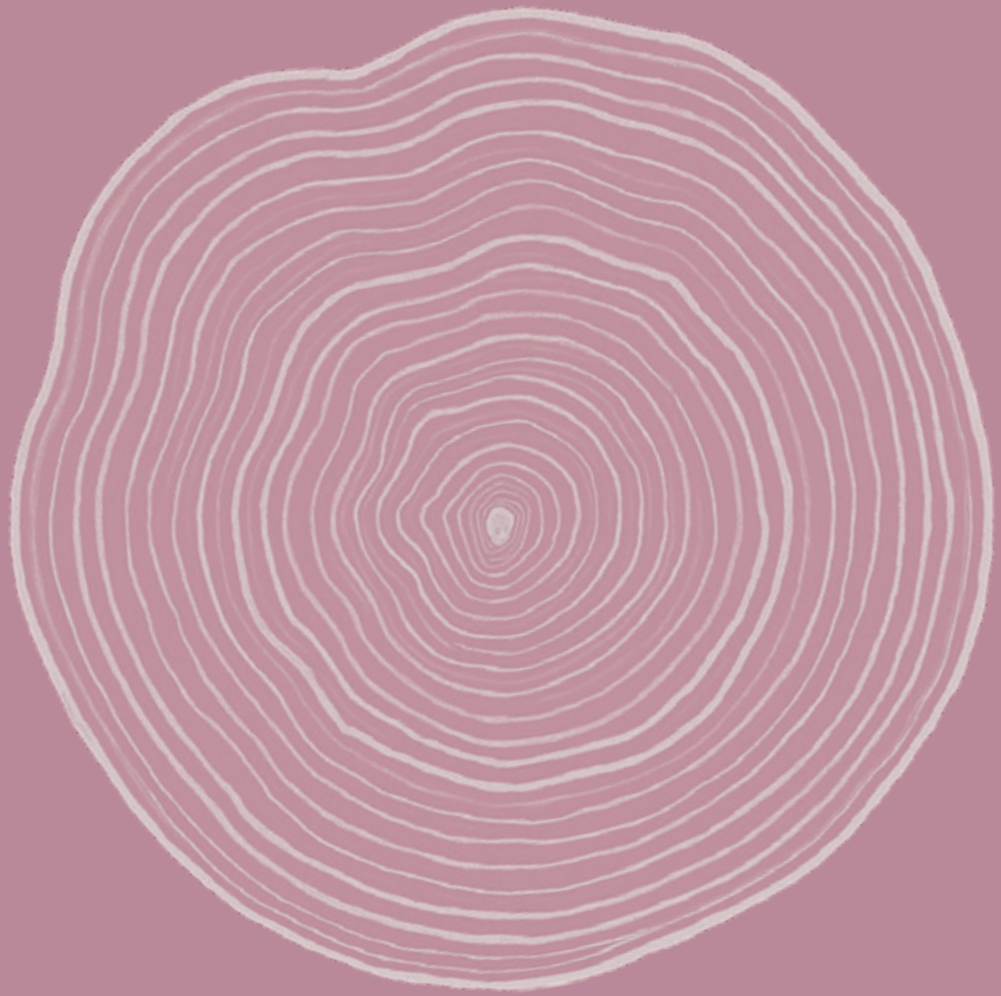
GROWING HARMONY

Where Food, Life and Architecture Thrive



„Growth takes time.
Harmony takes layers.“

ABSTRACT

Growing Harmony explores how urban architecture can integrate food production to support healthy, affordable and accessible diets within a sustainable city. Set in the harbour district of Leith, Edinburgh, the project responds to environmental, health and spatial challenges linked to global food systems, urban living and community well-being.

The core research question asks:

How can urban architecture integrate food production to promote healthy, affordable and accessible diets within a sustainable urban environment?

At the heart of the proposal lies a plant-based food strategy, translated into spatial needs through a detailed "Food Table." Food is cultivated using four complementary methods: open fields, greenhouses, vertical towers and indoor farms. These are embedded directly into residential buildings, courtyards and public zones transforming food production from a background process into a visible and integrated part of daily life.

The architectural response is a hybrid perimeter block typology, combining housing, food-growing infrastructure and shared community spaces in a cluster for 650 residents.
In addition a new masterplan solves this concept on a bigger scale, reimagining urban form, energy systems and public space all in one. The result is a resilient and self-sufficient neighborhood where food, life and architecture thrive in harmony.

CONTENT

LEITH DEVELOPMENT PLAN

The Leith Docks Development Framework is a proposal development for the main, eastern and western docks area as well as adjacent land and buildings. About 170 hectares of land is expected to become available in this area over a period of up to 30 years, since more and more industrial and port-related activities cease or are relocated to other ports around the Forth. For the development, different key elements are envisioned:

- A focus is set on mixed-used housing to meet different needs in size and affordability over the whole harbour area.
- A new business and retail center on a former industrial area.
- The extension of an existing tram connection to connect the new housing developments.
- New slow traffic routes, to enhance sustainable traffic options.
- Big green spaces that are linked to the existing Leith Links.
- And lastly, an extension of the existing industrial quarter with a new possible waste management (City of Edinburgh Council, 2016).

