GROOF

PROJECT

Communication report - 2023

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PREAMBLE

The GROOF project aims to reduce the CO^2 impact of the construction and agriculture sectors and promote urban agriculture. It is supported by the European Regional Development Fund and involves eleven project partners from five regions in North-West Europe.

The project involves building four greenhouses on rooftops in four European cities to study the synergies between the construction and agriculture industries and identify the advantages and challenges of rooftop agriculture.

The brochure provides detailed information and insights about this holistic concept.

The advantages are:

- A shorter distance to consumers gives fresher products, lower costs and emits less pollution from transport and storage. This is important in cities located far away from where the food is produced.
- Rooftop greenhouses in urban area can also give the population the opportunity to learn more about how food is produced. Building greenhouses on roofs instead of on the ground saves space that can instead be used for agriculture, green space, or other types of housing.
- A rooftop greenhouse integrated with the building below can use excess heat from this building, which saves energy.

An increasing number of rooftop greenhouses have been built in cities around the world. Some of these greenhouses are commercial and sell what they produce through supermarkets, restaurants (such as the FRESH rooftop greenhouse from IFSB), their own shops (like the project from Les Fermes de Gally, Paris), or food box schemes. Some rooftop greenhouses are also built by universities and schools and are used for educational purposes (such as the project by ULiège in Gembloux, Belgium). All these greenhouses use hydroponic systems for irrigation and fertilization of the plants.

PREAMBLE

Building a rooftop greenhouse (RTG) also presents certain challenges. If the greenhouse is to be built on an existing building, the building may not have the carrying capacity for an additional floor, requiring costly strengthening. Other factors that increase costs compared to a greenhouse on the ground include building access to the greenhouse and integrating it with the building below for heat and air exchange. Additionally, it can be challenging to obtain permission to build a rooftop greenhouse in a city centre due to aesthetic or regulatory reasons, such as limitations on the number of floors allowed in the area.

To address the high cost of rooftop greenhouse structures, companies can adopt various business models beyond just commercial use, such as offering guided tours and educational activities. Direct sales to consumers through the company's own shop or restaurant, or through a food box scheme, can also increase income as a larger share of the final price goes to the producer.

INTRODUCTION

Urban agriculture is part of the answer to the food resilience of territories, especially on surfaces such as the one we are working on here, which can be based on a real economic model.

This project also provides solutions for

- Urban renovation and renewal of the district, bringing new economic activity and a new landscape.

- Thermal insulation and treatment of roofs are also involved in the project. complete renovation of the building’s roof insulation (EBF pilot)

- Thermal regulation through the use of vegetation, retaining humidity and creating shaded areas.

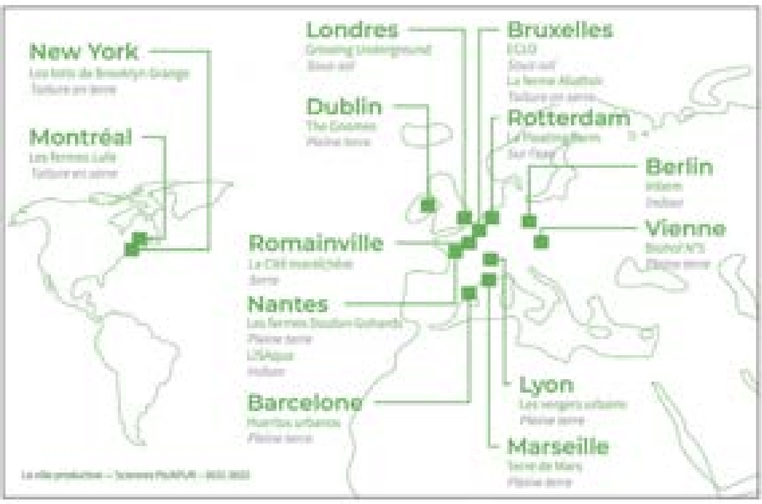
THE CHALLENGES OF URBAN AGRICULTURE

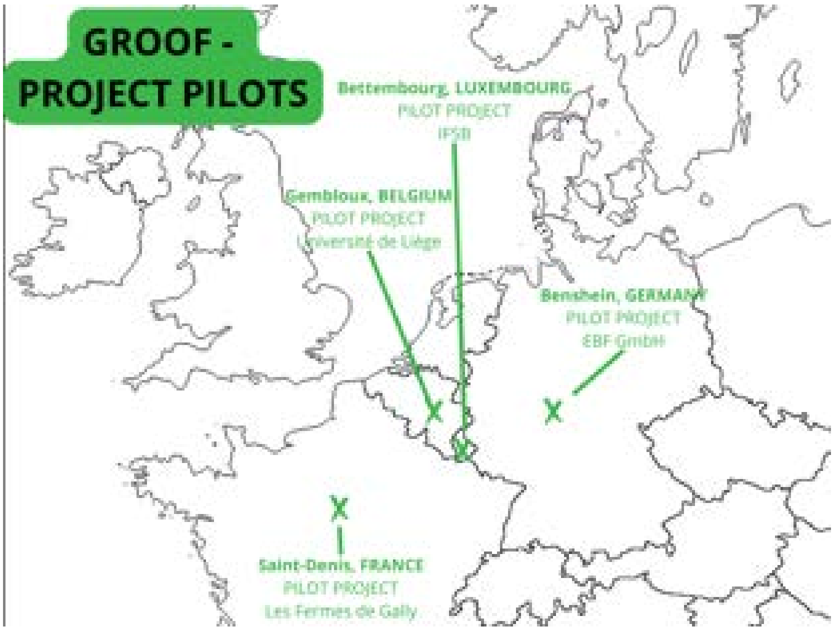
Cities are becoming increasingly densely populated and will continue to do so. According to the UN, nearly 70% of the world's population will be living in cities by 2050.

Urban growth on land and the decline of urban centres are among the main challenges in the search for a more resilient city. Concerns about product quality also reflect a shift in our relationship with food. Respect for biodiversity, quality of life, and food security are important elements in the discussion of food in the city and the concept of the productive city.

Urban agriculture is a tool that can be used to promote consumption, but it also presents challenges.

Using the Autonomous University of Barcelona's (UAB) reference building and a Rooftop Greenhouse (RG), savings of 11 tCO_2/y can be achieved compared to a conventional greenhouse. Based on this, it can be assumed that the four rooftop greenhouses in the GROOF project could save 39 tCO_2/y before any improvements made by PP.




GROOF -
PROJECT PILOTS
Bettembourg, LUXEMBOURG
PILOT PROJECT
IFSB
Gembloux, BELGIUM
PILOT PROJECT
Université de Liège
Benshein, GERMANY
PILOT PROJECT
EBF GmbH
Saint-Denis, FRANCE
PILOT PROJECT
Les Fermes de Gally


GROOF -
1ST COACHED PROJECTS
BRUSSELS, BELGIUM
COACHED PROJECT
L'Entrepote
Paris, FRANCE
COACHED PROJECT
Cueillette Urbaine
Nantes, FRANCE
COACHED PROJECT
J'habite mon jardin
Arcueil, FRANCE
COACHED PROJECT
Toits Vivants
Tours, FRANCE
COACHED PROJECT
Symbiose


Dublin, IRELAND
COACHED PROJECT
Dublin City Council
Cork, IRELAND
COACHED PROJECT
MTU
The Hague, NETHERLANDS
COACHED PROJECT
The New Farm
BRUSSELS, BELGIUM
COACHED PROJECT
City of Brussels
London, UK
COACHED PROJECT
Grosvenor Works
Damendorf, GERMANY
COACHED PROJECT
Himmelgrun Children Nursery
London, UK
COACHED PROJECT
Seedleaves
Lyon, FRANCE
COACHED PROJECT
Habiter une Ferme Urbaine
BRUSSELS, BELGIUM
COACHED PROJECT
Green Nest
GROOF -
2ND COACHED PROJECTS

The GROOF team initially conducted research on similar projects such as Lufa Farms, Urban Farmers, BIGH Farm, and Agrotopia to learn about RTG projects.

