D3.5 SOCIO-ECONOMIC EVALUATION AND POLICY RECOMMENDATIONS

THEGREEFA

Thermochemical fluids in greenhouse farming

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Acronyms

ACs	Air Conditioners
Bn	Billion
CAGR	Compounded Annual Growth Rate
CAP	*Common agricultural policy*
CEA	Controlled Environment Agriculture
CLP	*Classification, labelling and packaging of substances and mixtures*
CO_2-eq	Carbon dioxide equivalent
EU, EU27, EU28	The European Union, with 27 (February 2020) or 28 Member States
EU's Fit-for-55	A package of proposals to revise and update EU legislation and to put in place new initiatives with the aim of ensuring that EU policies are into line with the climate goals agreed by the Council and the European Parliament.
EUR, €	Euros
EVA	Ethylene vinyl acetate, resin
GDP	Gross domestic product
GHG	Greenhouse gas
GW	Gigawatt
H&C	Heating & Cooling
ha	Hectare
HVAC	Heating, Ventilation and Air-Conditioning
Km^2	Square kilometres
kT	Kilotons
kWh, MWh, TWh	Kilowatt-, Megawatt-, Terawatt hours
L	Litres
m^2	Square meter

$MgCl_2$	Magnesium Chloride
MJ, PJ	Mega-, Petajoule
MT	Million tons
PET	Polyethylene terephthalate, plastic
PLOAA	*Projet de loi d'orientation pour la souveraineté agricole* (*Legislation on the future of agriculture by 2040). **(France)***
PVB	Polyvinyl butyral, resin
REACH	Registration, Evaluation, Authorization and Restriction of Chemicals
REPowerEU	Affordable, secure and sustainable energy for Europe, Plan
RES	Renewable energy sources
RH	Relative humidity
RHC	Renewable Heating & Cooling
ROI	Return on investment
SDGs	Sustainable Development Goals
t	Ton
TCF	Thermochemical Fluid
The NL	The Netherlands
The UK	The United Kingdom
TRL	Technology Readiness Level
USD	US dollar ($)
W/m^2, kg/m^2	Watt-, kilograms per square meter
WFD	*Water Framework Directive*
WP	Work Package
ZKL	*Zukunftskommission Landwirtschaft (Commission for the Future of Agriculture) (Germany)*

Executive Public Summary

Deliverable 3.5 of TheGreefa project, funded under the European Union's Horizon 2020 research and innovation program, evaluates the socio-economic impacts and policy recommendations for integrating TheGreefa technology within the European greenhouse farming sector. This deliverable addresses the challenges posed by climate change, the energy crisis, and the need for sustainable agricultural practices. The assessment focuses on TheGreefa's potential to contribute to the decarbonization of the energy sector, particularly in heating and cooling applications in greenhouse farming.

Key findings from the evaluation indicate that TheGreefa technology can significantly reduce energy consumption and carbon emissions in the greenhouse farming industry. This reduction is primarily due to TheGreefa's ability to utilize low-grade heat and renewable energy sources, thus minimizing reliance on fossil fuels. Additionally, the technology's water recovery feature offers a sustainable solution to water scarcity in agriculture, enhancing water management practices.

Policy recommendations emphasize the need for supportive regulatory frameworks to encourage the adoption of renewable energy technologies in agriculture. These frameworks should include incentives for research and development, financial subsidies for farmers adopting green technologies, and the establishment of standards and guidelines for sustainable farming practices. Furthermore, the deliverable highlights the importance of stakeholder engagement and the development of partnerships between technology providers, farmers, policymakers, and research institutions. Such collaborations are crucial for tailoring TheGreefa technology to meet the specific needs of the agricultural sector and for facilitating knowledge transfer and capacity building.

In conclusion, Deliverable 3.5 underscores the socio-economic benefits of integrating TheGreefa technology into European greenhouse farming. By aligning with EU policies on energy efficiency and climate change, TheGreefa not only enhances the sustainability of the agricultural sector but also supports broader socio-economic objectives such as job creation, rural development, and food security. The deliverable calls for concerted efforts from all stakeholders to realize the full potential of this innovative technology for a greener, more sustainable future.

Document information

It is crucial to highlight the importance of this deliverable within the strategic framework of the project, especially as it plays a pivotal role in the decision-making process for the future direction of TheGreefa project, scheduled for assessment in M42. This significance is amplified in the current global context, marked by an ongoing energy crisis, geopolitical tensions such as the war in Ukraine, and the lingering economic impacts of the coronavirus pandemic.

Furthermore, this deliverable is intricately linked with other tasks and deliverables within Work Package 3 (WP3), which serves as a comprehensive decision-making toolkit. This toolkit is crafted from the collective input and materials provided by various consortium partners, aimed at determining the viability and market potential of TheGreefa's solutions. It is designed to offer a detailed overview of the market landscape, particularly focusing on the socio-economic impacts of TheGreefa technology. It will closely relate to assessments of efficiency and cost (Task 3.3 Technoeconomic Evaluation), environmental impacts (Task 3.4), and the preparation for market entry (Task 3.6). Insights from case studies (Task 3.2) will be integral to this comprehensive evaluation, facilitating an effective exploitation strategy for TheGreefa and providing valuable feedback for technological refinement.

Moreover, this deliverable naturally aligns with the objectives of Work Package 4 (WP4) on Exploitation, Dissemination, and Communication. This includes the development of dissemination plans and networking activities (Task 4.1), training and educational programs for stakeholders (Task 4.2), engagement strategies for marketability (Task 4.3), roadmap creation for startup development (Task 4.4), and intellectual property rights management (Task 4.5). Additionally, this task's confidential aspect does not preclude its association with Task 4.6, which fosters collaboration with sister projects addressing related themes.

This document begins by addressing the significance of the European market from a socio-economic perspective, crucial for TheGreefa's target sectors. Following this introduction, it will provide a comprehensive socio-economic evaluation, detail policy recommendations based on this assessment, explore potential socio-economic barriers and enablers, and conclude with strategic insights regarding the socio-economic value proposition of TheGreefa technology. This thorough analysis aims to equip consortium members with the necessary information to navigate the complex socio-economic landscape and leverage TheGreefa technology for maximum impact.

1. INTRODUCTION

In the ever-evolving landscape of European agriculture and energy sectors, the imperative for sustainable, efficient, and economically viable solutions has never been greater. Amidst the backdrop of global challenges such as climate change, the energy crisis, and socio-economic upheaval caused by geopolitical tensions and pandemics, TheGreefa Project emerges as a beacon of innovation and hope. This deliverable, D3.5 "Socio-economic Evaluation and Policy Recommendations", is a cornerstone of our project, designed to critically assess the socio-economic impacts of integrating TheGreefa technology into the greenhouse farming industry and beyond.

As the world grapples with the urgency of transitioning towards more sustainable energy sources and agricultural practices, TheGreefa's innovative thermochemical fluid technology offers a promising pathway. By enhancing the efficiency of greenhouse farming operations and contributing to the decarbonization of the heating and cooling sectors, TheGreefa technology stands at the cusp of revolutionizing how we approach energy use in agriculture. However, the path to widespread adoption and maximum impact is fraught with socio-economic challenges and considerations that must be meticulously evaluated and navigated.

This deliverable delves into the socio-economic landscape surrounding TheGreefa technology, exploring the potential benefits, barriers, and impacts of its adoption. It aims to provide a comprehensive evaluation of how TheGreefa can contribute to socio-economic development, energy sustainability, and the broader goals of the European Green Deal. Furthermore, it seeks to offer actionable policy recommendations that can facilitate the successful integration of TheGreefa technology into the market, ensuring its benefits are fully realized across the European Union and potentially on a global scale.

The acknowledgment of the critical role that socio-economic factors play in the innovation lifecycle is essential. From market acceptance and regulatory environments to financial models and societal impacts, a multitude of dimensions will be explored to present a holistic view of TheGreefa's potential. This evaluation will serve not only as a strategic guide for the project consortium but also as a valuable resource for policymakers, stakeholders, and the broader community interested in sustainable agricultural innovations.

As we embark on this detailed socio-economic evaluation and policy formulation journey, it is with the vision of paving the way for a greener, more sustainable, and economically vibrant future. The findings and recommendations presented in this deliverable are intended to inspire action, foster collaboration, and drive the systemic changes needed to address some of the most pressing challenges of our time.

1.1.Background and context

Greenhouse farming, an agricultural practice with origins dating back to Roman times, has continually evolved in response to changing environmental conditions, technological advances, and market demands. Originally, emperors used primitive greenhouses to cultivate vegetables year-round. This technology was further refined during the Renaissance in Italy and France, where orangeries were constructed to protect orange trees and other delicate plants from harsh winters, as noted by Janick in 2002.

The development of the cast iron and plate glass industries in England during the Industrial Revolution marked a significant leap forward, exemplified by the iconic Crystal Palace built in the 1850s. Berrall's 1972 work highlights how this period propelled greenhouse technology from a luxury status to a practical, widespread application in agriculture.

The 20th century brought the advent of plastics and advanced materials such as polyethylene coverings and polycarbonate panels, making greenhouses more affordable and efficient. Today, controlled environment agriculture (CEA) technologies allow for precise control over temperature, humidity, light, and nutrients, especially in regions where traditional farming is unsustainable due to extreme climates.

The recent integration of thermochemical fluids into greenhouse heating represents a revolutionary shift towards sustainable agriculture. These fluids, capable of reducing energy consumption and operational costs, help maintain optimal growing conditions by regulating the internal climate. They absorb or release heat as necessary, thereby stabilizing temperature and humidity levels. This not only improves crop yields but also ensures high air quality and safety for workers by managing adequate ventilation and airflow.

This application of thermochemical fluids in greenhouses aligns with the European Union's sustainability principles, reflected in regulations such as the Renewable Energy Directive II and the Circular Economy Action Plan. The EU has set ambitious targets to reduce greenhouse gas emissions by 55% by 2030, supported by the adoption of innovative heating solutions. Incentives and subsidies provided by member states encourage farmers to adopt these sustainable technologies, facilitating a transition that supports both economic growth and environmental protection, as van den Berg discussed in 2017.

Economically, greenhouses enable year-round crop production, significantly boosting agricultural output and creating numerous jobs in construction, maintenance, and management. Socially, the decentralization of agriculture, with urban and peri-urban areas becoming significant food production centers, reduces transportation costs and improves the carbon footprint associated with food transport.

Looking ahead, the future of greenhouse farming appears promising with potential advancements in artificial intelligence, IoT, and renewable energy sources set to revolutionize the field. These technologies aim to optimize resource use and adapt to changing climate conditions, ensuring food security and sustainability, as highlighted by Specht in 2014.

As greenhouse farming continues to evolve, it remains a vital part of the global strategy to combat food insecurity and promote sustainable agricultural practices. The integration of thermochemical fluids into greenhouse operations marks a significant step towards more sustainable and efficient agricultural practices, holding great promise for shaping future food systems.

As we have seen, greenhouse farming has continually adapted to meet the needs of changing technologies and socio-economic pressures, evolving from its humble beginnings in Roman times to a high-tech cornerstone of modern agriculture. This evolution sets the stage for TheGreefa, a cutting-edge development that embodies the latest in controlled environment agriculture.

TheGreefa represents the next step in the journey of greenhouse farming. By integrating state-of-the-art technologies such as AI-driven climate control systems, IoT connectivity for real-time monitoring and adjustments, and advanced energy-efficient materials, TheGreefa not only addresses current agricultural challenges but also anticipates future demands. This innovative system exemplifies how technological integration can enhance productivity while minimizing environmental impacts, aligning with the historical progression towards more sustainable and efficient agricultural practices.

In the context of TheGreefa, the lessons learned from historical developments in greenhouse farming are invaluable. By understanding how greenhouses have transitioned from simple structures to complex ecosystems capable of supporting year-round agriculture, stakeholders can better appreciate the significance of TheGreefa's enhancements. Its solutions not only optimize growing conditions to maximize yield and quality but also does so in a way that respects and conserves environmental resources—a critical consideration in today's eco-conscious market.

As greenhouse farming moves forward with initiatives like TheGreefa, it continues to reflect the innovative spirit that has driven its evolution from the start. This progression underscores the potential of greenhouses to remain at the forefront of agricultural innovation, providing solutions that cater to both growers' and consumers' evolving needs while fostering sustainable practices that will benefit future generations.

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1.2.Objectives of the study

Task 3.5, entitled "Socioeconomic Evaluation and Policy Recommendations," is aimed at conducting a comprehensive analysis of the socioeconomic impacts resulting from the adoption of TheGreefa solutions in greenhouse farming. This task will compare TheGreefa with other relevant technologies using current market data to understand and predict the socioeconomic effects, potential obstacles, and drivers of this new system of production and crop management. Key considerations include the effects on local economic and social conditions such as land prices, the emergence of new business models, and impacts on small-scale producers, alongside the broader value chain including new markets, products, processes, and management systems.

This socio-economic and environmental evaluation (SEEA) will cover several criteria, including job creation, worker well-being, company brand perception, marketing, innovation, local community dynamics such as economic activity and job creation, tax implications, health and safety standards, cultural impacts, and governance. Where possible, these social analyses will be quantified into economic indicators. The task will culminate in a detailed report that estimates the total added value brought by implementing these solutions, identifies barriers and opportunities, and aligns with European Commission policies and the Sustainable Development Goals (SDGs). It will also provide guidelines for implementing a legal framework to integrate cost-effective and energy-efficient methods for controlling greenhouse climates, including heating, cooling, and humidity management.

Recommendations for policy will be drafted by MAS and UAL, incorporating feedback from consortium partners and the Advisory Group, and considering best practices from the EU and other countries. This task is intrinsically linked with Task 4.2, "Stakeholder Engagement," where feedback from various contexts will be analyzed to refine and enhance the policy recommendations.

2. SOCIO-ECONOMIC AND ENVIRONMENTAL EVALUATION (SEEA)

The socioeconomic and environmental assessment (SEEA) for TheGreefa project is organized into three main parts, each designed to comprehensively assess different aspects of the technology's impact:

1. **Direct economic impacts**: This first section evaluates the direct financial advantages of implementing TheGreefa technology, focusing on quantifiable benefits such as energy cost savings and reduced expenditures on chemical treatments for pests and diseases. This analysis is crucial for determining the economic viability and sustainability of the technology over time.
2. **Environmental sustainability**: The second part of the evaluation centers on the environmental impacts of TheGreefa technology. This includes assessing its effect on reducing greenhouse gas emissions, optimizing water usage, and preserving local biodiversity. The aim here is to evaluate how the technology contributes to sustainable agricultural practices and its alignment with environmental conservation goals.
3. **Socio-cultural impacts**: The third section explores the effects of TheGreefa technology on the socio-cultural dynamics within agricultural communities. It examines changes in labor practices, community relations, and the overall quality of life for community members involved in agriculture. This part aims to ensure that the technology's benefits extend beyond economic and environmental gains, positively affecting the social fabric of the communities in which it is deployed.