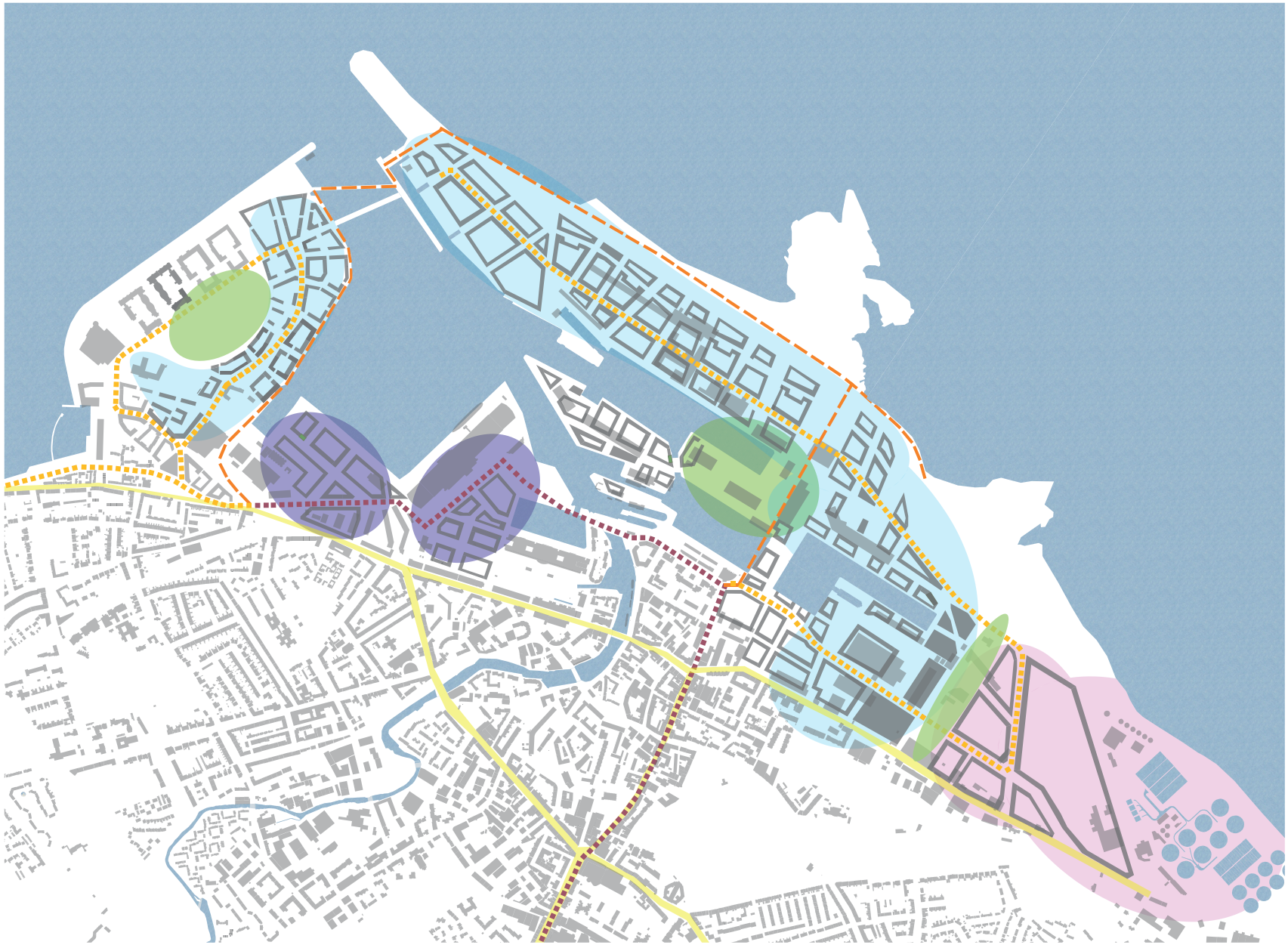


Figure 01 | Leith Development Plan - Own Illustration based on City of Edinburgh Council (2009)

SITE ANALYSIS

A site analysis of the western harbour reveals both the strengths of the existing urban fabric and opportunities for future development. Using a 1000-meter radius–approximately equivalent to a 15-minute walking distance–as a reference point, the analysis identifies a wide range of amenities and services that currently serve the area.

Within this walkable area, there is already an existing relatively robust social infrastructure in place. For educational needs a few kindergartens and schools offer access to early and primary education. Public transportation is supported by several bus stations and the new tram connection ending at the New Haven station. For daily necessities, multiple supermarkets, bakeries and healthcare institutions are located within walking distance, alongside a variety of other services such as restaurants, bars and leisure possibilities such as sports centers.

Despite these advantages, the analysis also identifies several service gaps that could significantly improve the social sustainability and livability of the area, if addressed. For instance, there is still the need for a public library, to support education. In addition, there are no dedicated youth spaces where teenagers can safely spend their time. Lastly, the number of co-working spaces is currently limited and may not meet future demand.

SITE VISIT AND PLOT SELECTION IN LEITH

In the early stages of this thesis, I visited Edinburgh's district of Leith. That visit really helped to get a personal understanding of the urban conditions, atmosphere and spatial dynamics of the Western Harbour area. While much of the research could be done through maps, data and satellite images, physically walking through the neighbourhood offered a very different perspective. It allowed me to observe not only the architectural character and infrastructure but also how people move, interact and inhabit the space.

During this visit, I explored several potential plots and evaluated them based on sun exposure, access to public transport, proximity to social infrastructure and the relationship to the existing urban fabric. The presence of open spaces, unused industrial zones and a sense of transition in the harbour area made it an ideal ground for a new architectural typology.

Finally, I chose a specific plot near the waterfront for my project, that offered both spatial openness and strong potential for community engagement. The site's connection to the tram line, nearby services and its in-between condition – neither fully urban nor isolated – aligned perfectly with the project's ambition to integrate food production, healthy living and social interaction within the city.

Figure 03 | Neighbour Building

Figure 04 | Existing Ponds

Figure 05 | Plot

THE SCOTTISH FOOD CONSUMPTION

In the initial analysis the average Scottish diet was reviewed and revealed the four main components in nutrient intake in Scotland. To begin with, cereal products are the main food group being consumed in Scotland. Followed by meat, which is consumed frequently by 86 percent of all people. The most common meat that is eaten is poultry, followed by pork and beef. Almost the same number of calories is consumed from milk products. In total milk products are consumed by 99 percent of the people in Scotland. The next food group is vegetables and potatoes, making up only a tenth of the whole calorie intake. It is reported that almost 75 percent of the people do not meet the recommended number of vegetables and fruits per day. In addition, it is generally reviewed that the most deprived areas tend to have a less healthy diet than the people living in the least deprived areas. Reasons for that are a higher intake of sugar containing soft drinks, processed potatoes and overall processed food consumption (ClimateXChange, 2024).

HEALTH ISSUES

Following a healthy, sustainable diet is associated with improved health outcomes mentally and physically. For example, it can reduce the risk of obesity, diabetes and heart diseases, which would lead to a total reduction in mortality of 6-16 percent.

However, changing the eating habits of the residents is not easy. The biggest problem is the affordability and accessibility of healthy foods. For people with a lower income almost 40 percent of their income must be spend to afford healthy food. For the richest fifth of the people it is only 7 percent (SEFARI, 2022).

Regarding the accessibility of healthy foods, there are about 16 percent of the people in Scotland living in so called „Food deserts", where there is only a limited offer of mostly fast food takeaways and convenience stores. To change the existing offer especially in those least deprived areas there needs to be a change in the market and regulatory intervention, focusing on healthy food and lifestyles that are affordable for everyone (Obesity Action Scotland, 2022).

FOOD PRODUCTION

Food production is significantly contributing to the global environmental challenges, being responsible for over a quarter (26 percent) of the total greenhouse gas emissions. Besides that, it also takes up half of the world's habitable land and consumes almost 70 percent of the global freshwater withdrawals. In addition, agriculture pollutes the oceans and freshwaters with nitrogen and other chemicals (Ritchie, 2022).

A big part of the agricultural emissions and resource consumption contributes to the meat production. In total, about 80 percent of the agricultural land is used for the production of animal-based products, even though these products only serve 18 percent of calories and 37 percent of proteins.

The reason for that high intake of resources is that about one-third of all grains, and even two-thirds of soybeans, corn and barley are fed to animals. Looking at more numbers it gets clear that meat production is not profitable: to get 8 grams of animal protein on the plate an average of 100 grams of plant protein is needed beforehand. It can be compared directly with the global available calories of cultivated crops, of which only 55 percent are used to feed people directly, the other half is used to feed animals in industrial livestock farming (ProVeg, 2022).

URBAN FOOD PRODUCTION

Due to the current challenges in conventional agricultural practices, new methods must be developed to meet future food demands–especially in sustainable and efficient ways. As urbanisation continues globally, food production must increasingly be integrated into cities. This would help reduce the environmental footprint of agricultural land while increasing the quantity of food that can be locally produced.

