



Escola Politècnica Superior  
d'Enginyeria de Vilanova i la Geltrú

UNIVERSITAT POLITÈCNICA DE CATALUNYA

## EPS - PROJECT

**TITLE:**

SEA CONTAINER BUILDING

**STUDENTS:**

BAUNACH MANUEL

BIN TUAN KAMARUDDIN TUAN NUR ARIF

GEDIK THIBAUT

IODACHE PAUL-GEORGE

RHATTIGAN JOSEPH

VAN BLOPPOEL KEVIN

**SUPERVISORS:**

RUIZ GORRINDO FÉLIX

LLORENS GARCIA ARIADNA

**DATE:**

14/06/2017

---

**TITLE: SEA CONTAINER BUILDING**

**FAMILY NAME: Baunach FIRST NAME: Manuel**  
**HOME UNIVERSITY: University of Applied Sciences & Arts Coburg**  
**SPECIALITY: Development and Management in Mechanical and Automotive Engineering**

**FAMILY NAME: BIN TUAN KAMARUDDIN FIRST NAME: TUAN NUR ARIF**  
**HOME UNIVERSITY: Escola Politècnica Superior d'Enginyeria de Vilanova i la Geltrú (EPSEVG)**  
**SPECIALITY: Mechanical Engineering**

**FAMILY NAME: Gedik FIRST NAME: Thibaut**  
**HOME UNIVERSITY: University of Antwerp**  
**SPECIALITY: Applied Engineering, Construction**

**FAMILY NAME: Iordache FIRST NAME: Paul George**  
**HOME UNIVERSITY: Politehnica University of Bucharest**  
**SPECIALITY: Industrial Design**

**FAMILY NAME: Rhattigan FIRST NAME: Joseph**  
**HOME UNIVERSITY: Glasgow Caledonian University**  
**SPECIALITY: Computer Aided Mechanical Engineering**

**FAMILY NAME: Van Bloppoel FIRST NAME: Kevin**  
**HOME UNIVERSITY: Hanze University of Applied Sciences**  
**SPECIALITY: Human Technology**

## Abstract

Sea containers are used globally for shipping and have been for over 60 years, there are millions of them worldwide sitting unused in ports, recently individuals and businesses are realising the potential of this and using them to construct permanent buildings faster and cheaper than traditional buildings. Neàpolis, an innovation agency situated in Vilanova i la Geltrú identified the potential of sea container for a new business property.

The present report details the project “Sea Container Building” during the European Project Semester 2017, completed by six international students at Escola Politècnica Superior d’Enginyeria de Villanova i la Geltrú (EPSEVG) in cooperation with Neàpolis

Neàpolis encountered a problem due to a lack of space to expand their business so they announced the above-mentioned project. The task given to the team was to design, analyse and plan a new multipurpose building using sea containers as the primary building material which should be constructed on the site next to the main Neàpolis headquarters.

First of all, general information about sea containers and existing sea container buildings was researched.

Secondly the requirements set by Neàpolis were written down. The new construction must consist of a cowork office space, a maker space, a bar/café and an exhibition hall offering space for at least 30 people altogether.

Thirdly the building site is examined and the urban regulations are analysed. At present the plot is qualified as a Green Zone, thus it is not allowed to build. However solutions to change this circumstance exist and should not limit the project.

Followed by various research about the climate and eco aspects which led to several exterior design concepts which were then refined into a final design and agreed upon by all stakeholders.

Based on the design and the plot characteristics a foundation type was chosen and the sewage piping was planned.

At the same time as the exterior finishing the interior layout started in close relation with each other. Floor plans and electrical plans are created. Furniture is chosen and the interior layout is completed.

Furthermore the construction process is planned to estimate the construction time and compare it to a classic concrete building.

Over the whole planning the costs are monitored and calculated with estimated and researched numbers for each element to give as precise a total cost estimation as possible and to also compare it to classic concrete buildings like the construction time.

A conclusion and an outlook (list of next steps) are completing this report.

### Key words:

**Construction Process, Cowork, Design, Innovation, Maker Space, Multipurpose, Neàpolis, Office,**

**Sea Container**

## Table of Contents

Abstract .....	III
Table of Contents .....	IV
List of Figures .....	VIII
List of Tables.....	XII
Statutory Declaration .....	XIII
1 Introduction .....	1
1.1 About the company “Neàpolis” .....	1
1.2 Problem Statement and Brief .....	2
1.3 Project Goal and Objectives .....	2
1.4 Structure of the Report .....	3
2 General Information about Sea Containers.....	5
2.1 Sea Container.....	5
2.2 Corten Steel – the material sea containers are made of.....	6
2.3 Manufacturing Sea Container.....	7
2.4 Dimensions of a 20ft HC Container .....	8
2.5 Repurposing Sea Containers.....	10
3 Research.....	11
3.1 What people think about sea container buildings .....	11
3.2 Existing Container Buildings .....	12
4 Requirements and Sections of the building.....	14
4.1 Requirements List.....	14
4.2 Sections of the Building .....	16
4.2.1 Cowork Office .....	16
4.2.2 Bar/Cafeteria .....	17
4.2.3 Exhibition Spaces.....	17
4.2.4 Maker space .....	18
5 Building Plot.....	19
5.1 Appearance and Area size .....	19
5.2 Urban laws.....	22

---

6	Exterior Design.....	24
6.1	Researches.....	24
6.1.1	Study on climate & environment in Vilanova i la Geltrú .....	24
6.1.2	Rain Fall.....	24
6.1.3	Sun’s Path and Positions.....	24
6.1.4	Wind Directions and Speed .....	25
6.1.5	Renewable Energy - Wind Turbine and Solar Panel .....	25
6.2	Initial Concepts .....	27
6.2.1	Concept Design 1 .....	27
6.2.2	Concept Design 2 .....	28
6.2.3	Concept Design 3 .....	28
6.3	Final Design.....	31
7	Structural Analysis .....	38
7.1	Single Container Test .....	38
7.2	Welded Container Test.....	41
7.3	Single Container test with simplified reinforcement.....	43
7.4	Non Container Structure .....	45
7.5	Conclusion of Structural Analysis .....	46
8	Foundation and Sewage .....	47
8.1	Foundation.....	47
8.1.1	Concrete pile foundation vs. concrete slab foundation .....	47
8.1.2	Concrete pile foundation.....	49
8.1.3	Foundation on wells .....	50
8.2	Sewage.....	52
8.2.1	General Study .....	52
8.2.2	Sewage Implementation in the plot .....	54
9	Interior Design .....	56
9.1	Regulations and Legislations on interior dimensions.....	56
9.2	Floor Plans .....	57
9.3	Electricity Plans.....	58
9.4	Water supply.....	60
9.4.1	Water supply implementation in the building .....	61
9.4.2	Specifications.....	62

---

9.5	HVAC.....	63
9.5.1	Indoor climate.....	63
9.5.2	The function of an A/C – heating unit .....	64
9.5.3	The multi split unit.....	64
9.5.4	HVAC implementation in the building.....	65
9.6	Insulation and Wall Finishing.....	66
9.7	Suspended ceiling .....	70
9.8	Flooring.....	71
9.9	Interior Design of the different sections of the building.....	74
9.9.1	Overview both floors .....	74
9.9.2	Cowork offices .....	76
9.9.3	Maker space .....	79
9.9.4	Common spaces.....	81
9.9.5	Kitchen/cafeteria .....	83
9.9.6	Toilets .....	84
10	Construction Process .....	86
10.1	Overview Construction Process.....	86
10.2	Site preparation and Foundation .....	87
10.3	Transportation, Storage and Preparation of the Containers .....	88
10.4	Exterior Work .....	92
10.5	Interior Work.....	95
11	Cost Estimation .....	99
11.1	Purchasing and transportation costs of container .....	99
11.2	Cost of site preparation and foundation.....	100
11.3	Costs of exterior work .....	101
11.4	Techniques costs .....	102
11.5	Costs of interior work.....	103
11.6	Equipment and Furniture costs.....	103
11.6.1	Costs Cowork .....	103
11.6.2	Costs Common Areas .....	104
11.6.3	Costs Bathrooms/Toilets .....	104
11.6.4	Costs Bar/Cafeteria with Kitchen .....	104
11.6.5	Costs Maker Space .....	105
11.7	Costs for the surrounding.....	105

---

11.8 Staff salary .....	106
11.9 Total costs – comparison.....	106
12 Conclusion and Outlook.....	109
Bibliography .....	111
Appendices.....	124
Official Project Brief .....	124
Appendix A .....	125
Appendix B .....	126
Appendix C .....	128
Appendix D .....	131
Appendix E.....	134
Appendix F.....	136
Appendix G .....	139
Appendix H .....	146
Appendix I .....	148
Appendix J .....	150
Appendix K .....	154
Appendix L.....	155

## List of Figures

Figure 1: Neàpolis headquarters [1].....	1
Figure 2: Sea Containers on a cargo ship (left) [2] and various container sizes (right) [3] .....	5
Figure 3: Floor structure of containers (left) and wooden container floor (right) [9] .....	7
Figure 4: 20ft HC Container isometric view (left) and front view (right) [10].....	8
Figure 5: 20ft HC Container side view [10] .....	8
Figure 6: 20ft HC Container top view [10].....	9
Figure 7: Container City in London [11] .....	10
Figure 8: Survey results [12].....	11
Figure 9: School/Classroom out of sea containers [13] .....	13
Figure 10: Office building out of sea containers [14].....	13
Figure 11: Sea container home [15].....	13
Figure 12: Sea container home 2 [15].....	13
Figure 13: Photograph of cowork office space in Neàpolis.....	16
Figure 14: Example of bar/cafeteria.....	17
Figure 15: Recent Event Held in the exhibition hall in Neàpolis [17].....	17
Figure 16: Photograph of maker space in Barcelona .....	18
Figure 17: Construction site (highlighted in dark green colour) .....	19
Figure 18: The building plot from the top of Neàpolis.....	19
Figure 19: The building plot from the street.....	20
Figure 20: Calculation of the whole building plot (left) and only the "triangle" area (right) [20] .....	20
Figure 21: Calculation of site length.....	21
Figure 22: The surrounding of the building plot .....	21
Figure 23: The Neàpolis building next to the building plot.....	22
Figure 24: Design Idea 1 - 3D View.....	27
Figure 25: Design Idea 2 - 3D View.....	28
Figure 26: Design Idea 3 – 3D View .....	28
Figure 27: Design Idea 3.1 - Top View .....	29
Figure 28: Design Idea 3.1 – 3D View .....	30
Figure 29: Final Design – 3D Street View .....	31
Figure 30: Final Design – 3D Back View.....	31
Figure 31: Final Design – Detail Main Entrance .....	32
Figure 32: Final Design –Detail Maker Space .....	33



---

Figure 33: Final Design – Detail Street View .....	34
Figure 34: Final Design – Detail Back View 2.....	34
Figure 35: Final Design – Detail Street View 2 .....	35
Figure 36: Final Design – Detail Back View 3.....	35
Figure 37: Final Design – 3D Surrounding View .....	36
Figure 38: Final Design – 3D Back View 2.....	37
Figure 39: Structure of the building in Solid Works .....	38
Figure 40: Single Container Stress Test in Solid Works .....	39
Figure 41: Mechanical properties of a container in Solid Works .....	39
Figure 42: Deformation single container stress test in Solid Works .....	40
Figure 43: Single Container Stress Test with wall sections in Solid Works .....	40
Figure 44: Deformation single container stress test with wall sections in Solid Works .....	41
Figure 45: Welded container stress test in Solid Works .....	42
Figure 46: Detail welded corners .....	42
Figure 47: Deformation welded container stress test with wall sections in Solid Works.....	43
Figure 48: Simplified container stress test with I-Beam reinforcement in Solid Works .....	43
Figure 49: Dimensions I-Beam reinforcement .....	44
Figure 50: Deformation simplified container stress test with I-Beam reinforcement in Solid Works..	44
Figure 51: I-profile and bended C-profile which will be used for the rounded part [25] .....	45
Figure 52: Example of a construction in the USA, I-profiles for the flooring structure [26].....	45
Figure 53: Bended zinc coil sheets as a finishing [27] .....	46
Figure 54: Foundation example [29] .....	47
Figure 55: Failing of slab foundation [32] .....	48
Figure 56: End bearing piles (left) and friction piles (right) [33] .....	49
Figure 57: Metal reinforcements in foundation piles [35].....	50
Figure 58: Horizontal beam structure (left) [36] and schematic illustration with container in Google SketchUp (right) .....	51
Figure 59: Location of pile and slab foundation.....	51
Figure 60: Connection of indoor sewage pipes to the main sanitary sewer [37] .....	52
Figure 61: Toilet and Basin connection to the main stack (left) and piping in the ground (right) [39]	53
Figure 62: Indoor connection the main waste stack, ventilated through the roof [40] .....	53
Figure 63: Ground floor (+0): indoor connection to the main stack and to the main sewage .....	54
Figure 64: First floor (+1): indoor connections to the main stack.....	54
Figure 65: Detail piping at the first floor (+1).....	55
Figure 67: Example of recessed lighting spacing in a room .....	59

---

Figure 68: Pressurised hot water system (left) and detailed electric water heater (right) [53] .....	60
Figure 69: Water supply system plan of the ground floor (+0) .....	61
Figure 70: Water supply system plan of the first floor (+1) .....	62
Figure 71: RHEEM hybrid electric water heating tank and HETCU copper piping to realise the connections [55] .....	62
Figure 72: AC - cooling cycle [57] .....	64
Figure 73: Multi-split unit with branch boxes to set the cabling path [58] .....	64
Figure 74: The multi-split unit at floor +0 .....	65
Figure 75: The multi-split unit at floor +1 .....	65
Figure 77: Suspended ceiling framework [72] .....	71
Figure 78: Suspended ceiling plates [72] .....	71
Figure 79: Forbo Sarlon Complete Step, used exclusively on stairs [73] .....	71
Figure 80: Allura Flex Decibel, mostly used in offices [73] .....	72
Figure 81: Sarlon Sparkling acoustic vinyl, Improves hygiene and safety in a building [73] .....	72
Figure 82: Textile flooring, used for access areas [73] .....	73
Figure 83: Dimensions flooring and ceiling .....	74
Figure 84: Interior Design – ground floor .....	75
Figure 85: Interior Design – 1. floor .....	76
Figure 86: Cowork office ground floor .....	78
Figure 87: Cowork office 1. floor .....	78
Figure 88: Meeting room and leisure area .....	79
Figure 89: Maker space ground floor .....	80
Figure 90: Maker space 1. floor (1) .....	80
Figure 91: Maker space 1. floor (2) .....	81
Figure 92: Service Point in detail .....	81
Figure 93: Entrance cowork in detail .....	82
Figure 94: Gallery 1. floor .....	82
Figure 95: Kitchen .....	83
Figure 96: Bar/cafeteria in detail .....	84
Figure 97: Toilets ground floor .....	84
Figure 98: Toilets 1. floor .....	85
Figure 99: Timeline Construction Process .....	86
Figure 100: Timeline Detail Site Preparation and Foundation .....	87
Figure 101: Placement of mobile crane .....	88
Figure 102: Delivery, Storage and Preparation of the containers .....	89

---

Figure 103: Timeline Detail Transport and Preparation Containers .....	89
Figure 104: Cutting windows and doors [75] .....	90
Figure 105: Container reinforcements pattern .....	91
Figure 106: Rectangular pipe (left) [76] for door and window frames (right) [77].....	91
Figure 107: Timeline Detail Exterior Work .....	92
Figure 108: Welding the containers together [78].....	93
Figure 109: Welding window and door frames (left) [79] & reinforcements (right) [80].....	94
Figure 110: Balcony structure and floor [81] .....	94
Figure 111: Balcony railing of the maker space balcony (left) and the main balcony (right) [82].....	94
Figure 112: Timeline Detail Interior Work .....	95
Figure 113: Insulation Steps 1. frame (left), 2. spray foam (middle) [83] and 3. strandboard panels (right) [84] .....	96
Figure 114: Plasterboard wall [85] [86].....	97
Figure 115: Non-breathable flooring underlayment [87] .....	97
Figure 116: Subcategory sheets cost calculation .....	99

## List of Tables

Table 1: Requirements list.....	15
Table 2: Pros and Cons of Both Internal and External Wall Insulations [61] .....	67
Table 3: Required U-Values in Barcelona .....	68
Table 4: General Organization of the cost estimation excel sheet .....	99
Table 5: Costs - Purchasing and transportation of containers .....	100
Table 6: Costs - Site preparation and foundation .....	101
Table 7: Costs - Exterior Work.....	101
Table 8: Costs - Techniques.....	103
Table 9: Costs - Interior .....	103
Table 10: Costs - Coworks furniture .....	104
Table 11: Costs - Common areas.....	104
Table 12: Costs - Toilets .....	104
Table 13: Costs - Bar/cafeteria.....	105
Table 14: Costs - Maker Space .....	105
Table 15: Costs - Surrounding .....	106
Table 16: Staff salary .....	106
Table 17: Costs - Finishing .....	106
Table 18: Costs - Complete clustered in cost centres .....	107
Table 19: Comparison Container building vs. "normal" building.....	108
Table 20: Advantages and Disadvantages – Container building vs. classic concrete building.....	110
Table 21: Calculation solar power .....	130
Table 23: Measurements dimensions kitchen .....	142
Table 24: The table above is for the ground floor of the sea container building. ....	149
Table 25: The table above is for the ground floor of the sea container building. ....	149
Table 26 : Materials for Internal Wall Insulation [113].....	150
Table 27: Materials for External Wall Insulation.....	151
Table 28: Company list - research different issues.....	155
Table 29: Company list – specialized container building companies.....	155
Table 30: Company list – Purchasing containers.....	156
Table 31: Company list – Transportation .....	156
Table 32: Company list – green roof .....	156

## **Statutory Declaration**

We declare that we have developed and written the enclosed project completely by our self, and have not used sources or means without declaration in the text. Any thoughts from others or literal quotations are clearly marked. The project was not used in the same or in a similar version to achieve an academic grading or is being published elsewhere.

# 1 Introduction

The present project report is the technical documentation of the “**Sea Container Building**” project. The project is a cooperation between the Escola Politècnica Superior d’Enginyeria de Vilanova i la Geltrú (EPSEVG) as a part of the Universitat Politècnica de Catalunya (UPC) represented by an international team of 6 students taking part in the European Project Semester 2017 (EPS) and the local company Neàpolis.

## 1.1 About the company “Neàpolis”

Neàpolis is a public innovation agency promoting different kinds of new technology fields. As a technology and business innovation park, Neàpolis provides working space for established technological companies but also for new small companies such as start-ups and entrepreneurs.

Also several other fields can be found under the roof of Neàpolis like the researching-cooperation with the UPC, a maker space<sup>1</sup>, an environment for training & further education of professionals and companies, as well as different kinds of media premises like the Catalonia film school, two big theatre rooms, a TV studio and more. Thus Neàpolis is a meeting point and business hub for people and companies involved in the ICT<sup>2</sup> and media sectors.

The aim of the company is to support local innovation and competitiveness through regional, national and international cooperation. It focuses on small and medium-sized business linked to public funding and research programmes. Moreover, its aim is to position Vilanova i la Geltrú as a prime location for creativity and innovation and hence attract companies and technological talent to the region. To achieve this Neàpolis uses links and synergies between the academic and business worlds, as found in the project cooperation.



Figure 1: Neàpolis headquarters [1]

<sup>1</sup> Maker space: makerspace or fabrication laboratory is a small workshop allowing (private) people to access (digital) production or fabrication (e.g. 3D-Printers)

<sup>2</sup> ICT: information and communications technology

## 1.2 Problem Statement and Brief

As it is well known the technology sector is growing – likewise Neàpolis has to expand physically. At the moment (start of the project) there are two existing coworks in the Neàpolis building itself and some more spread throughout the town. The main problem is that the existing spaces won't be sufficient for the future. Another aspect is that the spreading of the coworks is not very popular by the companies; they would like to be in or at least next to Neàpolis to profit more from the network. Consequently there is a big need of more working and technology related space in the town especially in the near surrounding of Neàpolis.

For this reason Neàpolis is cooperating with the UPC and announced the on hand project which the international student team will carry out

## 1.3 Project Goal and Objectives

The main task of the project is to design, plan & analyse an attractive multifunctional building using (primarily) Sea Containers. The design includes alongside the exterior look of the architecture, a proposal for the green space around and furthermore the interior arrangement of the rooms. Respecting the appearance of the town Vilanova i la Geltrú the construction has to fit in the neighbourhood and surroundings next to the already existing Neàpolis building on La Rambla Exposició, 59-69.

The newly designed building must contain cowork spaces, a maker space for adults as well as for kids, a small bar/cafeteria offering drinks and small snacks and common spaces (indoor and outdoor) for meetings, exhibitions and demonstrations for at least 30 people. Another main aspect is the modularity – the possibility to expand the space if more and different needs will appear. As an option the construction could contain in the second stage a music area for musicians to practice and record.

Considering the mentioned facilities the project will satisfies the need of more working spaces for start-up companies, entrepreneurs and established technology companies in the region.

To finish the project the exterior and interior design, a material research and structural analysis, the planning of the construction process and a cost estimation has to be made by the project team within a period of 20 weeks – February 2017 to June 2017.

## 1.4 Structure of the Report

This report is structured in a logical sequential order to ease the audience to understand what the project involves.

To introduce the project to the audience, the background of Neàpolis and explanations about the reasons why this project is required to be carried out and with what could be expected in the final result are mentioned.

The sea container is then also being introduced with its general information such as the original purpose of it and how it is made.

Next, the report continues with informing the result from the survey on people's opinions about home containers and showing what could potentially be built with sea containers with examples of existing sea container buildings around the world.

As everything in the introductory sections seems to be cleared, the main requirements for the project that have to be met and facilities needed by Neàpolis in the sea container building are listed and described.

After that, all of the researches about building plot, urban laws and geographical factors that could affect the exterior design as well as the implementation of renewable energies in the project are explained.

Then, the exterior designs from the first concept to the final agreed design, are shown in the following section.

The structure of the report continues with the structural analysis to show the possibility to construct the sea container building by referring to the project's final exterior design, followed by the research on the suitable foundation and how to connect the sea container building to the sewage system in Vilanova.

Next, the interior design is brought into the report's structure. All things related to the interior of the sea container building, for instance regulations, facilities, building features, insulations, surface finishing and placement of furniture, are included in this Interior Design section. Since this section appears to be the longest section in this report with details and explanations, most of the statements and parts will be supported by researches and documents provided in the appendices.

The report continues again with the carefully explanation of the sequential order of potential construction process and is followed by the cost analysis to estimate the overall cost for the project. It is also worth mentioning that in this cost analysis section a cost comparison between conventional building construction and sea containers as if they were used for this project is made.



A conclusion and the project outlook are made in the following section after the cost analysis. The report ends with bibliography and appendices to support all of the statements that had been written in the report.

## 2 General Information about Sea Containers

### 2.1 Sea Container

Sea containers or shipping containers as they are sometimes called are essentially large steel boxes used for transporting goods on cargo ships across the world. These containers have been rapidly mass produced over the last 50 years as the world has become more reliant on goods and services from other countries and continents.

Containers are manufactured to many different specifications ranging from 8ft up to 53ft in length with the most commonly used lengths being 20ft and 40ft, as these containers are designed to be shipped around the world multiple times they are made to be strong, durable and weather resistant.



Figure 2: Sea Containers on a cargo ship (left) [2] and various container sizes (right) [3]

However, with air transport becoming more common and the recent economic crash there is a large number of containers which have been left abandoned at ports as the rapidly growing supply has exceeded the demand. In 2016 the number of idle cargo ships increased from 238 vessels with a combined capacity of about 900,000 TEU<sup>3</sup> in 2015 to 435 ships, amassing a total of 1.7 million TEU. [4]

---

<sup>3</sup> TEU – Total Equivalent Units, Number of equivalent 20 foot containers, for example one 40 foot container = 2 TEUs. This was used as transport companies rarely show their actual fleet size and usually only the TEU is published.

## 2.2 Corten Steel – the material sea containers are made of

A sea container is made of Corten steel. This type of steel is referred to as weathering steel [5], an atmospheric corrosion-resistant steel, which is also used in bridges, chimneys, towers, and even outdoor sculptures. As expected from a steel, unpainted Corten steel also would rust under the influence of the weather the same way as ordinary steel, but it has the ability to slow down the corrosion effectively [5]. The alloying element in the Corten steel will react when rust is present by forming a protective surface layer of fine-textured rust [6]. This layer is responsible for suppressing the corrosion rate of the weather on the surface of the Corten steel. Therefore, this could save money for the maintenance costs like rust-prevention and indirectly, eliminate the need for painting [7]. However, painting the Corten steel is always a good precaution step to prevent it from oxidising.

When a sea container is manufactured, it comes with 2 lines of defence against corrosion [5]. The first line is the coating of marine grade paint applied to it. Once the paint wears off due to harsh conditions in the sea, the second layer of defence will take place, which is the properties of the Corten steel itself.

Below are the primary features of Corten steel [6]:

- High weather resistance – Corten steel weather resistance is 4-8 times better than ordinary steel
- Paint durability – Prolongs the service life of the paint
- Weldability – Can be welded manually, by gas-shield or submerged arc welding
- Workability – Can be cut using the gas cutting method

### 2.3 Manufacturing Sea Container

As mentioned previously sea containers are a mass-produced product. Almost all shipping containers are manufactured in China, which makes sense since China has some of the largest ports and highest exports in the world, in fact 98% of shipping containers are made there. [8]. The manufacturing process for sea containers is highly developed but very simple. Firstly, the wall panels of the containers are manufactured from large steel sheets which are cut down, corrugated and then welded together. Next the container floor is manufactured from I-beams as shown in Figure 3 below (left) with smaller beams being welded horizontally between two larger I beams. Following this, the doors and corner posts are manufactured and then welded with the walls and floor to form an open top box. Afterwards the roof is lowered onto the top of the open box and welded together completing the shell of the container. Next the container is painted and primed and the wooden floor is placed down (Figure 3 right). Finally, the container is decorated with logos and ID numbers before being waterproofed, tested and then put into use. [9]



Figure 3: Floor structure of containers (left) and wooden container floor (right) [9]

## 2.4 Dimensions of a 20ft HC Container

Sea containers come in numerous sizes with the most commonly used for construction being the “high cube” (HC) variants as they have an increased height of 2896mm exterior height which makes them more suited to carry diverse types of cargo but also makes them a better base for a building as a regular container building could feel cramped on the inside due to the low ceiling. The following images (Figure 4, Figure 5 & Figure 6) illustrate the dimensions of a 20ft HC Container.

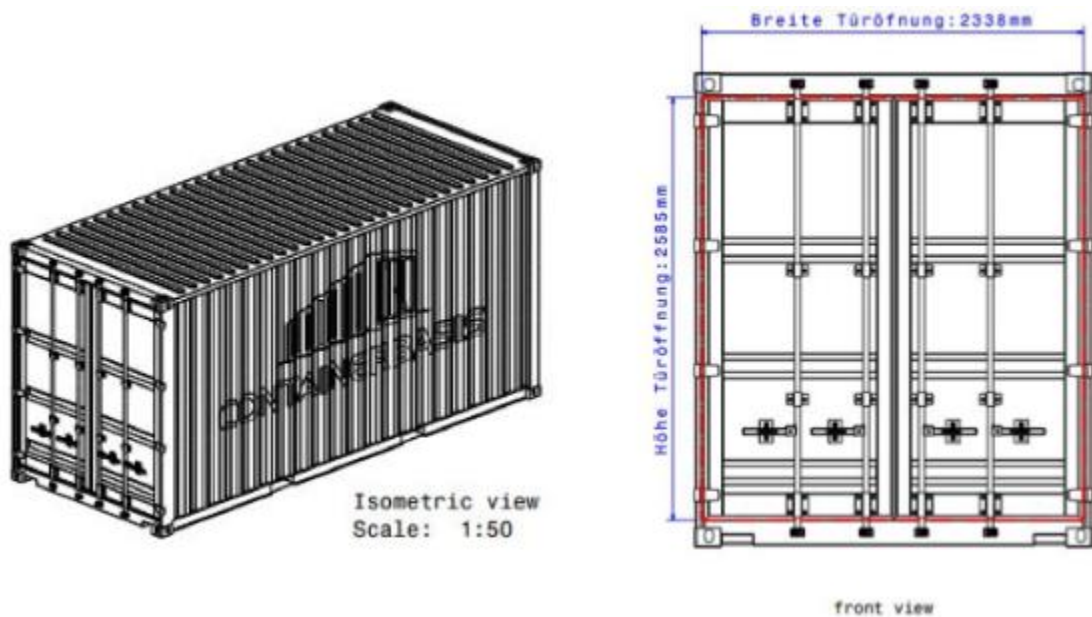


Figure 4: 20ft HC Container isometric view (left) and front view (right) [10]

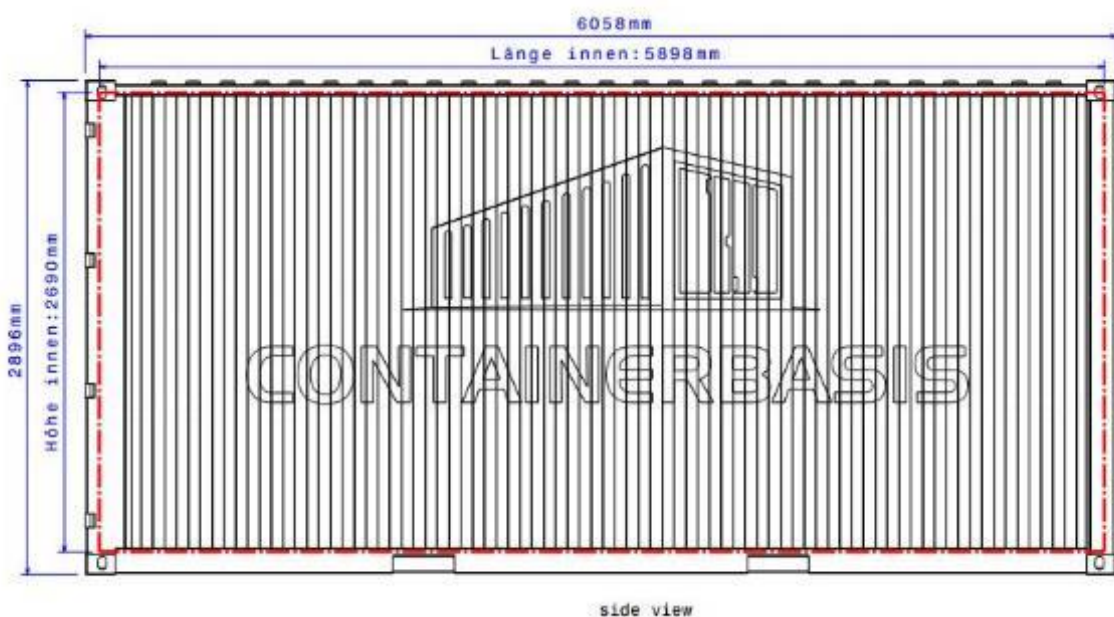


Figure 5: 20ft HC Container side view [10]

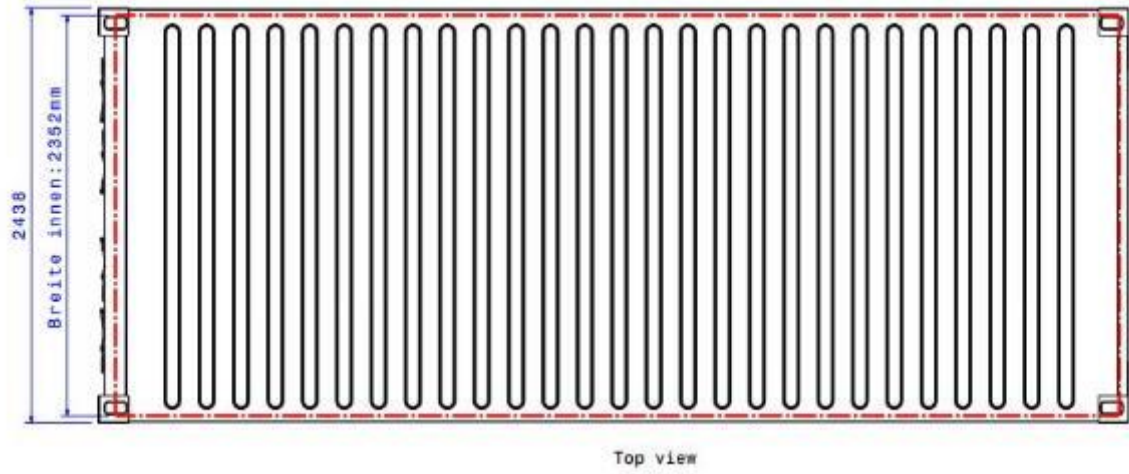


Figure 6: 20ft HC Container top view [10]

## 2.5 Repurposing Sea Containers

Due to the excessive number of containers lying dormant they are being repurposed above and beyond their original use, with examples of homes, schools and offices constructed with sea containers springing up around the world. Containers are often used as temporary space at construction sites but their recent availability has led to them being used to construct permanent buildings such as the Container City in London.

The main advantages of using shipping containers, as a primary building material is the time saved during construction by having a solid frame already in place as it can be reduced by up to half. [11] The modularity and expandability of a design made from containers is also highly attractive to growing businesses as they have the option of additional expansion, adding more containers to an existing design is usually not an issue. Another advantage is the cost and environmental benefits as purchasing used shipping containers and then reusing them is a highly eco-friendly and economical method of construction if it is done properly. They can be purchased worldwide and transported on the back of a truck making them easy to get to most building sites.



Figure 7: Container City in London [11]

Of course, sea containers also possess disadvantages. Many considerations must be made when building with containers; the condition of a used container is a major concern as they can be used for approximately a decade before general wear and tear renders it useless for construction sets in. A crane will be needed to place the containers and they will need to be modified to create a workable area due to the limited shape of a container. Therefore, as the containers are modified reinforcements will have to be added incurring additional costs over the container itself. Local regulations may be another obstacle and insulating a large steel box is usually a challenge, as well as there are the harmful pesticides used to prolong the life of a containers floor while it is in use. From this list of disadvantages some may be put off from construction but if proper considerations are made the finished product can be exceptional.

### 3 Research

#### 3.1 What people think about sea container buildings

The opinion of people about sea container is an important aspect for this project. A survey was conducted in the form of a poll asked the question *“Would you ever live in one of those houses made of shipping containers?”*

The poll was created in January 2015 and has been answered by 709 people, which makes the results reliable. To summarize the outcome, 61,5% would like to life in a sea container building, while 25,1% will not life in a sea container. The rest, 13,4% has no idea what a sea container building is.

**Would you ever live in a house made of shipping containers?**

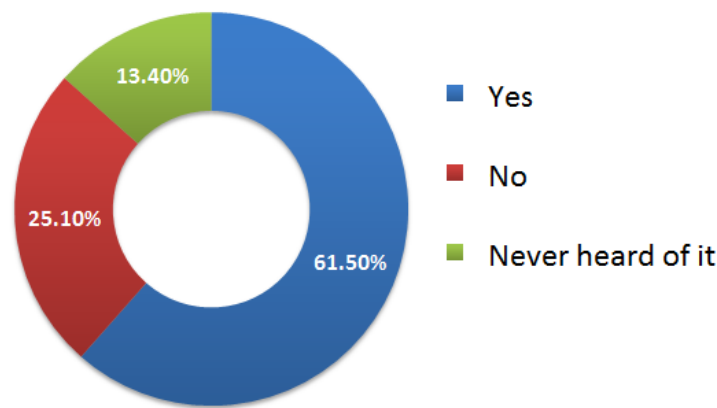


Figure 8: Survey results [12]

To find out the reasons behind the outcome of the poll, an e-mail has been sent to the responders of the poll to ask for their reasons behind their answer. A top five has been made from the many different answers given by the respondents. The top five will be listed in the next paragraph.

The price is the most given answer of the respondents to life in a sea container house. Many small sea container buildings costs less than 50.000\$ which makes it very attractive for people with low income. However, there are several sea container buildings which are more expensive, it mainly depends on the personal preferences and the budget but the option to build a sea container building for a low amount of money is possible.

The second most common answer was the ecological aspect of a sea container building. Take into account the eco aspect is a trend which becomes more popular because of the climate changes. The sea containers used for the constructions are being recycled in almost all of the cases which means 3500-kilogram steel will be re-used per container. Using the recycled containers also conclude that bricks and other building materials are used less.



The third reason why people would live in a sea container building is the speed of construction. Because the roof, the walls and the flooring are already done, this will save a lot of time. In the US they managed to build an office, made out of 73 containers within 8 days.

The number four most chosen reason to life in a sea container building is the outside appearance. Sea containers buildings have an unique and different look compared to buildings made from stone and other materials. Also, the sea containers are easy to modify so there is a large number of possibilities to design the building.

The fifth reason to life in a sea container building according to the respondents, are the off-grid capabilities, which means it is possible to live in a home which is self-reliant and self-sufficient no need to connect to the main electricity network. With solar panels the container can get enough power to heat the water and have electricity. [12]

### **3.2 Existing Container Buildings**

A research on the state of the art shows that there are a lot of possibilities when it comes to building with sea containers. With sea containers, the construction can be modular, which leads into flexibility. The designs and uses of sea containers for construction are vast; from personal accommodation to temporary shops there is not much that cannot be done.

A couple of examples where containers have been used; student accommodation, a cafe, office buildings, kids play ground, a warehouse, a school, shops, bars and many unique modern homes.

A brief look at some sea containers buildings:



Figure 9: School/Classroom out of sea containers [13]

This sea container classroom is an example of the adaptability, durability and low cost of sea containers. The sea container construction is as classroom with space for a garden that will supplement school meals. Classrooms like this are very common in the poorer countries because of the low cost and the functionality of sea containers. [13]



Figure 10: Office building out of sea containers [14]

Space constraints are a common problem in many countries. Sea containers have been effectively used to tackle this problem by architecturally modifying them as convenient and spacious office buildings. This building is in Japan, where space is a very big constrains. In 2012 an architecture company had trouble finding an office block so they built their own made from sea containers. [14]



Figure 11: Sea container home [15]

Casa Incubo is an example of a sea container home which was built in Costa Rica. The home was built using eight 40-foot-high cube containers and using containers helped reduce the construction time by around 20%. [15]



Figure 12: Sea container home 2 [15]

The beach box is built in the Hamptons, one of New York's most expensive areas. The home was built by Andrew Anderson using shipping containers. The structure of the sea containers is covered at the walls, but is still noticeable at the ceilig. [15]

## 4 Requirements and Sections of the building

### 4.1 Requirements List

It is widely common that projects need to fulfil several requirements given by the customer. To meet the customers expectations it is helpful to create a requirements list (shown in Table 1: Requirements list

) in which all the important specifications are precisely written down and in a short form thus everybody who is working on the project is able to understand and access them.

The requirements list in this specific case is clustered into the following five major points:

1. General
2. Size & Space
3. ECO Aspects
4. Design
5. Costs

Every main point is subcategorized in the specific requirements which are shortly described, divided in mandatory (M) or desirable (d) and added with a small comment. IDs are used to precisely assign them in the project process to the specific objects. The requirements list was created in close cooperation with the customer Neàpolis (represented by Félix Ruiz Gorrindo) and the project team.

Due to this list the project is sufficiently described and the general conditions are cleared so the project team is able to deliver a final proposal that satisfies the customer.

ID	Requirements	Specifiation	Type	Comment
<b>1</b>	<b>General</b>		<b>Mandatory M / Desirable d</b>	
1.1	What kind of space should be in the building?	cowork, common area, exhibition hall, maker space, bar/cafeteria	M	music space & extension of coworks in 2. building step
1.2	Accesability	Wheelchair/Disabled access	M	elevator if more than ground floor
1.3	Flexibility & Modularity	Expandable	M	changing of space within the next years should be possible
1.4	Central Square	Meeting Point & temporary exhibitions	M	square (for events & outside sitting area, ...), connection/link between the old & new Neàpolis building
1.5	Amount of people	30	M	the building has to fit for 30 people in total (1. Stage)
<b>2</b>	<b>Size &amp; Space</b>			
2.1	Cowork space	5- 10m <sup>2</sup> per Person, +/- 15 people	M	law and given by Neàpolis
2.2	Common areas	2m <sup>2</sup> per Person	M	law
2.3	Indoor Height	min. 2,5m	M	Regulations & Laws
2.4	Plot Size	3150.97 sqm	-	plot size is given
2.5	Maker Space	+/- 5 people	M	given by the Neàpolis
2.6	Bar/Cafeteria	+/- 10 people	d	dining area
<b>3</b>	<b>ECO aspects</b>			
3.1	Green Roof	Roof with plants	d	Insulation and ecofriendly
3.2	Renewable Energy	Solar pannels on the roof, Wind turbines	d	Energy production
3.3	Energy efficiency	High	M	Insulation
3.4	Surrounding	proposal of the green space	M	plants and central square
<b>4</b>	<b>Design</b>			
4.1	Exterior Design	Attractive & Expandable	M	fit in the surrounding and with the Neàpolis building
4.2	Interior Design	Attractive and optimal utalization	M	comfortable working environment
<b>5</b>	<b>Costs</b>			
5.1	Cost efficient	Balance Price & Quality	M	no fix budget given

Table 1: Requirements list

## 4.2 Sections of the Building

### 4.2.1 Cowork Office

A cowork is a shared office space where individuals or small businesses can rent workspace and work together in a shared environment with likeminded people. This idea is becoming more popular as there have been many benefits shown from working in this type of environment. People who work in shared offices feel more comfortable, they can work when they want and since most people will be from different fields or backgrounds there is no direct competition or internal politics to be dealt with. [16] People often feel part of a community and working with a wide variety of different people and backgrounds leads to new ideas and innovation. The project requires a minimum space for a total of 15 coworkers with space for meetings and relaxation. These are mainly startups and unexperienced employees. After they are more experienced and larger they may move into the official Neàpolis building.



Figure 13: Photograph of cowork office space in Neàpolis

#### 4.2.2 Bar/Cafeteria

There will be a small bar/café that will be open to the workers and also the public it should fit at least 10 people sitting comfortably.



Figure 14: Example of bar/café

#### 4.2.3 Exhibition Spaces

Space for any small indoor exhibitions or presentations and a larger outdoor exhibition space for different events held in and around the new building should be included, this is space where artists or designers can show their work to the public. In this section it is very important to consider the placement of lighting and windows to make it an attractive space for their demonstrations.



Figure 15: Recent Event Held in the exhibition hall in Neàpolis [17]

#### 4.2.4 *Maker space*

Maker spaces are open access workshops hosting a variety of new and older tools – varying from 3D printers and laser cutters through to sewing machines and soldering irons. Although maker spaces have existed for decades, they have rapidly grown in number in recent years. [18] It is a place for inventors, designers, entrepreneurs and other likeminded people. It's a place for creating something out of nothing and exploring your own interests. These spaces are also helping prepare those who need critical new skills in the fields of science, technology, engineering and math. These have been set up worldwide for public and educational use with many schools investing in this as part of their curriculum. While not a traditional part of education many studies have shown that doing hands on work improves learning and gives better understanding of concepts. [19] It is important that an open space is created within the containers allowing the workers to move and operate easily, this maker space should have space for 5 people working independently as a minimum.



Figure 16: Photograph of maker space in Barcelona

## 5 Building Plot

### 5.1 Appearance and Area size

This part of the report visualizes the construction site. The area highlighted in dark green colour in Figure 17 is the building plot where the future construction should be established.

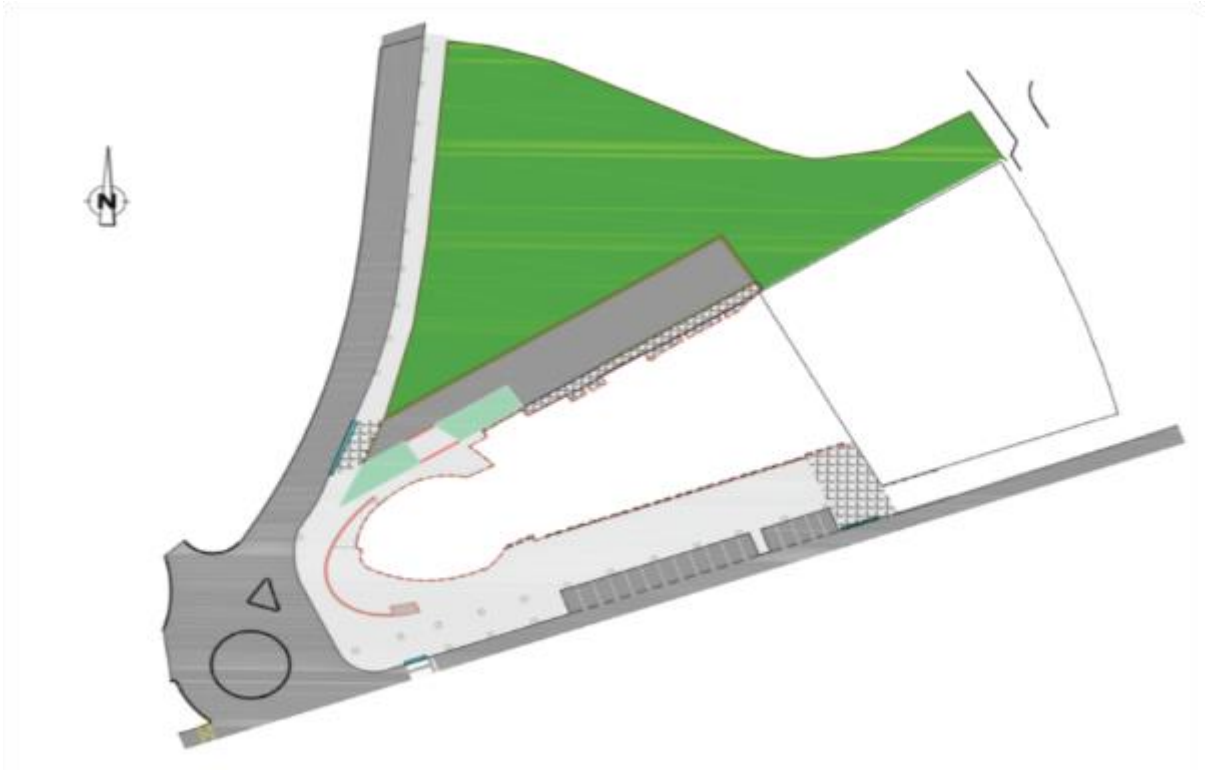


Figure 17: Construction site (highlighted in dark green colour)

The following images (Figure 18 & Figure 19) will give an overview how the plot looks in reality.



Figure 18: The building plot from the top of Neàpolis





Figure 19: The building plot from the street

Further images and drawings of the plot can be found in the Digital Appendix.

To estimate the total area of the construction site the online application tool called “Google Maps Area Calculator Tool” is used because no technical measurements of the plot are done yet. The calculation tool works with several pinpoints. To minimize the error and to achieve an accurate estimation the plot was outlined with a suitable amount of these points. Figure 20 is illustrating the method of the calculation tool.



Figure 20: Calculation of the whole building plot (left) and only the "triangle" area (right) [20]

The whole building plot (left side of Figure 20) is approximately  $3150.97 \text{ m}^2$ . Meanwhile, the “triangle” area (right side) is approximately  $2632.25 \text{ m}^2$ . This triangle area is calculated because it is sufficient to place the building that will fulfil the requirements in this space.

As shown in Figure 21 the “triangle” area is simplified further to get the approximate dimensions of the construction site. This is done with another online application named “Google Map Distance Calculator Tool”.



Figure 21: Calculation of site length

By using the measurement values obtained from the application, a sketch of the triangle is made in Siemens NX11, which is a CAD software. The dimensions of the site (see Appendix A) are required during the design stage of a building as it is important to make sure the designs fit perfectly in the actual site. Therefore it is definitely recommended to instruct an appropriate measurement of the building plot before starting to erect the building. This is important to make sure the proposal of the design fits perfectly in the shape and the dimensions of the plot. Redesign probably will happen if the estimation differs too much from the real measures.