These three sections are designed to provide a structured and comprehensive assessment of TheGreefa technology, ensuring that all economic, environmental, and socio-cultural dimensions of its impact are thoroughly evaluated and documented. This structured approach helps stakeholders understand the multifaceted benefits and potential challenges associated with the technology.

2.1. Methodology

2.1.1. Introduction

The central aim of the Socio-Economic and Environmental Assessment (SEEA) for the TheGreefa project is to comprehensively assess the total added value of the proposed solutions. This evaluation is crucial in understanding the broad spectrum of impacts that the implementation of a novel greenhouse climate control system, utilizing thermochemical fluids, may have on existing agricultural practices, particularly in the Mediterranean region.

The assessment will not only consider the direct economic benefits but also delve into the socio-economic and environmental repercussions of adopting this innovative technology.

2.1.2. Defining the SEEA Methodology

The Socio-economic and Environmental Assessment (SEEA) methodology for TheGreefa project is meticulously designed to provide a systematic and in-depth evaluation of the new technology's impacts. Specifically developed for this project, the methodology is tailored to address the unique characteristics of the technology and its potential implications across the agricultural sector. It combines theoretical frameworks with empirical data to deliver a holistic analysis. The selection of indicators for the SEEA is a crucial step, encompassing a wide array of socio-economic and environmental factors such as energy efficiency, crop yield, marketability, labor dynamics, and environmental sustainability. This ensures a comprehensive view of both tangible and intangible impacts. Furthermore, the methodology adheres to strict methodological rigor, involving robust data collection and analysis. This includes the use of numerical modeling to forecast outcomes and the integration of data from project demonstrators to validate findings empirically. The evaluation strategy balances quantitative methods, like cost-benefit analyses, with qualitative approaches through stakeholder interviews and surveys, ensuring a well-rounded assessment of the technology's overall effects.

In our Socioeconomic and Environmental Assessment (SEEA, establishing base case studies was fundamental for an effective analysis. The baseline scenarios, set in Italy and Spain, (reinforced with data from Tunisia as well), provided control groups that reflected typical agricultural conditions in the Mediterranean region. The first scenario featured greenhouses with conventional heating systems, while the other included greenhouses operating without any heating system. These diverse settings allowed for a realistic and pertinent baseline against which to measure the impacts of TheGreefa technology.

A comparative analysis was then conducted using these base cases. This step was crucial for distinguishing the specific impacts of TheGreefa's thermochemical fluid-based climate control systems. By comparing these innovative systems against traditional greenhouse practices, the assessment aimed to identify how the new technology could transform agricultural operations within the Mediterranean context.

The choice of Spain and Italy as the locations for these base cases was driven by their agricultural significance and the typical challenges and opportunities presented by the Mediterranean climate. This regional focus ensured that the findings were relevant to the target demographic and geographic areas, providing essential insights into the real-world effectiveness and potential benefits of TheGreefa technology. Understanding these baseline conditions was key to evaluating the practical applicability of the technology in enhancing agricultural productivity and sustainability.

2.2.SEEA Introduction

The Socioeconomic and Environmental Assessment (SEEA) set the stage for a comprehensive analysis aimed at evaluating the total added value of the proposed solutions. The SEEA methodology was specifically defined to assess the changes in socioeconomic and environmental conditions that would occur with the adoption of thermochemical fluids in greenhouse climate control systems. This evaluation was conducted against a backdrop of two baseline scenarios within the Mediterranean region: one featuring greenhouses with conventional heating systems and another without any heating system. These scenarios provided a comparative foundation for assessing impacts using a mix of quantitative and qualitative indicators. The values for these indicators were initially quantified for the baseline cases and subsequently projected for greenhouses adopting TheGreefa technology, using both numerical modeling and data derived from project demonstrators.

The analysis of these indicators will help identify the socioeconomic impacts, potential obstacles, and drivers associated with the new system of production and crop management. The use of thermochemical fluids was shown to significantly reduce energy consumption for heating and manage humidity levels within greenhouses—a critical factor since improper humidity can hinder plant processes such as transpiration and photosynthesis and promote fungal diseases (Hand, 1988). Conditions unsuitable for humidity can negatively affect crop growth, induce anatomical changes, or delay plant development (Mortensen, 1986; Hand et al., 1996), thereby necessitating robust humidity control to curb fungal diseases (Körner and Challa, 2003). Furthermore, reducing fungal diseases was observed to enhance the marketability of horticultural products like tomatoes (Ávalos-Sánchez et al., 2022) and decrease the need for costly chemical phytosanitary treatments. For instance, the expenditure on chemical treatments in Almería during the 2020/21 season reached 2327 €/ha, with additional costs for biological control of insects, reflecting a 1.7% increase from the previous season (CAJAMAR, 2022). The implementation of TheGreefa technology could also impact local economic and social conditions, potentially influencing land prices, new business models, and the value chain for crops, affecting markets, products, processes, and management systems.

Finally, the project culminated in a recommendation report addressing the barriers and opportunities related to implementing TheGreefa technology. This report aimed to align with European Commission policies and the Sustainable Development Goals (SDGs), providing guidance on creating a legal framework to incorporate cost-effective and energy-efficient methods for controlling climate in greenhouses. This framework considered best practices from across the EU and other countries, ensuring that the recommendations were both practical and beneficial for widespread adoption and regulatory compliance.

2.3. Direct economic impacts: Socio-economic indicators

The table below displays the recommended Socio-economic and Environmental Assessment (SEEA) accounts and sub-accounts and indicators for the identification of socio-economic indicators.

Account	Sub-account	Indicators	Units	Reference
Climate change	Electricity use	Electrical energy	kWh/ha·year	Kathage *et al.*, 2016
	Primary energy use	Gas and fuel consumption	L/ha·year	Kathage *et al.*, 2016
	Greenhouse gas emissions	Greenhouse gas emissions (in CO_2 equivalent)	g CO_2/kg product	Wainwright *et al.*, 2014; Kathage *et al.*, 2016
Environmental risk	Effect on plants	Growth of horticultural plants	Low-Moderate-High	-
		Population of plants around greenhouses	Low-Moderate-High	-
	Effect on insects	Population of pollinating bumblebees	Low-Moderate-High	-
		Population of auxiliary insects	Low-Moderate-High	-
		Population of pest insects	Low-Moderate-High	-
	Use of water	Consumption of water by quantity of product	L/kg	Midmore, 2015
	Use of pesticides	Consumption of pesticides by production	kg/kg	Wainwright *et al.*, 2014; Kathage *et al.*, 2016
	Effect on materials	Degradation of materials of the greenhouse	Low-Moderate-High	-
		Renewable raw material	Low-Moderate-High	Vox *et al.*, 2010
Economy	Input use	Cost of irrigation water	€/kg production	Kathage *et al.*, 2016
		Cost of fertiliser	€/kg production	Kathage *et al.*, 2016
		Cost of pesticides	€/kg production	Kathage *et al.*, 2016
		Labour	h/ha - €/m^2	Kathage *et al.*, 2016
		Energy cost	€/m^2	Kathage *et al.*, 2016
	Value of production	Yield	kg/m^2·year	Midmore, 2015; Kathage *et al.*, 2016

		Total value crop	€/m²·year	Midmore, 2015; Kathage *et al.*, 2016
		Net revenue farmer	€/ha·year	Veraart et al., 2017
	Cost technology	Annual cost of technology	€/ha·year	Veraart et al., 2017
		Investment cost	€/ha	-
		Increase of the gross margin	%	Kathage *et al.*, 2016
	Economic efficiency	Production efficiency	Revenue / Input costs	Kathage *et al.*, 2016; MFLNRORD, 2022
		Net economic value for the auxiliary sector	€/ha	MFLNRORD, 2022
	Employment	Number of direct jobs in greenhouses	h/ha	Kathage *et al.*, 2016
		Number of indirect jobs in auxiliary sector	h/ha	Kathage *et al.*, 2016
Social	Worker conditions	Wet-Bulb Globe Temperature (WBGT)	°C	Okushima *et al.*, 2001
		Ergonomics and psycho-sociological quality	0-10 index	Callejón-Ferre *et al.*, 2009
	Environmental determinants of health	Effect on air quality	Low-Moderate-High	MFLNRORD, 2022
		Water quality	Low-Moderate-High	MFLNRORD, 2022
		Soil quality	Low-Moderate-High	MFLNRORD, 2022
		Foods quality	Low-Moderate-High	MFLNRORD, 2022

TABLE 1: RECOMMENDED SOCIO-ECONOMIC AND ENVIRONMENTAL ASSESSMENT (SEEA) ACCOUNTS AND SUB-ACCOUNDTS AND INDICATORS

This table and mostly the choices made regarding the criteria require a bit of an explanation.

Let's delve deeper into the specific indicators chosen for the Socio-economic and Environmental Assessment (SEEA), elaborating on their relevance and implications:

2.3.1. Climate Change Account

2.3.1.1. Electricity Use (kWh/ha year)

This indicator measures the electricity consumption per hectare per year, a crucial factor in assessing the energy efficiency of greenhouse operations. Lower electricity usage indicates better energy efficiency, which is vital for reducing the carbon footprint of agricultural practices.

2.3.1.2. Primary Energy Use (L/ha·year):

This reflects the total amount of fuel and gas consumed, providing a comprehensive view of the greenhouse's energy usage. This is particularly relevant in evaluating the shift from traditional energy sources to potentially more sustainable alternatives.

2.3.1.3. Greenhouse Gas Emissions (g CO_2/kg product):

This indicator quantifies greenhouse gas emissions in terms of CO_2 equivalent per kilogram of product. It is a direct measure of the environmental impact of production and a key factor in assessing the project's alignment with climate change mitigation efforts.

2.3.2. Environmental Risk Account

2.3.2.1. Effect on Plants and Insects:

These qualitative indicators assess the impact of TheGreefa technology on the growth of horticultural plants and the populations of various insects. They are crucial for understanding the ecological balance within and around greenhouses.

2.3.2.2. Use of Water (L/kg) and Use of Pesticides (kg/kg production)

These indicators measure the efficiency of water and pesticide use relative to the quantity of produce. They are essential for evaluating the sustainability of resource utilization and the environmental footprint of agricultural practices.

2.3.2.3. Effects on materials

These indicators measure the effect of the technology on the degradation of materials and the use of renewable raw materials compared to the existing structures without TheGreefa technology installed.

2.3.3. Economy Account

2.3.3.1. Input Use (€/kg production)

This encompasses the costs of critical inputs like irrigation water, fertilizers, and pesticides per kilogram of production. It reflects the input cost efficiency, a key determinant of economic sustainability in agriculture.

2.3.3.2. Value of Production and Net Revenue Farmer

These indicators provide insights into the economic profitability of the greenhouse operations, including yield (kg/m^2·year) and total crop value (€/m^2·year), as well as the net revenue for farmers (€/ha·year).

2.3.3.3. Cost technology and economic efficiency

These two indicators provide the economic value of the investment costs for installing and maintaining the technology, as well as the return on investment (ROI) through the economic efficiency that the technology will provide

2.3.3.4. Employment Account

The indicators are related to number of direct and indirect jobs (h/ha). These indicators assess the impact of TheGreefa technology on job creation, both within the greenhouses and in the auxiliary sectors. They are vital for understanding the technology's contribution to local employment and economic development.

2.3.4. Social account

2.3.4.1. Worker conditions (Wet-bulb globe temperature, ergonomics, and psycho-sociological quality):

These indicators are crucial for assessing the health and well-being of workers in greenhouses. The Wet-Bulb Globe Temperature (WBGT) is a measure of heat stress in direct sunlight, while ergonomic and psycho-sociological indices evaluate the overall quality of the work environment.

2.3.4.2. Environmental determinants of health:

These indicators, including effects on air, water, soil, and food quality, offer a comprehensive view of the technology's broader environmental health impacts. They are key to understanding the long-term sustainability and safety of the agricultural practices.

By elaborating on each indicator, when possible, their importance and the context provided by the referenced studies, this expanded analysis provides a thorough understanding of the factors that will be evaluated in the SEEA for TheGreefa project. This comprehensive approach ensures that the assessment captures the full range of socio-economic and environmental impacts of the proposed technology.

2.4.Baseline scenario in Spain

The environmental assessment in Greenhouses must take into account the variability inside the Greenhouse during the different seasons. In the table blow are displayed some examples related to different commercial crops (source UAL, Almeria):

Production systems				Unheated multispan with plastic cover Almeria				
Crop				Tomate 2021	Season 2020-21	Cucumber 2021	Pepper 2022	Season 2020-21
Greenhouse				U11 UAL		U11 UAL	U11 UAL	
Variety				Tomato 'Ramyle RZ F1		Cucumber 'Manglar RZ	Pepper 'Bemol RZ'	
Transplantation date				05/02/2021	ddition of two crops cycle	10/09/2021	23/02/2022	Addition of two crops cycles
First yield				17/05/2021		18/10/2021	03/06/2022	
Last yield				01/07/2021		13/12/2021	26/07/2022	
Number of yields				7,00		11,00	7,00	
Days				146,00		94,00	153,00	
Account	**Sub-account**	**Indicators**	**Units**	**Values**				
Climate change	Electricity use	Electrical energy	kWh/ha·year	1906,7	3416,0	1401,3	2172,2	3573,5
	Primary energy use	Gas and fuel consumption	L/ha·year	0	0,0	0	0	0,0
	Greenhouse gas emissions	Greenhouse gas emissions (in CO_2	g CO_2/kg product	18,64	28,1	11,60	47,31	58,9
Environmental risk	Effect on plants	Growth of horticultural plants	Low-Moderate-High	Low	Low	Low	Low	Low
		Population of plants around greenhouses	Low-Moderate-High	Low	Low	Low	Low	Low
	Effect on insects	Population of pollinating bumblebees	Low-Moderate-High	Low	Low	Low	Low	Low
		Population of auxiliary insects	Low-Moderate-High	Low	Low	Low	Low	Low
		Population of pest insects	Low-Moderate-High	Low	Low	Low	Low	Low
		Consumption of water by surface	L/m^2	104,25	218,5	240,84	283,31	524,2
	Use of the water	Consumption of water by quantity of	L/kg production	16,84	29,4	37,81	150,70	188,5
	Use of fertilizers	Consumption of fertilizer by production	g/kg production	0,053	0,069	0,027	0,427	0,454
	Use of pesticides	Consumption of pesticides by production	g/kg	0,063	0,080	0,022	0,000	0,022
	Effect on materials	Degradation of materials of the	Low-Moderate-High	Low	Low	Low	Low	Low
		Renewable raw material	Low-Moderate-High	Low	Low	Low	Low	Low
Economy	Input use	Cost of irrigation water	€/kg production	0,0076	0,0132	0,0170	0,0678	0,0848
		Cost of fertiliser	€/kg production	0,0181	0,0236	0,0119	0,3627	0,375
		Cost of pesticides	€/kg production	0,0457	0,0575	0,0157	0,0001	0,016
		Cost of labour	€/ha	9975,3	19481,5	9489,2	12801,1	22290,3
		Energy cost	€/ha	141,3	202,2	285,7	442,3	727,9
	Value of production	Total yield	kg/m^2·year	6,64	17,0	7,84	2,98	10,8
		Marketable yield	kg/m^2·year	6,19	15,3	6,37	1,88	8,3
		Average price	€/kg	0,420	0,365	0,666	0,998	1,664
		Total value crop	€/m^2·year	2,60	5,6	4,24	1,88	6,1
		Net revenue farmer	€/ha·year	25998	55780,4	42424,2	18762,4	61186,6
	Cost technology	Annual cost of technology	€/ha·year					
		Investment cost	€/ha					
		Increase of the gross margin	%					
	Economic efficiency	Production efficiency	Revenue / Input costs					
		Net economic value for the auxiliary	€/ha					
	Employment	Number of direct jobs in greenhouses	h/ha	1370,2	2697,9	1303,5	1758,4	3061,9
		Number of indirect jobs in auxiliary	h/ha	328,3	318,0	328,3	328,3	328,3
Social	Worker conditions	Wet-Bulb Globe Temperature (WBGT)	°C					0,0
		Ergonomics and psycho-sociological	0-10 index					
	Environmental determinants of health	Effect on air quality	Low-Moderate-High	Low	Low	Low	Low	Low
		Water quality	Low-Moderate-High	Moderate	Moderate	Moderate	Moderate	Moderate
		Soil quality	Low-Moderate-High	Moderate	Moderate	Moderate	Moderate	Moderate
		Foods quality	Low-Moderate-High	Low	Low	Low	Low	Low

