THE *Elegance* OF VERTICAL FARMING

ARCHITECTURAL DESIGN OF BUILDING INTEGRATED PLANT FACTORIES WITH ARTIFICAL LIGHTING

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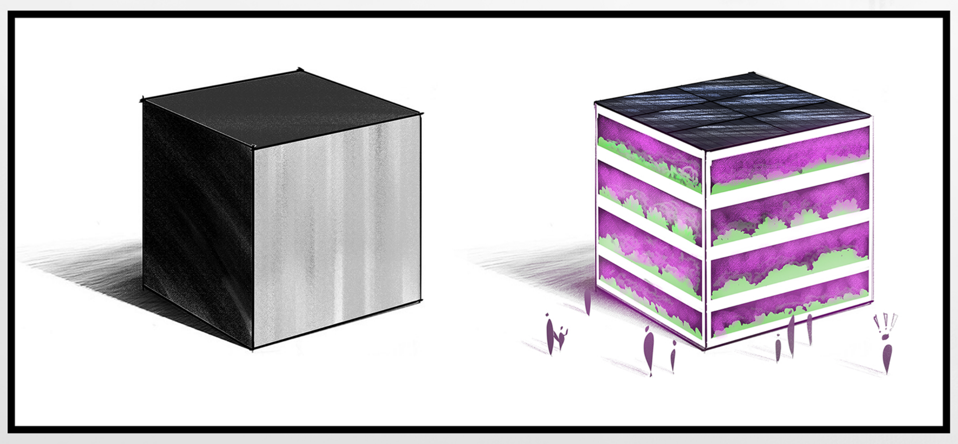
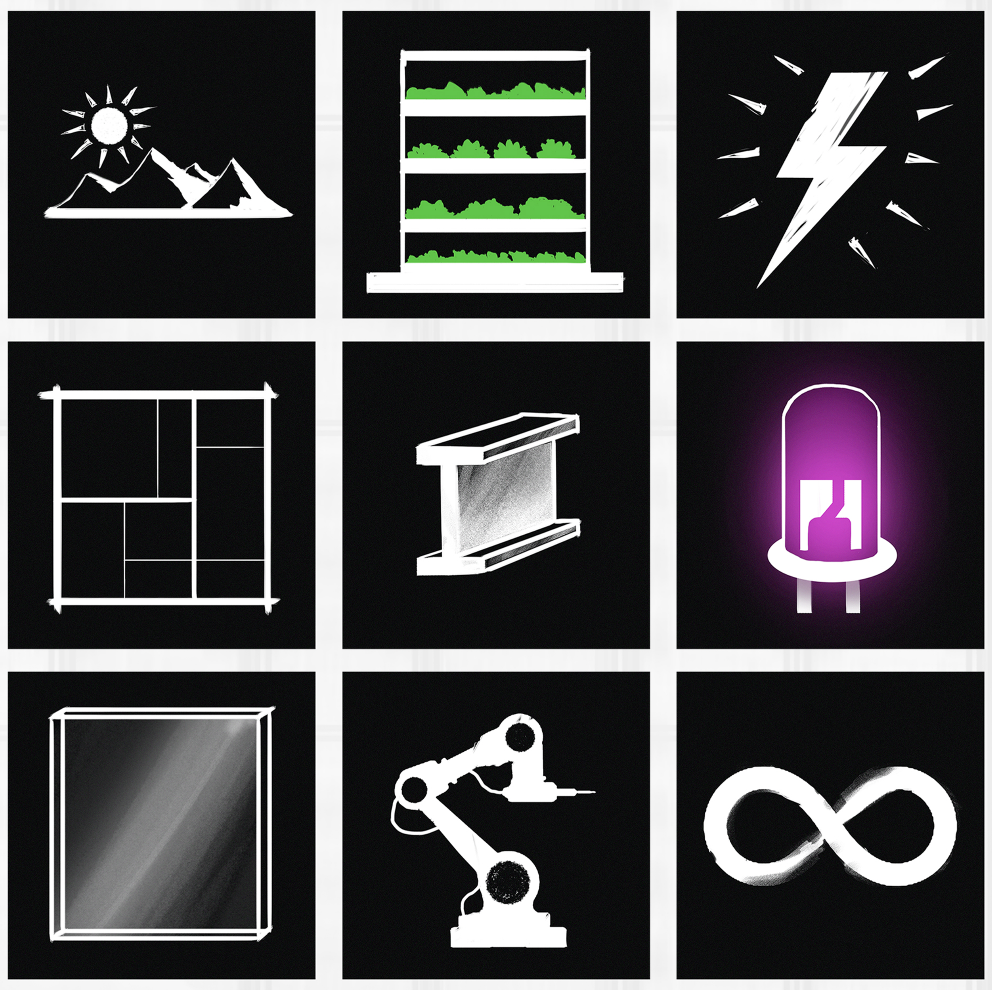
THEORETICAL BACKGROUND & PROJECT OBJECTIVE

With phenomena such as population growth and urbanisation, expanding cities no longer derive their food supply from their hinterlands but rely on the global food trade which includes vast open-field agriculture. Given the limited availability of land, water and nutrients together with the uncertainty of a changing climate, the sustainability of these networks becomes questionable.
Urban agriculture and in particular Plant Factories with Artificial Lighting (PFAL) offer the potential to positively adapt to these changes. In these PFALs, horizontal trays are stacked in a closed environment, using LEDs, HVAC and hydroponic systems to enable an optimal environment for plant growth. Besides the bottleneck of high energy demands, an architectural problem is emerging: when approached from the perspective of production quality and efficiency, PFALs are at risk of being architecturally translated as a closed box. Resulting in production nearer the consumer, yet these consumers remain oblivious about the making of what they consume on a daily basis.
This project aims to enable the architectural design of building integrated PFALs in such a manner, that the consumer and other involved actors benefit not only from the product but also learn about and experience the growth process, while retaining production quality and efficiency. To achieve this, a factor list is derived from existing literature, to provide a document for architectural reference when designing building integrated PFAL.

