

2022

GROOF **INVESTMENT COST** **COMPARISON STUDY**

▶▶ Greenhouses to reduce CO₂ on roofs



AGENDA

- 01** Introduction
- 02** Rooftop greenhouse projects
- 03** GROOF case studies
- 04** Investment cost comparison
- 05** Conclusion

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INTRODUCTION

The GROOF project is an innovative cross-sectorial approach to reduce CO₂ emissions in the building and agricultural sectors by combining energy use for heating and cooling with local food production. This CO₂ emissions reduction is possible thanks to (1) the recirculation of the heat generated by the building to a rooftop greenhouse (RTG) actively (through the ventilation system) and passively to promote plant production, (2) the collection of CO₂ produced by human activity and building activities to stimulate plants growth and improve yields, and (3) the reduction of transport-generated CO₂ emissions by producing fresh food locally.

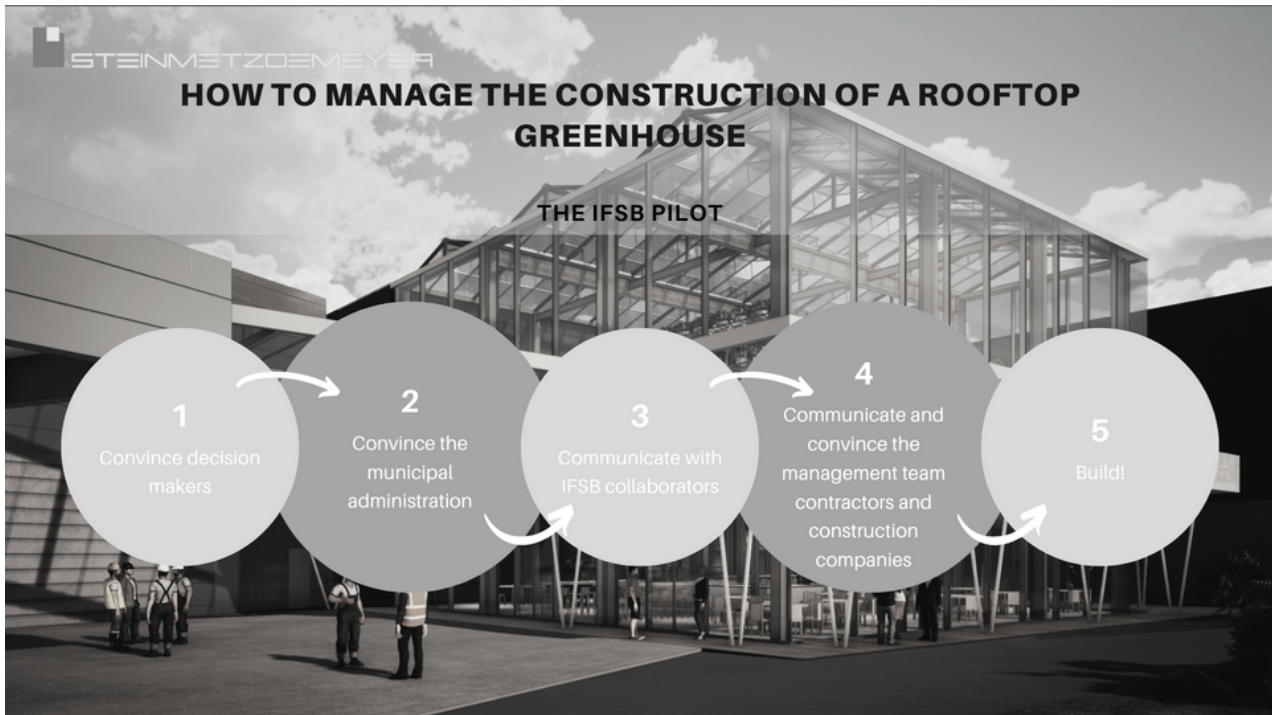
For each of these aspects, GROOF teams has :

- Identified barriers to market access,
- Created a state of the art based on literature and experience of existing rooftop greenhouse.
- Experimented, validated and demonstrated the effectiveness of rooftop greenhouses thanks to the study of 4 pilots.
- Coached early adopters of rooftop greenhouses (project holders) all over Northwest Europe.
- Gathered all the knowledge in dedicated guidelines to foster every company or individuals that want to develop a rooftop and/or integrated greenhouse project

This report focuses on key data regarding the construction cost of rooftop greenhouses in North West Europe area, gathered with four rooftop greenhouses developed within the GROOF project.