Lufa Farms is an example of how urban agriculture projects can adapt to the constraints of the city.

Such projects require adapting to technical constraints of the building, such as load-bearing capacity and accessibility, complying with the local regulatory framework for rooftop buildings and greenhouses, and establishing a partnership with the building owner to obtain a long-term renewable lease at a rate adapted to the project.

Outdoor cultivation in the city is strongly constrained by soil quality, with various traces of pollution, particularly lead, making soil unsuitable for growing edible products. However, solutions exist, such as decontamination, the containment of polluted soils using geotextiles, the cultivation of non-edible plants (floriculture, nursery), or the cultivation of edible plants above ground on tables or in containers.

The saturation of urban space has led project leaders to consider the use of rooftop spaces for urban agriculture, such as RTGs.

POLICY LEVERS : URBAN ARGICULTURE AS A PUBLIC SERVICE

Food strategies of cities can be designed to support the development of urban agriculture as a public service, such as providing financial support, developing policies to encourage the use of public spaces for agriculture, and providing education and training programs for citizens interested in urban agriculture.

These strategies can help promote food security, environmental sustainability, and social inclusion in cities.

GROOF
PRESENTATION

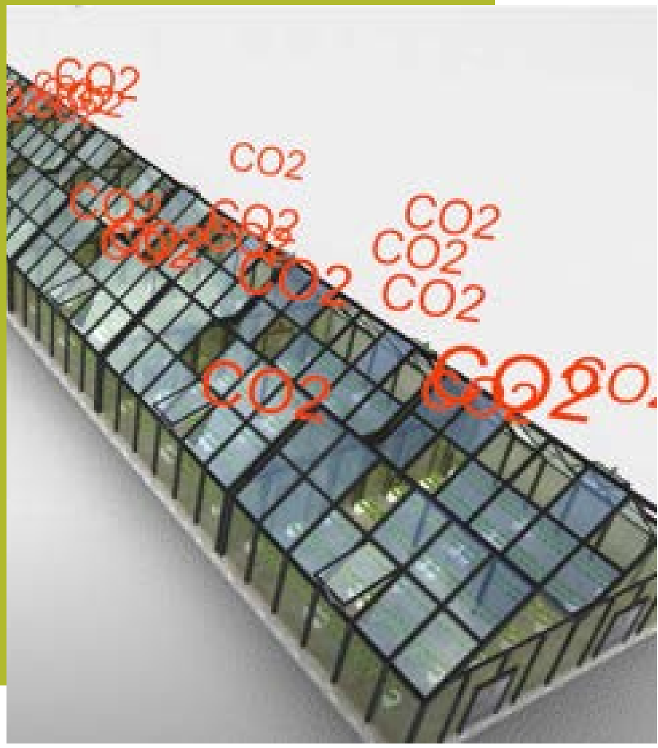
Reducing greenhouse gas emissions is a major international concern in the fight against global warming, which threatens our entire ecosystem. The construction sector obviously has a key role to play, and while energy-efficient building renovation is one way to contribute, another solution may well come from above. Let's look up and seriously consider the full potential of our roofs!

Project title	**Greenhouses to Reduce CO2 on Roofs**				
Project acronym	**GROOF**		Project Number		**NWE 474**
Name of the Lead partner organisation in English	Council for Economic Development of Construction				
Project duration in months	69 months	Start date	20-Sep-2017	End date	30-Jun-2023
Programme priority	Priority Axis 2 Low carbon				
Programme priority specific objective	SO3: To facilitate the uptake of low carbon technologies, products, processes and services in sectors with high energy saving potential, to reduce GHG emissions in NWE				
Total budget ERDF					**3 515 166.50**
Total budget					**5 927 926.50**

In this context, many European countries have committed to the GROOF project, which stands for "Greenhouses to Reduce CO_2 on RooFs". The project is an innovative cross-sector approach to reduce CO_2 emissions in the building and agricultural sectors by combining energy use for heating and cooling with local food production. It is supported by the INTERREG NWE programme and has a budget of approximately €5.9 million, with 60% co-funded by Interreg.

This report describes how CO_2 emissions can be reduced through various methods including:

- Re-circulating the heat generated by the building to a rooftop greenhouse (RTG) to actively and passively promote plant production.
- Collecting CO_2 produced by human activity and building activities to stimulate plant growth and improve yields.
- Reducing transport-generated CO_2 emissions by producing fresh food locally.



To address each of these aspects, the GROOF project team has:

- Identified barriers to market access.
- Created a state-of-the-art based on literature and experience of existing roof greenhouse.
- Experimented, validated, and demonstrated the effectiveness of rooftop greenhouses through the study of four 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 individual that wants to develop a rooftop greenhouse project.

The GROOF project started in September 2017 and will end in June 2023.

Within the framework of a partnership between 11 partners in France, Belgium, Germany, Spain, and Luxembourg, led by the CDEC (Conseil pour le développement économique du secteur de la construction) in Luxembourg, the Institut de Formation Sectoriel du Batiment (IFSB/LU), University of Liège (BE), Groupe One (BE), Cluster Eco-Construction (BE), Centre Scientifique et Technique du Bâtiment (CSTB/FR), Gally Farms (Fermes de Gally/FR), ASTREDHOR (FR), EBF GmbH (DE), University of Applied Sciences Trier (HS-Trier/IfaS/DE), and Universitat Autònoma del Barcelona (E).

The GROOF team has developed a benchmark of RTG (rooftop greenhouse) projects in NWE (Northwest Europe), Europe, and internationally. The aim of this work is to describe the diversity of projects, identify the tools implemented, and respective levers that cities and actors can deploy to promote the installation of RTGs.

Each partner brings valuable skills and knowledge to the project, such as construction process and methodology, building energy management, urban agriculture development, knowledge of plants and growing systems, entrepreneurship, socio-economic skills, and more.

The idea is to use rooftop greenhouses as an efficient equipment to

- Recover the heat produced and not consumed by the supporting building actively (through the ventilation and heating system) and passively (30% of heat lost through the roof on average) in a plant production.
- Collect the CO_2 produced by people and activities in the building to "feed" the plants.
- Reduce CO_2 emissions from transport by producing plants locally.

Thus, the ecosystem formed by the rooftop greenhouse and the existing support construction requires much less energy than if the greenhouse were separate. The greenhouse itself is an additional activity outside the building but shares energy in a way that makes both constructions more efficient.

WHY GROOF ?

Ancient civilizations incorporated agriculture production in their metropolis, but modern urban planning has separated agriculture from cities. The Food and Agriculture Organization (FAO) estimates that urban agriculture produces food for a quarter of the world's population, reducing the impact of food transport, packaging, waste, and improving food safety. However, five major challenges have emerged:

- The increase in urban population
- The decline in local food production leading to an increase in transportation
- The increase in commercial and residential buildings
- The decrease in fertile land and soils leading to industrial food production
- The increase in CO^2 emissions and loss of heat energy from buildings and roofs

Before implementing rooftop greenhouses (RTGs) as a solution, we must consider whether it is relevant to use underutilized spaces, if it is feasible from a technical standpoint, and the regulatory aspects such as building height, safety, and health risks. Additionally, the economic aspects, such as profitability and the reduction of CO^2, must also be considered.

