m	Link	46,47 €	46,47 €	
Pump (Irrigation System)	Esotec WaterDrops, Professional Solar Irrigation System	1	-	Link	119,00 €	119,00 €	
Soil	Soil peat-free & with biochar	8		Link	6,99 €	55,92 €	Available only in Germany
Wood Beams	Douglas fir	13	45 x 70 x 2000 mm	Link	15,95 €	207,35 €	
Wood Oil	Protective wood oil	1	-	Link	21,95 €	21,95 €	

Table 1 (continued): Bill of Material (BOM) for the outdoor prototype.

Item	Description	Quantity	Size	Link	Price per Unit	Price	Note
Wood Screws long	-	1	4,5 x 70 mm	Link	10,00 €	10,00 €	Pack of 100 Screws
Wood Screws	-	100	3 x 25 mm	Link	4,95 €	4,95 €	
Butterfly Hinges	-	2	90 x 60 x 1,25 mm	Link	1,95 €	3,90 €	
Water Container	With lid and base	1		Link	43,99	43,99	
Total							**576,94 €**

Building manual

This section explains the steps followed to design and build the outdoor version.

Step 1: CAD design

The CAD file was prepared using a CAD software. The purposes of having a CAD file are:

- Proof of concept: With a technical CAD design, it is possible to see (to a certain extent) if the design is feasible and stable. Some CAD software has integrated features to evaluate the mechanical properties of the project. Therefore, creating a 3D model makes assessing the idea's functionality easier.
- Clearer understanding of the materials to be purchased: With the CAD design, the dimensions are known; therefore, less waste is produced during the production phase.
- Reduce the error rate while producing and assembling: With a 3D model as a reference, it is easier to follow the idea. Furthermore, by designing the project digitally, the steps during the assembly are more transparent.
- Replicability: CAD files allow people to share their projects and replicate others'[2].

[2] This is particularly important when digital techniques (such as 3D printing, laser cutting and CNC milling) are used to produce the parts.

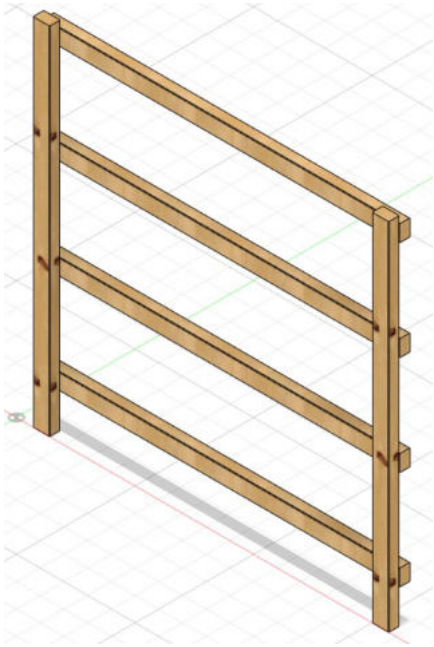

Figure 1: Back frame, CAD drawing.

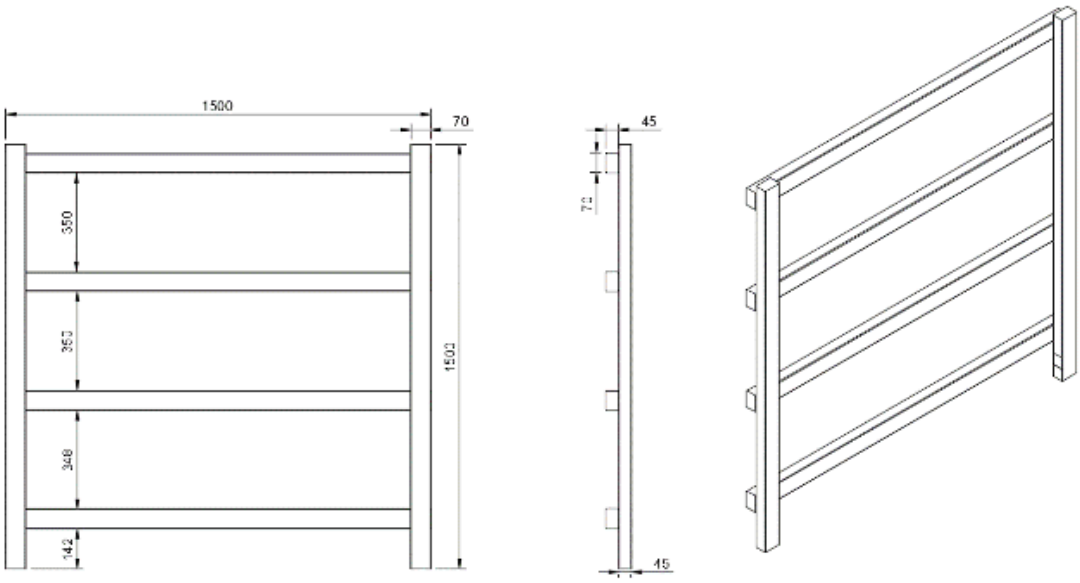

Figure 2: Back frame, technical drawing.

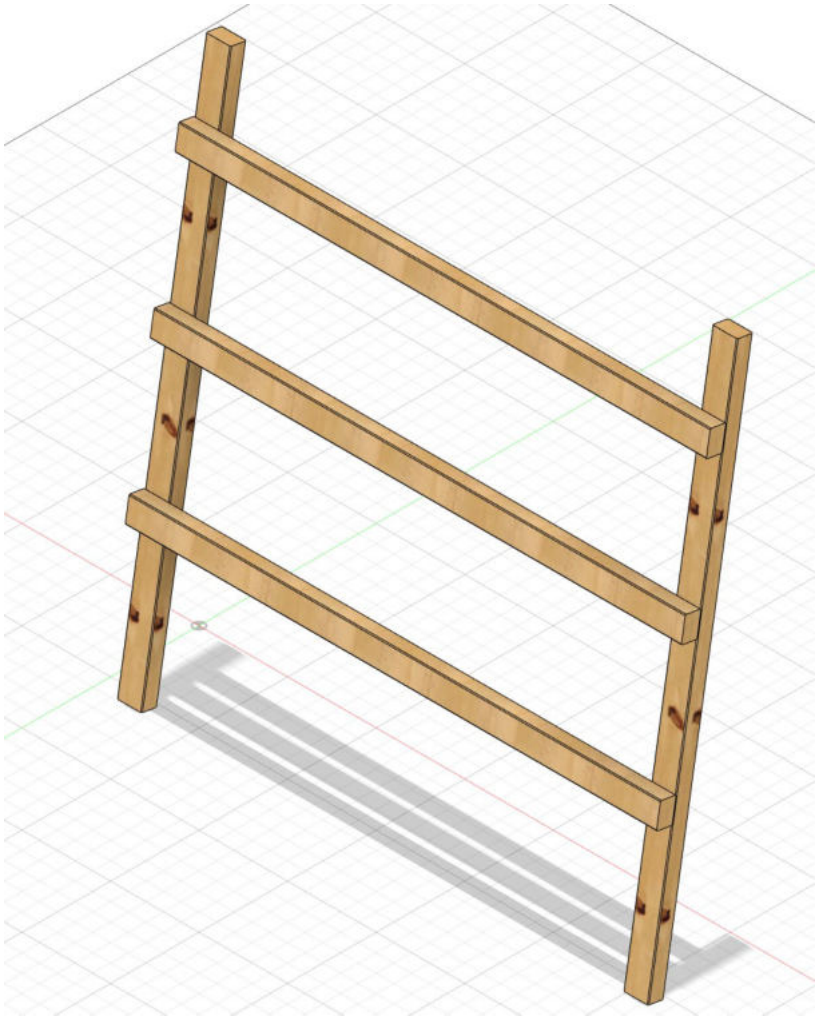

Figure 3: Front frame, CAD drawing.