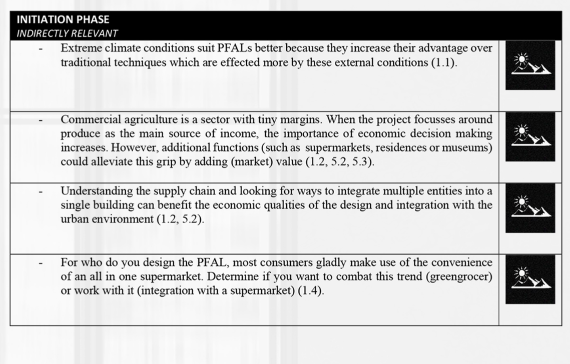


NINE RELEVANT CATEGORIES

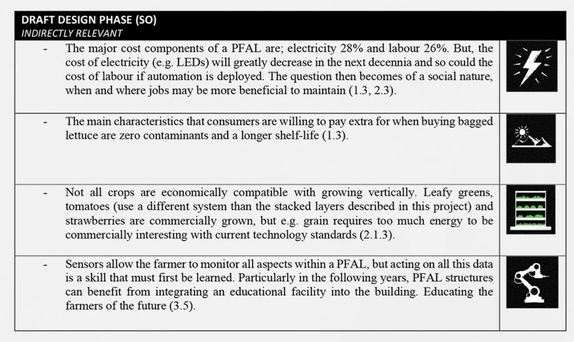


CONTEXT ; CEA SYSTEM ; ENERGETIC FLUXES ; FUNCTIONS ; LOAD BEARING STRUCTURE ; LIGHTING ; TRANSPARENCY ; AUTOMATION ; CLOSE THE LOOP

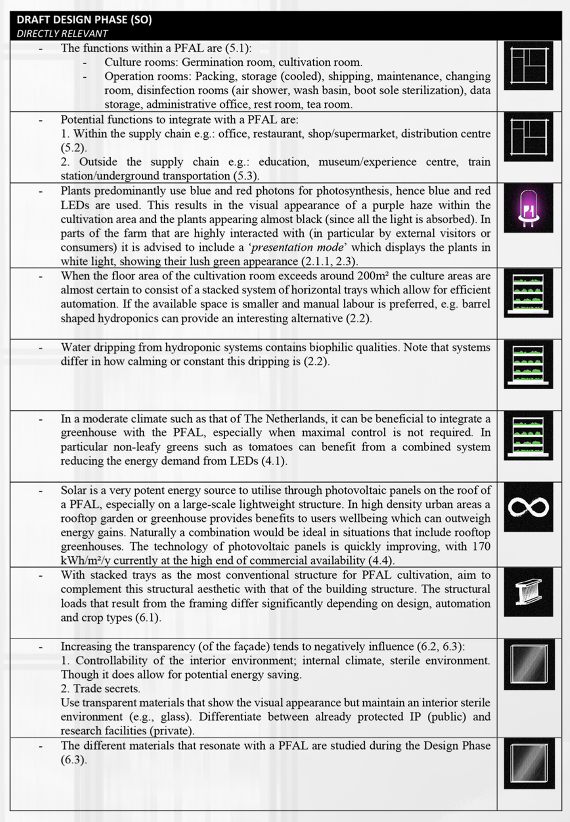
FACTOR LIST



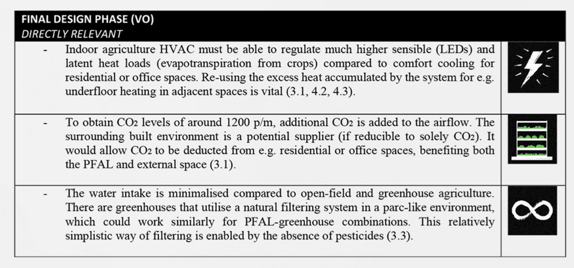
INITIATION PHASE
INDIRECTLY RELEVANT



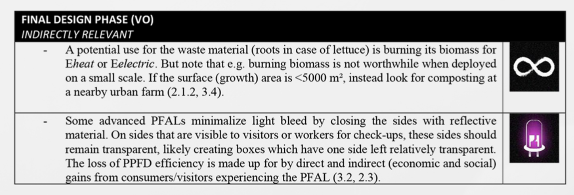
DRAFT DESIGN PHASE (SO)
INDIRECTLY RELEVANT



DRAFT DESIGN PHASE (SO)
DIRECTLY RELEVANT



FINAL DESIGN PHASE (VO)
DIRECTLY RELEVANT



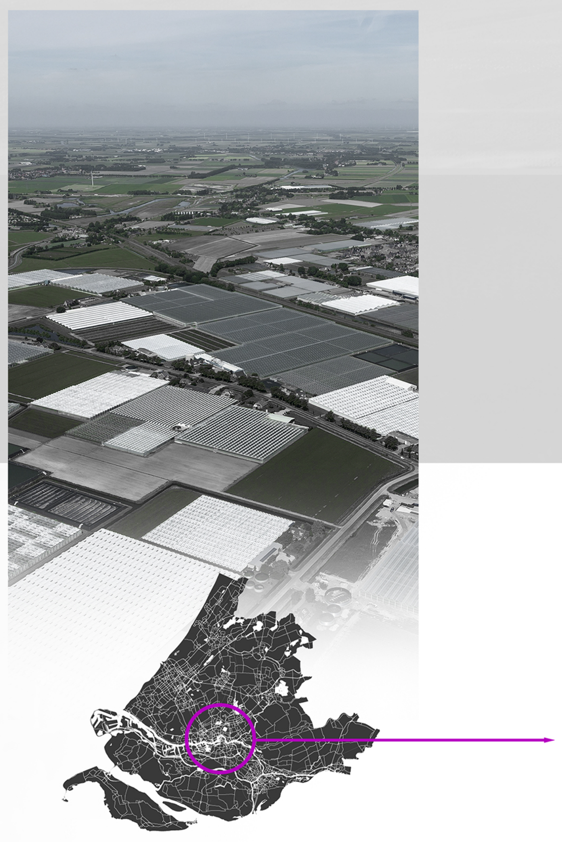
FINAL DESIGN PHASE (VO)
INDIRECTLY RELEVANT
- A potential use for the waste material (roots in case of lettuce) is burning its biomass for E*heat* or E*electric*. But note that e.g. burning biomass is not worthwhile when deployed on a small scale. If the surface (growth) area is <5000 m², instead look for composting at a nearby urban farm (2.1.2, 3.4).
- Some advanced PFALs minimalize light bleed by closing the sides with reflective material. On sides that are visible to visitors or workers for check-ups, these sides should remain transparent, likely creating boxes which have one side left relatively transparent. The loss of PPFD efficiency is made up for by direct and indirect (economic and social) gains from consumers/visitors experiencing the PFAL (3.2, 2.3).

Architecture is a multidisciplinary practise, with intuition playing a significant role in the creative process. This makes determining the exact relevancy of a PFAL-related aspect a difficult and often subjective discourse. For the relevancy of the described factors this implies that they can greatly vary per architect and per project. The following findings are deemed the most important, unexpected or fascinating and concluded to be (almost) without exception relevant for the architect to take into account.

RURAL

FREE UP LAND AREA

Switching from open land and greenhouse farming to plant factories for only the crop types that are currently economically viable already frees up a significant amount of land area. In case of the province South-Holland this is over 76 km2 which equals to 15 times the centre of Rotterdam. This can be given back to nature or used to accommodate the Dutch housing shortage.



CITY

IMPROVE RESILIENCE

A certain, local food supply has the ability to improve a city's resilience. Something that came increasingly apparent during COVID-lockdowns.