As requirement ID 4.1 includes the design of the building has to harmonize with the surrounding and the neighbouring buildings, a few photographs were taken. Figure 22 and Figure 23 display the neighbouring houses (Figure 22 left) and the Neàpolis building (Figure 22 right & Figure 23).



Figure 22: The surrounding of the building plot



Figure 23: The Neàpolis building next to the building plot

## 5.2 Urban laws

Another aspect to study in the project of a building is the existing urban regulation on the plot where the construction should be built.

According to information provided by the Department of Urbanism of the City Council of Vilanova i la Geltrú and the current General Plan of Urban Ordinance, the plot of the project is qualified as Green Zone. Therefore, with this urban qualification, it is not possible to build on this plot.

In order it's possible to build on this plot, it must be made a Specific Modification of the General Plan, so the plot changes its qualification from Green Zone to Equipment. It must be said that, in general, in Catalonia is usually difficult to change the urban classification of an area qualified as Green Zone. In order to approve a Specific Modification of the General Plan like this, two conditions must be met:

1. Justify consistently the need and convenience for the city of building a specific type of construction (which in this case is the projected building) on the plot currently qualified as Green Zone.
2. There is a plot of the city qualified as Equipment, that could be qualified as Green Zone, with the same surface of the actual building site, in order that the Specific Modification of the General Plan does not involve loss of surface of Green Zone in the city.

Regarding the first condition, the justification has already been demonstrated consistently in the framework of this project.

Regarding the second condition can be achieved through an existing plot on the street Josep Maria Bultó number 3. This plot has currently qualification of Equipment. According to information provided by the Department of Urbanism of the City Council of Vilanova i la Geltrú, several years ago it was planned to build a school on this plot. But this option was finally rejected, and there is no plan

to build on this plot. For this reason, it is considered possible that this plot can become qualified as Green Zone. And therefore, the plot of the project becomes qualified as Equipment. Consequently it would be possible to construct the building of the project on the plot.

It is considered that the duration of the processing of a file of Specific Modification of the General Plan, from its beginning until its end, is about one year.

It should be mentioned that another option considered, is to construct the building in another plot, which currently has qualification of Equipment. But it is considered, after consulting the Direction Team of Neàpolis, that from a conceptual and functional point of view, and in terms of efficiency, the best solution by far, is that the building project is located besides Neàpolis.

## 6 Exterior Design

### 6.1 Researches

#### 6.1.1 *Study on climate & environment in Vilanova i la Geltrú*

Research on the regional climate and environment is an important initial step in this project. Having knowledge of the climate factors are essential in building construction, civil operations and building designs [21]. The climate plays a key role when ensuring the sustainability and strength of a building against any kind of local climate event. Any unwanted incident such as damages and loss during the building construction due to bad weather also could be avoided if an immediate measure is taken beforehand by being aware to the regional weather condition.

In the following are the climate factors and environmental factors in Vilanova i la Geltrú that seem urgent to be considered. These factors are studied to prevent any possible error in the decision-making process such as in choosing the right material or in designing the sea container building for the customer Neàpolis. A great design that fully takes the advantages of the climate and the local environment could possibly save a lot of money in the project.

The data of the rainfall in the next sections are taken 40.2km away from Vilanova i la Geltrú. Nevertheless, it is believed that the difference between the values from the data and the actual values in Vilanova is relatively small. Therefore, they are accurate enough for analysis of the regional climate factors since the relatively small difference does not affect the reasons why these factors are studied in the first place.

#### 6.1.2 *Rain Fall*

One of the important aspects that clearly needs to be considered when designing a roof of a building is the regional rainfall. In typical building design in a rainy area, normally a gable roof is chosen to secure the roof from water stagnation as well as to reduce the water erosion. Therefore, this study of the amount of precipitation is meant to determine an adequate roof for the sea container building.

According to the data of average precipitation in Barcelona throughout a year (see Appendix B), it is believed that the amount of precipitation in Barcelona still needs consideration during the building design stage. However, all type of roof seems to be suitable to be adapted into the design.

#### 6.1.3 *Sun's Path and Positions*

This study is performed to examine the sun's path and positions throughout a year in order to make full use of solar power in the potential building design and for passive heating and cooling purposes. For this reason, an online application from [suncalc.org](http://suncalc.org) is used to gather the desired information. As the sun's path changes at different times, 2 dates are chosen which are the starts of summer (summer solstice) and winter (winter solstice) in Barcelona.

By referring to the results from the application (see Appendix B), the orientation of the building and the position of windows inside the sea container buildings would be placed accordingly to obtain the best natural lighting possible during the day. On the other hand, the indoor air temperature needs to stay comfortable. For that reason, the windows are not directly orientated towards the sun cycle. A good balance is required here.

#### **6.1.4 Wind Directions and Speed**

The wind direction at the construction site can be identified by studying out of which direction the wind is most frequently blowing. This type of wind is called prevailing wind. Having information about it is important in deciding the building orientation for passive heating and cooling of the building. If the building is settled properly, a lot of money possibly could be saved from spending on utilities for the purposes.

According to the wind statistic (see Appendix B), the average wind speed throughout a year in Vilanova i la Geltrú is about 1.029 m/s with its prevailing wind blows towards North East most of the time. By using this value, a study to examine whether it is worth taking into consideration or not to use the wind power to generate electricity in this project is made. More details about this will be explained in the next section.

#### **6.1.5 Renewable Energy - Wind Turbine and Solar Panel**

There is no doubt that spending money on solar and wind power to generate electricity is a good long-term investment that could save a lot of money. However, in economic terms this depends on the regional climate and laws in each country. A study is carried out to decide whether investing in either these two renewable energies is beneficial to Neàpolis.

#### **Wind Turbine**

A small wind turbine is a turbine that has rotor diameter less than 10 meters [22]. It could be considered as a wind turbine that required the least average wind speed to generate power. Without considering the amount of power needed by the potential sea containers building first, a comparison between the required average wind speed and the one that is available in Vilanova is made.

A 1.5kW rated wind turbine is possibly the smallest rated power that could be found in the market and seems to be adequate to be used in this project. Nevertheless, it requires a minimum wind speed of 3m/s for the blades to turn or in other words, to start generating the energy. [22] This minimum speed required is called cut-in speed. Meanwhile, as already mentioned in section 6.14, the average wind speed in Vilanova i la Geltru is just 1.029 m/s. As a side note, there is a time where the wind speed in Vilanova could reach up to 8.745 m/s but this is not the average speed of the wind and only occurs occasionally. Thus, the wind turbine may not be able to work in its full potential. In addition, even the 1.5 kW small-scale wind turbine could cost up to 1250 € [23].

As a conclusion, investing in wind power in this project probably would only lead to waste of money as the wind turbine could not work efficiently due to the climate factor in Vilanova i la Geltrú.

### **Solar Panel**

Abundant sun and scarce rain make Spain an ideal European country to take advantage of solar power to generate electricity. However, the presence of the “sun tax” in Spain has caused the adaptation of it into the building design for this project become a question either it is worth investing or not.

As the result to this research (see Appendix C), it is believed that at present, staying in the grid and not using the solar power is the best option. Due to the fees and tax that need to be paid if the PV system is installed, the investments on the solar power probably take a long time before being profitable. For instance, the new tax would extend the average time it would take for solar panels to pay for themselves from less than 10 years to over 20 years [24].

Considering the requirements of this project, it is suggested that to focus on the sea container building construction first. If by chance in the near future the law on the self-consumption is removed from the Spanish national law, then investing on the solar power would give more benefits to Neàpolis in a long run.

## 6.2 Initial Concepts

After the initial meeting with the company several concepts were created and presented to the supervisor for approval. The following section is showing the three main concepts.

### 6.2.1 Concept Design 1

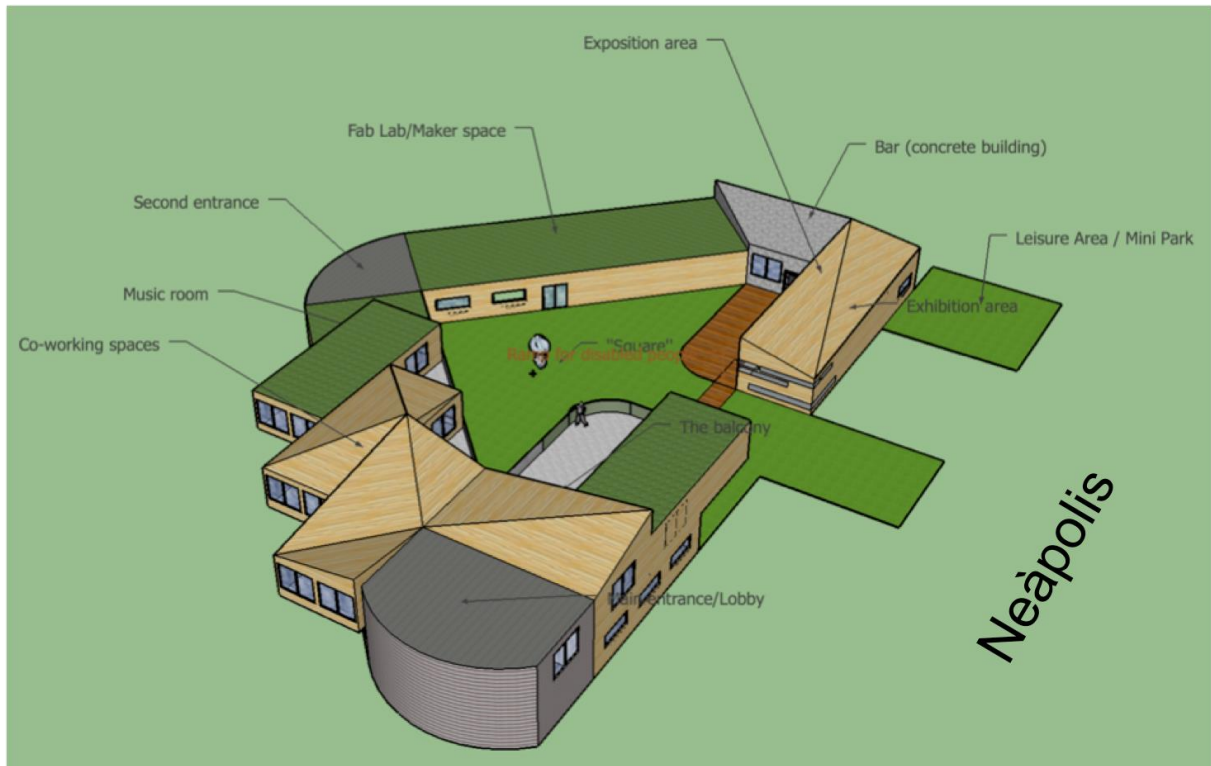


Figure 24: Design Idea 1 - 3D View

Figure 24 displays the first concept idea. The concept was designed before final specifications were agreed with the company. The curved and angled elements from the existing Neapolis building are integrated into the design. It features all the required spaces but is also about double the size that the company really requires. That is the reason why this design is not traced further.



### 6.2.2 Concept Design 2

The sketching process of Design 2 had also started before the definite requirements have been transmitted. The design is built up by 36 containers, and is made for a big working space. For the design 20ft standard containers were used. It utilizes more of the available space on the plot by using the V shape, which fits well on the plot and it is a modern approach in terms of design.

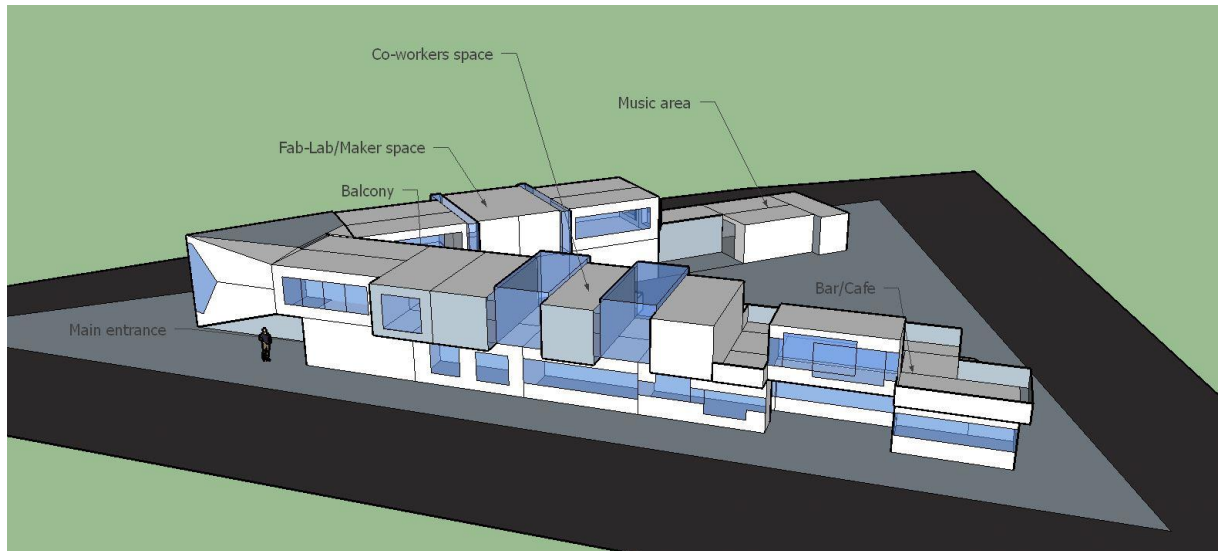


Figure 25: Design Idea 2 - 3D View

It features all the spaces/utilities that the company requires but it was agreed that a more conservative design and smaller building would fit better into the surrounding area.

### 6.2.3 Concept Design 3

It is a simple approach in terms of design with nothing extravagant other than the large angled glass section shown below.

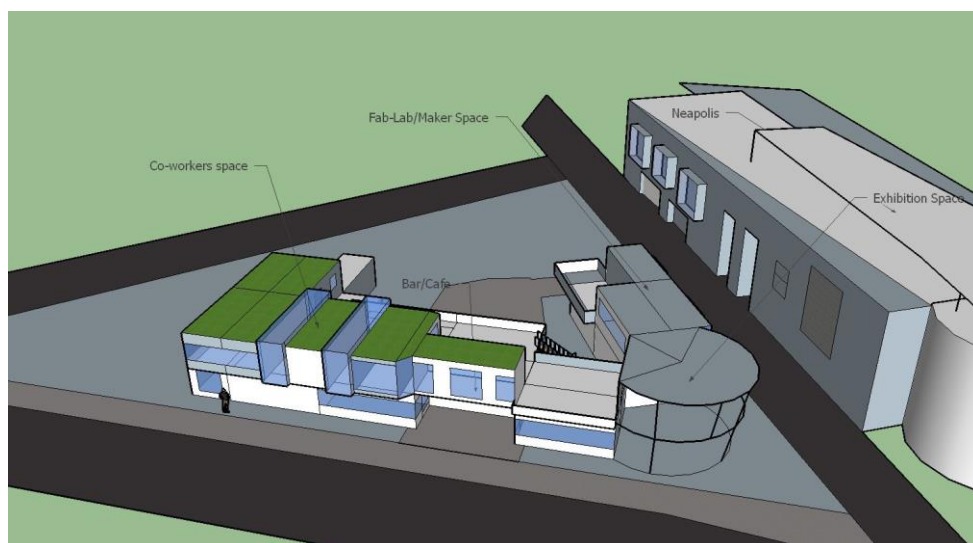


Figure 26: Design Idea 3 – 3D View

This design consists of 26 containers. It is also built up by 20ft standard containers, which is the most common container size and thus the most available. One of the main strengths of this design is the modularity and expandability. This design is based on a modular concept; it can be extended easily with additional containers if the company needs more space, which is an important factor for the company.

### Expandability Design 3

Based on the Design Idea 3 another Idea is generated. Shown below is an extension on the previous presented if the company wanted to expand it in the future.

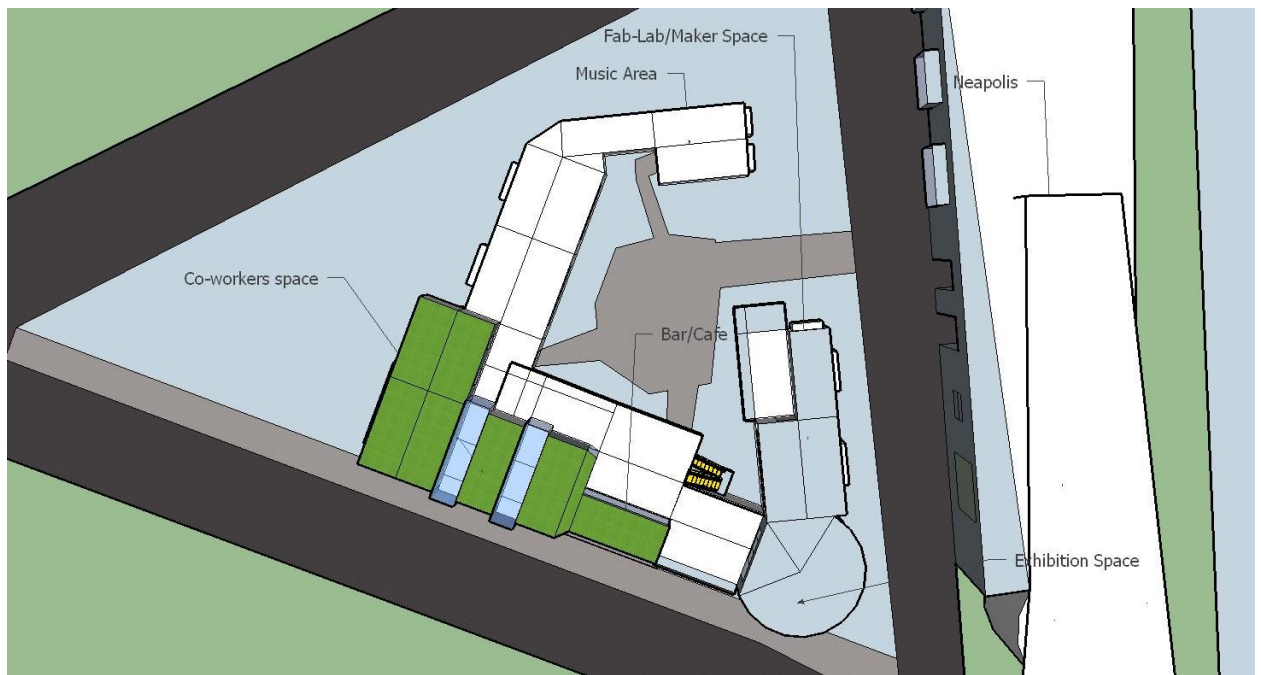


Figure 27: Design Idea 3.1 - Top View

This time it features the addition of 6 more containers, which extends the space for the coworks and a music space. The music area consists of 3 containers. This is only one shown possibility how the building could be expanded. Other enlargements are also possible like adding containers to the first floor.

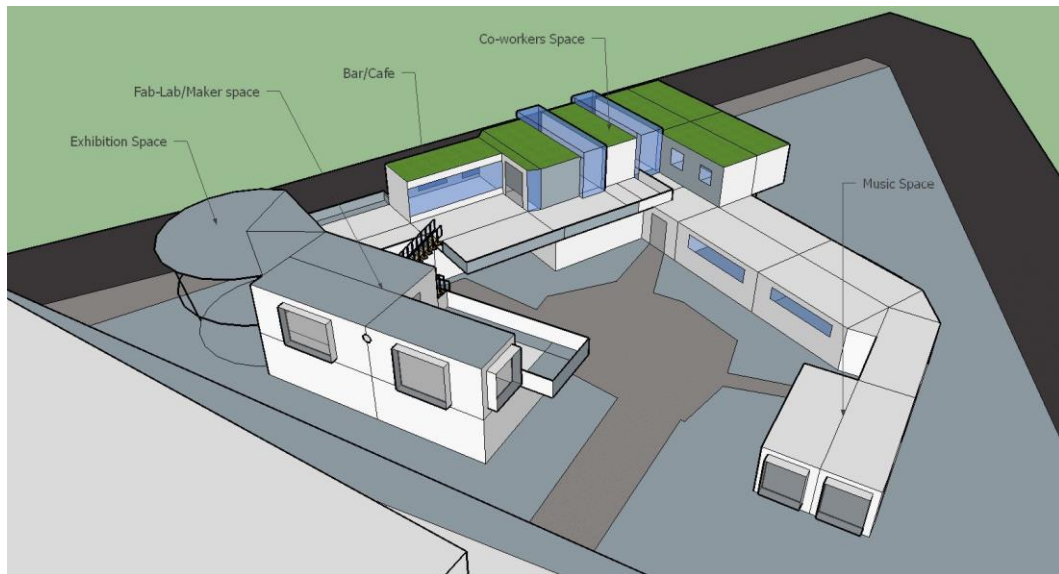


Figure 28: Design Idea 3.1 – 3D View

### 6.3 Final Design

The final design is based on the third concept which is explained previously.

As it can be seen in Figure 29 and in Figure 30 several changes had been made to the concept to get to this final design. As before the use of straight, clear lines in combination with large windows makes it look modern and it ensures that it fits in next to the modern looking Neapolis building. There are many windows on the front side to allow the light into the building as the day goes on providing a bright and natural environment to work in.

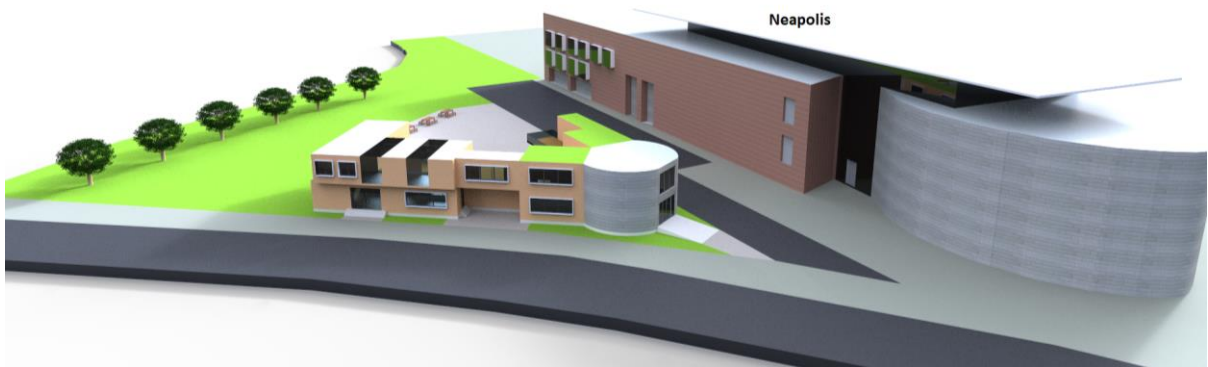


Figure 29: Final Design – 3D Street View

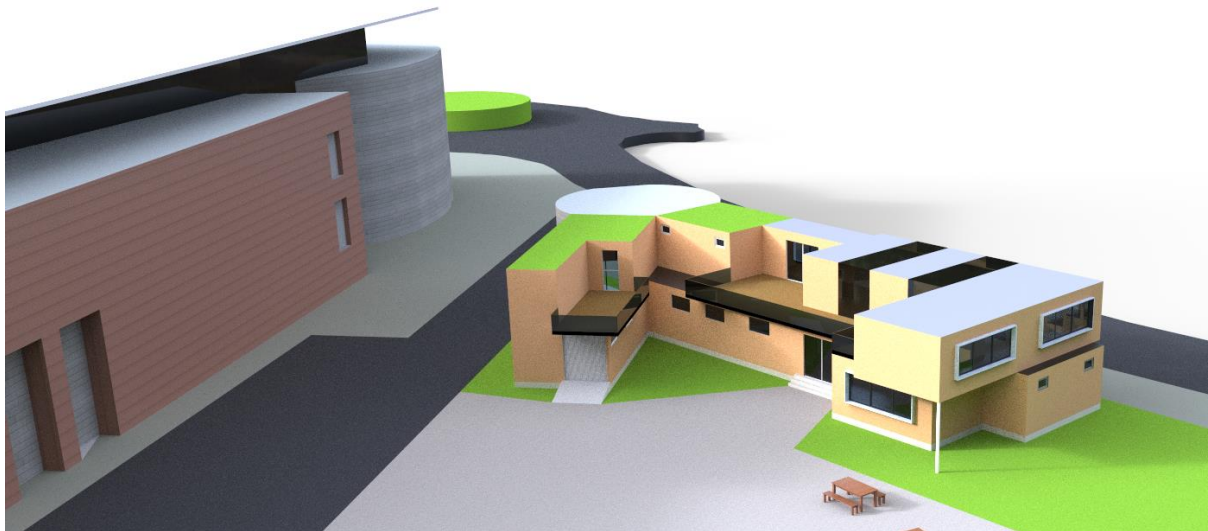


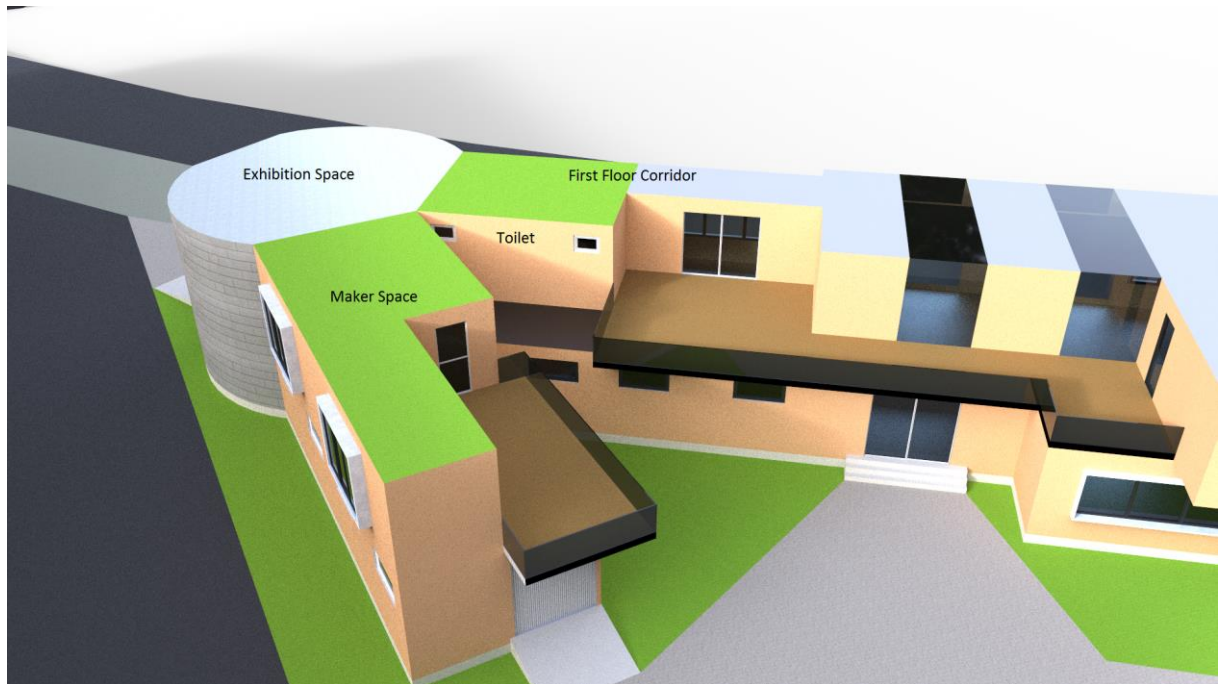
Figure 30: Final Design – 3D Back View

As stated this is a continuation of the third design with some changes and compromises, for practical and cost reasons. The size of container used in this design was the 20ft high cube container as it is widely utilized globally for shipping due to the extra height which will also make the final building vastly more open as a building made with standard 20ft containers can often feel cramped and confined on the interior which is obviously not the aim of this project.



**Figure 31: Final Design – Detail Main Entrance**

The first obvious change which can be seen in Figure 31 is that the rounded section is no longer at an angle because it would have been more difficult to build, requires more metal profiles and is more expensive. This approach also increases the interior space in the ground floor because the ground radius is the same as the top radius. It is also no longer constructed from glass, because custom-made rounded glazing is very expensive and that alone would have increased the price of the building considerably. It is not fully rounded but has a flat surface where the main sliding door and window are positioned, which allows the use of a conventional door and window, which is a lot cheaper than a custom made glass set. The window is there to brighten the interior because with only the glass door there would not have been enough interior light. The walls of it are made from metallic profiles and covered in sheet metal like the Neàpolis building. In this rounded section and the adjacent containers on the ground floor is the interior exhibition space. Disabled people can access the building via a ramp at the entrance. The ground print of the rounded section is 62.7 square meters while the whole construction has a ground print of a 314 square meters.



**Figure 32: Final Design –Detail Maker Space**

The maker space did not change from the concept as it consists of 7 containers like before and the door in the back is the actual doors of the container which is big enough to bring inside any large equipment and any tools they need. This cuts the price of a normal door and also shows the practical side when building with containers. The windows in the 1<sup>st</sup> floor are embossed to match the ones in Neàpolis. The ground floor has 4 containers and will have larger machinery while the first floor has 3 containers and one balcony where people can go out and have a break. The access to the balcony is given by a normal size glass door. It has 59 square meters on the ground print. All the mentioned aspects are displayed in Figure 32.

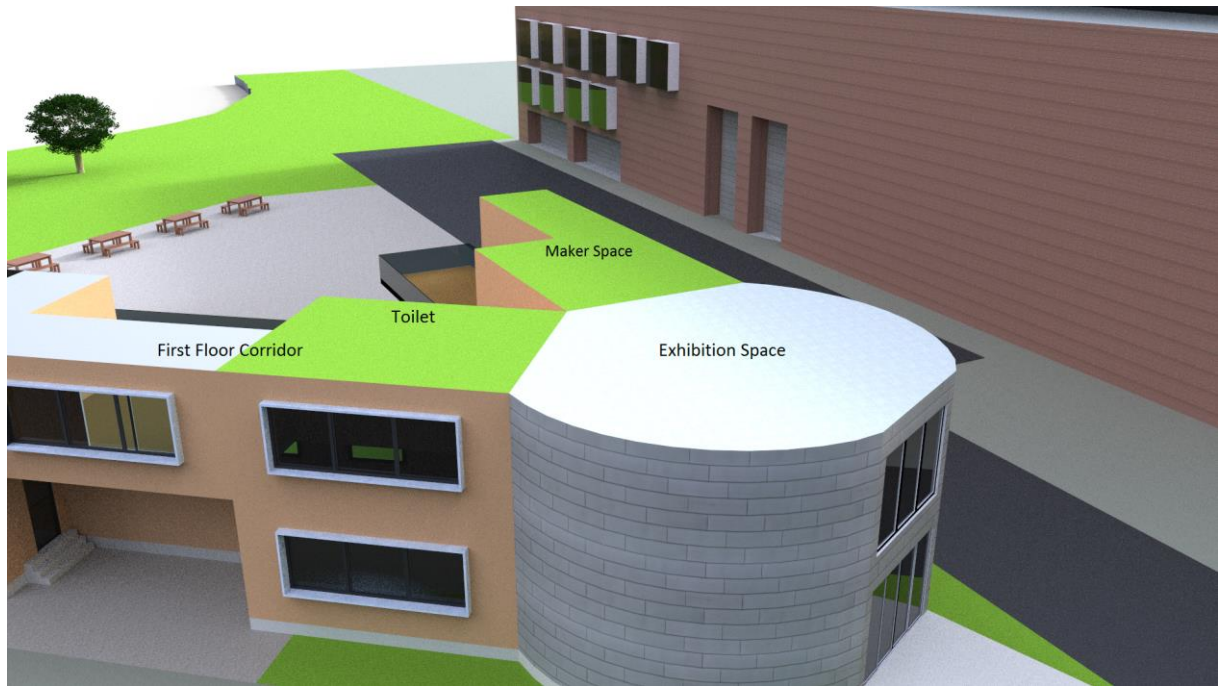


Figure 33: Final Design – Detail Street View

On top of the exhibition containers there are 2 more containers (Figure 33), this was to fix a flaw in the initial concept where it was not possible to move from one side of the building to another on the first floor without going onto the main balcony. In the first design, there was also no corridor for the ground floor. Two more containers were added for the same reason as for the corridor on the first floor, to link the building together and give access to the central square (Figure 34).

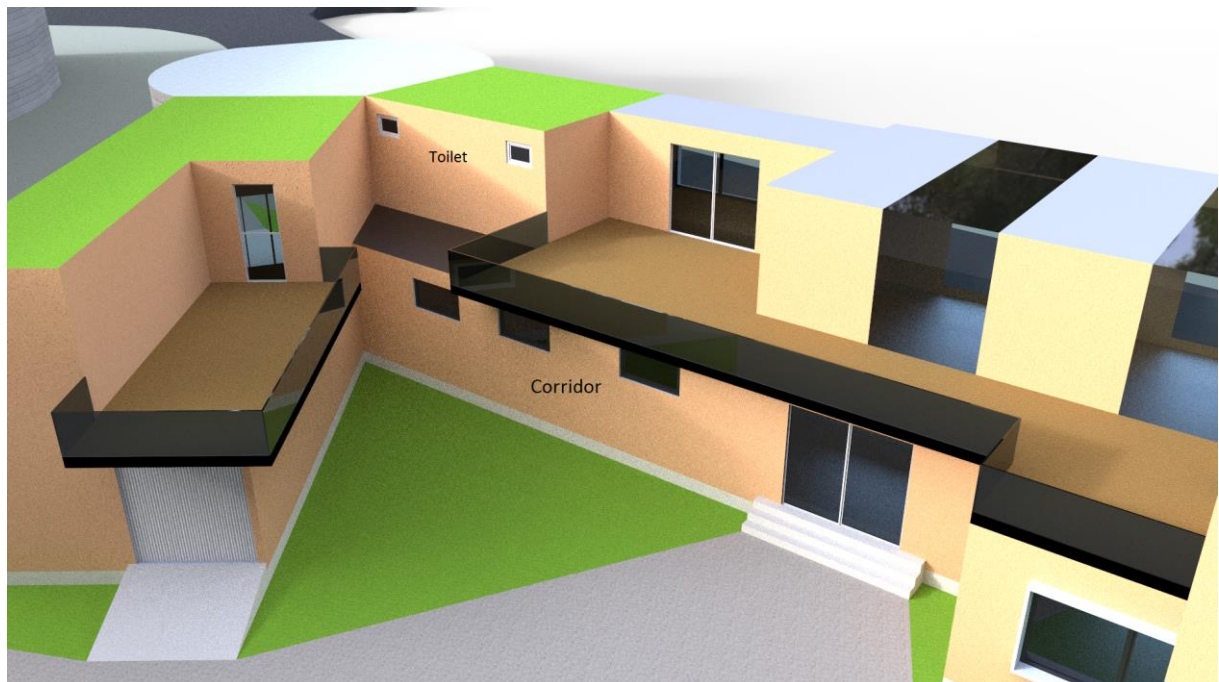


Figure 34: Final Design – Detail Back View 2

Moving on to the next part of the building (Figure 35) and the next 3 containers on the on the ground floor make up for the small bar/café. The bar/café entrance is through a small glass door beneath the “floating” container. The “floating” container above is part of the first floor corridor and has a big window on the street side and a sliding door on the opposite side which gives access to the main balcony, which has been extended since the first design.



Figure 35: Final Design – Detail Street View 2

And the last part and the most important is the cowork space. It has a main entrance of a glass sliding door from the front building on the street side (Figure 35).

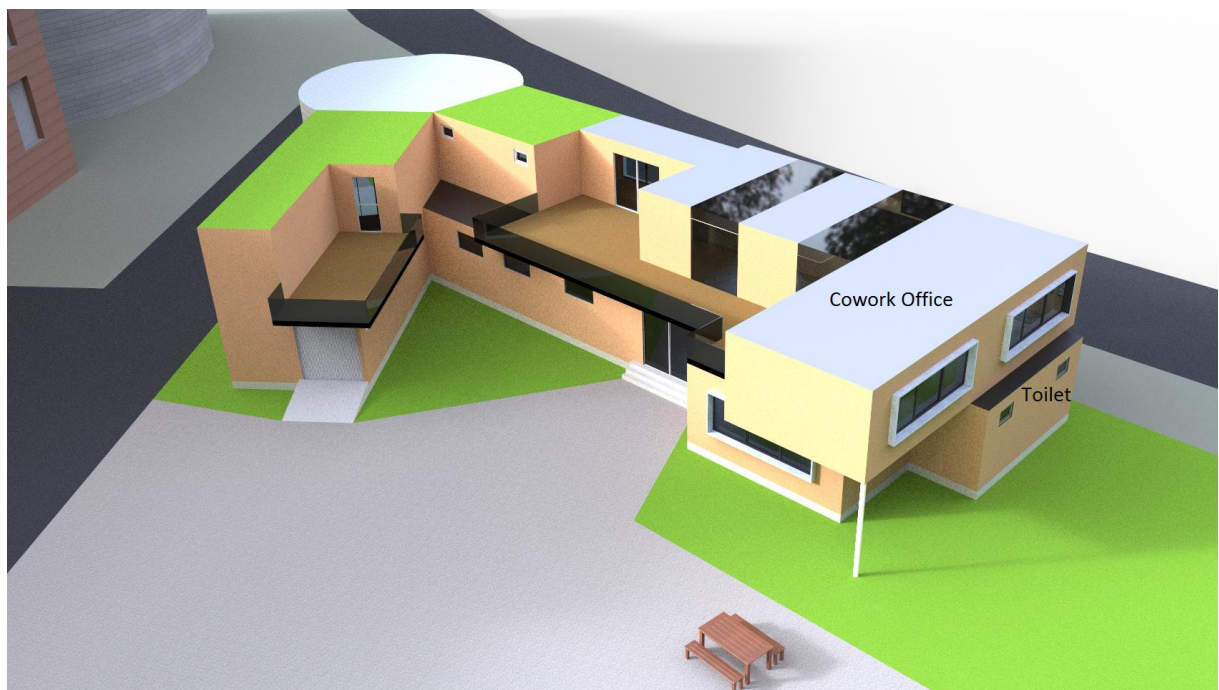


Figure 36: Final Design – Detail Back View 3



In the Figure 36 on the right side in the singular container is the toilet with 2 small windows for light and ventilation. In the back are 2 containers, there is the small working space with a big window towards the back side which gives a bright environment without direct sunlight radiation. On the first floor is the main cowork space composed of 4 containers plus the 2 large cubes combined with 2 containers that extend over the roof of the building. This part of the building has the most windows to give the workers a comfortable environment to work in.



**Figure 37: Final Design – 3D Surrounding View**

The balconies have a wooden floor and a railing made of glass. The walls will be clad with cork and painted in a suitable colour that fits in the surrounding next to Neàpolis and shows that the buildings belong together.

The remaining space on the plot is decorated with trees around the perimeter (Figure 37). This was done to leave space for any outdoor exhibitions and if the company decides to expand the building they don't have to remove the trees. In the central square are only things that can be taken out easily, like benches, tables and chairs.

The green roof seen in the Figure 38 is now implemented into the design and is located on the maker space and the 2 containers next to the rounded section. This location has been chosen for structural reasons, because the containers in these sections are stacked directly on top of each other. Containers stacked directly on each other are the strongest; they can take much more load than the ones that are not directly stacked.

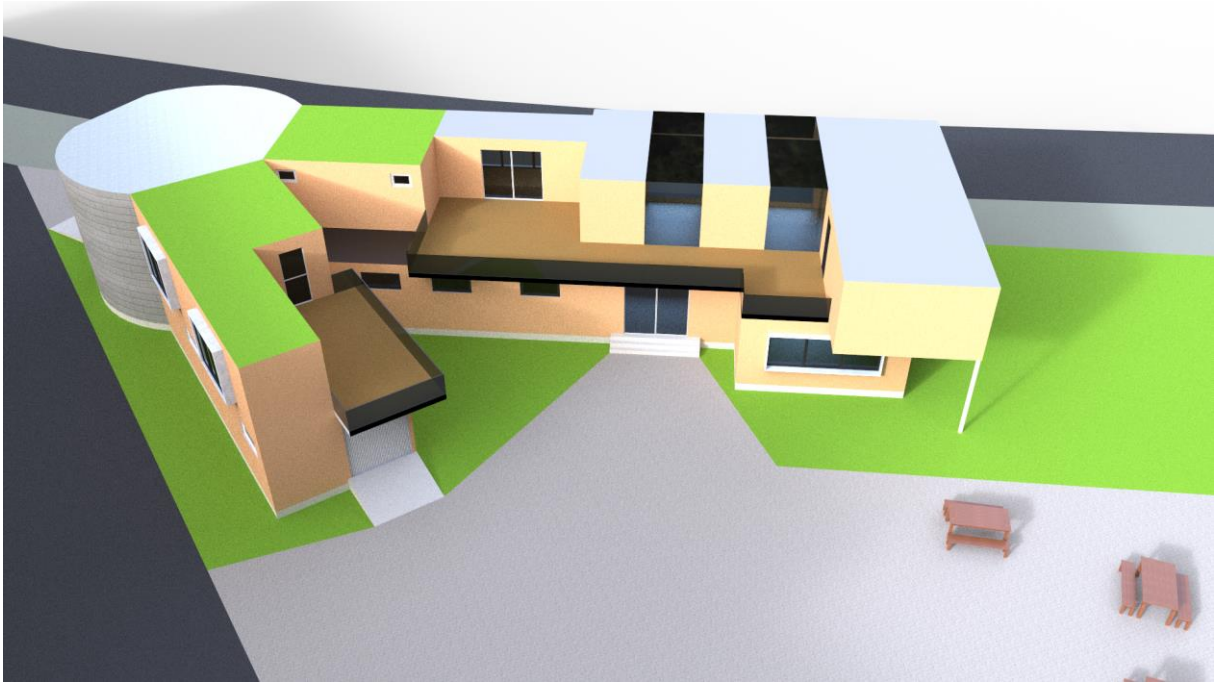


Figure 38: Final Design – 3D Back View 2

## 7 Structural Analysis

As a first estimation, simple structural analyses were made in Solid Works. To fulfil all the requirements in this project an in-depth analyses of the whole construction wasn't required. An analyse of the structural behaviour of a container was made by putting an estimative real world load on a single container, a single container with bits of its walls to show that the walls are a part of the structure, a welded containers stress test to demonstrate they are stronger together, and a test illustrating the necessity of reinforcements simplified with an I-profile beam.

But even though the whole structure wasn't analysed completely, a 3D-model with the main structure was assembled in Solid Works. The file can be found in the Digital Appendix.

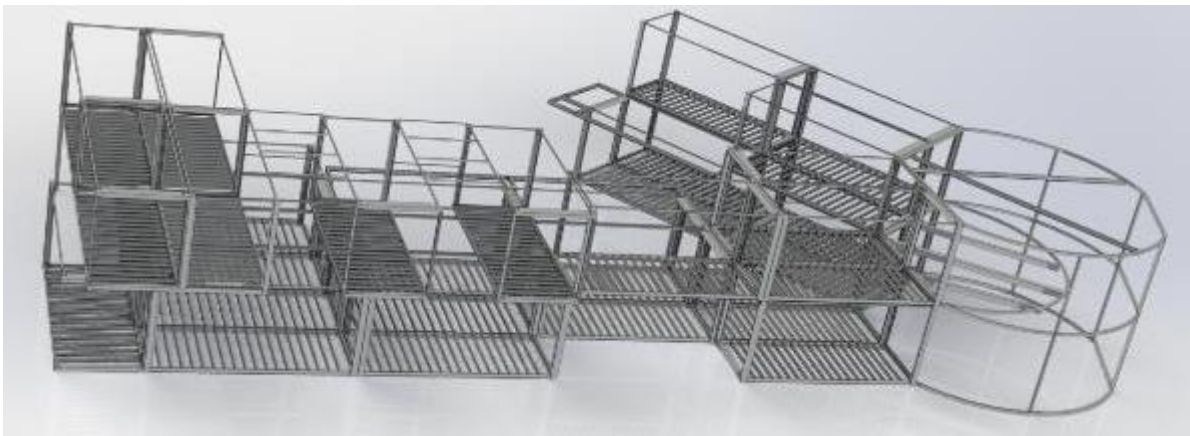


Figure 39: Structure of the building in Solid Works

### 7.1 Single Container Test

To ensure that a container can take a estimated load of 50.000 N (equals approx. 5 tons) the single container structure is tested. The container is fixed in the 4 corner points indicated with green arrows (Figure 40) those are the contact points with the foundation. The applied total force of 50.000 N is split equally to the four top corners indicated with pink arrows, these are the contact points between the containers of the ground floor and the 1. floor.

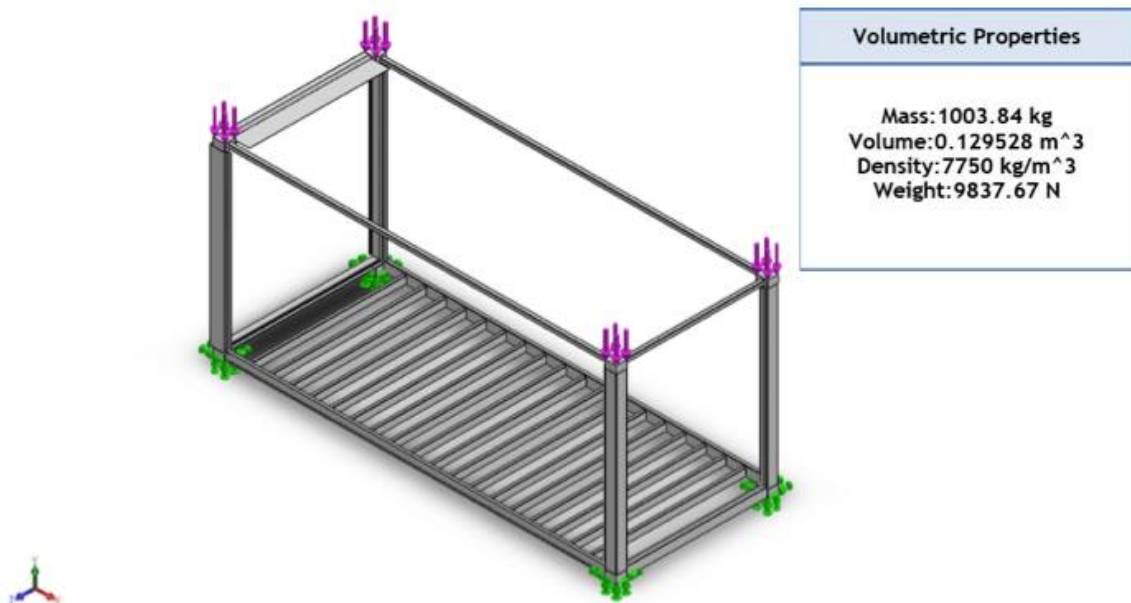


Figure 40: Single Container Stress Test in Solid Works

The mechanical properties of the material of Container are displayed in Figure 41.