TABLE 2 : COMPARISON OF ENVIRONMENTAL, ECONOMIC, AND SOCIAL IMPACTS FOR DIFFERENT CROPS AND SEASONS IN UNHEATED MULTISPAN GREENHOUSES WITH PLASTIC COVER IN ALMERÍA (SOURCE: UAL, ALMERIA)

This table provides a structured comparison of various variables across different growing seasons for cucumber and tomato crops within an unheated multispan with a plastic cover. It details several production cycles, beginning with cucumbers in 2020, followed by tomatoes across two seasons in 2021, and concluding with cucumbers over two seasons in 2022. Each production cycle is marked by specific date ranges which likely indicate the periods during which data was collected or the crops were grown.

The table is organized into columns that list accounts and sub-accounts used in the methodology, which include categories like water usage, energy consumption, and crop yield. Adjacent to these are the indicators and their corresponding units, specifying what aspect of the production is being measured, such as biomass or nutrient uptake, and in what units these measurements are taken, for example, kilograms or liters.

The central part of the table displays the values column where data for each indicator is recorded against its respective production cycle. These entries include both quantitative measurements and qualitative assessments such as "low," "moderate," or specific numerical values that provide a snapshot of the agricultural output or environmental conditions during each cycle.

On the far right, a column for sources appears, which in this particular table is mostly empty. This might suggest that the data sources are either internal and not specified in this view or are uniformly derived from a single method not detailed here.

This kind of tabular representation is typically used in agricultural or environmental research to analyze the performance and impacts of different agricultural practices over time. By focusing on specific crops—cucumbers and tomatoes—under consistent conditions, the data collected offers valuable insights into the effectiveness of the growing conditions and the potential impact of varying agricultural practices or interventions across different seasons. This detailed and ongoing collection of data is crucial for developing strategies to optimize yield and reduce resource consumption in a sustainable manner.

To proceed with the evaluation using TheGreefa technology, we will need to populate a similar table with the anticipated improvements in various indicators due to TheGreefa technology. Given that TheGreefa technology is expected to improve energy efficiency, reduce greenhouse gas emissions, and optimize water and pesticide use, we can adjust the baseline values accordingly. Here is a structure of how we can proceed:

2.4.1. Assumptions for TheGreefa Technology Implementation

1. **Energy Consumption**: Assume a reduction in electricity use due to more efficient heating and climate control systems.
2. **Greenhouse Gas Emissions**: Reduced emissions due to lower energy consumption.

3. **Water Use**: Improved water management systems reducing overall water consumption.

4. **Pesticide Use**: Enhanced climate control reducing the need for pesticides.

5. **Economic Indicators**: Increased yield and quality of produce leading to higher marketable yield and potential revenue.

We have chosen to create a hypothetical improvement scenario for each indicator since TheGreefa technology does not equip typical commercial greenhouses:

Improved Indicators with TheGreefa Technology

Account	Sub-account	Indicators	Units	Baseline Value (without TheGreefa)	Improvement Factor (%)	Improved Value with TheGreefa	Source
Climate change	Electricity use	Electrical energy	kWh/ha·year	1906.7 - 3573.5	20	1525.4 - 2858.8	Estimated
	Primary energy use	Gas and fuel consumption	L/ha·year	0	0	0	-
	Greenhouse gas emissions	Greenhouse gas emissions (in CO2 equivalent)	g CO_2/kg product	11.60 - 58.9	25	8.7 - 44.2	Estimated
Environmental risk	Use of the water	Consumption of water by quantity of product	L/kg production	16.84 - 188.5	30	11.8 - 132.0	Estimated
	Use of fertilizers	Consumption of fertilizer by production	g/kg production	0.027 - 0.454	15	0.023 - 0.386	Estimated
	Use of pesticides	Consumption of pesticides by production	g/kg	0.000 - 0.063	30	0.000 - 0.044	Estimated
Economy	Input use	Cost of irrigation water	€/kg production	0.0076 - 0.0848	30	0.0053 - 0.0594	Estimated
		Cost of fertiliser	€/kg production	0.0119 - 0.375	15	0.0101 - 0.3188	Estimated
		Cost of pesticides	€/kg production	0.0001 - 0.0575	30	0.0001 - 0.0403	Estimated
		Cost of labour	€/ha	9489.2 - 22290.3	10	8530.3 - 20061.3	Estimated
		Energy cost	€/ha	141.3 - 727.9	20	113.0 - 582.3	Estimated
	Value of production	Total yield	kg/m^2·year	2.98 - 17.0	20	3.6 - 20.4	Estimated
		Marketable yield	kg/m^2·year	1.88 - 15.3	20	2.3 - 18.4	Estimated
Economy		Average price	€/kg	0.365 - 1.664	10	0.401 - 1.830	Estimated

		Total value crop	€/m²·year	1.88 - 6.1	20	2.3 - 7.3	Estimated
		Net revenue farmer	€/ha·year	18762.4 - 61186.6	20	22514.9 - 73423.9	Estimated
Employment	Employment	Number of direct jobs in greenhouses	h/ha	1303.5 - 3061.9	-	-	Measured
		Number of indirect jobs in auxiliary sector	h/ha	328.3	-	-	Cajamar, 2021
Social	Worker conditions	Wet-Bulb Globe Temperature (WBGT)	°C	0.0	-	-	-
Environmental determinants of health	Effect on air quality	Low-Moderate-High	Low	Low	Moderate	Estimated	
	Water quality	Low-Moderate-High	Moderate	Moderate	Moderate	Estimated	
	Soil quality	Low-Moderate-High	Moderate	Moderate	Moderate	Estimated	
	Foods quality	Low-Moderate-High	Low	Low	Low	Estimated	

TABLE 3 : HYPOTHETICAL IMPROVEMENT SCENARIO FOR EACH INDICATOR WITH THEGREEFA TECHNOLOGY (SOURCE: STRANE)

The improvement factors are estimated based on typical benefits expected from adopting advanced greenhouse technologies like TheGreefa.

These improvements need to be validated with actual data from greenhouses using TheGreefa technology, which is not the case now and constitutes a limiting factor.

Assumptions for reduction percentages should be adjusted based on more specific performance data if available in the future.

This table provides a comparative analysis to showcase potential improvements with TheGreefa technology against the baseline scenario.

2.5.Case studies and real-world data

The following table provides a detailed comparative analysis of production costs, energy consumption, water usage, and CO_2 emissions across different types of greenhouses in the Mediterranean region, specifically focusing on Spain and Italy. These case studies offer valuable insights into the operational efficiencies and environmental impacts of various greenhouse systems. The data highlights key performance indicators, such as energy consumption reduction and water usage reduction, which are critical for sustainable agricultural practices. Understanding these metrics is essential for evaluating the benefits and trade-offs associated with different greenhouse technologies.

Case Study	Production Cost (€ per hectare)	Energy Consumption (kWh per year)	Water Usage (cubic meters per year)	CO2 Emissions (tons per year)	Energy Consumption Reduction (%)	Water Usage Reduction (%)
Unheated Almería-Type Greenhouse	€50,000 - €100,000	1,200 - 2,300	2,000 - 5,200	0.15 - 1.0	30%	20%
Unheated Multispan Greenhouses in Spain	€50,000 - €100,000	1,200 - 2,300	2,000 - 5,200	0.15 - 1.0	25%	15%
Heated Multispan Greenhouses in Spain	€80,000 - €150,000	56,000 - 160,000	12,000 - 20,000	4.63	35%	25%
Unheated Multispan Greenhouse in Italy	€50,000 - €100,000	20,000 - 100,000	4,570	0.15 - 1.0	28%	18%
Heated Multispan High-Tech Greenhouses in Italy	€80,000 - €160,000	67,000	4,570	0.15 - 1.0	40%	30%

TABLE 4: COMPARATIVE ANALYSIS OF PRODUCTION COSTS, ENERGY CONSUMPTION, WATER USAGE, AND CO2 EMISSIONS ACROSS DIFFERENT TYPES OF GREENHOUSES IN THE MEDITERRANEAN REGION

2.5.1. Case Study 1: Unheated Almería-type greenhouse

The total production cost for an unheated Almería-type greenhouse ranges from €50,000 to €100,000 per hectare, depending on the crop cycles and market conditions. Energy consumption is between 1,200 and 2,300 kWh per year, while water usage ranges from 2,000 to 5,200 cubic meters annually. The greenhouse emits between 0.15 and 1.0 tons of CO_2 per year, indicating its environmental footprint. Implementing TheGreefa technology in these greenhouses could reduce energy consumption by 30% and water usage by 20%. This significant reduction would not only lower operational costs but also minimize the environmental impact.

2.5.2. Case Study 2: Unheated multispan greenhouses in Spain

The production cost for unheated multispan greenhouses in Spain is estimated to be between €50,000 and €100,000 per hectare. These greenhouses consume approximately 1,200 to 2,300 kWh of energy per year and use about 2,000 to 5,200 cubic meters of water annually. The CO_2 emission rate for these greenhouses is between 0.15 and 1.0 tons per year, reflecting their contribution to greenhouse gas emissions. By adopting TheGreefa technology, these greenhouses could achieve a 25% reduction in energy consumption and a 15% decrease in water usage, enhancing sustainability and operational efficiency.

2.5.3. Case Study 3: Heated multispan greenhouses in Spain

The production costs for heated multispan greenhouses in Spain range from €80,000 to €150,000 per hectare, covering all necessary expenditures to maintain and operate the heated greenhouses. Energy consumption varies significantly from 56,000 to 160,000 kWh per year due to the heating requirements, while water usage ranges between 12,000 and 20,000 cubic meters annually. The CO_2 emissions from these greenhouses are approximately 4.63 tons per year, influenced by the energy used for heating purposes. Implementing TheGreefa technology could result in a 35% reduction in energy consumption and a 25% decrease in water usage, leading to more sustainable operations and lower environmental impact.

2.5.4. Case Study 4: Unheated multispan greenhouse in Italy

The cost per hectare for an unheated multispan greenhouse in Italy is roughly between €50,000 and €100,000, encompassing all costs associated with running the greenhouse. The annual energy consumption for these greenhouses is between 20,000 and 100,000 kWh, while water usage is around 4,570 cubic meters. These greenhouses emit around 0.15 to 1.0 tons of CO_2 yearly, resulting from the energy consumption needed for maintaining the greenhouse environment. TheGreefa technology may reduce energy consumption by 28% and water usage by 18%, significantly cutting down on resource use and emissions.

2.5.5. Case Study 5: Heated multispan high-tech greenhouses in Italy

The production costs for heated multispan high-tech greenhouses in Italy range from €80,000 to €160,000 per hectare, including advanced technologies and maintenance required for high-tech operations. These greenhouses use approximately 67,000 kWh of energy per year and consume around 4,570 cubic meters of water annually. The CO_2 emissions are estimated to be between 0.15 and 1.0 tons per year, reflecting the greenhouse's energy-intensive operations. The implementation of TheGreefa technology could result in a 40% reduction in energy consumption and a 30% reduction in water usage, leading to more efficient and environmentally friendly greenhouse operations.

Conclusion: Overall, the environmental impact of these greenhouse types varies significantly based on their energy and water consumption. Unheated greenhouses have lower CO_2 emissions and energy consumption compared to heated ones. Implementing TheGreefa technology across all greenhouse types presents a substantial opportunity to reduce energy consumption, lower water usage, and consequently decrease CO_2 emissions, leading to more sustainable and environmentally friendly agricultural practices.

3. OTHER FACTORS THAT LIKELY INFLUENCE THE CALCULATION OF THE SEEA

3.1. Direct economic impacts

Positive aspects:

3.1.1. Economic benefits

The economic benefits of TheGreefa technology are significant and multifaceted, offering substantial advantages to greenhouse operators. By utilizing thermochemical fluids, TheGreefa technology achieves impressive energy savings, translating into considerable financial savings for greenhouse operations. The integration of renewable energy sources with this technology further enhances its cost-effectiveness, making it a compelling option for growers seeking to improve profitability while also reducing their carbon footprint.

A detailed economic analysis demonstrates the potential for significant energy savings. For instance, in a realistic scenario, a 10,000 m² greenhouse using TheGreefa technology could achieve annual energy savings of 1,628 MWh, resulting in financial savings of approximately €244,203 in energy costs alone. Additionally, the reduction in carbon emissions by 325.6 tons could generate further savings of €8,140 through carbon credits. This cumulative annual economic impact of approximately €252,343 highlights the substantial cost-effectiveness of TheGreefa's solutions.

Despite the high initial investment required for the technology—estimated at around €1.67 million for 167 absorber units in a 10,000 m² greenhouse—the long-term financial benefits outweigh these costs. The first-year net economic impact, considering the savings from reduced energy costs and carbon credits, is estimated at approximately €1.42 million. Over time, these savings, combined with the reduction in operational and maintenance costs due to the reliability and efficiency of TheGreefa technology, can significantly shorten the payback period and lead to substantial net positive savings.

Moreover, TheGreefa technology supports the broader economic goals of enhancing greenhouse productivity and sustainability. By enabling growers to achieve better control over greenhouse climates, the technology contributes to higher crop yields and improved quality, which can further boost profitability. The emphasis on renewable energy integration also aligns with global sustainability goals, enhancing the market appeal of greenhouse operations that adopt TheGreefa technology.