A solution could be the controlled environment agriculture:
Controlled Environment Agriculture (CEA) refers to the cultivation of plants under the control of specific parameters that are important for successful plant growth: air temperature, soil temperature, humidity, light (duration and type of lighting) and more.
The goal of this approach is to use scientific data and technical tools to optimize plant growth, reduce pests and diseases and achieve maximum yield with a minimal energy input. Outdoor cultivation without any form of protection can never be considered Controlled Environment Agriculture. Examples of CEA are greenhouses, indoor farms or vertical farms. When implemented outdoors, at least some form of protection is required–such as tunnel greenhouses (Wikifarmer, 2024).

THE ENVIRONMENTAL IMPACT OF FOOD

To demonstrate the CO_2 difference between a plant-based and an omnivorous diet, the average Scottish diet was converted into a plant-based version. CO_2 emission values for different food groups were sourced from The World Data.

As a first step, the average Scottish diet was calculated from percentage values to kcal adapted to an average diet with 2,500 kcal per day. This daily intake was then multiplied by 365 to determine annual food consumption. Based on this, the yearly CO_2 emissions were calculated using the emission factors for each food type.

The result reveals that an omnivorous diet produces approximately 8,092 kg CO2 per year. In comparison a plant-based diet only emits about 1,219 kg CO_2 per year.

With an average lifespan of 80 years (Euronews, 2023) one person following a plant-based diet could save about 549,840 kg CO_2. To put this number into perspective, an average car with a consumption from 6l per 100 km emits 142 g CO_2 per km (U.S. Environmental Protection Agency, 2025). Hence the 549,840 kg CO_2 safed by a plant based person are equivalent to a 3,872,112 km car ride.

Average Scottish Diet in % per day:
31 % Cereal products
14 % Meat
11 % Dairy products
9 % Vegetables and Potatoes
18 % Other
5 % Confectionary
4 % Fruit
3 % Savoury snacks
3 % Misc
3 % Drinks

Average Scottish Diet in kcal per day:
775 kcal Cereal products
350 kcal Meat
275 kcal Dairy products
225 kcal Vegetables and Potatoes
450 kcal Other
125 kcal Confectionary
100 kcal Fruit
75 kcal Savoury snacks
75 kcal Misc
75 kcal Drinks

Average Scottish Diet in kg per day:
0.22 kg Cereal products
0.14 kg Meat
0.42 kg Dairy products
0.64 kg Vegetables and Potatoes
0.3 kg Other
0.03 kg Confectionary
0.2 kg Fruit
0.15 kg Savoury snacks
0.05 kg Misc
0.15 kg Drinks

Average Scottish Diet in kg CO_2 per day:
0.308 kg CO_2 Cereal products
11 kg CO_2 Meat
8.4 kg CO_2 Dairy products
0.26 kg CO_2 Vegetables and Potatoes
0.9 kg CO_2 Other
0.6 kg CO_2 Confectionary
0.1 kg CO_2 Fruit
0.45 kg CO_2 Savoury snacks
0.05 kg CO_2 Misc
0.1 kg CO_2 Drinks
= 22.168 kg CO_2/ day

kg CO_2 per year= 8,092 kg

CO_2 numbers (Ritchie, 2022.)

Average Scottish Diet plant-based in % per day:
31 % Cereal products
14 % Meat substitutes
11 % Milk alternative products
9 % Vegetables and Potatoes
18 % Other (vegan)
5 % Confectionary (vegan)
4 % Fruit
3 % Savoury snacks (vegan)
3 % Misc
3 % Drinks

Average Scottish Diet plant-based in kcal per day:
775 kcal Cereal products
350 kcal Meat substitutes
275 kcal Milk alternative products
225 kcal Vegetables and Potatoes
450 kcal Other (vegan)
125 kcal Confectionary (vegan)
100 kcal Fruit
75 kcal Savoury snacks (vegan)
75 kcal Misc
75 kcal Drinks

Average Scottish Diet plant-based in kg per day:
0.22 kg Cereal products
1.4 kg Meat substitutes
0.5 kg Milk alternative products
0.65 kg Vegetables and Potatoes
0.3 kg Other (vegan)
0.03 kg Confectionary (vegan)
0.2 kg Fruit
0.15 kg Savoury snacks (vegan)
0.05 kg Misc
0.15 kg Drinks

Average Scottish Diet plant-based kg CO_2 per day:
0.22 kg Cereal products
1 kg Meat substitutes
0.5 kg Milk alternative products
0.65 kg Vegetables and Potatoes
0.3 kg Other (vegan)
0.07 kg Confectionary (vegan)
0.1 kg Fruit
0.3 kg Savoury snacks (vegan)
0.05 kg Misc
0.15 kg Drinks
=3.34 kg CO_2/day

kg CO_2 per year= 1,219 kg

Figure 05 | Atmospheric Visual Courtyard

AIM OF THE PROJECT

Based on the environmental, health and spatial challenges outlined in the first two chapters, it becomes clear that new approaches to food production within the urban context must be explored. This leads to the central question of this thesis:

How can urban architecture integrate food production to promote healthy, affordable and accessible diets within a sustainable urban environment?

At the core of the design response lies the newly developed Food Table, which aims to offer residents a healthy, local and affordable diet. The table translates nutritional needs into spatial requirements, determining how and where food can be grown. In this project, production takes place through a combination of open fields, greenhouses, vertical towers and indoor farms–all seamlessly integrated into the residential setting.

Carbohydrates	kcal/kg	kg/day	kg/year	m^2	method	yield	harvest cycles	
Oats	4037	0.1	36.5	45.6	open field	0.8 kg/m^2		(The James Hutton Institute, 2019)
Wheat	3390	0.1	36.5	1.8	indoor	19.4 kg/m^2		(Asseng et al., 2020)
Potatoes	1100	0.2	73	3.36	tower	30 kg/tower		(Little Green Growers, 2021)
Sweet Potato	1027	0.15	54.3	5	tower	15 kg/tower		(GreenStalk Garden, n.d.)
Proteins								
Chickpeas	1640	0.1	36.5	14.6	greenhouse	2.5 kg/m^2		(Logineko, 2025)
> Microgreen	1200	0.15	54.5	0.009	indoor	6000 kg/m^2 (*10 layers)		
Mushrooms	413	0.2	73	7.3	indoor	10 kg/m2		(Oak and Spore Mushroom Farm, 2022)
Healthy Fats								
Chia seeds	4860	0.03	11		indoor	1 kg/m^2		(Njoka et al., 2022)
Hazelnuts	6278	0.033	10	26	openn field	0.3 kg/m^2		(Biolchim, n.d.)
sunflowers	5840	0.016	6	24	open field	0.25 kg/m^2		(Foundation for Arable Research, 2021)
		0						
Vitamins & Minerals								
Kale	276	0.05	18.25	0.84	tower/pots	30 kg/tower	2	(GreenStalk Garden, n.d.)
Spinach	233	0.05	18.25	1.26	tower/pots	13.5 kg/ tower	3	(GreenStalk Garden, n.d.)
Carrots	430	0.1	36.5	10	tower/pots	4.8 kg/ tower	2	(GreenStalk Garden, n.d.)
Tomatoes	211	0.1	36.5	1.68	tower/pots	30 kg/tower	2	(GreenStalk Garden, n.d.)
Broccoli	284	0.1	36.5	3.36	tower/pots	15 kg/ tower	2	(GreenStalk Garden, n.d.)
Garlic		0.004	1.5	0.18	tower/pots	0.5 kg/pot	1	
Blackberries		0.05	5.475	0.24	tower/pots	9kg / plant	1	(Wikifarmer, 2025)
Strawberries	277	0.05	5.475	0.5	tower/pots	15 kg/tower	2	(GreenStalk Garden, n.d.)
	*(U.S. Department of Agriculture, 2002)							
Total:		**1.54 kg**	**560 kg**	**145.73 m^2**				

Figure 06| Food Table

FOOD PRODUCTION

The result and foundation for the project are four different cultivation methods:

Open fields: Here the plants and trees are grown outside in the soil. The plants in this case are oats, hazelnut trees and sunflowers. The total need of open field per person is 95.6 m^2.