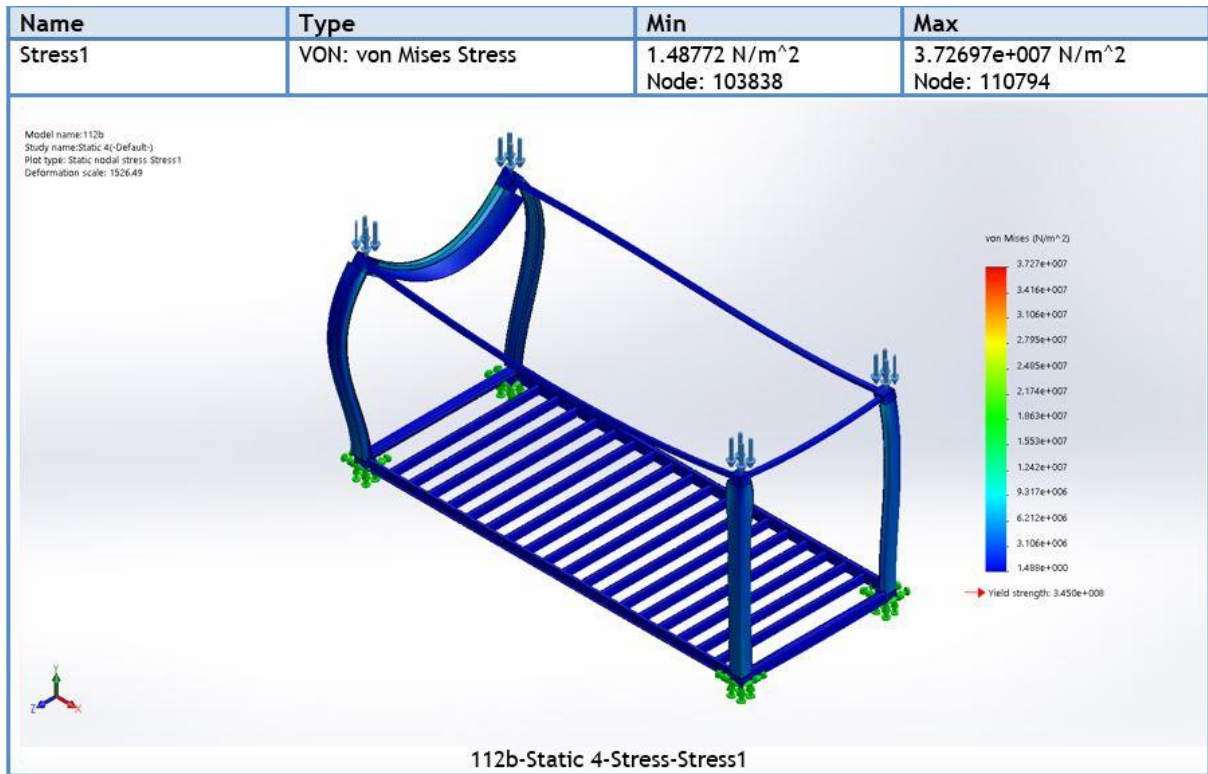
Model Reference	Properties
	<p><b>Name:</b> A588 Corten  <b>Model type:</b> Linear Elastic Isotropic</p> <p><b>Yield strength:</b> 3.45e+008 N/m<sup>2</sup>  <b>Tensile strength:</b> 4.83e+008 N/m<sup>2</sup>  <b>Elastic modulus:</b> 2.05e+011 N/m<sup>2</sup>  <b>Poisson's ratio:</b> 0.28  <b>Mass density:</b> 7750 kg/m<sup>3</sup>  <b>Shear modulus:</b> 8e+010 N/m<sup>2</sup></p>

Figure 41: Mechanical properties of a container in Solid Works

The next image illustrates the exaggerated deformation of the container. The maximum deformation is 0.402 mm on the door beams.



Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 116	0.402256 mm Node: 19965

Figure 42: Deformation single container stress test in Solid Works

The same stress test (same force and same constraints) is done with an container frame and a section of the walls, which are made of corrugated corten steel.

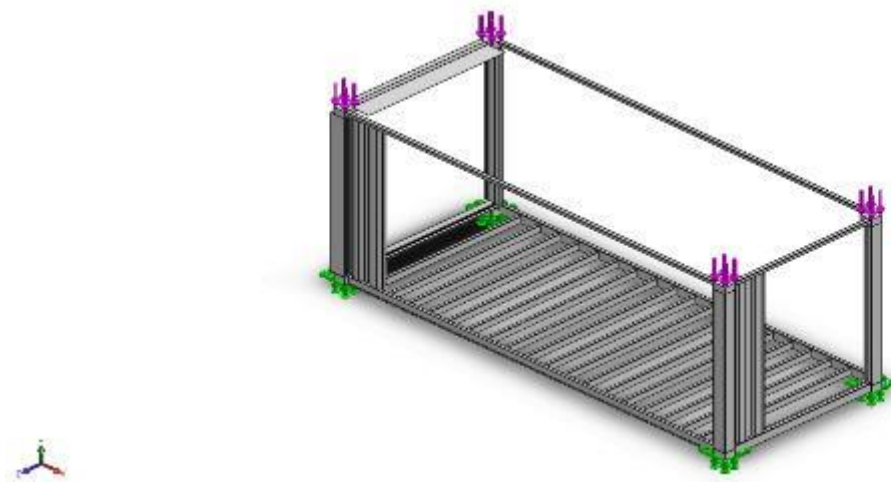
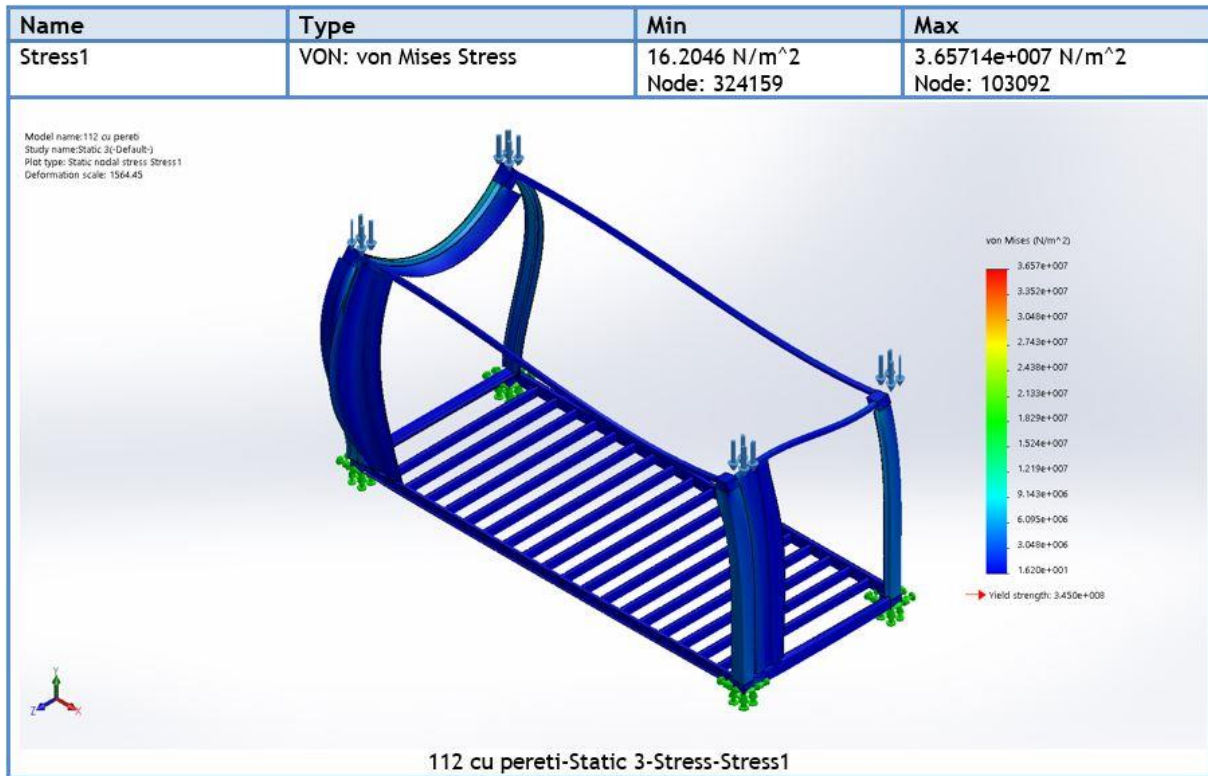


Figure 43: Single Container Stress Test with wall sections in Solid Works



Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 230	0.391269 mm Node: 53214

Figure 44: Deformation single container stress test with wall sections in Solid Works

The results show that the walls have a great impact on the container strength. With the added wall sections the maximum deformation is 0.391 mm. This fact leads to the conclusion that most of the used containers with wall sections will resist higher forces than the applied ones

## 7.2 Welded Container Test

The following stress test proves four containers welded together.

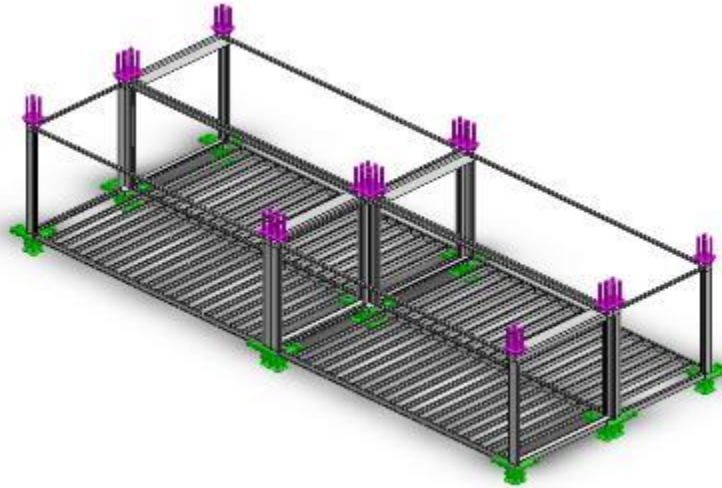


Figure 45: Welded container stress test in Solid Works

The fixed points are the bottom corners which are in contact with the foundation. The forces are applied on the top corners which are 12.500 N on each corner.

The containers next to each other are placed in opposite direction, which means the actual container door side faces a container backside. The reason for this can be seen in the single container stress test, the weakest part of the container are the door beams. Placing and welding the containers this way improves strength of the structure.

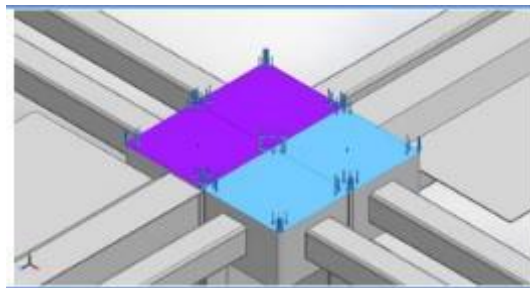


Figure 46: Detail welded corners

In this picture can be seen the fact that when they are welded together in this manner they become stronger.

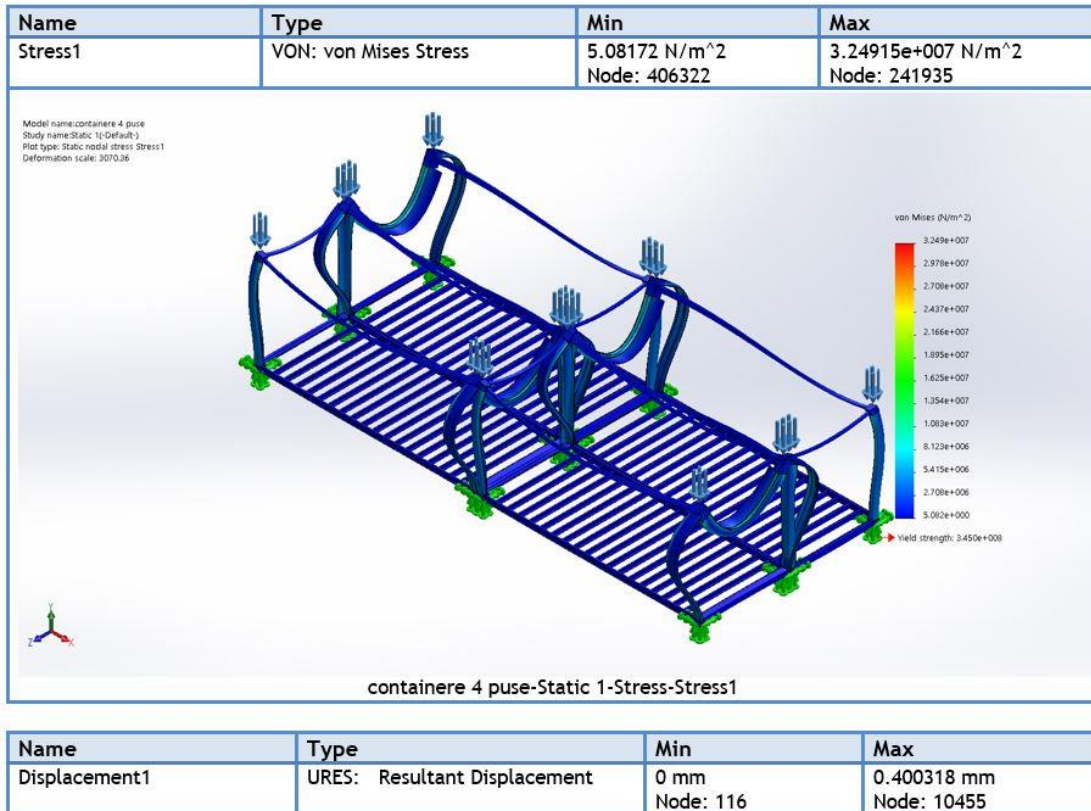


Figure 47: Deformation welded container stress test with wall sections in Solid Works

The maximum deformation in this case is 0.400 mm.

### 7.3 Single Container test with simplified reinforcement

A stress test with reinforcements has to be made because the containers of the cowork office on the 1. floor will not be placed directly on to the structure of the containers underneath. In this case researches have shown that I-Beams are used to support the container structure. Figure 48 simplifies the reinforcement by using an I-Beam laid on top of the container beams on which the force of 20.000 N is applied.

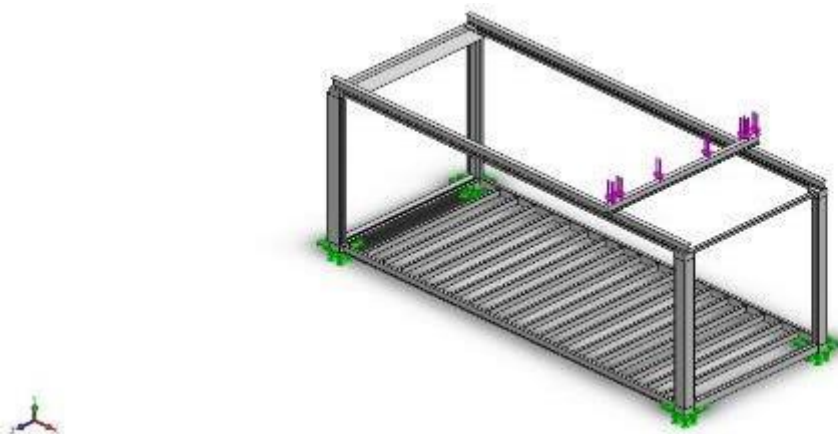


Figure 48: Simplified container stress test with I-Beam reinforcement in Solid Works



The Dimension of the integrated I-Beams can be looked up in the following Figure 49.

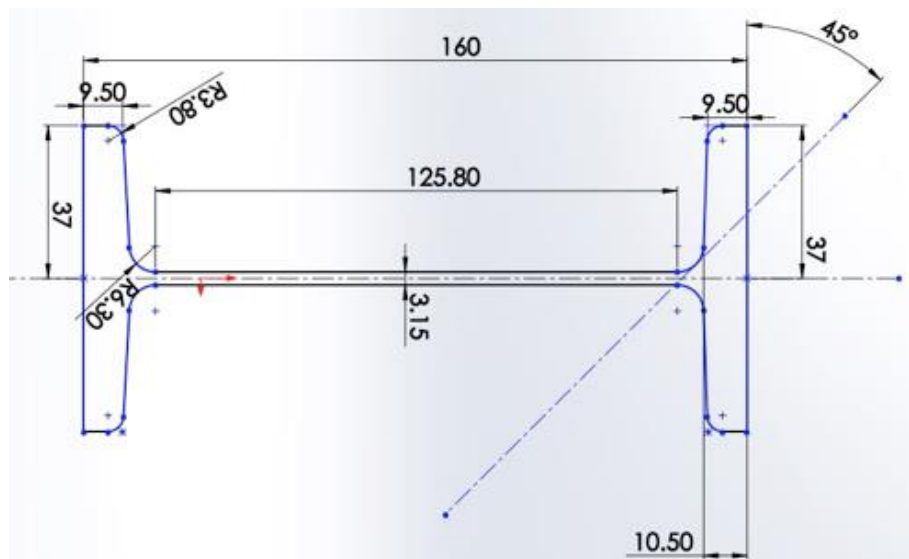
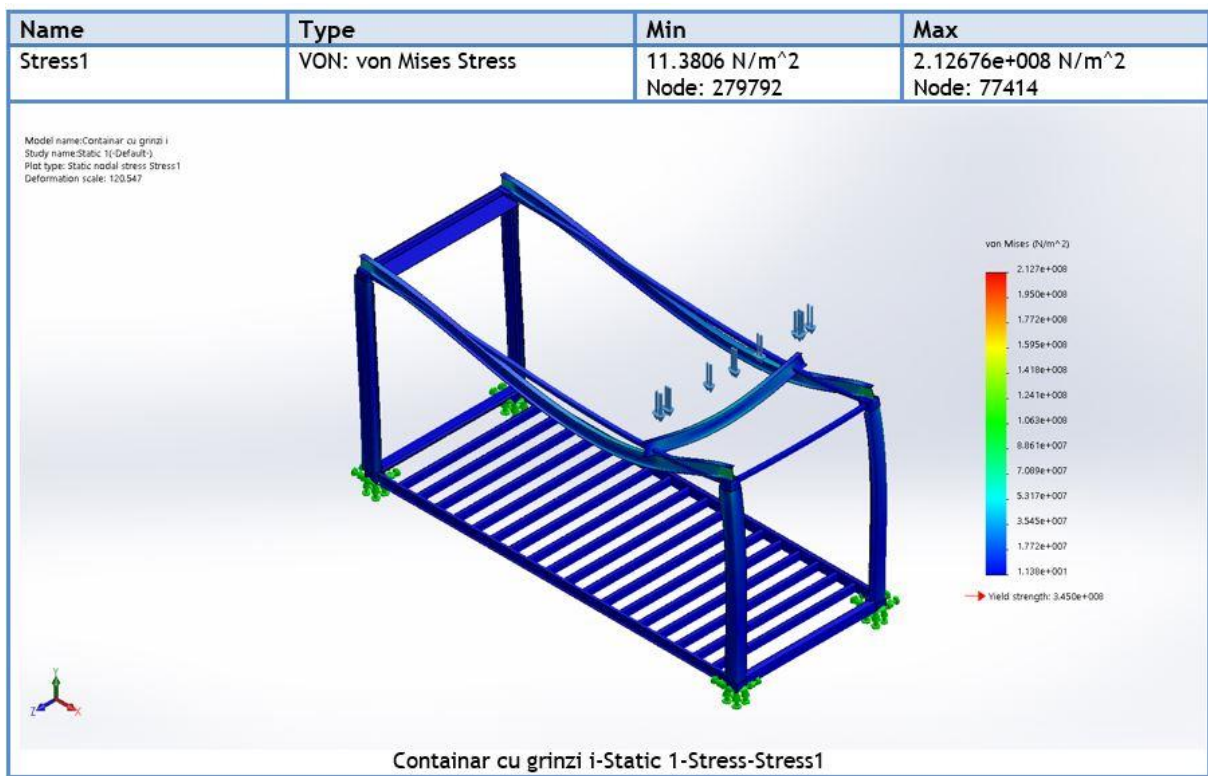


Figure 49: Dimensions I-Beam reinforcement



Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 132	5.36446 mm Node: 567898

Figure 50: Deformation simplified container stress test with I-Beam reinforcement in Solid Works

The maximum deformation in the test is 5.36mm.

## 7.4 Non Container Structure

The company desired to realise a resemblance between the newly built container office and the existing Neàpolis building. To match this resemblance, curved lines will be used in the design where the exhibition hall is situated. Here, the placement of a container is not possible. For this structure, bended construction profiles in steel will be used. Steel construction profiles exist in a wide variety. Steel companies use extensive, modern machinery to bend standard construction profiles. Profiles can be bent in 2D or 3D. Regarding the shape of the structure, a 2D model is sufficient.



Figure 51: I-profile and bended C-profile which will be used for the rounded part [25]



Figure 52: Example of a construction in the USA, I-profiles for the flooring structure [26]

The rounded section itself will be realised out of C-profiles. For the straight profiles, (inside of the rounded section: flooring) I-profiles will be used. I-profiles have a strong capacity to resist axial forces, forces which will be emerged by the users walking over the floor. The C-profiles will point with their flat side to the exterior so that a firm connection with the I-profiles can be realised. The different profiles will be welded together to form the skeleton of the exhibition hall. The second reason why the C-profiles will be bended like this, is for the finishing.



Figure 53: Bended zinc coil sheets as a finishing [27]

As shown in Figure 53 bended zinc coil sheets will be used as a finishing. It is easier to apply the finishing against a straight profile. [28]

The total exterior surface of the rounded section is 96 m<sup>2</sup>. The bended zinc panels will cost around 150 euro/m<sup>2</sup>, welding included. This results in an amount of 14 400 euro for the cladding in zinc. This is with the cost of the structure itself excluded.

## 7.5 Conclusion of Structural Analysis

As the simple test showed even without the walls the container structure can resist of a potential real world of a5 tones

To ensure that the design is possible to be built with containers, a few deformation tests were made. By referring to the outcome of the tests (single container deformation without walls and a load of 5000kg is 0.4mm), the structure of the whole building constructed with the containers is believed to be stronger when the containers welded together and reinforced compared to a single container alone.

In other words, multiple containers joined together seem to be able to support greater loads resulting in a more stable structure. Thus, it could be assumed that the sea container building could stand any potential loads such as live load and wind loads without trouble in the future. But as this tests are just first estimations detailed stress tests must be performed and the exact location of reinforcements should be identified before starting the construction

## 8 Foundation and Sewage

### 8.1 Foundation

#### 8.1.1 Concrete pile foundation vs. concrete slab foundation

In general precedent to a precise foundation decision and calculation a ground analysis had to be made. Therefore an exact Cone Penetration Test (CPT) needs to be executed before the construction can start. Because this could not be done by the project team, the following given estimations and information will lead to the recommended solution.

The soil in the area of Vilanova i la Geltrú, especially at the construction site, consists of mainly clay with a ground resistance of  $\sigma_{ad} = 0,2 \text{ N/mm}^2 = 2 \text{ kP/cm}^2$ . The soil consistency and the ground resistance are approximated numbers which were given by Neàpolis. Declaring that the soil consists of mainly clay is in this case enough for a first approach, even if the ground contains more soil types than one. It is also possible that the soil contains every few meters a part of sand material.

In the following section the type of foundation will be determined. In this case two foundation structures are examined: a full concrete slab foundation and a foundation on concrete piles. Figure 54 illustrates a slab foundation in the centre and on the sides beam structures with concrete piles are used.

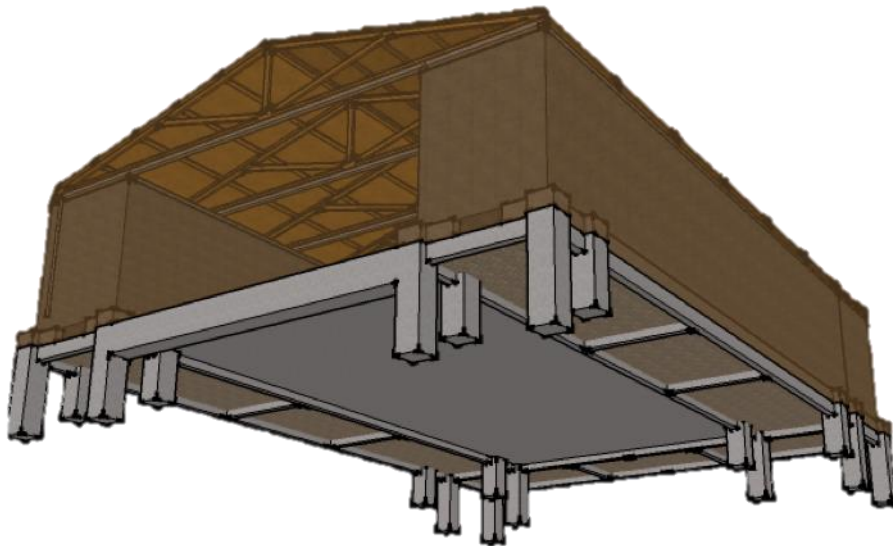


Figure 54: Foundation example [29]

The customer (Neàpolis) requested a concrete slab foundation over a pile foundation, arguing that a pile foundation is more expensive. Placing a pile foundation requires more heavy and specific machinery. After this request a critical analysis and a cost comparison of both foundation structures was made.

A full concrete slab foundation under the container building would cost approximately 17.100 €. This price includes insulation, formwork and construction foil. Stabilised sand under the concrete slab is excluded.

Realising the foundation with concrete piles would cost approximately 27.666 €. The detailed calculation sheet can be found in the Digital Appendix. [30]

But it has to be considered that a concrete slab foundation requires a constant support under every part of its structure. When the ground cannot provide an equal support under every part of the slab foundation, the whole structure can fail due to 'differential settlement'. Figure 55 visualizes this phenomenon.

Prior making a decision towards a slab foundation, it needs to be proven that the particular clay ground gives a similar support beneath every part of the foundation. This only can be done with a profound ground analysis carried out by a specialized company. Researches show that in only 30% of the cases a clay ground is constant enough to support a slab foundation. [31]

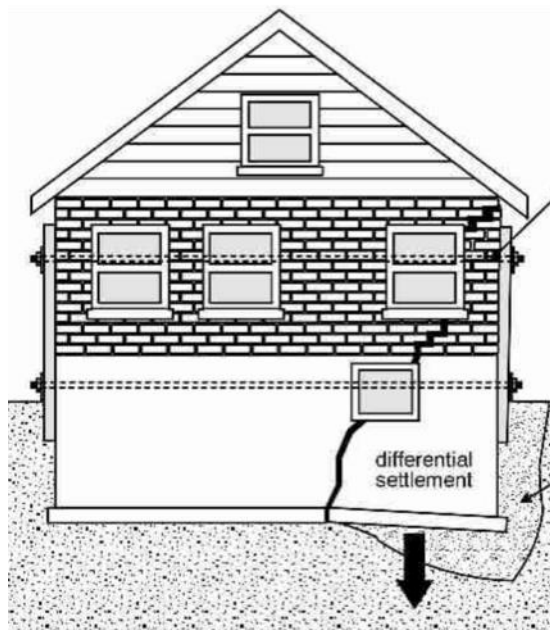


Figure 55: Failing of slab foundation [32]

Consequently to provide a safe container construction and to avoid problems in the future, a concrete pile foundation will be the recommended as a solution based on the given information..

### 8.1.2 Concrete pile foundation

A concrete pile foundation will give a higher support to the construction and minimizes the possibility to fail by using meter deep piles. Pile foundations are used in two types on specific situations:

1. When the type of soil located in the top layers is not strong enough to fully resist the force of the structure. Than the forces which come from the construction have to bypass this layer. The forces will be transferred to a deeper layer which consists of the stronger material.
2. When the construction has very concentrated loads.

In case of a container construction, the loads from the construction to the soil are yield by four contact points. The four points are the four corners of the container where the forces are concentrated. For this reason a concrete pile foundation with piles located in every corner of the container is a suitable solution for supporting the structure.

There are two ways of how the piles react with the ground. If the bottom of the pile rests on a layer of strong soil they are called “end bearing piles”. Friction piles work in a different way. The pile transfers the load across the full height of the pile, which is cylindrical in shape. The absence of the exact CPT leads to an assumption that the pile will get its resistance in a weak clay soil and that friction piles will be used. This is illustrated in Figure 56.

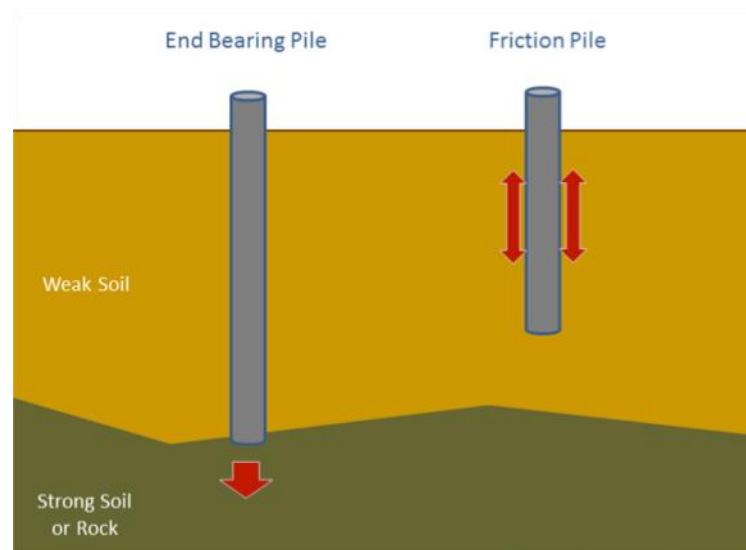


Figure 56: End bearing piles (left) and friction piles (right) [33]

### 8.1.3 Foundation on wells

For this project a special type of pile foundation called “foundation on wells” is recommended. Because in general thinking of a pile foundation it is usual to use piles with a depth of around 10 m. This method demands heavy machinery and a big amount of material. Normally pile foundations, as described, support enormous multi-level buildings such as hospitals or schools.

“Foundation on wells” in contrary is a smaller version of the original pile foundation. It usually will not be deeper than 10 m and only small machinery is required.

The main advantages of a foundation on wells in comparison to the deeper pile foundation are the lower costs and the absence of vibrations when realising the foundation. The existing Neàpolis building next to the container construction has a foundation that is vulnerable for vibrations. Using a foundation on wells will not affect any nearby buildings and saves money. [34]

The available diameters for the foundation are 80 cm, 100 cm and 120 cm. Regarding the weight of two stacked containers (approximately 10 tons) and the relative small surface of the contact points in the corners of the container, a diameter of 80 cm and an estimated pile depth of 3 m will be sufficient.

On top of the foundation piles a concrete beam structure will be placed (shown in Figure 58). The metal reinforcements (shown in Figure 57) combine all foundation elements (piles and horizontal beams) and form a skeleton for the container construction.



Figure 57: Metal reinforcements in foundation piles [35]

The beam skeleton is evaluated to be 40 cm x 40 cm. The 40 cm wide beams form enough surface to cover the container structure. Figure 58 visualizes the horizontal beam structure.

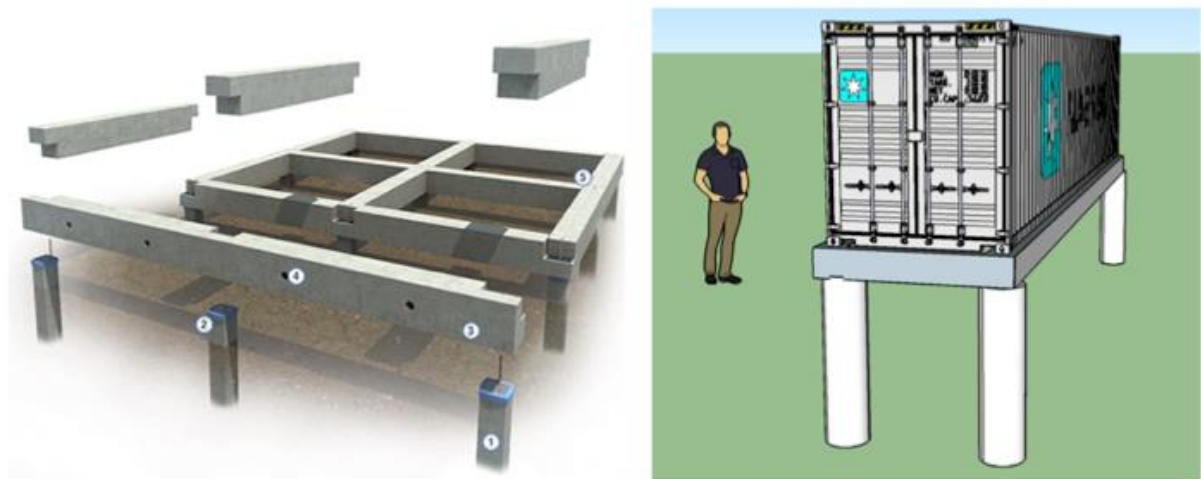


Figure 58: Horizontal beam structure (left) [36] and schematic illustration with container in Google SketchUp (right)

The layout of the foundation for the designed building is displayed in Figure 59. The piles are illustrated by black circles.

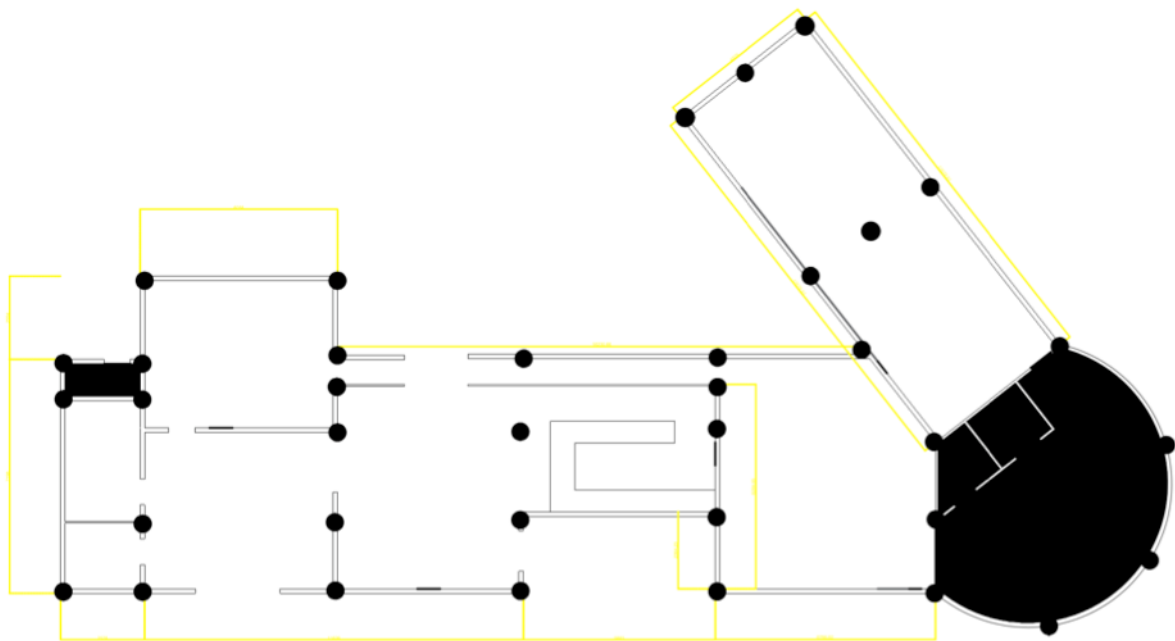


Figure 59: Location of pile and slab foundation

The two black coloured parts (exhibition hall and room of water heating tank) will be founded with a 15 cm thick concrete plate. This parts are not built up by containers and need a flat flooring. The corner lines will be supported by concrete beams likewise in the container areas. The yellow lines are for sizing. Realizing the foundation for the project in such a way will cost approximately 20.000 €, which is slightly more expensive than a full slab foundation but will reduce the risk of failing multiplied. The detailed information about the costing calculation can be found in Appendix D.



## 8.2 Sewage

Alongside the planning of the foundation and the location of the piles and beams, the location and direction of the sewage system has to be implemented. The following Figure 60 is displaying the connection of the buildings drainage system to the main sewage system of the town.

### 8.2.1 General Study

A drainage system refers to all the piping within private and public premises which conveys sewage and other liquid waste to the main sanitary sewer. "A stack" is a general term used for any vertical piping line. An indoor sewage system contains one main waste and vent stack. All the sewage piping is connected to the main waste stack. The waste stack requires ventilation at the top of the construction. The waste stack is ventilated through the roof (or an external wall) and this part is called "main vent". At the bottom and in the soil, the main waste stack is connected to the sanitary sewer with a waste line. In the project the same sewage built up will be used. Drainage systems do not depend on pressure, when comparing it to supply systems. Waste leaves the house because the drainage pipes all pitch or angle downwards. This transport method is driven by gravity.

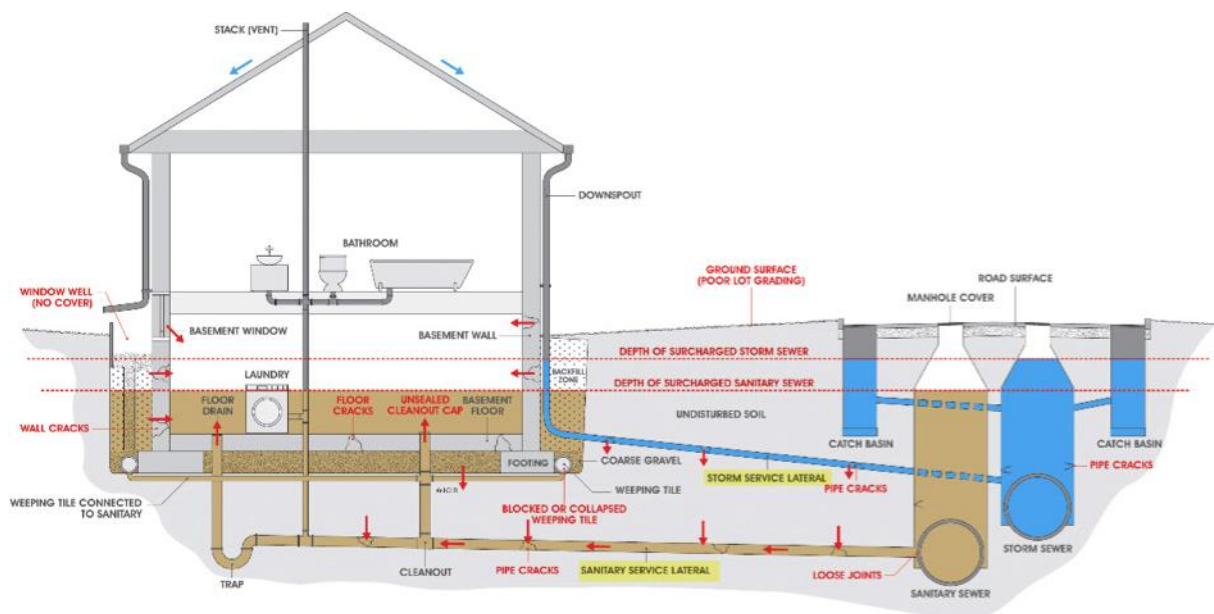


Figure 60: Connection of indoor sewage pipes to the main sanitary sewer [37]

Indoor facilities (like a sink or a basin) are connected to two different subsystems. One subsystem brings the fresh water in, the other system takes waste water out (the sewage system). All the indoor elements that contaminate water require a connection using sewage piping. This wire of piping goes through the walls and flooring. In Figure 61 a connection of a toilet and a sink to the main stack vent is shown. [38].

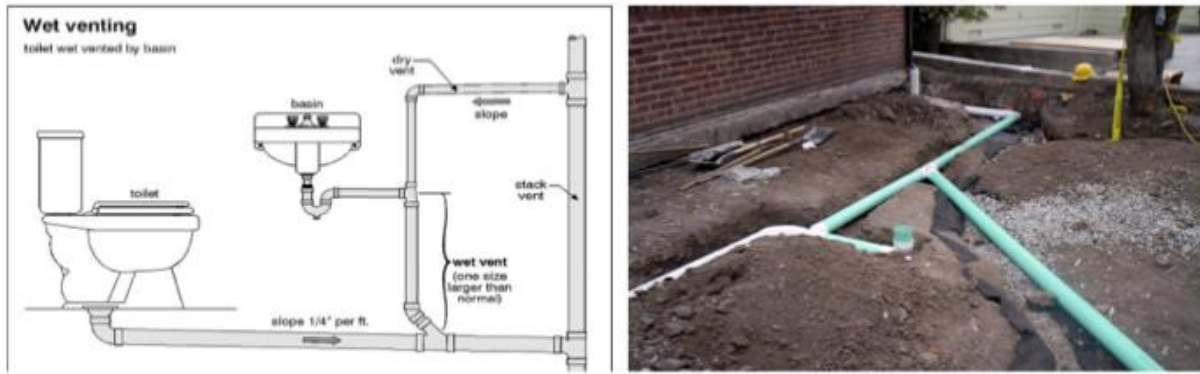


Figure 61: Toilet and Basin connection to the main stack (left) and piping in the ground (right) [39]

Clear sewage plans precede the start of the construction. At the ground floor under the foundation, savings will be made for the connection the the main sewage system, also visible in Figure 61.

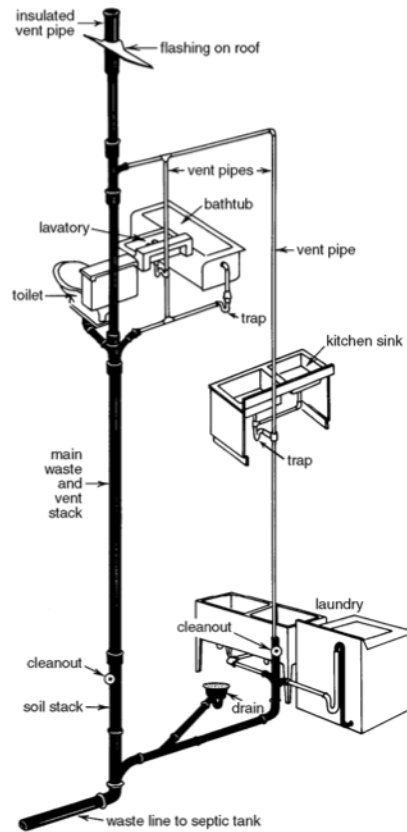


Figure 62: Indoor connection the main waste stack, ventilated through the roof [40]

**8.2.2 Sewage Implementation in the plot**

All the displayed plans in this chapter are made with AutoCad 2017 and can be found in both dwg and pdf in the Digital Appendix.

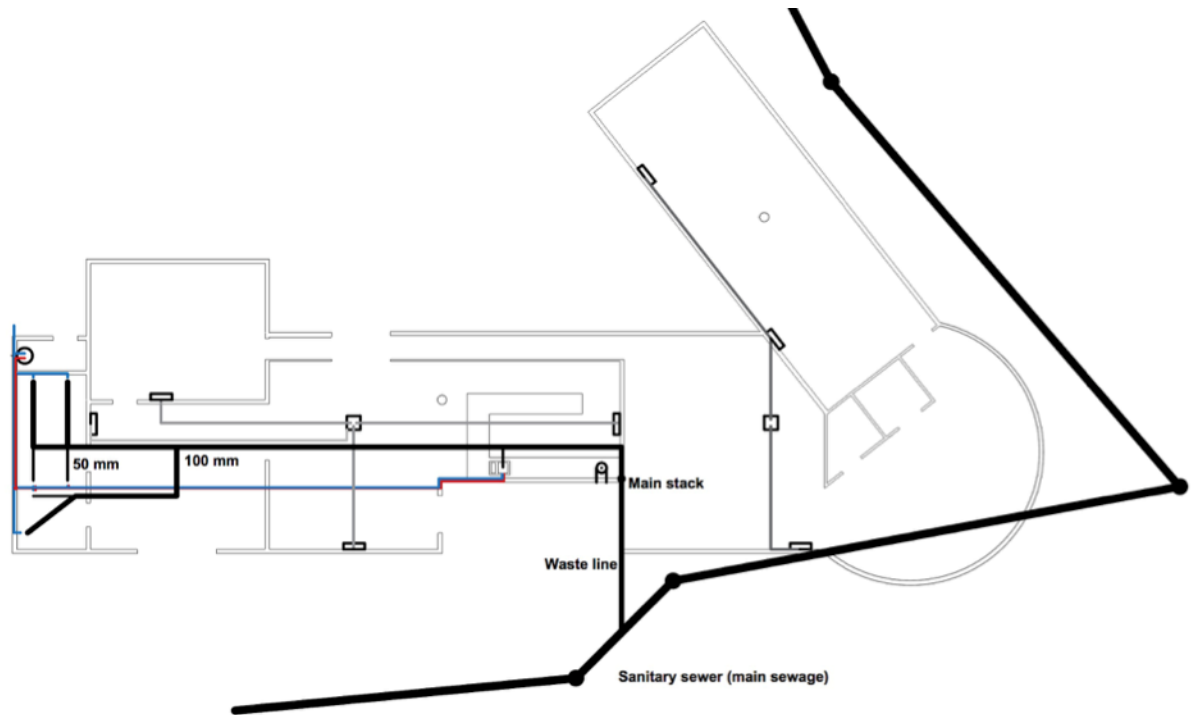


Figure 63: Ground floor (+0): indoor connection to the main stack and to the main sewage

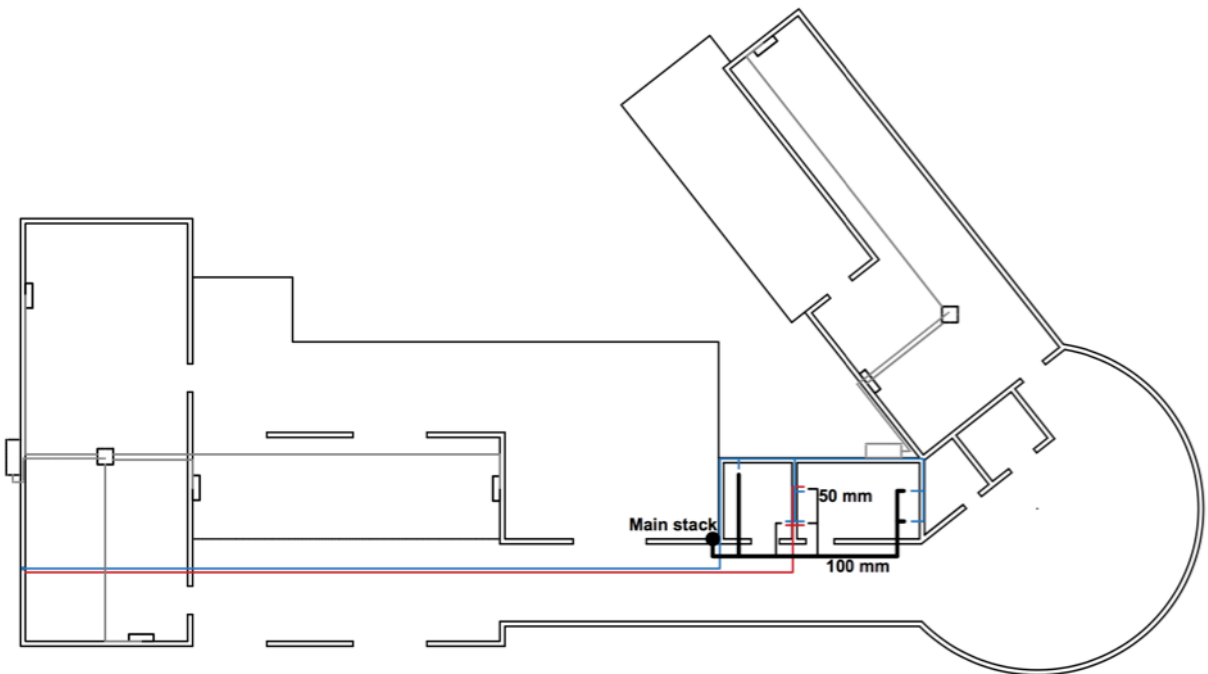


Figure 64: First floor (+1): indoor connections to the main stack

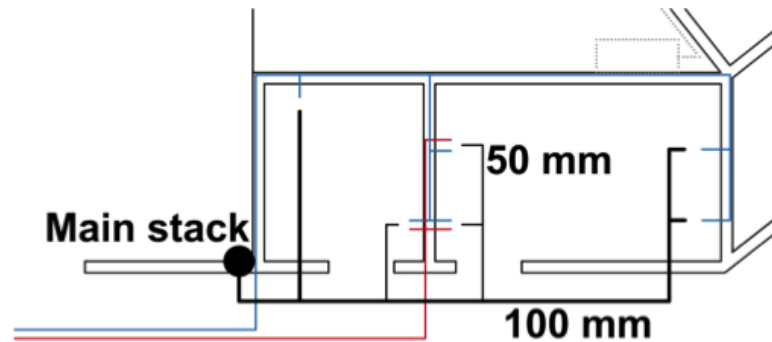


Figure 65: Detail piping at the first floor (+1)

In the plans different line colours were used to distinct both sub-systems from each other. Red and blue lines represent water supply lines. Black lines are the implementation of the sewage system.