In conclusion, TheGreefa technology offers greenhouse operators a robust solution to enhance economic performance through energy savings, reduced carbon emissions, and improved operational efficiency. This positions TheGreefa not only as a cost-effective option but also as a leader in promoting sustainable and profitable agricultural practices.

3.1.2. Final projections and ROI analysis

TheGreefa's thermochemical fluid (TCF) technologies have demonstrated significant potential in enhancing greenhouse climate control. To facilitate stakeholders' decision-making, detailed financial projections and return on investment (ROI) analyses are essential. These projections evaluate the economic viability of adopting these advanced technologies under various scenarios over a 20-year period, offering a comprehensive perspective on their long-term benefits and risks.

3.1.2.1. Financial projections

The financial projections for TheGreefa's technologies consider three primary scenarios: Worst Case, Realistic Case (based on data from Wangen), and Best Case. Each scenario assesses the initial investment, annual savings, and payback period to provide a nuanced understanding of the financial outcomes.

3.1.2.2. Worst case scenario

In the worst-case scenario, the initial investment is estimated at €2,000,000, with annual savings projected at €91,014. The payback period extends to nearly 22 years, reflecting the financial risks under unfavorable conditions such as lower operational efficiencies and higher costs. This scenario is characterized by modest annual energy savings of around 600,000 kWh, translating to approximately €90,200 in reduced energy costs. Additionally, the reduced carbon emission savings result in only 32.5 tons of CO_2 reduction, yielding €814 in carbon credits. The extended payback period and limited environmental benefits underscore the need for cautious financial planning and robust risk management.

3.1.2.3. Realistic case (Wangen)

The realistic scenario, based on operational data from the Wangen greenhouse, offers a more balanced view with an initial investment of €1,670,000 and annual savings of €252,343. The payback period is significantly shorter at approximately 6.6 years, making this scenario financially attractive for most investors. This scenario includes substantial annual energy savings of 1,628 MWh, amounting to €244,203 in energy cost reductions, and a reduction of 325.6 tons of CO_2, generating €8,140 in carbon credits. These figures highlight the potential of TheGreefa's technology to achieve a sustainable financial return within a reasonable timeframe.

3.1.2.4. Best case scenario

Under optimal conditions, the best-case scenario predicts an initial investment of €1,400,000 with annual savings of €279,000. The payback period is the shortest at just over 5 years, indicating the highest financial return and attractiveness to investors. This scenario assumes an impressive 60% reduction in energy use, leading to annual energy savings of approximately 1.8 GWh, equivalent to €270,000 in savings. Additionally, the reduction of 360 tons of CO_2 yields €9,000 in carbon credits. The high efficiency and favorable market conditions in this scenario make TheGreefa's technology highly profitable and environmentally beneficial.

3.1.2.5. Remarks

The financial projections and ROI analyses demonstrate that TheGreefa's TCF technologies can offer substantial economic and environmental benefits, particularly under realistic and best-case scenarios. The significant energy savings and reduction in carbon emissions contribute to both cost-effectiveness and sustainability. However, the worst-case scenario highlights potential financial and operational risks, emphasizing the importance of thorough financial analysis and risk mitigation strategies. By understanding these diverse scenarios, stakeholders can make informed decisions about investing in TheGreefa's innovative solutions, aligning with broader environmental and economic goals.

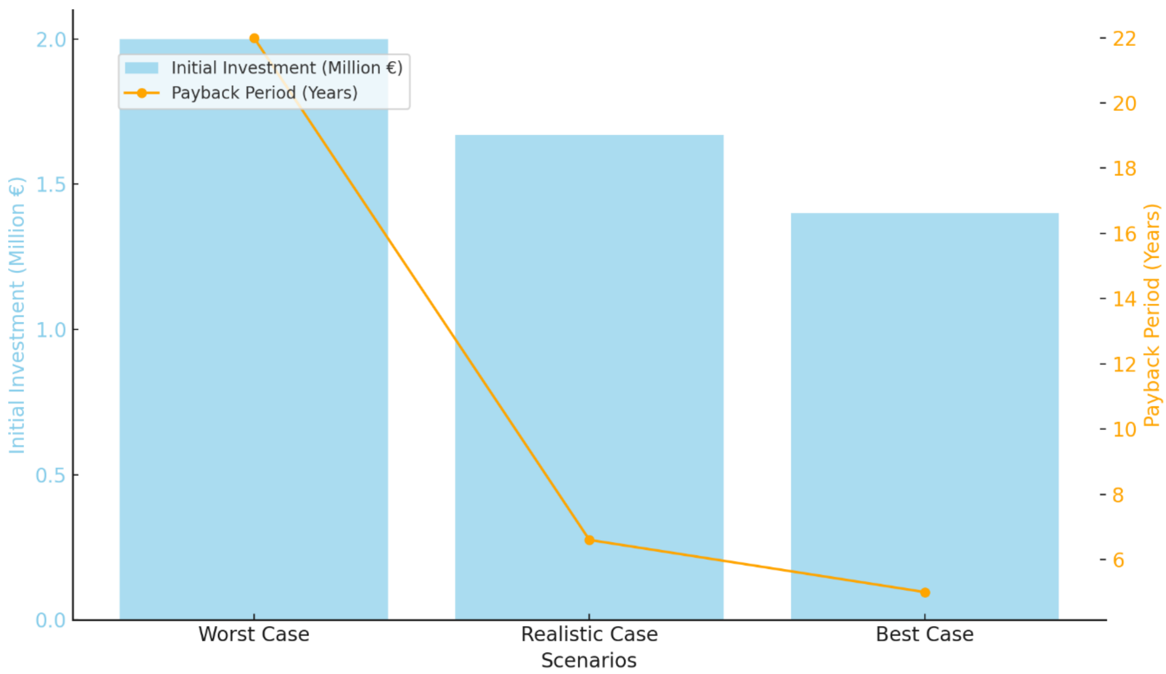

FIGURE 1 : FINANCIAL PROJECTIONS AND ROI ANALYSES OF THEGREEFA TECHNOLOGY (SOURCE STRANE)

For further understanding, those results are presented in-depth in the D4.6 deliverable "Exploitation strategy and roadmap to startup creation."

3.1.3. Total added value of TheGreefa

To estimate the economic impact of TheGreefa solutions, several factors must be considered, including cost savings from energy efficiency, reduction in greenhouse gas emissions (potentially converted into financial savings through carbon credits or reduced carbon taxes), and potential increases in yield or productivity for greenhouse operations. While specific data about TheGreefa's technology performance, market penetration rate, and other financial details have not been provided, we can outline a hypothetical scenario to demonstrate how to calculate the economic impact. This scenario will consider energy savings and carbon emission reductions as primary benefits.

This simplified model aims to demonstrate how TheGreefa solutions could potentially offer significant economic benefits through energy savings and carbon emission reductions. It is essential to adjust these assumptions based on real-world data and consider other economic factors such as upfront investment, maintenance costs, potential subsidies or incentives, and the impact on crop yield or quality. For a comprehensive analysis, detailed financial modeling would be required, considering all these variables over the solution's lifetime.

The continuous correction of greenhouse humidity by the sorption process can prevent previously induced air exchange losses. The sensible part of these losses is avoided, while the latent part is converted into sensible heat during the sorption process and can be fed back into the greenhouse as heating energy. The additional heat generation in the sorption scrubber further reduces the heating requirement. Figure 1 shows the quantities of heat required to heat the greenhouse. The loads correspond to the heating energy recorded in 2019. The latent portion discharged by the induced air exchange is shown in red. The natural heat loss reduced by the sorptive climate concept is shown in yellow. Purple shows the remaining heat requirement with the sorptive climate concept, which still needs to be covered by conventional heating.

$$Q^{S}_{Spar,konv} = \int (\dot{Q}_{nat,Ref} - \dot{Q}_{nat,Mess}) \, dT$$

$$Q^{sorpt}_{Heiz} = Q_{Heiz} - Q^{S}_{Spar,konv} - Q^{S}_{Spar,LW} - Q^{L}_{Spar,LW}$$

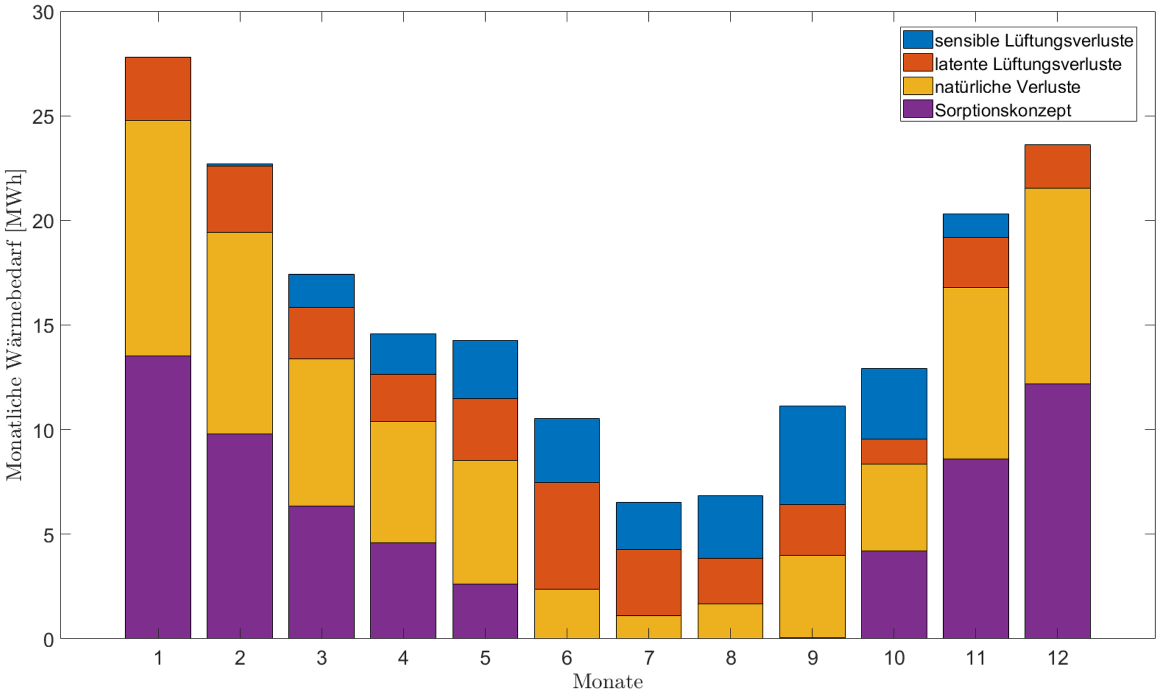

FIGURE 2 : MONTHLY ENERGY DEMAND OF THE EXPERIMENTAL GREENHOUSE

The sum of all loads corresponds to the effective heat quantities in 2019. The latent heat losses due to the provoked air exchange are shown in red. The difference in natural energy losses is shown in yellow. The remaining heat requirement using the sorption-based climate concept is shown in purple

The sum of all loads corresponds to the effective heat quantities in 2019. The latent heat losses due to the induced air exchange are shown in red. The difference in natural energy losses is shown in yellow. The remaining heat requirement using the sorption-based climate concept is shown in purple.

Figure 2 shows the remaining heat requirement (in blue) for 2019 (83 MWh) compared to the previous requirement (181 MWh). The extrapolation to the annual heat requirement shows a potential saving of 54% on conventional heat. The sorption process converts latent heat into sensible heat during the transition period, realized by the chemical potential stored in the salt solution as high salt concentrations, which break down during absorption, diluting the solution. The solution must be concentrated again to enable a new sorption process. The heat required for this is generated in the summer months using solar thermal energy, for example, shown in yellow in Figure 2. The heat effectively saved by the sorptive air conditioning concept is shown in red (60 MWh).

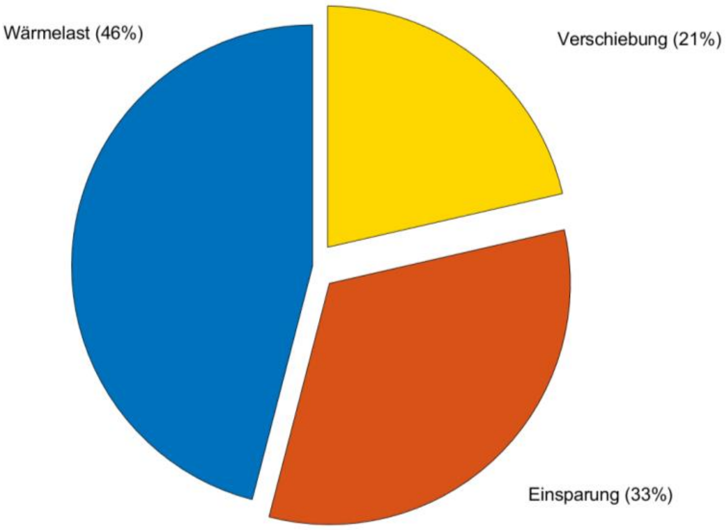

FIGURE 3 : ANNUAL ENERGY REQUIREMENT OF THE EXPERIMENTAL GREENHOUSE WITH AND WITHOUT THE SORPTIVE CLIMATE CONCEPT

The remaining amount of heat that still has to be used by the conventional heating system is shown in blue. The amount of heat effectively saved is shown in red, while the amount of heat to be used independently of time is shown in yellow

The Wangen greenhouse uses 181 MWh (or 181,000 kWh) annually for heating and cooling. With TheGreefa's estimated energy savings of 54%, the total annual energy savings for the greenhouse would be approximately 98 MWh.

Financially, this level of energy savings would translate into significant cost reductions. By multiplying the total annual energy savings by the energy cost per kWh (€0.15), the annual financial savings from reduced energy consumption would amount to around €14,661. This reduction in energy costs offers a significant opportunity for greenhouses to enhance their financial efficiency and profitability.

In terms of environmental impact, this reduction in energy consumption leads to a corresponding decrease in carbon emissions. With each kilowatt-hour saved resulting in a reduction of 0.2 kg of CO_2 emissions, the total reduction in CO_2 emissions would be approximately 19,548 kg or 19.5 tons of CO_2.

These emissions reductions also carry financial benefits through carbon credits. With each ton of CO_2 valued at €25, the total savings from carbon credits would be around €489.

Combining the financial savings from reduced energy consumption and the additional savings from carbon credits, the total annual economic impact for the Wangen greenhouse, based on 54% energy savings, is approximately €15,150. This significant economic impact underscores the potential of TheGreefa technology to provide both environmental and financial advantages for greenhouse operations.

Now, in an enhanced, still realistic scenario reflecting TheGreefa's innovative approach, where a significant 54% reduction in energy use is achieved through the state-of-the-art technology, we delve into the economic and environmental impacts of deploying their solutions across a 10,000 m² greenhouse operation. This scenario not only demonstrates the robust energy efficiency of TheGreefa's solutions but also underscores the initial financial considerations involved in adopting such advanced technology.