RTGs are an interesting option as they increase the green space in cities, create new agricultural spaces, and promote food self-sufficiency in urban areas.
They have several advantages, including

- The recovery of sealed land for food production,
- Increased property value,
- Improved environmental performance of the building,
- CO_2 capture,
- Waste heat recovery,
- Improving circular economy
- Increase local food availability,
- Reduce logistical chains and cooling demands,
- Provide direct and indirect local jobs,
- Contribute to the social economy.

CONTEXT AND TERRITORIAL ANALYSIS

As a cross-sectoral approach, the project addresses technical and socio-economic issues from two sectors. Since 2002, construction regulations and European recommendations are constantly pushing the sector into building and refurbishing in a more efficient and sustainable way. Currently, a building from the most representative stock (built before the year 2000) consumes 250kWh/m^2 on average. However, the market can't provide affordable solutions fast enough and when they come up, builders usually need time to master them.

The agricultural sector faces similar challenges to the construction sector, including regulations and market issues. Greenhouses, for instance, consume an average of 180kWh/m^2 to meet the growing demand for fresh and local food year-round. To address the need to reduce CO_2 emissions and energy waste in buildings while also providing fresh, local food to the population, these sectors must work together to find a solution that benefits everyone. One possible answer is urban agriculture, but it faces a major hurdle: food prices are still too low. Furthermore, heating greenhouses in NWE climates requires a significant amount of energy and land.
To make rooftop greenhouses economically viable, new business models must be developed, and regulations must be adapted to allow for their implementation. Currently, there are no open-source business models in Europe for reducing CO_2 emissions, reducing energy consumption, and producing fresh local food with rooftop greenhouses. Additionally, professionals in both sectors are hesitant to take the risk of changing their business. However, moving greenhouses to less profitable areas, such as rooftops, could be an attractive option for promoters.

- Not enough professionals are willing to take the risk of changing their business. There are no existing business models in Europe involving rooftop greenhouses to, at the same time, reduce CO_2 emissions, reduce energy consumption and produce fresh local food. The existing business models are not open source.
- Urban planning regulations and other regulations are not adapted to that model and need to be changed to allow the market to grow.
- There is currently more demand than offer for fresh local food, and urban farming. To produce goods all year round in regions with a Northern West European climate, a heated greenhouse is needed, which consumes a lot of energy and land. Therefore, projects involving urban agriculture need to find an economic outcome quickly to cover the investment and maintenance of the Greenhouse.
- We have a critical shortage of urban farmers with the necessary skills to take on a horticultural operation. In Europe, there are no existing business models for a rooftop greenhouse that can reduce CO_2 emissions, energy consumption and produce fresh local food at the same time. Furthermore, the existing business models are not open source.
- Urban planning regulations and other regulations are not adapted to this non-existing model and need to be changed to allow the market to grow.

To address these issues and promote the development of the European market, GROOF has brought together specialists from various sectors across the NWE region, who are recognized for their expertise in construction, energy management, agriculture, and business development. They all believe in the success of a cross-sectoral and transnational solution for reducing CO_2 emissions, which involves combining rooftop greenhouses and buildings to share energy. With its knowledge of the NWE region, the partnership will be able to identify risks and opportunities for early adopters of rooftop greenhouses with CO_2 reduction purposes, develop open-source business models, and test them with pilot projects on a larger scale in different countries. The collaboration also aims to address the significant issue of CO_2 emissions from long-range transportation of food.

Credit : Les Fermes de Gally

Rooftop greenhouses should function as food hubs and collaborate with local food producers to optimize transport to customers' locations. CO_2 emissions from transport are often caused by long-distance shipments and half-loaded small trucks (ADEME, FR).

GROOF addresses the territorial challenges of the heavily urbanized NWE region. Space is scarce and expensive, particularly in urban centres where the need for CO_2 reduction measures, local food production, and greenery is highest. Rooftop greenhouses offer a productive and space-efficient solution that differs from standard green infrastructure such as green roofs. They respond to the existing building stock in NWE. An initial scoping exercise indicates that in London alone, there are 300 hectares of rooftops suitable for rooftop greenhouses, 460 hectares in Paris, and 300 hectares in Amsterdam.

The project will also stimulate the economic growth of the region by promoting the adoption of service and product innovation in companies, enabling them to reach the global market.

TARGET GROUPS

The target groups for the GROOF project are:

- Building owners (public and private) interested in CO_2 savings.
- Agricultural sector and farm operators interested in urban farming potential with rooftop greenhouses.
- Local authorities interested in advocating low-carbon solutions in their area.
- Financing providers and public authorities interested in providing financing and regulatory framework.

WORK PLAN

The first step of the project is to ensure the sustainability of the efforts made, which involves identifying obstacles and opportunities to provide guidance to future project leaders in Northwest Europe. However, this is not the end goal. The work done by the project partners will be used to demonstrate the CO_2 reduction benefits of rooftop greenhouses to policy makers and public facilitators. GROOF partners will collaborate to improve the regulatory environment in NWE cities to encourage the development of rooftop greenhouse projects.

Credit : Les Fermes de Gally

The project's experts in construction, energy, and agro-socioeconomy seek to collaborate with existing European rooftop greenhouses to identify the keys to a successful implementation. Additionally, GROOF Partners will analyse the regulatory, construction, and urban agriculture context in FR, BE, LU, DE, NL, IR, CH, and UK in collaboration with local entities.

The second stage of the project includes developing pilots in France, Belgium, Germany, and Luxembourg, with two being commercial to demonstrate profitability, one being educational, and one being experimental. Throughout the project, GROOF's partners will monitor and evaluate the pilots, starting with analysing the greenhouse design to ensure CO_2 reduction requirements are met and following their development through various monitoring and improvement phases.

In the final stage, GROOF is seeking project developers for rooftop greenhouses in Northwest Europe. Applications were collected in 2019 and 2022 via an open call for projects, with selected applicants receiving a feasibility study by GROOF experts on their specific project. This approach aims to encourage the development of rooftop greenhouses to reduce CO_2 emissions and demonstrate their benefits.

GROOF aims to disseminate an alternative way to participate in reducing CO_2 emissions in compliance with EU directives. The project's progress and results are communicated through various channels, including a website hosted by the Interreg NWE program (www.groof.eu), Instagram, LinkedIn, and national media, with articles and news disseminated frequently through these channels.

WHY BUILDING A ROOFTOP GREENHOUSE ?

- **Proximity to consumers**
  - Reduced food transport = savings in both financial costs and CO_2 emissions
  - Fresher products all year round
  - Lower risk of contamination during transport and storage
  - Include wastewater from households

- **Using rooftops instead of urban or fertile ground**
  - Take unexploited urban space into usage
  - Can generate high yields per m^2 with a year-round production

- **Energy saving**
  - Use heat loss and CO_2
  - Add an insulation layer to the building below

- **Other advantages: less pesticide use, less vulnerable to extreme climate events, and education and social integration**
  - Give city dwellers the opportunity to see and experience how food is grown
  - Contribute to a revival of the local economy, create new knowledge, education and job in deprived areas.




THE FOUR PILOT PROJECTS

The GROOF project is investing in four pilots to prove the effectiveness and durability of different models related to various building types in Belgium, Germany, France, and Luxembourg.

The pilots aim to test the economic models of agricultural or horticultural greenhouses, and their energy performance will be evaluated.

Each pilot is unique, and the studied synergies vary, including innovative building materials, various greenhouse shapes and roofing materials, different types of connection to the building, whether through the roof or a side wall, and the reuse of CO_2 emissions from human activities in some cases.

IFSB PILOT

FRESH is a pilot project in Luxembourg installed on the rooftop of the Institut de Formation Sectoriel du Bâtiment (IFSB) restaurant extension.