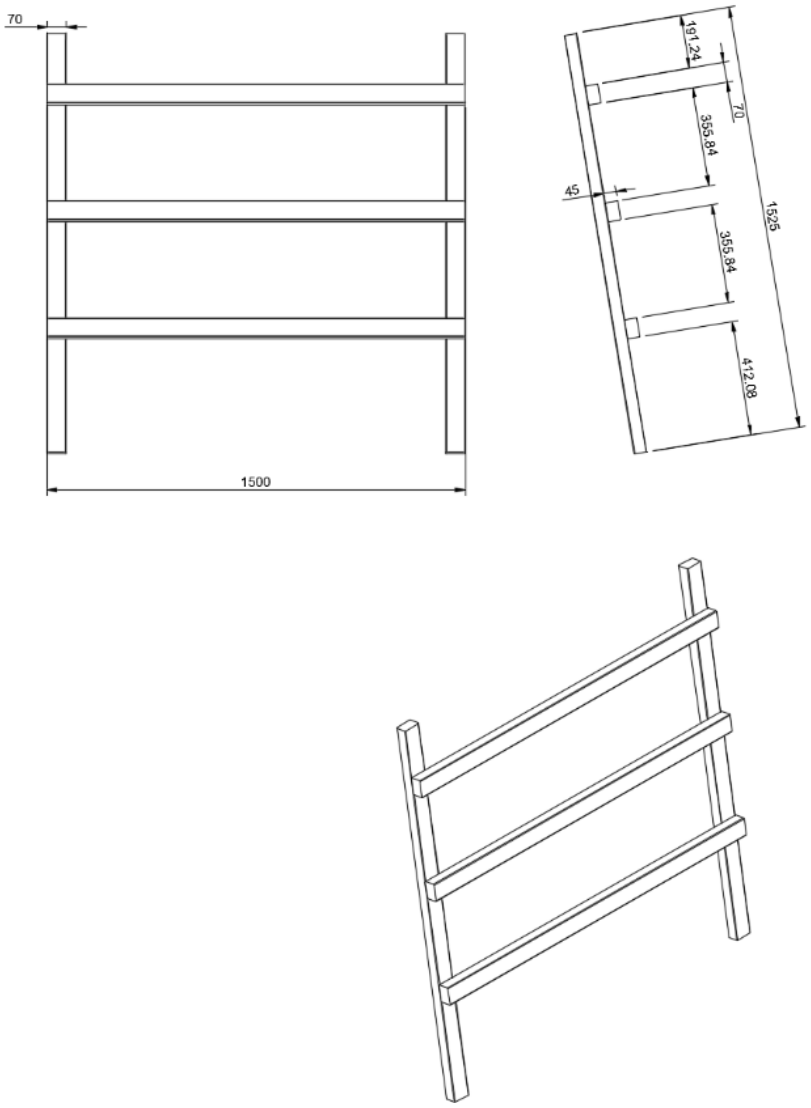

Figure 4: Front frame, technical drawing.

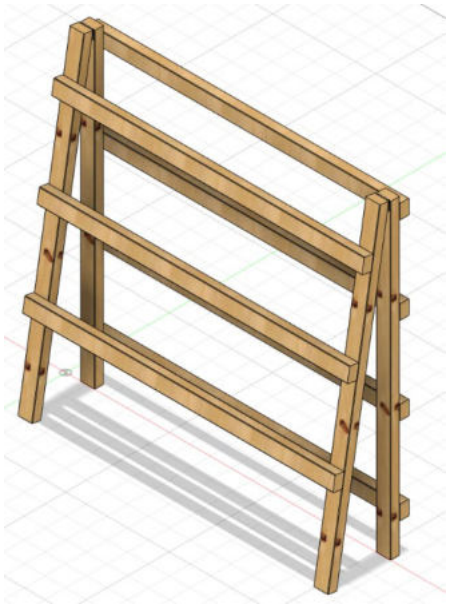

Figure 5: Ensemble, CAD drawing.

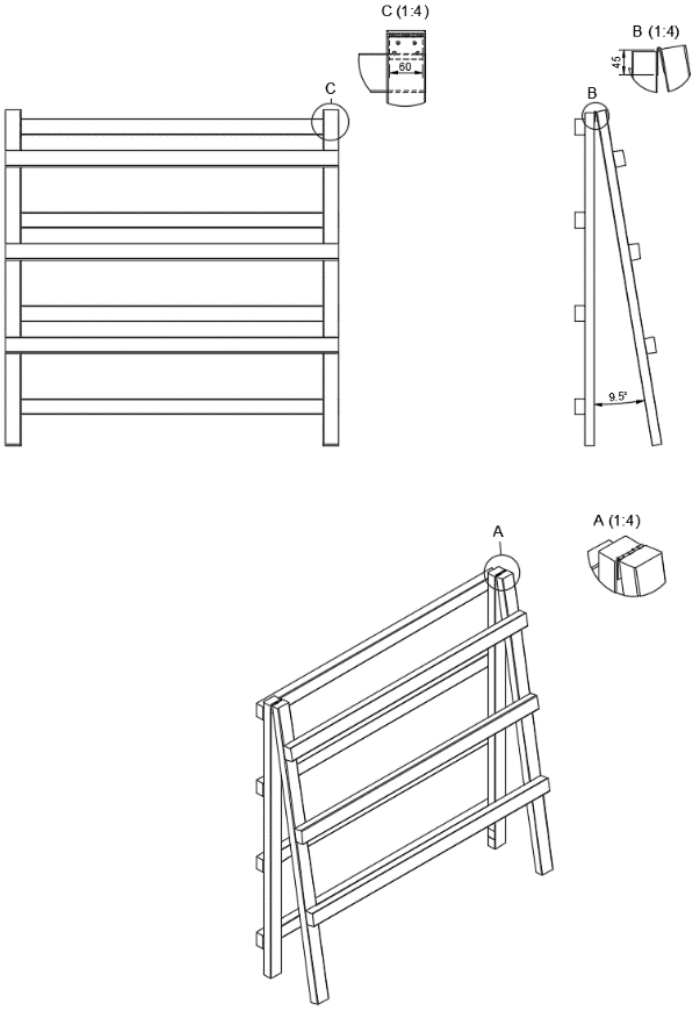

Figure 6: Ensemble, technical drawing.