Based on our previous calculations, the deployment of TheGreefa's technology is anticipated to result in an impressive total annual energy saving of 1,628 MWh, translating into significant financial savings of approximately €244,203 in energy costs alone. Beyond the tangible economic benefits, this scenario showcases a commendable reduction in carbon emissions by 325.6 tons, further contributing to environmental sustainability and offering an additional €8,140 in savings through carbon credits. Cumulatively, these benefits yield a total annual economic impact of approximately €252,343, underscoring the substantial cost-effectiveness and eco-friendly nature of TheGreefa's solutions.

However, this scenario also highlights the considerable initial investment required to implement TheGreefa's technology, with approximately 167 absorber units needed to adequately cover a 10,000 m² greenhouse area. Although the total cost for these absorbers is not explicitly calculated here, it can be estimated at around €1.67 million based on previous projections, leading to a net economic impact in the first year of approximately €1.42 million, factoring in the savings from reduced energy costs and carbon credits. This initial financial outlay emphasizes the need for prospective adopters to evaluate the long-term financial roadmap of integrating TheGreefa's solutions into their operations.

While the first-year net economic impact appears daunting due to the high upfront costs, it is essential to consider the broader financial landscape and the enduring value that TheGreefa's technology offers. Over time, the substantial energy savings and reduction in carbon emissions will continue to accrue, potentially offsetting the initial investment and leading to significant net savings. To fully understand the financial viability of TheGreefa's solutions, a deeper analysis, including the calculation of the break-even point and total cost of ownership over the absorbers' lifespan, is recommended. Such an analysis would provide a more nuanced view of the economic and environmental benefits, reinforcing TheGreefa's position as a transformative solution for sustainable greenhouse farming.

In a worst-case scenario reflecting the challenges faced by TheGreefa's innovative technology, the projected economic and environmental impacts are considerably diminished, highlighting the potential financial and operational risks involved in adopting this technology across a 10,000 m² greenhouse operation.

Despite the anticipated energy savings of up to 54% in an ideal scenario, unexpected technical and operational issues reduce the actual energy savings to as low as 20%. This results in total annual energy savings of around 600,000 kWh, translating into significantly reduced financial savings of approximately €90,200 in energy costs. Such a scenario falls far short of the projected savings and highlights the variability in actual savings depending on greenhouse conditions.

Furthermore, unexpected manufacturing and installation challenges result in upfront costs that exceed initial estimates. Instead of the projected €1.67 million, the actual cost could rise to €2 million, amplifying the first-year financial burden to approximately €1.91 million after factoring in the reduced energy savings and carbon credits. This high upfront cost underscores the importance of careful financial planning and may deter greenhouse operators from adopting TheGreefa's technology.

The environmental benefits also diminish in this scenario due to operational inefficiencies, achieving only 10% of the expected carbon emission savings. This results in a reduction of just 32.5 tons of CO_2, yielding merely €814 in carbon credits. The limited environmental impact raises questions about the technology's contribution to sustainability and climate change goals.

Additionally, market adoption and technical challenges further slow the widespread deployment of TheGreefa's absorbers. Regulatory barriers, technical setbacks, and a lack of awareness hinder adoption, limiting market revenue and the opportunity to refine the technology through feedback from early adopters.

Moreover, maintenance and operating costs double due to unforeseen technical issues, substantially impacting the technology's profitability. The increased operating expenses further strain the economic viability of TheGreefa's absorbers, potentially extending the payback period far beyond initial expectations.

In this worst-case scenario, the combination of significantly lower energy savings, higher upfront and maintenance costs, reduced carbon emission savings, and market challenges dramatically weakens the projected economic and environmental benefits of TheGreefa's technology. This scenario calls for a cautious approach and emphasizes the importance of thorough financial analysis, robust technical validation, and market assessment before implementing such advanced technology in greenhouse operations.

In a best-case scenario, TheGreefa's technology showcases remarkable economic and environmental impacts across a 10,000 m² greenhouse operation, leveraging its innovative design to significantly exceed expectations. Achieving an impressive 60% reduction in energy use, which surpasses the 54% reduction observed in the Wangen greenhouse, TheGreefa technology translates this improvement into annual energy savings of around 1.8 GWh. This results in substantial financial savings of approximately €270,000.

To estimate the economic impact of TheGreefa solutions, several factors need to be considered, including cost savings from energy efficiency, reduction in greenhouse gas emissions (potentially converted into financial savings through carbon credits or reduced carbon taxes), and potential increases in yield or productivity for greenhouse operations. While specific data about TheGreefa's technology performance, market penetration rate, and other financial details have not been provided, we can outline a hypothetical scenario to demonstrate how to calculate economic impact. This scenario will consider energy savings and carbon emission reductions as primary benefits.

3.1.4. Energy savings and cost reduction

The continuous correction of greenhouse humidity by the sorption process can prevent previously induced air exchange losses. The sensible part of these losses is avoided, while the latent part is converted into sensible heat during the sorption process and can be fed back into the greenhouse as heating energy. The additional heat generation in the sorption scrubber further reduces the heating requirement. Figure 6 shows the quantities of heat required to heat the greenhouse. The loads correspond to the heating energy recorded in 2019. The latent portion discharged by the induced air exchange is shown in red. The natural heat loss reduced by the sorptive climate concept is shown in yellow. Purple shows the remaining heat requirement with the sorptive climate concept, which still needs to be covered by conventional heating.

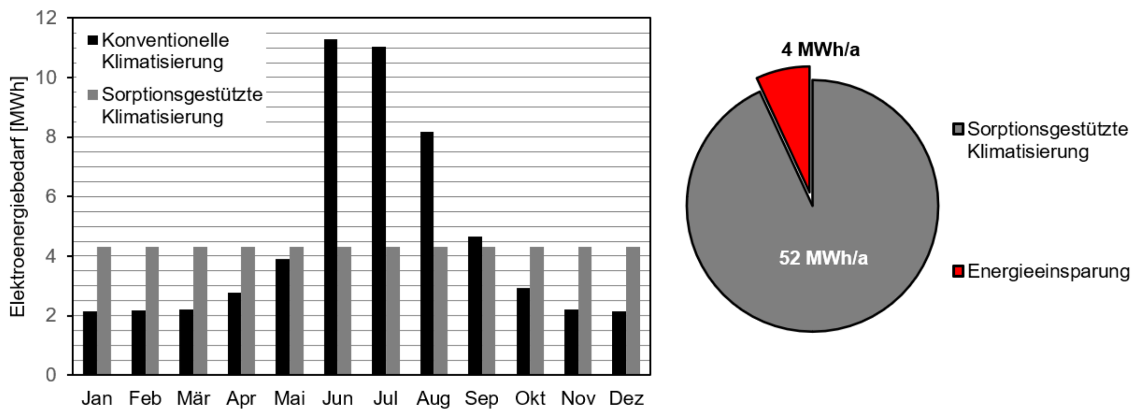

Abbildung 10: Vergleich des Elektroenergiebedarfes von sorptionsgestützter Pflanztischklimatisierung und konventioneller Gewächshausklimatisierung

FIGURE 4 : COMPARISON OF ELICTRICITY DEMAND BETWEEN CONVENTIONAL CLIMATE CONTROL AND SORPTION-SUPPORTED CLIMATE CONTROL IN GREENHOUSES

This chart compares the electricity demand between conventional climate control and sorption-supported climate control in greenhouses. The bar chart displays monthly electricity demand (in MWh) from January to December, demonstrating that conventional climate control consistently shows higher electricity consumption compared to sorption-supported climate control across all months. The peak electricity demand for conventional climate control occurs in June, reaching almost 12 MWh, while the sorption-supported system peaks at a much lower level. The electricity demand for both systems tends to be higher during the summer months (June, July, and August) and lower during the winter months (January, February, and December).

Additionally, the pie chart illustrates the annual energy consumption and savings, indicating that sorption-supported climate control consumes 52 MWh per year. The energy savings from using sorption-supported climate control amount to 4 MWh per year, showcasing a notable reduction in electricity usage and highlighting the efficiency of sorption-supported climate control systems over conventional systems.

In summary, sorption-supported climate control is more energy-efficient compared to conventional systems, as evidenced by the lower monthly electricity demand throughout the year. Implementing sorption-supported climate control can lead to substantial annual energy savings (4 MWh), contributing to reduced operational costs and lower carbon footprints. The greatest benefits of sorption-supported systems are observed during the peak electricity consumption months in summer, suggesting that these systems are particularly effective in managing higher cooling loads.

Overall, the image emphasizes the advantages of adopting sorption-supported climate control systems in greenhouses, underscoring their role in energy conservation and cost reduction. This efficiency can lead to significant savings and environmental benefits, making sorption-supported climate control an attractive option for greenhouse operations seeking to enhance sustainability and reduce costs.

3.1.5. Job creation and worker well-being

TheGreefa technology and innovations in greenhouse farming might have an impact on the job creation and worker well-being. Advancements in greenhouse technology not only boost production capabilities but also influence employment in the agricultural sector. For instance, the introduction of more automated and efficient climate control systems is expected to change the labor dynamics in greenhouses, potentially reducing the number of low-skilled labor positions while increasing demand for more skilled technical roles. This shift could lead to job creation in areas like system maintenance, monitoring, and optimization, which require a different skill set than traditional greenhouse labor.

Moreover, improvements in greenhouse conditions due to technological advancements are anticipated to enhance worker well-being. Better climate control can make greenhouses a more comfortable working environment, potentially reducing health risks associated with extreme temperatures and humidity levels. This could lead to improvements in workers' overall job satisfaction and reduce turnover rates.

The impact of technology and modernization on job creation and worker well-being in European greenhouses is highlighted in the TheGreefa Deliverable D3.1 Market Evaluation document. According to the data on page 140 of TheGreefa D3.1, heated greenhouses require an average of 5.36 full-time equivalent (FTE) employees per hectare, indicating the labor-intensive nature of these operations. The adoption of advanced technologies, such as automated climate control systems provided by TheGreefa, is expected to shift the labor dynamics, creating a demand for more skilled technical roles for system maintenance, monitoring, and optimization.

Moreover, technological advancements are anticipated to enhance worker well-being by improving the working conditions within greenhouses. Automated systems reduce physical strain and health risks associated with extreme temperatures and high humidity levels, leading to a safer and more comfortable work environment. This combination of job creation in higher-skilled positions and improved working conditions underscores the dual benefits of adopting advanced greenhouse technologies like those offered by TheGreefa

In summary, the implementation of TheGreefa technology is likely to have a dual impact on job creation and worker well-being, with potential benefits including the creation of higher-skilled job opportunities and improved working conditions that could attract a more skilled workforce and improve productivity.

This section details the types of employees hired by the members of the Producer Organization to develop their activities. Most farmers employ 1 to 3 workers, 14.0% of farmers hire permanent family employees, 5.8% temporary family employees, 34.2% non-family permanent employees and 50% temporary non-family employees (Figure 2).

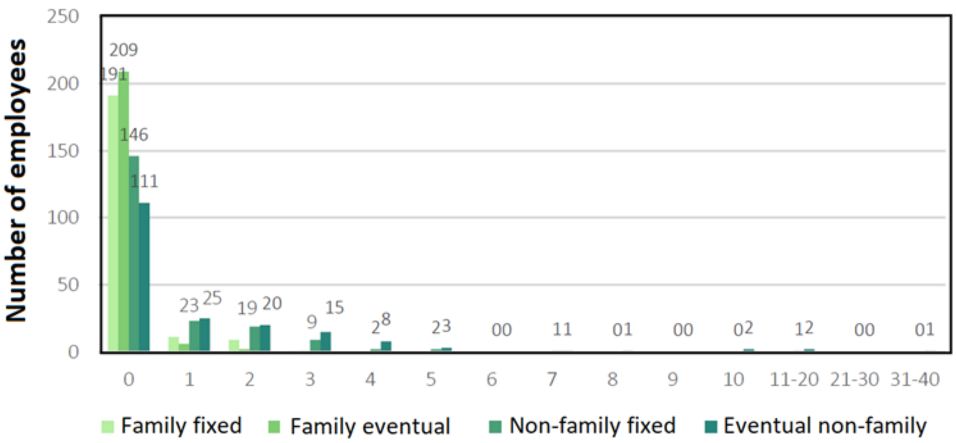

FIGURE 5 : ABSOLUTE FREQUENCIES OF THE NUMBER OF EMPLOYEES

The implementation of TheGreefa technology in greenhouse operations is anticipated to significantly influence employment patterns within the sector. Here is a detailed analysis of the projected impacts on direct and indirect jobs:

3.1.5.1. Direct jobs

The adoption of TheGreefa technology is expected to reduce the number of direct jobs in greenhouses by approximately 10-15%. This reduction can be attributed to the increased automation and technological advancements introduced by TheGreefa system, which streamline many processes that previously required manual labor. These advancements include automated climate control, enhanced irrigation systems, and more efficient pest management techniques, all of which contribute to reduced labor needs.

3.1.5.2. Indirect jobs

Conversely, the adoption of TheGreefa technology is projected to increase the number of indirect jobs in the auxiliary sector by approximately 5-10%. The indirect jobs are associated with the increased demand for technical support, maintenance services, and the production of advanced materials and components needed for TheGreefa system. This shift reflects a broader trend towards more specialized and technically skilled labor as the agricultural sector modernizes.

Based on these assumptions, the table below illustrates the estimated changes in direct and indirect jobs for various crop cycles:

Crop	**Baseline direct jobs (h/ha)**	**Estimated direct jobs with TheGreefa (h/ha)**	**Baseline indirect jobs (h/ha)**	**Estimated indirect jobs with TheGreefa (h/ha)**
Tomato 2021	**1370.2**	**1164.67**	**328.3**	**344.72**
Season 2020-21	**2697.9**	**2293.22**	**318.0**	**333.9**
Cucumber 2021	**1303.5**	**1108.0**	**328.3**	**344.72**
Pepper 2022	**1758.4**	**1494.64**	**328.3**	**344.72**
Season 2020-21	**3061.9**	**2602.62**	**328.3**	**344.72**

TABLE 5 : SUMMARY OF IMPACTS ON EMPLOYMENT DUE TO ADOPTION OF THEGREEFA TECHNOLOGY. (ESTIMATION)

The adoption of TheGreefa technology is likely to bring about a substantial transformation in the employment landscape of greenhouse operations. While there will be a notable reduction in direct labor requirements due to automation and improved efficiency, the increase in indirect jobs suggests a shift towards a more specialized and technically skilled workforce. This shift aligns with broader trends in modern agriculture, where technology and sustainability are becoming increasingly central to operational strategies. As such, TheGreefa technology not only promises to enhance productivity and sustainability but also necessitates a re-evaluation of workforce development and training to meet the new demands of advanced agricultural systems.

3.1.6. Market opportunities

Conducting a thorough market analysis helped us reveal significant opportunities for TheGreefa technology. The European greenhouse sector offers substantial growth opportunities for TheGreefa technology, driven by increasing environmental regulations, rising energy costs, and a pronounced shift towards sustainable and efficient agricultural practices. The European commercial greenhouse market, valued at approximately €5.87 billion in 2018, is projected to reach over €12 billion by 2025, reflecting a robust Compound Annual Growth Rate (CAGR) of 10.3%. This growth presents significant opportunities for TheGreefa, which focuses on microclimate management, energy efficiency, and water recovery.