ROOFTOP GREENHOUSES PROJECTS



The GROOF team has started the project by visiting other rooftop greenhouses to gather feedback and experience return. One of the key experience is translated in the urban farmers bankruptcy report :
<https://hdl.handle.net/2268/241639>

The building process from the idea of creating a rooftop greenhouse and actually having it ready to operate is a long process (at least, at the moment) in Northwest Europe.
Our colleague from IFSB gave us some key element to tackle the project before building it, in the above image.

The below analysis will focus on the key investment items from GROOF pilots experiences.

"Building a rooftop greenhouse is a long process which involved multiple stakeholders"

GROOF CASE STUDIES



Uliège Rooftop Greenhouse
2 669€/m²

The greenhouse is placed and weighted on the roof, which means that the waterproofing is not touched. And the RTG can be removed without any impact.

The RTG name: SERR'URE : "SERRe URbaine basse Energie" -> Low Energy URBAN GREENHOUSE



Type of building



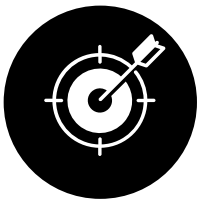
The Belgian pilot is built on a brand new research building center of the university of Liège :TERRA, in Gembloux (Wallon region). In addition, the RTG is part of a bigger research platform called WASABI, which stands for the "Wallon platform for innovative systems in agriculture and urban biodiversity". WASABI is also a teaching and research platform in urban peri-urban agriculture & biodiversity.

The Greenhouse



198 square meters divided in 3 areas. (1) technical, (2) production test and (3) the demonstration one. The north wall is isolated and the SERR'URE design is optimised to consume less energy than a classic chapel greenhouse.

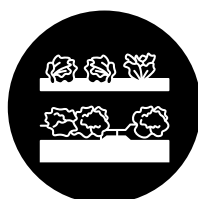
Objectives



This has been design for research purposes. The research that will take place in it will be linked to soilless and urban agriculture.

This GROOF RTG has already made linked with other international project such as (1) Optibiomasse (FEDER) and Bioonics projetc (SWIM) . It will be a key tool for future researches. Furthermore, Uliège has been selected in the strategic Innovation Initiatives (IIS) as part of the Smart Specialization Strategy of Wallonia (S3). With a WASABI 2.0 project, including more than 40 partners representing the entire food value chain link to innovative production systems.