Greenhouses: In these, the chickpeas can grow in the soil but are protected from the outside climate and weather. The total need of greenhouses per person is 14.6 m^2.

Indoor farms: Indoors chia seeds, chickpea sprouts and wheat are grown in the most compact way on shelves, thus reducing the space required to a minimum. The total need of indoor farm per person is 12.8 m^2.

Vertical towers: Here the plants are planted in pockets filled with soil. By stacking the pockets vertically, many plants can thrive in a small area. The total need of space for the plant towers per person is 20.7 m^2.

In total that sums up to an area of 145.7 m^2 food production per person.

In this design 650 people get their food and living space on a plot of about 28,000 m^2. The distribution of the different food cultivation spaces are showed in the axonometric view of the plot, figure 08.

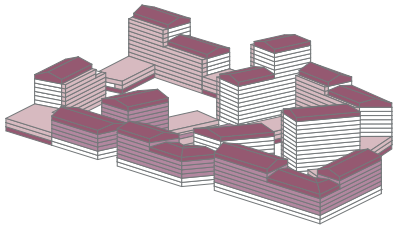


Figure 07 | Axonometry Buildings

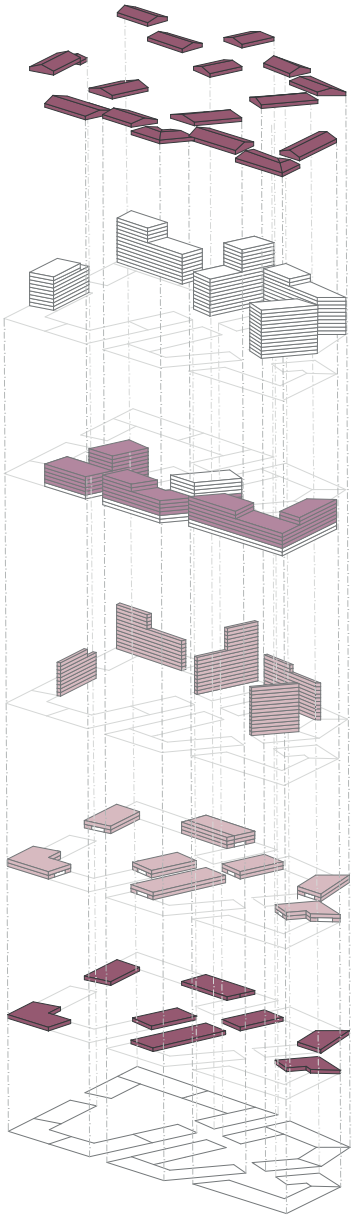


Figure 08 | Axonometry Food Production

URBAN SETTING

The project is located on the Western Harbour of Leith, where land was artificially created, initially for the industry. In the past 20 years this has changed and the land was used for housing development. Soon also other infrastructure, such as a new school and supermarket, was located nearby to serve the residents.

The land is now dedicated to mixed-housing development, focused on providing affordable housing for people with different needs. With the extension of the existing tram, this development site will have a great connection to public transport and no reliance on cars.

The plot has several benefits. First of all, it is connected to the existing housing and not isolated at all, by that, the new neighbourhood can easily be integrated within the existing situation. Secondly, the plot has a very central position, as the new tram line will directly pass by. The last stop on the western harbour will be located directly in front of the plot. In addition a new promenade will be located along the shore, making it attractive for people to come here, take a walk and make use of the new public spaces and services.