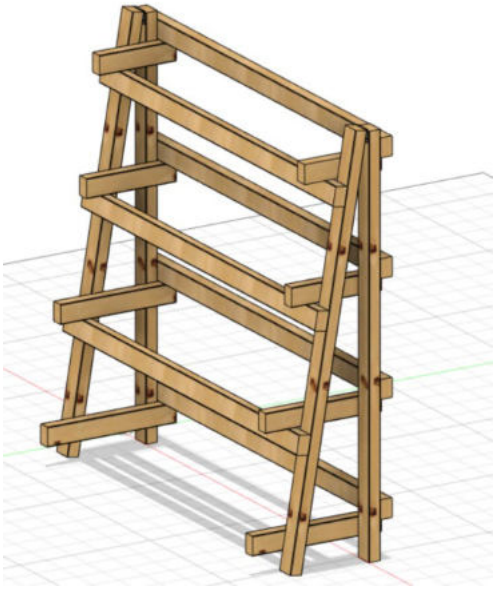

Figure 7: Complete frame, CAD drawing.

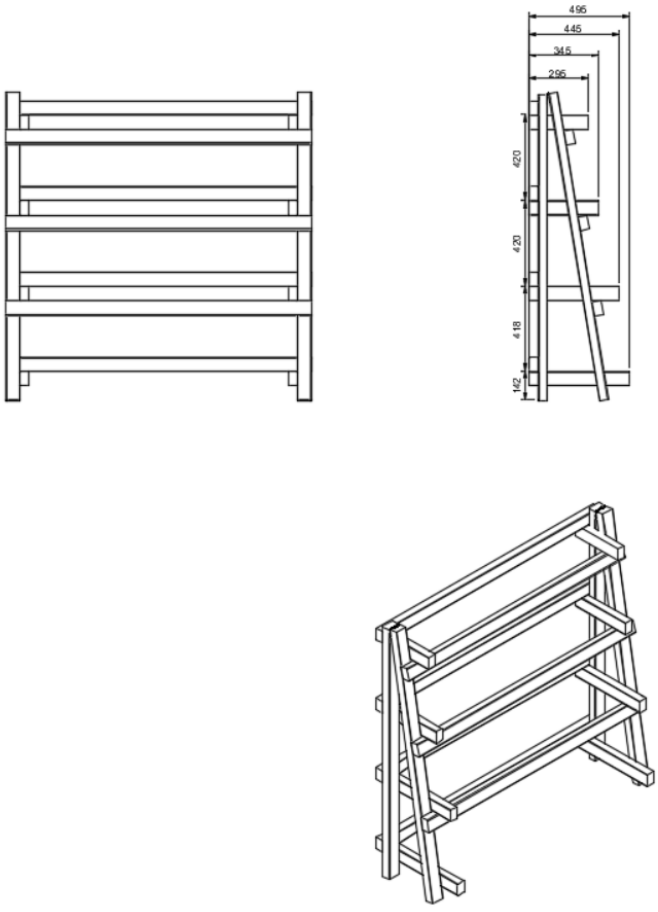

Figure 8: Complete frame, technical drawing.

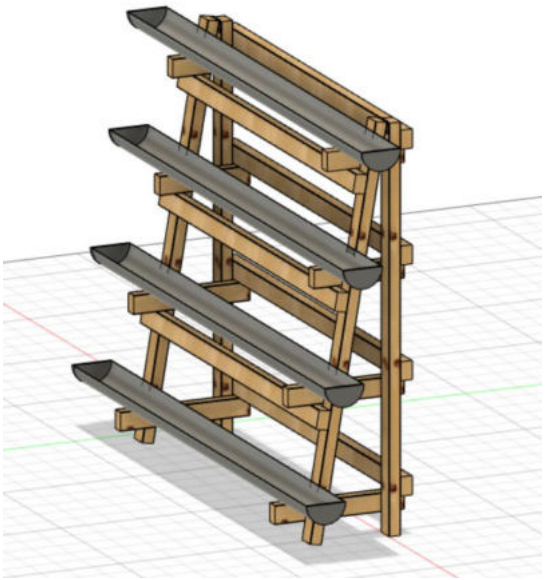

Figure 9: Indoor prototype, CAD drawing.

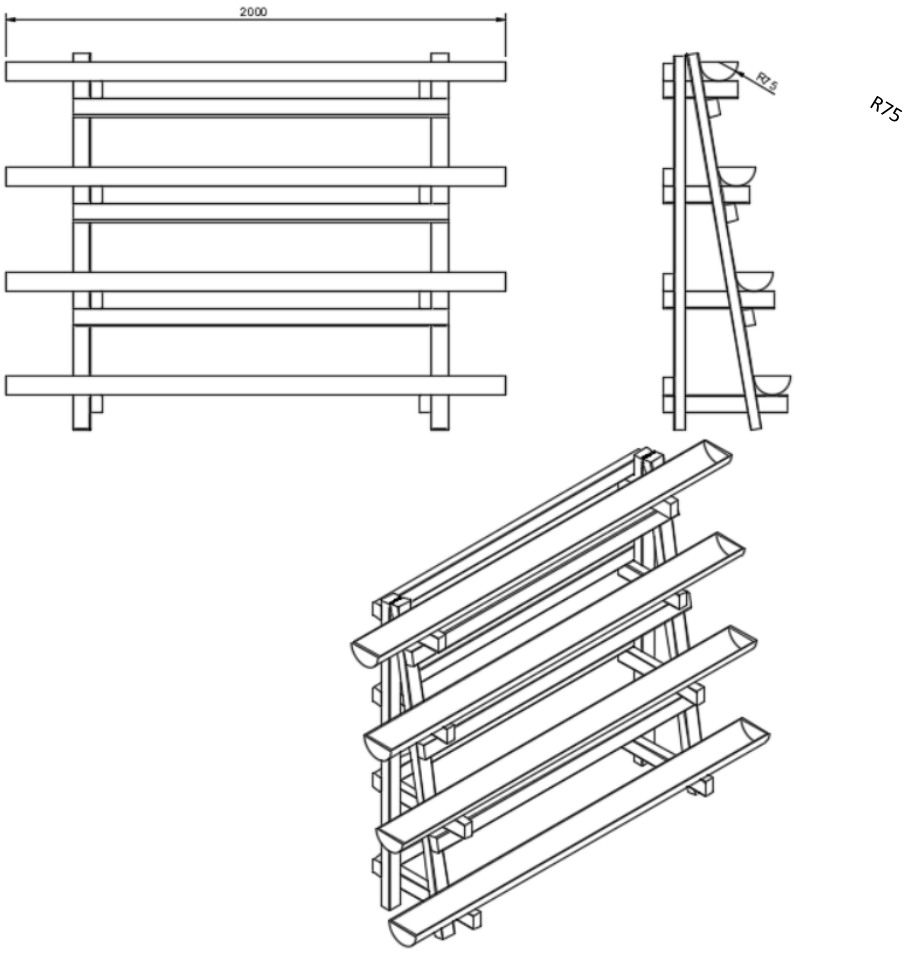

Figure 10: Indoor prototype, technical drawing.

Step 2: Materials procurement

Materials were purchased from different sellers, considering the price, quality, and shipping times. For a detailed view, refer to the Bill of Materials (BOM).