Two different piping diameters will be used: 50 mm and 100 mm. Sewage for toilet uses require a bigger piping size than sewage piping for waste water. In the plans line thicknesses are represented. One main stack is rising through the whole structure. The main stack is centrally located in the structure and in a place where floor +0, floor +1 and the roof can easily be connected. At the bottom the main stack is connected to the main sewage line. At the top it forms the ventilation for the whole indoor sewage system.

On the ground floor there are 3 toilets and 4 sinks (3 in the toilets and one in the kitchen) located. Every toilet and every sink requires a connection to the sewage system. The total piping length on the ground floor is 38,2 m (3,5 m for  $\varnothing$  50 mm and 34,7 m for  $\varnothing$  100 mm). On the first floor there are 3 toilets and 3 sinks located. The total piping length on the first floor is 13,1 m (3,7 m for  $\varnothing$  50 mm and 9,4 m for  $\varnothing$  100 mm). The height of the main vent stack going through the whole structure is 5,8 m.

*As a result an approximate 57 m of piping was used. This number is with traps excluded. An example of a trap under a sink is shown in Figure 61.*

The material that will be used for the realisation of the piping is PVC. PVC has a smooth interior for a good carrying capacity of waste matter. The smooth exterior also helps resist root anchorage.

To finish, a control point will be added at the surface above the connection point between the waste line and the sanitary sewer.

A detailed price calculation can be found in the Appendix D.

## 9 Interior Design

### 9.1 Regulations and Legislations on interior dimensions

Regarding regulations about crucial areas in spanish offices the following numbers are given by the supervisor Félix Ruiz Gorrindo.

- 5 m<sup>2</sup> of specific working space for one worker
- 10 m<sup>2</sup> per user of total space and
- 2 m<sup>2</sup> for each user in common spaces.

With an estimated calculation based on the dutch rules for common working spaces NEN 1824 the numbers were verified and adapted.

Based on the regulations of the previous norm, the calculation is showing the following results for a required working space for 15 workers.

#### **NEN 1824 [41]**

*15 workers: 15 x 5 m<sup>2</sup> → 75m<sup>2</sup>*

*15 flatscreens: 15 x 1 m<sup>2</sup> → 15m<sup>2</sup>*

*15 writing desks: 15 x 1 m<sup>2</sup> → 15m<sup>2</sup>*

*15 shelves: 15 x 1 m<sup>2</sup> → 15m<sup>2</sup>*

*1 meeting room for 6 persons: 6 x 2 m<sup>2</sup> → 12m<sup>2</sup>*

*→ 147m<sup>2</sup> for 15 workers*

*→ total required space of 9,8 m<sup>2</sup> for each worker*

The previous norm only applies for the minimum required office space, but as the building does not only contains office space more capacity is necessary. For the other sections of the building no specific laws and regulations were identified. Consequently the results are scaled and a certain security factor was added. Especially the area of the exhibition hall does not fall under any regulation but will add a considerable amount of space.

Nevertheless another regulation that has to be considered is the minimum indoor height in business buildings. The minimum ceiling or room height for any habitable room in Spain is 2.5m. [42] Even though there is no room or area in the sea container building that could be considered as habitable space, it is believed that this requirement still need to be taken seriously in this project as the minimum room height to avoid any conflict with the Spain Building Regulation in the future.

## 9.2 Floor Plans

In the design phase of the sea container building, it is believed that there are three main plans that need to be created first before going further. These plans are:

- Floor plan,
- Electrical plan and
- Water layout of the building. [43]

Please note that the final design of the sea container may slightly differ to these plans in term of the presence, dimensions, and positions of building features like doors, windows and stairs as these plans are made first to speed up the project progress.

As stated by Thesaurus dictionary, a floor plan is a scale drawing of a horizontal section through a building at a given level [44]. These floor plans are meant to show information about the location and type of construction, location and size of doors, windows, stairs, rooms, and both exterior and interior features for both floors [45].

To create the floor plans and electrical plans of the sea container building Siemens NX11 (CAD software) is used. It is decided that only 20ft high cube container are going to be used. Thus, the container with its exterior and the interior walls is drawn first before multiplying it and orientating them according to the final exterior design. The dimensions used to draw the container are already mentioned in Chapter Dimensions of a 20ft HC Container. It should be noted that the sea container dimensions can vary depending on the manufacturer. [46] For this reason it is highly advisable to buy all of the containers for this project from one manufacturer.

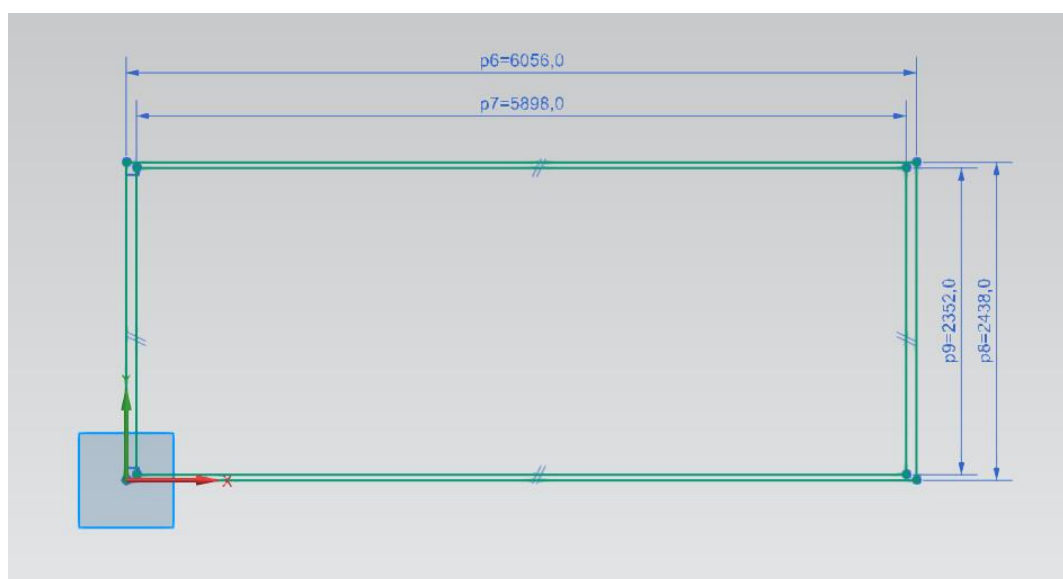


Figure 66: Drawing of a container in NX11

From there, the arrangement of the rooms, areas and facilities are made. Then, the walls of the containers in the drawing are removed and other necessary additional walls are added accordingly as well with their estimated thickness (see Appendix E) followed by doors, windows, stairs and balconies.

In a floor plan, it is not required to show the placement of insulations. However, for this project it is made for the purpose of easing the cost estimation for the thermal and the sound insulations that are planned to be installed. In addition to that, the placement of sound insulation in the floor plans for this project is decided according to the amount of possible noises produced in an area or the adjacent area so that the noises could be contained in one area only. This is important in order to create more productive working environment. It is also worth mentioning that if budget allows, it is also advisable to install the sound insulation on the rest of the not insulated walls as show in the floor plans (see Appendix E).

In making the building more accessible, the dimensions of door openings, door distance from nearest wall, doorway without door, elevator waiting area, and toilets are adjusted in the software to meet several accessibility requirements. These requirements are mostly taken from The Building Regulation 2010 for England 2015 edition [47] [48] and also from the Spanish Regulations called *Accesibilidad En Los Espacios Públicos Urbanizados* [49]. In addition to that most of the requirements are for the disabled people especially wheelchair user.

Even though the first source of the regulation is for the use in England, it seems that the requirements taken are still acceptable to be applied in this project. This is because of the amount of traffic of disabled people per year for the current Neàpolis building itself is believed to be relatively low. If all of the spaces in the sea container building meet these accessibility requirements for the disabled people, logically, there should not be any problem for normal people to access all the rooms & facilities inside the building. All of the applied requirements together with the measurements taken from the floor plans as a comparison are provided in Appendix G.

### 9.3 Electricity Plans

If in the floor plan it is necessary to show the location of windows, doors, and any other features in a building, in the electrical plan it should be included the location of the outlets, switches and which switch is connected to which lights. However, it should be noted that what is not included in this electrical plan is which circuit breaker in the electrical service panel controls which circuit in the building.

For this project, an electrical plan is created for both floors (see Appendix H). They are based on the floor plans made before to make the process easier. All of the electrical symbols like recessed light

and duplex outlets in the plans are drawn manually in NX11. There are several reasons why recessed lighting is chosen to be installed in the sea container building which are [50]:

1. It could make a room inside the sea container building feel bigger because it doesn't interrupt the visual space of the ceiling.
2. It is a safer option than hanging lights due to quite low ceiling height inside the container and it appears to be light so it probably not adds up much weight to the ceiling of the containers.

For the spacing of the recessed lighting in each area or room, a simple formula shown below is used [51]:

Distance between the lights  $\times$  2 (Distance between the end light to the edge of ceiling)

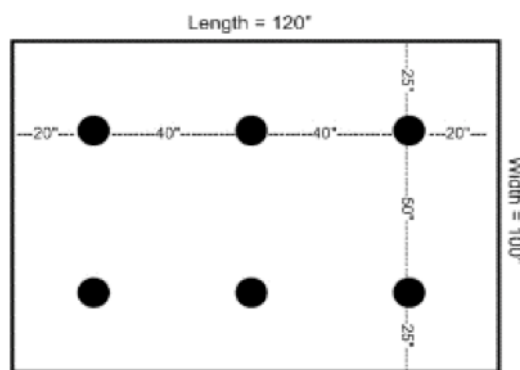


Figure 67: Example of recessed lighting spacing in a room

Each room and area has their own recommended lighting levels in order to create the right mood and adequate lighting as well for different activities. Poor lighting in working environment could lead to eye-strain, fatigue, headaches, stress, accident and all of these would reduce the productivity of the workers [52]. Hence, a simple calculation is made for each space to determine the right number of lumen<sup>4</sup> required for each light according to the number of the installed lights in that space in the electrical plans (see Appendix H). The results from this calculation will be used to find the right recessed lights or mount lights in the market for the cost analysis.

By considering how many electrical devices will be inside the area or room, the power outlets are added in the electrical plan accordingly. There is no specific calculation of it. However, for the height of the power outlets and the switches, The Building Regulation for England is used as a guide once again and it appears to be that these recommended heights are coherent with the Spanish Regulation. Thus, all switches are set at 1200mm to the top of the switch box while all outlets are set at 450mm to the bottom of the outlet box [48].

<sup>4</sup> Lumen: the SI unit of luminous flux, equal to the amount of light emitted per second in a unit solid angle of one steradian from a uniform source of one candela. Usually it is labelled on the packaging of a light bulb [112].



## 9.4 Water supply

A water supply system routes municipal water from the street to the construction itself. In the construction it branches out to deliver water to faucets, toilets and more indoor units. There are two types of supplying networks: hot water supply and cold water supply. The equipment for this delivery is a system of water pipes, fittings and faucets. The water supply type showed in Figure 68 will also be used in the project and is called a pressurised hot water system. The service line (1) connects the municipal water line to the electrical heating tank (4). The tank warms up water and pumps it to the different points of usage. When comparing a water supply system to a sewage system, no gravity is used. Water is pumped up by pressure, sewer flows down by gravity.

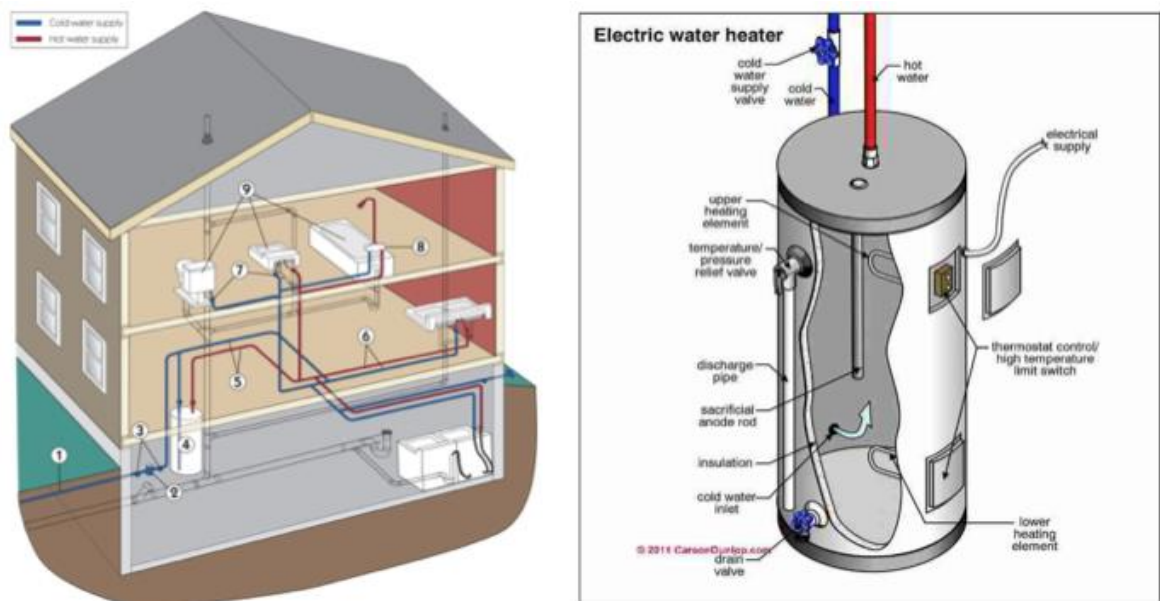


Figure 68: Pressurised hot water system (left) and detailed electric water heater (right) [53]

In the project, all parties agreed on an electrical heating system. An electrical water heating tank is easy to install and safer when comparing it to a complete gas heating system. Electrical water heating is the most common way of water heating in container constructions. Electric water heaters are connected to the main water supply. The main goal is to heat up water for domestic use. The tank contains two heating elements. The desired temperature can be controlled manually; modern water heating tanks also have Wi-Fi-connection. The material of the tank itself is metal and it is insulated to prevent heating losses. The tank gets its performance from electrical supply. [54]

### 9.4.1 Water supply implementation in the building

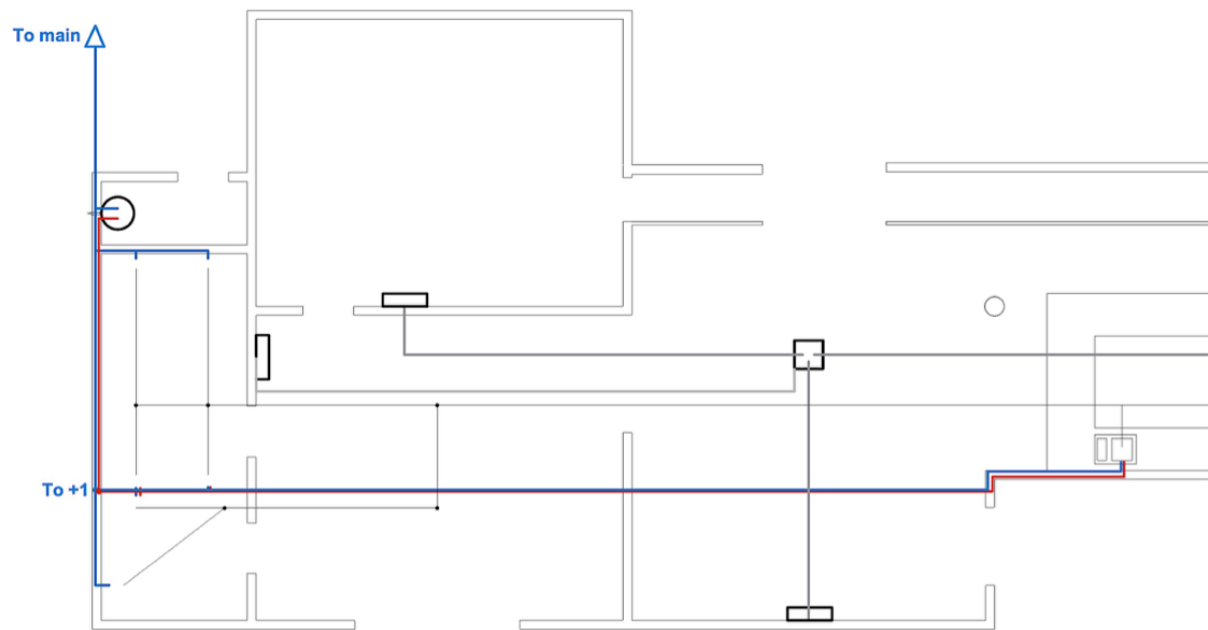


Figure 69: Water supply system plan of the ground floor (+0)

A section cut of the left wing of the construction (+0) was made to show the warm and cold water supply. Red lines represent the hot water supply, blue lines the cold water supply and grey lines the cabling of the A/C system. The A/C system will be analysed in 9.5 HVAC. Due to a lack of internal space, a small room will be built next to the container construction on floor +0. In this room the electrical water heating tank will be placed. Here the drain valve will be connected to a wall to drain the water outside the tank if needed. The heating tank is connected to the main water supply line. The company gave no information concerning this topic (location of the main water supply line) so an additional open post was kept in the costing calculation.

At floor +0 there are 3 toilets and 3 sinks located. Every toilet requires cold water supply and a sewer connection. Sinks require both hot and cold water supply and as well a connection to the sewage system. The piping of the water supply goes through the floor and the walls of the construction. In the walls the piping will be placed in the PU insulation. The coloured circles in blue and red represent the rising of the pipes to the first floor. (marked on the plan with 'To +1' in Figure 69).

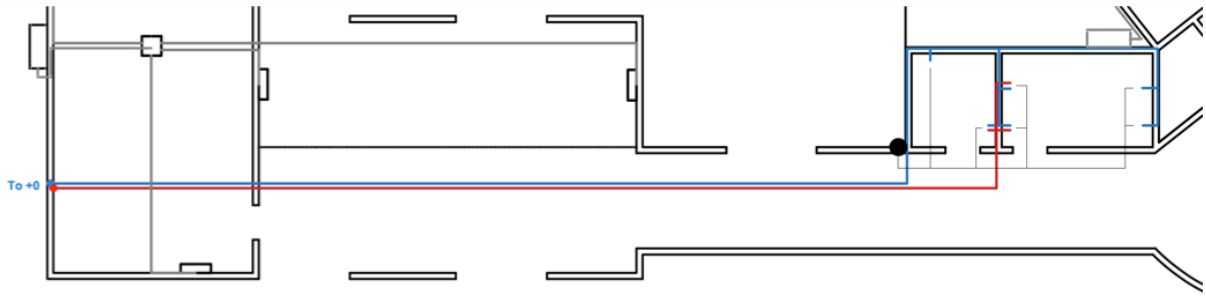


Figure 70: Water supply system plan of the first floor (+1)

Another section cut was made to show the water supply system on the first floor (+1). Left in Figure 70 is marked (in coloured circles) where the supply lines form its way up from floor +0 to floor +1. At floor +1, 3 toilets and 3 sinks are located. Every toilet requires cold water supply, the sinks require both warm and cold water supply. The built up of the sewage for the toilets is the same as the ground floor. Consequently, the same water supply is needed in this case.

At floor +0: 43 m of piping is used for both water supply types (hot water and cold water).

To cover the height difference between +0 and +1: 6 m of piping is necessary for both water supply types.

At floor +1: 55,9 m of piping is used for both water supply types.

An extra addition will be needed to cover the connection to the main water supply line.

A detailed costing calculation can be found in the Appendix D.

#### 9.4.2 Specifications



Figure 71: RHEEM hybrid electric water heating tank and HETCU copper piping to realise the connections [55]

#### Professional prestige RHEEM hybrid electric water heating tank

- Indoor 14 service points: 300 litre model is sufficient
- Hybrid heating pump inside to pump up the water

- Wi-Fi-connectivity for important mobile alerts
- Leak detection
- Almost 0 noise production

#### Heating tank in combination with HETCU copper piping

- Insulated copper tube
- Copper reduces germs and is antibacterial
- The extra outside insulation to prevent heating losses
- Same diameters for hot and cold water supply

For detailed product sheets see Digital Appendix.

## 9.5 HVAC

### 9.5.1 *Indoor climate*

Indoor climate is an important aspect regarding offices, especially when the outdoor climate is a relatively warm climate. Regarding this topic two words are essential: ventilation and cooling. Good ventilation is required to provide a high Indoor Air Quality (IDA). In working environments, a high amount of people work and produce damp in the same area. Two options are available concerning ventilation: mechanical ventilation or natural ventilation.

Mechanical ventilation is a type of ventilation system defined when an outdoor unit is connected to indoor units with the main goal of keeping the indoor air fresh (not to cool!). But this is often an expensive addition to the costing price. The second option is ventilation through natural systems. Natural means no machines or devices. In other words: using a lot of windows in the construction which can be opened to keep the indoor air fresh. In the project itself the natural ventilation system was implemented. In the design a high amount of windows were used. Almost all the windows have the ability to open. Most of the windows are not located directly to the sun to prevent the rooms from heating up.

The previously mentioned ventilation is only ventilation of the air. The second aspect is keeping the indoor air temperature at a certain desired level to provide a comfortable indoor working environment. Using indoor units can do this. Those units implemented in several rooms of the project have two modes: heating mode or cooling mode. Heating mode when a higher indoor air temperature is desired by the user. The cooling mode can be used in the warmer months of the season. The user will be able to control all the units manually and a specific temperature can be controlled in the different rooms. [56]

### 9.5.2 The function of an A/C – heating unit

An air conditioning system follows the same cooling cycle as a normal refrigerating system. The system is built up with two units: an indoor unit (in the room where heating/cooling is required) and an outdoor unit (outside). Both units are connected. In the connection pipes between the indoor unit and the outdoor unit flows R4-1A. A liquid which is able to absorb or generate heat easily

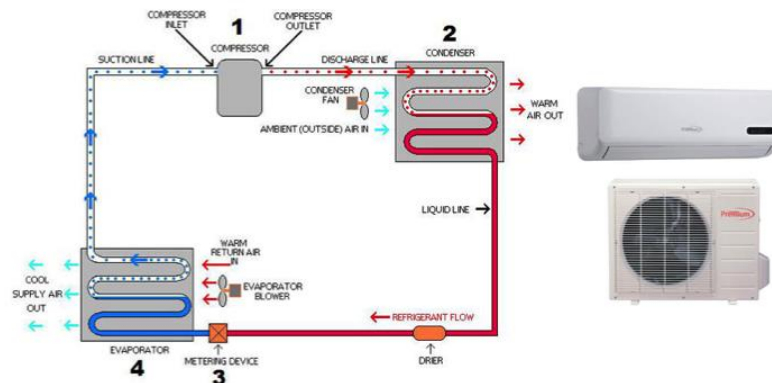


Figure 72: AC - cooling cycle [57]

In Figure 72 a cycle is shown in cooling mode. Warm return air from the room is blown into the indoor unit (4) and comes out as cool supply air. This is made possible because the liquid in the system absorbs the heat of the return air. In this stage the liquid will damp and becomes a gas. Afterwards the gas will condense, gives away his heat to the outside air (2), and becomes liquid again. The heat exchange with the outdoor air is provided by an outdoor unit, shown in Figure 72.

This cycle is called an A/C (air-conditioning) cycle. If the cycle is turned the other way around, the indoor unit is able to heat the air inside. An indoor unit has the capacity of either heating or cooling. [57]

### 9.5.3 The multi split unit

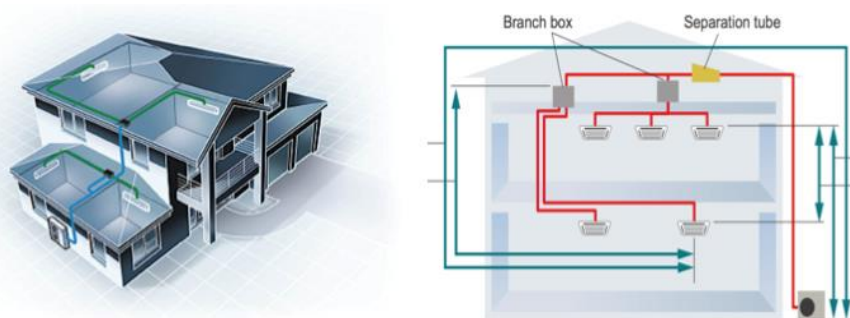


Figure 73: Multi-split unit with branch boxes to set the cabling path [58]

When one outdoor unit is connected to more than one indoor unit, we speak of a multi-split. The outdoor unit is connected to the indoor units through 'branch boxes'. One outdoor unit can contain up to 8 indoor units. A multi split unit is a common system to use in hospitals or offices. This type of system will cool of and heat the indoor air in the Neapolis project. The users can moderate the

indoor temperature by their needs. In every room, the indoor temperature can be controlled separately.

An outdoor unit makes a certain amount of noise. The advantage of a multi-split unit is the reduction of outdoor units. [59]

#### 9.5.4 HVAC implementation in the building

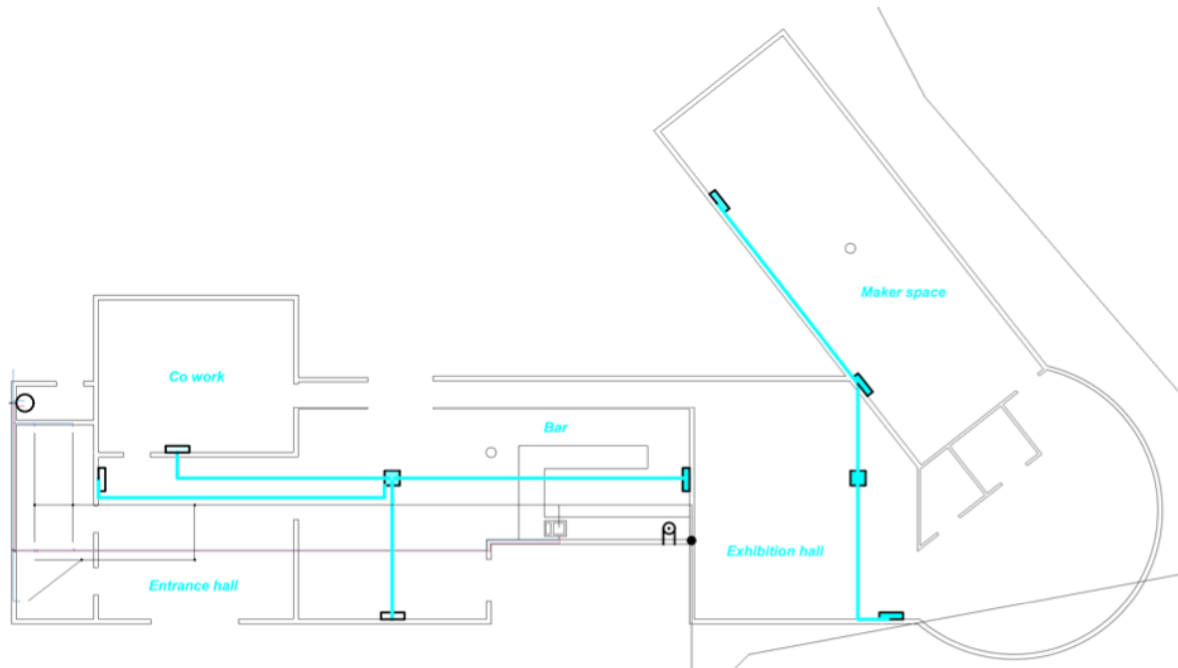


Figure 74: The multi-split unit at floor +0

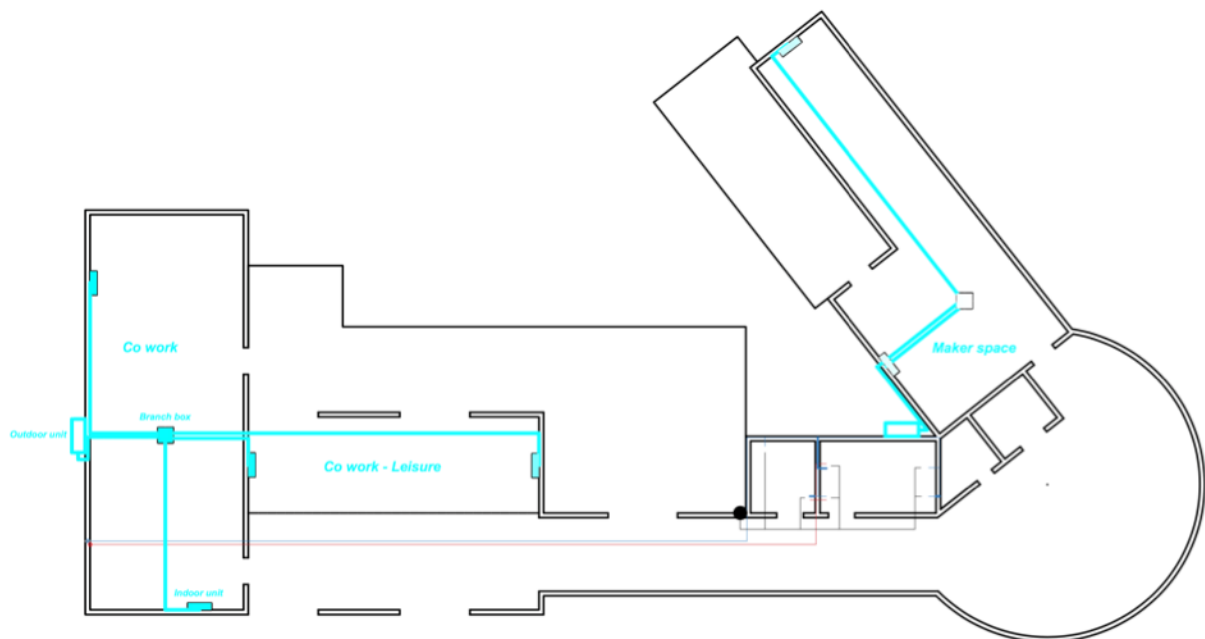


Figure 75: The multi-split unit at floor +1

With office spaces of this particular size, the most efficient approach is splitting the building up in a left wing and a right wing. This split up is shown in Figure 74 and Figure 75. One outdoor unit that

controls the left wing of the construction and one outdoor that controls the right wing of the construction. As a result, the cabling distance is diminished and energy will be saved because less transport losses are made.

In the left wing of the building, the outdoor unit is connected to two branch boxes. One branch box is situated on floor +0 in the bar (installed in the lowered ceiling - Figure 74). This branch box connects 4 indoor units in the cowork office, cowork entrance hall and in the bar. The areas mentioned require the most cooling. This is the reason why the units were implemented in these rooms. The second branch box is located on floor +1 in the cowork (installed in the lowered ceiling - Figure 75). This branch box also connects 4 indoor units in the cowork space and leisure area. As a result, the left wing of the building will be cooled off/heated by a 8x1 multi-split unit (8 indoor units connected to 1 outdoor unit).

In the right wing of the building, the outdoor unit is as well wired with two branch boxes. One branch box is located in +0 in the exhibition hall (lowered ceiling - Figure 74). This branch box is connected to indoor units in the maker space (2 units) and in the exhibition hall (1 unit). The maker space requires a high amount of cooling due to all the action that takes place while working with machinery. The maker space users are frequently moving and producing heat. In combination with the warmth the machinery produces this can lead to a higher indoor temperature. The other branch box is located at +1 in the fab lab, in the false ceiling (Figure 75). The last branch box is wired with two indoor units in the same place. The corridor on floor +1 does not require any indoor units. The sliding door here will provide an air flow to temper the indoor temperature. A well thought cohesion between ventilation and air cooling is made.

## 9.6 Insulation and Wall Finishing

One of the main reasons why insulation is important for the sea container building is to control the interior temperature inside the container. The building could either be scorching hot in the summer or freezing cold in the winter even though in the mild temperature of Vilanova. By insulating also, one can protect it from condensation and damp. This could prevent the container from rusting. Metal corrosion could lower the lifespan of a sea container and if a repair is needed, it could take a lot of time and is very expensive. These reasons seem to be enough to clearly show the importance of insulation for the sea container building.

As metal is believed to be a good sound reflector, a proper insulation could minimise the sound echo inside the container since it possibly could absorb some of the bouncing sound waves that cause the echo [60]. It also could contain sound from passing through the wall either the sound is coming from the outside or the inside of the container if the material is a good sound insulator as well. In addition to that, insulation should be given high consideration since one of the project's objectives is to build

a comfortable working space. Having a perfect room temperature, an ideal interior relative humidity and an excellent sound proofing space would serve perfectly for that purpose.

There are two methods to insulate a sea container building which are from the outside and inside of the building. The table below shows the pros and cons of both internal and external wall insulations.

External Wall Insulation	Internal Wall Insulation
<p>Pros</p> <ul style="list-style-type: none"> <li>• Could maximise the usage of internal space of the container for other purposes such as electrical installation and the placement of the furniture</li> <li>• Increase the energy efficiency of a building as least power is needed for heating or cooling the building</li> <li>• Could improve the external appearance by covering any imperfection presence on the container surface</li> <li>• Could minimize the amount of noise from the outside if the insulation is a good sound insulator as well</li> <li>• Could help warmth the interior by releasing back the stored heat into the building</li> <li>• Can be painted with any colour</li> </ul>	<p>Pros</p> <ul style="list-style-type: none"> <li>• Easier to install compare to the external wall insulation</li> <li>• Increase the energy efficiency of a building as least power is needed for heating and cooling the building</li> <li>• Doesn't need any permission to install</li> </ul>
<p>Cons</p> <ul style="list-style-type: none"> <li>• Probably an extended roof is needed to prevent moisture from entering the space between the wall and the insulator. This may add cost to the project</li> <li>• Possibility to require planning permission if the insulation is not in local building code.</li> </ul>	<p>Cons</p> <ul style="list-style-type: none"> <li>• Would lose the limited space inside the container. Normally it could take space up to 6cm on the roof and sides of a sea container.</li> <li>• Could have penetrating damp issue due to improper installation</li> </ul>

**Table 2: Pros and Cons of Both Internal and External Wall Insulations [61]**

The term U-value is used to measure the effectiveness of a material as an insulator in buildings. It is also known as thermal transmittance. Generally, the lower the U-value, the greater the insulating effectiveness [62]. To determine the most efficient and economical insulation to use in this project, a research on the materials of insulation for both internal and external wall has been done (see Appendix J).



The table below shows the translated and simplified version of the minimum requirements of U-values in Barcelona according to Código Técnico de la Edificación (CTE) (see Appendix K). It could be assumed that as long as the potential insulations have equal U-values or lower than the values stated in the table, the building insulations have met the requirements.

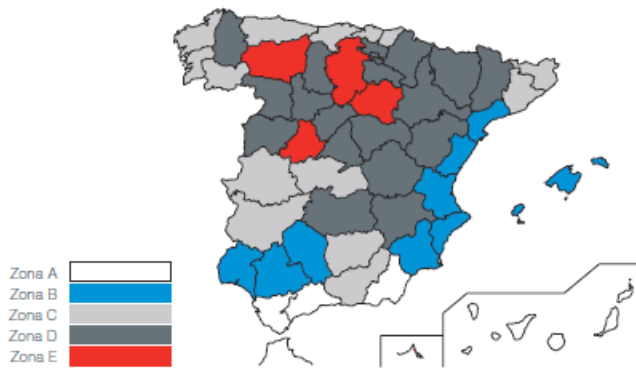


Figure 76: Barcelona is in Zone C

	Zone C (Barcelona)
Walls	$0.73 \text{ W/m}^2\text{K}$
Floors	$0.5 \text{ W/m}^2\text{K}$
Roofs	$0.41 \text{ W/m}^2\text{K}$

Table 3: Required U-Values in Barcelona

As the result from the research, at first, using cork for exterior wall insulation seems could provide more benefits than the other type of insulation especially to the environment but it is feared that it may cause an unwanted problem if it is used. Due to the wavy surface of the sea container and board's flat hard surface, there will be air gaps left in between the expanded corkboard and the surface of the container. There is a doubt that these air gaps might cause condensation in the future and this is something that should be prevented.

Besides, concerning the price, cork's price for insulation use in Barcelona is not as cheap as expected, even spray polyurethane foam (SPF) seemed to be cheaper than the cork insulation. According to the Cork Shop BCN website [63], the price for cork insulation board is believed to be about  $19.2 \text{ €/m}^2$  for 50mm of thickness. Meanwhile for the same amount of thickness, the SPF's price appears to be just around  $6.75 \text{ €/m}^2$  [64] and not to mention it gives superior U-value than the cork insulation. That's not including yet the additional cost that is needed to build the extended roof if cork insulation is used as it is possibly required to cover the top part of the cork insulation to prevent water from entering the gaps between the cork and the wall in case of rain.

Indeed, the cork insulation is more environmental friendly compare to the SPF. However, as this project's budget also should be given high priority, plus as a precaution to the air gaps problem mentioned before, it is decided that closed cell spray polyurethane foam (ccSPF) insulation is going to be used in this project as the internal wall insulation.

The reasons why the closed cell spray polyurethane foam (ccSPF) is chosen, apart from leaving no gap between the insulation and the container wall that could minimize the risk of condensation, are because it could provide superior U-values with minimal thickness of insulation compare to other materials and seamless vapour barrier that could prevent corrosion and formation of mould on the surface of the container. It could increase the structural strength of the sea container building itself as well. Furthermore, it doesn't attract pest which is important as green roof is going to be used in this project. As it is also a good air barrier, it could improve indoor air quality by preventing the penetration of dust, pollen or other allergens and reduce the noise transfer from the outside. Last but not least, it is claimed that it could absorb the sound or in other words could help in reducing the echo problem and appears to be the best insulation considering the usage of sea container in this project [65].

Some calculations are made to estimate the minimum thickness of ccSPF needed to achieve the required U-values in Barcelona according to the table and the calculations are shown below. The thermal conductivity of SPF used in this calculation is when the SPF already stabilized to guarantee better performance of the SPF insulation in the future:

$$Uvalue = 1/R \qquad R = e/\lambda \text{ [64]} \qquad e = \lambda/Uvalue$$

$$\lambda = \text{Thermal conductivity of ccSPF, } W/mK = 0.028 W/mK \text{ (stabilized) [64]}$$

$$U \text{ value required} = 0.73 W/m^2K, \text{ and } 0.50 W/m^2K, 0.41 W/m^2K$$

$$R = \text{Thermal resistivity, } m^2K/W$$

$$e = \text{Minimum thickness of ccSPF needed, m}$$

For $0.73 W/m^2K$ (Walls)	For $0.50 W/m^2K$ (Floors)	For $0.41 W/m^2K$ (Roofs)
$e = \frac{0.028}{0.73} = 0.0383m =$ $38.3mm$	$e = \frac{0.028}{0.50} = 0.0560m =$ $56.0mm$	$e = \frac{0.028}{0.41} = 0.0683m =$ $68.3mm$

To conclude, the minimum thickness of ccSPF needed to achieve the required U values of the walls, floors and roofs are **40mm**, **60mm** and **70mm** respectively. The estimated price for spray polyurethane foam will be searched by referring to these commercial thicknesses.

### Sound Insulation: Airborne sound & Impact sound

There are two types of sound insulation in buildings which are airborne sound and impact sound:

- a) **Airborne sound** is sound that is transmitted through the air. When the travelling sound waves reach a building element, they will vibrate and the vibrations will travel through the

element and are radiated out the other side [66]. People's voice, sound from television or radio, dog barking on the street and the sound coming from the traffic nearby are some of the examples of airborne sound transmissions sources [67].

The airborne sound from the exterior of the sea container building is believed could possibly been taken care of by the spray polyurethane foam (SPF) insulation as it is a good sound barrier [68]. However, for the interior, additional sound insulation material appears to be essential to be installed between the interior walls and the ceiling of the ground floor in order to create a tranquil working environment.

Thus, to serve for this purpose, cotton insulation panel seems to be a good choice as it is an excellent acoustic and even thermal insulation, biodegradable and also has ability to self-extinguishing fire [69].

- b) **Impact sound** is the sound arising from the impact of an object on a building element like wall, floor, or ceiling. This impact sound is normally coming from footsteps, jumping, and dropped objects. This type of impact causes both sides of the building element to vibrate, which generates sound waves that transmit the impact sound [66].

Impact sound should be prevented because it is believed that it could reduce someone's productivity and increase the blood or stress levels of a person [70]. There are a few ways that could be done to minimize the impact sound in the sea container building [70]:

- Installing a false / suspended ceiling system or raised floors to improve impact sound insulation.
- Installing soft carpets could be effective at reducing middle to high level frequencies, but are less effective at isolating low frequency sound.

## 9.7 Suspended ceiling

A suspended ceiling is a secondary ceiling installed under the original ceiling of a building, very popular in offices and commercial structures [71]. It is an effective way to hide cabling and pipes for a good-looking finishing. A suspended ceiling consists of a metal framework (Figure 77) and panels (Figure 78) within the frame, hence they are handy and easy to install. There are a big variety of styles and colours available, so the design can be customised to the purpose of the room and the wishes of the user.

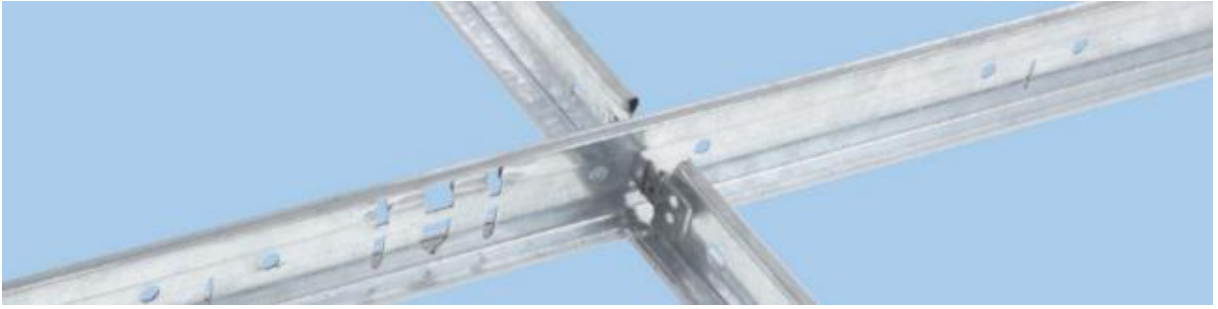


Figure 77: Suspended ceiling framework [72]



Figure 78: Suspended ceiling plates [72]

## 9.8 Flooring

Except for the access areas, vinyl flooring will be used in the resting part of the building because of the variety of styles and colours and the acoustic aspect. The average amount of sound insulation of the different kinds of vinyl is 17-19 decibel. [73]

There are many kinds of vinyl flooring, which all have their own benefits for the intended places. Below, different figures (Figure 79, Figure 80, Figure 81) will show vinyl floors with the intended place for every kind of flooring.



Figure 79: Forbo Sarlon Complete Step, used exclusively on stairs [73]



Figure 80: Allura Flex Decibel, mostly used in offices [73]



Figure 81: Sarlon Sparkling acoustic vinyl, Improves hygiene and safety in a building [73]

### Access areas

The entrance is an important part of a building. By using textile (Coral) floorings for access areas, maintenance costs will be lower; the appearance of the building will be the same throughout the day and prevents the entry of dirt and other contaminants. In other buildings, door mats are lay down to prevent dirt. However, in buildings with many people passing the door during the day a door mat outside is not enough. Research shown that 94% of the dirt in a building comes along with shoes and wheels. [73]

This dirt can damage the floor and furniture, which can lead to health complaints on a longer period. Using a quality access area can lengthen the lifecycle of the flooring and furniture, reduce the maintenance and necessity of reparation. Figure 82 shows a textile flooring at an access area of a building.



Figure 82: Textile flooring, used for access areas [73]

### Floor layers

Figure 83 shows the dimensions of the container wall dimensions. It shows the flooring has a total of 15mm thickness. This includes the three different layers; a non breathable-underlayer, floor sound isolation layer and the vinyl finishing floor. The underlayer must be placed because of the possibility that the container floor is toxic. With this layer, the toxic will not be inhaled. The floor sound isolation layer must be placed for the reduction of sound, essential for placed as the cowork office. On top the vinyl-finishing floor will be placed, which also has its acoustic benefits. The main reason for the vinyl-finishing floor is to give the building a modern and sleek look, and the comfort to keep the building easily clean.

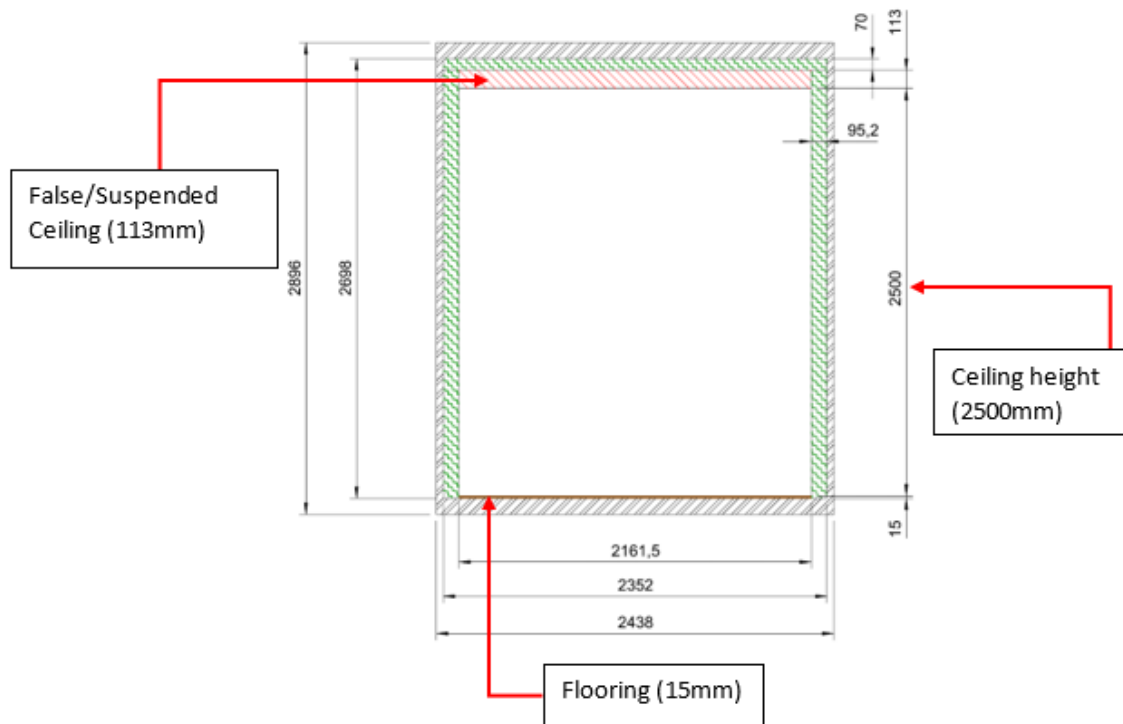


Figure 83: Dimensions flooring and ceiling

## 9.9 Interior Design of the different sections of the building

This chapter visualizes the designed building from the inside. Every figure will conclude an explanation which choices were made and why the building is designed this way. The first figures show the complete floors on both levels. After, the cowork offices, maker space, common spaces, kitchen/cafeteria and toilets are discussed.

### 9.9.1 Overview both floors

Figure 84 shows the complete ground floor interior design of the building with the different areas labelled. Later in this chapter the all the different areas will be shown in detail. The interior was influenced by the requirements, as the different uses were already determined. As visible in the image, the main entrance is located on the right side in the exhibition hall. From there it is possible to access the elevator or use the stairs to the 1. Floor. To the right of the main entrance/exhibition hall the maker space is located. To the left a hallway leads to the bar/cafeteria, the ground floor cowork and the toilets. There is a total of five doors to get into the building which are located at the main entrance, cowork entrance, cafeteria, hallway and the maker space. However, the door at the maker space is meant to be used only for supplying the maker space with machinery and stocks. The building contains two common spaces. One of them is located in the same area as the service point and the other common space is next to the cowork entrance, between the ground floor toilets and the cafeteria.