BUILDING

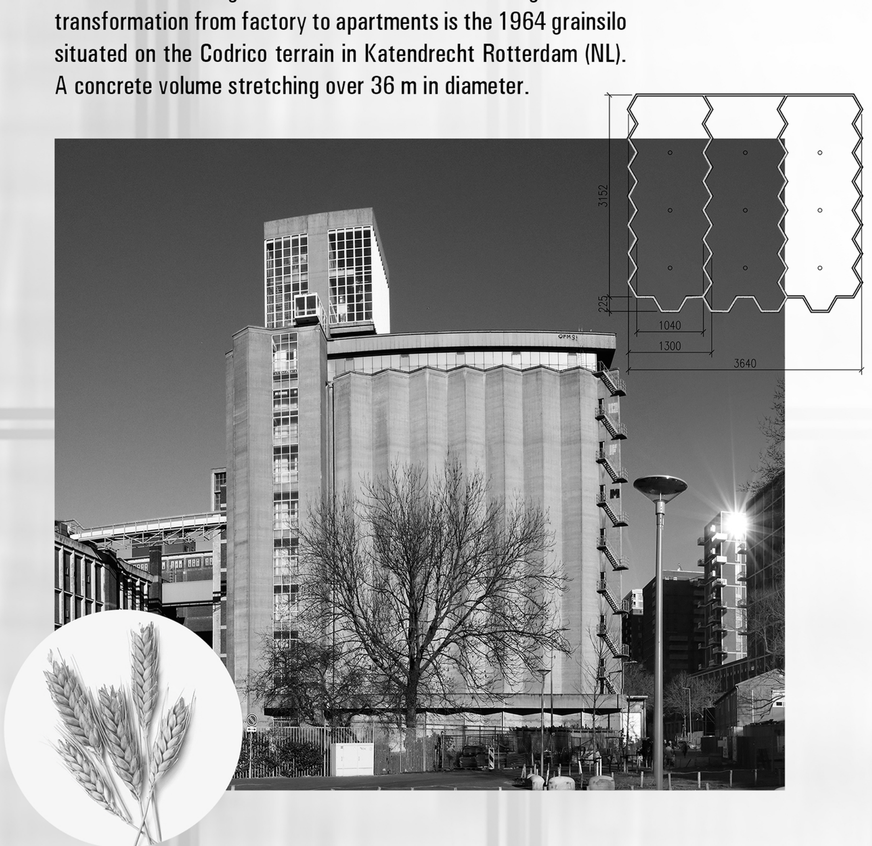
RECONNECT THE CONSUMER WITH THE GROWING OF THEIR FOOD

For buildings situated within cities, it is difficult to economically compete with the efficiency of PFALs located just outside the city. The potential rather lies in reconnecting the consumer with the growing of their food as an increasing percentage of citydwellers has no clue how and where their food is grown.

BUILDING AS A TESTCASE "The Urban Amethyst"

GRAIN SILO OF FACTORY LATENSTEIN, ROTTERDAM

One such building that is on Rotterdam's agenda for transformation from factory to apartments is the 1964 grainsilo situated on the Codrico terrain in Katendrecht Rotterdam (NL). A concrete volume stretching over 36 m in diameter.

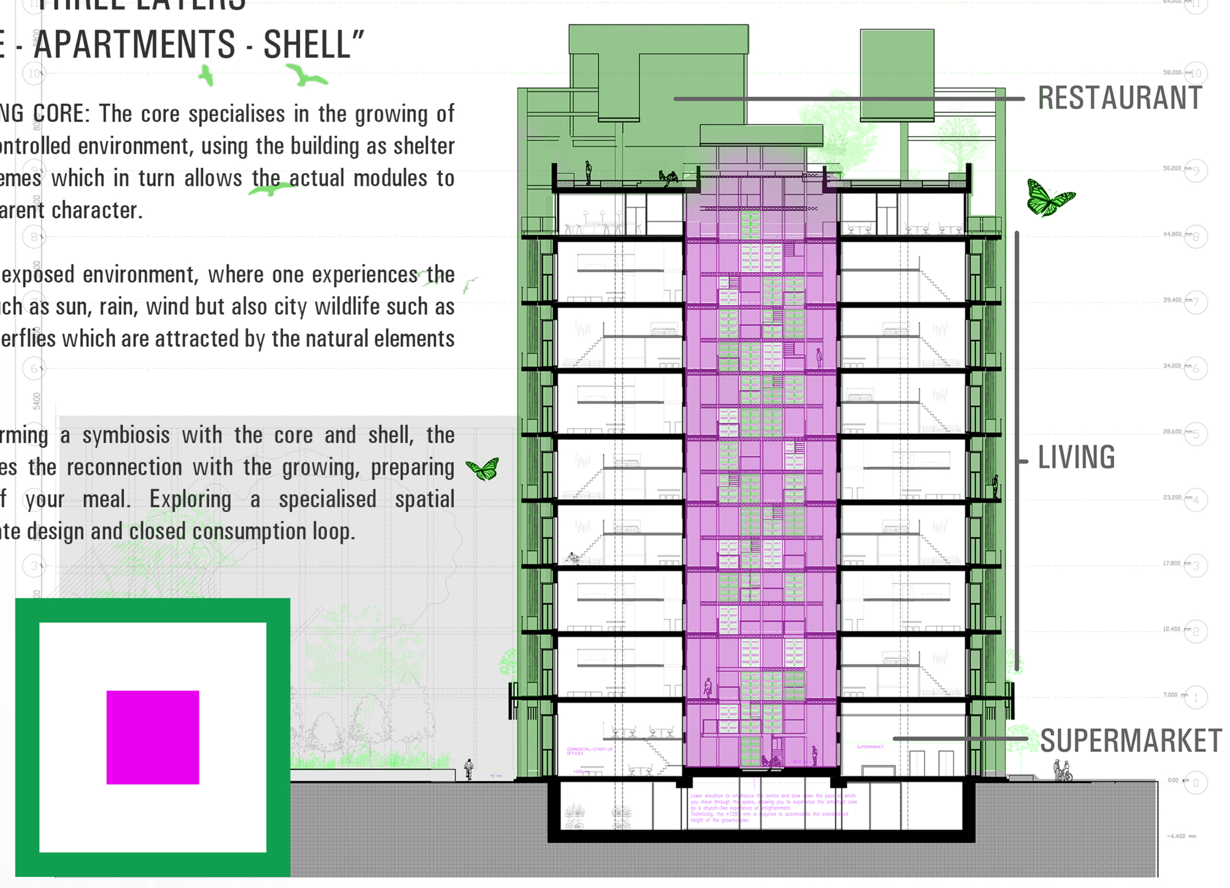


BUILDING CONCEPT
THREE LAYERS
"CORE - APARTMENTS - SHELL"

VERTICAL FARMING CORE: The core specialises in the growing of your food. It is a controlled environment, using the building as shelter from weather extremes which in turn allows the actual modules to have a more transparent character.