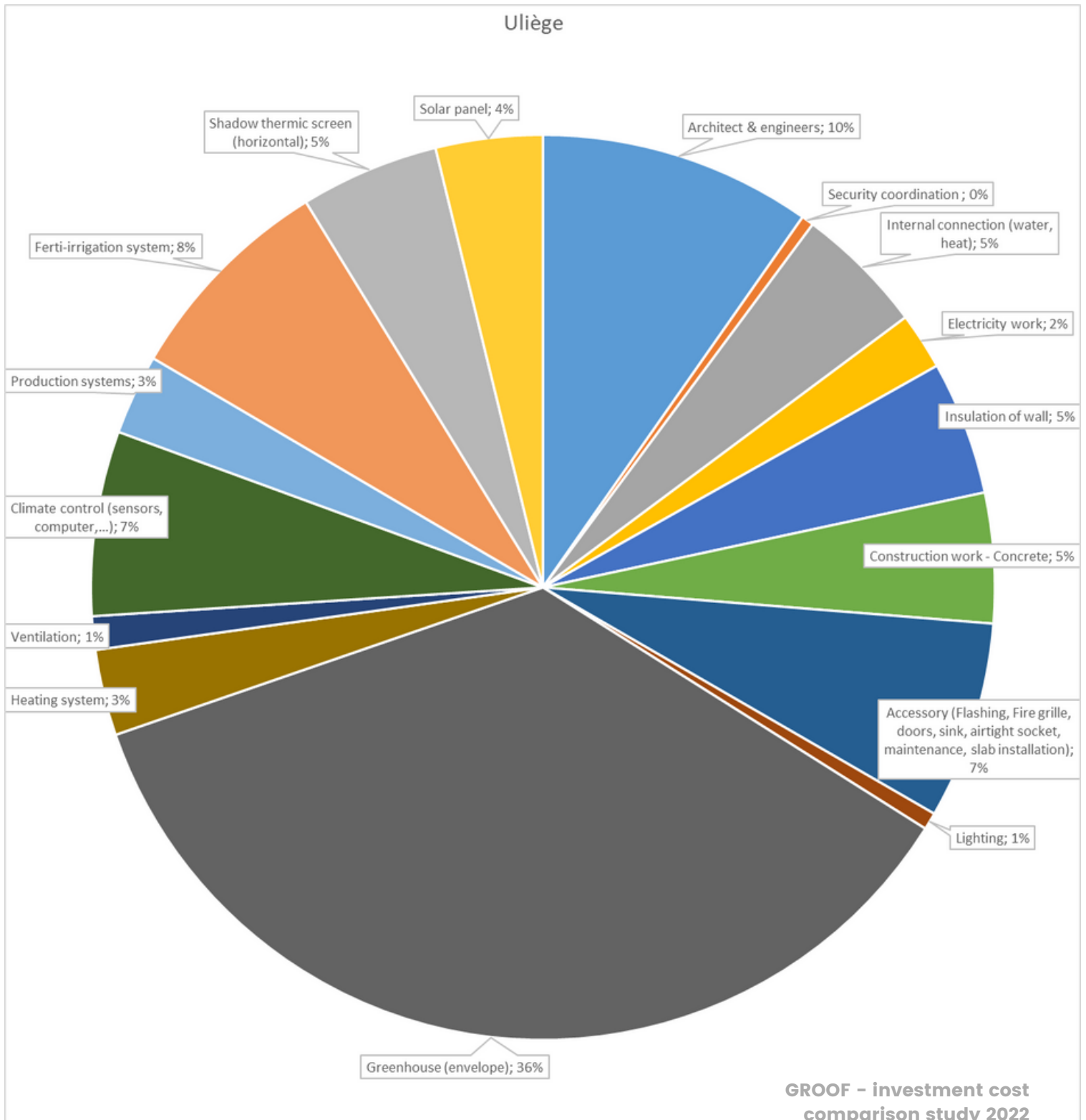
Production system



To be flexible to the diversity of cultures and research thematics, Goponic system was implemented. Such system can be adapted to be used as NFT, DWC or Drip irrigation system. It offers then multiple uses as required in small space and in urban environment.

GROOF CASE STUDIES

 **Uliège Rooftop Greenhouse**
Detailed Cost



GROOF CASE STUDIES



EBF Rooftop Greenhouse
2 366€/m²

This Sunlight Greenhouse is designed to show how a low energy demand greenhouse on a rooftop can help with reducing the heat losses of the support building while at the same time generating power for the combined system.



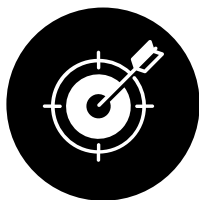
Type of building

From the 1950s, it was used for processing and packing of the products of the farm. Now it is being renovated and will additionally serve as an office space.



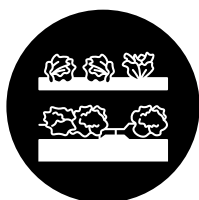
The Greenhouse

Lean-to style greenhouse of 154 m² based on a historical Chinese greenhouse design called Sunlight Greenhouse. It has insulation and opaque sidewalls and roof with only a large south facing arch being transparent. In winter or when there is no sunlight a thermal blanket can be spread over the film area to increase insulation and reduce heat losses. The greenhouse is designed to be low energy demand and can even be operated passively.



Objectives

The rooftop greenhouse will serve mainly as a show case for the capabilities of the sunlight greenhouse in an urban setting. As such the greenhouse growing space is rented out to a professional chili grower who cares for the greenhouse and makes it presentable and harvests his high value crops.