**Figure 84: Interior Design – ground floor**

Similar to the ground floor Figure 85 shows the complete 1. floor interior design of the building with the different areas labelled. There are three ways to reach the first floor; the main stairs, the elevator or the stairs in the maker space. However, the stairs in the maker space should only be used by the people working in this section preventing the workers to be disturbed. While going up with the main stairs or elevator there are two ways to go: to the maker space or through to hallway. The first floor contains likewise the ground floor a toilet (same layout), the second level of the maker space and the second cowork office. Besides this there is a meeting room and a leisure area situated in the left wing of the building. The two rooms are separated by a movable glass wall makes it easy to extend the meeting room size. Furthermore, two balconies are located on the 1. floor. The small balcony is only accessible from the maker space. The big balcony is reachable through a main sliding door in the hallway or for the workers in the second cowork through a small balcony door.





Figure 85: Interior Design – 1. floor

### 9.9.2 Cowork offices

A survey from August 2016 was given by Neàpolis hoping the team could use it to find out the user needs of the new building of the project. For this specific project the survey which had already been conducted did not cover the specific fields which were required. The survey from Neàpolis is about indicators of creativity, innovation and technology and what the workers think would bring these factors to a maximum level. The importance and benefits of cowork offices came forward with this survey, but as the project brief already indicated that the office should be a cowork office, this was already decided. This was the reason for not using the survey and making another for this project to find out the end user (coworkers) needs. Both of these surveys can be looked up in the Digital Appendix.

The new survey has been completed at different cowork offices in Vilanova I la Geltrú. The survey was available in English and Spanish so more people would be able to fill in the questionnaire. There were two problems why the survey did not go as planned. The communication was hard because the team did not have much skills in the Spanish language, while the coworkers had trouble with speaking English. Hereby the questionnaires were not fully filled in which makes them not valuable. Another problem was the availability of the coworkers. Since the people were busy with their jobs, not everyone had time to fill in the questionnaire. As a result, the response was lower than expected. Nevertheless, the results filled in by the six coworkers will be written in the following section.

## Results

The main reasons why the respondents like the cowork offices is the atmosphere in the office. They like the possibility to work with others and share their businesses. The possibility to communicate with other companies is a very important aspect for most of the respondents. However, the amount of people in a single office area should be no more than fifteen, according to the results.

The respondents also said what they like about their current cowork office and the negatives of it. Most of the respondents like the big windows at the office which makes the office having a natural light, which is a good environment to work in. Also, the respondents like the modern look/layout of the office. These are two points which should be kept in mind while designing the new building.

Things what the respondents do not like about the cowork office is the lack of privacy. The respondents prefer an area close to the office where they can speak out loud on the phone without disturbing other coworkers. Also, the lack of communal space is something what should be in mind while designing the new building. A communal space is something the respondents would like to have close to the office. The respondents like to have a big working space, with working trays or drawers to keep their properties ordered. This is something what is currently missing in their working area.

Reffering to the requirements, the total amount of coworkers is 15. To respect the requirements two cowork offices are situated in the building. One of them is located the ground (Figure 86) with space for six people. There are two doors to enter the office. The main door is located towards the entrance/lounge area. Another small door lead to the hallway. The office contains a screen projector for good meeting oppertunities. The desks in both offices are equipped with shelves to store the properties of the coworkers.

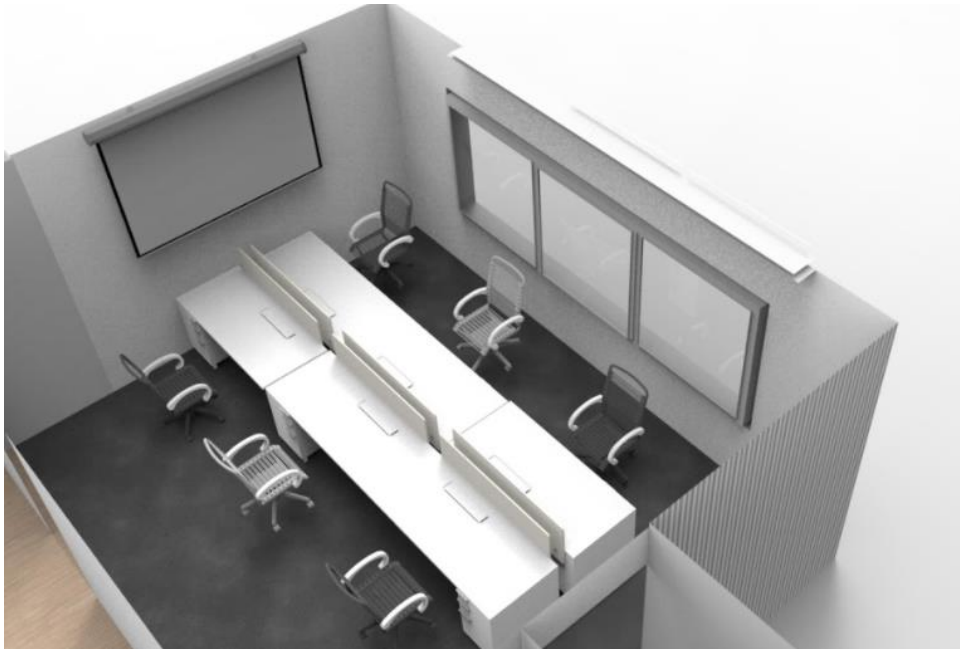


Figure 86: Cowork office ground floor

Figure 87 visualizes the big cowork office on the 1. floor, situated at the end of the building. There is twice as much space as in the cowork on the ground floor which adds 12 more workspaces. Thus, in total there are 18 cowork workplaces available in the new building which means it meets the minimum requirement of 15 people.

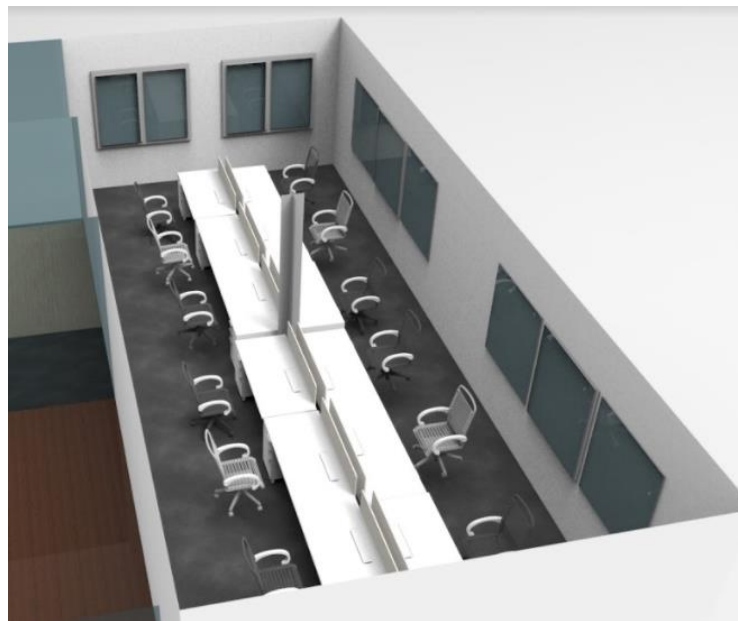


Figure 87: Cowork office 1. floor

Figure 88 details the meeting room and leisure area, which are greatly appreciated by coworkers, next to the office on the 1. floor. The middle wall between the meeting room and the leisure area is as mentioned a moveable glass wall when more space is needed for a bigger meeting.



Figure 88: Meeting room and leisure area

### 9.9.3 *Maker space*

Figure 89 shows the maker space on the ground floor. The container door has been untouched so it can be used for supplying the machinery, tools and stocks. After doing research to necessities of a maker space, a good indication was made of what the maker space should contain. The ground floor contains the biggest machinery, so this part of the building do not need extra reinforcements. The lighter equipments are located on the first floor, which is accesable using the stair inside the maker space. The ground floor maker space contains shelves, a milling machine, working tables with chairs, a small laser cutter, a big laser cutter and the stairs.

Figure 90 and Figure 91 are showing the maker space on the 1. floor. with the lighter equipment necessary for maker spaces. This floor contains a drawing table, working tables, storage shelves, three small format 3D printers and working space. The stairs are coming up in the corner, illustrated through the rectangle.



Figure 89: Maker space ground floor

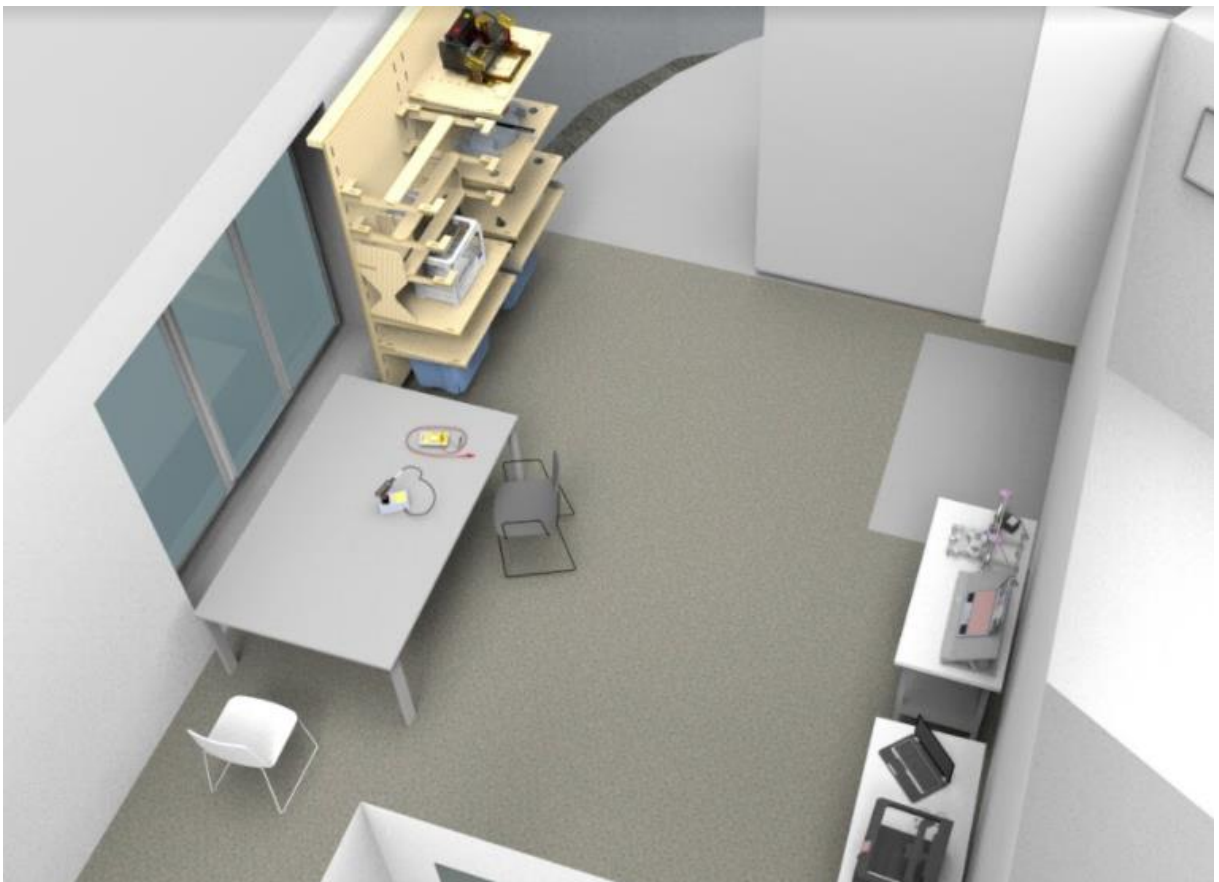


Figure 90: Maker space 1. floor (1)

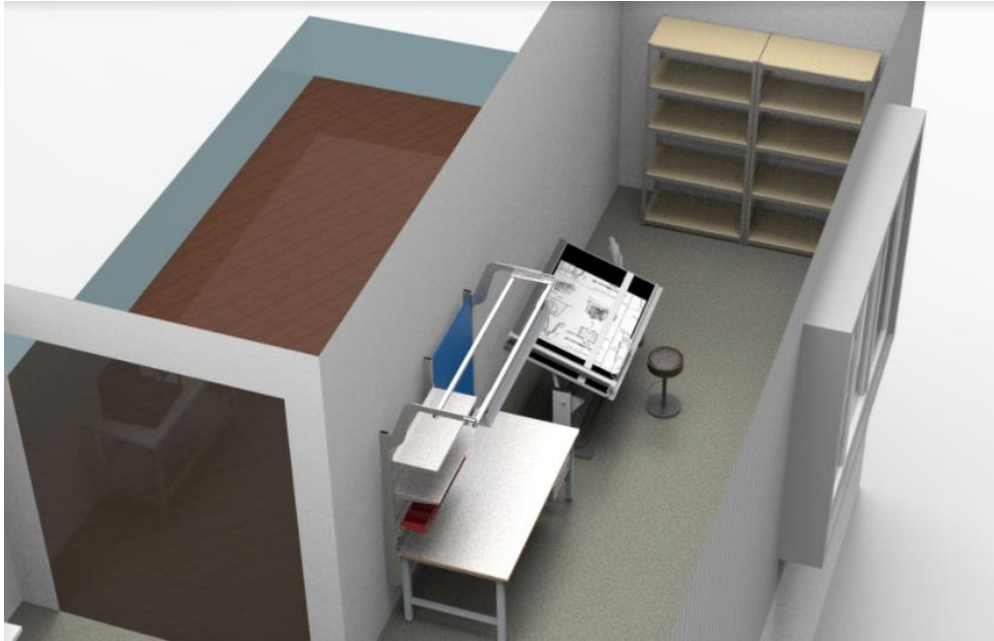


Figure 91: Maker space 1. floor (2)

#### 9.9.4 Common spaces

Close to the main entrance, the service point is located in Figure 92, which is a central area which will be passed while getting to other parts of the building. This area contains a service point to inform visitors and functions as a reception. Next to it a waiting area is located where it is possible to get drinks from the vending machine and a water cooler with a few chairs to wait.



Figure 92: Service Point in detail



Figure 93: Entrance cowork in detail

Figure 93 shows the entrance for the coworkers with a small lounge area. Workers or visitors can sit there, waiting or having a conversation without disturbing others in the cowork office. The bar/cafeteria and toilet is connected with this area

Figure 94 views the two possible options where to go from the gallery of the 1. Floor. On the right side the 1. floor entrance to the maker space is shown and on the left side the hallway which leads to the cowork office, the meeting room, balcony and the access to the toilets on this level.

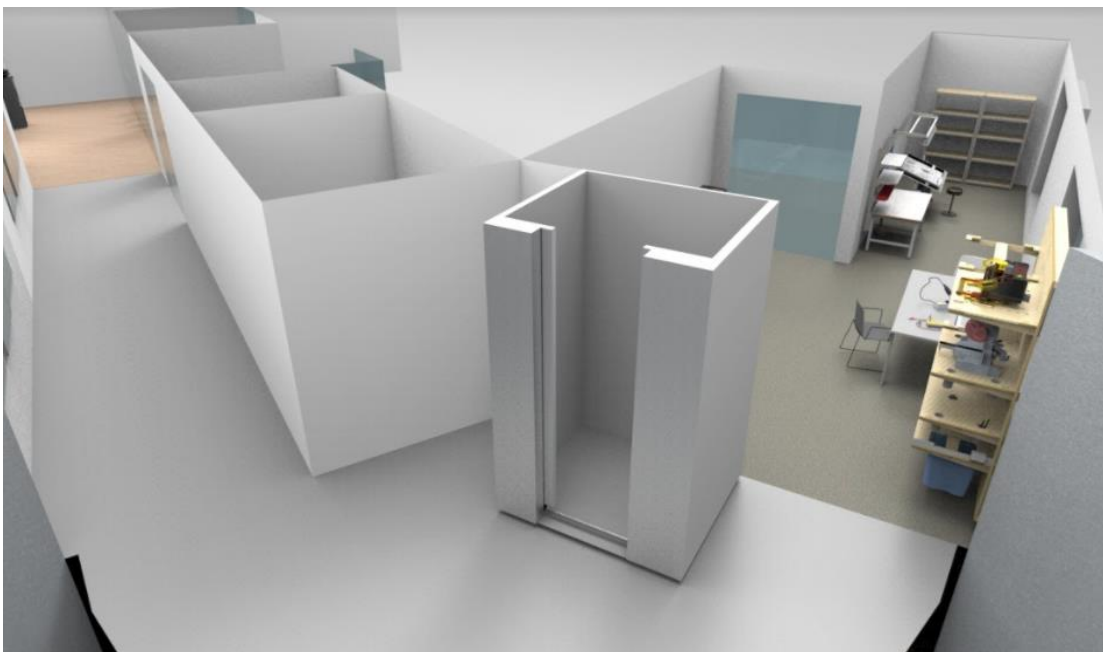


Figure 94: Gallery 1. floor

### 9.9.5 Kitchen/cafeteria

Figure 95 shows the layout of the kitchen which contains a electrical cooking pit, an oven/microwave, dish washer, sink, two low reffridgerators and storage for the cooking tools and dinning items. The kitchen is located next to the dining area and has its own glass door, as shown on the figure below.

The dining area (Figure 96) is an open place with modern wooden furniture to give it a sleek look, but keeps the looks of a bar. Inside there is place for sixteen people which fits the requiremnts comfortably. The bar/cafeteria has its own entrance door consequently people who are not active as coworkers at Neápolis can also take advantage of the food and drink services.

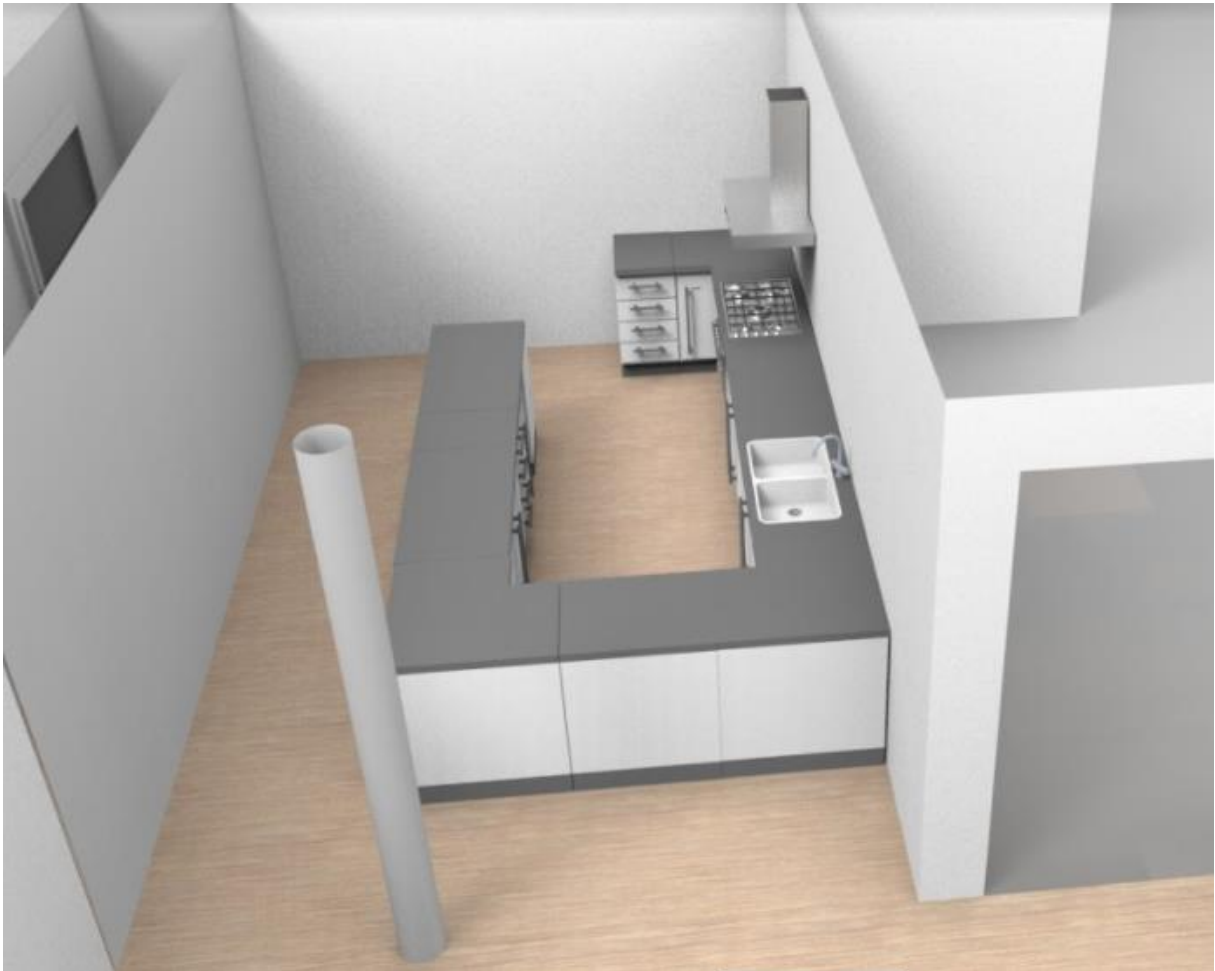


Figure 95: Kitchen





Figure 96: Bar/cafe in detail

#### 9.9.6 Toilets

The building contains two toilets services, one on each floor. The toilet on the ground floor is located next to the lounge area and is accesable for all users of the building. There is a mixed toilet for men and women and a toilet for disabled people, respecting the requirements. The toilet on the 1. floor is designed the same way and is also placed in a common area, next to the elevator and escalator.

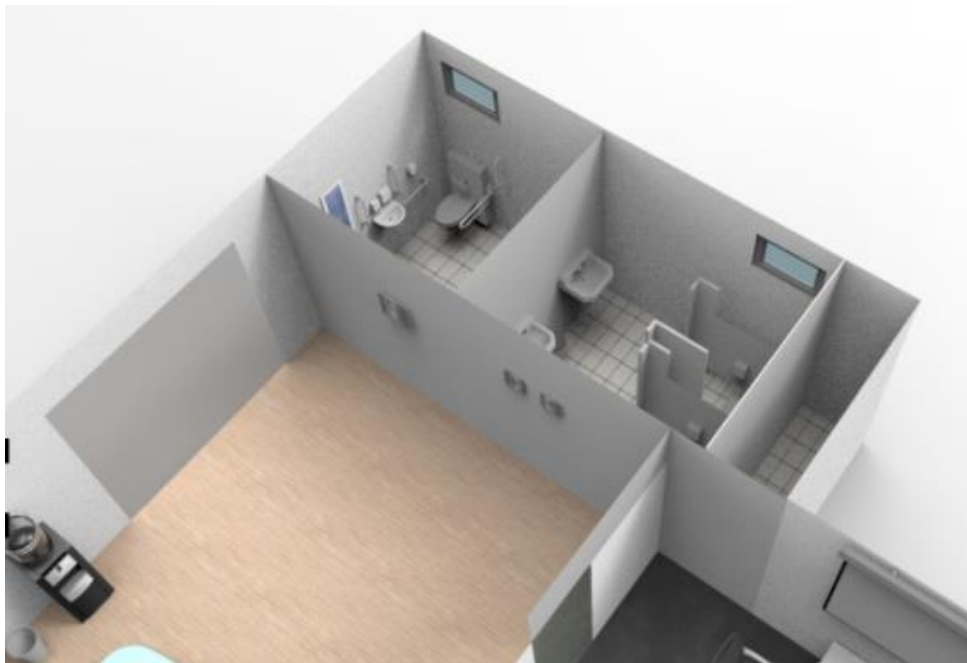


Figure 97: Toilets ground floor

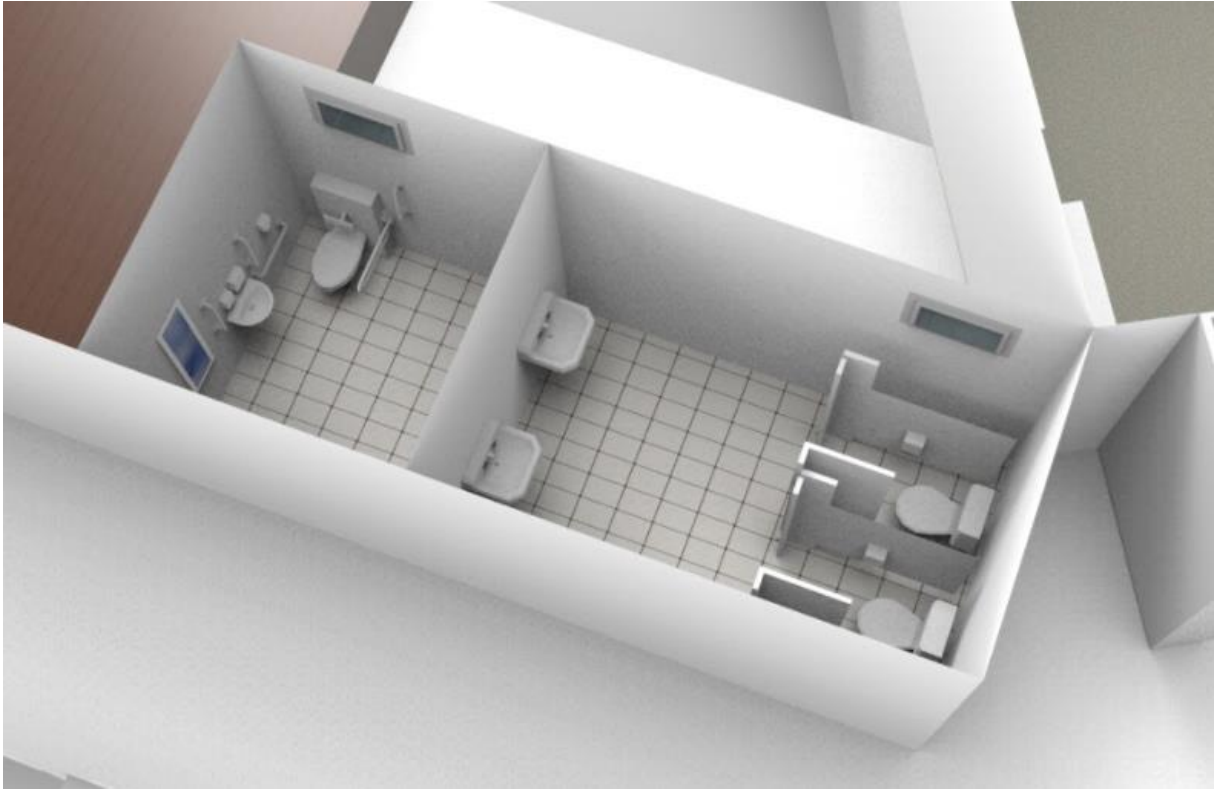


Figure 98: Toilets 1. floor

## 10 Construction Process

As described in the introduction one of the main tasks besides the design itself and the structural analysis is the planning of the construction process of the designed container building. Especially because the building consists of containers there are some special and different steps compared to the construction processes of normal concrete buildings. It is important to plan the different stages to be aware of which steps have a direct connection to one or more previous steps and which tasks can be done simultaneously. In the following chapters the construction process is described using a Gantt chart. The software to create the Gantt chart is called “Gantt Project” and is available for free on the Internet. This is essential to access the *Construction\_Process.gan* file that is included in the Digital Appendix.

### 10.1 Overview Construction Process

First of all a complete overview of the construction process is shown in Figure 99 to demonstrate the amount of different activities and to visualize the necessary time for each activity. The times are estimated by using former projects of the team members, research on the Internet about container construction and discussion with project supervisors. Arrows indicate tasks that have a direct relationship to each other.

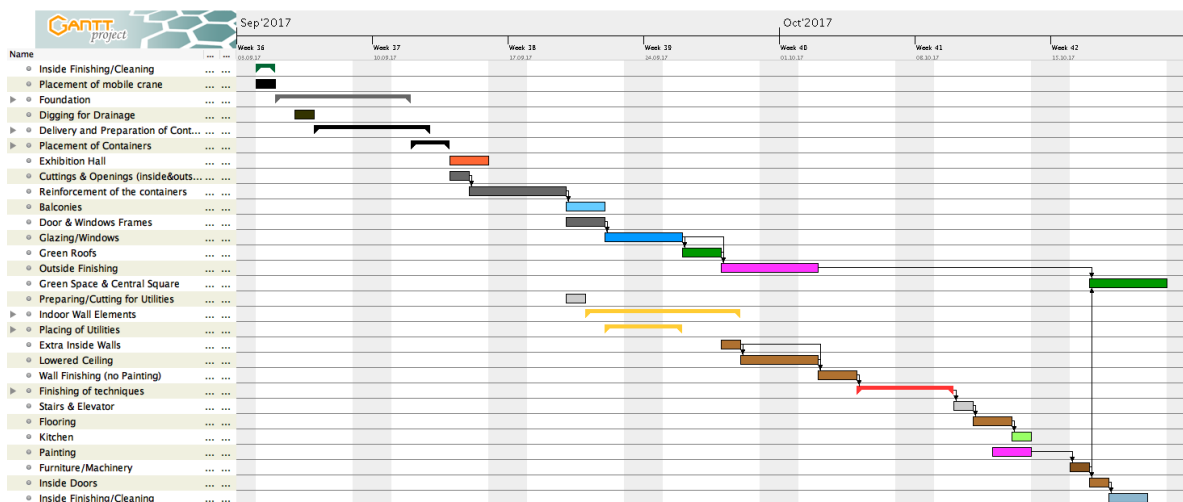


Figure 99: Timeline Construction Process

It is estimated that over all the construction period it is necessary to employ one construction manager/engineer, 8 general construction workers and for a smaller period of time electricians, plumbers and insulation specialists. The calculation of their salary and overall workdays is shown in detail in the Chapter Staff salary. For the complete process a 5-day workweek with an 8h workday is assumed. That means the duration of the building process will be approximately 7 weeks excluding

theoretical holidays. Comparing this estimated time to the construction of “classic” concrete buildings which takes about 5 months, the construction time is reduced by approximately 50%. [74]

### 10.2 Site preparation and Foundation

Before the actual construction can start, site preparation work has to be done. As it is shown in following Figure 100 the site preparation is the first task. This task should be done within one day.

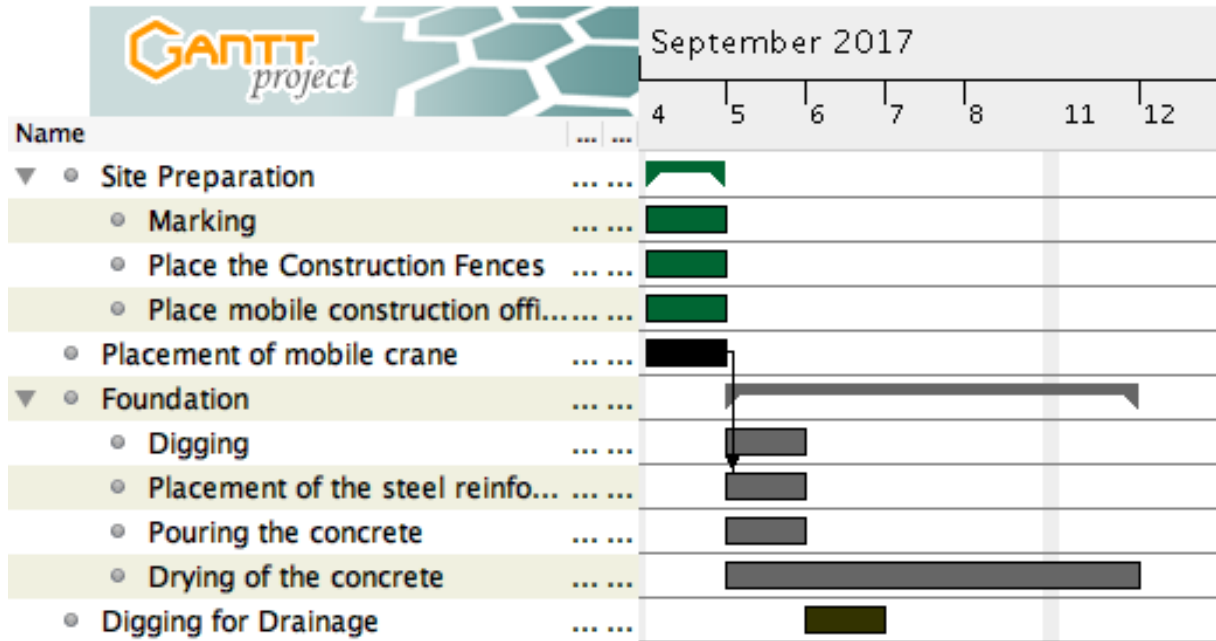
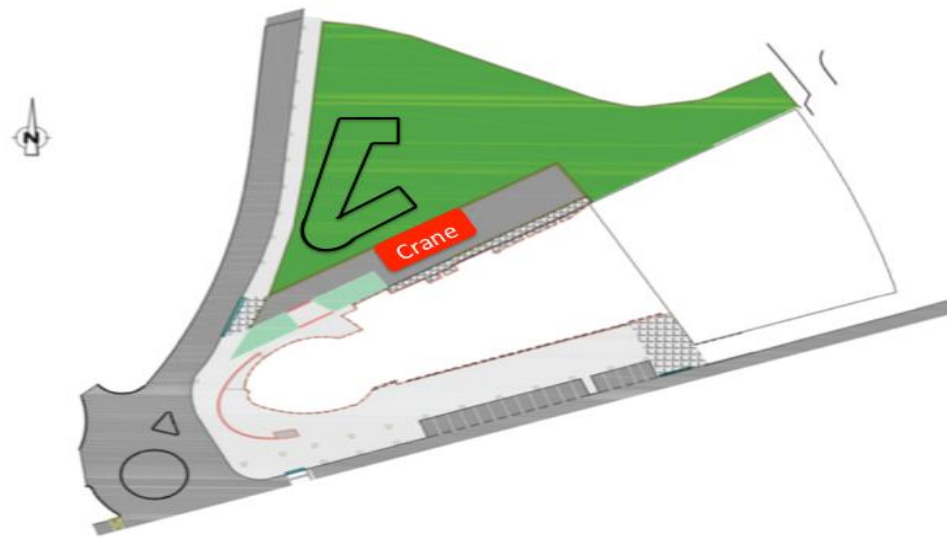


Figure 100: Timeline Detail Site Preparation and Foundation

To ensure the safety of inhabitants of Vilanova i la Geltrú it is necessary to set up construction fences around the area where the building will be placed on the plot. Fencing the entire plot would not be practical therefore it is recommend to only fence around the actual building site, storage and preparation area of the containers. This will require approximately 190m of fencing.

At the same time the accurate construction area can be marked for the following digging and foundation process as well as the placement of the mobile office for the construction manager and containers used as storage and break rooms for the workers. Meanwhile the mobile crane can be located which is necessary for some parts of the foundation and the stacking of the containers. The location of the crane placement is illustrated in Figure 101.



**Figure 101: Placement of mobile crane**

It is important to choose a crane that is capable of carrying at least 4-5 tonnes over a radius of 40m, so the crane can stay at the shown position all the required time. In the Digital Appendix the PDF document (*Crane\_Technical\_Sheet.pdf*) suggests a suitable mobile crane for this project.

The Foundation itself consists out of two different types as already explained in Chapter Foundation and Sewage. After the digging, the pouring of the concrete for the slab foundation and the wells can start. The largest amount of time spent in this section is the drying of the concrete. In general it takes about 5-7 days till the concrete with the steel reinforcements is dry so the containers can be placed on top. During the drying the digging for drainage and sewage can occur. After all these mentioned tasks the site preparation is finished.

### **10.3 Transportation, Storage and Preparation of the Containers**

For transporting the containers to their final destination several methods are available. The most common way to transport containers is by ship or railroad and later by truck. But the best way to transport the containers in this case is via truck and placing with the pre-located mobile crane. This is the best option due to the space available on site and it is also the easiest way to transport because there is no need to reload and transfer the containers from one transportation method to the other. Purchasing the containers in the near surrounding is possible either from Barcelona or Tarragona, both cities are located within a 50km radius of Vilanova i la Geltrú.

The delivery of the containers should occur in two stages and from the back of the plot (as illustrated in Figure 102) so the mobile crane does not have to be relocated.

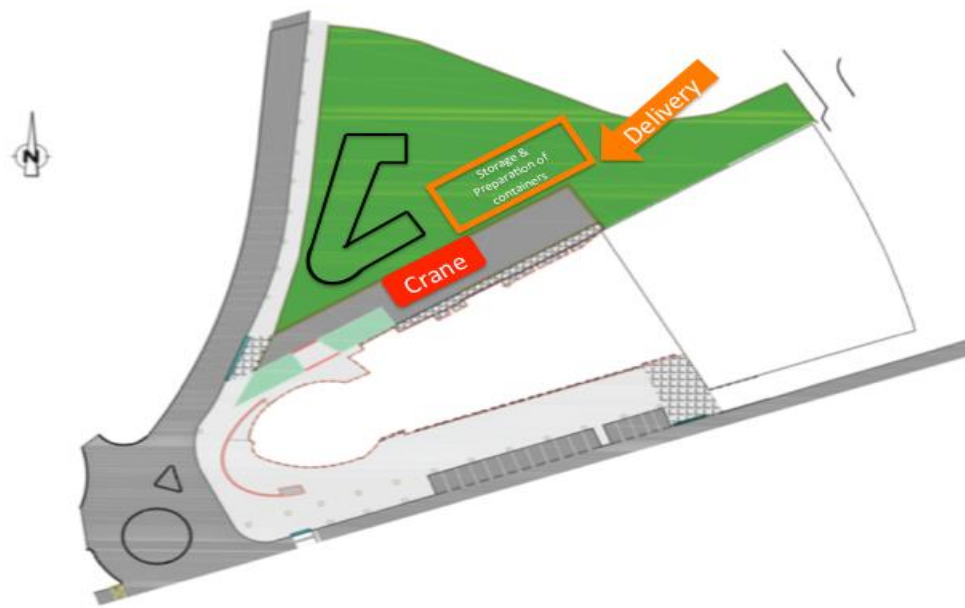


Figure 102: Delivery, Storage and Preparation of the containers

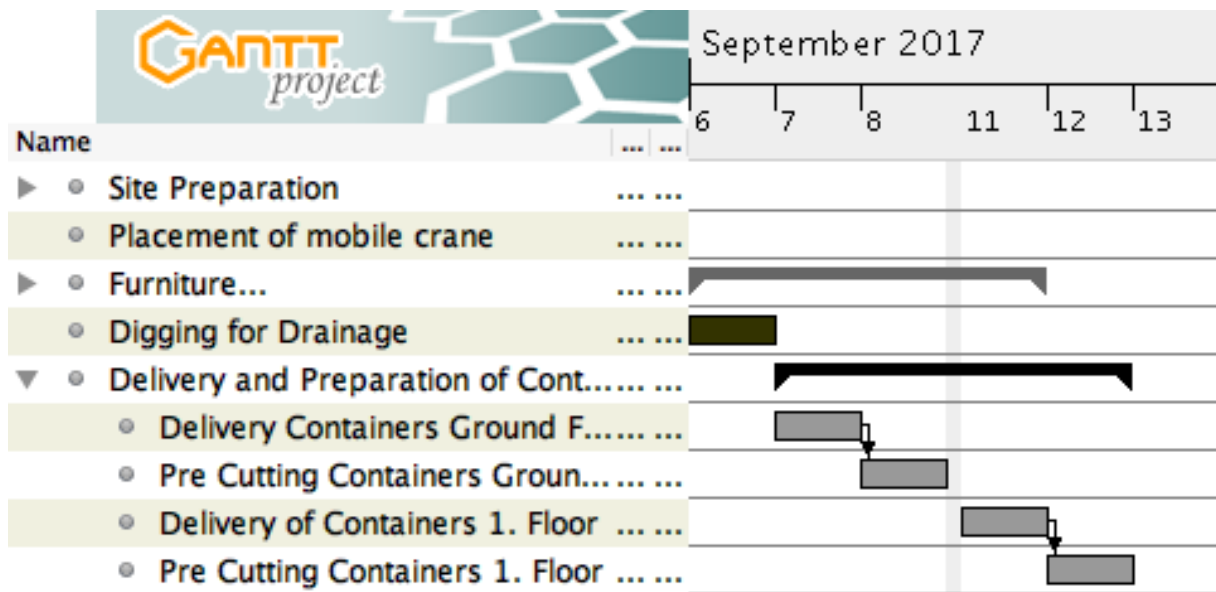


Figure 103: Timeline Detail Transport and Preparation Containers

In the first stage only the containers for the ground floor will be delivered and afterwards pre-cut which will save time in the later on process and it is easier to cut big sections of the wall at this point while the containers are separated and not joined with each other.

In countries where container buildings are more common than in Spain like the US, the UK or Australia companies have been established focusing on preparing and offering model houses made from containers as well as developing individual container home designs. A company list with web-

links to these companies can be found in the Appendix L. In the case of this project there is no company, as far as the research is right, in the near of Vilanova I la Geltrú which is offering a complete service on container buildings. Hence all the work on the container has to be done at the plot and by different subcontractors.

While cutting the container walls it is highly recommended to cut in small parts or to be sure the wall will fall in a chosen and predictable direction because if cutting the wall in once the falling part could be unquestionably heavy.



Figure 104: Cutting windows and doors [75]

To cut the container wall there are three main methods:

- Cutting disk (slow, low cost, uneven)
- Reciprocating saw (slow, middle cost, uneven)
- Plasma cutter (fast, higher cost, straight & clean) = recommended

After the major openings are cut it is essential to reinforce the container walls but also the container structure (Figure 105).

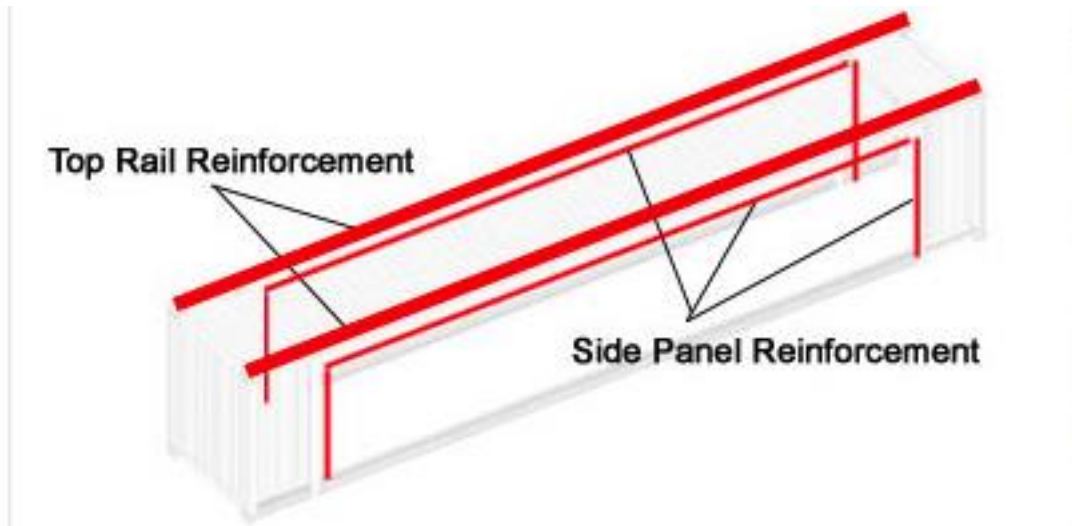


Figure 105: Container reinforcements pattern

The window and door reinforcements will be done with welding rectangular pipes (Figure 106) to simultaneously function as frames for the windows and doors while reinforcing the container.



Figure 106: Rectangular pipe (left) [76] for door and window frames (right) [77]

Containers with walls completely removed will be reinforced in the placed location.

The same happens with the containers for the 1.Floor after the ground floor containers are located on the foundation. This solution makes it easier to store the containers on the plot while the concrete is drying because less space is needed.



## 10.4 Exterior Work

The Exterior Work is divided in a variety of different tasks as it is displayed in Figure 107.

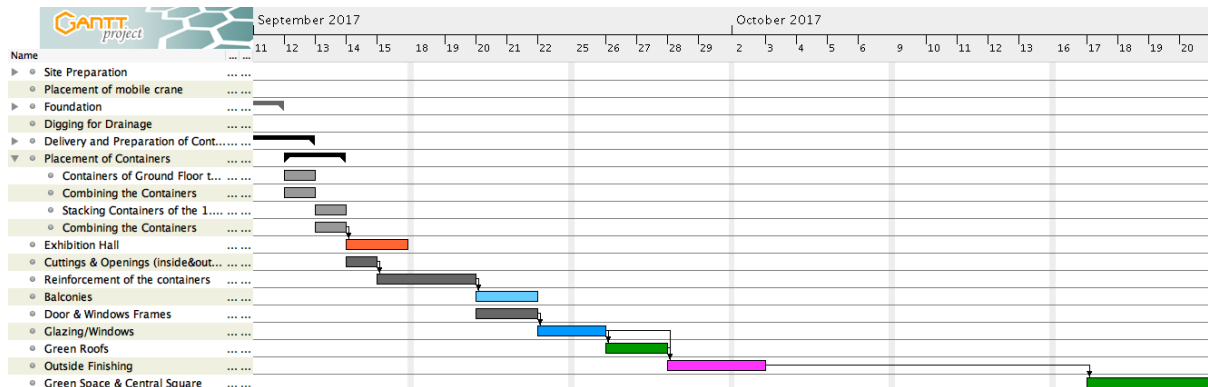


Figure 107: Timeline Detail Exterior Work

The whole building process starts with the placement of the containers assisted by the mobile crane. Firstly the containers of the ground floor toilet and the coworks will be placed. Secondly the containers of the coworks entrance and the bar/cafeteria area will be lifted in their right position. The process will continue in this direction until the exhibition hall (rounded section) is reached. The following list is showing the 7 steps. It is recommended to follow this direction so there are no objects (containers) in the way of the crane movement and it is not necessary to lift containers over another.

- A. 1 Container Toilet (Ground Floor)
- B. 2 Containers Cowork (Ground Floor)
- C. 2 Containers Entrance Cowork
- D. 3 Containers Dining Area & Hallway
- E. 2 Containers Kitchen & Hallway
- F. 3 Containers Exhibition Area 2
- G. 4 Containers Maker Space (Ground Floor)

The exhibition hall will be built up after both container floors are stacked because it is necessary to attach the steel structure to all the adjacent containers on both floors.

While the ground floor containers of the maker space area are placed the welding of the containers to the foundation and the neighbouring containers of all the previous placed containers could take part. For welding the containers together it is advisable to use a flat steel to fill the small gap between the containers. Figure 108 visualize how the welding of the containers should look like it. At the front and the back the containers are only welded with small steel plates at the corners of the structure.



Figure 108: Welding the containers together [78]

The order of the container placement on the first floor matches the sequence of the ground floor. The stacking also begins with the coworks' containers and follows the same direction towards the maker space.

- A. 4 Containers Cowork (1.Floor)
- B. 1 Container Meeting Room (next to cowork)
- C. 1 Container Leisure area
- D. 2 Containers Hallway (1. Floor)
- E. 1 Container Toilet (1. Floor)
- F. 3 Containers Maker Space (1. Floor)

After the both floors of the containers are built up and the containers are welded, the construction of the rounded exhibition hall and main entrance can start. This part of the building is not made out of containers, in this case a steel frame/structure is used which will be cladded likewise the Neàpolis building with sheet metal.

In the next step the necessary reinforcements of the container take place. The reinforcements, of the complete structure are made with I-beams (dimensions depending on the load of the building). These I-beams are welded to the structure of the container and the roof, to ensure that the building can take the loads that are brought in by the windows, the green roof, all the interior equipment, the users and more.



Figure 109: Welding window and door frames (left) [79] & reinforcements (right) [80]

Once the complete construction is reinforced the construction of the balconies can begin. For the overhanging part of the balcony and the general structure I-beams are required. These beams will be welded to the containers underneath to ensure the load capacity. On top of the beams the actual balcony floor under structure will be mounted and then the floor itself can be installed. Figure 110 displays the set-up of the wooden balcony floor.