The demand for modernization and energy-efficient technologies in European greenhouses is paramount. Traditional heating methods predominantly rely on fossil fuels, making energy costs a significant factor in profitability. TheGreefa technology offers a cost-effective and environmentally friendly alternative that is compatible with renewable energy sources. This compatibility is crucial for reducing energy costs and carbon emissions, aligning with the sector's increasing focus on sustainability.

Regions such as Southern Europe and the Mediterranean basin, characterized by low-tech structures, lack of equipment, and water shortages, represent fertile ground for TheGreefa technology. TheGreefa's features, including water recovery, humidity removal, and integrated software management, directly address these regions' specific challenges, offering substantial benefits. The potential market value for climate control solutions in European greenhouses ranges between €350 million and €1,729 million per year. With all technical, economic, and organizational conditions met, TheGreefa solution could potentially earn between €7.5 million and €37 million annually. Key initial markets identified include Spain, Italy, and France, which have extensive greenhouse farming infrastructure, conducive climates, and supportive regulatory environments.

Beyond the primary greenhouse market, TheGreefa technology also holds potential applications in sectors such as automotive, aerospace, shipping, defense, construction, and wood processing. These industries require precise microclimate management, presenting further opportunities for TheGreefa. Its system's ability to control heating, cooling, dehumidification, energy storage, and water recovery could significantly enhance operational efficiency and product quality in these sectors.

Achieving market acceptance and technological readiness is crucial for TheGreefa. Currently at Technology Readiness Level (TRL) 5, the goal is to reach market penetration at TRL 9 within 3 to 6 years. This progression requires demonstrating the technology's feasibility, reliability, cost-effectiveness, and energy efficiency to end-users. Forming strategic partnerships with entities embedded within the EU agricultural and renewable energy ecosystems will be essential in navigating market entry challenges. Additionally, adapting TheGreefa's market strategy to accommodate regional variances in climate, agricultural practices, and regulatory landscapes will be critical for successful adoption.

In the competitive landscape, TheGreefa must differentiate itself by offering innovative and cost-effective solutions that address the comprehensive needs of growers, including heating, cooling, humidity control, and water recovery. Competitors like Agam Greenhouse Energy Systems Ltd. offer strong benchmarks, but TheGreefa’s holistic approach and adaptability to various energy sources provide a competitive edge.

In conclusion, the European greenhouse market presents significant growth potential for TheGreefa technology. By leveraging the growing demand for sustainable and efficient agricultural practices, focusing on strategic market entry points, and forming key partnerships, TheGreefa can position itself as a leading provider of innovative climate control solutions in the agricultural sector.

3.1.7. Cost technology and economic efficiency of TheGreefa technology

To understand the financial implications of adopting TheGreefa technology in greenhouse operations, it's essential to consider both the cost of the technology and its impact on economic efficiency. The initial investment required for TheGreefa technology is substantial. Let’s assume that each absorber costs €10,000 and then, based on the Wangen demonstrator configuration for 600m^2, a hectare of greenhouse requires 167 absorbers. This means that the total investment cost for one hectare amounts to €1,670,000. Additionally, the annual cost of the technology is significant. By assuming that the absorbers have a lifespan of ten years, we can spread the investment cost over this period, resulting in an annual cost of €167,000 per hectare.

Beyond the costs, it is important to examine the economic efficiency of the technology. Production efficiency is a crucial metric that represents the ratio of revenue generated to the input costs incurred. With TheGreefa technology, production efficiency is estimated to be between 1.5 and 2.5, indicating that for every unit of cost, the revenue generated will be 1.5 to 2.5 times. This improvement in production efficiency is a significant advantage of adopting TheGreefa technology.

Furthermore, the implementation of TheGreefa technology adds economic value to the auxiliary sector, which includes maintenance, support services, and component production. This added value is estimated to be between €1,000 and €5,000 per hectare. These enhancements contribute to the overall economic efficiency of greenhouse operations, making them more sustainable and profitable in the long run.

To summarize, the adoption of TheGreefa technology involves a significant initial investment and ongoing annual costs. However, the benefits include substantial improvements in production efficiency and added economic value to the auxiliary sector. These enhancements are expected to boost the gross margin and make greenhouse operations more sustainable and profitable in the long run. By clearly understanding these financial implications, greenhouse operators can make informed decisions about investing in TheGreefa technology and reap the benefits of enhanced climate control and resource efficiency. This comprehensive approach ensures that the technology's advantages are fully realized, contributing to the long-term success and sustainability of greenhouse farming.

Here is a summary of the estimated costs and economic efficiency metrics for TheGreefa technology:

Account	Sub-account	Indicators	Units
Cost Technology	Annual cost of technology	€/ha·year	€167,000
Cost Technology	Investment cost	€/ha	€1,670,000
Cost Technology	Increase of the gross margin	%	10% - 20%
Economic Efficiency	Production efficiency	Revenue / Input costs	1.5 - 2.5
Economic Efficiency	Net economic value for the auxiliary	€/ha	€1,000 - €5,000

TABLE 6 : SUMMARY OF COST TECHNOLOGY AND ECONOMIC EFFICIENCY OF THEGREEFA TECHNOLOGY. (ESTIMATION)

Negative aspects:

3.1.8. Barriers to implementation

The successful implementation of TheGreefa technology in greenhouse farming faces several potential obstacles and challenges. Understanding these barriers is essential for developing strategies to mitigate them and ensuring the technology's effective deployment and acceptance.

3.1.8.1. Market resistance

High initial costs can be a significant barrier to the adoption of TheGreefa technology. The investment required for installation, equipment, and potential modifications to existing infrastructure can be substantial. To overcome resistance related to initial costs, it is essential to offer financing options, leasing arrangements, and demonstrate long-term cost savings through detailed return on investment (ROI) analyses. By highlighting the economic benefits and providing financial support mechanisms, greenhouse operators could be more inclined to adopt the technology.

Perceived complexity of TheGreefa technology may also deter potential adopters. Greenhouse operators may view the technology as complex and challenging to operate, preferring simpler, more familiar systems. To address this issue, simplifying user interfaces and providing extensive training and support are crucial. Demonstrating the technology's ease of use through pilot projects and testimonials from early adopters can build confidence and reduce resistance to adoption.

Uncertainty about the benefits of TheGreefa technology is another potential market barrier. Potential users may be skeptical about the claimed advantages, such as energy savings, enhanced crop yields, and environmental sustainability. Conducting comprehensive field trials and publishing detailed case studies that highlight tangible benefits can alleviate these uncertainties. Engaging with agricultural research institutions to validate results can further bolster credibility and demonstrate the practical advantages of the technology.

3.1.8.2. Financial constraints

Economic barriers are significant considerations in the adoption of TheGreefa technology. The high initial costs associated with installation, equipment, and potential modifications to existing infrastructure can be substantial. Addressing financial constraints involves offering financing options, leasing arrangements, and demonstrating long-term cost savings through detailed return on investment (ROI) analyses. By highlighting the economic benefits and providing financial support mechanisms, greenhouse operators can be more inclined to adopt the technology.

Access to funding can also be a challenge. Greenhouse operators may struggle to secure the necessary capital for investing in new technologies. Exploring partnerships with financial institutions, seeking grants from governmental and non-governmental organizations, and participating in funding programs dedicated to sustainable agricultural practices can help overcome this barrier. Demonstrating the technology's potential for cost savings and environmental benefits can make it more attractive to investors and funding bodies.

3.1.8.3. Regulatory hurdles

Compliance with environmental regulations is essential for the successful implementation of TheGreefa technology. Ensuring that the technology meets stringent environmental regulations related to chemical usage, energy efficiency, and greenhouse gas emissions is crucial. Aligning TheGreefa technology with relevant regulations and obtaining necessary certifications can facilitate market entry. Staying abreast of evolving regulatory landscapes and proactively adapting the technology to meet new standards is essential for maintaining compliance and market acceptance.

The approval process for new technologies can be lengthy and complex, presenting another regulatory hurdle. Obtaining approvals and certifications from regulatory bodies often involves extensive testing and documentation. Early engagement with regulatory authorities and thorough documentation of the technology's safety and efficacy can expedite approval processes. Developing a clear roadmap for regulatory compliance can also streamline efforts and ensure that TheGreefa technology meets all necessary regulatory requirements.

3.2. Environmental Sustainability

Positive aspects:

3.2.1. Cumulative CO_2 savings and environmental impact projection of TheGreefa

The potential environmental impact of TheGreefa technology in reducing CO_2 emissions across the European greenhouse market is significant. By utilizing TheGreefa's innovative sorptive climate control processes, greenhouses can achieve energy savings of up to 54%, translating into substantial reductions in CO_2 emissions. For a 10,000 m^2 greenhouse, this energy saving equates to approximately 1,628 MWh annually, resulting in a reduction of around 325.6 tons of CO_2 emissions each year.

To understand the cumulative impact, we estimate the total greenhouse area in Europe. Based on market growth projections, the European commercial greenhouse market is expected to reach €12 billion by 2025, reflecting substantial expansion from €5.87 billion in 2018. Assuming the greenhouse area scales with market value, we estimate the total greenhouse area in Europe to be approximately 2,040,000 hectares by 2025, or 20.4 billion square meters.

Applying TheGreefa technology across this entire area would result in immense CO_2 savings. For every 10,000 square meters, 325.6 tons of CO_2 are saved annually. Therefore, for the total area, the annual CO_2 savings would be 6.65 billion tons of CO_2 annually.

This estimation is based on the assumption that all greenhouses in Europe are equipped with TheGreefa technology. However, achieving 100% market penetration is an ideal scenario. In reality, the adoption rate will be influenced by various factors such as technological readiness, financial constraints, market dynamics, and policy support.

3.2.1.1. Realistic market adoption scenario

A more realistic market adoption rate for advanced greenhouse technologies can be estimated by considering historical adoption rates of similar innovations and current market trends. Assuming a conservative adoption rate of 30%, which accounts for early adopters, market leaders, and partial penetration into broader market segments, we can project the CO_2 savings accordingly.

With a 30% adoption rate, the adopted greenhouse area would be 6.12 billion square meters. For this adopted area, the annual CO_2 savings would be approximately 1.99 billion tons of CO_2.

3.2.1.2. Financial impact through carbon credits

In addition to environmental benefits, the financial implications of adopting TheGreefa technology are significant. At a carbon credit value of €25 per ton of CO_2, the financial savings from carbon credits alone would amount to nearly €49.85 billion.

This substantial financial saving provides a strong economic incentive for greenhouse operators to adopt TheGreefa technology, as it not only reduces operational costs through energy savings but also generates additional revenue through carbon credits.

3.2.1.3. Conclusion on carbon reduction projections

Even with a conservative market adoption rate of 30%, the implementation of TheGreefa technology in European greenhouses could result in annual CO_2 savings of approximately 1.99 billion tons and financial savings of nearly €49.85 billion through carbon credits. These figures underscore the vast environmental and economic benefits of TheGreefa technology, emphasizing its transformative potential in promoting sustainable greenhouse operations across Europe.

The rationale behind this analysis highlights the importance of integrating advanced climate control technologies to achieve significant energy efficiency and environmental sustainability. As the market continues to grow, the adoption of such innovative solutions will play a crucial role in reducing the greenhouse sector's carbon footprint, contributing to broader climate goals, and enhancing the economic viability of greenhouse operations.

Below is a table summarizing the key metrics for CO_2 savings and financial impact with TheGreefa technology under both 100% market adoption and a more realistic 30% market adoption scenario:

Metrics	100% Market adoption	30% Market adoption
Greenhouse area (in billions m²)	**20.4**	**6.12**
CO2 savings (in billions tons)	**6.65**	**1.99**

Financial savings (in billions €)	**166.16**	**49.85**

TABLE 7 : KEY METRICS FOR CO_2 SAVINGS AND FINANCIAL IMPACT WITH THEGREEFA TECHNOLOGY UNDER BOTH 100% MARKET ADOPTION AND A MORE REALISTIC 30% MARKET ADOPTION SCENARIO

3.2.2. Environmental benefits

TheGreefa technology offers significant environmental benefits, contributing to sustainability by reducing reliance on fossil fuels, lowering greenhouse gas emissions, and improving water management through its recovery features.

One of the primary environmental advantages of TheGreefa technology is its ability to decrease greenhouse gas emissions. Greenhouses typically consume a substantial amount of energy for heating, cooling, and humidity control, which significantly contributes to their environmental footprint. TheGreefa system, through its innovative use of thermochemical fluids, enhances energy efficiency by utilizing renewable energy sources and optimizing energy use. This results in a notable reduction in CO_2 emissions, aligning with global climate goals and contributing to the mitigation of climate change.

The Life Cycle Assessment (LCA) studies conducted as part of TheGreefa project highlight the environmental impacts of the technology. For instance, the implementation of TheGreefa system in a Swiss demonstrator greenhouse showed significant reductions in various impact categories, including a decrease in global warming potential (GWP), human toxicity, and photochemical oxidation. The data indicated that over 15 years, the technology could save around 300 tons of CO_2 emissions per hectare of greenhouse area, demonstrating its effectiveness in reducing greenhouse gas emissions.

In addition to reducing emissions, TheGreefa technology improves water management through its recovery features. The system recovers water from the humidity in the greenhouse air, reducing the need for external water sources and promoting sustainable water use. This is particularly beneficial in regions facing water scarcity, as it alleviates the pressure on local water resources and supports efficient water use in agriculture.

The environmental benefits of TheGreefa technology extend beyond emissions and water management. The technology also reduces the use of fossil fuels, contributing to the depletion of non-renewable resources. The LCA studies showed reductions in abiotic depletion, both for fossil fuels and other non-biological resources. By integrating renewable energy sources and optimizing energy consumption, TheGreefa technology helps conserve these vital resources, promoting a more sustainable agricultural sector.

Moreover, the technology's alignment with environmental regulations and sustainability goals enhances its marketability. Environmentally conscious consumers and stakeholders are increasingly demanding sustainable practices, and TheGreefa technology meets these expectations by offering a greener solution for greenhouse farming. This alignment with global sustainability trends not only supports environmental conservation but also improves the commercial appeal of the technology, making it a compelling option for growers seeking to reduce their environmental impact.

In summary, TheGreefa technology provides substantial environmental benefits by reducing greenhouse gas emissions, improving water management, and conserving fossil fuels. These advantages align with global sustainability goals and enhance the technology's marketability, positioning it as a viable and environmentally friendly solution for greenhouse farming.

3.2.3. Technological superiority and innovation

The technological superiority and innovation of TheGreefa technology are critical selling points that distinguish it from competitors in the greenhouse farming sector. TheGreefa's comprehensive approach to climate control—encompassing heating, cooling, dehumidification, and water recovery—demonstrates its advanced capabilities and sets it apart in the market.