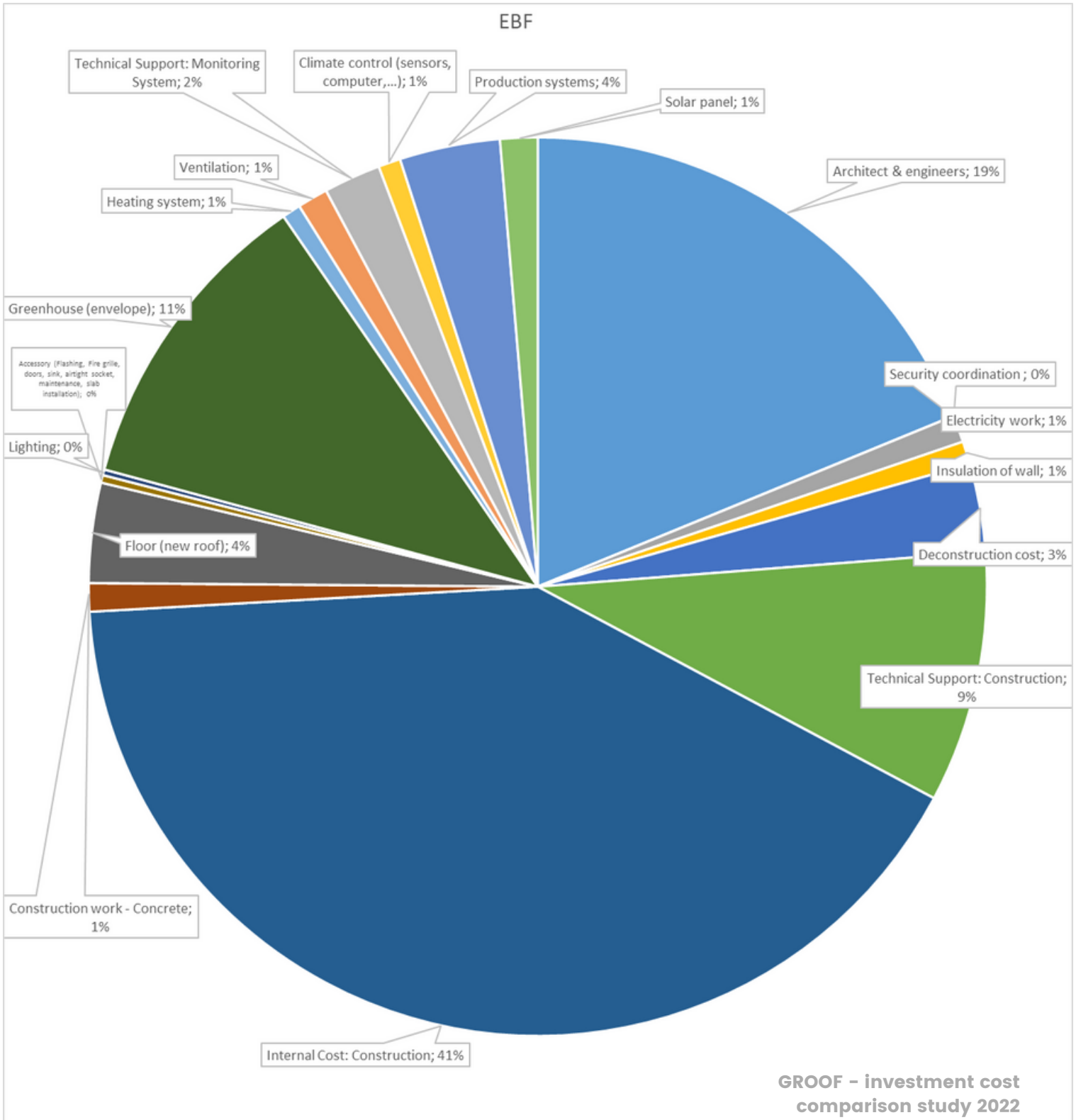
Production system

In the greenhouse, a dutch growing bucket system is used, and a substrate based hydroponic system. The buckets are filled up with lava clay granulate at the bottom for a weight reduction and better drainage. The buckets don't have to be filled completely with growing soil, since the roots are not reaching far enough down. The growing substrate itself is a mixture of soil and charcoal (Terra preta) which is rich in nutrients and gives optimal growing conditions.

GROOF CASE STUDIES



EBF Rooftop Greenhouse
Detailed Cost



GROOF CASE STUDIES



IFSB Rooftop Greenhouse
2 313€/m²



FRESH is a greenhouse promoting the construction of rooftop greenhouses in the Grand Duchy of Luxembourg.

FRESH is located in the commune of Bettembourg.



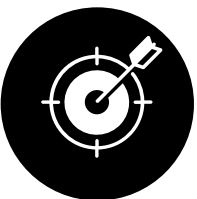
Type of building

It has been built on the extension of the restaurant of the Sectoral Training Centre of the construction sector (IFSB).