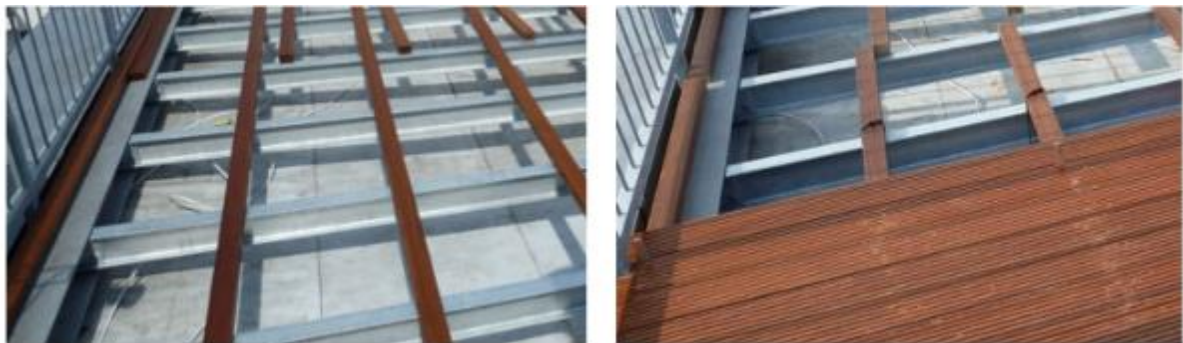


Figure 110: Balcony structure and floor [81]

Subsequently the balcony railing can be put into place and connected to the floor and the container walls at each end. Both balconies will receive a glass railing hold together by small metal poles as shown in Figure 111.



Figure 111: Balcony railing of the maker space balcony (left) and the main balcony (right) [82]

Next the installation of windows and doors as well as the glass in the two big glass cube sections is started. The big glass cubes are held together with a small steel structure made out of small rectangular steel pipes. The dimensions of the glass cube structure must be further calculated.

Placing the green roofs on the part of the building is only achievable if all previous steps concerning the structure of the building are finished. Otherwise the structure could fail because the green roof adds almost another 1500kg. (<https://www.sky-garden.co.uk/shop/full-systems/wildflower-blanket-system.php>) of weight per container.

The last but not least step for the exterior work at the building itself will be the outside finishing which means the applying of the cladding to the outside container wall and the painting in the chosen colours afterwards.

As the last step of the complete construction process the terrace the central square and the planting of grass and trees can start but this will begin first after the interior is almost finished otherwise it might be destroyed. This explains the big gap in the Gantt chart detail (Figure 107).

## 10.5 Interior Work

Like the exterior, the process for interior construction is divided into a variety of different tasks. Figure 112 visualizes the details of the interior work and which tasks depend on each other.

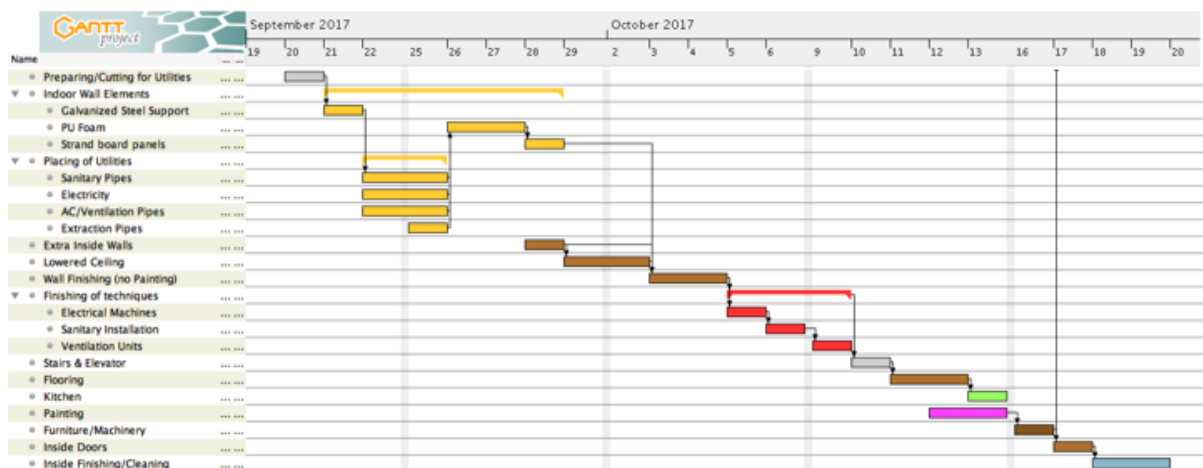


Figure 112: Timeline Detail Interior Work

Prior to the insulation of the walls and the roof, all the cuttings for the utilities have to be made. In the second step the steel supports for the insulation have to be installed thus the sanitary pipes, the electricity cables and all the other facility wiring (HVAC) can be attached to the frame by the construction workers and electricians.

The Insulation of the walls and the roof consists of three different parts as already explained in previous chapters.

1. Steel support (already installed at this point)
2. Spray foam insulation (SPF Polyurethane)
3. Strand board panels

Each step has to follow the other. For this part of the construction process insulation specialists are required. The insulation of the floor will take place at another step in combination with the flooring itself. After the wiring and piping is finished the spray foam can be applied to the structure. Figure 113 illustrates this process.



Figure 113: Insulation Steps 1. frame (left), 2. spray foam (middle) [83] and 3. strandboard panels (right) [84]

On the left side the frame (in this case a wooden frame is used, but the way stays the same either steel or wood frame) with the attached cabling and piping is shown, in the middle the second step the spray foam insulation is applied in between the frame to the container wall and on the right side the fully insulated container with the strandboard panels give the container walls a straight surface and look. The roof insulation will be the same as the wall insulation only the finish will look different. For the ceiling a general office ceiling is used which offers more space and the possibility to lay and change electric cables during the use life of the building.

At this stage the created electrical plans make the installation of the electricity in the building easier. By referring to the electrical plans (Appendix H), all location of the switches and outlets could be marked inside the container after the process of cutting and reinforce the walls of the container. Then, framing process of the container can take place with taking into accounts all of the locations of the outlets and switches [43]. As the next step, three electrical cable lines housed in a plastic tubing will be installed according to these marked locations behind the finishing board [43].

In the ground floor at this stage the extra inside wall, separating the Kitchen and the hallway, as well as the electric room can be built up. For both issues, plasterboard walls are used. Plasterboard walls are built up by a steel frame and plasterboard finish. The advantages of these walls are:

- Cheap
- Easy to built and easy to remove
- Very thin

Because none of the facility wiring must be covered this kind of wall is suitable for the mentioned issues. Figure 114 views the set up of such a wall.



Figure 114: Plasterboard wall [85] [86]

When all the walls and the roofs are finished all the power plugs, the sanitary outlets, the lights and all the electrical components which are not standing on the floor (e.g. the air conditioning) can be finished.

After the previous steps the stairs in the exhibition hall and the maker space as well as the elevator can be build in. For all the previous steps, construction stairs are in use as a reason to not destroy the real stairs by the workers and possible falling obstacles.

One of the last steps in the interior process is the flooring. Firstly the floor is covered with a non-breathable underlayment (Figure 115) like it is installed in almost every normal building roof. Over the previous layer a noise absorption foil will be placed and finally the top layer, the vinyl floor will finish the look.



Figure 115: Non-breathable flooring underlayment [87]

Once the flooring in the kitchen area finished the installation of the shelves, the sink and all the electrical components of the kitchen can take part.

Before putting all the other furniture and electrical machines, especially in the maker space it is recommend to paint the walls.

The penultimate step is the installation of the interior doors which could be a handicap for placing the furniture if installed earlier.

Last but not least the interior has to be cleaned and checked for errors. If this is done the outside finishing of the surrounding can be take part and the building can be signed off.

## 11 Cost Estimation

One of the main parts while planning a construction are the costs, especially in this project it is of high interest how many costs a container building will incur, to compare it afterwards against a normal classic concrete or steel construction. At this point it is good to remember the requirement ID 5.1 that no fix budget is given.

In this project the costs are only an estimation made by the project team by researching prices for the main parts of the building, mainly on the Internet. No real local construction companies were contacted and asked for particular prices but a list of local companies offering different necessary services to construct the building can be found in Appendix L.

The complete cost calculation is done within Microsoft Excel. The cost calculation excel sheet can be found in the Digital Appendix. Table 4 displays the general organization of the main sheet. In this report the column with the references will be left out but all references can be looked up in the file itself. To be consistent each price has a reference.

Description	Single Cost	Amount	Cost	Comment	Reference

Table 4: General Organization of the cost estimation excel sheet

Furthermore the excel file contains four more subcategory sheets which delivering the cost for electrics, the calculation of inside and outside wall, roof and floor areas as well as the estimation of the amount of reinforcements and frame structure (see Figure 116). This sub-sheets delivering numbers to the main cost calculation which are connected.



Main Calculation	Electric	Interior Wall & Roof Area	Exterior Wall & Roof Area	Reinforcements & Steel Frames	+
------------------	----------	---------------------------	---------------------------	-------------------------------	---

Figure 116: Subcategory sheets cost calculation

In the following subchapters the main cost centres are split to give a detailed insight into the calculation and to clarify where the main costs come from and how they are estimated and assembled.

### 11.1 Purchasing and transportation costs of container

Purchasing containers is possible almost everywhere in the world, although they are mainly produced in China. In the surrounding of Vilanova i la Geltrú the nearest purchasers were found in Barcelona and Tarragona, both cities are approximately 50km distance. A decision has to be made between new containers and used containers. In this project the decision is in favour of used



containers because of the lower price and the ecological aspect of recycling. Researches on this have been made but will not be explained in this report.

Table 5 shows the estimated costs for purchasing and transporting the 29 20ft HC containers, which are used for the design, from a 50km distance to the building plot. It also illustrates the price difference between used and new containers (light grey). As it is written in the comment column for the transportation the price for the transportation is estimated with the help of an American container home website. It is obvious that the delivery will take a significant amount of money. Transportation by train or ship would be possible and might be cheaper but is not researched due to limited time and knowledge.

Description	Single Cost	Amount	Cost	Comment
<b>Seacontainter</b>				
20' HIGHCUBE Container new	5.000,00 €			
20' HIGHCUBE Container used	2.000,00 €	29	58.000,00 €	approximately
<b>TOTAL</b>			<b>58.000,00 €</b>	
<b>Transportation</b>				
Ship				0,75€ per km per 20' Cont with Truck in America
Train				might be possible but not researched
Truck (per Container & km)	0,75 €	1450	31.537,50 €	might be possible but not researched
<b>TOTAL</b>			<b>31.537,50 €</b>	if buying & delivery from barcelona or tarragona

Table 5: Costs - Purchasing and transportation of containers

Together the purchasing and the transportation of the containers will add up almost 90.000 €.

### 11.2 Cost of site preparation and foundation

The costs for the site preparation and the foundation are similar to those of normal concrete constructions as it is already mentioned in the construction process. The main costs in this category will come from the foundation. General Work and Sewage & Drain Piping will account for a minor amount.

The sizes of the concrete piles for the “foundation on wells” along with the slab foundation are estimated with a Belgium engineer’s blog, several container home websites and the weight of the whole construction. Nevertheless the numbers are not 100% precise but good enough to give an estimation for the costs. For details see Table 6.

Description	Single Cost	Amount	Cost	Comment
<b>Site Preparation, Foundation &amp; Sewage</b>				
<b>General Work (Marking, Fences, mobile offices)</b>				
Marking the ground plan	300,00 €	1	300,00 €	assumed
Fence (per 3m per week)	3,50 €	443	1.551,67 €	7 weeks, approx 190m, rent at remsa.net possible
Office Container (per month)	175,00 €	2	350,00 €	
Construction Container (per month)	100,00 €	2	200,00 €	
Excavator (rent per day)	250,00 €	2	500,00 €	
Crane (rent per h)	109,00 €	32	3.488,00 €	4 working days = 32 h
<b>Foundation</b>				
Slab/Plate (per m <sup>2</sup> )	77,30 €	49,7	3.841,81 €	needed at the exhibiton hall & wate heating room
"Foundation on wells" (per 1m depth)	128,00 €	111	14.208,00 €	ø800mm, 3m depth, 37 "wells"
Horizontal Beams under structure (per m <sup>3</sup> )	95,00 €	24,248	2.303,56 €	400mm x 400mm, Length 151,55m
<b>Sewage &amp; Drain Piping</b>				
Control Point ø 300mm	121,90 €	1	121,90 €	
ø 50mm (per m)	19,30 €	7,2	138,96 €	
ø 100mm (per m)	32,40 €	49,9	1.616,76 €	
Traps, Connections, cleanout plugs,...	800,00 €	1	800,00 €	
<b>TOTAL</b>			<b>29.420,66 €</b>	

Table 6: Costs - Site preparation and foundation

In total this part of the construction process will cause expenses about 30.000 €.

### 11.3 Costs of exterior work

General construction costs (exterior work costs) is one of the biggest cost centre in this project. This part is comparable with the shell of classic concrete buildings and is split up in another six subcategories (see Table 7).

Description	Single Cost	Amount	Cost	Comment
<b>Construction/Exterior Work</b>				
<b>Modifying Containers</b>				
Cutting Openings for Window & Doors	300,00 €	29	8.700,00 €	across board for each container assumed
Window & Door Frames Structure (per kg)	1,45 €	938,6	1.332,02 €	50mm x 50mm x 3mm, 1m = 4,28kg
Reinforcement of Structure (per kg)	0,92 €	2268	2.086,56 €	1-Beams, 1m = 36,2kg
Roofing	2.700,00 €	1	2.700,00 €	for 7 Containers
Welding (per m)	0,50 €	533,50	266,75 €	Welding, price and length very rough!
<b>General</b>				
Exhibition Hall (per m <sup>2</sup> )	150,00 €	96	14.400,00 €	Zinc clad, as Naipoli
Rounded Stairs (Entrance)	5.000,00 €	1	5.000,00 €	
Stairs (Maker Space)	3.000,00 €	1	3.000,00 €	
Elevator	20.000,00 €	1	20.000,00 €	rough estimation (incl. Mounting)
<b>Exterior Doors</b>				
Main Entrance Sliding Door (electric)	2.500,00 €	1	2.500,00 €	2200 x 3035 mm, contacted company
Bar Entrance	931,77 €	1	931,77 €	2200 x 860 mm
Cowork Entrance Sliding Door (electric)	2.500,00 €	1	2.500,00 €	2200 x 3035 mm, contacted company
Central Square Sliding Door (electric)	2.200,00 €	1	2.200,00 €	2200 x 2426 mm, contacted company
Sliding Door to Balcony 1. Floor	1.077,25 €	1	1.077,25 €	2200 x 2426 mm
Normal Doors to Balconies	503,00 €	2	1.006,00 €	2200 x 860 mm
<b>Glazing</b>				
Glascubes Side (per m <sup>2</sup> )	50,00 €	24,32	1.216,00 €	One Side 6,08m <sup>2</sup> (4 Sides)
Glascubes Overhead (per m <sup>2</sup> )	107,50 €	25,44	2.734,80 €	One Roof 12,72m <sup>2</sup> (2 Roofs)
<b>Windows</b>				
General Big Windows	566,00 €	7	3.962,00 €	1450 x 4000 mm
Middle Size Windows Cowork	250,00 €	2	500,00 €	1450 x 1700 mm
Middle Size Windows Makerspace	511,00 €	2	1.022,00 €	1850 x 2400 mm
Window Exhibition Hall	530,00 €	1	530,00 €	2050 x 3000 mm
General Small Windows	146,00 €	9	1.296,00 €	750 x 1500 mm
Toilet Windows	88,00 €	6	352,00 €	550 x 800 mm
<b>Outside Finishing</b>				
Cork (per m <sup>2</sup> )	9,42 €	484,5	4.563,72 €	70,66€ per 7,5m <sup>2</sup> , 1000x500x20 mm
Painting (per m <sup>2</sup> )	15,00 €	484,5	7.267,08 €	
Balkony Floor (per m <sup>2</sup> )	85,00 €	86	7.310,00 €	two different pads
Balkony railing	7.000,00 €	1	7.000,00 €	online calculation tool, 2 balkony railings
Green Roofs (per m <sup>2</sup> )	63,00 €	73,8	4.652,36 €	
<b>TOTAL</b>			<b>110.106,31 €</b>	

Table 7: Costs - Exterior Work

For the modifying of the container especially for the cuttings and openings for the windows and doors a package price is estimated by the project team. For the frames the width and height of all the windows & doors are added up. The amount, length and dimensions of reinforcements are taken out of the structural analysis. An estimation of this part is difficult due to the fact that building with containers is not very common in Spain compared to other countries like the United States and no specialised companies exists in the surrounding of Vilanova i la Geltrú.

Under the subcategory “General” all part of the exhibition hall plus the stairs in the maker space are included. The costs for the exhibition hall are estimated by Félix Ruiz Gorrindo (Neàpolis) because the normal way to receive a price for this special part of the building (contacting a specific company) was not possible at this stage. Also the elevator, included in this part of the building, is listed in this category and estimated with Internet references.

Furthermore all the doors located towards the outside of the building are catalogued here. The main entrances at the exhibition hall, the ground floor cowork office and the door to the central square are equipped with electric sliding glass doors commonly used in new office buildings and shops. All the other doors are manually operated.

The next subcategory contains the glazing for the two big glass cubes on the first floor where the meeting room and the leisure area are located.

All the windows which will be installed throughout the construction are clustered afterwards. Care was taken that the windows are standardized windows available on the Spanish market to keep the expenses low otherwise customized windows would be needed which would increase the costs rapidly.

The last but not least part of the exterior work category is the outside finishing. This group contains the cladding of the container walls with thin cork panels from the outside to hide the wavy steel structure, the painting of the entire exterior as well as the balcony floors and the railing. For the balcony a dark wooded floor and a glass-aluminium railing is suggested.

Summing up all the costs in this category 95.000 € can be added.

### **11.4 Techniques costs**

In the techniques section all the electricity wiring, the air conditioning and further the sanitary piping with the required water-heating tank are recorded. With an amount of about 31.000 € (Table 8) this part should not be underestimated.

Description	Single Cost	Amount	Cost	Comment
<b>Techniques</b>				
Electricity - wiring (per 60m <sup>2</sup> )	1.900,00 €	8,15	15.485,00 €	489m <sup>2</sup>
<b>HVAC</b>				
Multi Split 1	1.298,00 €	1	1.298,00 €	= 2 Indoor + 1 outdoor unit
+ additional Indoor units	1.200,00 €	6	7.200,00 €	8 units needed for Multi split 1
Multi Split 2	1.298,00 €	1	1.298,00 €	= 2 Indoor + 1 outdoor unit
+ additional Indoor units	1.200,00 €	3	3.600,00 €	5 units needed for Multi split 2
<b>Sanitary Piping</b>				
Cold Water Piping	7,25 €	59,1	428,48 €	extra calculation made
Hot Water Piping	7,25 €	45,8	332,05 €	extra calculation made
Connections, Valves,....	200,00 €	1	200,00 €	
Water Heating Tank	1.704,21 €	1	1.704,21 €	
<b>TOTAL</b>			<b>31.545,74 €</b>	

Table 8: Costs - Techniques

## 11.5 Costs of interior work

The interior subcategory contains all the wall finishing (insulation and painting), the ceiling with lights and flooring as well as the doors to the toilets, coworks and maker space and extra walls. In this section the main cost points are the flooring, the ceiling and the movable glass wall which separates the meeting room and the leisure area from the hallway in the 1. Floor.

Description	Single Cost	Amount	Cost	Comment
<b>Interior</b>				
Thermal Insulation Side Walls (per m <sup>2</sup> )	9,05 €	410,9	3.718,20 €	
Thermal Insulation Exhibiton Hall (per m <sup>2</sup> )	9,05 €	96,0	868,80 €	
Thermal Insulation Roof (per m <sup>2</sup> )	9,05 €	221,5	2.004,26 €	
Acoustical Insulation (per 0,5m <sup>2</sup> )	3,90 €	229	893,10 €	
Seperation Wall Hallway (per 5m, 2,5m Height)	380,00 €	2	760,00 €	approx. 10m Wall
Wall Electric Room	380,00 €	1,75	665,00 €	approx. 8m Wall
Permanent Glass Wall (Meeting Room)	6.555,00 €	1	6.555,00 €	9000 x 2500 mm
Movable Glass Wall	3.166,00 €	1	3.166,00 €	2930 x 2500 mm
Doors indoor wood (per Unit)	154,60 €	6	927,60 €	
Doors indoor glass (per Unit)	204,00 €	5	1.020,00 €	
Painting (per m <sup>2</sup> )	10,00 €	411	4.108,50 €	
Lights	1.909,06 €	1	1.909,06 €	complete interior
Flooring Nonbreathable underlayer (per 45m <sup>2</sup> )	40,00 €	11	440,00 €	
Flooring Acoustic (per 5m <sup>2</sup> )	47,00 €	47,2	2.216,76 €	
Flooring Vinyl (per m <sup>2</sup> )	32,11 €	449,5	14.433,15 €	
Ceiling	12,00 €	402,29	4.827,49 €	
<b>TOTAL</b>			<b>43.925,92 €</b>	

Table 9: Costs - Interior

## 11.6 Equipment and Furniture costs

### 11.6.1 Costs Cowork

The working desks, the office chairs and the shelves basically compose the furniture costs for the two coworks. All other equipment, like computer and electrical devices are in general not provided in a cowork. Consequently the costs of 6.000 € are relatively low.

Description	Single Cost	Amount	Cost	Comment
<b>Cowork Offices</b>				
Working Desk	149,00 €	18	2.682,00 €	
Office Chairs	69,99 €	18	1.259,82 €	
Shelf	129,00 €	18	2.322,00 €	
Chalkboard wallpaper (per m <sup>2</sup> )	4,13 €	11,5	47,50 €	2,5m x 4,6m
<b>TOTAL</b>			<b>6.263,82 €</b>	

Table 10: Costs - Coworks furniture

### 11.6.2 Costs Common Areas

In the common areas which include both entrance areas (coworks & exhibition hall), the hallways, the meeting room and the leisure area, the costs cover tables, chairs & seats, water cooler and a projector for the meeting room. Table 11 lists all the items and summate 4.700 €.

Description	Single Cost	Amount	Cost	Comment
<b>Common Areas (Entrance/ Meeting Room/Hallway)</b>				
Meeting Table	338,00 €	1	338,00 €	
Coffee tables	99,00 €	3	297,00 €	
Office Chairs	69,99 €	6	419,94 €	
Seats	199,00 €	10	1.990,00 €	
Water cooler	249,00 €	2	498,00 €	
Basic Chairs	30,00 €	6	180,00 €	
Reception Desk	642,00 €	1	642,00 €	
Electrical Components (Projector)	336,99 €	1	336,99 €	
<b>TOTAL</b>			<b>4.701,93 €</b>	

Table 11: Costs - Common areas

### 11.6.3 Costs Bathrooms/Toilets

The toilets in the building are simple equipped and the costs are listed in the following table (Table 12)

Description	Single Cost	Amount	Cost	Comment
<b>Bathrooms/Toilets</b>				
Toilets	84,15 €	6	504,90 €	
Sinks	74,00 €	4	296,00 €	
Hand Dryer	146,99 €	2	293,98 €	
<b>TOTAL</b>			<b>1.094,88 €</b>	

Table 12: Costs - Toilets

### 11.6.4 Costs Bar/Cafeteria with Kitchen

The fact that the Bar/Cafeteria will be open to the public makes it necessary to built in an industrial kitchen which rises the price compared to normal household kitchen a little. Nevertheless the tables

and chairs in the cafeteria area and components of the kitchen constitute only a small amount (approx. 9.000 €) of the total building costs.

Description	Single Cost	Amount	Cost	Comment
<b>Bar/Cafeteria</b>				
<b>Kitchen</b>				
				industrial style
Sink	540,00 €	1	540,00 €	
Shelfs	625,00 €	1	625,00 €	
Open Shelfs	365,00 €	3	1.095,00 €	
Fridge	695,00 €	2	1.390,00 €	
Extractor	539,40 €	1	539,40 €	
Electric Pit & Oven	2.706,00 €	1	2.706,00 €	
Dish washer	1.269,00 €	1	1.269,00 €	
<b>Dining area</b>				
Table & Chair Combi (2Pers)	158,98 €	2	317,96 €	
Table & Chair Combi (4Pers)	258,96 €	3	776,88 €	
<b>TOTAL</b>			<b>9.259,24 €</b>	

Table 13: Costs - Bar/cafeteria

### 11.6.5 Costs Maker Space

The maker space with its expensive machinery is one of the biggest cost centres in this project. As it is visible in Table 14 the laser cutters and the milling machines add up together more than 50.000 €. In contrary the other necessary furniture is relatively economical. In the maker space computers will be provided (contrary to the cowork) because they are mandatory to use the laser cutters, 3D printers and the milling machine.

Description	Single Cost	Amount	Cost	Comment
<b>Maker Space</b>				
3D Printer (Home Format)	500,00 €	3	1.500,00 €	
Laser Cutter	30.000,00 €	1	30.000,00 €	
Milling Machine	15.000,00 €	1	15.000,00 €	
Laser Cutter Small	12.000,00 €	1	12.000,00 €	
Computer	716,00 €	3	2.148,00 €	
Tables	149,00 €	2	298,00 €	
Chairs	30,00 €	6	180,00 €	
Shelf	113,29 €	3	339,87 €	
<b>TOTAL</b>			<b>61.465,87 €</b>	

Table 14: Costs - Maker Space

## 11.7 Costs for the surrounding

To achieve a comfortable working environment and adapt the rest of the plot which is not used for the building to the surrounding; grass, a number of plants and a terrace/central square is needed. For this category a few numbers are estimated to procure an approximately expense. This calculation should not be taken too seriously; it highly depends on the kind of grass, the type of plants and stones used.

Description	Single Cost	Amount	Cost	Comment
<b>Surrounding</b>				
Grass (per m <sup>2</sup> )	3,35 €	2182	7.309,70 €	Plot Size = 2632m <sup>2</sup> , Building Size = 300m <sup>2</sup>
Plants (Trees, Flowers, ...)	150,00 €	15	2.250,00 €	Palm Trees
Terrace/Central Square (per m <sup>2</sup> )	7,50 €	150	1.125,00 €	150m <sup>2</sup>
<b>TOTAL</b>			<b>10.684,70 €</b>	

Table 15: Costs - Surrounding

## 11.8 Staff salary

Almost all the previous calculated costs do not include the salary for the staff that is fundamental to establish the building. On the basis of the construction process planning it is estimated that over all 7 weeks of the construction 8 general construction workers, at least one construction manager/engineer who is supervising the project and at specific moments individual specialists for different tasks are needed. Table 16 includes the different essential workers with their approximated hourly earnings multiplied with the work time during the project.

Description	Single Cost	Amount	Cost	Comment
<b>Staff (Salary per h)</b>				
				34 working days estimated
Construction Worker	12,00 €	2176	26.112,00 €	8 workers a day over all the time
Construction Manager/Engineer	120,00 €	272	32.640,00 €	1 per day over all the time
Electrician	40,00 €	64	2.560,00 €	4 people 2 days
Plumber	35,00 €	32	1.120,00 €	2 people 2 days
Insulations Expert	35,00 €	64	2.240,00 €	4 people 2 days
<b>TOTAL</b>			<b>64.672,00 €</b>	

Table 16: Staff salary

## 11.9 Total costs – comparison

All the previous calculated costs added together plus a small amount for the overall finishing (Table 17) will lead to the overall costs of the construction.

Description	Single Cost	Amount	Cost	Comment
<b>Finishing</b>				
Cleaning	500,00 €	1	500,00 €	assumed
Inspection & Sign off	200,00 €	1	200,00 €	assumed
<b>TOTAL</b>			<b>700,00 €</b>	

Table 17: Costs - Finishing

In Table 18 all the previous cost centres with their total summation are listed. In the third column the percentage of the individual task costs compared to the total amount of the construction costs is specified. As it is visible several categories add a higher amount of expenses to the total costs than

others. The differentiation and listing in this way makes it easy to identify the tasks with the highest costs.

Cost Centre	Cost	Percentage of total costs
Seacontainer	58.000,00 €	12,52%
Transportation	31.537,50 €	6,81%
Site Preparation, Foundation & Sewage	29.420,66 €	6,35%
Construction/Exterior Work	110.106,31 €	23,76%
Techniques (Electricity wiring, sanitary piping, etc.)	31.545,74 €	6,81%
Interior (Insulation, Flooring, Painting, etc.)	43.925,92 €	9,48%
Coworks Furniture	6.263,82 €	1,35%
Common Areas Furniture	4.701,93 €	1,01%
Toilets	1.094,88 €	0,24%
Bar/Cafeteria and Kitchen	9.259,24 €	2,00%
Maker Space (Machinery & Furniture)	61.465,87 €	13,26%
Surrounding	10.684,70 €	2,31%
Sallary	64.672,00 €	13,96%
Finishing (Cleaning & sign off)	700,00 €	0,15%
<b>TOTAL COST (all incl.)</b>	<b>463.378,56 €</b>	<b>100%</b>
<b>TOTAL COST (without MakerSpace Interior)</b>	<b>401.912,69 €</b>	
<b>TOTAL COST (without any Interior)</b>	<b>381.687,70 €</b>	

Table 18: Costs - Complete clustered in cost centres

In this case the exterior work takes about 25% of the total costs, followed by almost 20% purchasing and transporting the containers, around 14% salary and 13% for the maker space machinery and furniture.

Because of the high costs of the maker space interior the total building costs are also listed without this category. And the last row in Table 18 displays only the construction costs without any interior.

Comparing the calculated prices for the container construction to the expenses of a classic concrete building, saving money while using containers is a big aspect. Using a general number for concrete buildings in Germany which is stated with 1.400 € per m<sup>2</sup> (without interior) [88] the same size building within an effective interior area of 490 m<sup>2</sup> would cost 686.000 € which means the container building is almost half the price (56%) (see Table 19).



<b>Comparing costs</b>	Single costs	Area	Total	Percentage
<b>TOTAL COST (all incl.)</b>			<b>463.378,56 €</b>	<b>68%</b>
<b>TOTAL COST (without MakerSpace Interior)</b>			<b>401.912,69 €</b>	<b>59%</b>
<b>TOTAL COST (without any Interior)</b>			<b>381.687,70 €</b>	<b>56%</b>
<b>General Costs "normal building" per m<sup>2</sup></b>	<b>1.400,00 €</b>	<b>490</b>	<b>686.000,00 €</b>	<b>100%</b>

**Table 19: Comparison Container building vs. "normal" building**

To eventually reduce the costs it is possible to choose less expensive solutions, especially in the interior, e.g. exchanging the glass walls (permanent and movable) in the meeting room/leisure area to plasterboard walls. Furthermore if the original exterior look of sea containers is preferred the cladding can be dispensed and only a special painting is needed.

Altogether it was taken care that the relation between high quality comfortable working space and costs is balanced.

## 12 Conclusion and Outlook

This present report shows it is possible to construct an innovative multifunctional building using mainly sea containers. But it is also not as simple as it looked in the beginning. A lot of different aspects must be taken into consideration and have to be respected.

Before the project had started a lot of research was done. Many different examples all over the world show that almost every design is possible. In most of the cases how the final solution will look depends on the plot, the urban regulations and of course the budget.

The urban laws have been considered in this project and even if it is not permitted to build on the plot right now several solutions to change this circumstance are given. The site itself is well suited for a container construction - a lot of space is available to establish the building as well as to prepare the containers before stacking.

As the project progressed the requirements changed slightly leading to various design ideas, these sketches eventually became one final design which all the stakeholders agreed to move forward with. The new multipurpose building is now offering space for at least 30 people to work, create and innovate. To achieve this the property covers two cowork offices, a maker space, a café/bar and an exhibition hall in the interior and appears with a clean, innovative but also modular design harmonizing with the surrounding. Furthermore eco-friendly aspects like green roofs and renewable energy supplies were examined and implemented when they were economically viable.

To ensure the stability of the construction several parts of the building were analysed and tested in Solid Works. While this proves the stability of the building with several reinforcements as a first approach a further professional structural analysis must be performed. The same applies to the foundation calculation. With no exact data given on the ground resistance or composition a profound foundation calculation was not possible. However with the received information recommendations towards a foundation on wells in combination with a slab foundation in two areas (exhibition hall & water heating room) can be given.

After the designing the complete construction process was planned out – including the entire process from digging and pouring the foundations to the furnishing of the interior. This planning shows that the construction time can be reduced by more than 50%, from 5 months to 2 months, compared to classic concrete buildings.

Based on all previous challenges and collected information the costs of the construction were estimated. Also the cost calculation shows a 40% saving of expenses compared to classic concrete buildings even when using quality products. However a reduction of the price is still possible by exchanging furniture and walls with low cost solutions.

In conclusion a lot of advantages of container buildings stand against a few but serious disadvantages. The disadvantages – toxic indoor flooring, space regulations, knowledge of container constructions – have to be kept in mind when making decisions if building with sea containers or not.

<u>Advantages</u>	<u>Disadvantages</u>
Time saved during construction due to the frame already being in place	Local Regulations around a container building could restrict it
Cost of container building is typically less	Condition of a used container
Modularity and expandability of a container design is typically easier	Limited shape of a container requires modification to make a workable space
Eco-friendly if repurposing containers	Toxic pesticides used on the floor of containers
Available worldwide due to global shipping industry	

**Table 20: Advantages and Disadvantages – Container building vs. classic concrete building**

Besides all the achieved tasks there is still a small amount of tasks that were considered as optional but have to be done before making a decision and starting the construction process.

Following are the next steps that have not been included in the report are listed.

Firstly a detailed structural analysis of the entire building was not made – but has to be made – as Neàpolis did not require this and only wanted a confirmation that the building was structurally secure.

Secondly a professional analysis of the ground resistance was not performed, only the given approximated numbers were used to calculate the foundation specifications. This has to be done to ensure the stability of the building and calculate the dimensions of the foundation structure.

Thirdly a detailed fire proofing and evacuation plan has not been completed.

Furthermore accurate details of the electrical requirements are not completely known, details such as the exact sizes of electrical wiring, the connection to the main electrical supply and the exact size and model of electrical server needed is not known.

Also the grounding of the building should be researched properly to protect from lightning strikes.

Last but not least the approval from the local council for the building plot has not yet been secured.

Even though there are some missing parts to finish the project entirely, the team achieved all of the main goals set out by Neàpolis. All stakeholders - the team members, the supervisors and Neàpolis are very satisfied with the outcome of the project and hope that the project will be continued after the EPS 2017 and is fully completed in the near future.

## Bibliography

- [1] "SEO Personal," [Online]. Available: <https://www.seopersonal.com/es/sample-levels/blog/solo-marketing-online/seopersonal-se-traslada-a-neapolis-vilanova-i-la-geltru>. [Accessed 26 02 2017].
- [2] ""Vessel details for: NYK ATLAS (Container Ship) - IMO 9262728, MMSI 354614000, Call Sign H8TS Registered in Panama | AIS Marine Traffic"," MarineTraffic.com, [Online]. Available: [http://www.marinetraffic.com/en/ais/details/ships/shipid:414899/mmsi:354614000/imo:9262728/vessel:NYK\\_ATLAS](http://www.marinetraffic.com/en/ais/details/ships/shipid:414899/mmsi:354614000/imo:9262728/vessel:NYK_ATLAS). [Accessed 02 06 2017].
- [3] ""2017 International Container Shipping Rates & Costs"," moverdb, [Online]. Available: <https://moverdb.com/container-shipping/>. [Accessed 02 06 2017].
- [4] ""Drewry: Idle Containership Fleet Surges amid Overcapacity"," World Maritime News, [Online]. Available: <http://worldmaritimeweb.com/archives/207947/drewry-idle-containership-fleet-surges-amid-overcapacity/>. [Accessed 10 05 2017].
- [5] R. Herr, "What is CORTEN Steel and why are shipping containers made from it?," 4 April 2014. [Online]. Available: <http://containerauction.com/read-news/what-is-corten-steel-and-why-are-shipping-containers-made-from-it>. [Accessed 21 February 2017].
- [6] "NIPPON STEEL & SUMIMOTO METAL," [Online]. Available: [https://www.nssmc.com/product/catalog\\_download/pdf/A006en.pdf](https://www.nssmc.com/product/catalog_download/pdf/A006en.pdf). [Accessed 28 February 2017].
- [7] LAN, "Cor-Ten Steel: The Essential Guide," 27 February 2015. [Online]. Available: <https://landarch.com/cor-ten-steel-essential-guide/>. [Accessed 1 April 2017].
- [8] ""13 erstaunliche Fakten über Seecontainer - Containerbasis.de",," Containerbasis, [Online]. Available: <https://www.containerbasis.de/blog/allgemein/13-fakten/>. [Accessed 31 05 2017].
- [9] ""How Are Shipping Containers Made? | Container Home Plans"," Containerhomeplans, [Online]. Available: <http://www.containerhomeplans.org/2015/07/how-are-shipping-containers-made/>. [Accessed 31 05 2017].
- [10] containerbasis, [Online]. Available: <https://www.containerbasis.de/containermasse/>. [Accessed 09 06 2017].

- [11] "Containercity," [Online]. Available: <http://www.containercity.com/about>. [Accessed 10 05 2017].
- [12] Tom, "Container Home Plans," 14 01 2016. [Online]. Available: <http://www.containerhomeplans.org/2016/01/what-are-shipping-container-homes/>. [Accessed 23 04 2017].
- [13] [Online]. Available: <http://containertech.com/creative-uses/shipping-container-schools/>. [Accessed 02 04 2017].
- [14] [Online]. Available: <http://www.containerhomeplans.org/2015/03/top-10-shipping-container-offices/>. [Accessed 02 04 2017].
- [15] [Online]. Available: <http://www.containerhomeplans.org/2015/04/what-i-wish-id-known-before-building-my-shipping-container-home/>. [Accessed 02 04 2017].
- [16] ""Why People Thrive in Coworking Spaces"," Harvard Business Review, [Online]. Available: <https://hbr.org/2015/05/why-people-thrive-in-coworking-spaces>. [Accessed 04 06 2017].
- [17] ""Neapolis (@neapolisvng) | Twitter"," [Online]. Available: <https://twitter.com/neapolisvng?lang=en>. [Accessed 05 06 2017].
- [18] ""Report: Ours to Master - how makerspaces can help us master technology for a more human end - RSA"," [Online]. Available: <https://www.thersa.org/discover/publications-and-articles/reports/ours-to-master>. [Accessed 04 06 2017].
- [19] ""Benefits of Hands-On Learning in Makerspaces | Formaspace"," [Online]. Available: <https://formaspace.com/articles/education/benefits-hands-on-learning-in-makerspaces/>. [Accessed 04 06 2017].
- [20] [Online]. Available: <https://www.daftlogic.com/projects-google-maps-area-calculator-tool.htm>. [Accessed 1 April 2017].
- [21] K. A. Z. Sarieh Zareaian, "The Role of Climate Factors on Designing and Constructing Buildings," (*From Urbanization Architecture Approach*). *Bull. Env. Pharmacol. Life Sci.*, Vol 3 (1), pp. 197-200, Dec 2013.
- [22] Sonkyo Energy, [Online]. Available: <http://usa.windspot.es/home-wind-turbines/products/88/windspot-15-kw/>. [Accessed 10 March 2017].

- [23] [Online]. Available: <https://www.milanuncios.com/iluminacion/aerogenerador-1600w-regulador-a-217943776.htm>. [Accessed 4 May 2017].
- [24] D. Wright, "Spain to tax the sun," [Online]. Available: <https://www.linkedin.com/pulse/spain-tax-sunreally-david-wright>. [Accessed 16 May 2017].
- [25] Albinaco, 2015. [Online]. Available: [https://www.albinaco.com/images/gridobject\\_images/steel-bending-profiles/Channel\\_Flanges\\_Out\\_sm.png](https://www.albinaco.com/images/gridobject_images/steel-bending-profiles/Channel_Flanges_Out_sm.png).
- [26] Appliedconceptengineering, 2017. [Online]. Available: <http://appliedconceptengineering.com.au/wp-content/uploads/2012/07/rounded-steel-frames-constructions.jpg>.
- [27] Neufert, 2014. [Online]. Available: [http://neufert-cdn.archdaily.net/uploads/photo/image/58859/full\\_L-ELLIPSE02\\_\\_2\\_.jpg?v=1492111764](http://neufert-cdn.archdaily.net/uploads/photo/image/58859/full_L-ELLIPSE02__2_.jpg?v=1492111764).
- [28] KerstenEurope, 2016. [Online]. Available: <https://www.kersteneurope.com/en/profile-bending>.
- [29] Containerhome, "Containerbooks," 15 05 2017. [Online]. Available: <http://www.containerhome.info/shipping-container-homes-book-series-book-116.html>.
- [30] Livios, "Foundation prices," 14 05 2017. [Online]. Available: <http://www.livios.be/nl/bouwinformatie/ruwbouw/beton/fundering/richtprijzen-fundering-en-beton/>.
- [31] Tom, "Container foundation," 2 09 2015. [Online]. Available: <http://www.containerhomeplans.org/2015/09/shipping-container-home-foundation-types/>. [Accessed 20 05 2017].
- [32] "Types of settlement," [Online]. Available: <http://www.ashireporter.org/photos/thumbnails/2004-2002/types-of-settlement.gif>.
- [33] U. construction, "Pile foundation," [Online]. Available: [http://www.understandconstruction.com/uploads/1/7/0/2/17029032/\\_2848588\\_orig.png](http://www.understandconstruction.com/uploads/1/7/0/2/17029032/_2848588_orig.png).
- [34] "Pile foundation," 2017. [Online]. Available: <http://www.understandconstruction.com/pile-foundations.html>. [Accessed 20 05 2017].

- [35] "Pile foundation," 2015. [Online]. Available:  
[http://www.euroblok.nl/downloads/bouwtechniek/03\\_02\\_wapening.html](http://www.euroblok.nl/downloads/bouwtechniek/03_02_wapening.html).
- [36] 2017. [Online]. Available: <http://www.epsglobalng.com/supplier/wp-content/uploads/2017/02/Piling-3-800x336.jpg>.
- [37] 2015. [Online]. Available: <http://www.simplifydiy.com/plumbing-and-heating/mains-water-systems/drainage-systems>.
- [38] F. I. Club, "Indoor plumbing," 02 05 2010. [Online]. Available:  
<http://home.howstuffworks.com/home-improvement/plumbing/plumbing-basics-ga1.htm>.  
[Accessed 18 05 2017].
- [39] 2008. [Online]. Available: <http://inspectapedia.com/plumbing/1625s.jpg>.
- [40] N. D. University, 2017. [Online]. Available: <https://www.ag.ndsu.edu/publications/home-farm/individual-home-sewage-treatment-systems/figure-1-house-plumbing.png>.
- [41] Nederlands Normalisatie-instituut, NEN 1824 - Requirements of the space and height of office workplaces, 1995.
- [42] Construction Buena Vista, [Online]. Available:  
<http://www.constructionbuenavista.com/articles-advice/converting-an-underbuild/>.  
[Accessed 10 03 2017].
- [43] "ContainerHome," [Online]. Available: <https://containerhomes.net/learning-center/how-to-center/how-to-install-electricity-on-a-shipping-container-home/>. [Accessed 15 May 2017].
- [44] "The Free Dictionary," [Online]. Available: <http://www.freethesaurus.com/floor+plan>.  
[Accessed 26 May 2017].
- [45] "Engineering Training," [Online]. Available:  
<http://engineeringtraining.tpub.com/14069/css/Floor-Plan-334.htm>. [Accessed 26 May 2017].
- [46] "Premier Shipping Container," [Online]. Available:  
<http://premiershippingcontainers.com.au/shipping-container-dimensions.html>. [Accessed 10 May 2017].
- [47] "GOV.UK," [Online]. Available:  
[https://www.gov.uk/government/uploads/system/uploads/attachment\\_data/file/441786/BR\\_PDF\\_AD\\_M2\\_2015.pdf](https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/441786/BR_PDF_AD_M2_2015.pdf). [Accessed 28 May 2017].

- [48] "nationalarchives.gov.uk," [Online]. Available: [http://webarchive.nationalarchives.gov.uk/20151113141044/http://www.planningportal.gov.uk/uploads/br/br\\_pdf\\_ad\\_m1\\_2015.pdf](http://webarchive.nationalarchives.gov.uk/20151113141044/http://www.planningportal.gov.uk/uploads/br/br_pdf_ad_m1_2015.pdf). [Accessed 25 May 2017].
- [49] "Fomento," [Online]. Available: <https://www.fomento.gob.es/NR/rdonlyres/EC23F871-B5EB-4482-8E3D-10B40D251397/116390/ACCESSEspaPublicUrba.pdf>. [Accessed 29 May 2017].
- [50] "Root Electric," [Online]. Available: <http://www.rootelectric.com/benefits-recessed-lighting/>. [Accessed 30 May 2017].
- [51] A. Schmitz, "Recessed Lighting," [Online]. Available: <http://recessedlighting.com/recessed-lighting-spacing/>. [Accessed 25 May 2017].
- [52] [Online]. Available: [http://www.ilo.org/wcmsp5/groups/public/---americas/---ro-lima/---sro-port\\_of\\_spain/documents/presentation/wcms\\_250198.pdf](http://www.ilo.org/wcmsp5/groups/public/---americas/---ro-lima/---sro-port_of_spain/documents/presentation/wcms_250198.pdf). [Accessed 8 Jun 2017].
- [53] 2017. [Online]. Available: <http://www.ecology.com/wp-content/uploads/2012/11/whole-system-1100.jpg>.
- [54] T. Klenck, "Indoor water supply," 32 09 2005. [Online]. Available: <http://www.popularmechanics.com/home/interior-projects/how-to/a153/1275141/>. [Accessed 01 06 2017].
- [55] 2017. [Online]. Available: [http://www.homedepot.com/catalog/productImages/1000/e5/e547a158-5862-4de6-8a1b-0aa7b3714dee\\_1000.jpg](http://www.homedepot.com/catalog/productImages/1000/e5/e547a158-5862-4de6-8a1b-0aa7b3714dee_1000.jpg).
- [56] D. d. Torres, "Ventilation for Designing Better Buildings," 15 09 2017. [Online]. Available: <http://info.zehnderamerica.com/blog/natural-ventilation-vs-mechanical-ventilation>. [Accessed 09 05 2017 ].
- [57] "Central air conditioning," 2015. [Online]. Available: [http://www.central-air-conditioner-and-refrigeration.com/Refrigeration\\_Cycle.html](http://www.central-air-conditioner-and-refrigeration.com/Refrigeration_Cycle.html).
- [58] 2015. [Online]. Available: <https://www.thecoolshop.com.au/wp-content/uploads/2016/03/Sunshine-Coast-Multi-Split-air-conditioning-zones.jpg>.
- [59] F. climate, "Multisplit systems," Fujitsu, 2015.
- [60] "Soundproofing FAQ," [Online]. Available: <http://www.tmsoundproofing.com/soundproofing-faq.html>. [Accessed 6 Jun 2017].