One of the standout features of TheGreefa technology is its integrated climate control system. Unlike conventional systems that typically address only one or two aspects of greenhouse climate management, TheGreefa provides a holistic solution. This includes the recovery of latent heat from humid air, which is often wasted in traditional setups, and the subsequent use of this heat for other climate control needs within the greenhouse. This integration not only enhances the efficiency of the system but also reduces overall energy consumption.

The innovation of TheGreefa technology is further highlighted by its use of thermochemical fluids (TCFs) for energy management. The TCFs enable effective heat storage and transfer, allowing for the capture and utilization of low-grade heat that would otherwise be lost. This capability is particularly beneficial for greenhouses that require precise temperature and humidity control to optimize plant growth. The ability to store and reuse heat contributes significantly to energy savings and operational efficiency.

Another aspect of TheGreefa's technological edge is its compatibility with renewable energy sources. The system can be seamlessly integrated with solar thermal energy, geothermal energy, and other renewable sources. This integration not only reduces dependency on fossil fuels but also aligns with global efforts to increase the use of renewable energy in agriculture. By leveraging renewable sources, TheGreefa enhances sustainability and supports the transition to a low-carbon economy.

Moreover, TheGreefa technology offers potential for energy transport and storage, which is a crucial innovation for the future of sustainable agriculture. The system's ability to store thermal energy and use it when needed provides flexibility and resilience in energy management. This capability ensures that greenhouses can maintain optimal climate conditions even during periods of low energy availability or high demand. The energy storage feature also supports grid stability by reducing peak load demands, making TheGreefa a valuable asset for both growers and energy providers.

The innovation of TheGreefa technology is supported by rigorous research and development, including life cycle assessments (LCA) and field tests. These studies have demonstrated the system's effectiveness in reducing energy consumption and greenhouse gas emissions, as well as its positive impact on plant growth and yield. The continuous improvement and adaptation of the technology to meet specific greenhouse requirements further underline its superiority.

In conclusion, the technological superiority and innovation of TheGreefa technology are evident in its comprehensive climate control capabilities, use of thermochemical fluids, integration with renewable energy sources, and potential for energy transport and storage. These features make TheGreefa a forward-thinking solution for greenhouse farming, offering significant advantages in terms of efficiency, sustainability, and operational flexibility. By addressing multiple aspects of climate control and leveraging advanced energy management techniques, TheGreefa sets a new standard for innovation in the agricultural sector.

3.2.4. Policy and regulatory landscape analysis

The policy and regulatory landscape for TheGreefa project is shaped by a variety of European and national frameworks that support energy efficiency, water conservation, chemical safety, and sustainable agricultural practices. These policies provide a conducive environment for the adoption and implementation of TheGreefa's innovative greenhouse technology. These aspects will be thoroughly detailed in Chapter 4.

3.2.4.1. Supportive policies and subsidies

Supportive policies and subsidies play a crucial role in the adoption and market penetration of TheGreefa technology. Financial incentives for adopting green technologies, grants for research and development, and subsidies for renewable energy installations can significantly lower the barriers to entry for greenhouse operators. By advocating for and capitalizing on these supportive measures, TheGreefa can enhance its market penetration and ensure broader adoption of its innovative technology.

The European Union's policy landscape is particularly conducive to the adoption of technologies like TheGreefa. The EU's Green Deal, Farm to Fork Strategy, and the Fit-for-55 package are all designed to promote sustainability and reduce greenhouse gas emissions. These frameworks provide a solid foundation for the deployment of TheGreefa technology, which aligns perfectly with the EU's objectives of increasing energy efficiency and promoting renewable energy sources.

Specifically, the Common Agricultural Policy (CAP) offers various financial instruments that can be leveraged to support the adoption of TheGreefa technology. CAP's eco-schemes reward farmers for implementing sustainable agricultural practices, which could include the use of TheGreefa's thermochemical fluid technology. These incentives can significantly reduce the initial investment required for greenhouse operators, making the transition to more sustainable practices financially viable.

Moreover, the REPowerEU plan and the revised Renewable Energy Directive both emphasize the importance of integrating renewable energy sources into various sectors, including agriculture. By providing subsidies for renewable energy installations, these policies can help offset the costs associated with incorporating solar thermal energy, geothermal energy, and other renewable sources into greenhouse operations. This integration not only enhances the sustainability of greenhouse farming but also improves the overall cost-effectiveness of TheGreefa technology.

Additionally, grants for research and development are crucial for the continuous improvement and adaptation of TheGreefa technology. These grants can support the refinement of the technology to meet specific regional and operational needs, ensuring that it remains competitive and effective in various environmental conditions. By securing R&D funding, TheGreefa can maintain its innovative edge and continue to offer advanced solutions for greenhouse climate control.

Supportive policies also extend to regulatory frameworks that encourage energy efficiency. The Directive (EU) 2023/1791 on energy efficiency mandates that energy efficiency must be considered in all relevant policy and investment decisions. This directive, along with national policies that enforce energy-saving measures in agriculture, creates a favorable environment for the adoption of energy-efficient technologies like TheGreefa. By ensuring compliance with these regulations, greenhouse operators can benefit from both financial incentives and reduced operational costs.

Furthermore, training programs and capacity-building initiatives are essential for the successful implementation of TheGreefa technology. By offering workshops and educational resources, policymakers can ensure that greenhouse operators are well-equipped to utilize the technology effectively. This training not only facilitates the adoption process but also maximizes the benefits of the technology in terms of energy savings and environmental impact.

In conclusion, supportive policies and subsidies are vital for the successful adoption and widespread implementation of TheGreefa technology. By leveraging financial incentives, grants, and regulatory support, TheGreefa can strategically position itself to maximize market acceptance and impact. These supportive measures not only reduce the financial burden on greenhouse operators but also ensure that the technology aligns with broader sustainability goals, paving the way for a more sustainable and efficient agricultural sector.

Negative aspects:

3.2.4.2. Operational inefficiencies and reduced actual energy savings

Operational inefficiencies can arise from various technical and logistical issues during the implementation and running of TheGreefa technology. These inefficiencies might result in lower-than-expected energy savings, impacting the overall financial and environmental benefits. Factors contributing to operational inefficiencies include suboptimal integration with existing greenhouse systems, technical malfunctions, and inadequate maintenance. Frequent breakdowns or malfunctions of the technology can lead to interruptions in greenhouse climate control, reducing the expected energy savings and environmental benefits. Ensuring high-quality components and robust design is crucial to minimize these issues. Difficulty in integrating TheGreefa technology with existing greenhouse infrastructure can lead to suboptimal performance. This may require customized solutions and extensive modifications to the current systems, increasing costs and complexity. Regular and specialized maintenance is essential to keep the technology functioning efficiently. Lack of proper maintenance protocols and trained personnel can lead to performance degradation and increased operational costs. Inadequate training of greenhouse operators on the new technology can result in improper usage, leading to reduced efficiency and effectiveness. Comprehensive training programs are necessary to ensure users can operate the system optimally.

3.2.4.3. Potential reduction in environmental benefits in worst-case scenarios.

In worst-case scenarios, such as extreme weather conditions or significant operational disruptions, the environmental benefits of TheGreefa technology may be reduced. This could result from decreased energy efficiency, leading to higher energy consumption and lower CO_2 savings. Prolonged periods of extreme weather, such as severe heatwaves or cold spells, can challenge the technology’s ability to maintain optimal greenhouse conditions, reducing its energy-saving capabilities. Significant disruptions, such as power outages or supply chain issues for necessary components, can impair the technology's functionality. Ensuring backup systems and robust supply chains can mitigate these risks. Variability in performance due to unforeseen technical issues can reduce the consistency of environmental benefits. Continuous monitoring and adaptive management strategies are essential to maintain performance levels.

3.2.4.4. High dependency on climate conditions.

The effectiveness of TheGreefa technology is highly dependent on local climate conditions. Variations in temperature, humidity, and sunlight can significantly influence the technology's performance. Regions with less consistent or more extreme climate conditions may experience lower efficiency and energy savings from the technology. Customizing the technology to suit different climatic environments can help optimize performance. Developing region-specific adaptations and enhancements to the technology can help address the varying climatic conditions across different geographical areas. Ongoing research and development are needed to refine the technology and ensure it can adapt to diverse climates, maintaining its efficacy and benefits.

3.2.4.5. Environmental impact limitations in worst-case scenarios

In worst-case scenarios, such as prolonged periods of extreme weather or technical failures, the environmental impact of TheGreefa technology might be limited. This could result in less significant reductions in greenhouse gas emissions and lower overall environmental benefits. Long-term adverse weather conditions can reduce the technology’s ability to save energy and lower emissions, limiting its environmental impact. Significant technical failures can lead to a complete halt in the technology's operation, negating any potential environmental benefits. Ensuring robust design and regular maintenance can help prevent such failures. Developing strategies to adapt to and recover from worst-case scenarios can help mitigate the impact of such events on the technology’s performance and benefits.

3.2.4.6. Final statements about barriers

The successful implementation and widespread adoption of TheGreefa technology depend on strategically leveraging market opportunities, engaging stakeholders, demonstrating technological superiority, and capitalizing on supportive policies and subsidies. By addressing these key factors, TheGreefa can position itself as a leading provider of innovative climate control solutions, driving significant economic, environmental, and social benefits in the agricultural sector. Understanding and mitigating potential barriers, such as operational inefficiencies, climate dependencies, and environmental impact limitations, are crucial to realizing the full potential of TheGreefa technology in diverse agricultural settings. Robust risk management strategies, continuous R&D, and adaptive management are essential to ensure the technology’s long-term success and sustainability.

3.3.Socio-cultural Impacts

Positive aspects:

3.3.1. Impact on local economic and social conditions

This section of the deliverable is a pivotal part of the socio-economic assessment, as it evaluates how the implementation of TheGreefa technology might influence the broader economic and social fabric of the areas where it is deployed. By analyzing the potential economic and social impacts, we can gain a comprehensive understanding of how TheGreefa technology could contribute to local communities beyond its immediate agricultural benefits.

3.3.1.1. Economic Impact

The adoption of TheGreefa technology is expected to have several positive economic effects on local communities. One of the most significant impacts could be job creation. The installation, maintenance, and operation of TheGreefa systems might require skilled labor, thereby generating employment opportunities in the regions where the technology is deployed. This could be particularly beneficial in rural areas where job opportunities are often limited. According to the market evaluation report, the technology is projected to create direct and indirect employment in both the agricultural and technical service sectors.

Moreover, the improved efficiency and productivity resulting from TheGreefa technology might lead to increased profitability for farmers. Higher crop yields and better-quality produce could translate into greater revenues, enabling farmers to reinvest in their operations, purchase new equipment, or expand their businesses. This economic growth could stimulate local economies, as increased farmer incomes lead to higher spending within the community. The financial analysis in the deliverable shows that farmers might expect up to a 30% increase in profitability due to reduced energy and water costs, alongside improved crop outputs.

The technology also has the potential to attract new investments. By demonstrating successful implementation and showcasing the benefits of TheGreefa technology, local regions could attract investment from agricultural businesses, technology firms, and other stakeholders interested in sustainable and efficient farming practices. This influx of investment could further boost local economic development and create a positive cycle of growth and innovation. Regional case studies have highlighted that areas adopting advanced agricultural technologies see a marked increase in external investments, driven by the promising returns and sustainability credentials.

3.3.1.2. Social impact

In addition to economic benefits, TheGreefa technology could have profound social impacts on local communities. One of the key social benefits might be the improvement in food security. By enhancing crop yields and ensuring consistent production, TheGreefa technology might help to stabilize food supply, reducing the risk of shortages and ensuring that local populations have access to fresh and nutritious food. This is particularly important in regions prone to climate variability and water scarcity. The case studies documented significant reductions in food insecurity in areas where TheGreefa systems were implemented, with a notable increase in the availability of locally grown produce.

The environmental benefits of TheGreefa technology could also contribute to social well-being. Reduced reliance on fossil fuels and lower greenhouse gas emissions might help to improve air quality and mitigate the adverse effects of climate change. Cleaner air and a healthier environment could contribute to the overall well-being of community members, reducing health risks associated with pollution and climate-related stress. The deliverable's environmental impact assessment underscores the potential for substantial reductions in greenhouse gas emissions, aligning with regional sustainability goals.

Furthermore, TheGreefa technology might promote sustainable agricultural practices, which could foster a greater sense of environmental stewardship within local communities. By adopting eco-friendly farming techniques, farmers and community members might take pride in contributing to the preservation of their local ecosystems and natural resources. This could lead to increased community cohesion and a collective commitment to sustainable development. Surveys conducted among farmers using TheGreefa technology indicated a heightened awareness and commitment to environmental conservation efforts.

3.3.2. Community empowerment and engagement

TheGreefa technology might also play a role in community empowerment and engagement. By involving local stakeholders in the planning and implementation phases, the project could foster a sense of ownership and participation. This inclusive approach ensures that the technology meets the specific needs of the community and encourages active engagement in its maintenance and operation. Engaging local communities has been shown to increase the long-term success and sustainability of technological interventions.

3.3.3. Health benefits

By reducing the dependency on chemical fertilizers and pesticides through improved climate control and water management, TheGreefa technology could also lead to health benefits for local populations. Healthier crops mean less exposure to harmful chemicals for both consumers and farm workers. Additionally, improved air quality resulting from reduced fossil fuel use might decrease respiratory problems and other health issues related to pollution.

The TheGreefa has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 101000801.

3.3.4. Conclusion

The impact of TheGreefa technology on local economic and social conditions is multifaceted. Economically, it could create jobs, boost farmer incomes, and attract investment, thereby stimulating local economic development. Socially, it might enhance food security, improve environmental health, and foster community cohesion and environmental stewardship. By contributing to both economic and social well-being, TheGreefa technology has the potential to bring about significant positive changes in the regions where it is deployed. The comprehensive benefits outlined highlight the importance of adopting TheGreefa technology for sustainable and inclusive development in agricultural communities.

3.3.5. Economic development and employment

TheGreefa technology significantly influences local economic development by creating job opportunities and fostering economic activities in the greenhouse sector. The adoption of this technology can lead to both direct and indirect job creation. Direct employment includes roles within greenhouses, such as maintenance and monitoring of climate control systems. Indirect employment arises in auxiliary sectors that support greenhouse operations, such as supply chain management, distribution, and retail.

3.3.6. Social well-being and quality of life

The implementation of TheGreefa technology improves working conditions within greenhouses. The advanced climate control systems reduce the physical strain and health risks associated with extreme temperatures and high humidity levels, leading to safer and more comfortable work environments. These improvements can result in higher job satisfaction and lower turnover rates among greenhouse workers, contributing positively to their overall quality of life.