The country's fast-developing real estate industry cannot keep up with the demographic pressure, so the IFSB decided to create a tool for the construction sector to anticipate future food needs.

The project involves a 380 m^2 greenhouse above the restaurant, with some of the plants served directly to the restaurant below. The objective is to raise awareness about food production and reconnect people to it. Popular products such as tomatoes will be prioritized to meet the restaurant's needs. A corridor around the greenhouse allows visitors to view the production area without disrupting operations. The connection to the building for CO^2 and heat recovery is also beneficial for the building sector, which is facing upcoming challenges in CO_2 recovery in Luxembourg.

IFSB PILOT

DISCOVER IFSB PILOT

The greenhouse aims to be efficient

<u>From an energy point of view, we have :</u>

- A greenhouse heated by pellet boilers and thermal solar panels.
- Heat recovery from the air extracted from the building (at the exit of the plate exchanger of the double flow ventilation) (minimum temperature 8°C even with -10°C outside)
- Insulation between the restaurant and the greenhouse which allows the floor to be at an acceptable temperature.
- Significant thermal inertia (concrete floor and north wall) to recover heat from the sun (when available)
- Energy efficient double glazing (Ug = 1.1 W/m2K) and high light transmission (89% to 91%)

<u>From a Horticultural Production point of view</u>

- Hydroponics allows us to have a maximum weight per square meter of soil of 40kg (knowing that 50cm of soil can go up to 900kg/m2),
- Use of rainwater collected from the buildings around the greenhouse,
- Anti-insect netting on the roof openings to limit access to pests,
- The slab is nevertheless planned with an overload of 500kg/m2 to allow us to test different growing systems,
- A very short distance to the restaurant immediately under the greenhouse.

<u>From a CO2 point of view</u>

- Use of the CO^2 produced by the trainees and staff in the IFSB building (thanks to ventilation)

<u>From an Architectural point of view</u>

- The building massing was designed to be sympathetic to that of its neighbouring buildings.

TECHNICAL OVERVIEW :

Internal Area $380m^2$
· Internal Height 7.50m
· Installation cost €870,000
· CO^2 Savings Target: 45 tCO^2/annum
· Steel used: 28t
· Aluminium used: 5.5t
· Glass weight: 18t

EBF PILOT

The RTG is in Bürstadt, Germany, on the roof of the packaging hall on a farm owned by EBF. The packaging hall is a building from the late 1950s and is currently heated by fossil fuels, but the heat supply on the entire site will be replaced by renewable heating in the coming years. The solar greenhouse covers 160 m^2 and is designed to have a low heating demand, produce electrical energy, and serve as a solar collector for the support building, achieving a net positive energy balance over one year of operation.

EBF specializes in industrial and horticultural energy management and is implementing new technologies and systemic solutions in the food production sector to make it more sustainable and future-proof.

The RTG serves as a unique selling point for the farm and shows how RTGs can increase farming capacity without increasing land use.

DISCOVER EBF PILOT

EBF PILOT

Business – value creation

The RTG project and the entire farm serve as a showcase of the EBF approach for an economically competitive horticulture business. Due to the low energy demand of the solar greenhouse and its flexible year-round operation, the farm can supply markets, restaurants, and customers with fresh vegetables directly from the farm all year round. The greenhouse growing space and the rest of the farm are being rented out to a chili pepper specialist who uses the site for organically grown products and ships them directly from there.

This gives EBF the opportunity to examine the energy flows and function of a fully operational solar greenhouse, responsibly handled by an expert in horticulture.

Construction

The packaging hall is constructed traditionally with sturdy walls and foundations, providing structural stability even after 50 years. However, the old roof made of wooden beams was only able to support the previous roof covering and not the corrugated Eternit® roof, which had partially damaged and was no longer fully sealed. The old roof and the entire beam structure were removed to install a new rooftop platform. A concrete ring beam was placed on top of the walls, followed by the addition of wooden roof beams and a platform made of OSB boards. These changes increased the bearing capacity of the platform to 2.5 kN/m^2 depending on the location, with the potential load being substantially higher on the backside of the greenhouse due to the beam range.

The greenhouse is built using a light-gauge steel frame connected directly to the wooden roof beams. The platform and the connection to the steel frame are coated with a special waterproofing material that prevents water damage to the bearing structure. The outer shell of the greenhouse is heavily insulated with a hempcrete wall on both sides and the back, and parts of the roof are insulated with lightweight hemp straw. The arched south side is covered with a highly transparent double layered ETFE coating, and a thermal blanket is used to reduce thermal radiation losses during cold nights. Additionally, a walkway around the greenhouse was built for easy access from all sides and to collect rainwater.

EBF PILOT

Energy Management

The primary objective of the solar greenhouse is to decrease the energy consumption of food production while maintaining year-round operation. This is accomplished by constructing a heavily insulated outer shell that minimizes heat loss.

One of the significant problems encountered by greenhouses in the summertime is overheating. The solar greenhouse will employ PV systems installed inside directly beneath the film to create shading while also generating electricity. If shading isn't needed, the PV system will be rotated out. Furthermore, ventilation flaps are installed on the bottom south side and at the highest point in the greenhouse. These strategically placed openings create a natural flow through the greenhouse, which cools it down with fresh air without requiring forced ventilation, thus avoiding energy usage. This is feasible because of the high transparency of the ETFE film. Since the PV panels are not exposed to atmospheric conditions, they can be thin and lightweight.

Due to the insulated and opaque side walls, the total incoming sunlight is reduced compared to other greenhouse types. As a result, internal heat management becomes more important. This is mostly handled through insulation that reduces radiative heat loss, and a thermal blanket that will save energy and avoid direct sunlight during the intense summer heat.

TECHNICAL OVERVIEW

Internal Area 150m^2
Internal Height 4.0m
·Installation cost €364,000, €2,366/m2

CO_2 Savings Target: 45 tCO_2/annum
GH Shell Cost: €45,000 (12%)

GALLY PILOT

LES FERMES DE GALLY

Credit : Les Fermes de Gally

One of the four GROOF pilot rooftop greenhouses (RTGs) is located at the urban farm of Saint-Denis, near Paris, France. The farm is dedicated to production and education, and visitors include citizens, families, and companies interested in learning about farming, healthy food, nature, and the workings of the farm.

The farm is managed by Les Fermes de Gally, a company that specializes in landscaping and is devoted to bringing nature and farming into and around cities. The 360-m^2 RTG is dedicated to vegetable production, specifically increasing the tomato and herb production of the farm. The greenhouse is designed for flexible production using hydroponic systems and aims to be easily manageable, sustainable, and dedicated solely to production. Visitors will be able to walk on a platform located on the east and south sides of the RTG. In addition to the research aspect, the project is based on four distinct and complementary functions: receiving the public, promoting direct and local sales, hosting training and awareness-raising workshops, and training gardeners for other places and companies.

The greenhouse on the roof of the Ferme Ouverte in Saint-Denis is focused on four main areas: local production, energy saving, materials used for construction, and irrigation.

Local production

The greenhouse has been designed for local production to extend the productive window while limiting pest risks. In the first year, the greenhouse focused on tomato production, which met local customer demands. The production system allows for flexibility to switch to other crops based on market needs.

GALLY PILOT

Energy saving

The greenhouse was modelled by an M+E Engineer to maximize energy savings through its connection to the building. Two features enable passive energy savings: a concrete wall supplements the north face's plastic wall to reduce heat loss and allow for energy storage, and the connection between the building and the greenhouse is a concrete slab designed to promote heat transfer. The greenhouse provides insulation for the building, and the building's heating system maintains the greenhouse frost-free.

