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Structural and optimised elements for aquaponic systems design

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The 2030 Agenda

In September 2015, 193 countries adopted 17 SDG Sustainable Development Goals: an agenda of commitments to promote well-being and ensure the prosperity of individuals and the planet to be achieved by 2030.

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In the nineteenth century, for the first time in human history the world population reached a billion inhabitants.
Since then there has been an exponential growth of growth. In 2011 it reached 7 billion, and it is expected that by 2050 it will reach 10 billion. At the same time, there was a phenomenon of progressive transfer from rural to urban areas. In 1950 only 30% of people lived in an urban context while it is expected that in 2050 it will reach 60%.

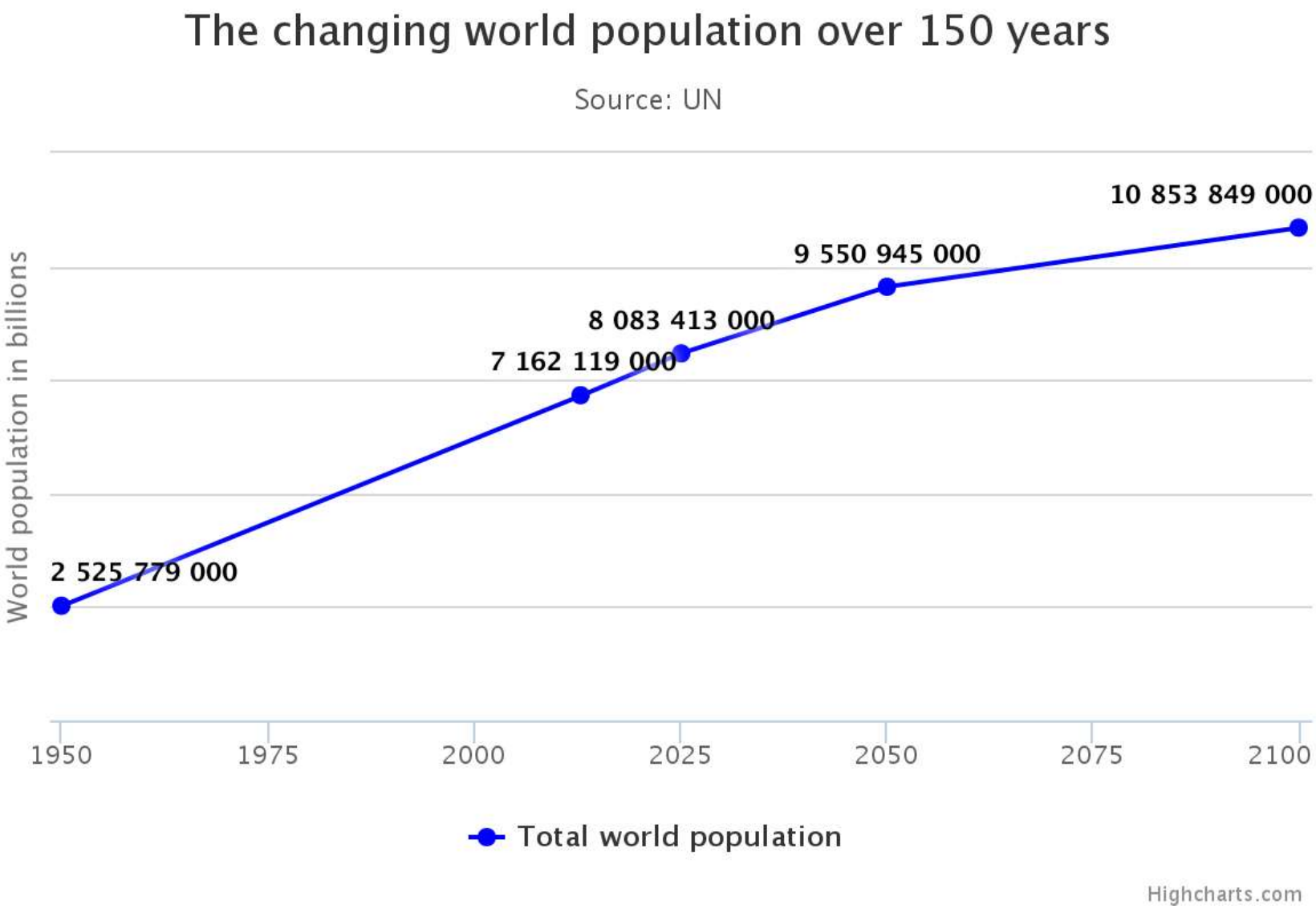

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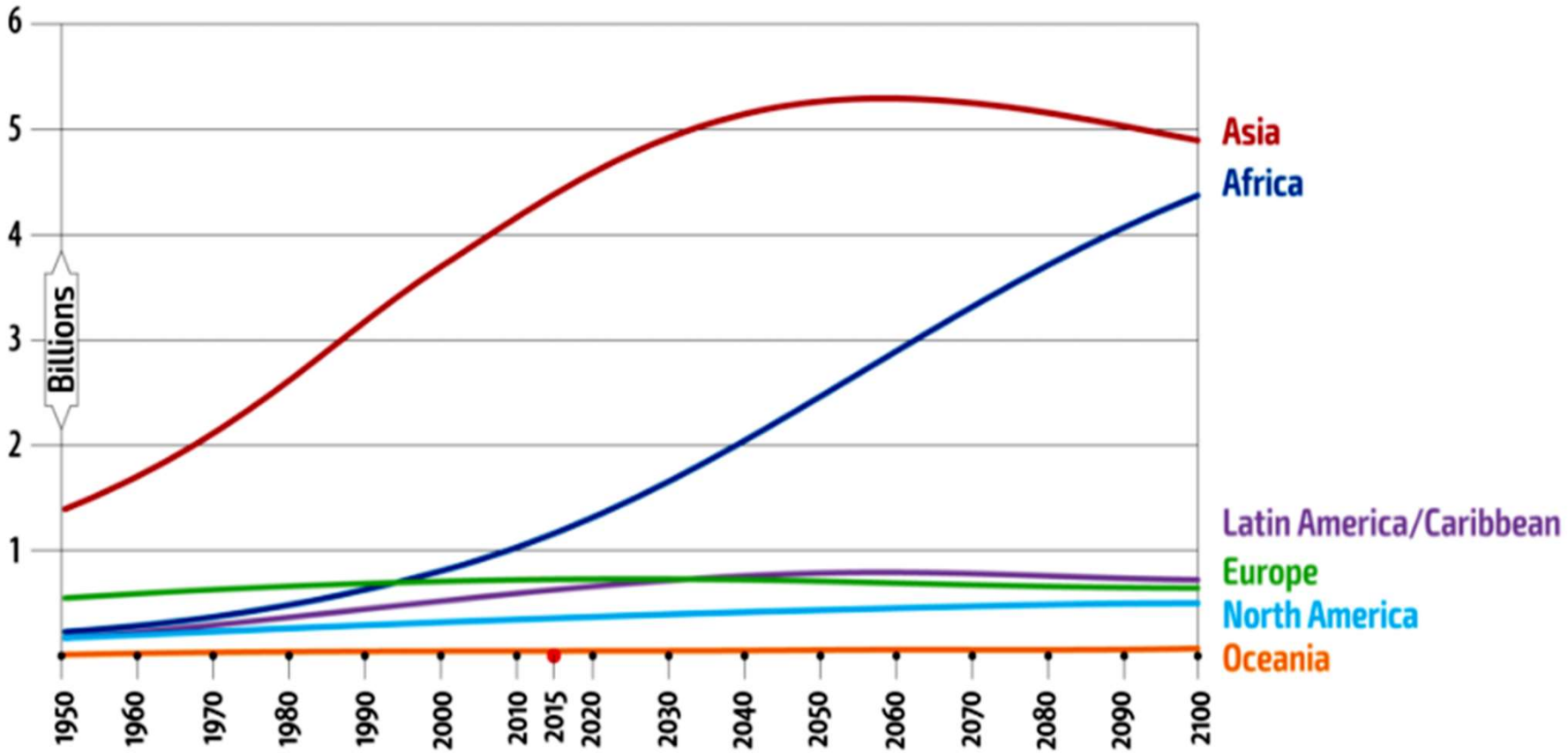
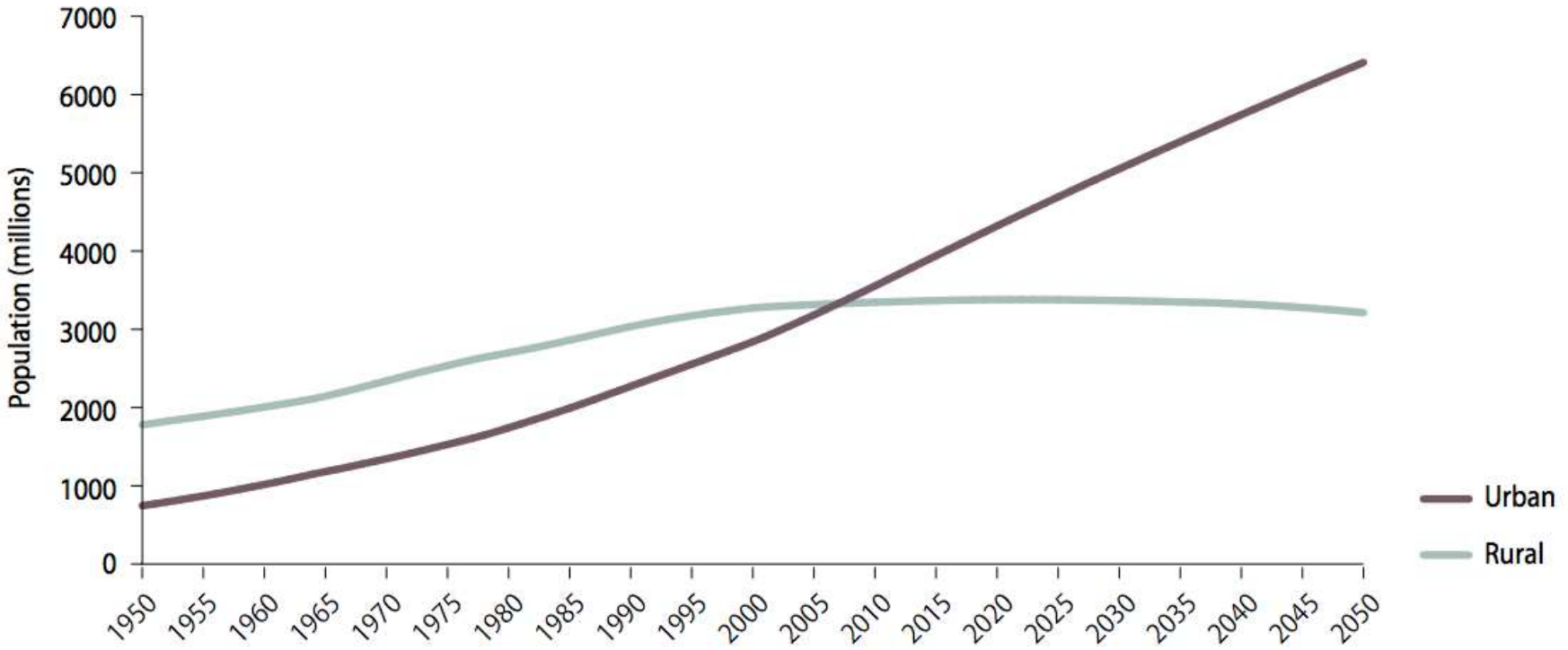
Figure 1.2 Population growth to 2100, by region (medium variant)



Source: UN, 2015.

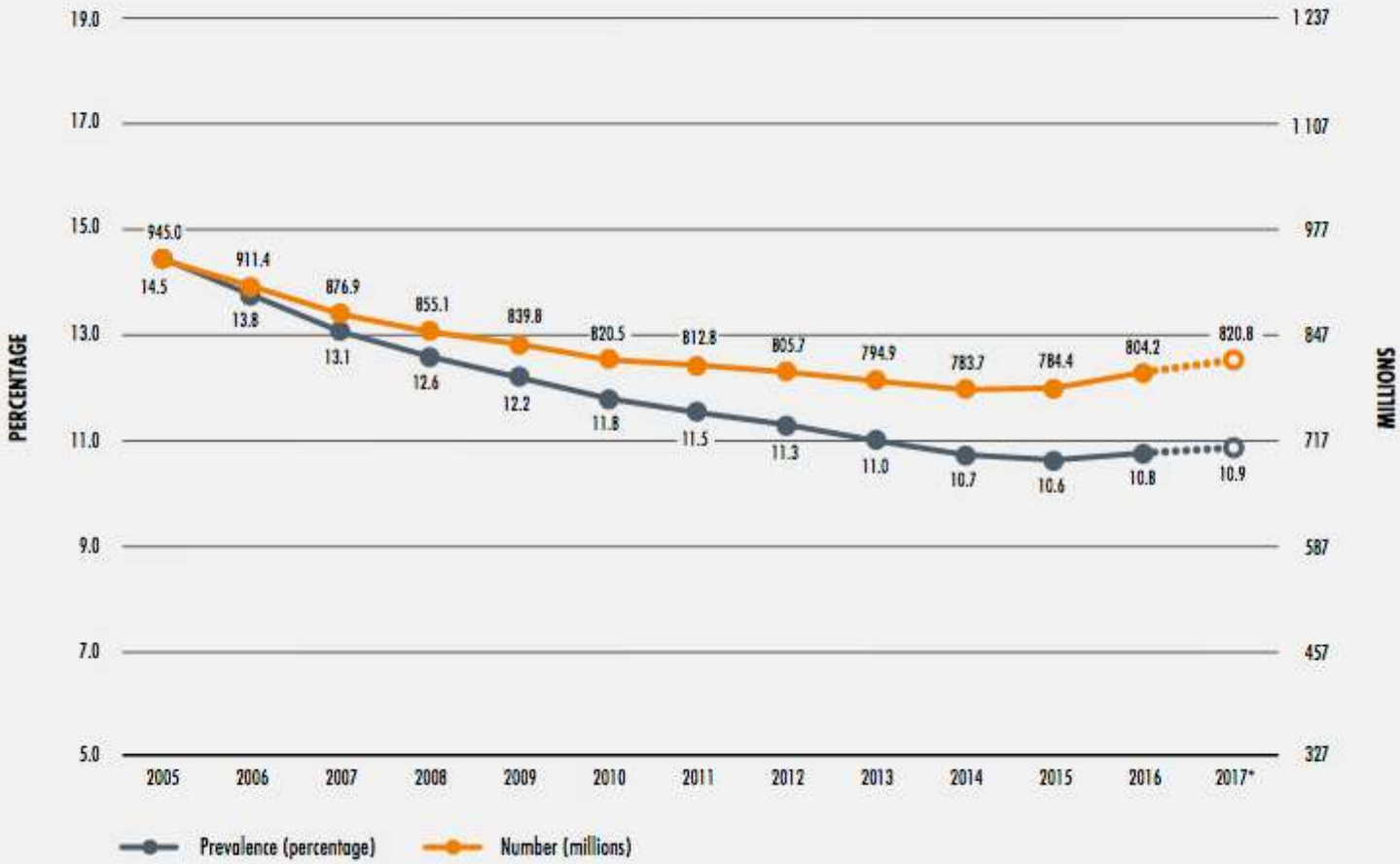
Urban and rural population of the world, 1950–2050