- [61] "External Wall Insulation versus Internal Wall Insulation," 12 November 2014. [Online]. Available: <http://www.thegreenage.co.uk/external-wall-insulation-versus-internal-wall-insulation/> . [Accessed 2 April 2017].
- [62] G. H.Hart, "K-Value, U-Value, R-Value, C-Value," 1 March 2009. [Online]. Available: <http://insulation.org/io/articles/k-value-u-value-r-value-c-value/>. [Accessed 2 April 2017].
- [63] "Cork Shop BCN," [Online]. Available: <https://www.corkshopbcn.com/en/thermal-insulation/142-thermal-aglocork.html>. [Accessed 5 Jun 2017].
- [64] "Poliuretano Projectado," [Online]. Available: <http://www.caatlleida.cat/Fitxers/CentreDocumentacio/Biblioteca/NBibliografiques/Index/BD-7132.pdf>. [Accessed 5 Jun 2017].
- [65] "How to Install Insulation in a shipping container home," [Online]. Available: <https://containerhomes.net/learning-center/how-to-center/how-to-install-installation-in-a-shipping-container-home/>. [Accessed 7 Jun 2017].
- [66] "Impact and Airborne Sound," [Online]. Available: [http://www.gypsumsolutions.com.au/uploaded/files/client\\_added/powerscape\\_impact\\_and\\_airborne\\_sound\\_overview%5B1%5D\(1\).pdf](http://www.gypsumsolutions.com.au/uploaded/files/client_added/powerscape_impact_and_airborne_sound_overview%5B1%5D(1).pdf). [Accessed 6 Jun 2017].
- [67] "Airborne Sound," [Online]. Available: [https://www.designingbuildings.co.uk/wiki/Airborne\\_sound](https://www.designingbuildings.co.uk/wiki/Airborne_sound). [Accessed 6 Jun 2017].
- [68] "Closed Cell spray foam insulation in commercial buildings," [Online]. Available: <https://www.honeywell-blowingagents.com/?document=closed-cell-spray-foam-insulation-for-commercial-buildings&download=1>. [Accessed 5 Jun 2017].
- [69] "Placa aislante de algodón," [Online]. Available: <http://www.ecogreenlan.com/?product=placa-aislante-de-algodon>. [Accessed 6 Jun 2017].
- [70] "Impact Sound," [Online]. Available: [https://www.designingbuildings.co.uk/wiki/Impact\\_sound](https://www.designingbuildings.co.uk/wiki/Impact_sound). [Accessed 6 Jun 2017].
- [71] "Do it yourself," [Online]. Available: <http://www.doityourself.com/stry/pros-and-cons-of-having-a-suspended-ceiling>. [Accessed 02 06 2017].
- [72] OWA - Odenwald Faserplattenwerk GmbH, Preisliste 1/2013, Amorbach, 2013.

- [73] Forbo Flooring, [Online]. Available: <http://www.forbo.com/flooring/es-es/>. [Accessed 01 06 2017].
- [74] M. Hammermeister, 01 05 2017. [Online]. Available: <http://www.massivhaus.de/ratgeber/wie-lange-ist-die-bauzeit-von-einem-massivhaus.html>. [Accessed 27 05 2017].
- [75] C. Taylor, "Intrinsic Landscapes," 14 08 2014. [Online]. Available: <http://intrinsiclandscapes.com/?p=135>. [Accessed 06 06 2017].
- [76] Hornbach, "Hornbach," [Online]. Available: <http://www.hornbach.de/shop/Vierkantrohr-Stahl-80x80x2-5-mm-1-m/7810826/artikel.html>. [Accessed 06 06 2017].
- [77] Constructin Mentor Online, "Construction Mentor Online," [Online]. Available: <https://constructionmentor.net/removing-metal-door-frame/> . [Accessed 06 06 2017].
- [78] Tom, "Container Home Plans," 27 02 2015. [Online]. Available: <http://www.containerhomeplans.org/2015/02/delivering-and-siting-your-shipping-containers/>). [Accessed 04 06 2017].
- [79] "Our Container House," [Online]. Available: <http://www.ourcontainerhouse.com/diy-home-construction.html>. [Accessed 31 05 2017].
- [80] Ben's Containers, "Ben's Containers," [Online]. Available: <http://www.benscontainers.com/gallery.html>. [Accessed 31 05 2017].
- [81] Mobil Heim, "Mobil Heim," 25 09 2016. [Online]. Available: <http://www.mobilheim.com/terrasse-holz-unterkonstruktion-fotos-das-sieht-erstaunlich-fur-dich-hauptentwurf-bewertung/>. [Accessed 08 06 2017].
- [82] "Gelaenderladen," [Online]. Available: <https://www.gelaenderladen.de/edelstahlgelaender/designen/>. [Accessed 27 05 2017].
- [83] Tom, "Container Home Plans," 22 05 2017. [Online]. Available: <http://www.containerhomeplans.org/2017/05/this-couple-turned-2-shipping-containers-into-a-home/> . [Accessed 06 06 2017].
- [84] "Super Cubes LLC," 05 09 2014. [Online]. Available: <https://www.supercubes.com/blog/2014/9/insulated-20-container-shed-in-minneapolis>. [Accessed 04 06 2017].
- [85] "Carpentry Tips and Tricks," [Online]. Available: <http://www.carpentry-tips-and-tricks.com/cutting-plasterboard.html> . [Accessed 02 06 2017].

- [86] "Benz 24," [Online]. Available: <https://benz24.de/trockenbauwand/>. [Accessed 02 06 2017].
- [87] Tom, "Container Home Plans," 04 10 2016. [Online]. Available: <http://www.containerhomeplans.org/2016/10/should-you-remove-the-plywood-floors-in-your-shipping-containers/>. [Accessed 23 05 2017].
- [88] Bundesvereinigung Bauwirtschaft, "Baukostenplanung," 2016.
- [89] [Online]. Available: <https://weather-and-climate.com/average-monthly-Rainfall-Temperature-Sunshine,vilanova-i-la-geltru-catalonia-es,Spain>. [Accessed 31 03 2017].
- [90] [Online]. Available: <https://www.windfinder.com/windstatistics/vilanova> . [Accessed 08 March 2017].
- [91] [Online]. Available: <http://www.suncalc.org/#/41.2237,1.7334,19/2017.06.21/21:53/1/0> . [Accessed 03 March 2017].
- [92] A. Williams, "Off grid free yourself," [Online]. Available: <https://www.off-grid.net/spains-sun-tax-axed/>. [Accessed 15 May 2017].
- [93] "renewableenergyworld," 23 October 2015. [Online]. Available: <http://www.renewableenergyworld.com/articles/2015/10/spain-approves-sun-tax-discriminates-against-solar-pv.html>. [Accessed 23 March 2017].
- [94] "PV-magazine," 9 October 2015. [Online]. Available: [https://www.pv-magazine.com/2015/10/09/spains-government-approves-the-sun-tax\\_100021485/](https://www.pv-magazine.com/2015/10/09/spains-government-approves-the-sun-tax_100021485/). [Accessed 15 May 2017].
- [95] "Resuelve tus dudas sobre el rd de autoconsumo," [Online]. Available: <http://es.krannich-solar.com/es/autoconsumo/que-es-la-energia-solar/dudas-rd-autoconsumo.html>. [Accessed 15 May 2017].
- [96] I. M. & K. H.Lincke, "Mariscal&Abogados," [Online]. Available: <http://www.mariscal-abogados.com/sun-tax-on-photovoltaic-systems-in-spain/>. [Accessed 21 March 2017].
- [97] "hm sistemas - energia solar," [Online]. Available: [http://www.hmsistemas.es/shop/catalog/calculadora\\_hsp.php](http://www.hmsistemas.es/shop/catalog/calculadora_hsp.php). [Accessed 16 May 2017].
- [98] "Solar Electricity Handbook," [Online]. Available: <http://solarelectricityhandbook.com/solar-irradiance.html>. [Accessed 15 May 2017].

- [99] J. Sanchez, "homepower," [Online]. Available: <https://www.homepower.com/articles/solar-electricity/design-installation/pv-array-sizing-kwh>. [Accessed 14 May 2017].
- [100] "what is sun tax?," [Online]. Available: <https://www.b2bio.bio/en/noticias-productos-ecologicos/what-is-the-sun-tax>. [Accessed 5 May 2017].
- [101] "iberdrola," [Online]. Available: <https://www.iberdrola.es/homeowners-associations/information/bill/electricity-bill/iberdrola-comercializacion>. [Accessed 16 May 2017].
- [102] "pvgrid," [Online]. Available: <http://www.pvgrid.eu/es/national-updates/spain.html>. [Accessed 16 May 2017].
- [103] I. Woofendedn, "home power Off or On grid," 2009. [Online]. Available: <https://www.homepower.com/articles/solar-electricity/design-installation/or-grid>. [Accessed 16 May 2017].
- [104] Livios, "Richtprijzen riolering en afvoer," 2017. [Online]. Available: <http://www.livios.be/nl/bouwinformatie/techniek/sanitair-en-water/richtprijzen-riolering-en-afvoer/>. [Accessed 23 05 2017].
- [105] H. depot, "Pricing sheets HVAC," 2017. [Online]. Available: <http://www.homedepot.com/p/Rheem-Performance-Performance-Platinum-Hybrid-Electric-80-Gal-Tank-Water-Heater-High-Efficiency-Mobile-Alert-Compatible-10-Yr-Wnty-XE80T10HD50U0/300620269>.
- [106] W. S. G. bv, "Pricing sheet HETCU," 2015. [Online]. Available: <https://www.warmteservice.nl/Installatiemateriaal/Leidingen/Koperen-leiding/Hetcu-buis-met-Gastec-QA-keur-15-mm/p/40852155>.
- [107] Fujitsu, "Pricing sheets units," 2016. [Online]. Available: <http://barcelona.solofujitsu.com/multisplit/?gclid=CKCJ9aaQI9QCFZUV0wodCMUItA>. [Accessed 23 05 2017].
- [108] "Residential Shipping Container Primer," [Online]. Available: <http://www.residentialshippingcontainerprimer.com/Shipping%20Container%20Plan%20and%20Section%20Details>. [Accessed 2017 May 15].
- [109] "Steel Stud," [Online]. Available: [http://www.gyprock.com.au/documents/gyprock-544-steel\\_frame\\_wall\\_systems-201201.pdf](http://www.gyprock.com.au/documents/gyprock-544-steel_frame_wall_systems-201201.pdf). [Accessed 7 Jun 2017].

- [110] "Kitchen Dimension," [Online]. Available: <http://www.houseplanshelper.com/kitchen-dimensions.html>. [Accessed 25 May 2017].
- [111] "Calculator.net," [Online]. Available: <http://www.calculator.net/stair-calculator.html?ctype=one&printit=0&totalheight=12&totalheightunit=centimeter&run=11&rununit=centimeter&totalrun=15&totalrununit=foot&x=102&y=21>. [Accessed 29 May 2017].
- [112] "Lighting Calculation," [Online]. Available: <http://www.houseplanshelper.com/lighting-calculation.html>. [Accessed 25 May 2017].
- [113] Tom, "5 Methods to Insulate Your Shipping Container Home," 23 March 2015. [Online]. Available: <http://www.containerhomeplans.org/2015/03/5-methods-to-insulate-your-shipping-container-home/>. [Accessed 10 March 2017].
- [114] "Benefits of E: Zero Spray Foam," [Online]. Available: <https://uvaluesprayfoaminsulation.ie/spray-foam-insulation-benefits.html>. [Accessed 5 Jun 2017].
- [115] [Online]. Available: <http://www.ewis-ukltd.co.uk/spray-foam-insulation/>. [Accessed 2 April 2017].
- [116] [Online]. Available: <http://farmfolly.com/2012/05/installing-sheep-wool-insulation-batts/>. [Accessed 2 April 2017].
- [117] "Energy," [Online]. Available: <https://energy.gov/energysaver/insulation-materials>. [Accessed 17 May 2017].
- [118] "The advantages of sheep wool insulation," 28 March 2014. [Online]. Available: <https://www.thegreenage.co.uk/advantages-sheep-wool-insulation/>. [Accessed 2 April 2017].
- [119] "Insulation Recommendation," [Online]. Available: [https://www.buildinggreen.com/sites/default/files/BG\\_Insulation\\_Recommendations.pdf](https://www.buildinggreen.com/sites/default/files/BG_Insulation_Recommendations.pdf).
- [120] [Online]. Available: <https://uvaluesprayfoaminsulation.ie/container-insulation.html>. [Accessed 2 April 2017].
- [121] T. Owens, "The Pros and Cons of Straw Bale Wall Construction In Green Building," [Online]. Available: <http://buildingwithawareness.com/the-pros-and-cons-of-straw-bale-wall-construction-in-green-building/>. [Accessed 2 March 2017].

- [122] "Comparison of natural insulation materials," [Online]. Available: <http://www.sustainablebuildingresource.co.uk/files/serve/files/serve/1503/8fcba7c07791983996701f58577cf78406b722d4/>.
- [123] "Corkstore24," [Online]. Available: <http://corkstore24.co.uk/shop/11-thermal-and-sound-insulation-expanded-cork-boards/>. [Accessed 4 Jun 2017].
- [124] [Online]. Available: <https://www.alibaba.com/showroom/1.5kw-wind-turbine.html> . [Accessed 15 March 2017].
- [125] Agencia Estatal BOLETÍN OFICIAL DEL ESTADO, 27 December 2013. [Online]. Available: [https://www.boe.es/diario\\_boe/txt.php?id=BOE-A-2013-13645](https://www.boe.es/diario_boe/txt.php?id=BOE-A-2013-13645) . [Accessed 21 March 2017].
- [126] [Online]. Available: <https://www.rmets.org/weather-and-climate/observing/beaufort-scale> . [Accessed 08 March 2017].
- [127] [Online]. Available: <http://bigfablab.com/get-connected/what-is-a-maker-space/>. [Accessed 02 April 2017].
- [128] [Online]. Available: [http://www.joostdevree.nl/shtmls/paalfundering\\_voorbeelden.shtml](http://www.joostdevree.nl/shtmls/paalfundering_voorbeelden.shtml) . [Accessed 01 April 2017].
- [129] [Online]. Available: <https://www.packtpub.com/books/content/fab-lab-digital-fabrication>. [Accessed 02 04 2017].
- [130] [Online]. Available: <http://design-engine.com/makerspaces-the-future-of-education/>. [Accessed 02 04 2017].
- [131] Gruascano, [Online]. Available: <http://www.gruascano.com/?ack=1490804260> . [Accessed 30 March 2017].
- [132] Emilio Aguilar, [Online]. Available: [http://www.alquiler-gruas-transportes.com/es\\_ES/index.php](http://www.alquiler-gruas-transportes.com/es_ES/index.php). [Accessed 30 March 2017].
- [133] Ricard Mateu, [Online]. Available: <http://www.ricardmateu.com/es/>. . [Accessed 01 April 2017].
- [134] EixVerd, [Online]. Available: <http://www.eixverd.cat/en/>. [Accessed 01 April 2017].
- [135] Igniagreen, [Online]. Available: <http://www.igniagreen.com/en/>. . [Accessed 01 April 2017].
- [136] Verdjardins, [Online]. Available: <http://www.verdjardins.com/>. . [Accessed 01 April 2017].

- [137] Reteco, [Online]. Available: <http://www.reteco.es/reteco.en/index.html>. . [Accessed 30 March 2017].
- [138] Titan Containers, [Online]. Available: <http://titancontainers.com/ES.aspx>. [Accessed 30 March 2017].
- [139] Remsa, [Online]. Available: <http://www.remsa.net/en/used/shipping-containers>. [Accessed 30 March 2017].
- [140] Caru Containers, [Online]. Available: <http://www.carucontainers.com/int>. [Accessed 30 March 2017].
- [141] [Online]. Available: <http://www.greenroofs.org/index.php/about/aboutgreenroofs>. [Accessed 31 03 2017].
- [142] [Online]. Available: <http://www.greenroofs.org/index.php/about/aboutgreenroofs>. [Accessed 31 03 2017].
- [143] [Online]. Available: <http://legal-planet.org/2014/04/16/ipcc-report-highlights-need-for-rapid-shift-to-renewable-energy-delay-will-be-costly/>. [Accessed 31 03 2017].
- [144] [Online]. Available: <http://commons.bcit.ca/greenroof/faq/why-green-roofs-benefits/>. [Accessed 31 03 2017].
- [145] 2 4 2017. [Online]. Available: <http://www.dsv.com/sea-freight/sea-container-description/dry-container>.
- [146] [Online]. Available: <http://www.dsv.com/sea-freight/sea-container-description/dry-container> . [Accessed 02 04 2017].
- [147] [Online]. Available: [https://en.wikipedia.org/wiki/Intermodal\\_container](https://en.wikipedia.org/wiki/Intermodal_container). [Accessed 22 02 2017].
- [148] "Basic U-Values for Different Thicknesses of Sprayed Polyurethane Foam Insulation," [Online]. Available: <http://www.usemyloft.com/content/u-values>. [Accessed 2 April 2017].
- [149] "Panel Specification," [Online]. Available: <http://site.dyd.com.ph/main/3000/index.asp?pageid=131313&t=panel-specification>. [Accessed 2 April 2017].

- [150] "Thickness of solid wall insulation and U-values you can achieve," 12 August 2015. [Online]. Available: <http://www.thegreenage.co.uk/thickness-solid-wall-insulation-u-values-can-achieve/>. [Accessed 2 April 2017].
- [151] "Comparison of natural insulation materials," [Online].
- [152] [Online]. Available: <http://www.northerncorks.com/cork-panels.html> . [Accessed 2 April 2017].
- [153] J. Lee, "All about Shipping Containers Floors," [Online]. Available: <https://containerhomes.net/articles/all-about-container-floors/> . [Accessed 2 April 2017].
- [154] Tom, "Should You Remove the Plywood Floors in Your Shipping Containers?," 4 October 2016. [Online]. Available: <http://www.containerhomeplans.org/2016/10/should-you-remove-the-plywood-floors-in-your-shipping-containers/>. [Accessed 2 April 2017].
- [155] [Online]. Available: <http://www.eurima.org/resource-centre/facts-figures/u-values-in-europe.html>. [Accessed 27 02 2017].
- [156] [Online]. Available: <https://logistikknowhow.com/twenty-foot-equivalent-unit-teu/>. [Accessed 12 06 2017].
- [157] "Recommended Lux Level," [Online]. Available: <http://www.reconelectrical.co.uk/image/data/pdfs/Recommended%20Lux%20Levels.pdf>. [Accessed 6 Jun 2017].
- [158] U. construction, "Pile foundation," [Online]. Available: [http://www.understandconstruction.com/uploads/1/7/0/2/17029032/\\_2848588\\_orig.png](http://www.understandconstruction.com/uploads/1/7/0/2/17029032/_2848588_orig.png).



## Appendices

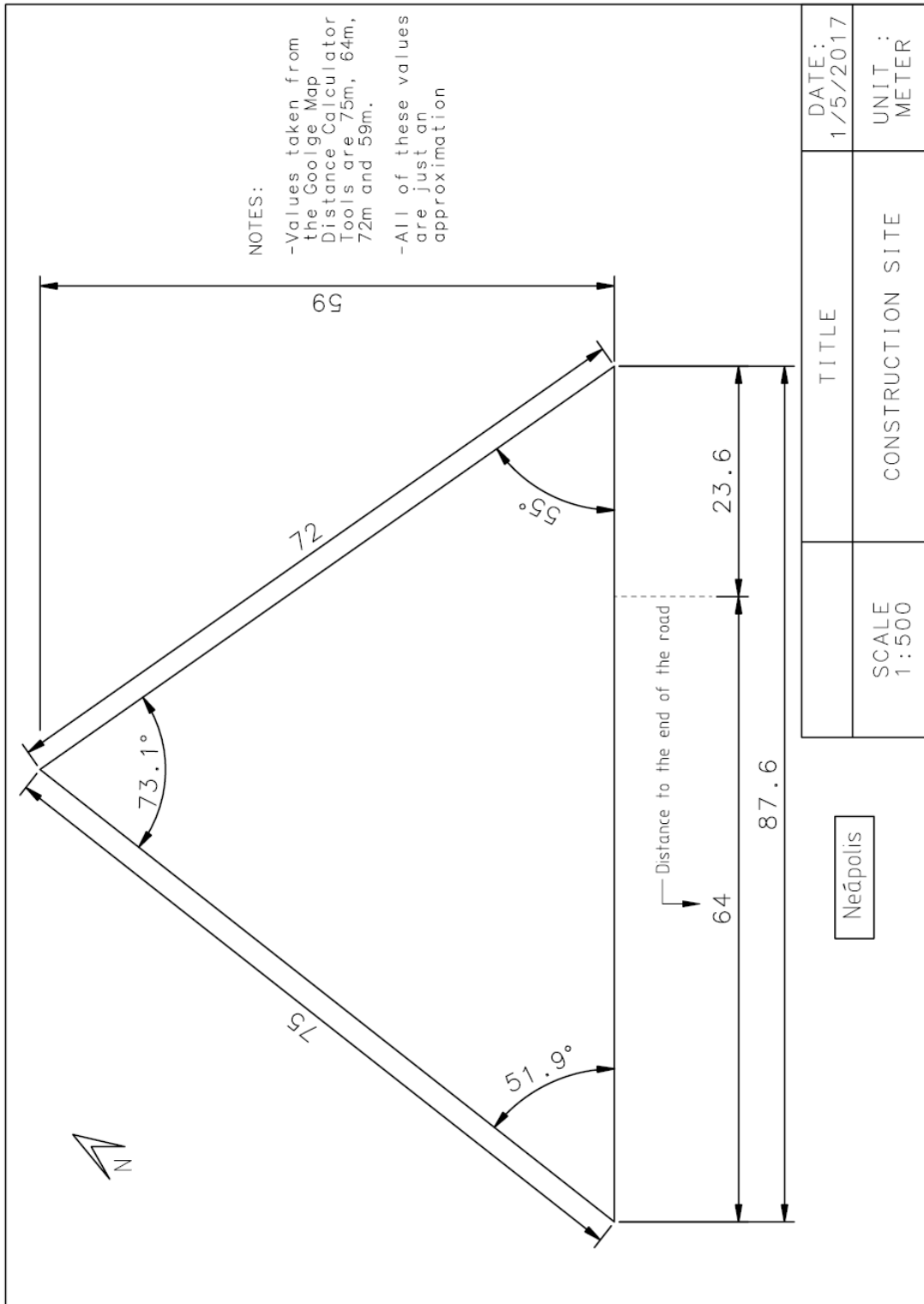
### Official Project Brief

The Outcome of this project is to design a cowork using sea containers. The main goals to be fulfilled are the following:

1. The general design of the construction has to be attractive.
2. The urban norms that correspond to this lot must be complied with.
3. Studies of resistance of materials and of terrain resistance should be made, in order to ensure the stability of the construction.
4. Adequate design of the interior space must be made.
5. Studies of materials, thermal insulation and facilities should be made, in order to comply with current regulations and ensure the comfort of cowork users.
6. Studies of the construction process should be made, including the whole process, from the transport and placement of the maritime containers, the interior conditioning, etc.
7. The cost of this construction must be calculated.
8. A proposal must be made to adapt the rest of the lot, with gardens and / or urban elements. The design must be attractive and in accordance with the innovative spirit of Neàpolis and with the new cowork built with seacontainers

### Appendix A

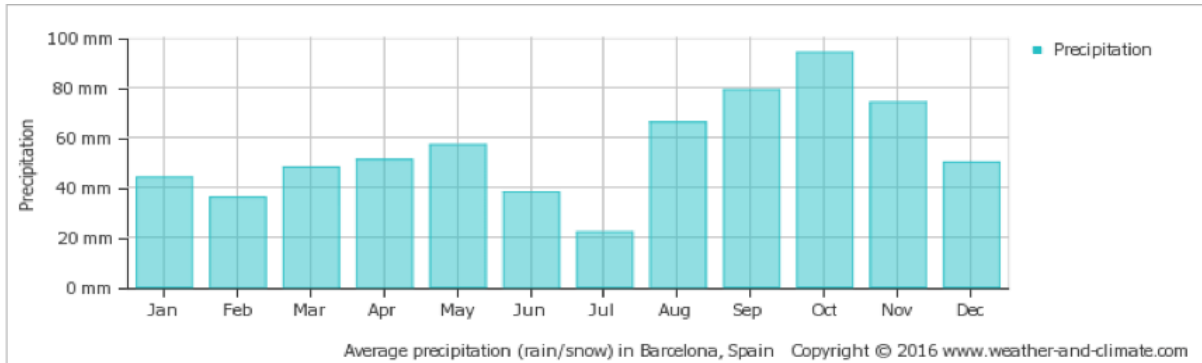
Figure 117: Drawing of the simplified triangle of the construction site with its dimensions



## Appendix B

*These are the data of the rain fall, wind direction and speed, and the sun’s path and positions for the study on the climate in Vilanova i la Geltru*

### Rain Fall



**Figure 118: Graph of average precipitation in Barcelona, Spain [89]**

The bar chart above shows the average precipitation in Barcelona throughout a year.

Data from the graph:

- Range of average precipitation: 22mm – 95mm
- Month with highest precipitation: October with 95mm
- Average annual precipitation: ~675mm

### Wind Direction and Speed

Month of year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
	01	02	03	04	05	06	07	08	09	10	11	12	1-12
Dominant wind direction	↖	↗	↖	↘	↖	↖	↖	↘	↘	↖	↖	↖	↖
Wind probability >= 4 Beaufort (%)	1	1	1	1	0	0	0	0	0	0	1	1	1
Average Wind speed (kts)	2	3	3	3	3	2	2	2	2	2	2	2	2
Average air temp. (°C)	12	13	15	17	20	24	26	27	25	21	17	13	19

**Figure 119: Wind statistic based on observations taken between 12/2010 - 02/2017 daily from 7am to 7pm local time [90]**

**Unit conversion:**      1 kts = 0.514 m/s      2 kts = 1.029 m/s      3 kts = 1.543 m/s

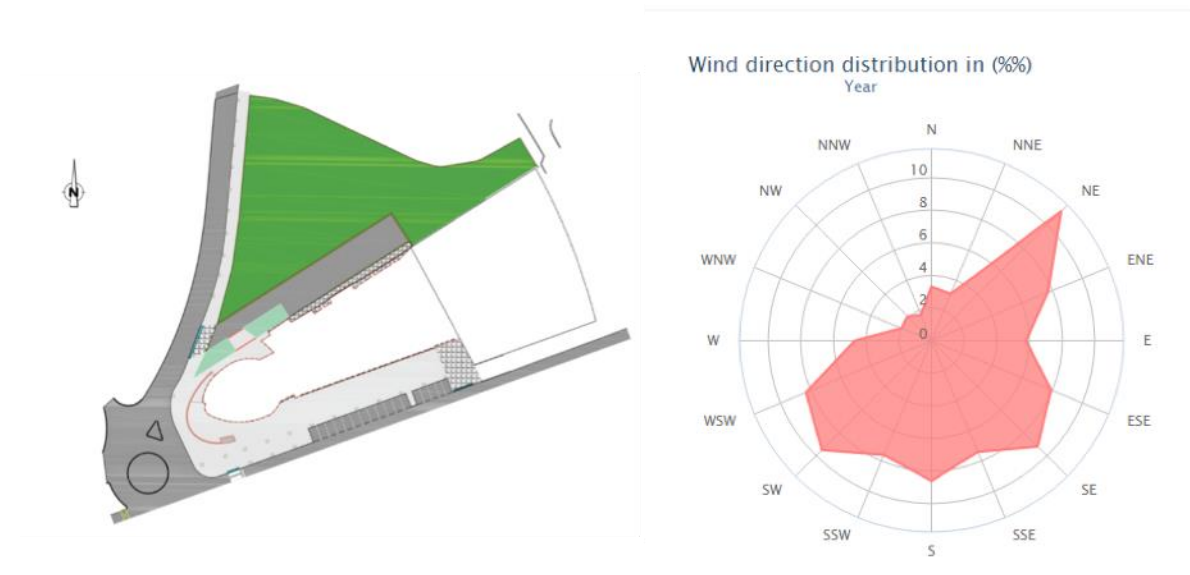


Figure 120: Construction site side by side with wind direction distribution [90]



Sun's Path and Positions

Figure 121: Sun's path during summer solstice (left) and during winter solstice (right) [91]

The orange line indicates the sunrise while the red line indicates the sunset.

## Appendix C

### *Research details of the solar power.*

It all began when the law on the self-consumption of energy was approved by Spain's government in October 2015 [92]. The following are conditions that has to take into consideration by Neàpolis if the photovoltaic (PV) or solar panel system is going to be used in this project:

1. PV system owner has to pay the same grid fees as non-solar panel user. Keep in mind that this is not just for the power that in contract with the electricity company but also for the power from the PV system [93]. Also, please note that this grid fees are only applicable if the sea container building is going to be connected to the grid and at the same time using the solar power. So why choose to be in the grid? This will be discussed later at the end of this research.
2. If the PV system is bigger than 10 kW, another tax called second "sun tax" need to be paid for the electricity generated and use from the PV system even though it is off grid. In other words, the owner of PV system that is under 10kW will be exempt from paying this second "sun tax" [92].
3. The usage of batteries is allowed but it cannot be used to lower the amount of the tax that need to be paid based on the capacity of PV systems [94].
4. Any PV systems up to 100 kW is prohibited from selling electricity and required to donate the extra electricity generated to the grid for free [92].
5. Only systems over 100 kW are allowed to sell the extra electricity produced in the spot market<sup>5</sup> but the owner must register first [92]. The registration has to made with RIPRE (Registro de Instalaciones Productoras en Régimen Especial) [95].
6. For PV systems up to 100 kW, the owner of the installation must be the owner of the contract with the electricity company [93].
7. Community ownership of the PV system whether the system is up to 100kW or over, is prohibited [93].
8. Permissions need to be obtained before installation takes place. Every grid-connected electricity system needs authorization from its electricity supplier and the Spanish Government [96].

---

<sup>5</sup> Spot market: where assets are sold for cash and delivered immediately **Invalid source specified.**

If any of these conditions mentioned above is not met, the owner could be subjected to high penalty fee of up to 60 million euros [93]. Now, the information about the regulations seem to be clear enough but which taxes or fees has to be paid if a PV system is installed on the sea container building?

According to Neàpolis, they normally consume about 560,000 kWh of energy per year. By using this value as a reference, a calculation is made to know how much roughly the power of the PV system needed. Several assumptions as follow are made to simplify the calculation:

- The sea container building is assumed to need only one-third of the energy averagely consumed by current Neàpolis building per year by considering the size of the building and also the estimated number of facilities and workers.
- Average peak sun-hours/day in Barcelona in January which is its coldest month is 2.692 hours/day [97]. This average peak sun-hour is calculated with a Spanish online application called “Calculadora De Horas Solares Pico”. In the application, Barcelona is selected as the province, month is set to January as to get the max power output needed from the PV system and the inclination of the solar panel is set to 50°. This is the closest value that can be set in the application to the actual optimum angle of solar panel for a year-round in Barcelona which is at 49° [98].
- Average efficiency factor of solar panel system is 72% or 0.72 [99].

Calculation:

$$560,000 \text{ kWh/year} \div 3 = 186,667.67 \text{ kWh/year}$$

$$186,667.67 \text{ kWh/year} \div 365 \text{ days/year} = 511.42 \text{ kWh/day}$$

$$511.42 \text{ kWh/day} \div 2.69 \text{ sun-hours/day} = 189.98 \text{ kW}$$

$$189.98 \text{ kW} \div 0.72 \text{ efficiency factor} = \mathbf{263.85 \text{ kW}}$$

From the result of the calculation, about 264 kW of PV system is required to fully power up the sea container building over the course of a year. Since there is also possibility that Neàpolis want to use the solar power to supply electricity to only some part of the building, further calculations are made and the results are shown in the table below.

Percentage of energy consumption generated from PV system (%)	20 %	40 %	60 %	80 %	100 %
Max capacity of PV system required (kW)	52.77 kW	105.54 kW	158.31 kW	211.08 kW	263.85 kW

**Table 21: Calculation solar power**

By referring to the result above, even to generate 20% of the electricity consumption of the sea container building per day, about 53 kW of PV system is needed. Please note that this is the maximum capacity required in a year as in the summer, this value could be lower since the average peak sun-hour is longer. Thus, if this is the case, Neápolis has to pay both the grid fees and also the second “sun tax”.

The current exact amount of the sun tax is still uncertain but they appear to be around 9 euros plus VAT per kW of the installed power of each panel and about 5 cents per kWh to produce and consume it [100]. As for the grid fees, they seem to consist of access toll and the backup toll. Access toll is a toll that is corresponding to the supply point for accessing the grid [101] while the backup toll is basically a fee that need to be paid for every MWh of electricity produced and self-consumed as a contribution to the fixed cost of the grid [102]. It is believed that their rate varies depending on the contracted power with the electricity company.

Back to the question mentioned before, why not just completely going off grid to avoid the grid fees? By not relying to the grid at all would significantly increase the initial construction cost because a complete PV system is needed to be installed first in order for the sea container building to become completely functional. Since Neápolis budget is reported to be quite limited, this probably could be an obstacle for them in realizing this project. Besides, off-grid system needs batteries to store the generated electricity and over time, these batteries need maintenance and replacement [103]. All of these definitely cost a lot of money.

## Appendix D

### Price calculation foundation

Prices are with placement and transport included

#### Concrete beams under structure (40 cm x 40 cm)

Stortbeton - betoncentrale - Klasse C25/30	m <sup>3</sup>	95,00
--------------------------------------------	----------------	-------

Total length of the beams: 151,55m

Total volume of the beams:  $0,4 \times 0,4 \times 151,55 = 24,248 \text{ m}^3$

Total price:  $95 \times 24 = 2\,280 \text{ eur}$

#### Full plates (electrical water heating room and exhibition room)

Vloerplaat in beton, 15 cm dik, inclusief wapening en randbekisting	m <sup>2</sup>	77,30
---------------------------------------------------------------------	----------------	-------

Water heating room: 2,5 m<sup>2</sup>

Exhibition area: 47,21 m<sup>2</sup>

Total price:  $3\,843 \text{ eur}$

#### Foundation on wells, diameter 80cm – 128eur/m

37 x 3m deep =  $14\,208 \text{ eur}$

**Total costs for the foundation: 20 331 eur**



**Detailed price calculation: sewage**

*The prices in the source are estimations. Placing costs and costs for the digging are excluded.*

*+ extra additions for traps and cleanout plugs*

Control point, pvc, d 30cm – 121,9eur/st.

PVC, d 50mm – 19,3eur/m. – total 138,96eur

+0: 3,5m (ground length) -> 67,55eur

+1: 3,7m (ground length) -> 71,41eur

PVC, d 100mm – 32,4eur/m. – total 1 616,76eur

+0: 34,7m (ground length) -> 1 124,28eur

+1: 9,4 (ground length) -> 304,56eur

+0 -> +1: 5,8m (main vent going through the whole structure) -> 187,92eur

+ an additional 800eur for traps, connections and cleanout plugs

**Total: 2 678eur**

[104]

**Detailed price calculation: water supply**

**Electrical water heating tank** (placement costs excluded)

RHEEM Hybrid Tank – 1 704,21eur

[105]

**Water service pipes** (placement costs excluded)

Cold water piping, hetcu – 7,25eur/m – total 428,45eur

+0: 23,9m + 3m (height) -> 195eur

+1: 32,2m -> 233,45eur

Hot water piping, hetcu - 7,25eur/m – total 332,06eur

+0: 19,1m + 3m (height) -> 160,23eur

+1: 23,7m -> 171,83eur

An additional 200eur for connections and valves

[106]

**Total: 960,5eur**

**Price calculation: HVAC**

**Multi-split** (*indoor and outdoor units included, placement costs included*)

Left wing of construction: 8x1 multi-split unit

*8 498eur*

Right wing of the construction: 5x1 multi-split unit

*4 898eur*

**Total: 13 396eur**

[107]

## Appendix E

### Estimation of wall thickness

For the final thickness of the walls without the exterior cladding, it could be assumed that there are not differ much from an example of a home container project found online [108]. The following are the estimated thickness of the walls that are used in the drawing:

#### 1. Thickness of walls from the interior wall of the container

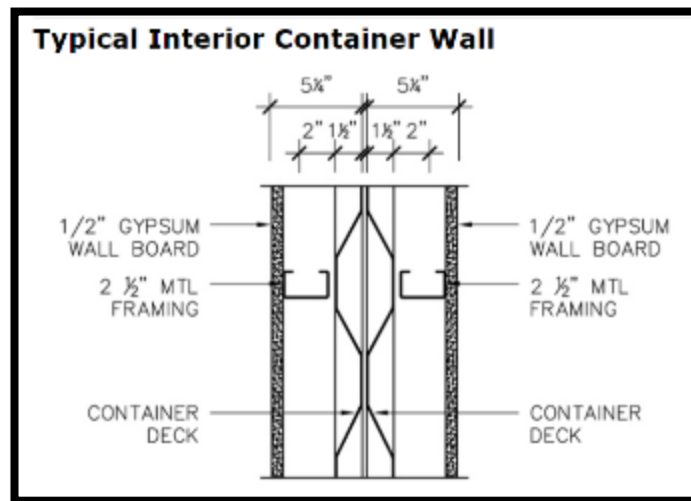


Figure 122: Typical interior container wall [108]

A related point to consider is that in this project, the spray polyurethane foam (SPF) insulation is going to be installed from the inside. By referring to the diagram above, for both part of the walls that either require the SPU insulation or not, the thickness that will be added into the drawing is 95.25mm, which is about 3.75inch.

Even though the same amount of thickness is added to each sides of the interior walls, it seems that the total thickness for the front and the back of the container are different from the side walls. This is because of the way of a container is drawn as shown in Figure X in the previous page. The 1.5 inch could be excluded as the interior walls of the container is already included in the NX11 drawing.

$$5.25inch - 1.5inch = 3.75inch \text{ or approximately } 95.25mm$$

#### 2. Thickness of additional wall

The same way of estimation is applied to the additional wall. It will consist of 2.5inch or 63.5mm metal framing and 2 finishing board on both sides of the frame with either a sound blocking insulation inside or not.

$$2.5inch + 0.5inch + 0.5 = 3.5inch \text{ or approximately } 88.9mm$$

### 3. Thickness of curved exterior wall (Steel Framing)

If a non-loadbearing internal wall that has height greater than 5792mm (total height of the sea container building) needs steel studs that have at least 92mm of depth of web [109], logically, the thickness of the curved exterior wall should be double or triple that figure. This is because of the curved exterior wall probably has to support load far greater than the internal wall. Thus, it is estimated that the thickness of the curved exterior wall is to be about **300mm** with insulation and finishing included. Please note that this estimation might be not accurate due to lack in knowledge and information about the steel frame structure. However, this estimation is needed in order to make the drawing of the floor plans as close to the real scale as possible.

### 4. Thickness of wall for the spacing left for the elevator installation (Steel Framing)

The same way of estimation made before is used for this part as it is also planned to be constructed with steel frame. Thus, the wall for the spacing left for the elevator installation is estimated to be about 100mm.

## STUD SELECTION TABLES

Table 8 and 11 provide stud selection information suitable for all CSR Gyprock non-fire rated and fire rated non-loadbearing internal wall systems that are to be designed for a Uniform Distributed Load (UDL) of 0.25kPa.

Table 9 provides stud selection information suitable for specialised fire rated non-loadbearing wall systems that are required to be designed for a UDL of 0.35kPa. Refer to Rondo for other design pressures and for loadbearing walls.

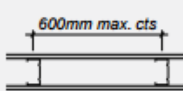
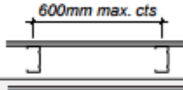
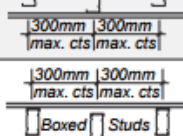
TABLE 8: MAXIMUM WALL HEIGHT WITH RONDO LIPPED STEEL STUDS – NON-LOADBEARING WALLS – WALLS GENERALLY (LOAD = 0.25kPa)														
Wall Frame and Lining Configuration	Stud Size	51		64			76			92			150	
	BMT	0.5	0.75	0.5	0.75	1.15	0.55	0.75	1.15	0.55	0.75	1.15	0.75	1.15
	Linings (mm)	Maximum Wall Height (m)												
	10	2.77	2.91	3.33	3.93	4.17	3.70	4.43	4.65	4.54	4.83	5.11	6.55	7.22
	13	3.20	3.32	3.72	4.22	4.43	4.13	5.02	5.22	4.94	5.50	5.75	6.99	7.54
	16	3.38	3.52	3.91	4.35	4.52	4.30	5.25	5.42	5.18	5.71	5.92	7.19	7.65
	CSR 080(-/180/180)	2.60	2.60	3.30	3.60	4.30	3.80	4.10	5.00	4.40	4.80	5.00	7.00	7.65
	10	2.32	2.60	2.72	3.13	3.53	3.20	3.58	4.05	3.61	4.13	4.69	5.33	6.81
	13	2.32	2.60	2.72	3.25	3.58	3.24	3.82	4.05	3.61	4.18	4.69	5.37	6.81
	16	2.32	2.60	2.75	3.28	3.59	3.25	3.87	4.05	3.61	4.20	4.69	5.37	6.81
	10			2.37	2.83	3.51								
	10			2.93	3.61	-								

Table 22: Table used to estimate the walls made of steel frame structure. [109]

# Appendix F

Figure 123: Ground floor plan

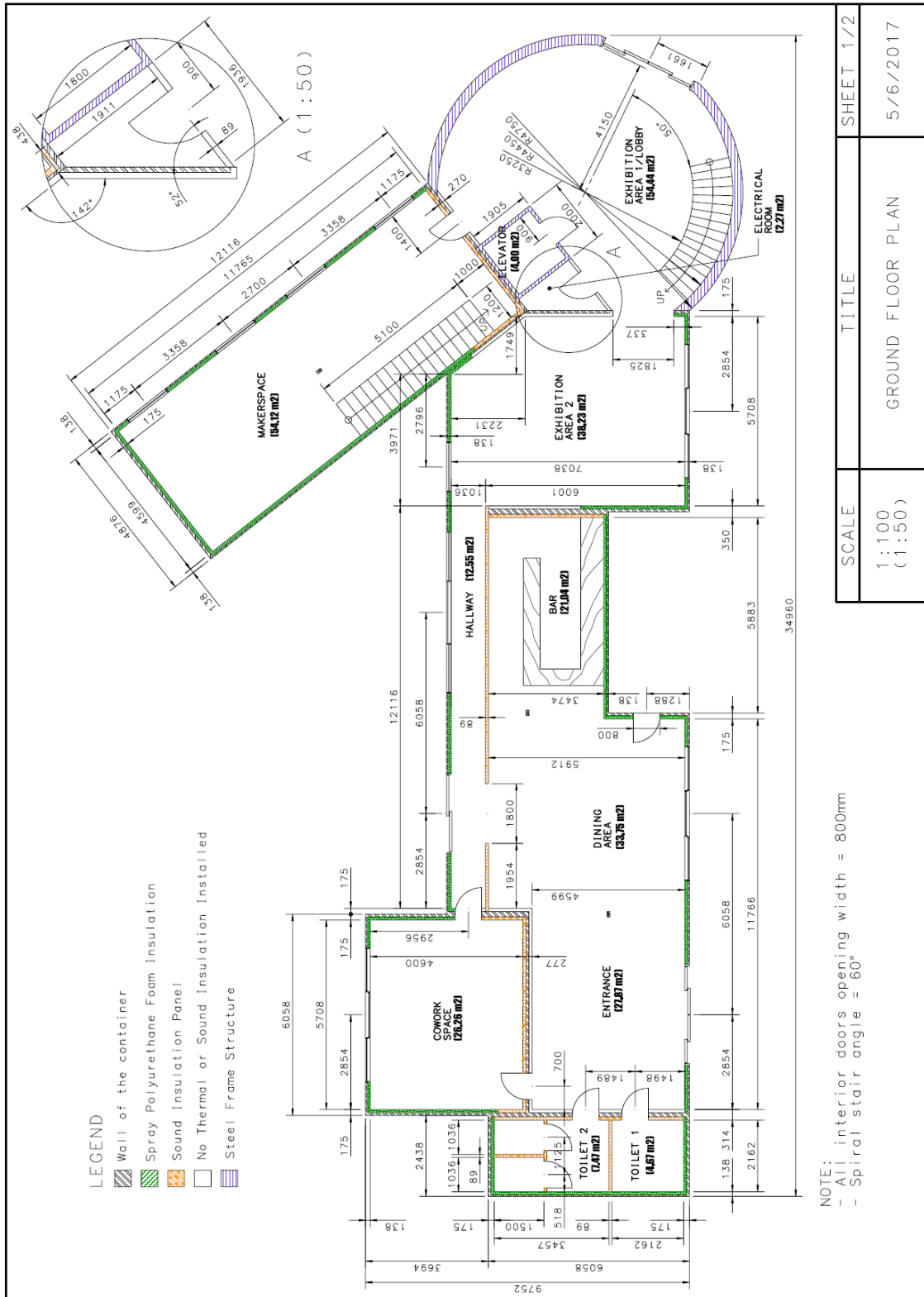


Figure 124: Kitchen details from the ground floor plan

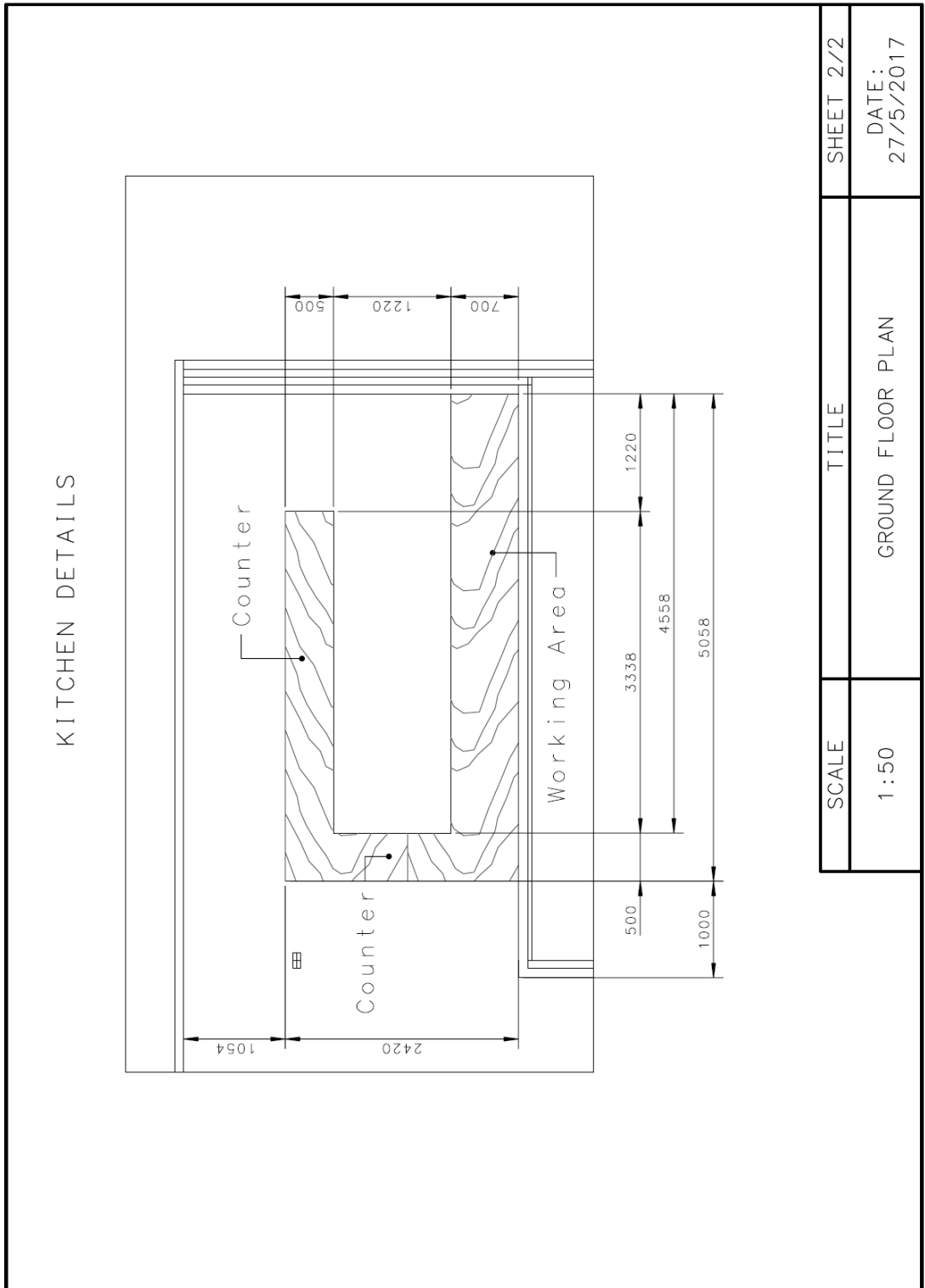
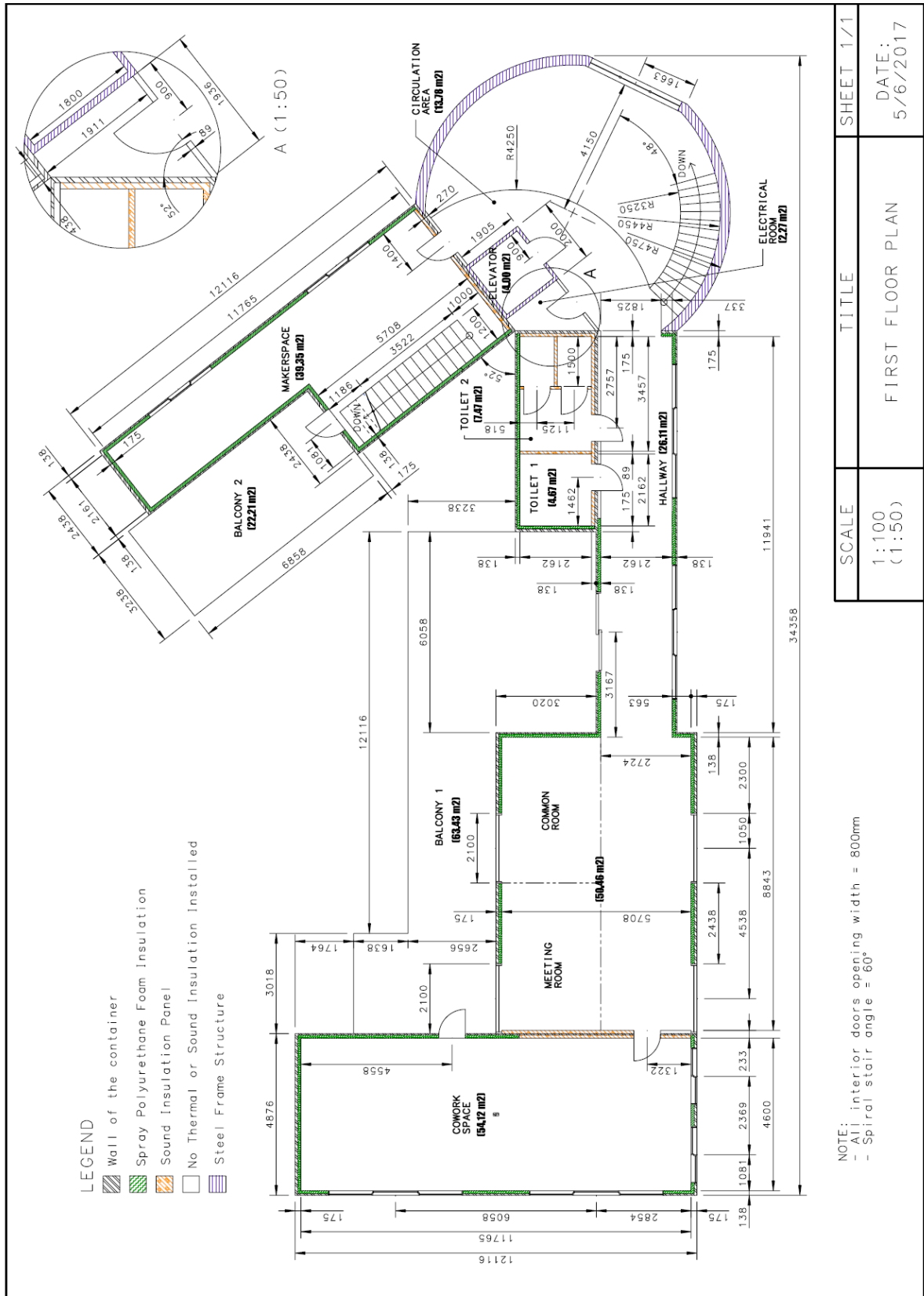


Figure 125: First-floor plan



## Appendix G

This appendix is about all of the accessibility requirement applied in the floor plans.