Materials used for the construction

The greenhouse is based on an agricultural and thrifty model, using a stainless-steel structure, polycarbonate walls, and a plastic covering composed of two layers of Ethylene tetrafluoroethylene (ETFE) of 200µm each. The steel structure anchors the greenhouse in the concrete slab, the polycarbonate walls combine insulation, light transmission, and mechanical resistance, and the air pillow of ETFE adds more light diffusion inside the greenhouse while being resistant and providing good insulation. The concrete wall only serves as insulation and was added inside the greenhouse. The concrete slab is thin but allows an operational load of 500 kg/m^2.

Irrigation

The irrigation system is a classical dripping system where a mix of water and nutrients flows through it, and any wastewater is collected on a gutter beneath the substrate bags.

Monitoring Tools and Frequency of Readings

The monitoring system comprises various sensors, mainly measuring climate parameters such as humidity and temperature inside and outside the greenhouse, as well as electricity and heat meters. A weighing system for production and waste is also in place. Some data is collected every hour, while others are recorded daily. The option for an automated system for collecting all data is still being evaluated.

TECHNICAL OVERVIEW :

Internal Area 360m^2
Total Farm Area 2.3ha (1ha committed to vegetable production)
Total Cost €210,000, €583/m2
GH Shell Cost: €85,000 (41%)

DISCOVER GALLY PILOT

ULIEGE PILOT

The greenhouse, named SERR'URE (SERRe URbaine basse Energie), is located on the rooftop of the Gembloux Agro-Bio Tech faculty building in Belgium. The 198m^2 (5.5 x 36m) greenhouse is developed by the Research Centre in Urban Farming of Liège University and is dedicated to research on production systems for rooftop farming.

The greenhouse is equipped with various sensors for monitoring climate parameters, electricity, and heat meters, and a weighing system for production and waste. It can be easily removed without affecting the waterproofing of the building. The research center focuses on developing low-tech and high-tech approaches for urban farming, such as SPIN, agroforestry, aquaponics, rooftop farming, and indoor cultivation. The RTG will research and demonstrate innovative production systems adapted to RTG applications and also host educational activities.

DISCOVER ULIEGE PILOT

Construction

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

ULIEGE PILOT

The Greenhouse

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

Objectives

This greenhouse has been designed for research purposes. The research that will take place in it will be linked to soilless and urban agriculture. SERR'URE has already made links with other international projects such as (1) Optibiomasse (FEDER) and Bioponics project (SWIM). It will be a key tool for future research. 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 linked to innovative production systems.

Production systems

To be flexible to the diversity of cultures and research subjects, a Goponic system was implemented. Such a system can be adapted to be used as an NFT, DWC, or Drip irrigation system. It offers multiple uses as required in small spaces and urban environments.

TECHNICAL OVERVIEW :

Internal Area 198m^2
Total Cost €528,000, €2,669/m2
GH Shell Cost: €182,000 (34%)

LONGTERM EFFECTS

This international project has three main objectives to maximize its long-term impact:

- **TODAY**: Set up four pilot projects in France, Belgium, Germany, and Luxembourg to demonstrate technical feasibility and profitability.
- **TOMORROW**: Support rooftop greenhouse project developers in the Northwest by providing a free feasibility study.
- **MAKE THE EFFORT SUSTAINABLE**: Identify the legal, financial, and technical obstacles and opportunities for the implementation of a rooftop greenhouse in North-Western Europe with the objective of reducing CO^2 emissions.

The experience gained during the project is being shared through guidelines that will be disseminated throughout the project.

Since the beginning of the GROOF project, our consortium has worked to build a community around the project.

Through communication activities, we have succeeded in creating:

- A website about our guidelines that generates more than 350 visitors per month
- Another website where we publish articles on different topics
- 1 newsletter per month with 450 subscribers
- 3700 subscribers to our social networks, mostly LinkedIn (2550 subscribers)

Our challenge is to create a real community around these communication activities and tools. We have decided to use two different strategies: one focused on external stakeholders and another one focused on our own consortium's network of internal stakeholders.

- **External Stakeholders**

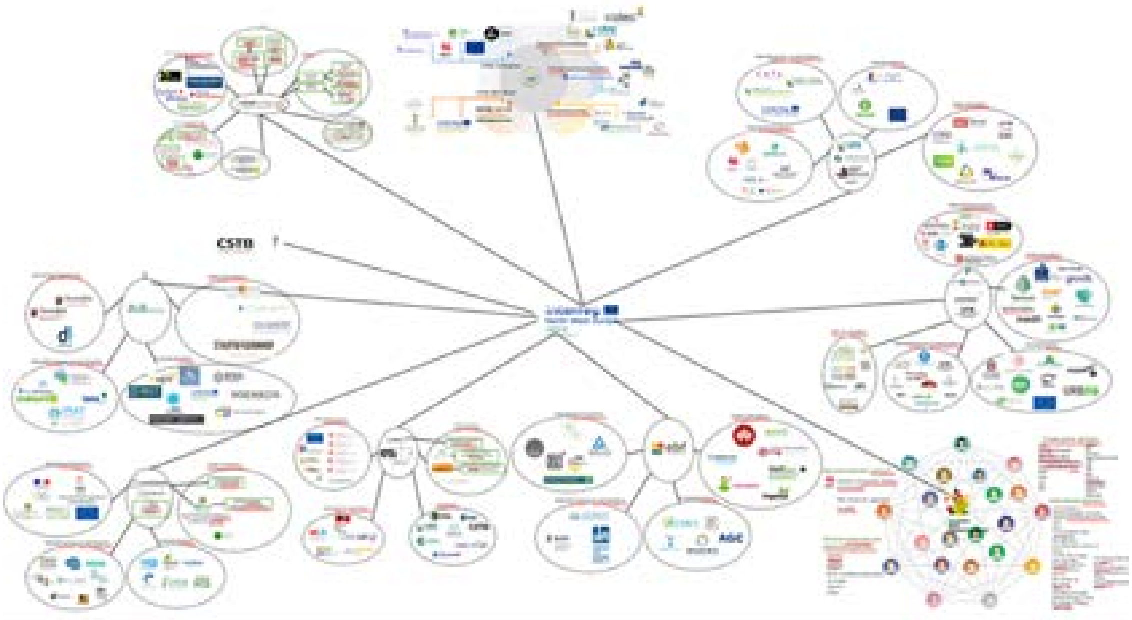
The project aims to target three categories of external actors within our consortium:

- Political decision makers and city administrations who are interested in supporting urban rooftop greenhouse (RG) projects with the goal of reducing GHG emissions and improving city resilience with respect to food security. They will be invited to visit GROOF pilots and provided with advice and innovative solutions.
- Public and private building owners such as municipalities, hotels, food providers, etc. who may be interested in GROOF's innovative solutions for their existing or planned buildings or for the benefit of their citizens
- Actors interested in learning about RGs such as architects, educational institutions, urban farmers, etc., in order to design and build them. They will be involved and stimulated through media and network.

Key messages: How to create a sense of community?

- **Internal stakeholders**

We have mapped our own consortium network (related stakeholders) that can be reached by GROOF's results. Each partner focused on its own network. Below are the results of the survey:



Our reach is as follows...

- 50 National public institutions
- 55 National Research and Educational institutions
- 60 Other international partners (NGO's, Institutions from countries out of NEW area)
- +2 500 Private actors (from construction to agriculture)

Conclusion of long-term effect

Our community strategy is based on two main activities: First, we focus on external stakeholders and use communication tools to generate interest in GROOF. Then, we leverage our GROOF partners and their traditional networks to create a community of different stakeholders around GROOF. In the future, our guidelines website, our four pilots, and our current consortium network will be the three main tools to sustain the GROOF community.