Step 3: Construction

a. Cutting the wood beams

The wood beams were cut to the correct size according to the BOM with a circular saw:

- 2 x 1525 mm
- 2 x 295 mm
- 2 x 345 mm
- 2 x 445 mm
- 2 x 495 mm
- 9 x 1500 mm

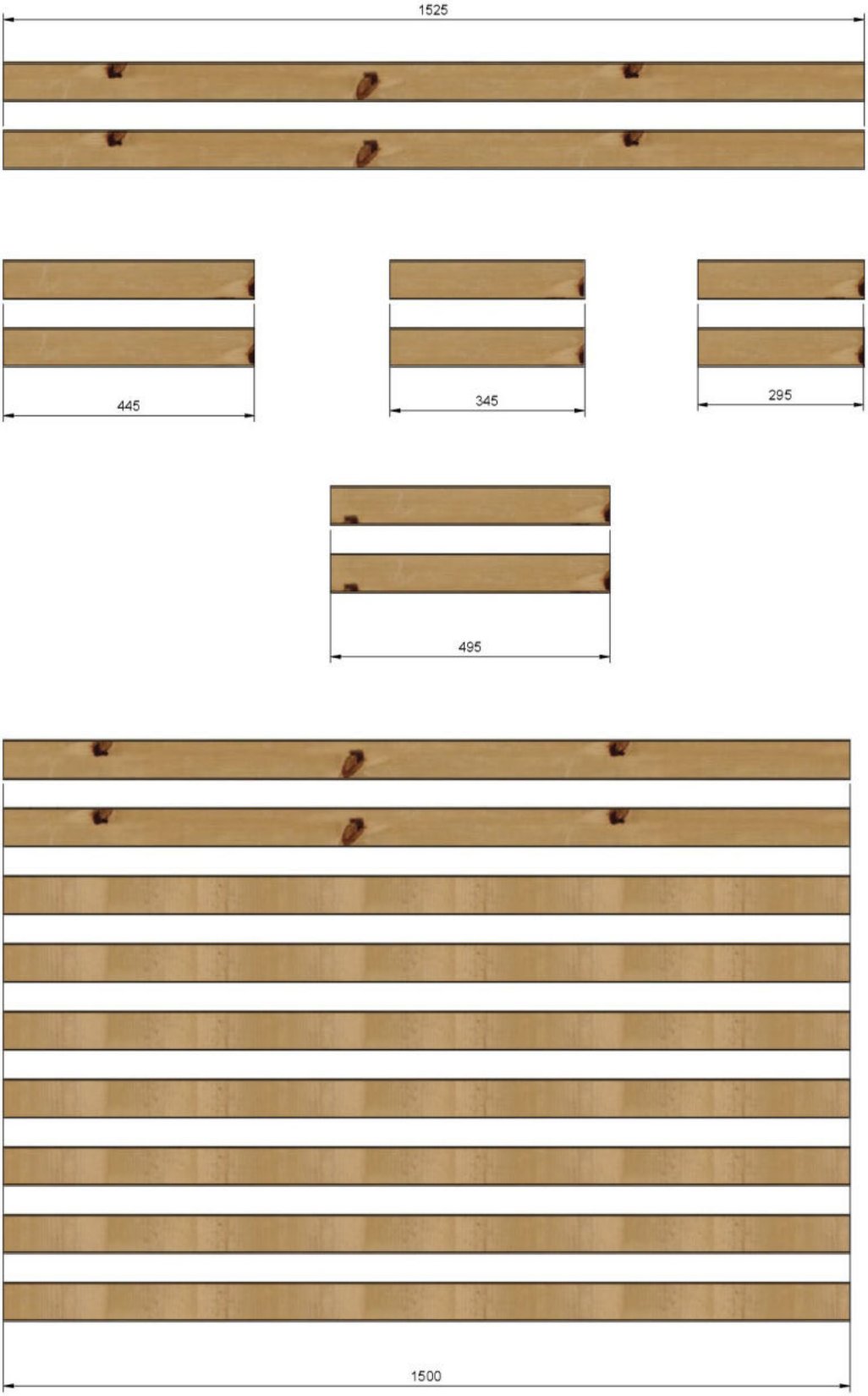

Figure 11: **Guideline for sawing the wooden beams.**

b. Building the back frame

For this step we used:

- 6 x 1500 mm wooden beams
- 6 x wood screws

The frame was built according to the CAD drawing. The 6 x 1500 mm wooden beams and 8 x long wood screws (1 per contact point) were used.

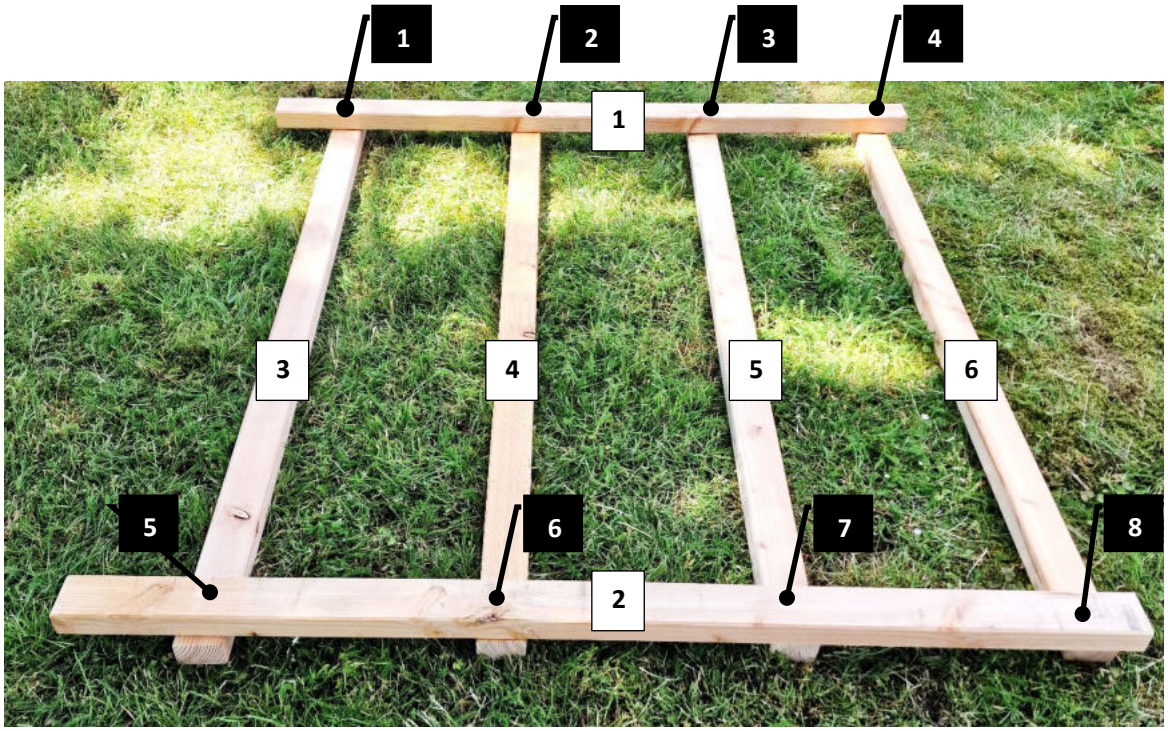

Figure 12: Assembly of the back frame using the wooden beams (1-6) and the screws (position 1-8).

c. Building the front frame

For this step were used:

- 2 x 1525 mm wooden beams
- 2 x butterfly hinges
- 16 x wood screws

The 1525 mm wooden beams were connected to the back frame with hinges.