Faced with the scenario of increasing population and urbanization, guaranteeing healthy, good and sufficient food to satisfy the nutritional, cultural and social needs of the world's population is one of the greatest and most important challenges of the 21st century, to be combined with sustainable development and respectful of the planet's limits. FAO data shows that food production rates have risen faster than population growth over the past two decades. Nevertheless, today 820 million people are undernourished and 2 billion have vitamin and mineral deficiencies compared to 2 billion overweight people and 650 million obese people with an increase for children and adolescents 10 times compared to 1975.

FIGURE 1

THE NUMBER OF UNDERNOURISHED PEOPLE IN THE WORLD HAS BEEN ON THE RISE SINCE 2014, REACHING AN ESTIMATED 821 MILLION IN 2017



* Projected values, illustrated by dotted lines and empty circles.
SOURCE: FAO.

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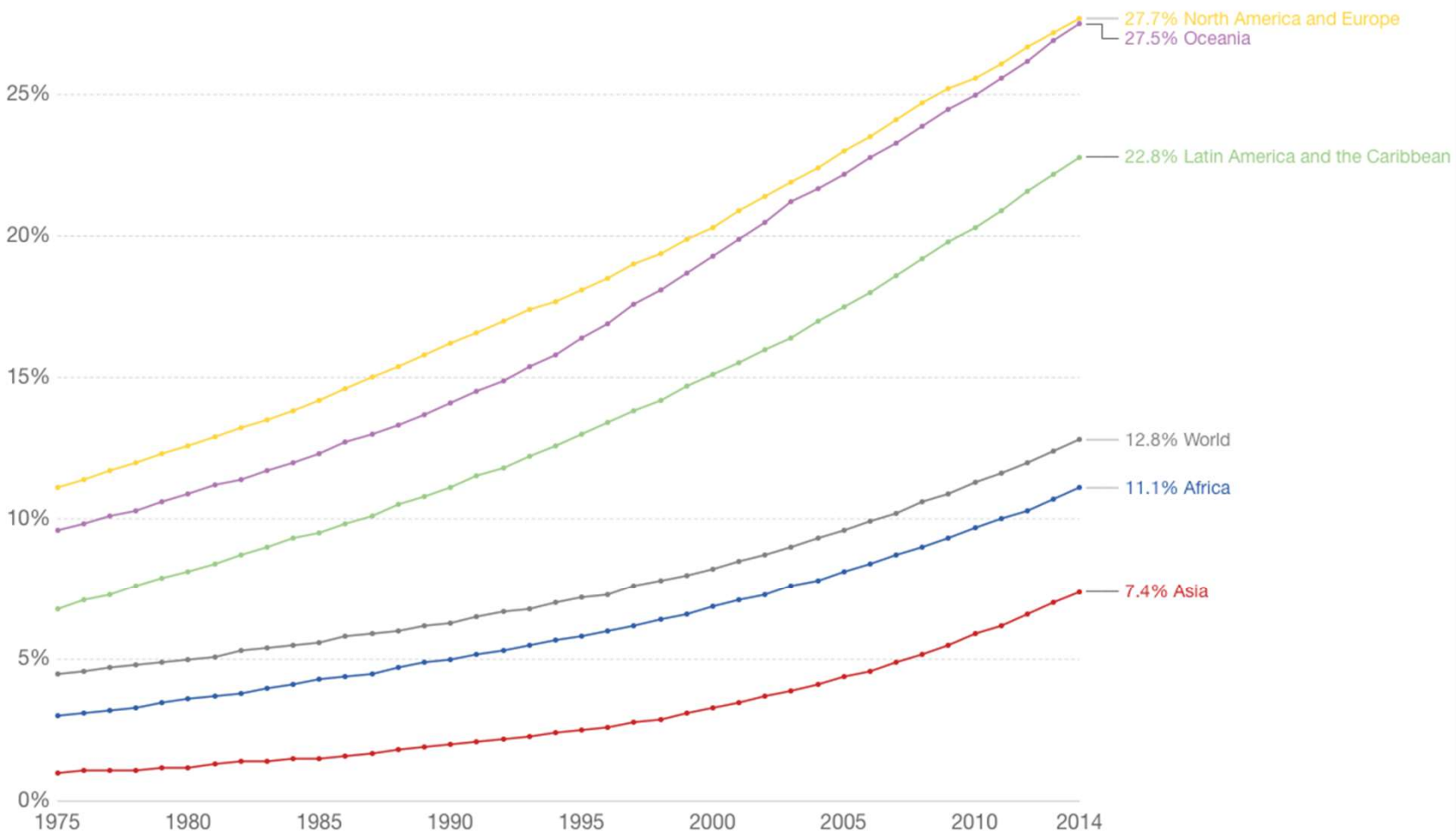
Prevalence of obesity in adults by region

The prevalence of obesity in adults, measured as the percentage of adults aged 18 years and older (both male and female) with a body-mass index (BMI) greater than 30 kilograms per metre squared.

Our World in Data



Source: UN Food and Agricultural Organization/WHO

OurWorldInData.org/obesity/ • CC BY

1975 2014 CHART DATA SOURCES

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Among the causes of obesity is the nutritional transition, that is the tendency to deviate from a traditional diet towards a greater consumption of meat, dairy products, sugars, fats and foods with high energy density and a simultaneous reduction of fish, fruit, vegetables, cereals wholegrain, walnuts, legumes which combined with a general decrease in physical activity also leads to an increase in health expenditure.

Food production systems are among the main causes of environmental pollution and the exploitation of resources such as water and soil, one of the causes of ongoing climate change.
Food represents over 90% of humanity's water footprint, or water consumed daily.
Irrigated agriculture alone is responsible for 70% of total fresh water consumption.
Food production systems are among the causes of biodiversity loss and responsible for the emission of greenhouse gases in the atmosphere for a variable percentage between 21 and 37 percent; they also contribute to the eutrophication of water (fertilizer leaching -> increase in phytoplankton -> decrease in oxygen -> fish loss) and to the degradation of soil fertility (which in the last 20 years has decreased by about 20%).

The decrease in soil productivity causes an increase in deforestation and expansion of agricultural lands which contribute significantly to climate change.
It should be noted that a large part of agricultural production is not intended for human consumption: 36% of world cereal production is used for feed and 9% for biofuels.

Added to this are food losses and waste, which represent one third of world food production, with losses linked to the post-harvest and transformation agricultural phase (located in the least developed countries due to a lack of infrastructure and investments, eg. cold chain) and with the typical waste of the last phases of the food supply chain (from retail to the final consumer, especially in countries with advanced economies).

IL PARADOSSO GLOBALE DELLO SPRECO &

1/3
del cibo che produciamo viene sprecato

potrebbe nutrire

4 volte

795 milioni
di persone che soffrono la fame

OBIETTIVO DEL PROTOCOLLO DI MILANO

- 50% spreco alimentare **entro il 2020**

NEI PAESI OCCIDENTALI SPRECHIAMO PIÙ DI QUANTO PESIAMO

cibo sprecato pro-capite per anno
95-115 kg

peso medio di una persona
65-80 kg

Fonte: elaborazione BCFN su dati FAO, WWF, Segré e Falasconi

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LO SPRECO IN ITALIA*

L'IMPATTO AMBIENTALE DELLO SPRECO DOMESTICO

14,3 milioni tonnellate di CO_2 l'anno

Per assorbirle servono

800.000 ettari di bosco

più dell'intera superficie boschiva della Lombardia

Fonte: elaborazione BCFN su dati FAO, WWF, Segré e Falasconi

*Dati medi per anno

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Feeding urban centers sustainably is therefore a crucial challenge of the 21st century, given that 80% of food in 2050 will be consumed in urban areas.
City administrations are starting to become protagonists of a new cultural approach to the problem.
In October 2019, 14 mayors of big cities signed a charter of intent:

C40 Good Food Cities

to promote sustainable diets in their communities, with the goal of halving food waste by 2030.

The big theme is therefore to redesign the food system with choices compatible with urban spaces, to prevent food waste and to change diet, returning to the Mediterranean, declared, in 2010, by UNESCO, the Intangible Heritage of Humanity.

In this perspective aquaponics is one of the various tools that by combining technique, work, knowledge and inventiveness can contribute to that cultural push towards changing eating habits.

Aquaponics: a brief history

The term aquaponics represents the symbiotic union of two activities:

Aquaculture

Hydroponics

Aquaculture is every form of aquatic animal breeding in tanks (snails, fish, shrimp).

Hydroponics is every form of plant breeding in the water.

The applications of acquaponics are historically traced back on the one hand to the Aztecs who on fixed and/or mobile islands placed on shallow lakes cultivated plants by irrigating them with waste water from the nearby cities, and on the other to China where, attested since 5 AD, rice was grown in paddy fields in combination with fish, and where an agricultural manual from the 13th century also describes aquaponic activities.

Aquaculture in the sea.

Aquaculture in indoor tanks.

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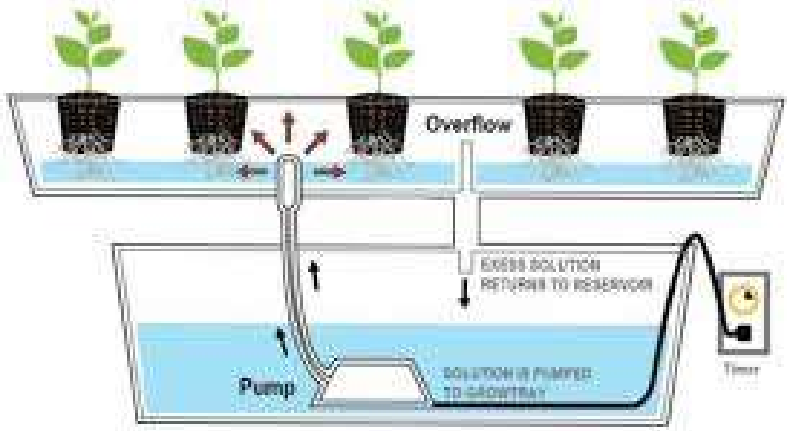
Typical hydroponic system.

Vertical repetition of hydroponics with flat linear development.



Hydroponic system diagram.

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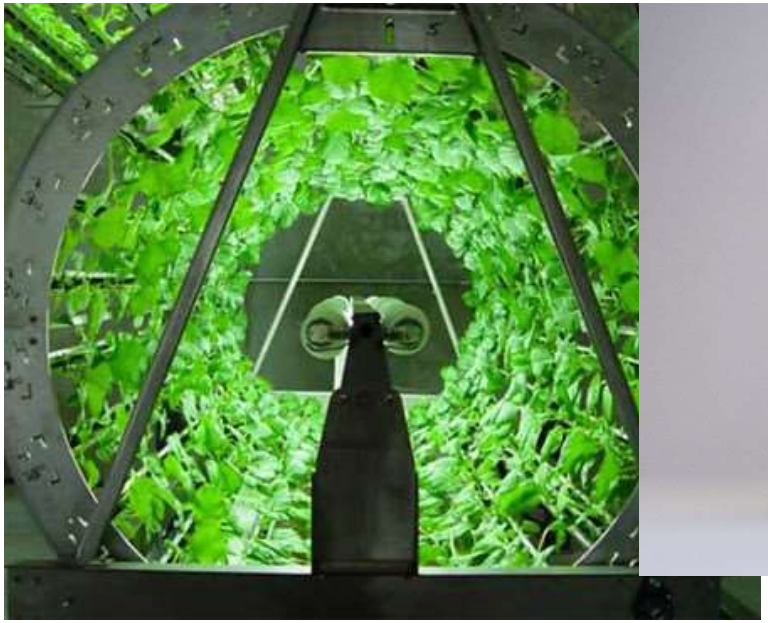
Hydroponics with vertical development in towers resting on ground.



Rotating hydroponic systems.