COACHING

The first coaching sessions took place from 2019 to 2021 with five early adopters who benefitted from GROOF expertise. In 2022, a new coaching programme began with ten new projects.

Our expertise includes knowledge and expertise in construction, such as design, stability, materials, technical assessment, calculation, risk analysis, and specialisms in roofing and structure. We also have knowledge in material behaviour and innovative combinations, as well as skills in technical project analysis.

We provided analysis of the energy flows of the existing building and the RTG project itself and advised on techniques to reduce energy demand and exploit existing local metabolic flows to reduce CO^2 emissions.

We also provided expertise in the design of plant production systems and their management. This includes existing off-the-shelf growing systems, plant nutrition, light recipes, pest and disease management, and operational logistics.
We evaluated the viability and durability of the coached projects against their vision. We analysed the stakeholders, the cultural, social, and geographical context, the commercial opportunities, the environmental ambitions, and advised on any key threats.

DISCOVER OUR PROJECTS

DISCOVER ONE OF OUR FIRST COACHED PROJECT

SYMBIOSE

CALL 1 - 2019 -2020

Since September 2019, GROOF has already supported 10 greenhouses projects located exclusively on rooftops. The coaching involved a total of 175 hours of individual coaching and 5 on-site visits to help the project owners build, develop, and implement their projects.

Phase 2 coaching: 5 projects selected to accelerate implementation.

Out of the 10 projects, 5 have been selected to continue the coaching in phase 2, with a focus on accelerating the implementation of their projects.

CALL 2 - 2022 -2023

In 2021 GROOF launched a new call for projects offering a year of coaching to early adopters located in UK, Ireland, The Netherlands and Germany.

This time, the scope of the coaching program was opened to non-rooftop greenhouse projects, such as greenhouses on facades or on the ground, as long as they are connected to a building to exploit synergies. The 10 selected Building Integrated Greenhouse projects utilize various techniques (hydroponic, aquaponics, soil-based vegetable gardens, etc.) and serve different purposes (educational, social, private, etc.).

GUIDELINES

The guidelines provide a summary of GROOF's experience in designing and building energy-efficient rooftop greenhouses (RTGs). They include feedback from existing projects and advice for each stage of project development. The purpose of the guidelines is to help RTG project owners integrate energy, construction, and production synergies with the host building in their business model to strengthen its robustness while reducing CO^2 emissions.

Existing buildings that do not meet current thermal regulations can lose up to 30% of stored heat on average through their roofs in winter. Additionally, heat and CO^2 can be collected through ventilation systems. The amount depends on the building's usage and the technical specifications of installed systems. Each building is unique (in size, use, location, materials, energy equipment configuration, bearing capacity, etc.), so each situation requires customized treatment.

However, these specificities do not necessarily require the use of expensive technical innovations to connect the greenhouse to the building. Any greenhouse manufacturer should be able to build and implement RTGs aimed at reducing CO^2 emissions.

GUIDELINES

The innovation lies in the combined work of the construction and agriculture sectors in the design and construction stages to connect the greenhouse to the building in an efficient and cost-effective manner, as well as in terms of its management and operation. A successful collaboration will result in a project that consumes less energy than the two structures managed separately.

These guidelines are designed to meet the needs of four major stakeholders who will use them in practice: building owners, financial partners, farmers, and project partners.

- **Are you motivated by the idea of growing vegetables and plants and distributing them locally?**
- **Are you an expert in one of the skills required by the project but maybe not in all of them?**
- **Are you wondering how to start such a project, the steps to take, the priorities, and how to streamline the process?**

Our team of experts conducted several observations (visits to existing RTGs, meetings with project stakeholders, etc.) and tested four pilot projects exclusively owned by GROOF. They also provided coaching to 20 other early adopter projects. Based on this experience and collected data, we organized this document according to the success factors identified for RTG projects with a reduced carbon impact.

To learn more about our guidelines, please visit our website!

INTERIM RESULTS

The potential synergies between buildings and integrated rooftop greenhouses have been described in previous reports and articles. This article presents an overview of the interim results of greenhouse gas emissions (GHG) from the GROOF pilots. To achieve this, research institutes HS Trier/IfaS and CSTB developed a method and reference scenarios to compare the GROOF pilots with commercial greenhouse vegetable production.

The main challenge in this research field is the size and diversity of the horticulture sector with respect to production systems and greenhouse types. For this reason, four reference scenarios were developed, which are described in previous reports.

The GROOF pilots have individual greenhouse construction and production systems, which requires the use of reference scenarios for comparison to obtain average values for greenhouse design, crop production, and organic waste. Each pilot was assigned its own reference scenario based on several studies analysed.

The basis of GHG abatement from the pilots is their individual monitoring system, which was developed in collaboration with HS Trier/IfaS and the pilots. However, challenges in implementing the monitoring tools arose, resulting in data gaps and implausible data for this monitoring period. To close these gaps, the energy team developed a modelling method and analysed beneficial data with continuous exchanges with the pilots.

The article presents interim results of the potential GHG emission savings, and the final results will soon be available as monitoring of the pilots is ongoing.

EBF PILOT

The EBF Chinese lean-to greenhouse is designed for energy efficiency, using hempcrete and a wooden structure on the east, north, and west walls, and ETFE film as a double layer on the south side. The greenhouse is used as a solar collector for GHG emissions savings.

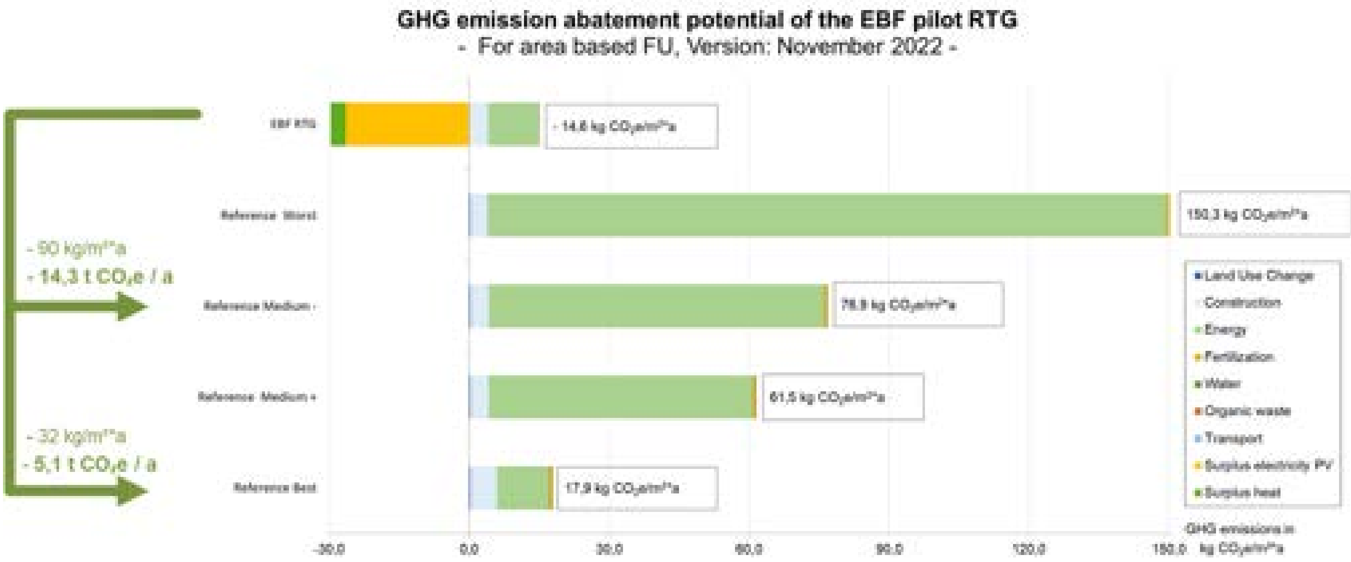
Additionally, the EBF greenhouse uses synergies between crop and energy production, such as integrated PV panels that generate electricity and provide shading to the plants. The excess heat energy produced by the greenhouse can also be utilized in the support building.