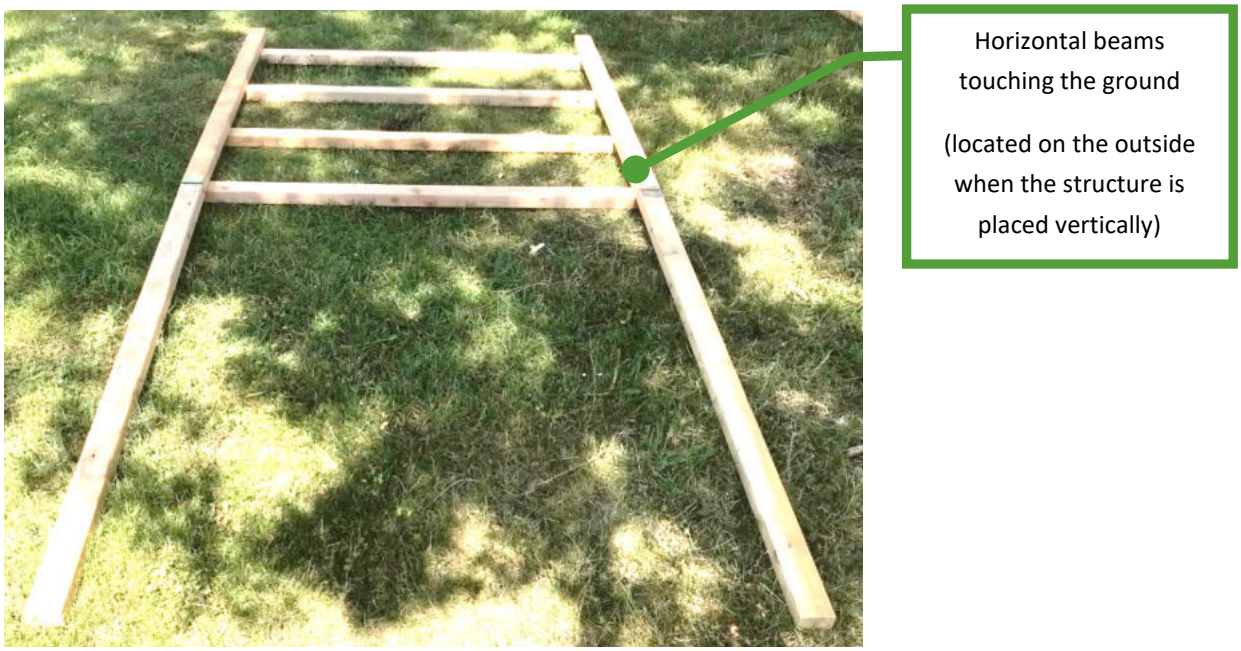

Figure 13: Assembling of the front frame.

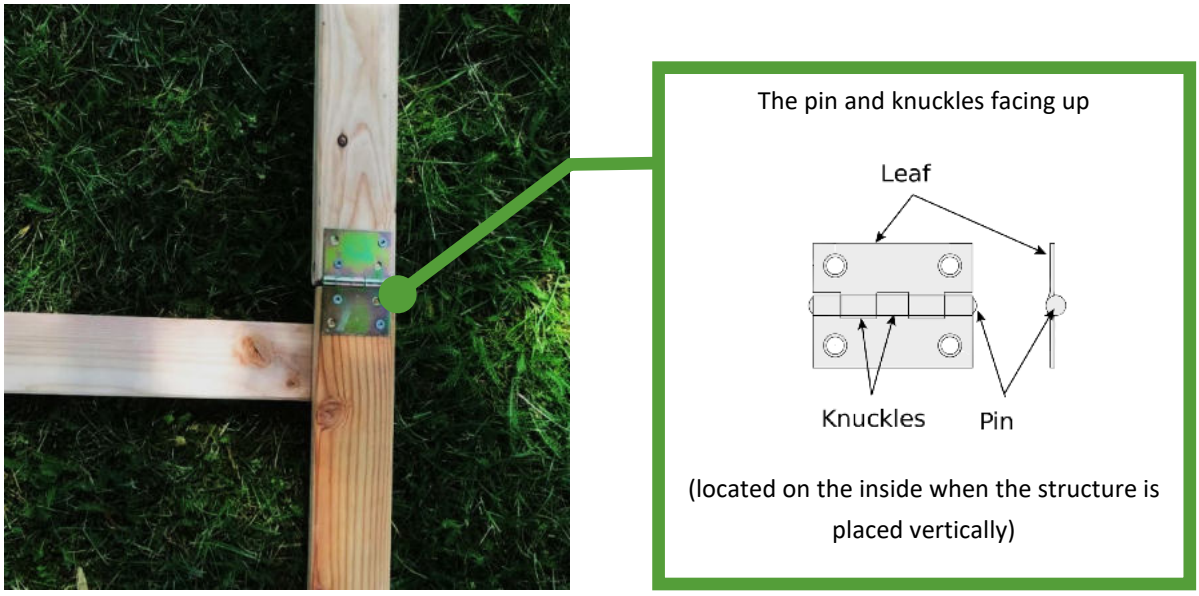

Figure 14: Assembling of the front frame using hinges – in detail.

d. Fastening the struts

For this step were used:

- 2 x 295 mm wooden beams
- 2 x 345 mm wooden beams
- 2 x 445 mm wooden beams
- 2 x 495 mm wooden beams
- 32 x long wood screws

For this step the so-far-assembled structure was set up flush against a wall. The angle created between the back and front frames was set to be approximately 9,5° in regard to stability. The struts were fastened, longest at the bottom and shortest at the top.

Figure 15: Adding the struts.

Figure 16: Assembling of the struts – in detail.