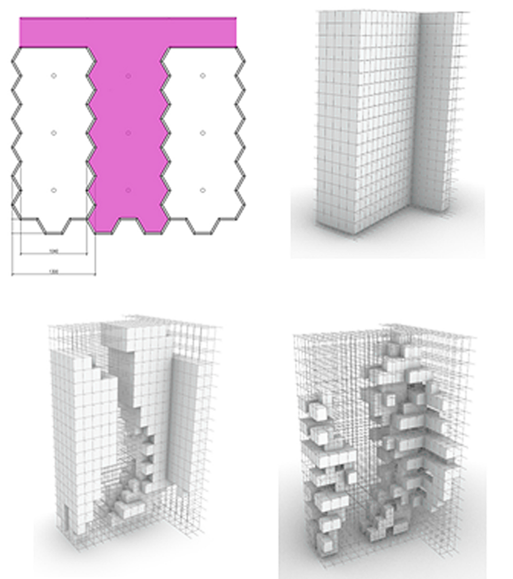
GREEN SHELL: An exposed environment, where one experiences the natural elements such as sun, rain, wind but also city wildlife such as birds, bees and butterflies which are attracted by the natural elements of the shell layer.

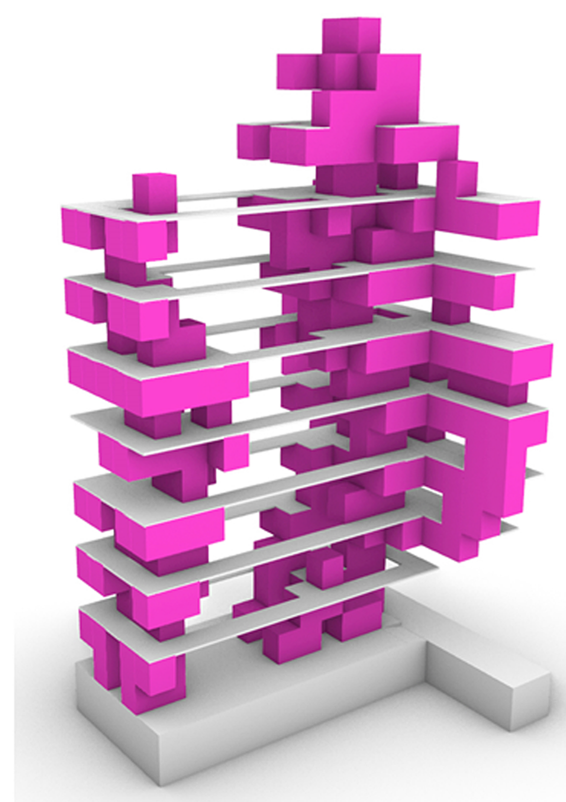
APARTMENTS: Forming a symbiosis with the core and shell, the apartment facilitates the reconnection with the growing, preparing and consuming of your meal. Exploring a specialised spatial configuration, climate design and closed consumption loop.