The Greenhouse

The greenhouse is 380m² and the structure is made of steel and aluminium. It is designed to be energy efficient, that's why it has : double glazing, energy recovery from the building, use of rainwater, recovery of CO₂ emitted by classrooms and offices.



Objectives

The FRESH greenhouse as a pilot project, aims to demonstrate the feasibility of such a structure in Luxembourg, its integration into the architecture of buildings and its interest in terms of energy savings and reduction of the CO₂ impact, both for the building and for the greenhouse.

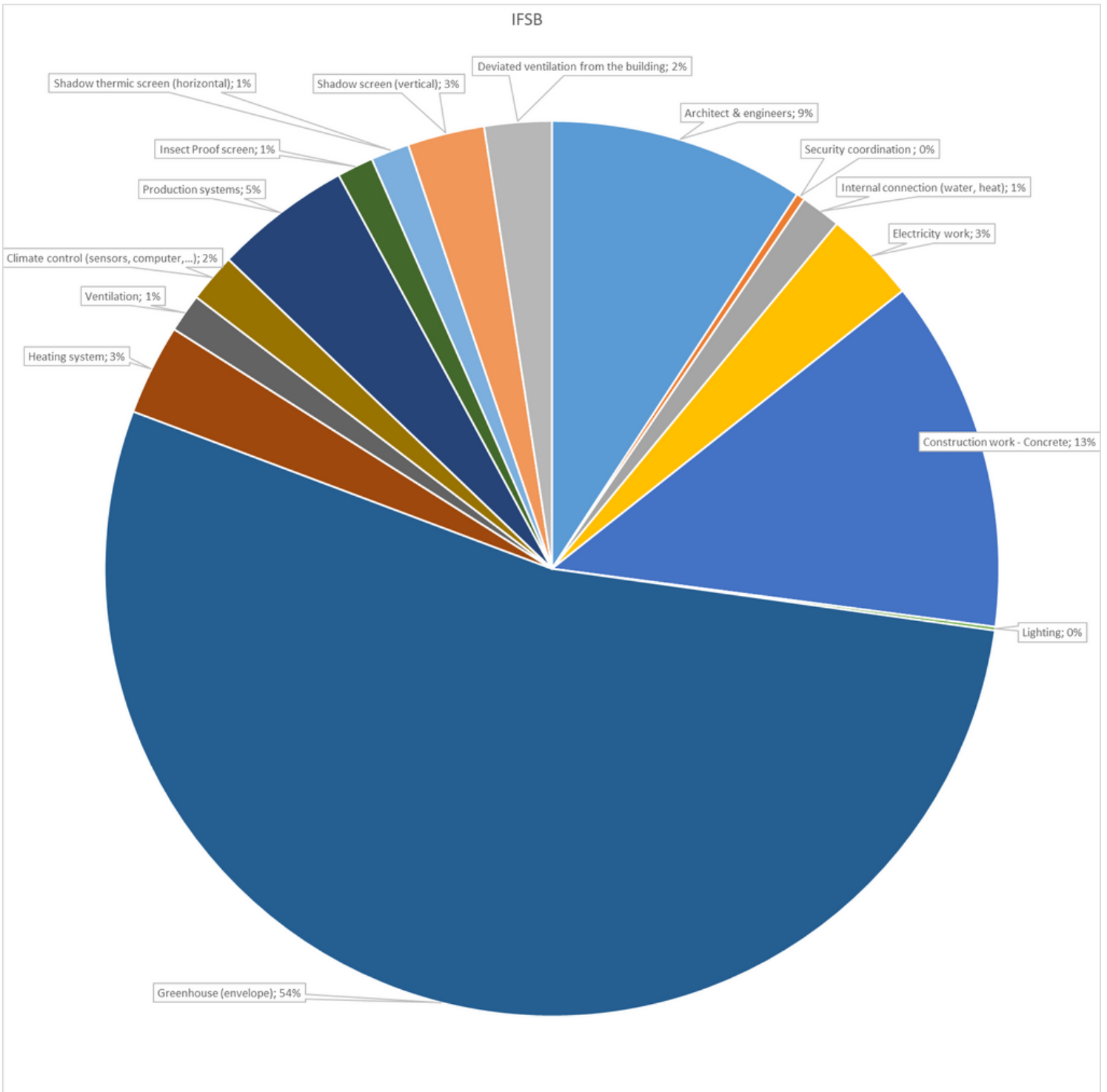


Production system

In order to respect the maximum load constraint on the roof, the chosen growing system is hydroponics.