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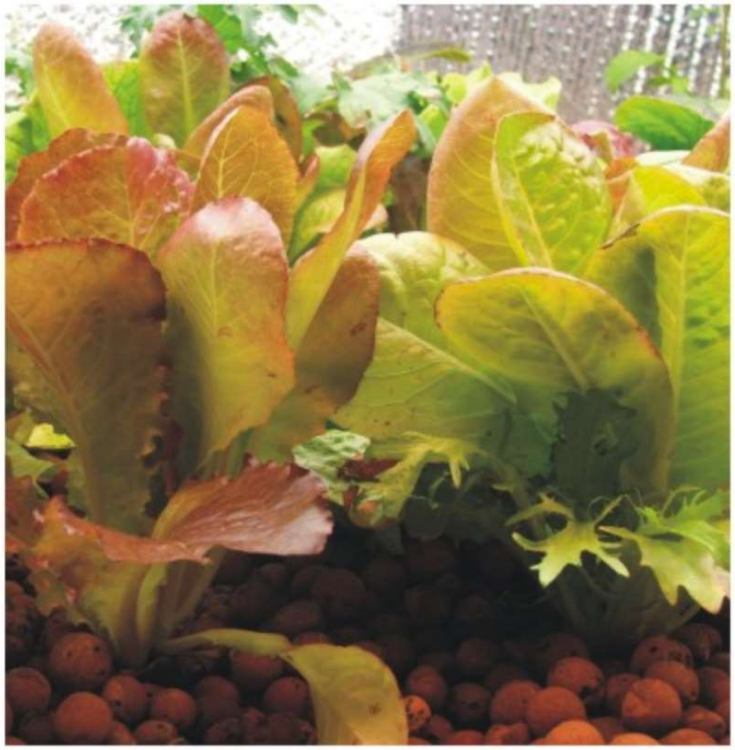
aquaponic systems: live components

breeding fish in a controlled environment

beneficial bacteria that turn fish waste into plant nutrients



plants growing in soil-less media

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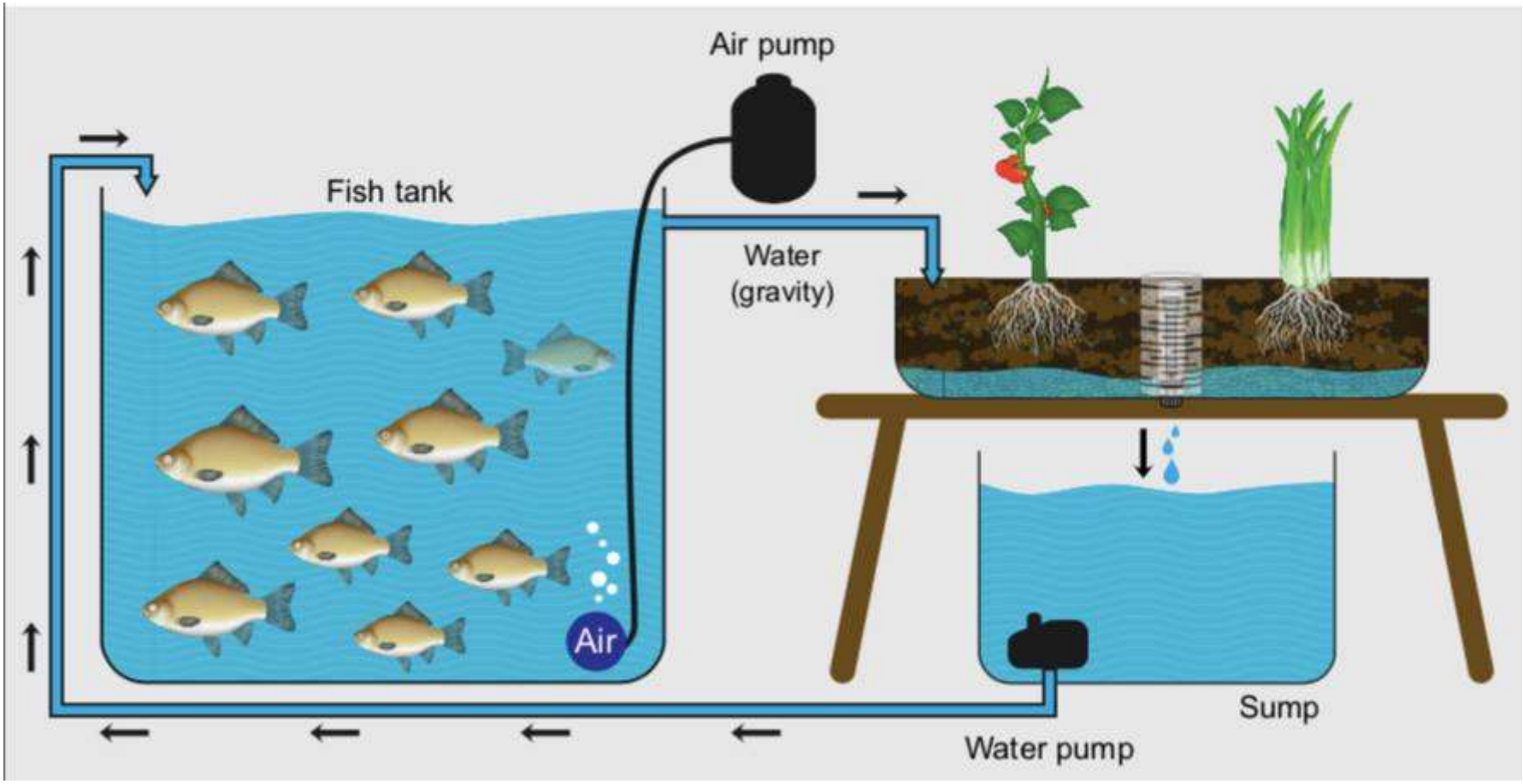
aquaponic systems: operating scheme



water recirculates with savings of over 80% vs. other systems

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AQUAPONICS VS HYDROPONICS

1. NUTRIENTS

Expensive Hydroponic nutrients are replaced by less expensive fish feed

2. AQUAPONICS MIMICS NATURE

Aquaponics must be organic, by nature

3. ZERO WASTE

Unlike Hydroponic systems, Aquaponics never requires discharging water.

4. MORE PRODUCTIVE

Aquaponics (vs Hydroponics) is more productive

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aquaponic growing systems: deep water culture

With this method, polystyrene rafts on which the plants are placed float in tanks filled with water from the plant.

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aquaponic growing systems: nutrient film tecnique

In this method holes are made in pvc pipes and in the holes are inserted baskets with inert material (rock wool, coconut fiber) to support the plants whose roots remain in a moving water layer

aquaponic growing systems: vertical towers

They are usually made using PVC slings of various diameters, with a 45 ° graft. Inside the towers can be inserted or not an inert substrate (expanded clay for example). Water is dropped into the tower from above, humidifying the interior.

aquaponic growing systems: growbed

Inside suitable containers a layer of expanded clay is inserted which will support the cultivated plants and will also be the "home" of beneficial bacteria.

MANUALE DI ACQUAPONICA

Diventa un acquaponico in pochi semplici passi!

Edizione
2019

A cura di:
Francesco Lombardo
Luca Settanni
Gian Marco Tamborra

Optimized home aquaponics plant (by Aquaponic Design)

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The realization of an aquaponics plant as a cultural choice and more (four themes of Aquaponic Design)

1. To guarantee to the restaurant an on-site production of aromatic herbs, sprouts, micro vegetables, baby leaf and much more, always fresh, abundant and available, with a management reduced to the minimum.

2. To allow the children of the home to discover both the plant and the aquatic world while having fun and learning to produce quality vegetables.

3. To make a business a unique space. What better way to involve new customers and increase your business, if not to differentiate yourself, characterizing your brand and your style, even with a custom-made aquarium, full of ornamental plants and colorful fish?

4. To help schools that want to teach their students of all ages the natural sciences, environmental education and biology through a new and interactive solution.

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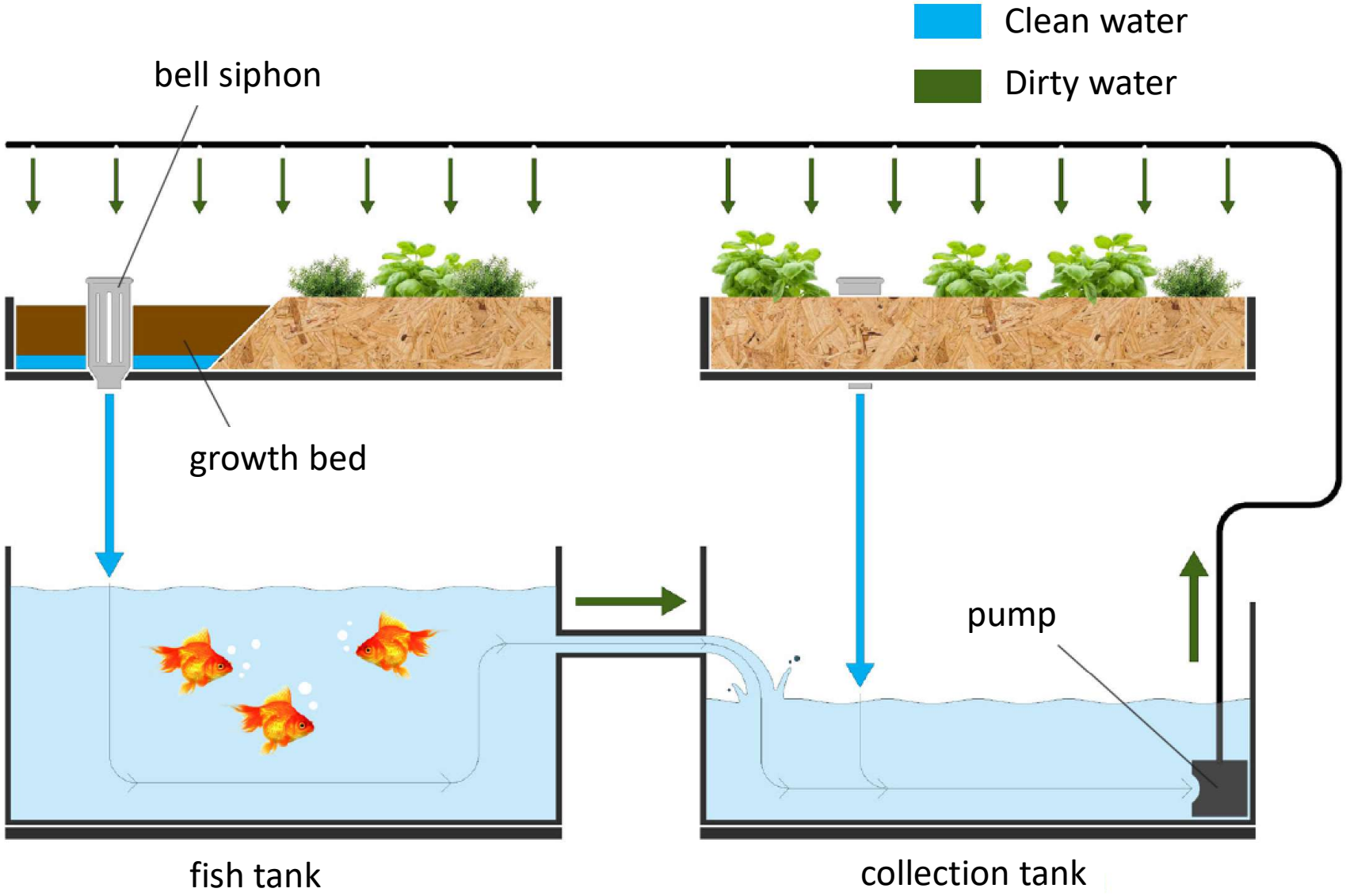
Operating scheme of the home aquaponics plant



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rendering of the design scheme of the aquaponics home system with space optimization

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details of the growth bed, at the top, and of the fish tank below

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Gli **strumenti** che vi serviranno durante i lavori sono: avvitatore o trapano, frese a tazza di vario diametro, martello, chiodi a testa piatta e viti per legno. Futuri acquaponici, ora che avete recuperato tutto il necessario **siete pronti per iniziare!** Basta testi però, è il momento di mostrarvi passo passo la realizzazione quindi passiamo ai video!