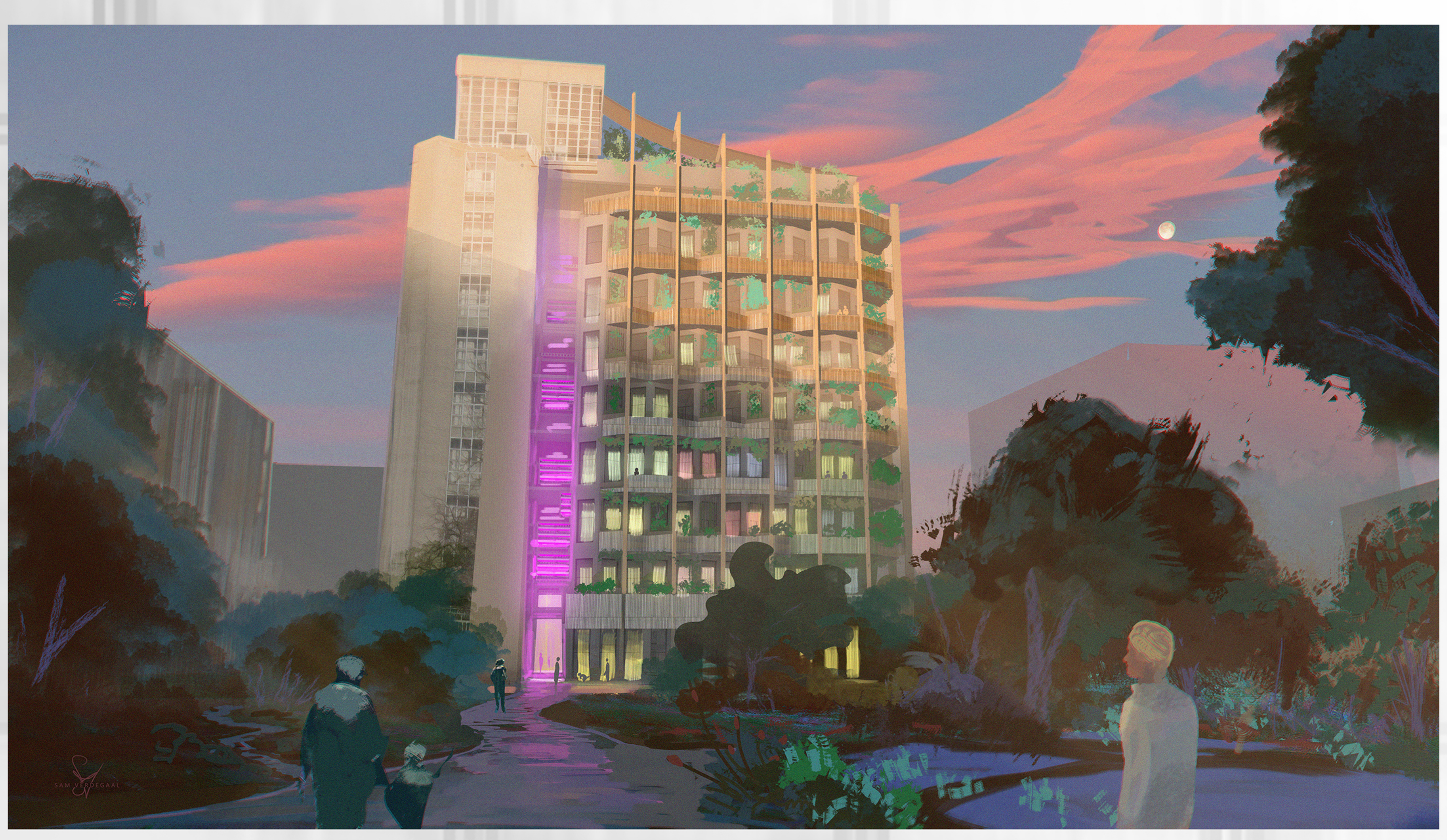


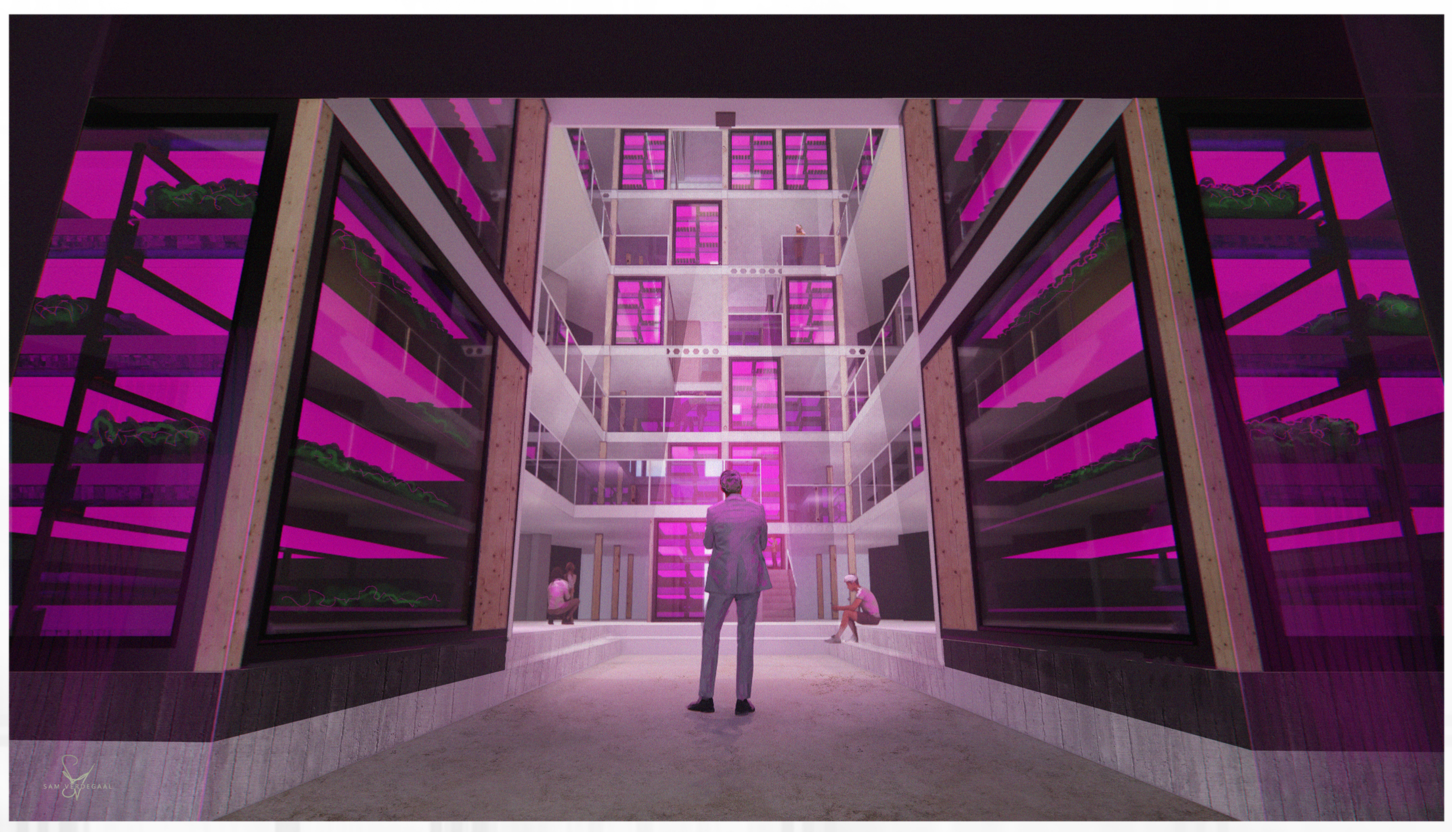
CARVING OUT THE AMETHYST

Carving out the amethyst according to a set of design parameters, which included: aesthetic qualities of the guiding sketch; accessibility of the apartments; access to growmodule from at least one side.
From there on there was the freedom to design for work, play, relax or dining spaces within the negative space of the growmodules.









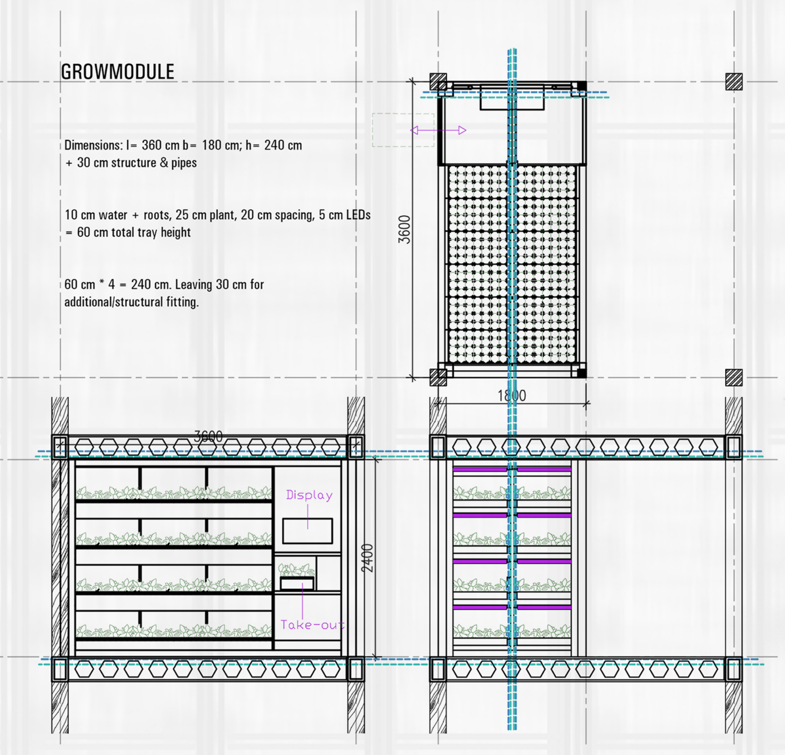
GROWMODULE SYSTEM PROTOTYPE

GROWMODULE & STRUCTURAL SYSTEM

Providing a tailormade design specific to each project requires significant knowledge on a variety of fields including plant specialists and plant factory engineers. To make this still novel high-tech growing more accessible for city buildings, I've chosen to explore the route of a more standardised design that can be fitted into a variety of spaces. The downside is that it hands in potential production efficiency but the upside is that it becomes much more accessible for architects and project developers to implement the growmodules into their buildings.