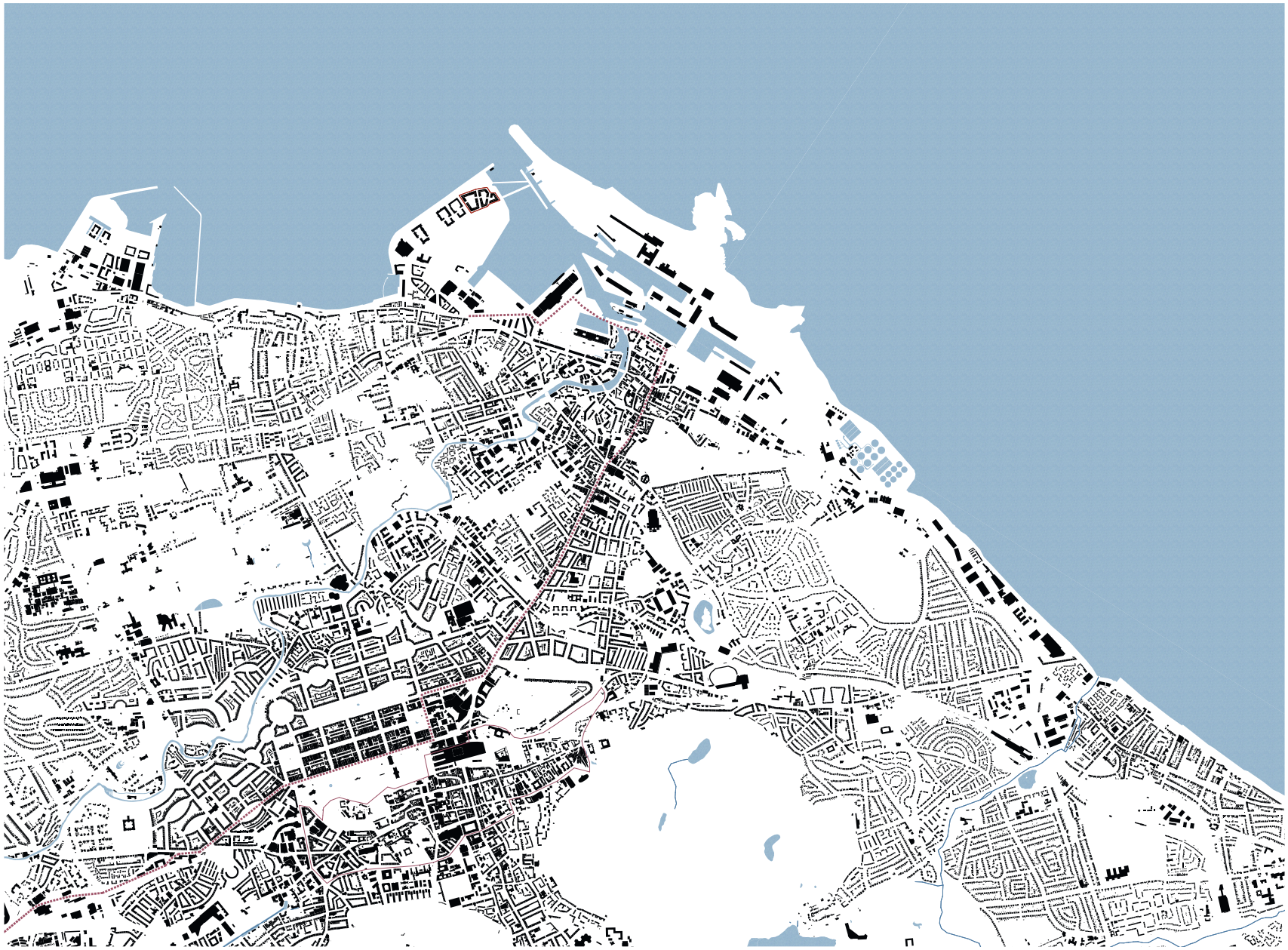


Figure 09 | Edinburgh Figure-Ground Plan

REVISED DEVELOPMENT PLAN

With the introduction of the new concept, aligned with the proposed Food Table, the existing Leith Docks Development Framework was adapted to support a new vision of sustainable urban living. The revised masterplan is designed to provide both housing and food for approximately 12,000 residents.

The urban layout maintains the originally proposed perimeter block typology but re-imagines these buildings as hybrid structures– combining residential space with integrated food production. The internal courtyards of the blocks are transformed into productive gardens, primarily cultivating sunflowers and hazelnut trees. In addition, several larger green spaces are designated as open fields for the cultivation of oats, fulfilling the agricultural requirements defined by the Food Table.

The existing street infrastructure is reduced to prioritize greenery and food production instead of cars. Wide tree allees, with fruit- and nut-bearing trees, now replace traditional roads. Private vehicle use within the residential zones is minimized, supported by parking facilities, that are located along the main access road, while shared car hubs are distributed throughout the neighbourhood, allowing occasional car access without compromising pedestrian space.

To support sustainable infrastructure, a new biogas fermenter with a combined heat and power plant are proposed adjacent to the existing wastewater treatment facility. This system not only processes organic waste but also generates renewable energy and heat, contributing to the self-sufficiency and resilience of the new community.

Figure 10 | Leith Development plan - Own illustration based on City of Edinburgh Council (2009)

ENERGY CONCEPT

The total annual energy demand for the new development area for 12,000 people was calculated based on both energy required for living and the indoor food production. Based on these facotrs each resident is estimated to require approximately 1,904 kWh per year, combining heating and electricity for living and the indoor food production. Hence, for all 12,000 residents, the total energy need sums up to 22,848,000 kWh per year.
To reduce the energy consumption, the buildings are designed with a low U-value that significantly reduces heat loss. In addition, a heat recovery ventilation system is implemented across all residential and farming areas to further minimize the heating demand, particularly in the colder months. These strategies allow to optimize the energy use and contribute to the project's goal of becoming energy-positive.

To fulfill the energy need, three different energy systems will serve the neighbourhood:

First of all, a new tidal system, integrated into the existing water basin (470,000 m^2) and using the existing dam (250 m) will produce 31.5 percent of the energy.

Secondly, a new biogas plant using all the farm and organic waste of the people, also including the blackwater, will produce 7 percent of the energy.

Lastly, the tidal turbines placed outside the harbour producing 61.5 percent of the total energy demand.

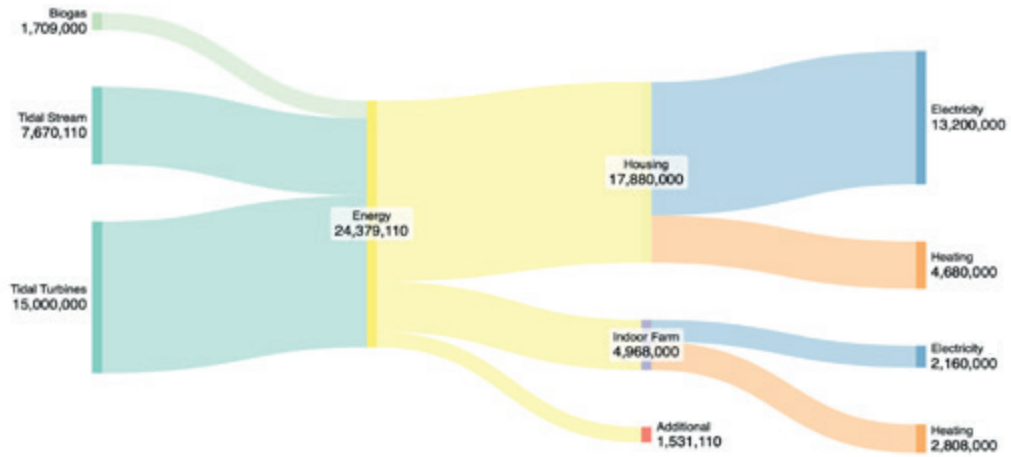


Figure 11 | Energy flow diagram. Created by the author using SankeyMATIC (https://sankeymatic.com)