1. *Assembliamo la vasca dei pesci e quella di raccolta*
2. *Realizziamo struttura di supporto ed il letto di crescita*
3. *Sveliamo i misteri del troppo pieno!*
4. *Costruiamo il sistema di scarico continuo*
5. *É giunto il momento di allestire le vasche!*
6. *Riempiamo il growbed e organizziamone la distribuzione dell'acqua*
7. *Il sistema Venturi e l'ossigenazione dell'impianto*
8. *Si parte! Facciamo il punto e avviamo il sistema acquaponico*

Ora che l'impianto è pronto vediamo insieme come farlo maturare!

the sequence of steps necessary for self-construction

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the home-made aquaponic system actually built

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another general view of the home aquaponic plant

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detail of the fish tank

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detail of the growth bed with the irrigation pipes

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detail of the growth bed with bell siphon

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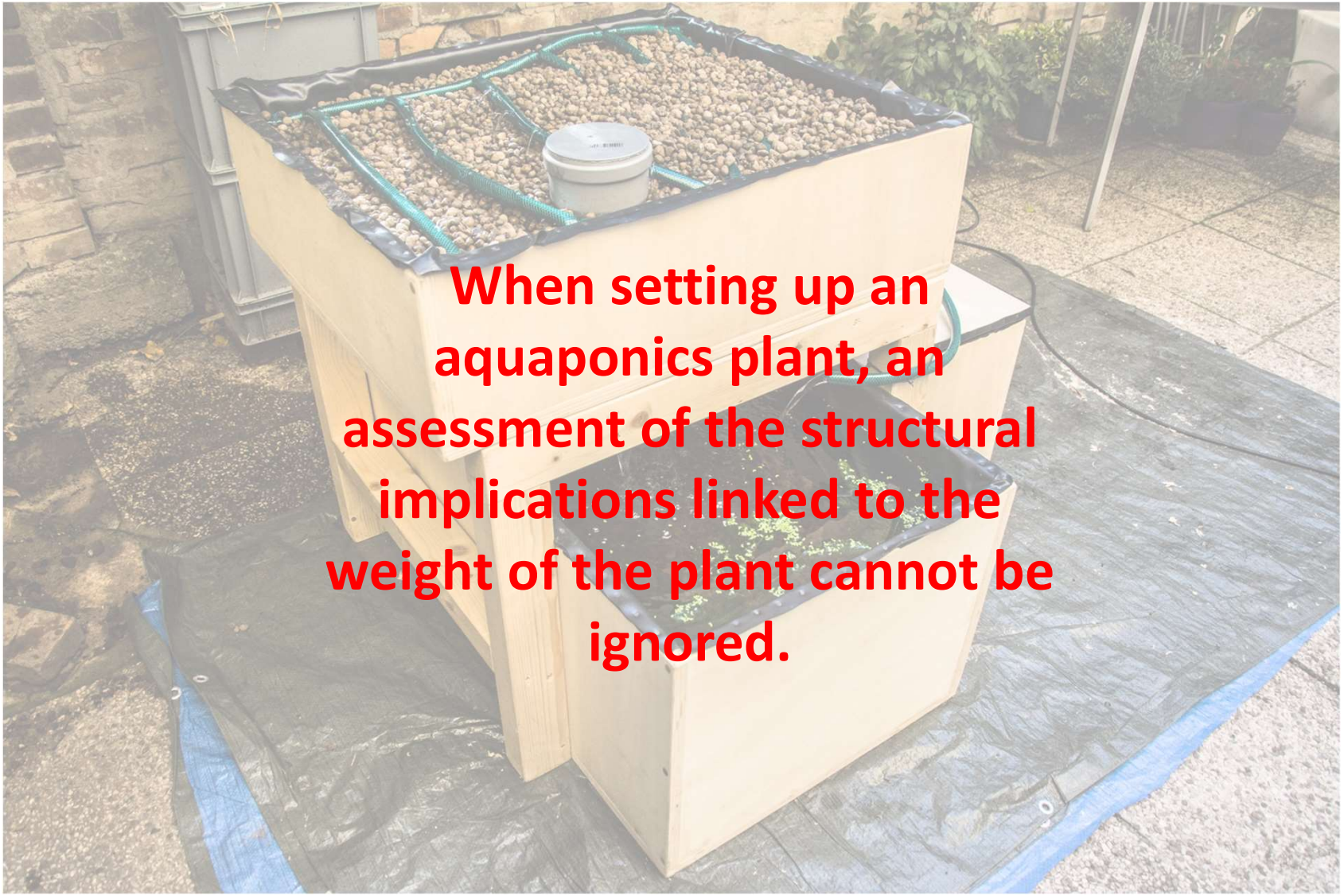

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Load analysis of the domestic aquaponics plant

1) the fish tank (included) weighs about 160kg, overestimated (130kg of water, 15kg of wood structure, 7-8kg of volcanic lapillus, 1kg of fish);
2) the collection tank weighs about 60kg overestimated (45kg of water, 7-8 kg of wood, 2-4kg of volcanic lapillus)
3) the growing bed is placed above a wooden structure (no metal rack is present), weighs about 40kg overestimated, while the wooden structure supports it no more than 10kg.
4) the plant, water distribution pipes and pump, has a weight not exceeding 10kg.

Total of 280kg, overestimated.

It is therefore a weight of about 280 kg which stands on an area of about 0.93x0.56 + 0.57x0.39 = 0.74 m^2

If this system is placed on the ground, there is a modest unit pressure of about 0.04 kg / cm^2 which does not create problems.

If the system is placed on a floor inside a residential building, different scenarios are opened.
In fact, it is different if the plant is self-produced by the owner or tenant of the apartment from the one in which it is supplied, turnkey, by a third party. In the latter case, a non-harmful structural impact must also be guaranteed.
Even if the system is a condominium, rather than a home-based, or a decidedly public one (for a shop, a restaurant etc.), structural checks are necessary.

In the assessment of the stresses on a residential building, the reference standard is the NTC2018 and the relative Circular of 2019.

Referring to paragraph 2.5.1. - Classification of actions,
the load in question is to be considered as being between:
- Direct actions: concentrated forces, distributed loads, fixed or mobile (par. 2.5.1.1. - way of explication, point a));
- Static actions: actions applied to the structure that do not cause significant accelerations of the same or of some of its parts (par. 2.5.1.2. - structural response, point a));
- Variable actions (Q): actions that act with instantaneous values that can be significantly different from each other during the nominal life of the structure: overloads, wind actions, snow actions, temperature actions (par. 2.5.1.3. - variability of the intensity over time, point b)).

With reference to Chapter 3 - Construction Actions, paragraph 3.1. - Civil and industrial works, and under paragraph 3.1.4. - Overloading, the definition is:
The overloads, or imposed loads, include the loads linked to the intended use of the work; the models of these actions can consist of:
- Uniformly distributed vertical loads qk;
- Concentrated vertical loads Qk (this is our case);
- Horizontal loads Hk.
From table 3.1.II we have the following nominal and / or characteristic values for the cases of interest.

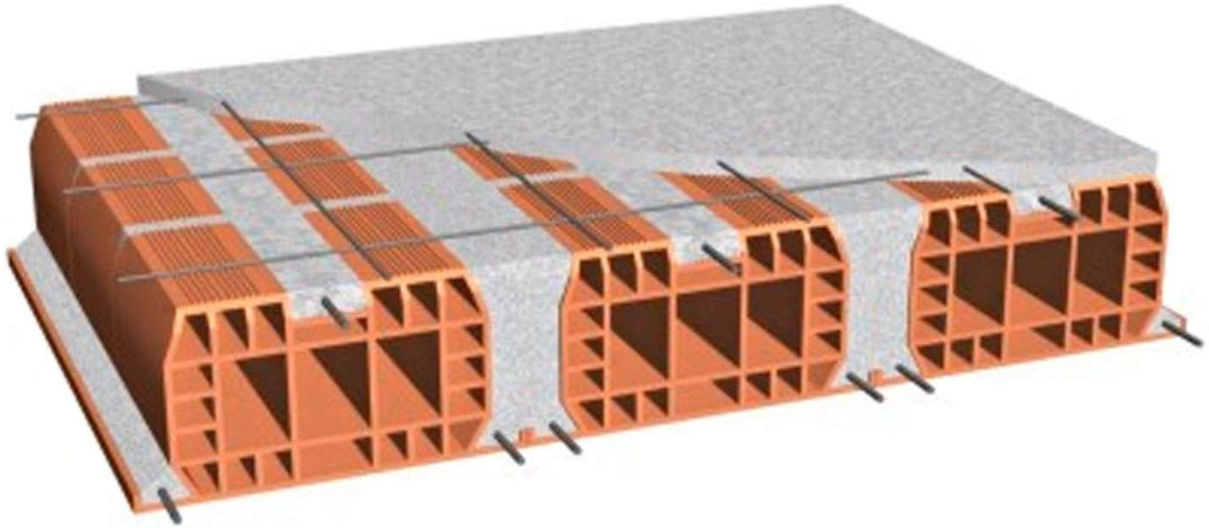
Extract from table 3.1.II of the NTC2018

Cat.	Ambienti	q_k [kN/m²]	Q_k [kN]	H_k [kN/m]
A	**Ambienti ad uso residenziale**			
	Aree per attività domestiche e residenziali; sono compresi in questa categoria i locali di abitazione e relativi servizi, gli alberghi (ad esclusione delle aree soggette ad affollamento), camere di degenza di ospedali	2,00	2,00	1,00
	Scale comuni, balconi, ballatoi	4,00	4,00	2,00
H-I-K	**Coperture**			
	Cat. H Coperture accessibili per sola manutenzione e riparazione	0,50	1,20	1,00
	Cat. I Coperture praticabili di ambienti di categoria d'uso compresa fra A e D	secondo categorie di appartenenza		
	Cat. K Coperture per usi speciali, quali impianti, eliporti.	da valutarsi caso per caso		

At the end of table 3.1.II it is specified that the values refer to conditions of current use of the respective categories and also, subsequently, that in the presence of atypical loads (such as machinery, tanks, internal deposits, plants, etc.) the intensities must be evaluated case by case, based on the maximum foreseeable: these values must be explicitly indicated in the project and static test documentation.
Circular 2019 in relation to the same point specifies that the design values of the table are values to be adopted in relation to the functional destination of the environments. And also that in the design phase, to take into account possible modifications of the functional destination, it may be appropriate to adopt the values relevant to the most critical functional destination for overloads.

For our case, the home aquaponics plant, is valid as described in paragraph 3.1.4.2. - Concentrated vertical overloading:
- The concentrated Qk vertical overloads shown in Tab. 3.1.II are subject to separate local checks and do not apply simultaneously to the vertical loads distributed used in the checks of the building as a whole; they must be applied to loadprints appropriate to the use and shape of the floor; in the absence of precise indications, it can be considered a square load shape of 50 x50 mm ...

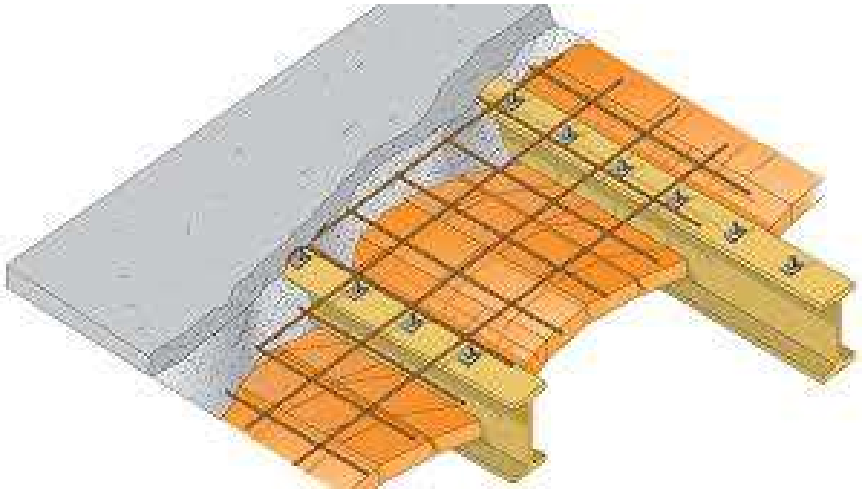
The above is related to the design phase.
This means that in the case of new constructions the floors of rooms for residential use are designed to withstand at least 2kN of uniformly distributed load and therefore able to withstand the weight of a home aquaponic system.
Any localized verification can be done with the actual load on the actual footprint.



Example of a modern brick and concrete slab.

In the case of existing buildings we need to learn more about the supporting structure.
If this structure is made of reinforced concrete (building built since the end of the Second World War) it is very likely that it will be possible to rely on an accidental overload of 2kN per square meter adopted in the design phase. Fact that would allow us to have no installation problems.
But if the construction is older, in masonry or with a mixed structure (in masonry and concrete), and the floors are made with other construction techniques (for example with masonry vaults or steel joists and brick vaults, with or without collaborating slab, if not even with a wooden supporting structure) it is necessary to carry out adequate structural checks.

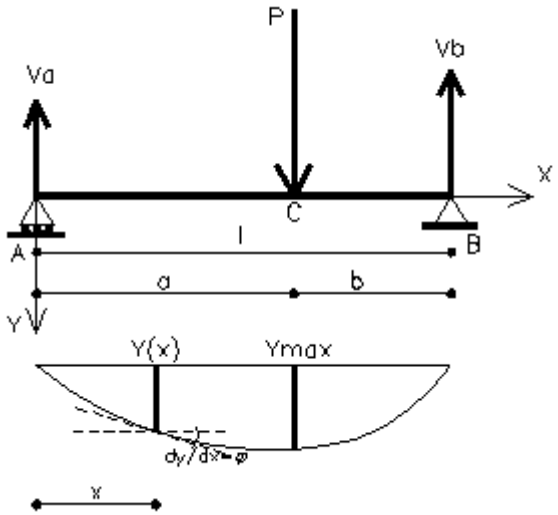
Reinforcement of a masonry vault.



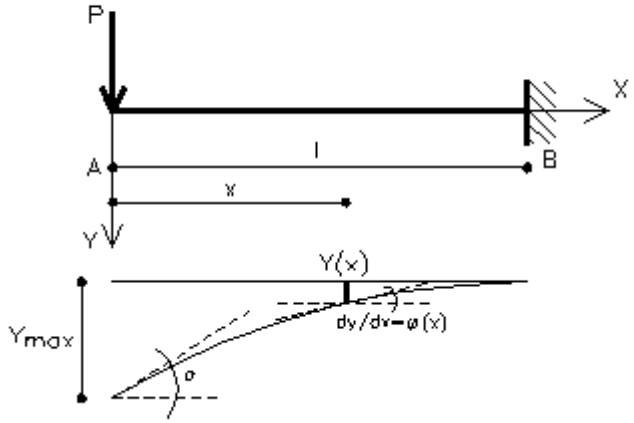
Floor in steel beams and brick vaults with collaborating slab.