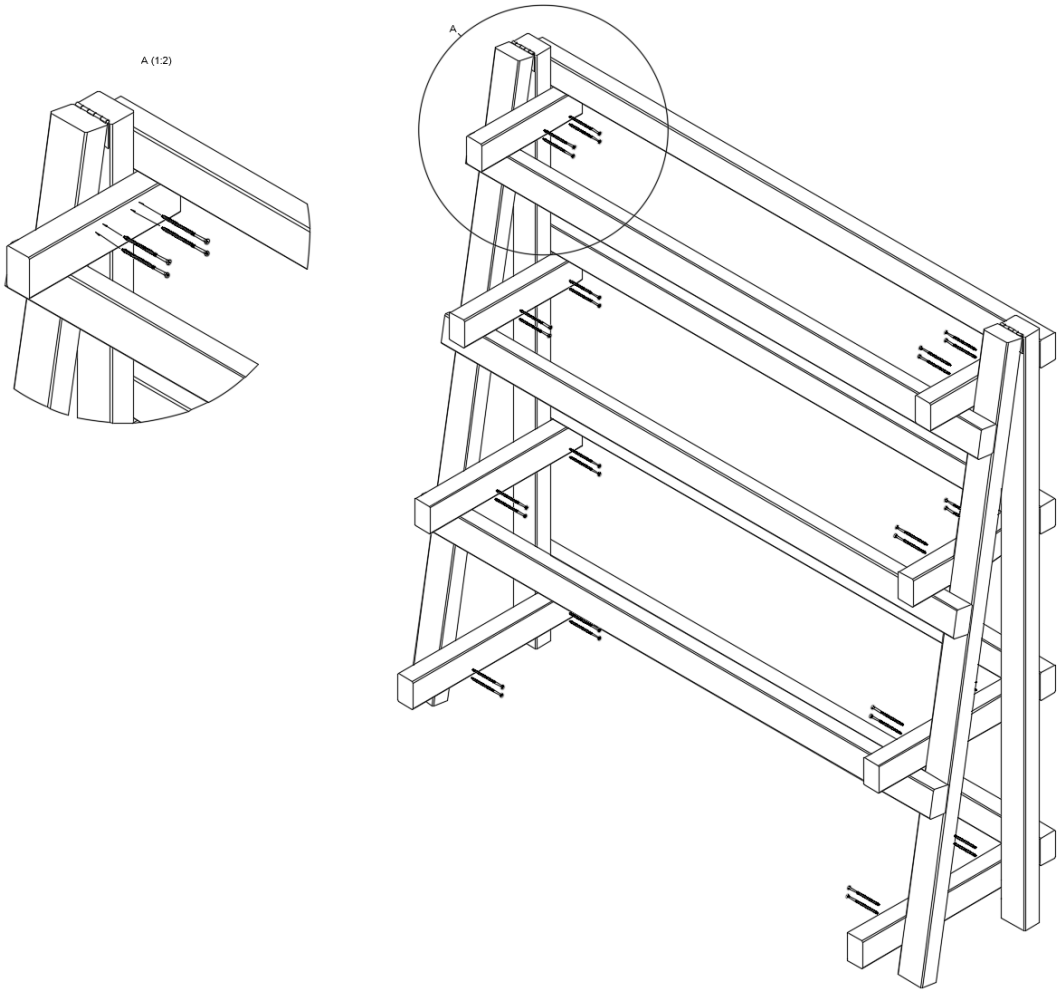

Figure 17: Position of the screws to attach the struts.

e. Staining the frame

To protect the wood from all weather conditions, the structure was stained with protective eco-friendly oil.

Figure 18: Staining of the wooden frame.

Step 4: Final assembly at the chosen location

In our case, the frame was transported to the "Umweltzentrum Gut Karlshöhe" of the Hamburger Klimaschutzstiftung in the North of Hamburg.

a. Securing the frame to the wall

The structure was secured and attached to the wall using brackets, screws, and plugs.

Figure 19: Placement of the frame in its final position.

b. Fastening the rain gutters

The rain gutters with the end pieces were secured to the front frame through 1 short wood screw on each side. The struts give support thanks to gravity force.

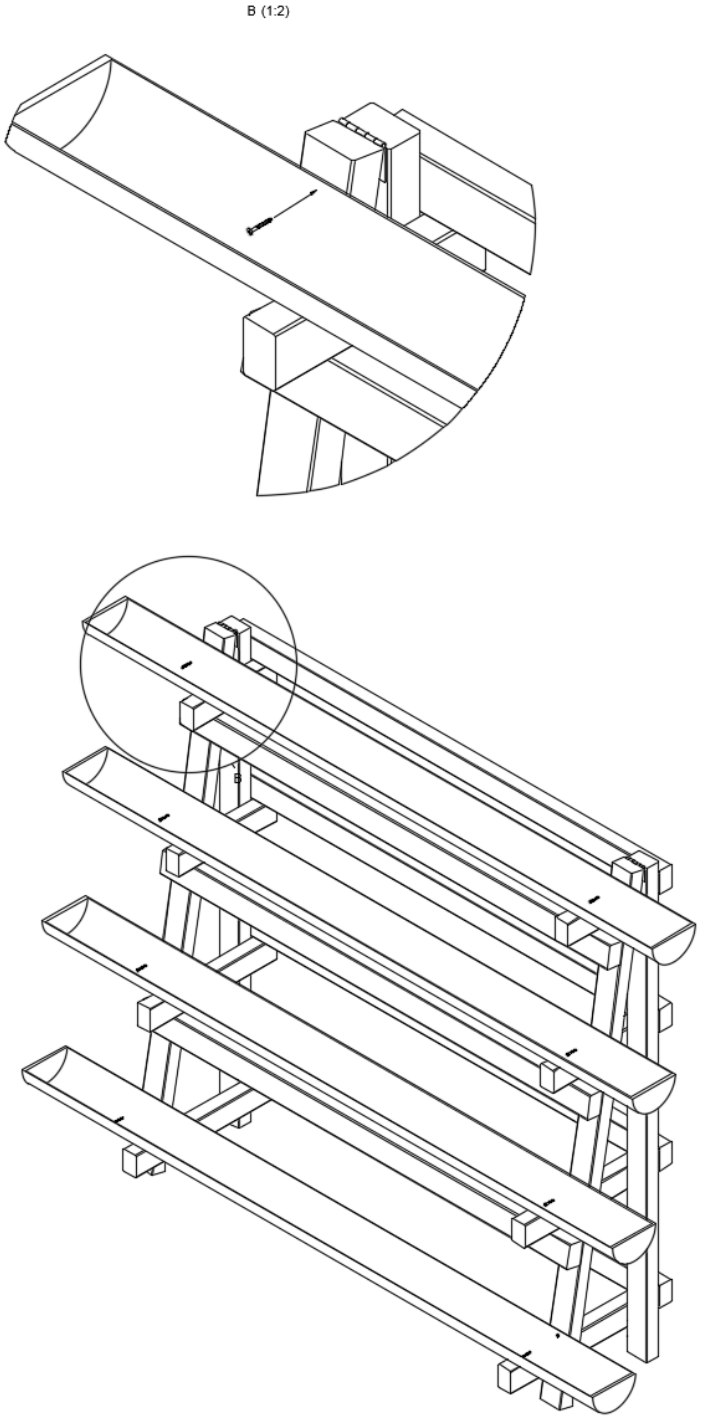

Figure 20: Position of the screws to fix the rain gutters.