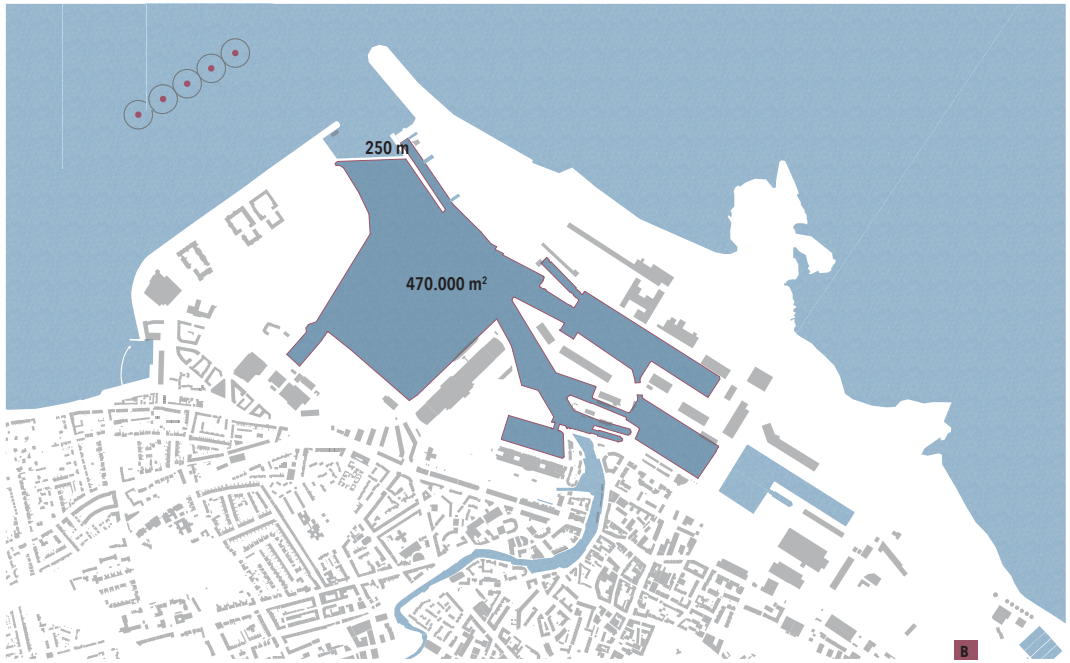


Figure 12 | Energy Production Map

WESTERN HARBOUR

Western Harbour
1940

1996

2000

2005

2015

Figure 13 | Western Harbour Development

Figure 14 | Western Harbour Site Plan

BUILDING TYPOLOGY

The architectural typology of Growing Harmony is based on a hybrid perimeter block that forms central courtyard gardens within a cluster of three buildings, designed to provide food and living space for around 650 people. Rather than separating functions, food production is integrated into circulation areas, community spaces and courtyards.

Winter gardens act as both access routes and communal zones, featuring vertical plant towers that bring cultivation into daily life. As transitional spaces, they adapt to seasonal changes.

The three-storey greenhouses support different functions: ground floor chickpea cultivation, first-floor community spaces combined with plant towers and second-floor vertical farming benefiting from maximum sunlight. These greenhouses connect directly to the living spaces via the winter gardens.

Courtyards and surrounding areas are planted with fruit trees, oats and sunflowers, while a central path links the cluster to the broader neighbourhood. These gardens double as social and recreational spaces, encouraging interaction and a close connection to nature.

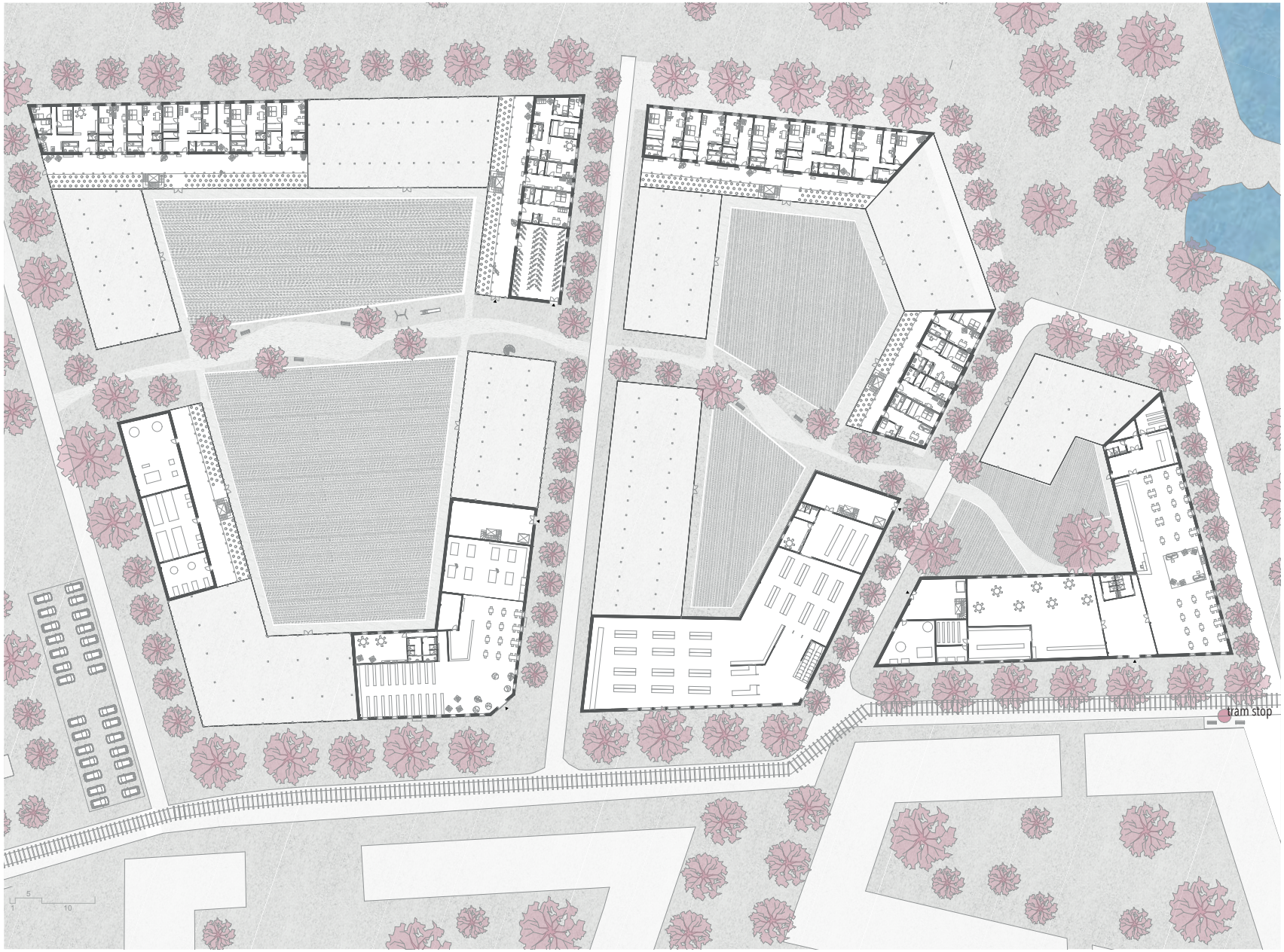


Figure 15| Ground Floor Plan

USAGE

The buildings serve for different usages:

The living parts are serving different-sized apartmens, between one and four bedrooms, to invite different people with different needs, in size, affordability, age and so on. As already mentioned the food production is also integrated into the living part of the building mostly with the plant towers in the circulation area.

The public spaces are located alongside the tramline on the ground floor of the buildings. These public spaces offer different usages: a library of things, a repair cafe, a supermarket of the local foods, a restaurant and an open community kitchen. Those usages are focused on strengthening a sustainable and resilient community, supporting the people to share but also support each other. The public spaces furthermore invite people from the surrounding neighbourhoods.
On the upper floors of the public spaces food processing is taking place. Above that the indoor farming areas are located, efficiently using the heat coming from underneath.

The cultivation of the plants is also combined with shared spaces for the community in the greenhouses. The first floors of the greenhouses include different shared spaces: a youth room with working tables, table tennis, other games, a chill lounge, a creative workshop space where people can create art and work on handicrafts, a fitness and yoga room with an ocean view and lastly, a common meeting and working space with seating areas and a calm atmosphere between the plants.