Wooden floor with main and secondary beams.

If the type and direction of the floor (interior or balconies) is known, a first rough assessment can be made with simplified models: double-supported beams and cantilever beams with the concentrated load equivalent to the home aquaponic system.



Double-supported beam.



Cantilever beam.

Design of a condominium aquaponics plant (Aquaponic Design)

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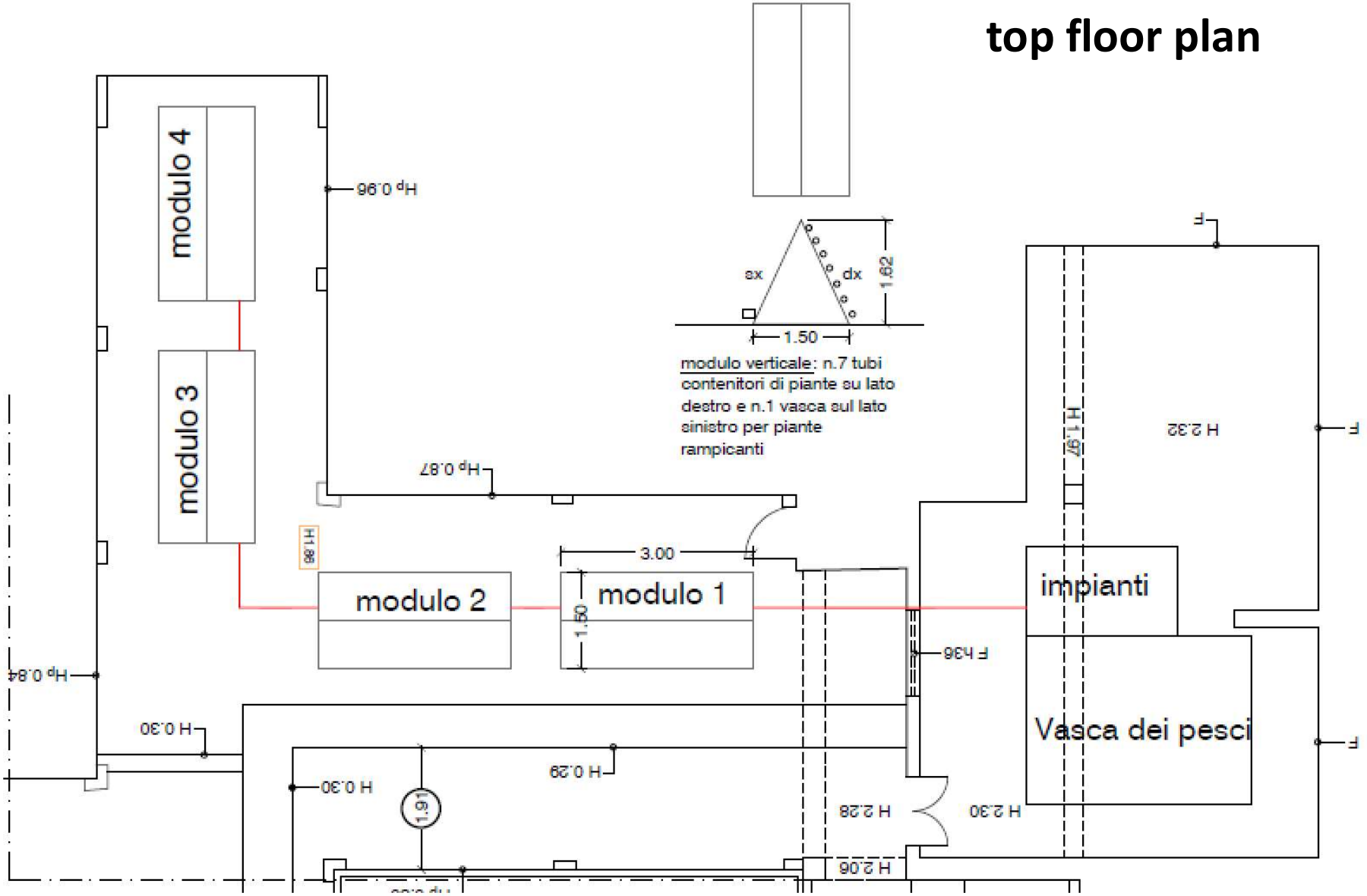
top floor plan



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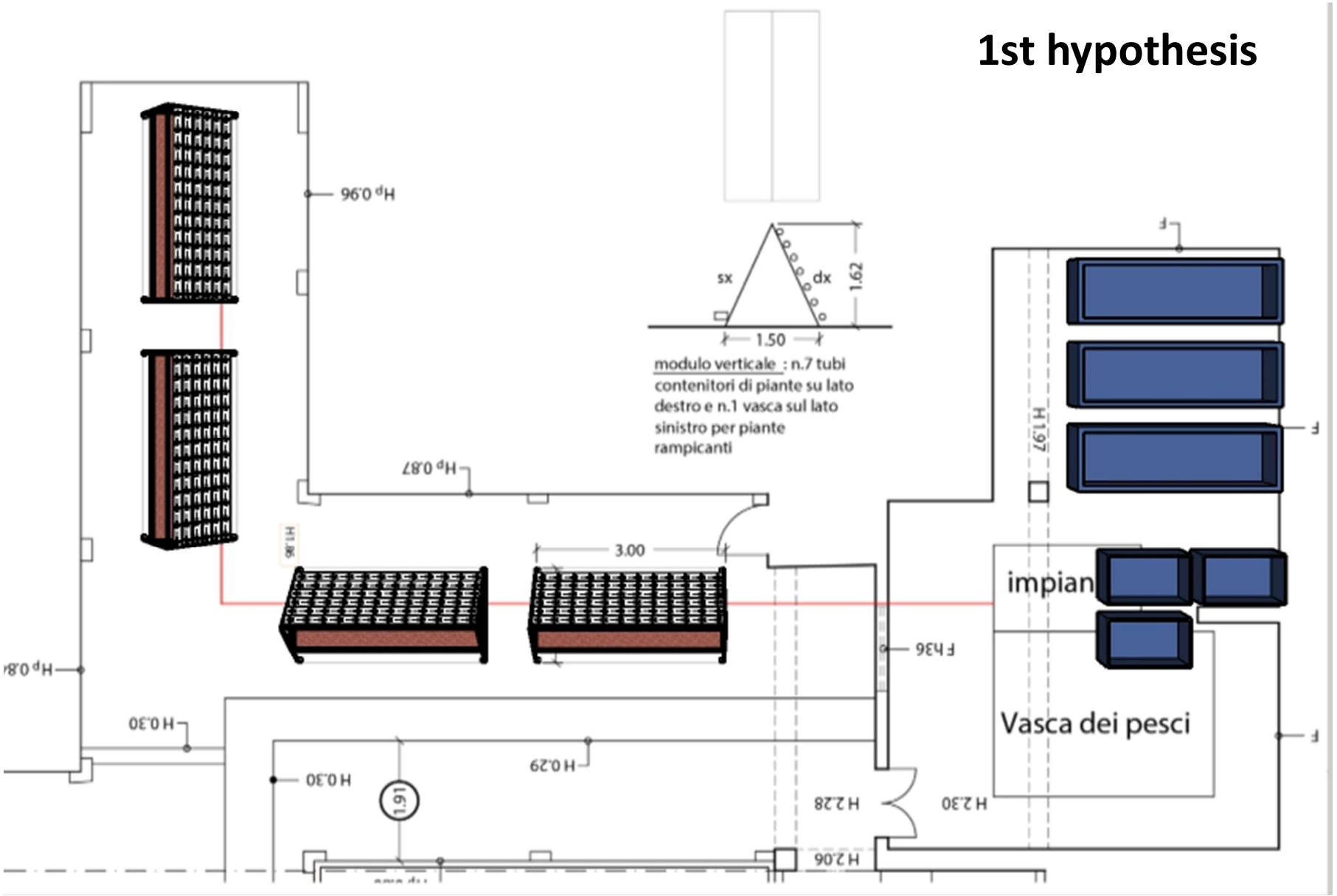
1st hypothesis



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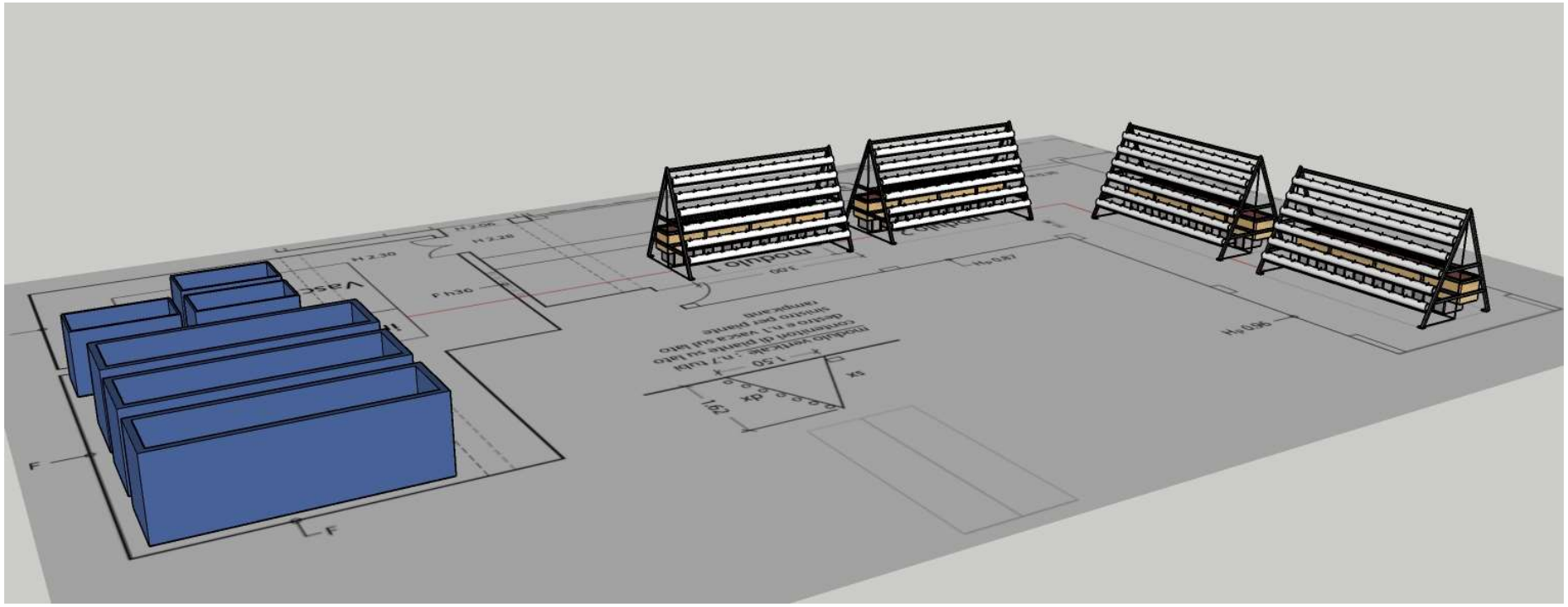
axonometric view



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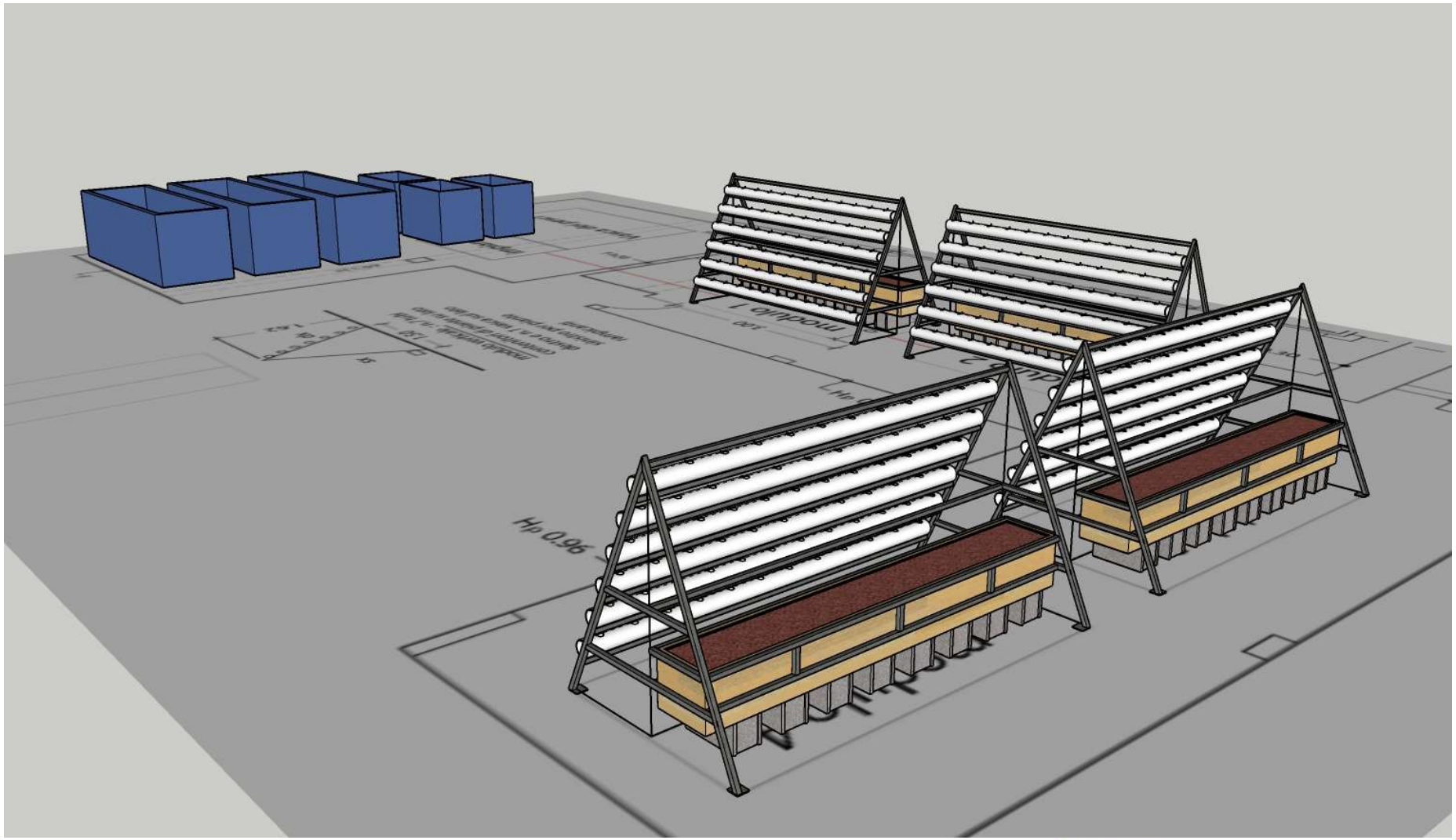
axonometric view