The type of vegetables produced will depend on the seasons and on customers demand.

GROOF CASE STUDIES



GROOF CASE STUDIES



GALLY Rooftop Greenhouse
583 €/m²

Gally's rooftop greenhouse was designed to supplement the offer for fresh products of the urban farm of Saint-Denis, while not having more ground space, and still being able to preserve the farm's landscape.



Type of building



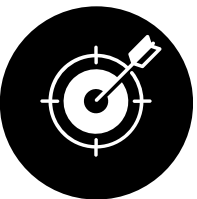
The French pilot takes advantage of the construction of a new building on an urban farm. The building has been designed to support a productive greenhouse on top of it.

The Greenhouse



The 360m² greenhouse is made of steel for its structure and plastic (polycarbonate and ETFE film) for the covering. The very simple design is based on an agricultural model, to be as cheap and efficient as possible.

Objectives



The aim is purely commercial. The greenhouse allows the production of crops that can't be grown in the farm's open fields (due to a soil pollution), therefore completing the offer for fresh products sold on site, e.g. tomatoes, cucumbers, eggplants or peppers.

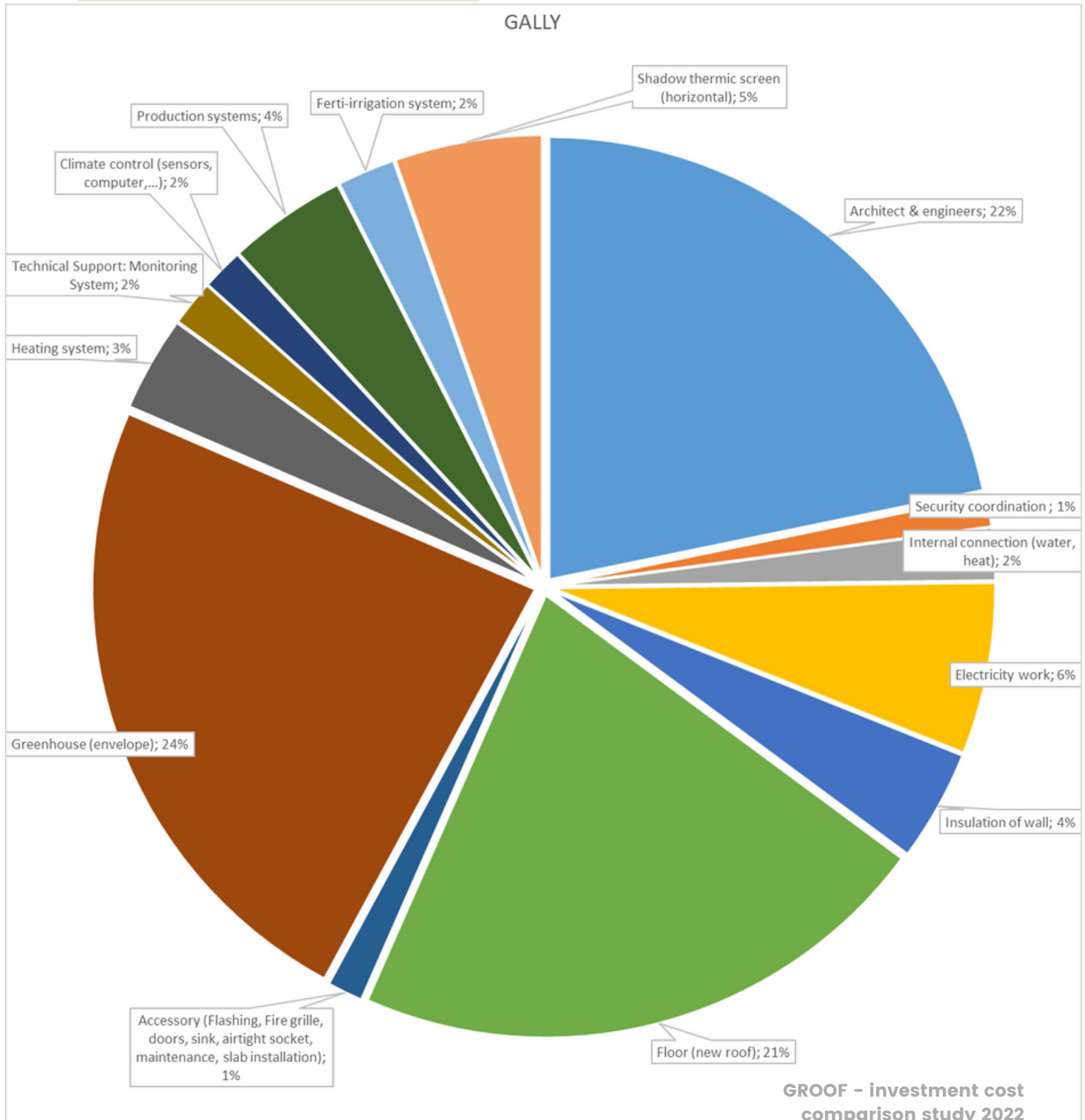
Production system



The greenhouse uses an hydroponic dripping system paired with cultured breads placed on gutters on one hand, and with garden plots on the other hand. The system is designed to be very simple, light, and easy to use/maintain by the team.

GROOF CASE STUDIES

 **GALLY Rooftop Greenhouse**
Detailed Cost



INVESTMENT COST COMPARISON

In a nutshell, the construction up to the greenhouse envelope is between 70 and 90% of the total construction cost. One of the main reason could be that project as greenhouses on roofs are not yet usual work for the multiple building & design stakeholders involved in the greenhouse construction. Therefore, it implies higher costs compared to usual on-ground-greenhouses, which could be around 200 and 400/m².

The bellow table is detailing the investment cost ratio for each rooftop greenhouse pilots, as well as the price cost per square meter. This cost depends on the objective of the greenhouse and therefore the design and materials used.

	Utiège	EBF	Gally	IFSB	
m ²	198	154	360	380	
Key culture	Hemp	Chilli	Tomato	Tomato	