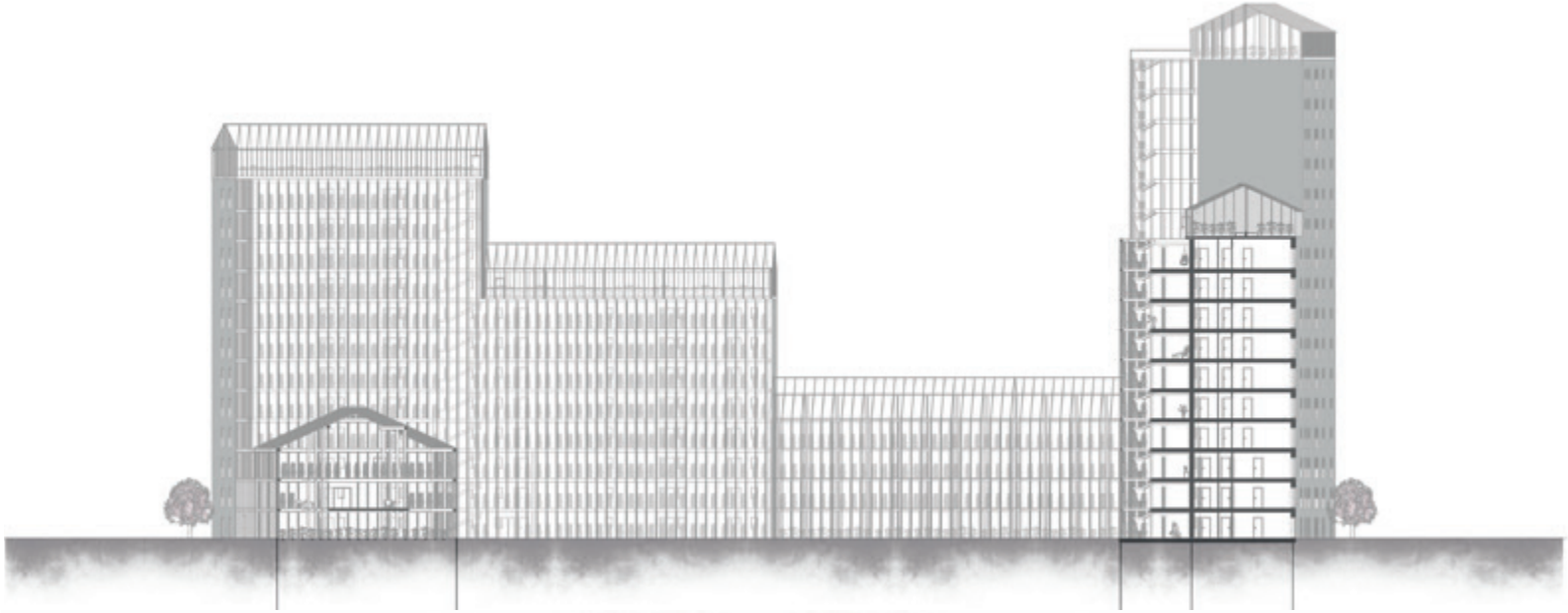


Figure 16 | Section Two

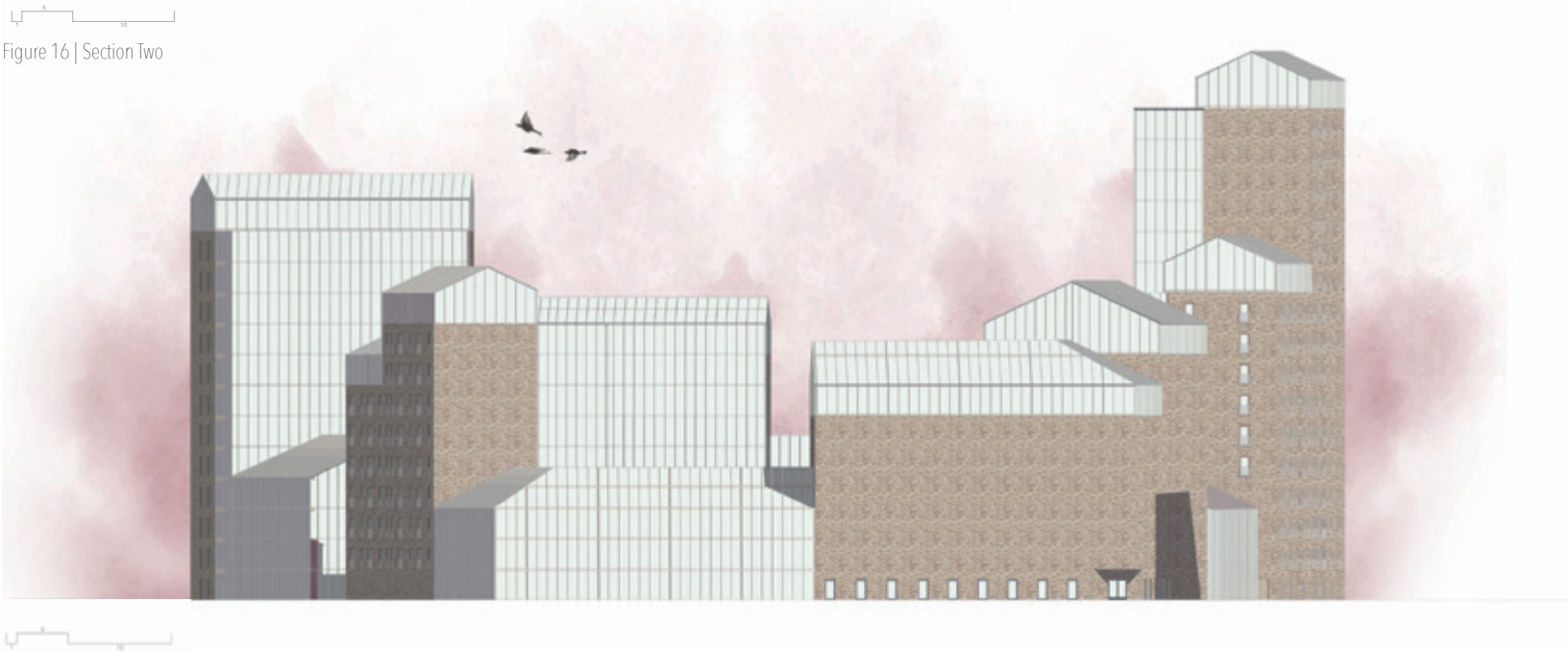


Figure 17 | Elevation South

CONSTRUCTION

The construction of the building is a wooden frame construction, which stands on steel posts, that enable the floor slab to be ventilated from underneath and make it possible to eliminate concrete. As with the other floor ceilings, the load-bearing element of the floor slab is the board stack ceiling, which is visible from below in the apartments and thus creates a pleasant atmosphere.

From the outside there are two different facade sides on the buildings. On the one side, the facade, which is oriented towards the interior of the courtyard and stands between the winter garden shell from the curtain wall facade.. On the other sides of the building, the other type of facade, which is also visible from the streets, this one is covered with a natural stone wall shell and is intended to underline the industrial look of the harbour area. The two facade structures thus form a contrast, however, they work together to create harmony.

As already mentioned, the wooden facade is preceded by a curtain wall facade, which forms the winter garden and access area. The wood and glass are intended to create a pleasant lounge area. Furthermore, the load-bearing elements of the glass facade are made from wooden supports, which are placed visibly in the access area. In addition, the cantilevered balcony is supported on wooden columns in order to be able to safely transfer the loads.