### 1. Door opening width and its position

Direction and width of approach	New buildings (mm)	Existing buildings (mm)
Straight-on (without a turn or oblique approach)	800	750
At right angles to an access route at least 1500mm wide	800	750
At right angles to an access route at least 1200mm wide	825	775
External doors to buildings used by the general public	1000	775

**Note:**  
The effective clear width is the width of the opening measured at right angles to the wall in which the door is situated from the outside of the door stop on the door closing side to any obstruction on the hinge side, whether this be projecting door opening furniture, a weather board, the door or the door stop (see Diagram 9). For specific guidance on the effective clear widths of doors in sports accommodation, refer to "accessible sports facilities".

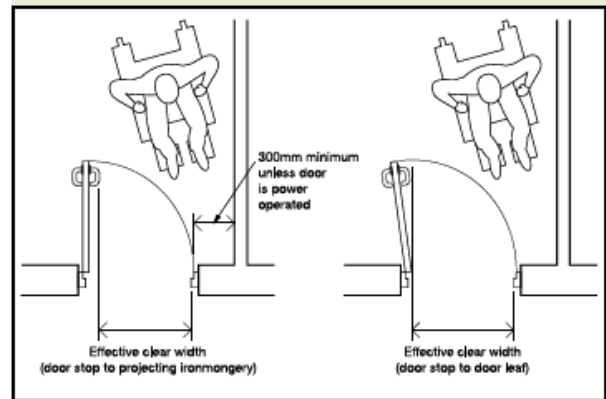


Figure 127: Minimum effective clear widths of doors [47]

Figure 127b: Effective clear width of doors and door distance from nearest wall [47]

Note:

- All of the interior doors opening width in the floor plan is 800mm.
- The main external sliding door meant for general public used has opening width more than 1000mm.
- All the interior doors except a door in between the cowork space and the hallway in the ground floor are placed at least 300mm from the nearest wall.

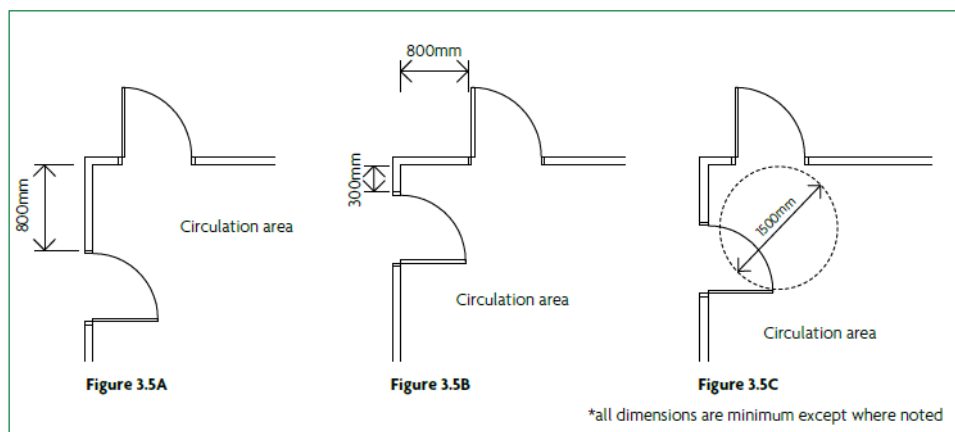


Figure 128: Outward opening doors in a corner [48]

Note:

- All doors comply with these requirements



2. Doorway without door

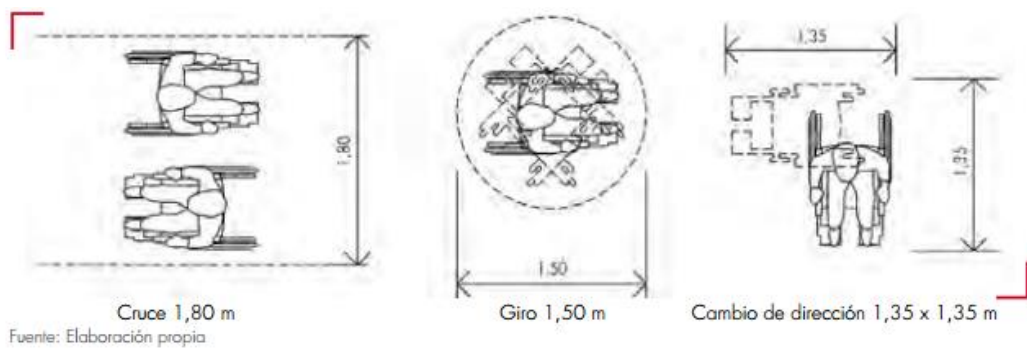


Figure 129: Universal dimensions for crossing (cruce), rotation (giro) and turning (cambio de dirección) of wheelchairs [49]

Note: All of the doorways without door have at least 1800mm of opening width.

3. Elevator waiting area

ACCESIBILIDAD DE LOS ASCENSORES						
CC.AA.	Ancho mínim. de puerta <sup>1</sup>	Dim. de cabina (fondo x ancho, m)	Pasamano cabina (altura, m)	Botonera Braille (altura, m)	Señal acústica	Diametro espera ascensor, m
Cataluña	0,80	1,40 x 1,10	SÍ (0,90-0,95)	SÍ (1-1,40)	n.d.	1,50

Figure 131: Accessibility of the elevators [49]

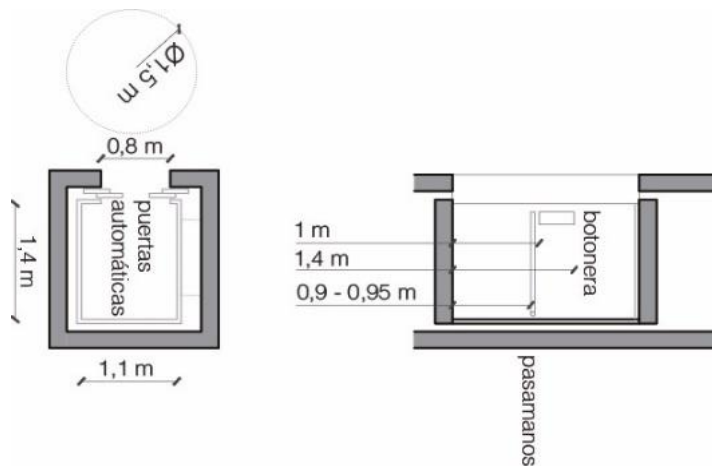


Figure 131b: Elevator diagram as reference to the table above Invalid source specified.

Note: Both elevators in ground and first floor have 1500mm in diameter for their waiting area and 800mm of opening width of the door.

4. Toilets

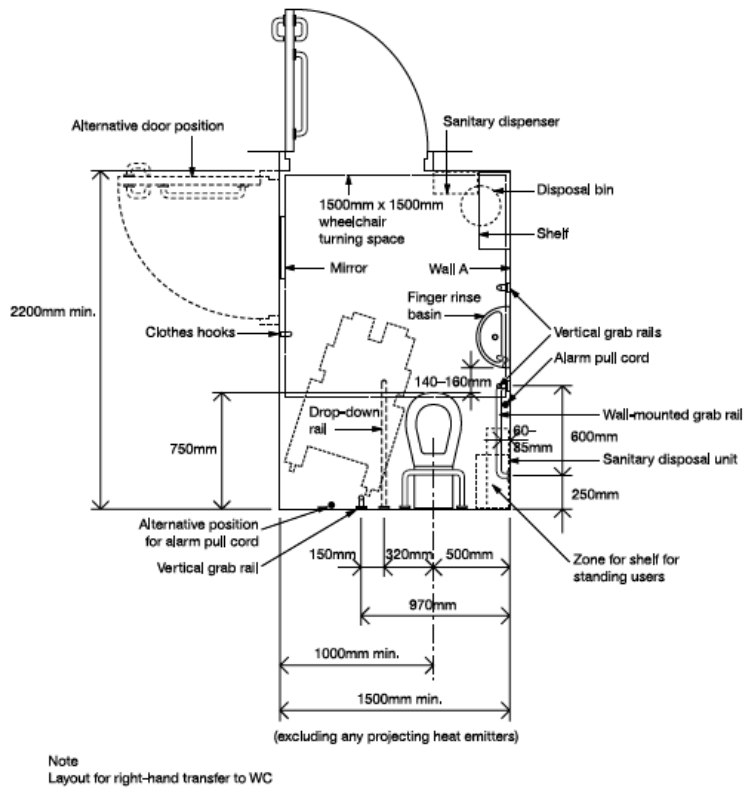


Figure 133: Example layout of a unisex wheelchair-accessible toilet [47]

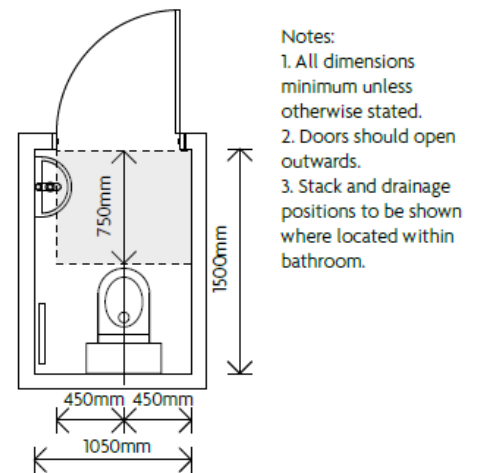


Figure 133b: Example layout of Frontal Access WC [48]

- Notes:
1. All dimensions minimum unless otherwise stated.
  2. Doors should open outwards.
  3. Stack and drainage positions to be shown where located within bathroom.

Note:

- All toilets for disabled people have dimensions of 2162mm x 2162mm
- All frontal toilets have dimensions of 1174mm x 1500mm

5. Kitchen

Since Spanish Regulations for the dimensions of the kitchen could not be found, the dimensions of the kitchen in the floor plan are followed some recommendation and guidelines for the United States instead [110]. It is believed that these guidelines also are suitable to be applied in this project as they are also meant to optimize the working experience in the kitchen. For this reason, it is recommended that to place the countertop, appliances and other kitchen features by referring to the measurements made for the kitchen in the floor plan. Below are the guidelines followed in the floor plan:

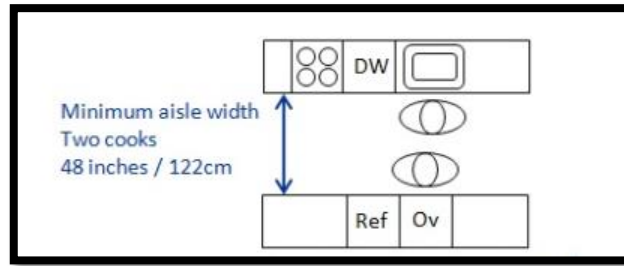


Figure 134: Minimum kitchen aisle width for two workers [110]

1. Minimum aisle<sup>6</sup> width

In the floor plan, the aisle width is at minimum which is 1220mm due to limited space in the area. However, this distance seems to be enough to allow two workers to work comfortably in the opposite areas. In addition to that they could take advantage of the space to perform different tasks or dishes at the same time.

2. Other dimensions

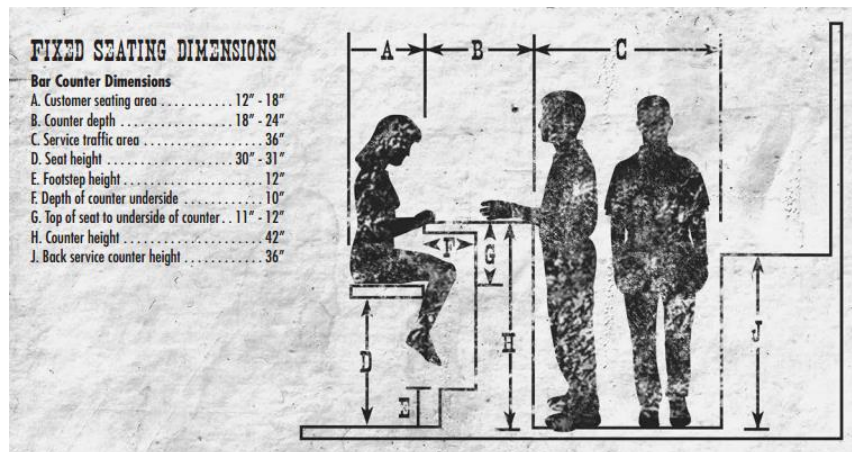


Figure 135: Fixed seating dimensions for kitchen eating bar Invalid source specified.

Only A, B and C measurements are used as a guide since the floor plan is from aerial point of view.

Measurements	Recommended	In Floor Plan
A – Customer Seating Area	457.2mm	1054mm
B – Counter Depth	457.2mm	500mm
C – Service Traffic Area	914.4mm	1220mm

Table 23: Measurements dimensions kitchen

In the floor plan, the dimension for A is 1054mm to allow other people passing through that space without any hassle if someone is eating.

<sup>6</sup> Aisle: a long, narrow space between the rows of shelves in a large shop Invalid source specified.

### 6. Straight Stair

If a straight stair is going to be used inside the sea container building, there are some aspects especially space inside the building that has to be kept in mind.

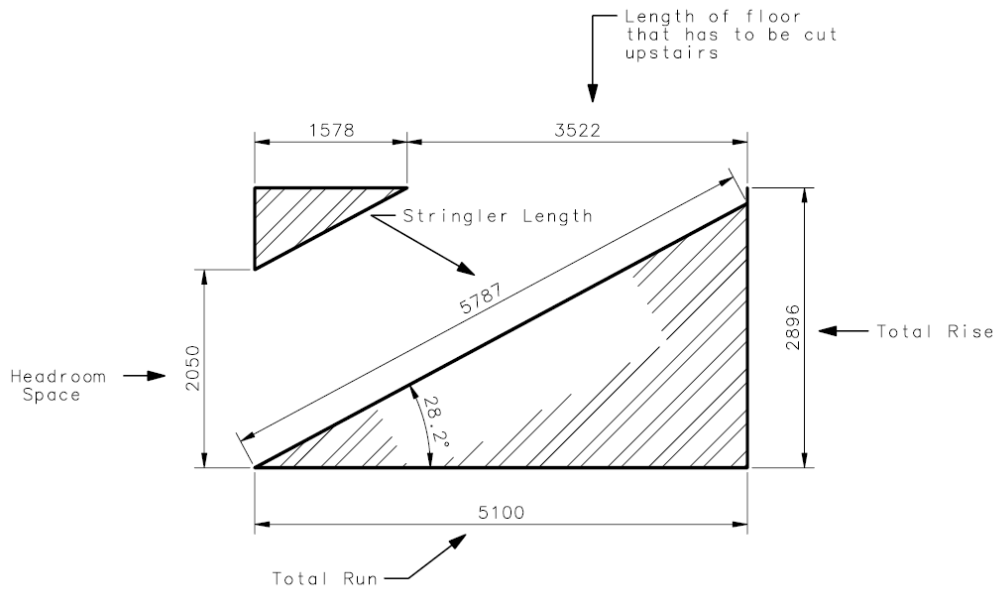


Figure 136: Dimensions of the straight stair according to calculation's result

The following are how the calculation is made:

According to Spanish Regulations, there are requirements that have to be met for safety reasons and ease of use.

CONCEPTO	España*
Ancho mínimo libre (m)	1,20
Altura de contrahuella (m)	0,16
Contrahuellas cerradas	Si
Profundidad de huella (m)	0,30
Pasamanos a ambos lados de la escalera	Si
Altura de pasamanos (m)	0,95
	1,05
	-
	0,65
	0,75

Figure 138: Standard dimensions for straight stairs [49]

#### Partes de una Escalera

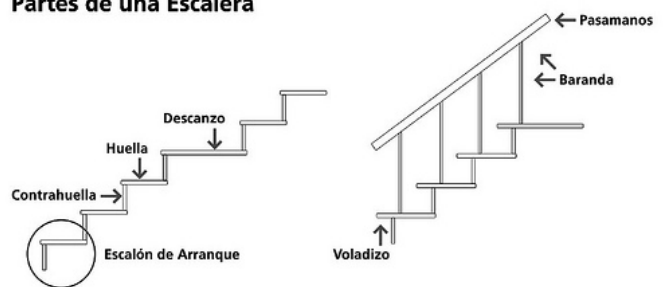


Figure 138b: Straight stairs diagram as a reference to the table on the left Invalid source specified.

These are the items from the table in the previous page that need to take in account when using the stairs online applications:

Minimum width (*Ancho minimo libre*): 1200mm

Height of rise (*Altura de contrahuella*): 160mm

Depth of run (*Profundidad de huella*): 300mm

The height of the stairs is seemed to be the same as the height of the container used. For example, by referring to the dimensions of the container that are used as a guide before, the external height of it is 2896mm. Thus, the height of the stairs will be 2896mm as well. This can be proved by a simple diagram below in conditions that both containers have the same height and floor height:

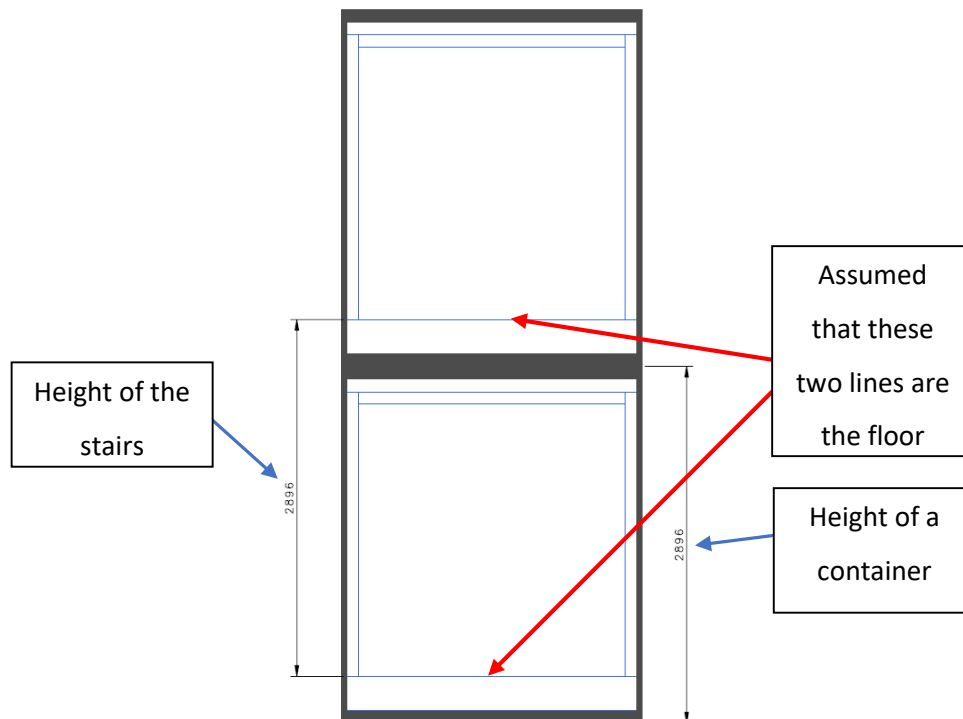


Figure 139: Estimation of stairs height from floor to floor

The following are the ways how the estimated dimensions of the straight stair are obtained:

An online application is used to estimate the stair dimensions and it is called “Stair Calculator” [111]. In the application, an option “Use One Run” is chosen (refer to Figure 15 below). Then, the “Total Rise” box is filled with the height of the stair which is 289.6cm and for the “Run”, 30cm is given as the depth of the run should be 300mm.

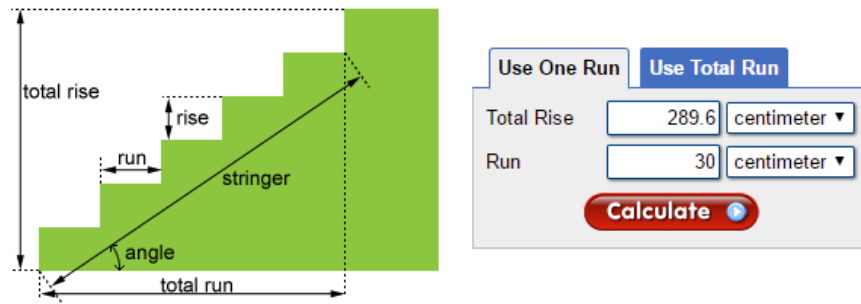


Figure 140: Stair diagram as reference (left). The "Stair Calculator" (right) [111]

After the “Calculate” button is clicked, many options of result appear on screen and each options is depends on the amount of runs of the stairs. Since according to the regulations the height of rise required is 160mm, so the correct option should be:

If 17 Runs	
# of Rise	18
# of Run	17
Rise	6.33 inches or 16.09 cm
Total Run	16 feet 8.79 inches or 510.00 cm
Stringer Length	18 feet 11.84 inches or 578.71 cm
Angle	28.20°

Figure 141: Result from the "Stair Calculator"

As a final result, the stair is going to have 5100mm of total run that consists of 17 runs in it.

This result is in recommended measurements not just from the Spanish Regulation but also from the guidelines from the website that is believed to increase the safety and comfort of usage. Below are the guidelines that are taken directly from the website [111]:

- The run length should be 9 inches (23 cm) or longer for enough foot space.
- The riser height should be 8.25 inches (21cm) or lower.
- The nosing protrusion length should be 1.25 inches (3.2 cm) or lower to prevent tripping on the nosing.
- The headroom is recommended to be 6 feet and 8 inches (203 cm) or higher.
- The stair width is recommended to be 35 inches (89cm) or longer.
- The height of the handrail, measured from the nose of the tread, is recommended to be between 34 and 38 inches (86 to 97 cm).
- The comfortable size of handrail diameter is between 1.25 and 2.68 inches (3.2 to 6.8 cm).
- Doors are normally not allowed to swing over steps. The arc of doors should be on the landing or floor completely.

Appendix H

Figure 142: Electrical plan for the ground floor

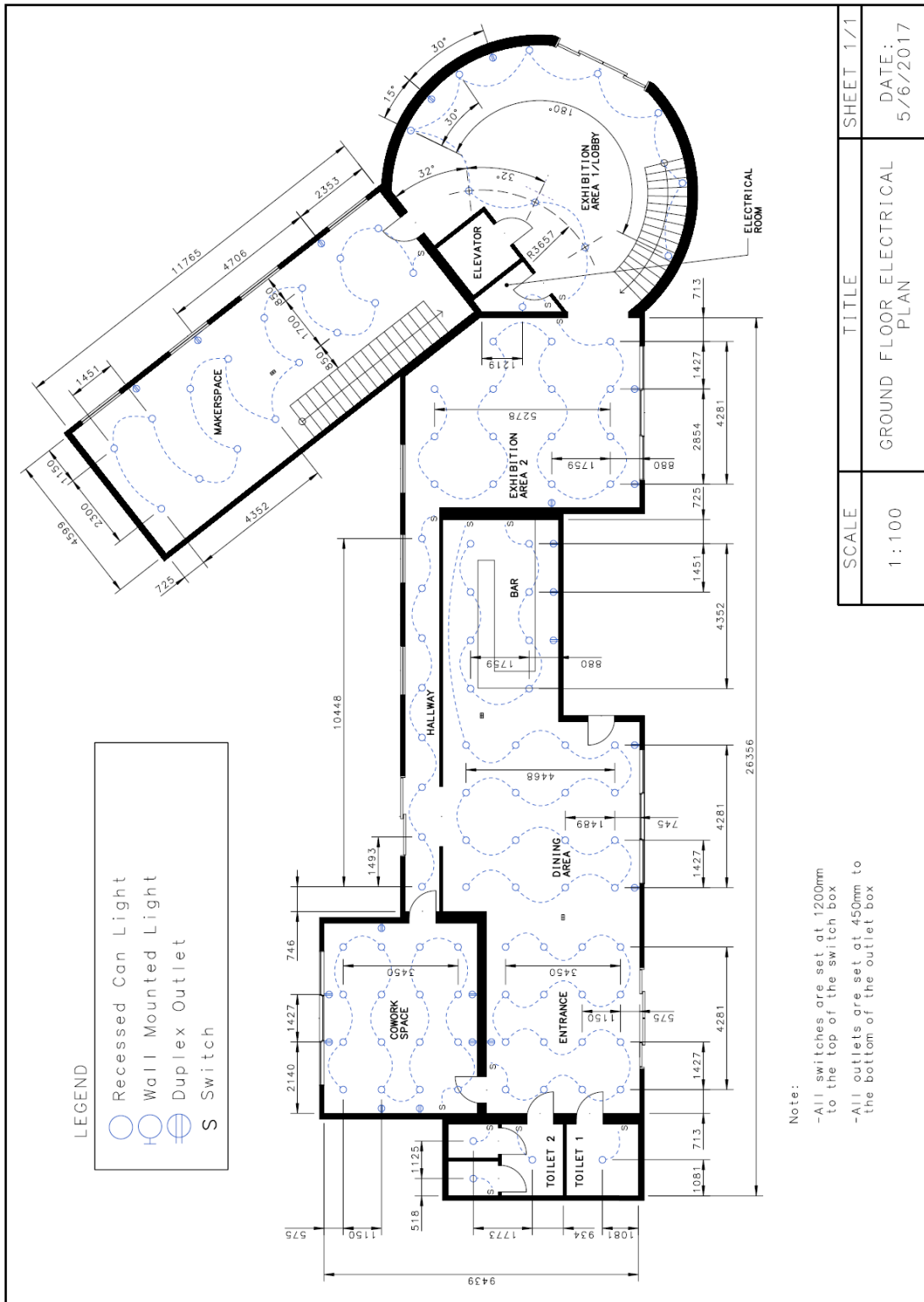
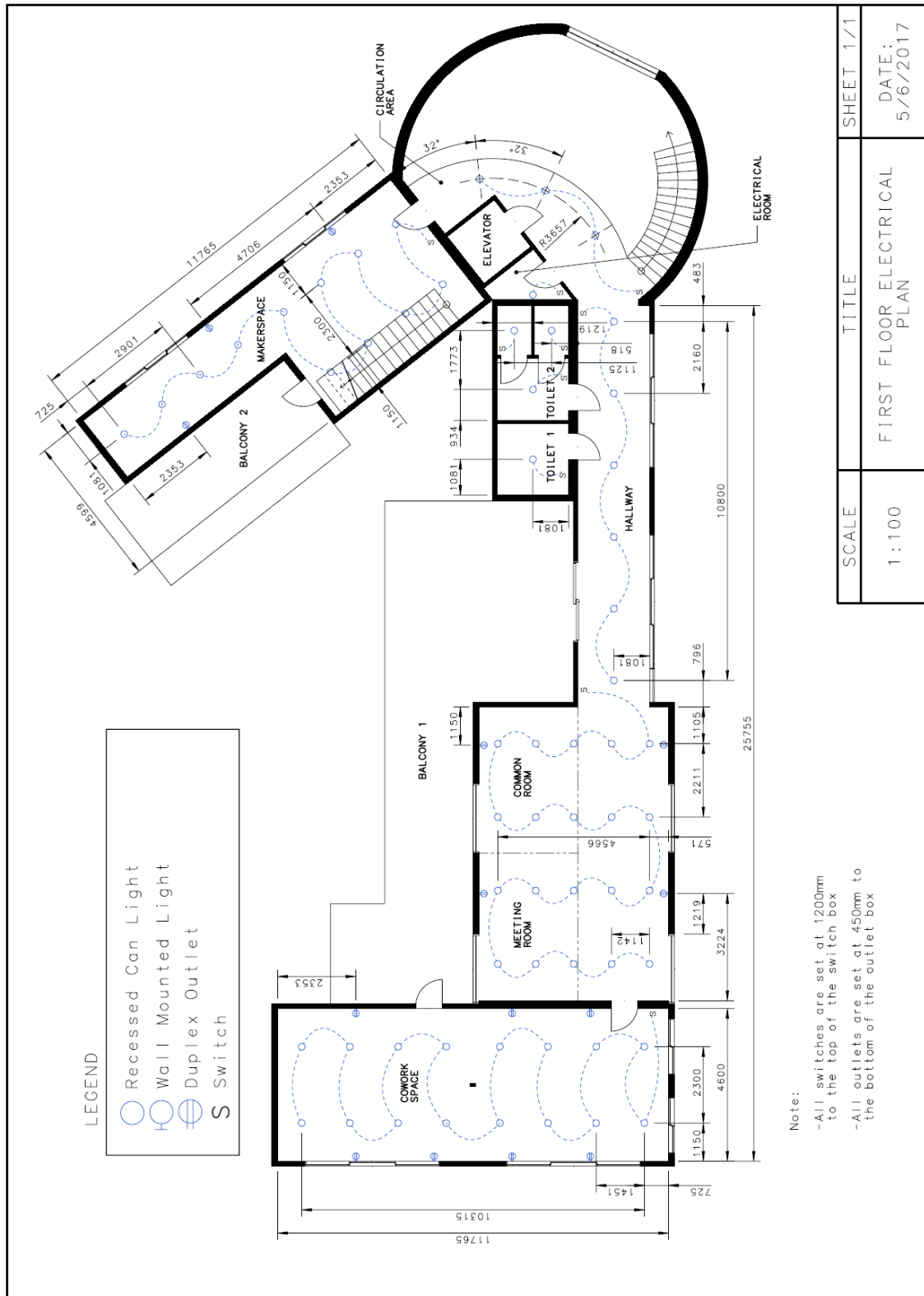


Figure 143: Electrical plan for the first floor





## Appendix I

This appendix is about how the lighting calculation is made in order to get the optimum lighting condition for different activities in different areas.

The table below shows the amount of lux that is suggested to be required for some rooms and areas in order to assure safety and comfort during work. These lux<sup>7</sup> values are used as guidance in this lighting calculation.

Public Houses	Suggested Lux Level
Cashier desk, till	300
Kitchen	500
General lighting	250

Exhibitions & Libraries	Suggested Lux Level
General lighting	250
Very illuminated	500

Hotels & Restaurants	Suggested Lux Level
Reception & porters desk	300
Kitchen	500
Self-service restaurant	300
Buffet	300
Conference rooms	500
Corridors	100
Bathroom (hotel suite)	150
Toilets (hotel suite)	100
Foyers	200
Dining room	250
Halls	120
Bathrooms (general)	250

Offices	Suggested Lux Level
Filing, copying etc...	300
Writing, typing, reading, processing	500
Technical drawing	750
CAD workstations	500
Conference & meeting rooms	500
Reception area	300
Archives	200
Design office	1,000
Toilets	250
General lighting	120
Precision assembly	1500

Figure 144: Suggested lux level that are used as guidance. These figures are based on the recommended lux levels by CIBSE (Chartered Institute of Building Services Engineers) [157]

As the amount of lights for each area are already known by referring to the electrical plans, a calculation is made based on this number and the suggested lux level to obtain the minimum number of lumens required for each light bulb to have for each area. After the result is obtained, the light bulb or led that has to be bought has to have superior number of lumen than the value in the corresponding result.

<sup>7</sup> Lux: Lux is a measure of illuminance which basically means it's a measure of how much light there is over a given surface area. [112]

Formula used [112]:

Units - Lux = lx Lumen = lm Area = m<sup>2</sup>

$$1 \text{ lx} = 1 \text{ lm/m}^2$$

$$\text{Min Lumen needed} = \frac{\text{Area} \times \text{Suggested Lux}}{\text{No of lights installed}}$$

Example (For Cowork Space):

$$\text{Min Lumen needed} = \frac{54.12\text{m}^2 \times 500 \text{ lx}}{16} = 1691.25 \text{ lm}$$

- As a conclusion, it is required to buy led lights that could emit more than 1691lm, for instance, led lights with 1800lm if led lights with 1700lm could not be found in the market. This number of lumen normally is labelled in the light packaging.

Item	Estimation Area (m2)	Lux	Lux x Area	No of lights installed	Min lumen needed for a light bulb/led
Cowork Space	54.12	500	27057.5	16	1691
Meeting Room + Common Room	50.46	500	25230.0	20	1262
Hallway 2	26.11	100	2611.0	6	435
Toilet 1	4.67	250	1167.5	1	1168
Toilet 2	7.47	250	1867.5	3	623
Electrical Room	2.27	200	454.0	1	454
Area in front of elevator	13.78	100	1378.0	3	459
Makerspace	39.35	500	19673.0	12	1639

Table 24: The table above is for the ground floor of the sea container building.



Item	Estimation Area (m2)	Lux	Lux x Area	No of lights installed	Min lumen needed for a light bulb/led
Cowork Space	26.26	500	13130.0	16	821
Bar	21.04	500	10520.0	8	1315
Dining Area	33.75	250	8437.5	16	527
Hallway	12.55	100	1255.0	8	157
Toilet 1	4.67	250	1167.5	1	1168
Toilet 2	7.47	250	1867.5	3	623
Electrical Room	2.27	250	567.5	1	568
Exhibition Area 2	38.23	300	11469.0	15	765
Exhibition Area 1	54.44	250	13610.0	10	1361
Makerspace	54.12	500	27060.0	16	1691
Entrance	27.87	250	6967.5	16	435

Table 25: The table above is for the ground floor of the sea container building.

## Appendix J



This appendix is about the research of the materials for both internal and external wall insulations

**Table 26 : Materials for Internal Wall Insulation [113]**


Material	Pros	Cons
<p><b>Closed Cell Spray Polyurethane Foam (ccSPF) [114]</b></p>  <p>Figure 145: Interior Spray Foam Insulation or Spray Polyurethane Foam [115]</p>	<ul style="list-style-type: none"> <li>• The quickest and efficient method of insulation</li> <li>• Could increase structural strength</li> <li>• Strong water and hail resistance</li> <li>• Resist pest</li> <li>• Provide a seamless vapour barrier that could prevent corrosion and formation of mould on the surface of the container</li> <li>• Could absorb sound and reduce noise as it is excellent air barrier [68].</li> <li>• Has the lowest U-value</li> </ul> <p>U-value <math>0.56 W/m^2\text{°C}^8</math> for 50mm thickness [64]</p>	<ul style="list-style-type: none"> <li>• Expensive compare to others</li> <li>• Untidy finish that probably could worsen the appearance</li> <li>• Not environmental friendly since it might contain hydrochlorofluorocarbon that could damage the ozone layer</li> <li>• The U-value could increase due to increasing of its thermal conductivity after installation until it finally stable</li> </ul>
<p><b>Sheep Wool Insulation</b></p>  <p>Figure 146: Wool Insulation in Normal Home [116]</p>	<ul style="list-style-type: none"> <li>• Easy to install</li> <li>• It requires less energy to be produced</li> <li>• A breathable insulator. It could prevent internal condensation and mould growth</li> <li>• Eco-friendly</li> <li>• Could resist pest, fire and mold [117]</li> </ul> <p>U-value of <math>0.70 W/m^2K</math> for 50mm thickness [118]</p>	<ul style="list-style-type: none"> <li>• It requires the installation of stud walls first to place the insulation in. This will add cost to the project.</li> <li>• Not an air barrier [119]</li> </ul>

<sup>8</sup> This is the U-Value after the SPF has stabilized. Its initial U-value for the first 9 months for 50mm is about  $0.44W/m^2\text{°C}$  [64]

Table 27: Materials for External Wall Insulation

Material	Pros	Cons
<p><b>Closed Cell Spray Polyurethane Foam (CCSPF) [114]</b></p>  <p><b>Figure 147: Spray Foam Insulation for the Exterior [120]</b></p>	<ul style="list-style-type: none"> <li>• Fast installation</li> <li>• Efficient insulating material</li> <li>• Could increase structural strength</li> <li>• Strong water and hail resistance</li> <li>• Resist pest</li> <li>• Provide a seamless vapour barrier that could prevent corrosion and formation of mould on the surface of the container</li> <li>• Could absorb sound and reduce noise as it is excellent air barrier [68].</li> <li>• Has the lowest U-value.</li> <li>• Can be applied to the underneath surface of the container as well to secure it from any moisture</li> </ul> <p>U-value of <math>0.56 W/m^2\text{°C}</math><sup>9</sup> for 50mm thickness [64]</p>	<ul style="list-style-type: none"> <li>• Expensive compare to others</li> <li>• Untidy finish that probably could worsen the appearance</li> <li>• Not environmental friendly since it contains hydrochlorofluorocarbon that could damage the ozone layer</li> <li>• The U-value could increase due to increasing of its thermal conductivity after installation until it finally stable</li> </ul>
<p><b>Straw bale [121]</b></p>  <p><b>Figure 148: Straw Bale Building [121]</b></p>	<ul style="list-style-type: none"> <li>• Made of waste product</li> <li>• Good sound insulation</li> <li>• Could add aesthetic value to the building as the thickness of the wall increase</li> <li>• The thick wall could</li> </ul>	<ul style="list-style-type: none"> <li>• If straw bale building codes are not part of local codes, it may be a bit more work to get the plans approved.</li> <li>• Areas of extreme humidity and rain may not be appropriate for straw bale construction since it needs to be kept</li> </ul>

<sup>9</sup> This is the U-Value after the SPF has stabilized. Its initial U-value for the first 9 months for 50mm is about  $0.44W/m^2\text{°C}$  [64]

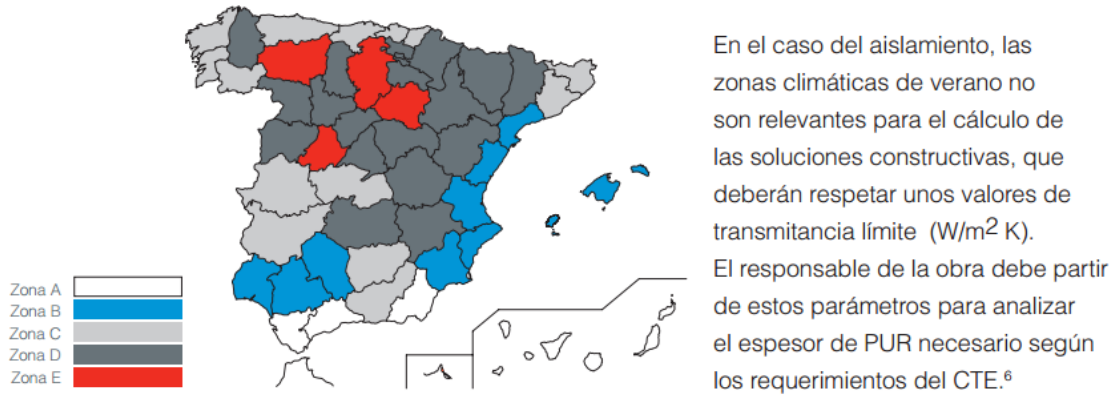
	<p>reflect sunlight throughout the room.</p> <ul style="list-style-type: none"> <li>• The installation procedure is easy to learn</li> <li>• Has a low-embodied energy.</li> <li>• 100% biodegradable</li> <li>• Cheap</li> <li>• Good fire resistance</li> <li>• Could achieve the lowest U-value by increasing the thickness of the wall</li> </ul> <p>450mm thick gives a U value of <math>0.13 W/m^2\text{°K}</math> [121]</p>	<p>dry as possible</p> <ul style="list-style-type: none"> <li>• Could take a lot of space of the construction site. Not ideal to use if the area of the construction site is limited</li> </ul>
<p><b>Cork [122]</b></p>  <p><b>Figure 149: Cork Insulation Board</b></p>	<ul style="list-style-type: none"> <li>• Has a low embodied energy</li> <li>• Bio-degradable</li> <li>• A breathable insulator which mean could prevent internal condensation and mould growth</li> <li>• Good resilience and good thermal and acoustic insulation performance</li> <li>• Good sound proofing insulation [123].</li> <li>• Stable durable and rot-proof.</li> <li>• No protective equipment required to install.</li> <li>• Comfortable and attractive, can be used as flooring or wall covering.</li> <li>• Has low U-value</li> </ul>	<ul style="list-style-type: none"> <li>• Take into account that some manufacturers may use chemical binders.</li> <li>• Not an air barrier [119]</li> </ul>

---

	U-value of $0.55 \text{ W/m}^2\text{K}$ for 50mm thickness [119]	
--	---------------------------------------------------------------------	--

## Appendix K

Figure 150: Original version of the simplified table of minimum requirements of U-values in Barcelona



### TRANSMITANCIAS LÍMITE ( $W/m^2 \cdot K$ )

	A	B	C	D	E
<b>Fachadas</b>	0,94	0,82	0,73	0,66	0,57
<b>Suelos</b>	0,53	0,52	0,50	0,49	0,48
<b>Cubiertas</b>	0,50	0,45	0,41	0,38	0,35

### ESPESORES EN MM DE PUR SEGÚN APLICACIONES<sup>7</sup>

	Fachadas		Suelos	Cubiertas
	Puentes térmicos Sin aislar	Puentes térmicos aislados		
<b>Zona A</b>	30-40	30-35	30-45	30-50
<b>Zona B</b>	30-40	30-40	30-45	40-55
<b>Zona C</b>	40-55	35-45	30-45	45-65
<b>Zona D</b>	60-80	40-50	30-45	50-70
<b>Zona E</b>	80-100	40-55	35-50	55-75

En concreto, los espesores estándar serían los recogidos en el cuadro adjunto, aunque podrían ser superiores en función de otros parámetros, como los puentes térmicos o la transmitancia de huecos.

## Appendix L

### Research on different issues

Name	Weblink	Type
Eco Vida Homes	<a href="https://www.ecovidahomes.com/blog/can-you-build-with-shipping-containers-in-spain/">https://www.ecovidahomes.com/blog/can-you-build-with-shipping-containers-in-spain/</a>	Blog
Europages	<a href="http://www.europages.co.uk/companies/Spain/Barcelona%20and%20Catalonia/containers.html">http://www.europages.co.uk/companies/Spain/Barcelona%20and%20Catalonia/containers.html</a>	Search List
Amorim	<a href="http://www.amorimisolamentos.com/en/">http://www.amorimisolamentos.com/en/</a>	Insulation
Asescuve	<a href="http://www.asescuve.org">http://www.asescuve.org</a>	Eco friendly

Table 28: Company list - research different issues

### Specialized Container building companies

Company	Weblink	Location	Type
Container Home Plans	<a href="http://www.containerhomeplans.org">http://www.containerhomeplans.org</a>	USA	Information & Blog
Residential Shipping Container Primer (RSCP)	<a href="http://www.residentialshippingcontainerprimer.com/action%20it">http://www.residentialshippingcontainerprimer.com/action%20it</a>	USA & UK	Specialized Company & Information page
Bens Container	<a href="http://www.benscontainers.com/home.html">http://www.benscontainers.com/home.html</a>	Australia	Container Modifications
Rhino	<a href="http://www.rhinocubed.com/the-cubes/building-process/">http://www.rhinocubed.com/the-cubes/building-process/</a>	USA	Container Houses
Storstac	<a href="http://www.storstac.com/shipping-container-housing/">http://www.storstac.com/shipping-container-housing/</a>	USA	Container Houses
Honomobo	<a href="http://www.honomobo.com">http://www.honomobo.com</a>	USA	Container Houses

Table 29: Company list – specialized container building companies



**Purchasing Containers**

Company	Weblink	Location	Container Type
Reteco	<a href="http://www.reteco.es/reteco.en/index.html">http://www.reteco.es/reteco.en/index.html</a>	Madrid	Refurbished
Titan Containers	<a href="http://titancontainers.com/ES.aspx">http://titancontainers.com/ES.aspx</a>	Worldwide	New
Remsa	<a href="http://www.remsa.net/en/used/shipping-containers">http://www.remsa.net/en/used/shipping-containers</a>	Valencia	Used
<u>Balat</u>	<a href="http://www.balat.com/index.aspx">http://www.balat.com/index.aspx</a>	Barcelona, Tarragona	Refurbished
Caru Containers	<a href="http://www.carucontainers.com/int">http://www.carucontainers.com/int</a>	Worldwide	New

Table 30: Company list – Purchasing containers

**Crane/Transport Companies**

Company	Weblink	Location
Gruascano	<a href="http://www.gruascano.com/">http://www.gruascano.com/</a>	Reus, Tarragona
Gruas Transportes	<a href="http://www.alquiler-gruas-transportes.com/es_ES/index.php">http://www.alquiler-gruas-transportes.com/es_ES/index.php</a>	Madrid

Table 31: Company list – Transportation

**Green Roof Companies**

Company	Weblink	Location
Eixverd	<a href="http://www.eixverd.cat/en/">http://www.eixverd.cat/en/</a>	Barcelona
Igniagreen	<a href="http://www.igniagreen.com/en/">http://www.igniagreen.com/en/</a>	Girona
Verdjardins	<a href="http://www.verdjardins.com/">http://www.verdjardins.com/</a>	Reus

Table 32: Company list – green roof