Although there are clear biophilic benefits for growing your own food, not everyone is willing to spend half an hour a day tending their crops in an urban community farm. The aim of the growmodules is to allow its users to experience the growing of their food, under a minimal threshold. Translating into automated growmodules that are similar in operation to a coffee machine and similar to an aquarium in user experience as one can see the plants grow from seed to harvest-ready.

Design parameters in clude: user experience; flexible fit in any building space; aesthetic qualities; production efficiency.



GROWCUBE

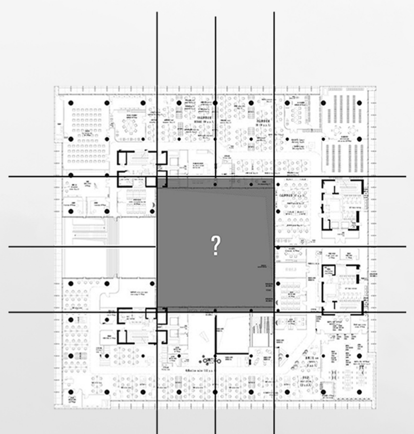
A driving factor for this project was the ambition to bring the project into actuality. For such a system to be deployed on a large scale it has to be more than an idealistic architectural intervention. Or rather, it has to be just that but also be economically viable. During the second part of this graduation project I participated in the TU Delft Impact Contest, which allowed me to validate the architectural concept as potential startup idea. This allowed me to develop a business model and learn whether this concept can solve 'hair on fire'-problems for the paying customer.

It was an unique experience to explore the (theoretical) boundaries of an architectural vision and on the other hand dive into the (economic) practicalities of the built environment.
I will continue to validate the concept under the working title "GrowCube", together with two mechanical engineering MSc students.

FINALIST

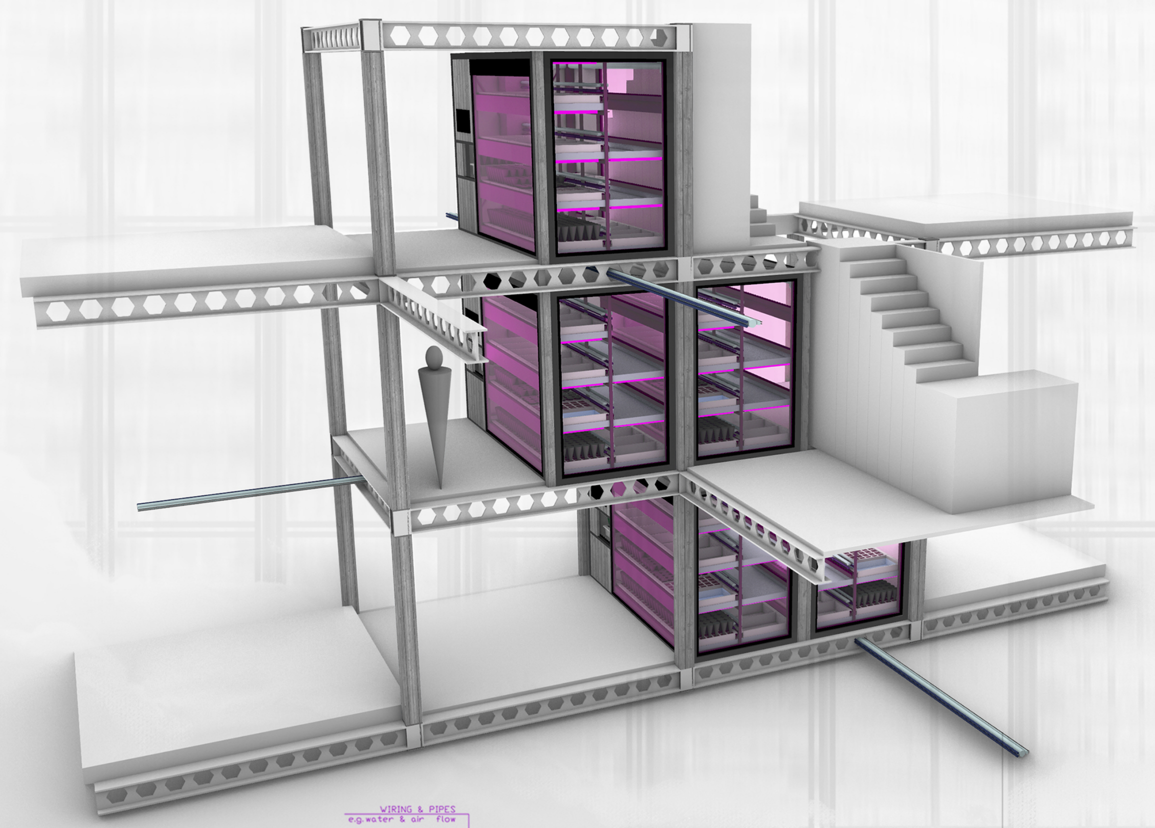
TU Delft **Impact Contest**
Launch your start-up idea

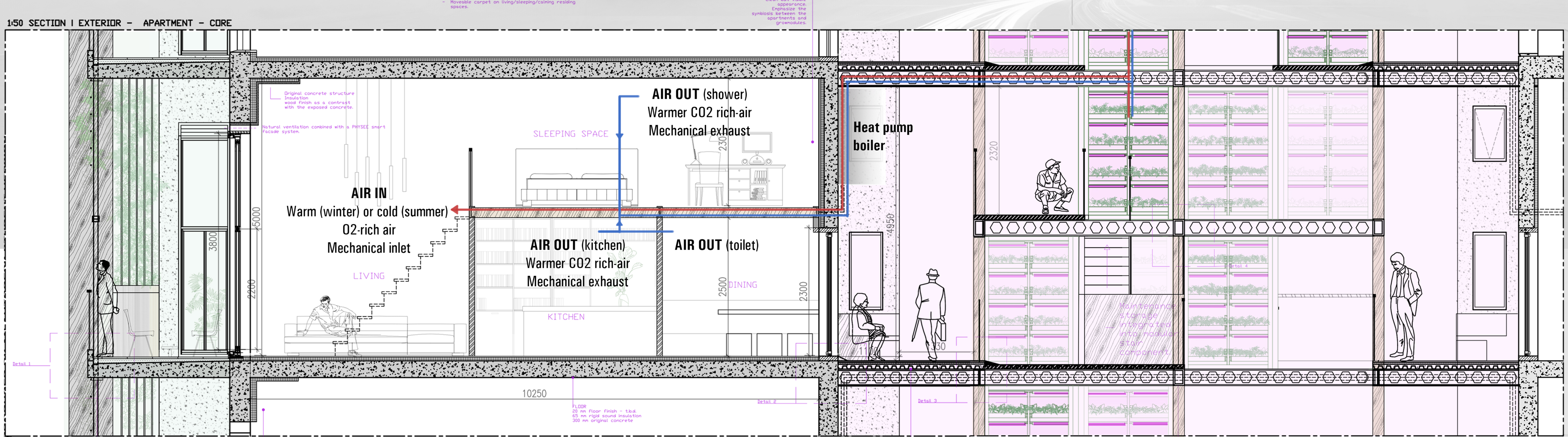
TRANSFORMATION OF LARGE OFFICES & FACTORIES TO RESIDENTIAL USE



When transforming large office or factory buildings to apartment spaces, the following challenge often emerges: with the large open floorplan and the daylight requirements for working the building functioned just fine. However, with its new residential function, this open floorplan is divided into apartments, reducing the natural light and interest of the central space.
The typical result is an unattractive core with storage and a hallway.