Production type	Go ponics	Soilbased hydroponic	Hydroponic drip system kit	NFT	
Total cost	528.556,71 €	364.486,16 €	210.049,75 €	878.987,00 €	Medium
Price / m ²	2.669,48 €	2.366,79 €	583,47 €	2.313,12 €	1.983,22 €
Architect & engineers	10%	19%	22%	9%	15%
Renovation work	0%	0%	0%	0%	0%
Security coordination	0%	0%	1%	0%	0%
Internal connection (water, heat)	5%	0%	2%	1%	2%
Electricity work	2%	1%	6%	3%	3%
Insulation of wall	5%	1%	4%	0%	2%
Deconstruction cost	0%	3%	0%	0%	1%
Technical Support: Construction	0%	9%	0%	0%	2%
Internal Cost: Construction	0%	41%	0%	0%	10%
Construction work - Concrete	5%	1%	0%	13%	5%
Floor (new roof)	0%	4%	21%	0%	6%
Accessory (Flashing, Fire grille, doors, sink, airtight socket, maintenance, slab installation)	7%	0%	1%	0%	2%
Lighting	1%	0%	0%	0%	0%
Greenhouse (envelope)	36%	11%	24%	54%	31%
Heating system	3%	1%	3%	3%	3%
Ventilation	1%	1%	0%	1%	1%
Technical Support: Monitoring System	0%	2%	2%	0%	1%
Climate control (sensors, computer,...)	7%	1%	2%	2%	3%
Production systems	3%	4%	4%	5%	4%
Ferti-irrigation system	8%	0%	2%	0%	2%
Insect Proof screen	0%	0%	0%	1%	0%
Shadow thermic screen (horizontal)	5%	0%	5%	1%	3%
Shadow screen (vertical)	0%	0%	0%	3%	1%
Forced ventilation	0%	0%	0%	0%	0%
Cooling (FOG ou coolbox)	0%	0%	0%	0%	0%
Solar panel	4%	1%	0%	0%	1%
Deviated ventilation from the building	0%	0%	0%	2%	1%
Vérification	100%	100%	100%	100%	100%

Table 1 - GROOF rooftop greenhouse : investment ratio comparison

INVESTMENT COST COMPARISON

In the case of EBF (energy consultancy firm), the employees worked directly on the construction site to gather knowledge in order to launch a business around it. It is why the cost items construction (internal) is the highest one. The architect is taking an important part of the cost (compared to other RTG) due to a lot of technical advice given, more than foreseen. In addition, EBF has used as much as possible already purchased older material, for which the installation cost is within the scope of "Staff Cost to construct the greenhouse". At last, their technical support cost includes a lot of administrative work for organization with the building office, execution support on site, organization of material suppliers and workers.