Finally, the surrounding roof surfaces of the building are utilized for electricity production, as well. This design enables the greenhouse and the building to produce food and generate energy in a synergistic manner.

EBF PILOT

In terms of energy production, the greenhouse produces more energy than it needs, with an average consumption of around 6,400 kWh/annum for heat and 200 kWh/annum for electricity during the last monitoring period. The PV systems generated around 7,100 kWh/annum of electricity, and the greenhouse provided 1,800 kWh/annum of heat to the support building. Due to this energy production and the use of renewable construction materials, the EBF greenhouse can reduce GHG emissions by around 14.3 tCO^2e/y compared to the Reference Medium Minus scenario, or around 91 $kgCO^2e/m^2y$. In comparison with the Reference Best Scenarios, a reduction of around 5.1 tCO^2e/y and 31 $kgCO^2/m^2y$ could be achieved.

The comparison with the reference scenarios is shown in the following illustration.



$tCO_2e/a = tCO_2$ / year

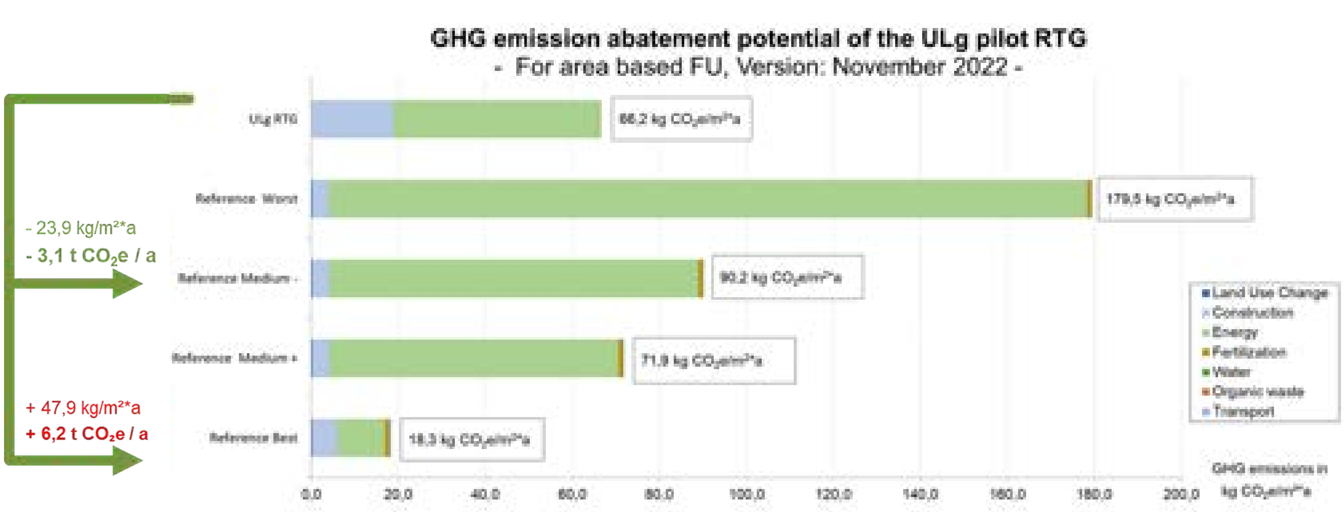
ULG PILOT

The ULG RTG will be constructed on top of the technical unit's terrace between two other buildings, which have ventilated facades that can be negatively affected by the greenhouse's climate conditions. To overcome this constraint, the greenhouse will have a separate wall with sandwich panels and a "floating foundation" on the existing flat roof insulation. A lean-to structure was chosen due to its lighter weight and 13% lower energy demand than other possible greenhouse types. Sandwich panels with a lower U-value (0.35 to 0.55 W/m^{2}K) will be used up to a height of 0.9 m on the western, southern, and eastern sides of the greenhouse, while heat-protecting glass (U-value 1.1 W/m^{2}K, 70% light transmission rate) will be used for the transparent envelope material. To achieve higher energy efficiency, the installation of one thermal screen is also integrated.

However, the standalone greenhouse construction poses challenges in terms of physical connection to the building and has effects on the construction materials.

ULG PILOT

This impact is demonstrated by the GHG emissions for construction. Furthermore, the high energy efficiency standard of the greenhouse construction/design (e.g.: heat protecting glasses etc.) leads to higher GHG emissions in construction material compared to the Reference scenarios. According to this greenhouse design, a reduction of the GHG emissions of around -3,1 tCO^2e/y compared to Reference Medium Minus scenario has been calculated. Based on the area, a reduction of around -23,9$kgCO^2e/m^2y$ has been calculated. In comparison with the Reference Best scenarios, the ULG greenhouse has around 6,2tCO^2e/y and 47,9$kgCO^2/m^2y$ higher GHG emissions. The following illustration shows the comparison with the reference scenarios.



tCO2e/a = tCO2 / year

Further opportunities to reduce GHG emissions through energy usage are available and have been described in previous reports. Depending on the feasibility and the heat management of the rooftop greenhouse (RTG), a reduction in GHG emissions from heat energy could be possible. In addition, integrating a PV system into the greenhouse is another option to reduce GHG emissions. These options will be analysed in the future.

IFSB PILOT

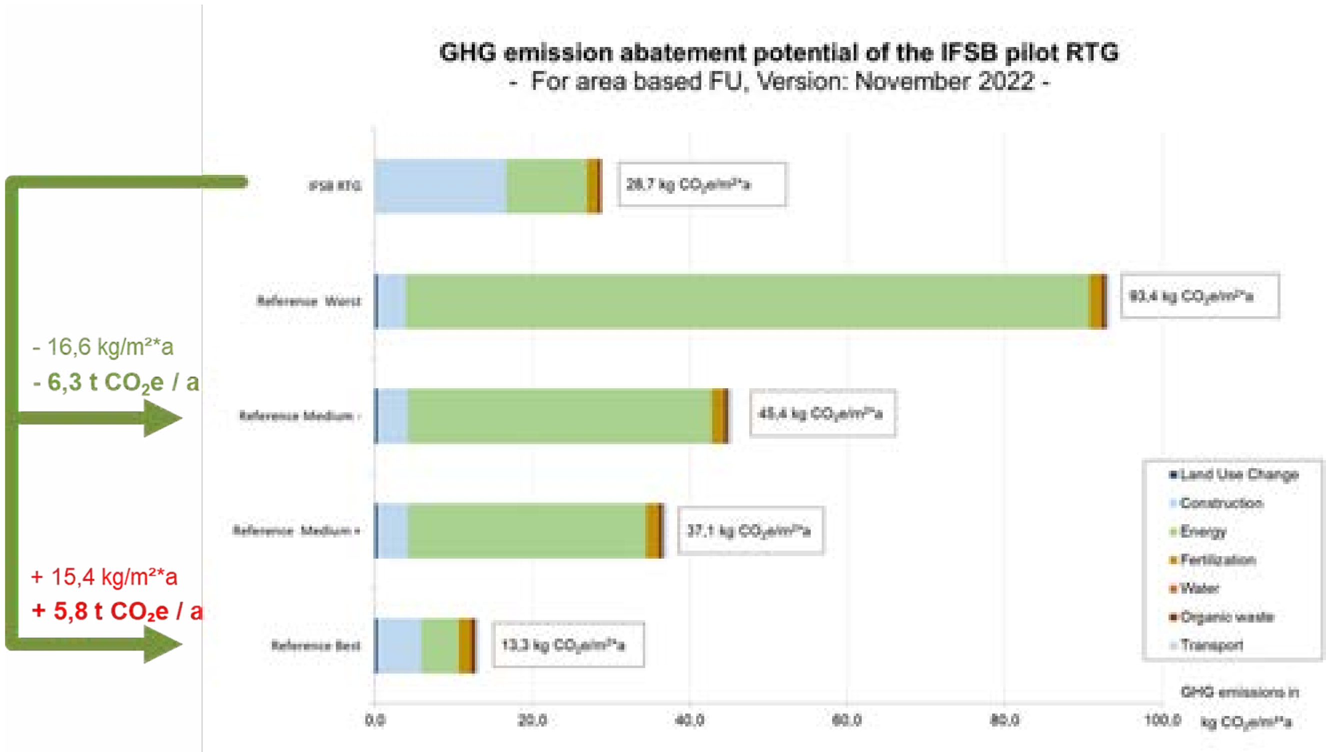
The IFSB rooftop greenhouse is constructed as an extension of the canteen, located on the south side of the main building. This pilot has been designed as a highly energy-efficient greenhouse using heat-protecting glass panels and a thermal screen.