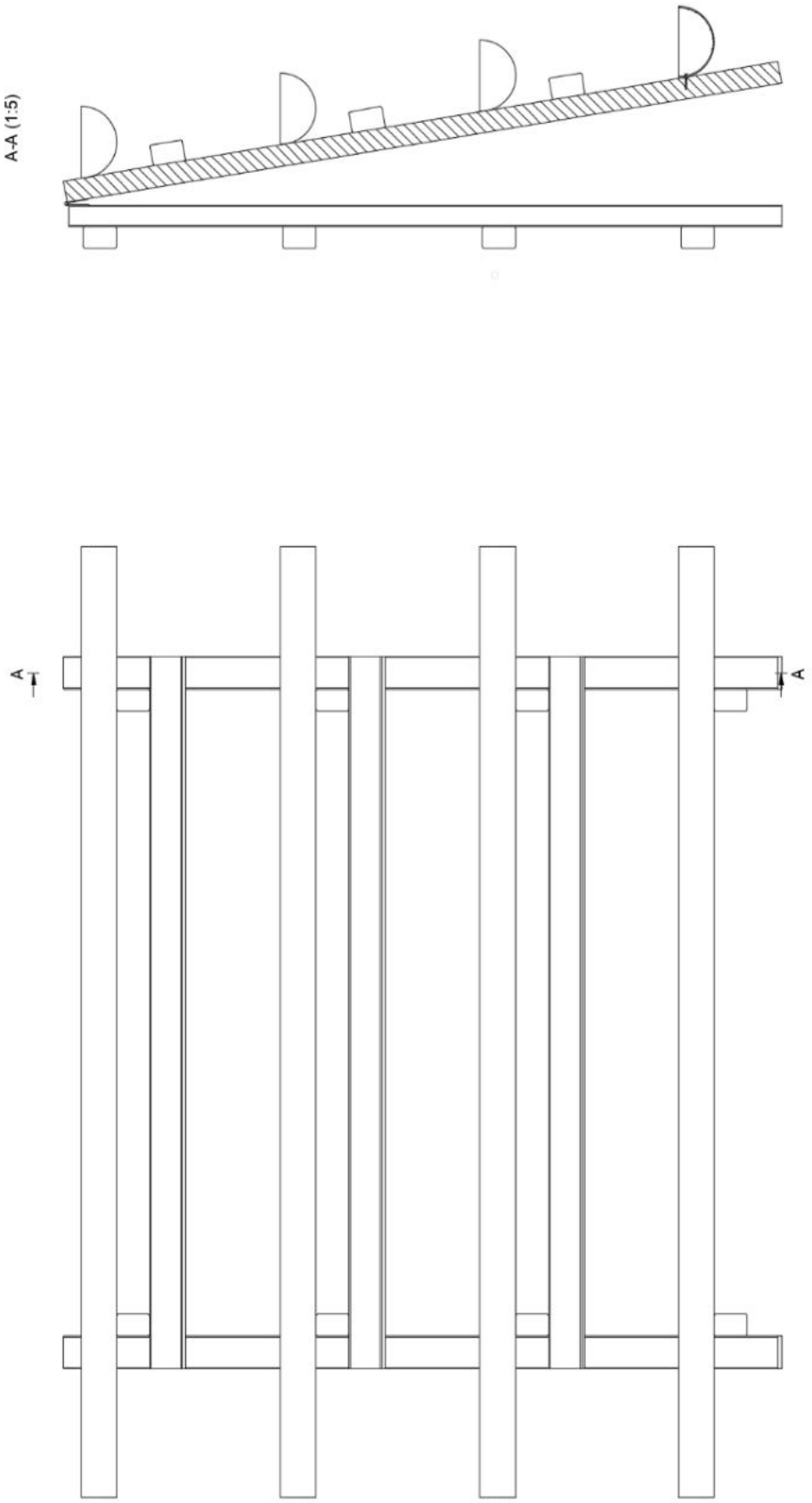

Figure 21: Attaching the rain gutters to the frame in a section detail, technical drawing.

Figure 22: Rain gutters fastened to the frame.

Figure 23: Complete structure with the rain gutters.

Drainage holes were drilled along the whole length of the gutters at intervals of approximately 15 cm.

Figure 24: Drilling the drainage holes.

c. Preparing and placing the coconut fiber mat

The gutters were covered on the inside with coconut fiber mats to prevent the soil from falling out. They further act as a filter for the draining water, so the plants on the lower level are not getting dirty. The mat was cut in pieces as long as the gutters and wide twice the half circumference of the gutters. In our case, the mat was cut in rectangles 2000 x 470 mm ca. (This step doesn't require high precision, as long as the gutters are entirely covered by the mat.) The mats were then placed in the gutters in a double layer (by bending it along the centerline).

Figure 25: Preparation of the coconut mats.

Figure 26: Placing the coconut fiber mats in the gutters.

d. Filling the rain gutters with the soil

The rain gutters were filled with at least 20 l of soil and topped off after a couple of days.

Figure 27: Rain gutters filled with soil.

Step 5: Planting

a. Laying out the seedlings

The seedlings still in their pots were laid out to visualize their final position.

These general recommendations were followed:

- Taller plants were placed at the top.
- Climbing plants were placed close to the wood beams.
- Plants that may take over others (for example, mint) were given their own gutter (when possible).

Because of the sloped frame, exposure wasn't an issue: Each level can get sunlight and is not covered by the other layers.

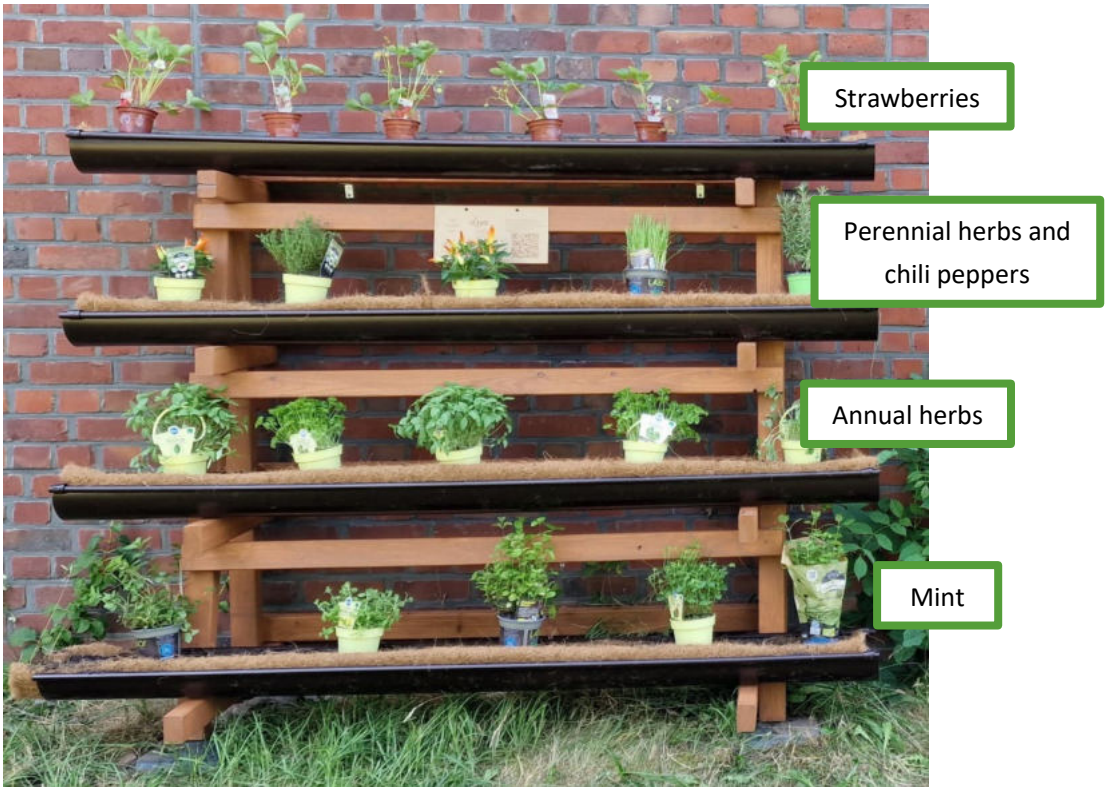

Figure 28: Layout of the plants (first unit).