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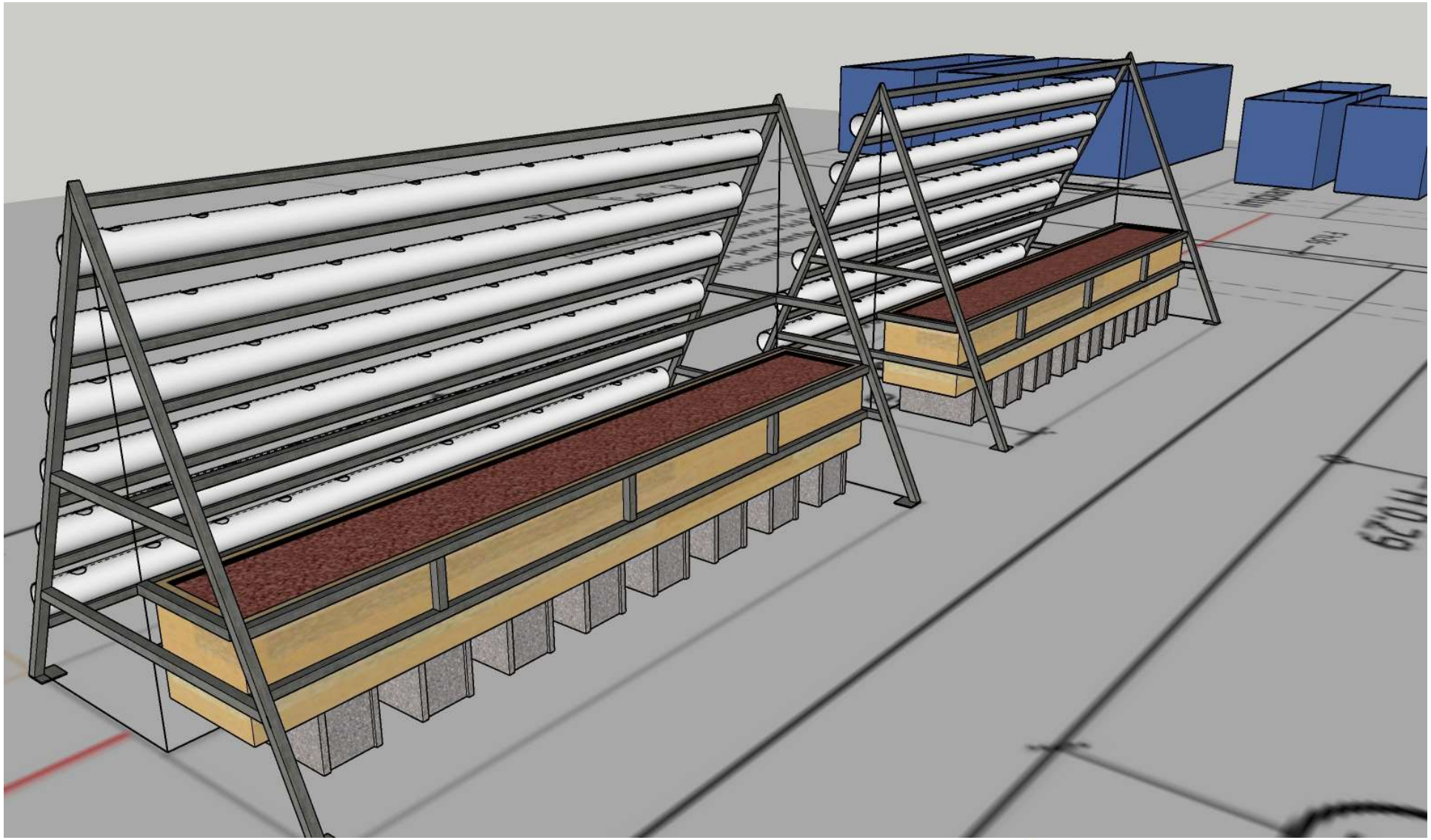
detail of growbeds



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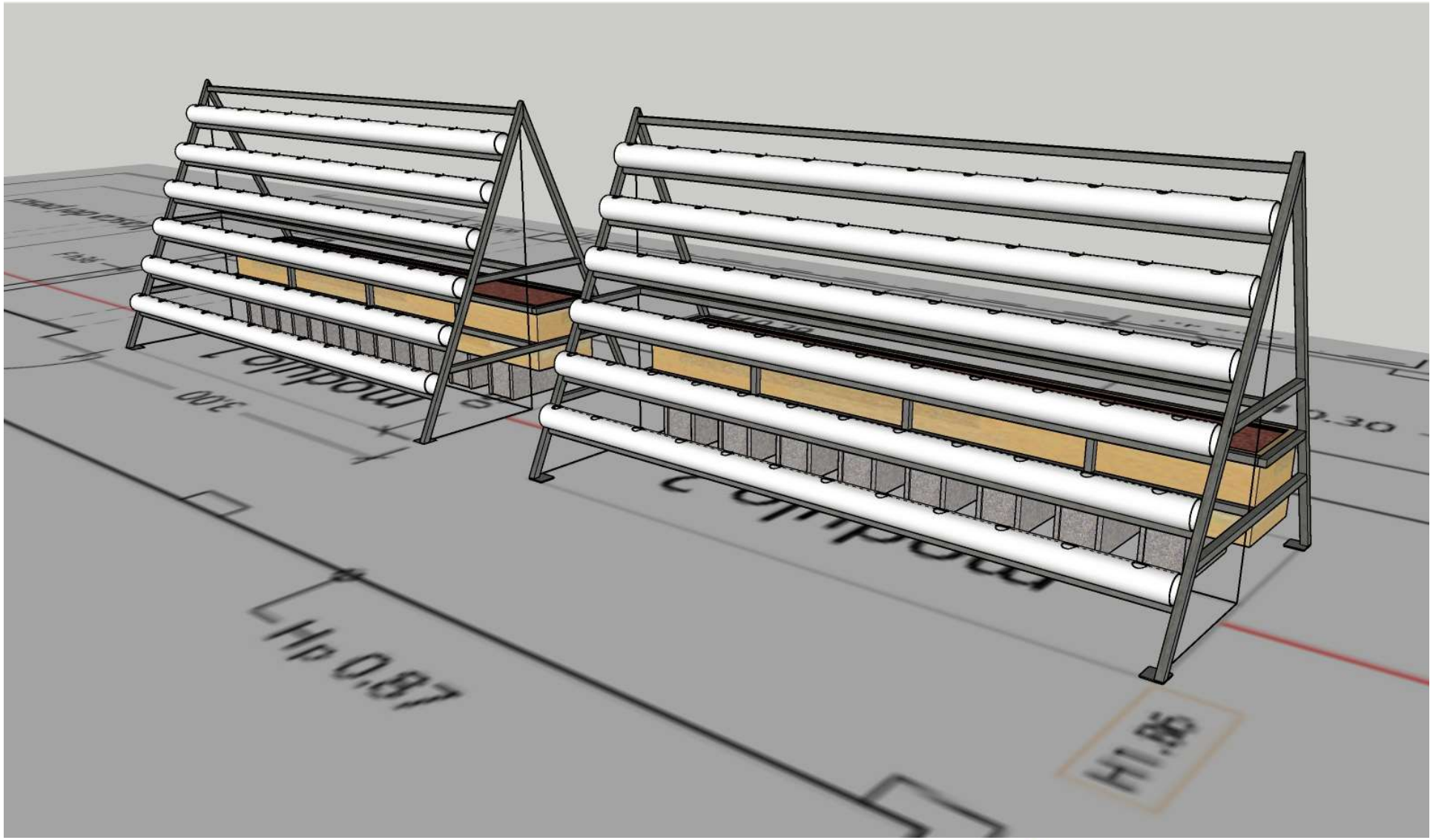
detail of pvc pipes



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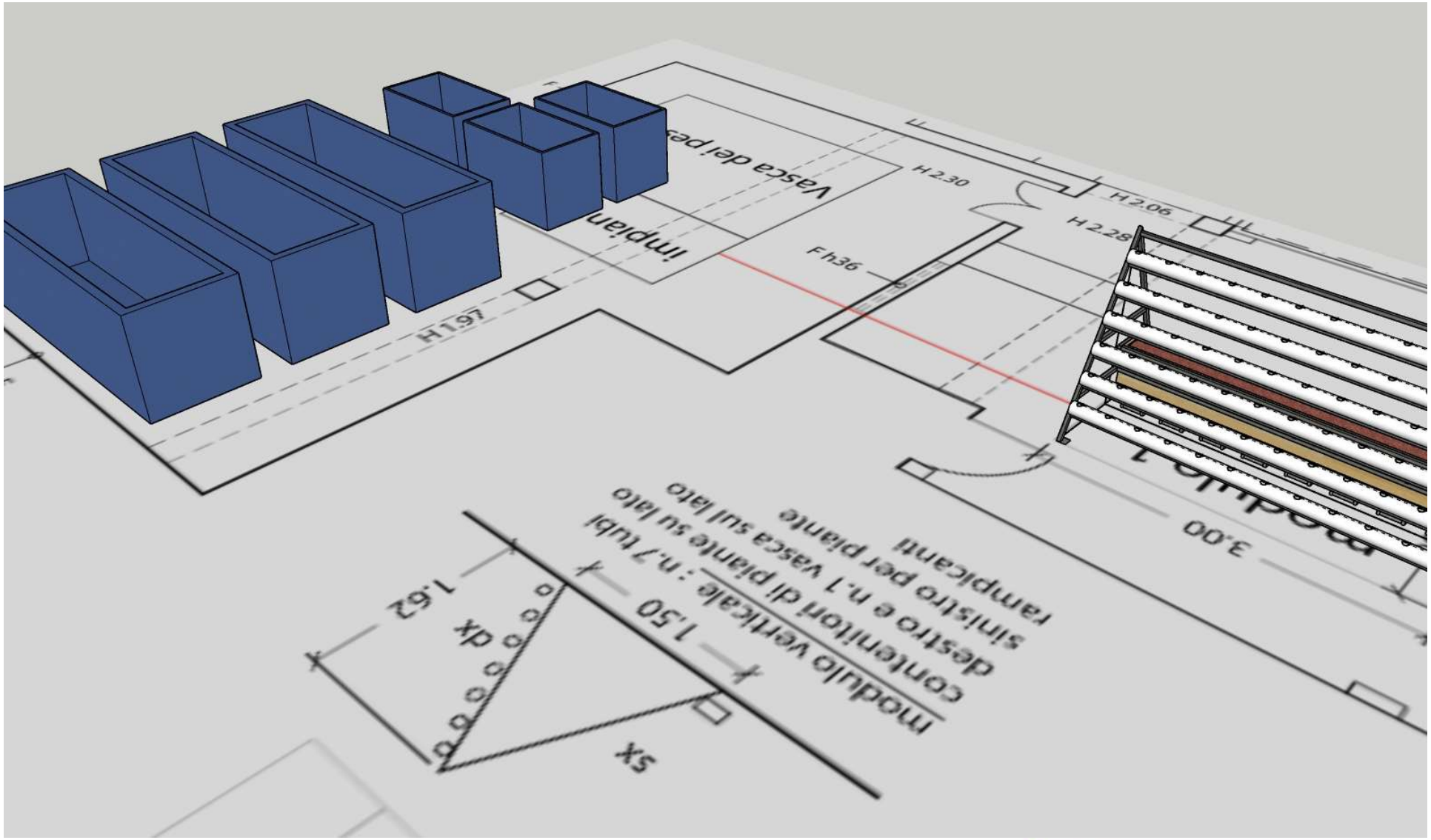
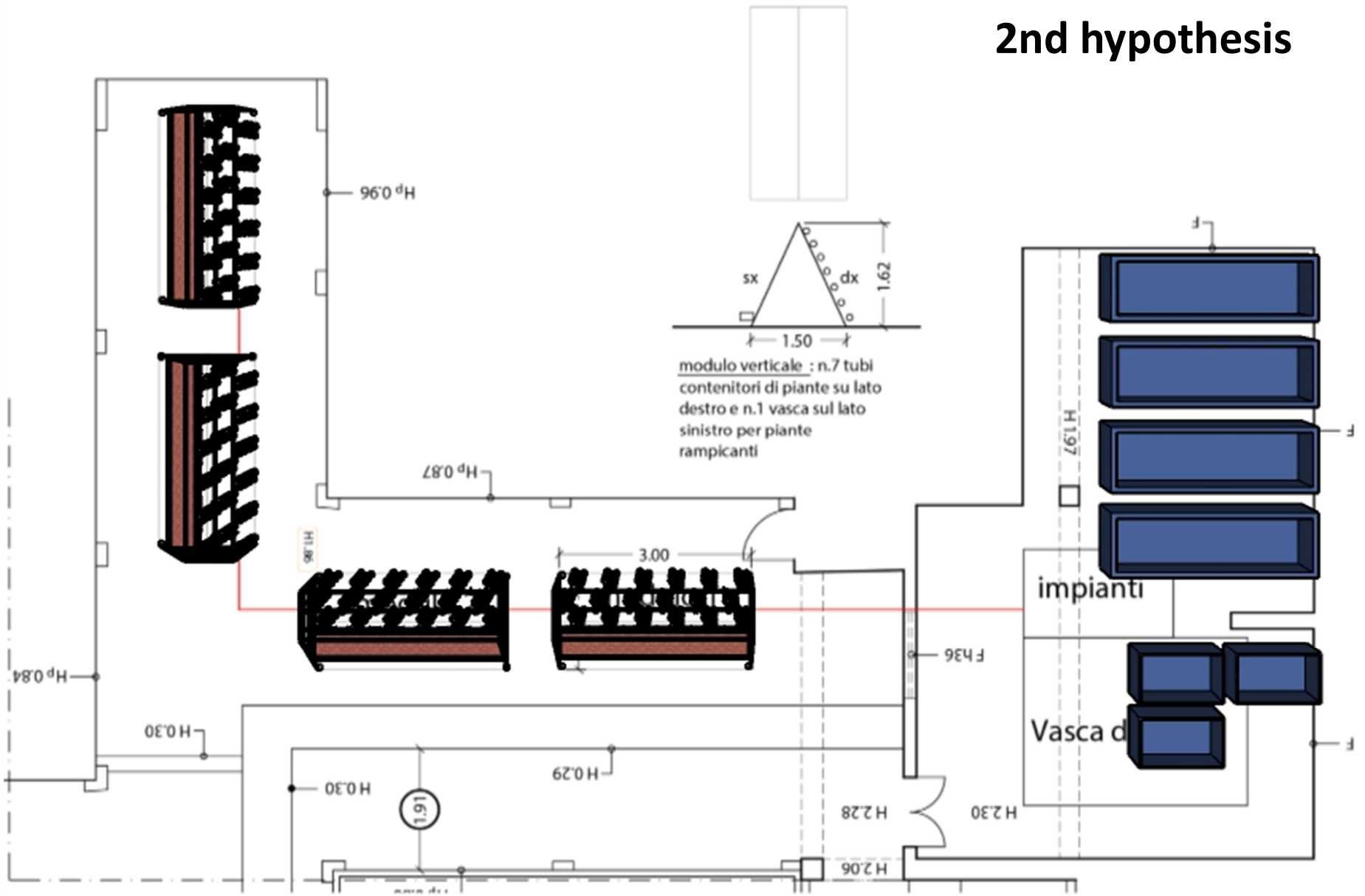
detail of fish and collection tanks