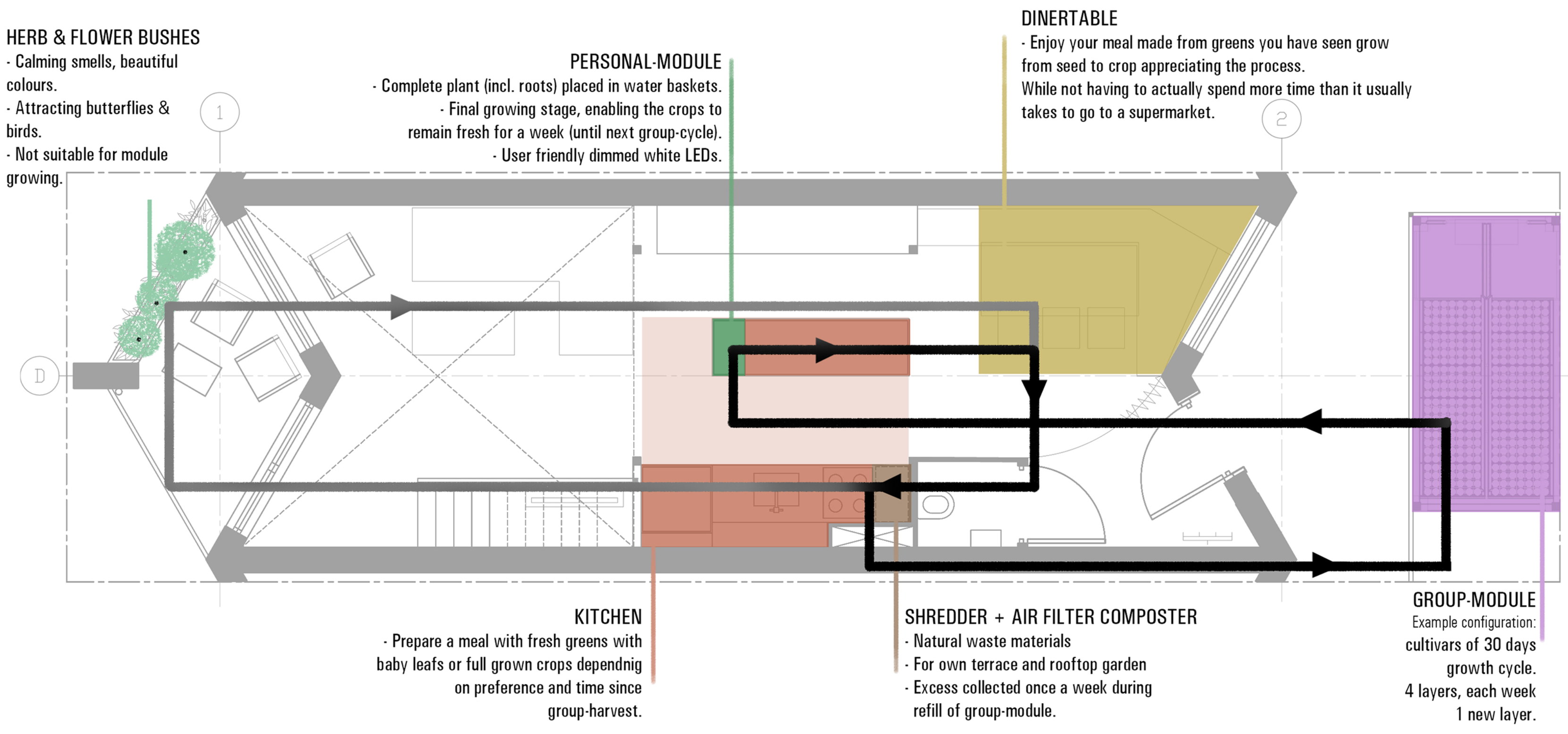
But what if, that unattractive building core could look like this? Growmodules, lighting up the dark core and producing fresh crops & filtering air for the residents. Here, the core becomes a place of value instead of burden. The project developer does not have to demolish part of the building (huge cost reduction), and the end user (residents) experiences a fascinating process that improves their living space. On top of that, highly nutritious, fresh and delicious crops.