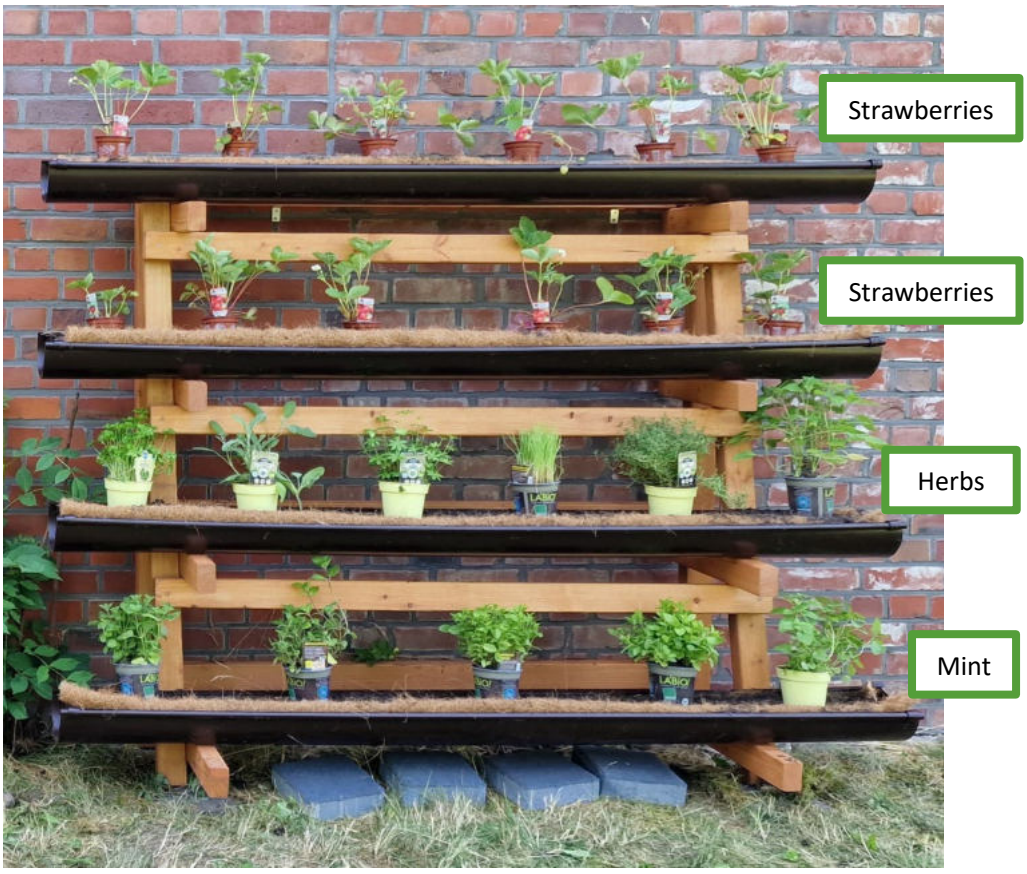

Figure 29: Layout of the plants (second unit).

b. Installing the water dropping irrigation system

The irrigation system was installed according to the instructions. The droppers and soil spikes were placed closed to where the seedlings were later transplanted.

Figure 30: The irrigation system
(Source: https://www.amazon.de/gp/product/B08Z7VJPNF/ref=ox_sc_act_title_1?smid=A3CYEBNQ2OKI7M&psc=1)

Figure 31: From left to right: Droppers and soil spikes
(Source: https://www.amazon.de/gp/product/B08Z7VJPNF/ref=ox_sc_act_title_1?smid=A3CYEBNQ2OKI7M&psc=1).

Figure 32: Placement of the droppers.

The small solar panel that charges the pump was mounted in a sun-exposed area, and the water tank (300 l) was placed between the pump and the prototype.

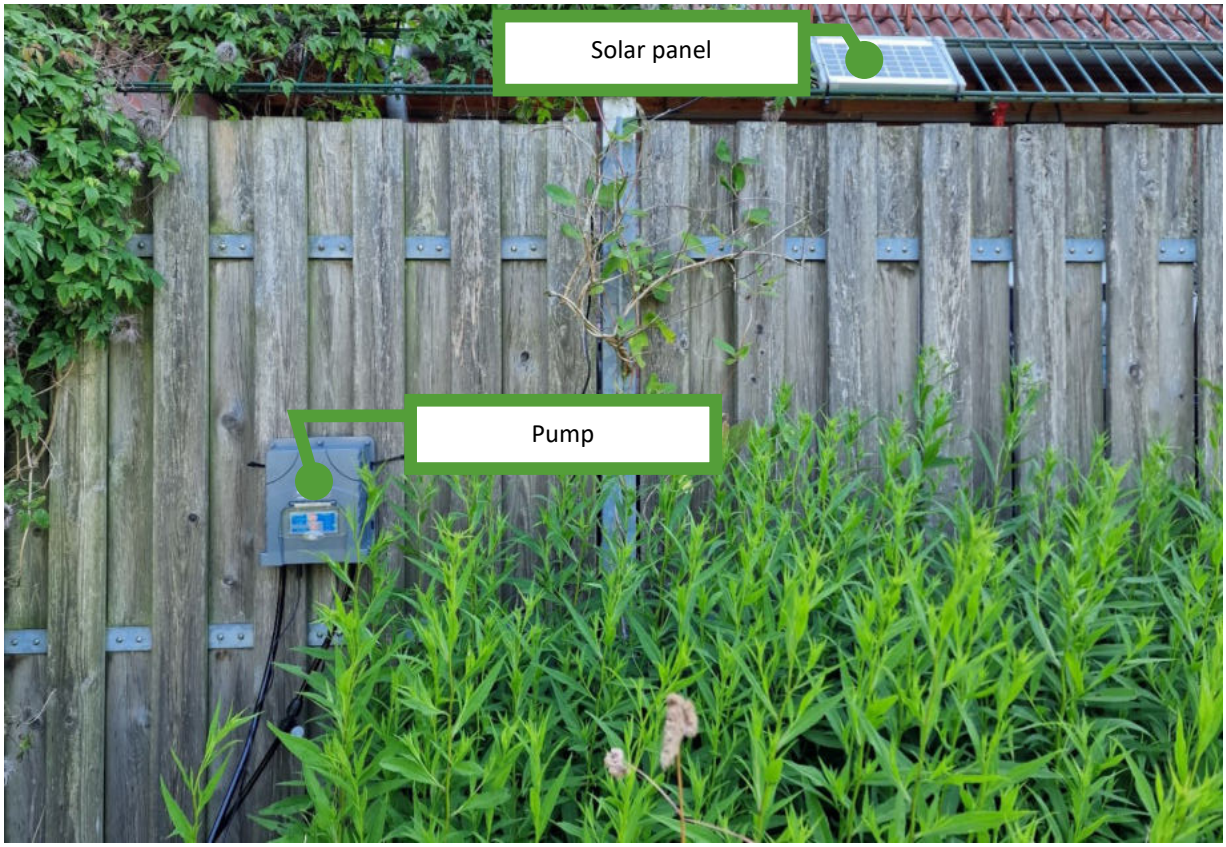

Figure 33: Setup of main components of the watering system.

The seedlings were then transplanted into the soil. However, some of the gutters were left free for the workshop's participants to enjoy in a hands-on transplant.

Figure 34: Transplanting the seedlings.

Figure 35: Setup of the outdoor prototype before the workshop.

USEFUL LINKS

https://www.fabcity.hamburg/agriculture/

https://www.gut-karlshoehe.de/

https://agya.info/

https://visicut.org/

https://naturezedge.com/how-to-start-a-hydroponic-vegetable-garden

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