Finally, the flat roofs of the houses are covered with a layer of soil substrate of 400 mm, through the glass protective cover, the area can be used as a greenhouse and the cultivation of chickpeas is possible.

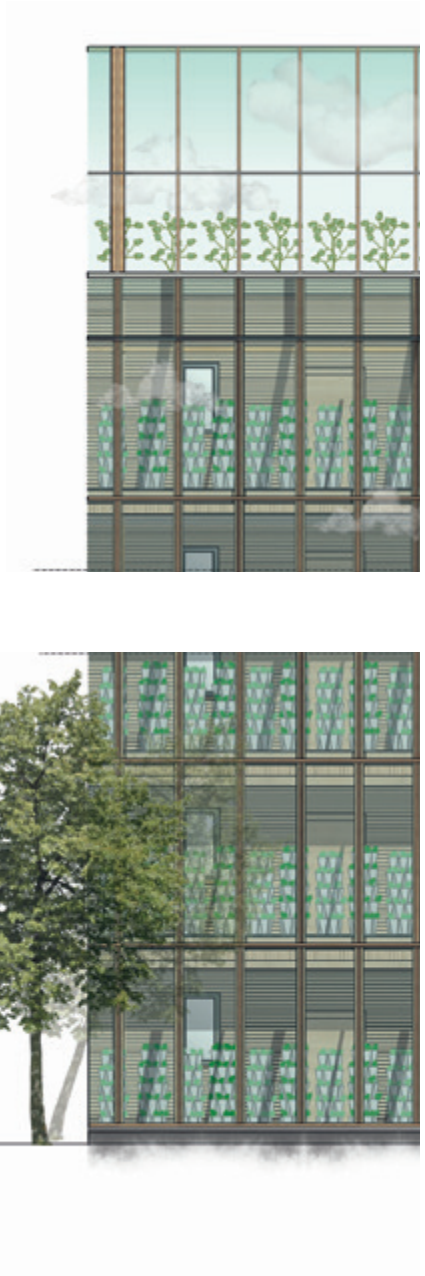


Figure 18 | Detail Elevation

Flat roof to Greenhouse:
400 Substrate
10 Drainage
5 Fleece
EPDM Waterproofing membrane
120 Hemp-lime board
5 Hemp fleece
180 Board stack ceiling

U-Value: 0.15

Ceiling:
15 Hardwood parquet (multi-layer)
10 Hemp fleece
60 Clay-heating plates
30 Footfall sound insulation wood fiber
80 Gravel fill (lime)
5 Hemp fleece
180 board stack ceiling

Ceiling Wintergarten
25 Terrazzo finish
60–70 Pedestal supports (adjustable pedestals)
10 Drainage mat
EPDM Waterproofing membrane
120 Hemp-lime board
5 Hemp fleece
180 Board stack ceiling

External wall:
25 Wood facade
30 Ventilation gap
Wind paper
70 Wood fiber insulation
240 Seaweed insulation with timber frame
Vapor barrier
30 GFM diagonal panel
50 Installation layer with fiberboard
12.5 Clay board
15 Clay plaster

U-Value: 0.145

Ground floor slab:
15 Multi-layer parquet
60 Clay heating panels
10 Hemp fleece
30 Impact sound insulation
20 Wood fiber carrier board (HDP)
200 Eelgrass insulated timber beam layer
Vapor retarder
180 Board stack ceiling
500 Ventilation gap

U-Value: 0.144

Ground floor Wintergarten:
25 Terrazzo finish
60–70 Pedestal supports
400 Lime fill
5 Fleece

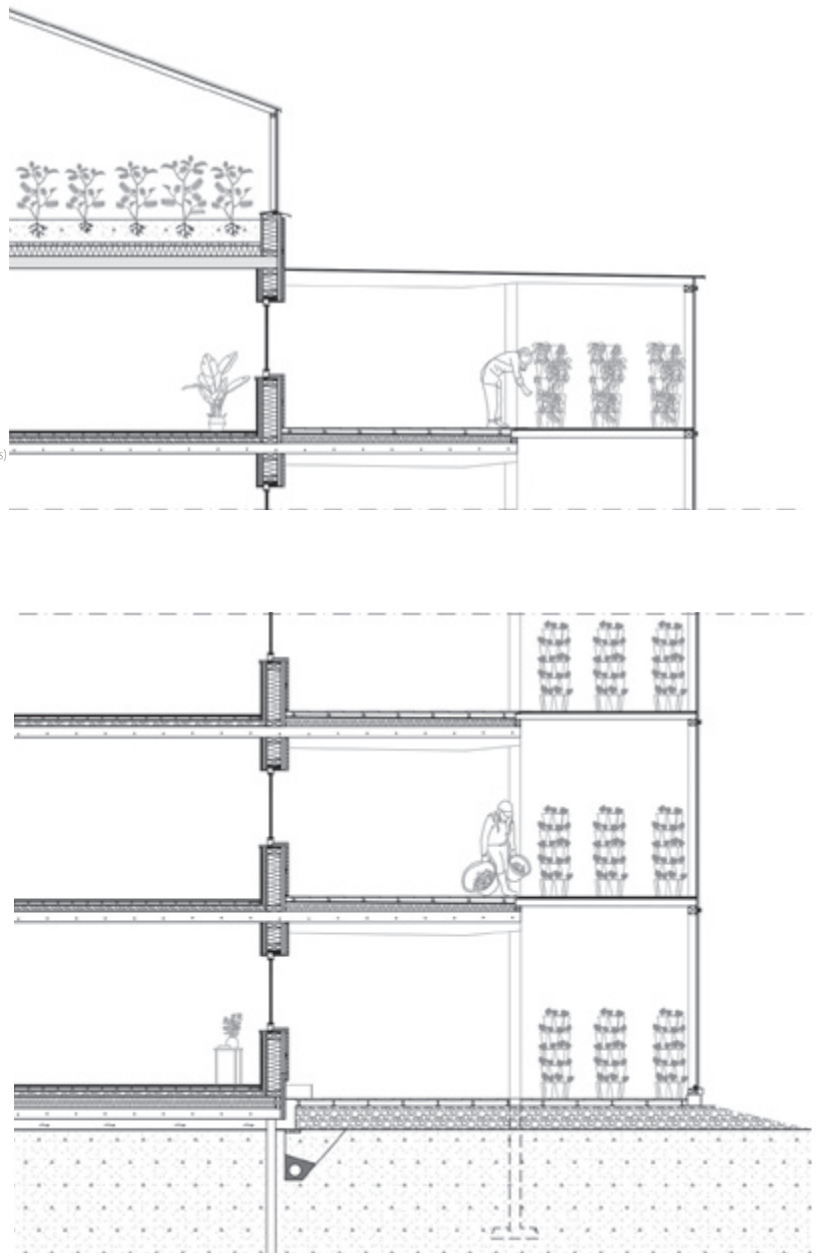


Figure 19 | Detail Section

Figure 20 | Modell 1:100 One

Figure 21 | Modell 1:100 Two

Figure 22 | Modell 1:100 Three

Figure 23| Atmospheric Visual Access Area

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