For Uliège, the greenhouse envelope costs a lot due to its purpose: scientific research. To succeed it, the climate conditions need to be optimised compared to commercial conditions. As well as a high quality and constant climate control system.

For Gally, the objective was to have the more "standard" design and materials, the cheaper it would be. As a result it has the first position (among the pilots RTG) regarding the cost optimised rooftop greenhouse per square / meter : 583.47€/m².

The IFSB greenhouse case is a commercial production area and also an educative one. The cost of the greenhouse is therefore influenced by the techniques used (double glazing, connection to the ventilation of the existing building) and by the architecture (height of the greenhouse, large-scale glazing) which had to be striking to highlight the aestheticism of such a structure. For the training and promotion of the greenhouse, they built a walkway around the greenhouse to increase its visibility as guided tours and visits.

In a rooftop greenhouse building project, the two main cost are:

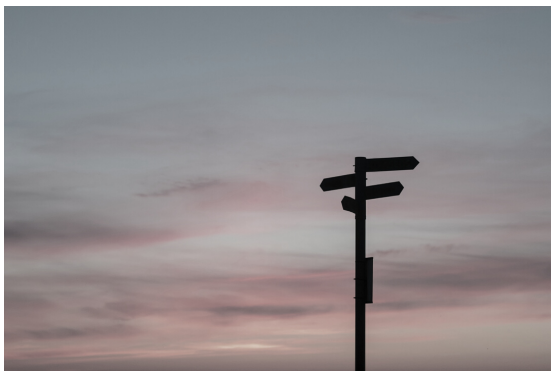
- 31% of the total cost: the greenhouse envelope, which include the frame and cover material
- 15% of the total cost: architect and engineers

As a rooftop greenhouse project holder, on which cost item do you need to focus on ? all is depending of your project objectives. Up-to-now, there is no mainstream cost items. Nonetheless, this report is aiming to give you key information on our own related cost. the more standard design and materials we select, the cheaper it is. As in the GROOF case, Gally has the cheapest greenhouse per square / meter : 583€/m² (compared to the other pilots). How they did it? Since the principal aim was to have a productive tool for commercial use, they imagined a greenhouse which could be as cheap as possible while being the most efficient possible, and so the greenhouse looks like a standard tunnel greenhouse put on top of a building : a two-hooded greenhouse covered with ETFE on top. The sidewalls are made of polycarbonate to resist the wind and improve insulation, while the structure is made of steel to remain strongly anchored. A plastic envelope reduces the investment and is lighter, thus not requiring a very strong structure to support it, decreasing even more the investment needed.

CONCLUSION

GROOF is a cross-sectoral project aiming to combine skills of construction and agricultural sector to jointly reduce CO₂ emissions and energy waste by creating a European market for integrated rooftop greenhouses. As showed, GROOF has concretely tested the technology with several designs by implementing pilot rooftop greenhouses. Lessons learned from the pilots are used to raise awareness and support early adopters into the implementation of their project.

Like every emerging and innovative sector, some projects failed even if they seem to have a strong business plan. Nonetheless, rooftop greenhouses continue to be built and have good potential of success. These sustainable projects have strong linked to environmental, and social aspect with a key part of economic opportunity. Key data of this report can help your decision.



The further study of the 4 pilots will complete scientific knowledge of such concepts, will provide tools to overcome the barrier and facilitate new projects. It will also strengthen an additional ongoing mission of GROOF: coaching 20 stakeholders to build their own RTGs also based on CO₂ emissions reduction.

The GROOF main steps until mid-2023 will be;

Coaching



10 new early adopters are receiving dedicated advice and training days to foster not only rooftop greenhouses, but every type of energy connected greenhouses. You can find a video and a presentation of the early adopters on www.GROOF.eu



Operational monitoring



Of the presented greenhouse. A report on this specific matter will follow.

Guidelines



Regularly updated , you will find them on <https://urbanfarming-greenhouse.eu/> or by scanning this QR code ----->



THANKS

To all the GROOF partners, early adopters, business partners and supporters.



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