2nd hypothesis



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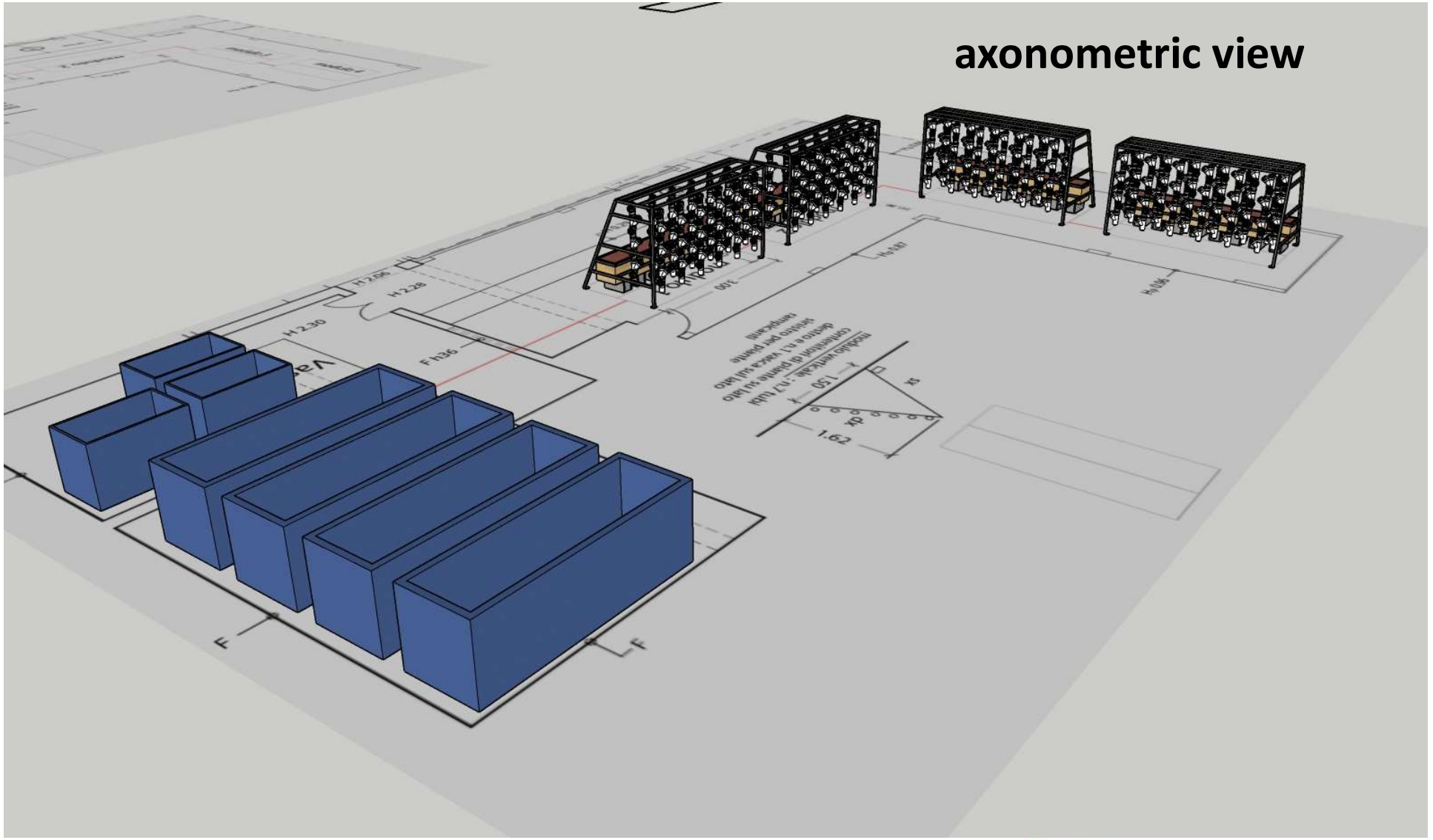
axonometric view



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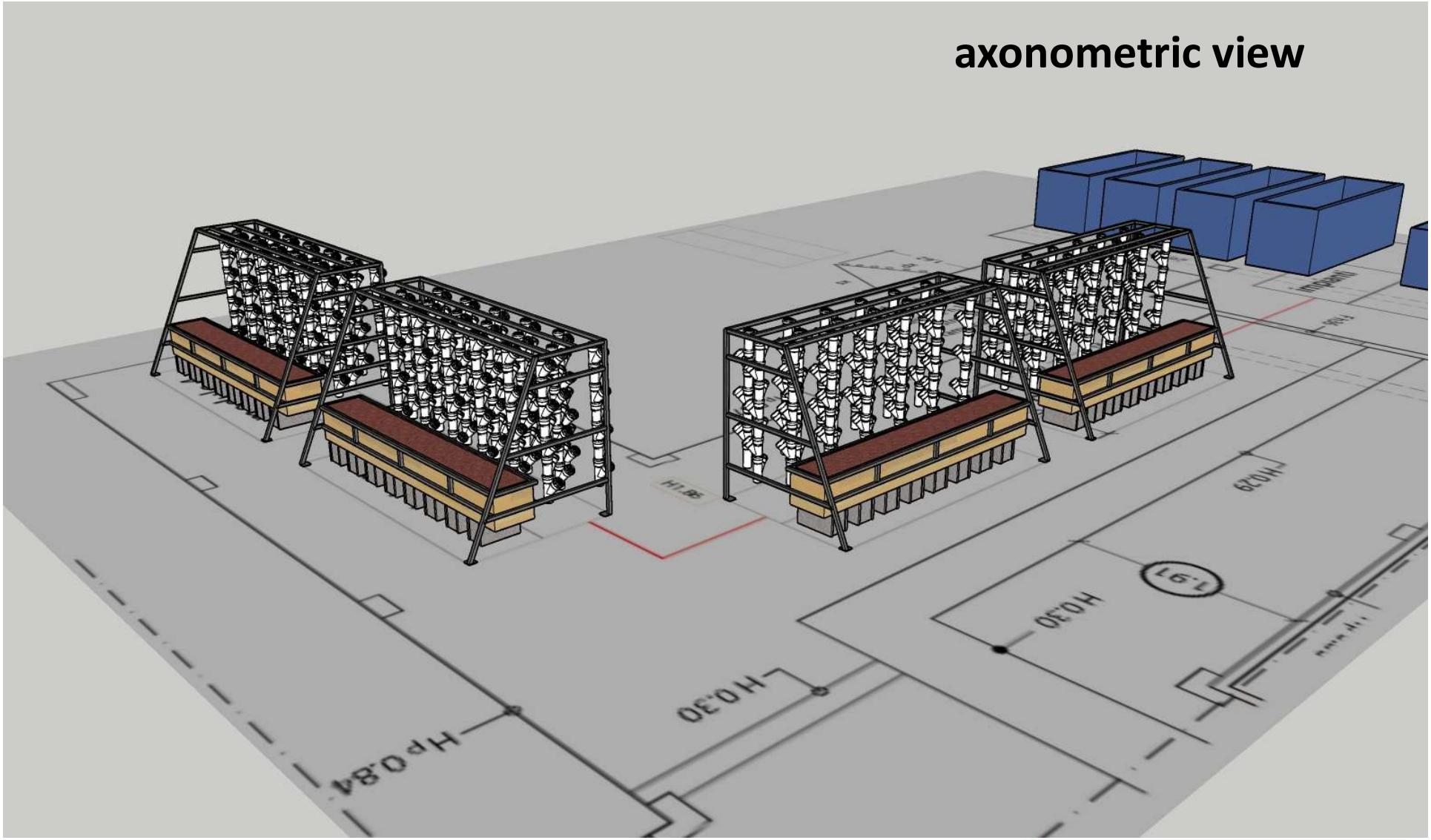
axonometric view



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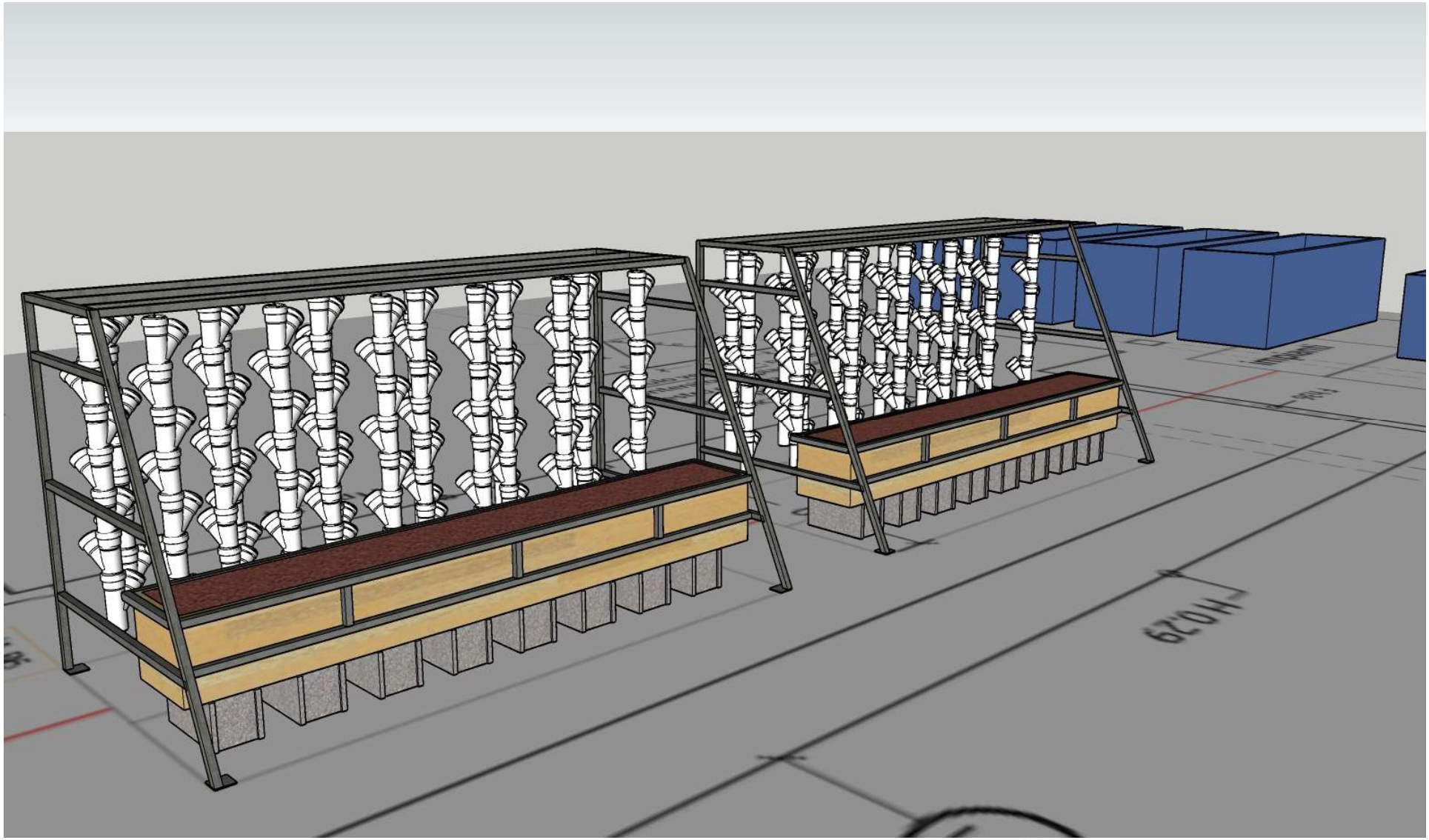
detail of growbeds