The glazing consists of double glass with a heat coefficient of 1.1 Wm^2K and a light transmission of 80%. The greenhouse also uses symbiosis between the building and the RTG, making use of the fertiliser potential inside the waste air streams of the ventilation system. The CO^2 rich exhaust air from the ventilation system, which can contain up to 700 ppm of CO^2 during the day, is used as a fertiliser for the plants.

Furthermore, the north wall of the greenhouse is integrated into the building, and the canteen located below the RTG helps to heat up the greenhouse as well. The renewable energy system comprising a pellet boiler and solar thermal system for the building and the greenhouse has a positive impact in terms of GHG emission reduction.

IFSB PILOT

The IFSB pilot has a high energy efficiency standard with heat-protecting glass panels, but the construction material leads to higher GHG emissions compared to reference scenarios. The use of renewable energy sources for heat production leads to significant GHG emission savings compared to reference scenarios. The monitoring period and modelling method show a reduction of approximately -6.3 tCO^2e/y compared to the reference medium minus scenario. A reduction of around -16.6 $kgCO^2e/m^2y$ has been calculated based on the area. However, compared to the reference best scenarios, the IFSB greenhouse has approximately 5.8 tCO^2e/y and 15.4 $kgCO^2/m^2y$ higher GHG emissions. The monitoring is ongoing, and final results will be available soon.



tCO2e/a = tCO2 / year

GALLY PILOT

Credit : Les Fermes de Gally

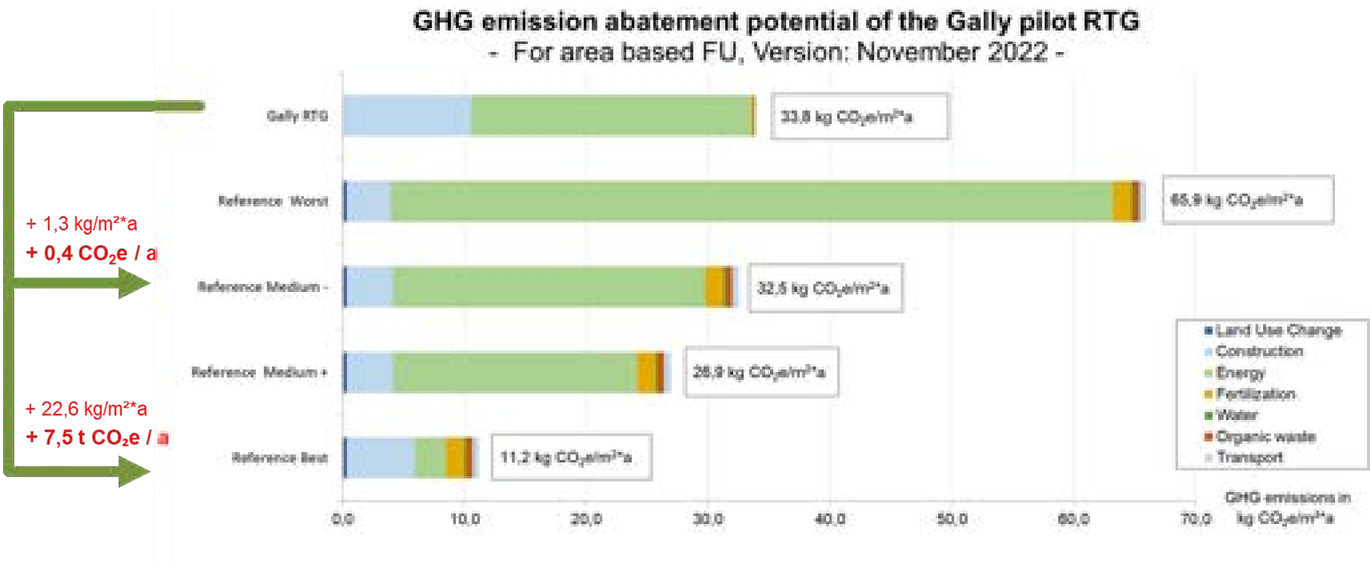
The Gally pilot is constructed on a redesigned building at St. Denis farm with an area of 380 m2. The building has a concrete first floor slab and a concrete wall on the northern side, resulting in lower heat energy consumption in the greenhouse and the building during the heating period, as the wall is used as thermal mass. This design leads to a 2°C temperature increase inside the greenhouse during the winter. Additionally, the given structure and cubature of the building is advantageous for the greenhouse as it results in an optimum ratio between the envelope and surface area of the greenhouse.

A summer production was chosen, leading to a low-temperature strategy between December to March, thereby reducing energy demand. No significant GHG emission savings can be achieved until October November, based on the reference scenarios used in the same operation time and production system. According to the monitoring period and energy demand modelling, a GHG emission reduction prospect cannot be achieved until the end of the project.

GALLY PILOT

Credit : Les Fermes de Gally

Final results will be available and published in the near future. According to this greenhouse design and the modelling method, no GHG emissions are present compared to Reference Medium Minus and the Reference Best scenario. The following illustration shows the comparison with the reference scenarios.



tCO2e/a = tCO2 / year

Credit : Les Fermes de Gally

POLICY RECOMMANDATION

Building Integrated Greenhouses offer the following benefits...

- Reducing the Urban Heat Island Effect
- Lowering energy and greenhouse gas emissions by decreasing the distance that food products are transported.
- Providing economic benefits within communities.
- Building energy optimization.
- Generating new business opportunities.

Building Integrated Greenhouses face the following barriers...

- Urban planning/architecture (visual/aesthetic impact, structural load limitations in buildings, building height limits).
- Economic (low income, lack of economic benefits, high costs of infrastructure, restrictions on food sales grown in residential areas).
- Social acceptance (not considered true agriculture, residents opposed to agricultural roofs on their buildings).
- Policies and regulations (lack of specific law framework, administrative processes, land-use zoning laws).
- Education (hydroponics, aquaponics, experienced farmers, lack of promotion).
- Health risks.
- Rooftop accessibility difficulties.
- Cost of water.

THANK YOU

Do not hesitate to visit GROOF website : www.groof.eu

Discover GROOF Guidelines : https://www.urbanfarming-greenhouse.eu/
This is a summary of GROOF's experience in designing and building an energy efficient rooftop greenhouse.