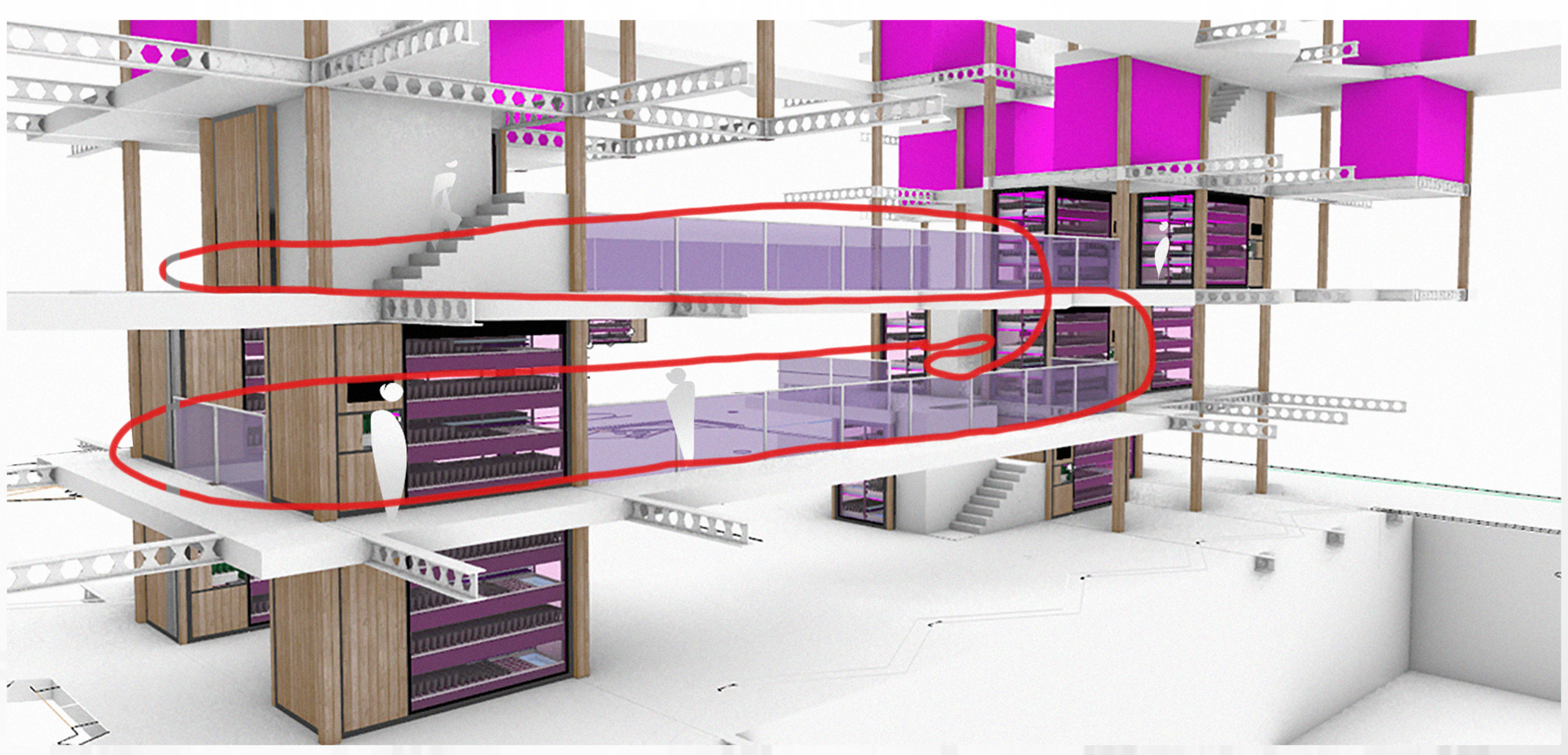




HUNTER GATHERING & CIRCULAR CONSUMPTION

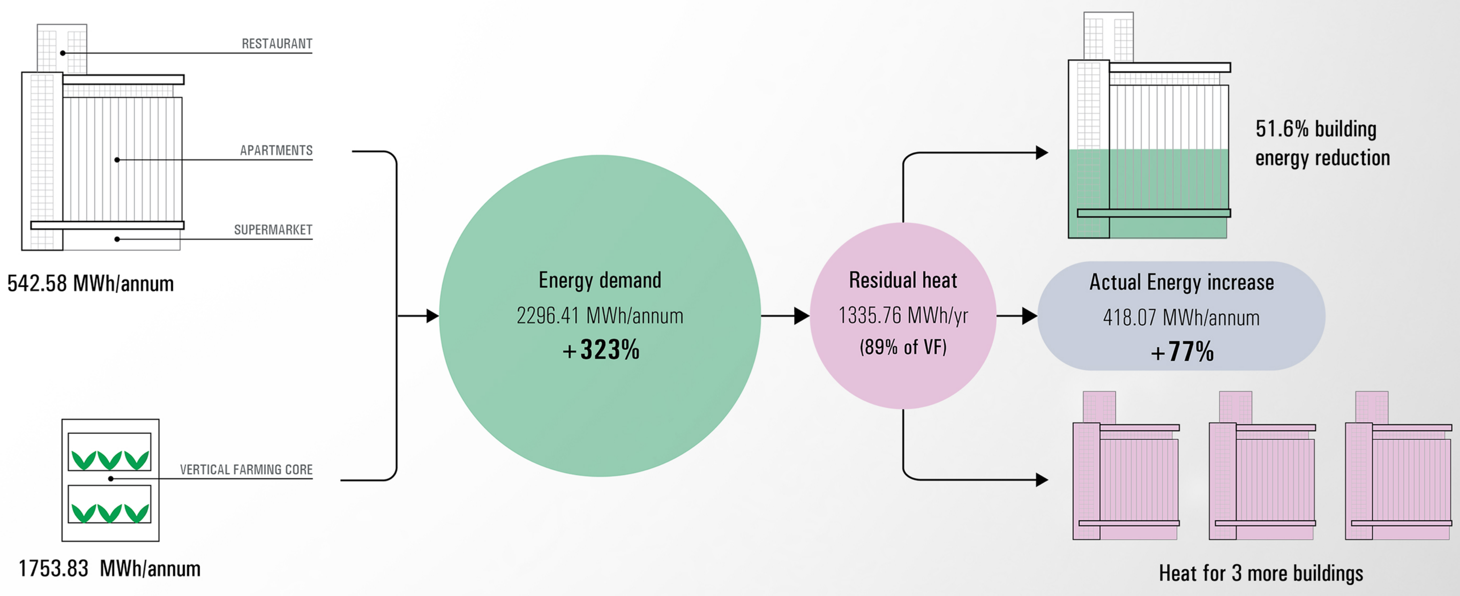
To optimize growing conditions, each module grows a single crop type. When preparing their lunch or diner, the residents go on a short hunter-gathering-mission to compile their meal. During this process they may come into contact with other residents who are also gathering their fresh greens.



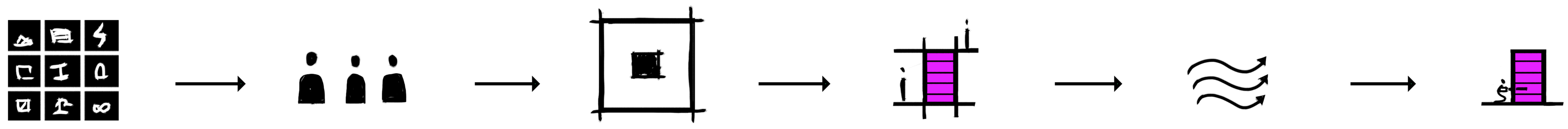


ENERGETIC SYMBIOSIS

PFALs require a significant energy input, predominantly for LEDs and HVAC. If the residual heat from the growmodules is used to warm up the other functions of the building its actual energy demand can be drastically reduced.



STRATEGY FOR FUTURE IMPLEMENTATION



FACTOR LIST

1. Consult the factor list for a basic understanding of what & when.

USER & DEMAND

2. Define user & demand e.g.; residents, restaurant, supermarket, offices or cafeteria. Who operates the growmodules determines the level of transparency possible while maintaining a sterile environment.

(DARK) SPACES

3. Identify the (dark) spaces to place the vertical farm. The more enclosed the space, the easier it is to maintain a year-round steady crop production.

DESIGN SPACES

With GROWMODULES
OR
From scratch

4. Design the spaces with the growmodules; check how many modules are required to accommodate the production demand & design focussing either on efficiency (more modules, higher production) or user experience (interplay with other functions). Or design from scratch, this has the potential of a tailormade design but is more time and cost intensive.

CLIMATE SYSTEM

5. Connect the climate system of the farm with the building to reduce or nullify the heating demand, improve air quality and reduce overall energy requirements.

MAINTENANCE

6. Suggest a maintenance service to complete the process.