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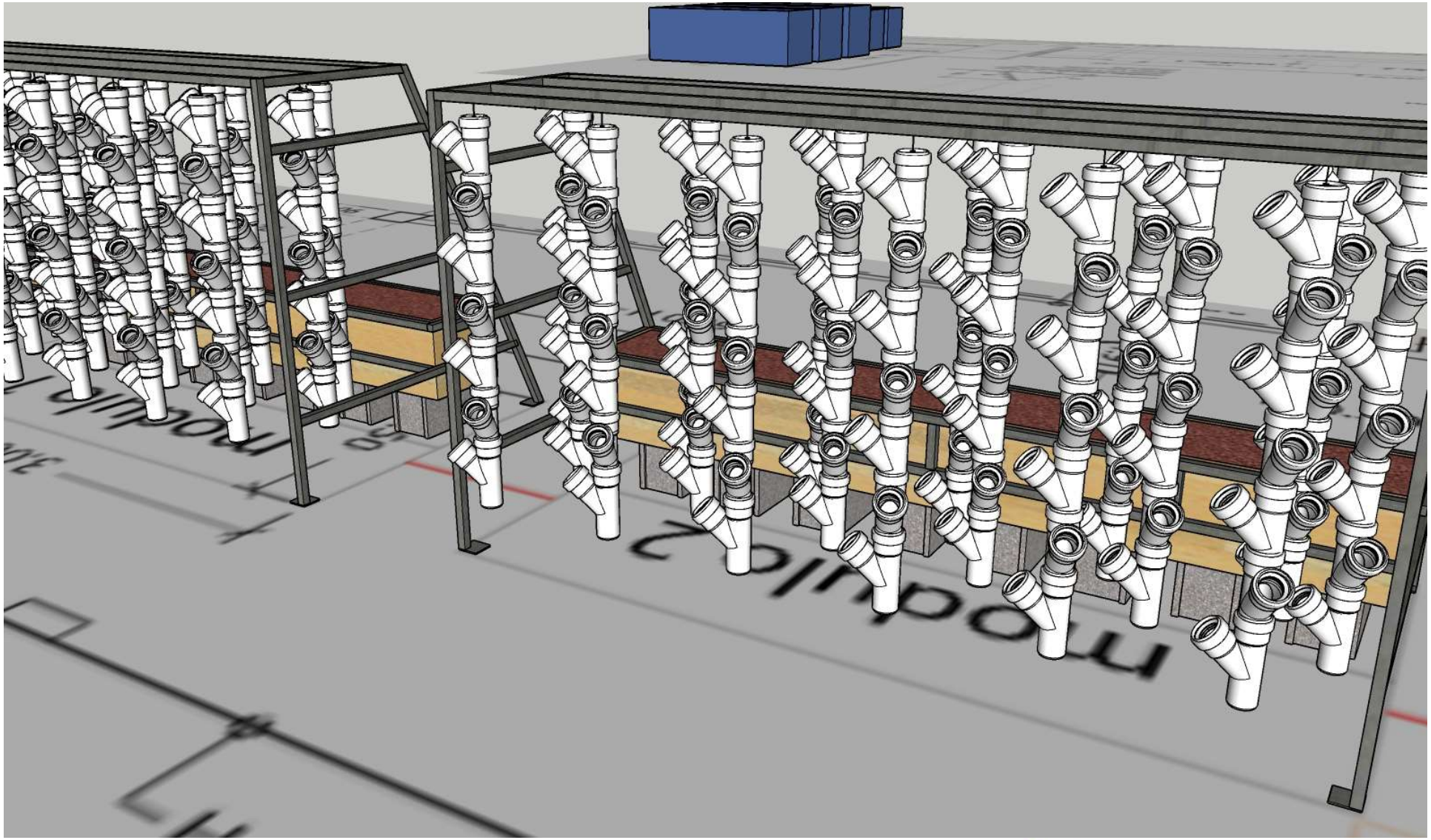
detail of pvc vertical towers



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For the condominium plant there is the following estimate of the loads.
Each fish tank contains about 3000 liters of water, plus the weight of the tank and fish for a total of at least **3080kg**.
For **each smaller collection tanks**, a weight of about **900kg** can be assumed.
The total weight of **each production module** is around **500kg**, oversizing, both in the version with horizontal tubes and with vertical towers.

With this loads a complete structural verification of the floor, beams and pillars involved is necessary.

A design idea of Aquaponic Design and Hortown of space optimization with the conversion of containers into aquaponic production plants.

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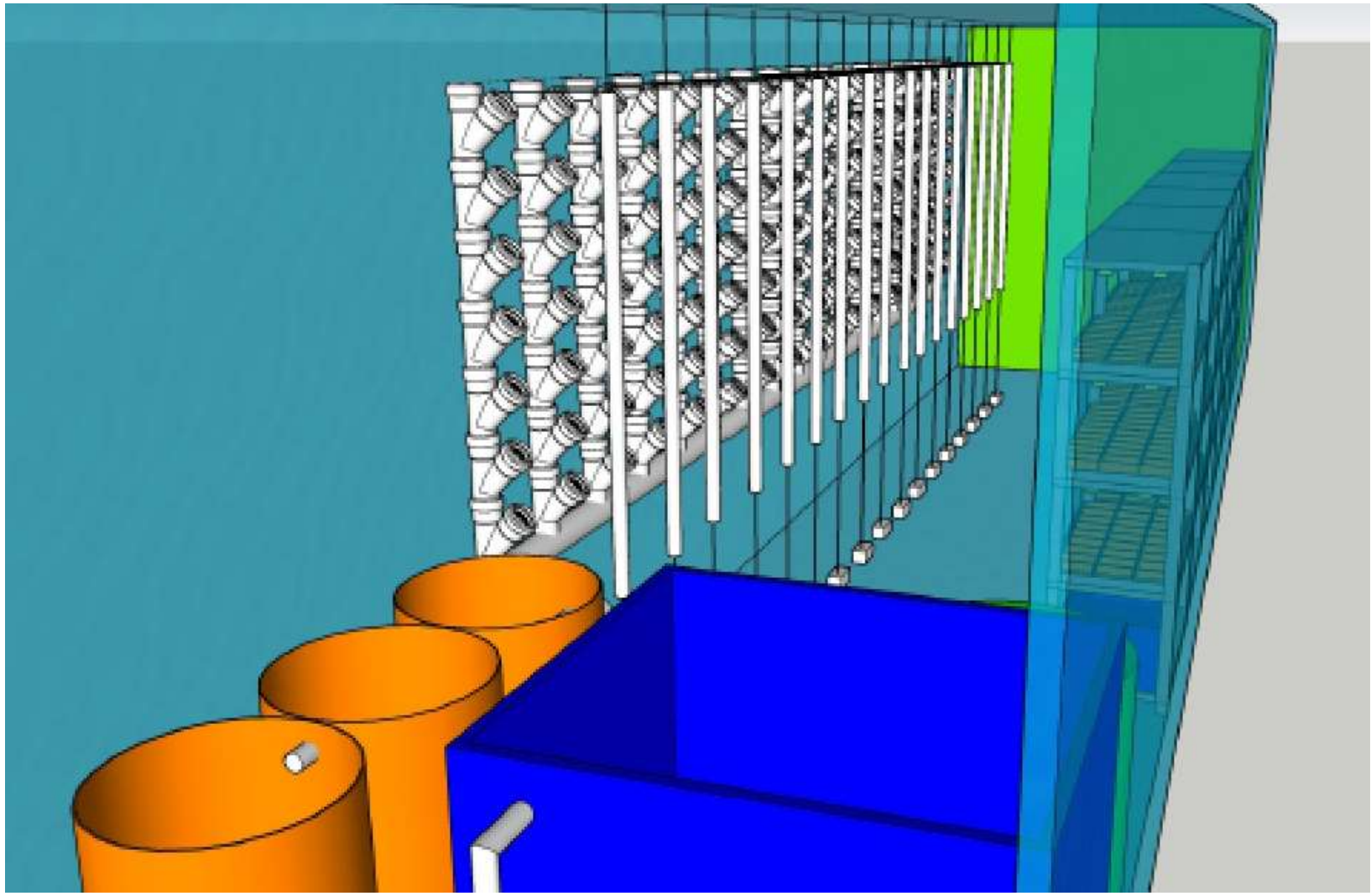
view of the interior of the container



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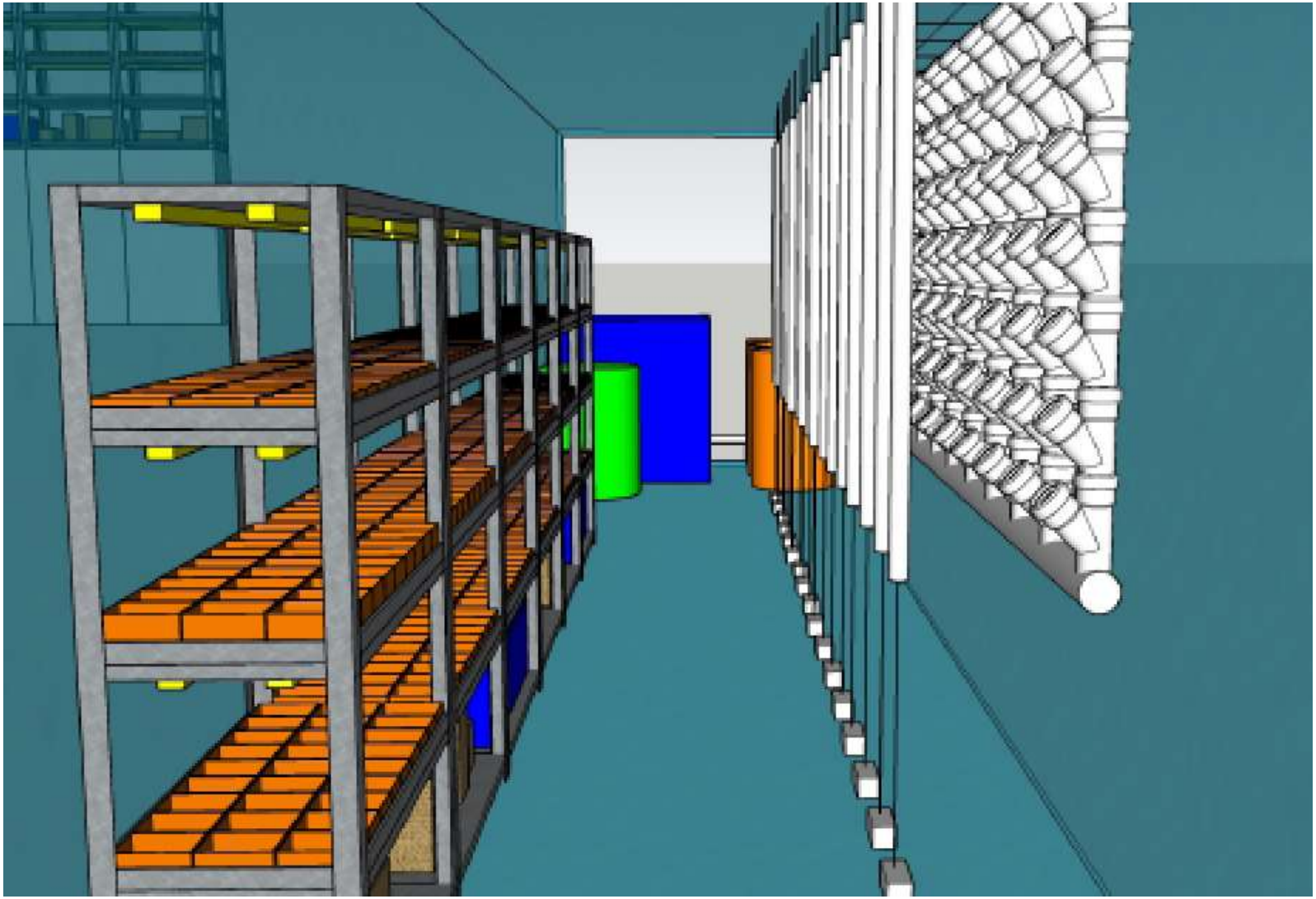
view of the interior of the container



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Thanks to Aquaponic Design for the illustrative materials provided.

Aquaponic Design si occupa della progettazione, della realizzazione e della vendita di **impianti di acquaponica per privati, scuole e attività commerciali**, convinto che un nuovo modo di immaginare e vivere le nostre città, più verdi, più solidali e sostenibili, sia possibile.

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Thank you for your kind attention

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