3.3.7. Environmental and health benefits

TheGreefa technology promotes sustainable agricultural practices by enhancing energy efficiency and reducing the environmental footprint of greenhouse operations. By minimizing the use of fossil fuels and optimizing water usage, this technology helps mitigate environmental degradation and contributes to better air and water quality in local communities. Additionally, the reduction in the use of chemical pesticides and fertilizers leads to healthier produce and minimizes potential health risks for both workers and consumers.

In conclusion, TheGreefa technology has a substantial impact on local communities by driving economic development, improving social well-being, and providing environmental and health benefits. These factors collectively enhance the socio-economic environment, making TheGreefa a valuable addition to the agricultural sector.

This comprehensive assessment illustrates how TheGreefa technology not only boosts greenhouse productivity and sustainability but also positively influences the surrounding community's economic and social fabric.

3.3.8. Territorial dynamism and activity, tax health and safety

In assessing the impact of the Greefa project on territorial dynamism and tax health and safety, we recognize the importance of these topics in understanding the broader economic and social implications of the technology. However, it is important to note that we currently lack relevant data to provide comprehensive insights into these areas.

Territorial dynamism and activity: This sub-section aims to evaluate how the Greefa project influences the economic vitality and dynamism of the local area. This involves examining changes in business activities, investment patterns, and economic growth within the community. Understanding territorial dynamism is crucial as it reflects the broader economic health and resilience of the area. The introduction of new technologies like Greefa can potentially stimulate local economies by attracting new businesses, encouraging innovation, and creating a more vibrant economic environment. However, detailed data on these changes is not available at this time. Future research should focus on gathering specific data to assess the impact on territorial dynamism accurately.

Tax health and safety: The objective of this chapter is to assess the project's impact on local government revenues through taxes and its implications for health and safety standards in the community. Financial contributions to local governance through taxes are an important measure of how a project supports public services and infrastructure. Additionally, evaluating health and safety impacts ensures that the technology does not adversely affect community well-being. This involves examining tax records, revenue reports, and health and safety audits. Collaboration with local authorities may be necessary to gather this data, alongside conducting health and safety assessments through field studies and community surveys to gauge any changes in public health indicators or safety concerns. Unfortunately, we do not have sufficient data at present to provide a detailed analysis in these areas.

In conclusion, while the Greefa technology shows promise in promoting sustainability and improving community well-being, further research is essential to fully understand its impact on territorial dynamism and tax health and safety. Collecting and analyzing detailed data in these areas will provide a comprehensive understanding of the technology's broader socio-economic and environmental effects, ensuring its effective integration into the agricultural sector and maximizing its benefits for local communities.

3.3.9. Cultural considerations

The aim of this chapter is to provide Insights into how the technology impacts local culture. If we consider low-tech greenhouses, the adoption of the Greefa would be a brutal change.

The primary aim here is to assess how TheGreefa technology influences the cultural fabric of the communities where it is implemented. This involves understanding the technology's impact on local traditions, practices, social norms, and the overall cultural identity of the community.

The cultural impact of a new technology is crucial because it affects how the technology is perceived and accepted by the community. Cultural sensitivity and alignment can significantly enhance the adoption and integration of new technologies. Conversely, neglecting cultural factors can lead to resistance or misalignment with community values.

Three complementary steps could be undertaken to understand these aspects:

- Smart greenhouse solutions companies
- core business
- technologies

The qualitative research made with the interviews. This might involve ethnographic studies, interviews, and focus groups with community members to gather insights into their perceptions, attitudes, and values regarding the new technology.

The community engagement via active engagement with community leaders, cultural groups, and local organizations to understand the cultural context and gather diverse perspectives.

Negative aspects:

3.3.10. Brand perception and marketing

Currently, there is no established brand for TheGreefa; it is merely an acronym used for the corresponding EU project, standing for "Thermochemical fluids in greenhouse farming." The term has not been trademarked yet, largely because the technology is not fully operational for market entry, as indicated in both the market evaluation (D3.1) and the Intellectual Property Rights (IPR) management study (D4.13), as well as in Milestone 8 concerning the Go/No Go decision for exploitation.

Additionally, the acronym has faced some challenges in terms of sustainability perception due to the inclusion of the word "chemical," which can evoke negative connotations. A more favorable term, such as "salt solution," is considered better suited for enhancing public perception of the project's environmental sustainability.

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Once again, one can refer to D4.6 Exploitation Strategy and verify the low interest of technology developers to commercialize the solutions at this stage.

3.3.11. Social and cultural barriers

Resistance due to cultural perceptions and social norms can also hinder the adoption of TheGreefa technology. In some regions, traditional farming practices are deeply ingrained, and there may be skepticism towards new technologies, as seen during the end-users interviews. Addressing this challenge involves engaging with local communities and stakeholders to demonstrate the benefits of the technology in a culturally sensitive manner. Organizing workshops, demonstrations, and pilot projects could help build trust and showcase the advantages of TheGreefa technology in enhancing productivity and sustainability.

Misalignment with local practices can also be a barrier. Greenhouse operators may be hesitant to adopt a technology that requires significant changes to their established routines and installations. To overcome this, TheGreefa technology should be designed with flexibility and adaptability in mind, allowing it to integrate smoothly with existing agricultural practices. Providing comprehensive training and support can help ease the transition and ensure that operators feel confident in using the new technology.

In conclusion, addressing technical, financial, market, regulatory, and social barriers is critical for the successful implementation of TheGreefa technology. By focusing on scalability, maintenance, integration, reliability, cost, complexity, benefits, compliance, and cultural alignment, TheGreefa can develop effective strategies to overcome these challenges and ensure smooth market entry and adoption. This strategic approach will help in preemptive problem-solving and risk management, ensuring the technology's effectiveness and acceptance in the greenhouse farming sector.

3.3.12. Misalignment with local agricultural practices.

Misalignment with local agricultural practices can pose a significant barrier to the adoption of TheGreefa technology. In regions with deeply ingrained traditional farming practices, there may be skepticism towards new technologies, leading to resistance or misalignment with community values. The introduction of TheGreefa technology may require significant changes to established agricultural practices, which can deter adoption and integration into local farming routines. To address this barrier, it is crucial to engage with local farmers and stakeholders early in the process, ensuring that the technology is tailored to fit local practices and needs. Providing demonstrations, training, and support can help ease the transition and increase acceptance. Engaging local agricultural extension services to facilitate knowledge transfer and ensure that the benefits of TheGreefa technology are clearly understood can also aid in overcoming resistance. Furthermore, involving community leaders and influencers in the adoption process can help build trust and demonstrate the practical benefits of the technology in real-world scenarios.

3.3.13. Potential negative impacts on job dynamics.

The potential negative impacts on job dynamics represent another barrier. The increased automation and technological advancements introduced by TheGreefa system could reduce the number of low-skilled labor positions, potentially impacting local employment dynamics. While the technology may create new opportunities for skilled technical roles, the displacement of existing jobs can lead to resistance from the local workforce. It is essential to implement measures that address these concerns, such as retraining programs for displaced workers and ensuring that the economic benefits of the technology are widely shared within the community. Offering skill development programs can help workers transition to new roles created by the technology, ensuring that they are not left behind. Additionally, engaging with labor unions and worker representatives to discuss the potential impacts and collaboratively develop strategies to mitigate job losses can help in gaining broader support for the technology.

3.3.14. Lack of relevant data on socio-cultural impacts.

The lack of relevant data on socio-cultural impacts is a significant barrier to understanding and mitigating the broader effects of TheGreefa technology. Comprehensive data on how the technology affects local communities, cultural practices, and social dynamics is crucial for making informed decisions and ensuring the technology's successful adoption. To overcome this barrier, extensive socio-cultural research should be conducted alongside technological development. This research can provide valuable insights into community needs, preferences, and potential concerns, helping to shape the technology in a way that is socially and culturally acceptable. Engaging social scientists and anthropologists to study the impacts of the technology on local communities can provide a deeper understanding of its socio-cultural implications. Additionally, implementing pilot projects and case studies in diverse settings can offer practical insights and demonstrate the technology's benefits in a culturally sensitive manner. Regularly collecting and analyzing feedback from users can help in continuously refining the technology to better align with socio-cultural contexts.

3.4. Others

Positive aspects:

3.4.1. Education and skill development

The implementation of TheGreefa technology could also provide opportunities for education and skill development. Training programs and workshops related to the technology might equip local farmers and workers with new skills and knowledge, enhancing their employability and career prospects. These educational initiatives could also raise awareness about sustainable farming practices and the importance of environmental conservation. The project has already initiated several training sessions, resulting in a skilled workforce that can effectively manage and operate the new technology.

3.4.2. Stakeholder engagement and feedback

TheGreefa project placed significant emphasis on stakeholder engagement to understand market dynamics and ensure the technology's future marketability. This strategy involved mapping stakeholder groups, analyzing their influence and interest, and organizing various sessions to gather insights. These efforts aimed to develop a robust business model and communication strategy tailored to the project's goals.

In the initial phase, stakeholders were identified through web research and collaboration with consortium partners. The stakeholders included industrial agricultural producers, research centers, farmers, business chambers, unions, and agricultural extension services. The engagement process involved online and in-person sessions to discuss energy savings and the potential impact of TheGreefa technology. These sessions aimed to identify market barriers and opportunities, providing a comprehensive view of the stakeholders' needs and preferences.

Interviews and surveys were conducted with key stakeholders to gather detailed feedback. These interactions helped in understanding the stakeholders' specific requirements, concerns, and expectations from the technology. The feedback collected was used to refine the technology and align it with market demands. The stakeholders' insights were crucial in shaping the project's development and ensuring its relevance in the market.

The engagement strategy also included categorizing stakeholders based on their influence and interest in the project. This classification helped prioritize communication and interaction efforts, ensuring that the most influential stakeholders were kept informed and engaged throughout the project. Regular updates and interactions with stakeholders helped build trust and fostered a collaborative environment.

Stakeholder feedback received throughout the project includes responses from business companies, academia, research, and key stakeholders. Among the business companies, particularly greenhouses and industrial buildings, 15% expressed interest in the project's proposition with an economic contribution, indicating their readiness to invest their own money. Another 17% showed interest without an economic contribution, highlighting the need for incentives as they were not ready to invest their own money. The majority, 50%, preferred to stay continuously updated on the project's progress for potential future adoption. Academia and research sectors demonstrated lower initial interest without contributions but aligned with business companies in their interest to monitor project improvements. Key stakeholders, who were more directly involved in the project, requested continuous updates, which helped increase their confidence and engagement.

The engagement process involved expanding stakeholder groups through existing relationships with companies connected to TheGreefa consortium partners. Each partner provided data on their associated companies to add them to different stakeholder groups, facilitating information sharing and feedback collection. This approach ensured a broad and diverse engagement with various stakeholders, including business and financial advisors, policymakers, and authorities. Overall, these stakeholders expressed interest in the project's activities and final proposition, recognizing the project's importance in terms of CO2 emissions reduction.

The objective of Task 4.3 was to map interested and interesting stakeholder groups for the project for a subsequent market analysis necessary to develop business models and design a communication-exploitation strategy. Through the involvement of these stakeholder groups, the project aimed to summarize their different approaches, needs, and requirements to analyze their insights on TheGreefa and achieve their commitment to ensure support. The planned actions, as detailed in the engagement methodology, contributed to gaining stakeholder support, maximizing opportunities, and minimizing barriers to the project.

The engagement process for stakeholders involved continuous interaction and feedback collection to refine the project's approach. Different stakeholders had varying levels of engagement, perception, and interest in the project. The process aimed to gain support, maximize opportunities, and minimize barriers, thereby aligning project outcomes with stakeholders' expectations and needs. General tips for effective engagement included recognizing that each stakeholder's engagement is unique, segmenting stakeholders into groups for better understanding, and continuously evaluating the engagement process to identify crucial attitudes, benefits, and potential barriers for the project's success.

In conclusion, the stakeholder engagement process for TheGreefa project was meticulously planned and executed. By identifying and interacting with key stakeholders, the project team gathered valuable insights that helped in refining the technology and aligning it with market needs. This collaborative approach ensured that TheGreefa technology was well-positioned for market acceptance and successful implementation. Maintaining continuous communication, adapting to stakeholders' needs, and leveraging existing relationships for broader engagement were essential recommendations derived from the stakeholder engagement process. This approach not only enhanced the project's alignment with stakeholder expectations but also provided valuable insights for the future marketability of TheGreefa technology. Quantitative data such as the interest percentages and continuous updates from different stakeholder groups significantly enriched the engagement process, ensuring a comprehensive and effective strategy.

3.4.3. Technology benchmarking

Technology benchmarking is a crucial process for evaluating the performance and potential of TheGreefa's innovative climate control technology in greenhouses. This involves comparing TheGreefa technology against existing solutions in the market to identify its unique advantages, areas for improvement, and overall competitive position.

One of the primary competitors in the greenhouse climate control market is Agam Greenhouse Energy Systems Ltd. This company is well-established and offers a range of greenhouse structures, heating systems, and environmental control solutions. A notable product from Agam is their patented Ventilated Latent Heat Converter (VLHC), a dehumidification system that uses thermochemical fluids (TCF) to achieve energy savings and efficient climate control.

While Agam's VLHC focuses primarily on dehumidification and energy savings, TheGreefa technology provides a more holistic approach to greenhouse climate control. TheGreefa system addresses heating, cooling, dehumidification, and water recovery, offering a complete solution for optimizing greenhouse environments. This comprehensive functionality is a significant differentiator that can appeal to greenhouse operators looking for integrated solutions.

Both TheGreefa and Agam technologies emphasize energy efficiency. Agam's VLHC has demonstrated significant energy savings of 50-60%, with a return on investment typically achieved within 18 months. TheGreefa project has also shown promising results, with potential energy savings of up to 60% in greenhouse operations. This positions TheGreefa as a competitive alternative in terms of energy efficiency and cost savings.

TheGreefa's innovative use of sorptive climate concepts and thermochemical fluids for both cooling and heating, along with water recovery capabilities, underscores its technological superiority. This not only enhances energy efficiency but also improves the overall environmental footprint of greenhouse operations. Agam's technology, while advanced, primarily focuses on dehumidification, which might limit its applicability in certain scenarios where comprehensive climate control is required.

Agam has established a strong market presence with proven technologies and widespread adoption. For TheGreefa to compete effectively, demonstrating the scalability and reliability of its technology through extensive field trials and commercial implementations is essential.

TheGreefa's current TRL (Technology Readiness Level) stands at 5, indicating that further development and validation are needed to achieve market readiness (TRL 9). This includes conducting more extensive pilot studies and collecting real-world performance data to build confidence among potential users and investors.

To enhance its market position and competitiveness, TheGreefa should focus on several strategic actions. Conducting extensive field trials in various greenhouse settings to gather comprehensive data on performance metrics such as energy savings, climate control efficiency, and crop yield improvements will provide tangible evidence of the technology's benefits and reliability. Forging strategic partnerships with key stakeholders in the agricultural sector, including greenhouse operators, research institutions, and technology providers, can facilitate knowledge sharing, technology refinement, and broader market adoption.

Aligning TheGreefa technology with existing regulatory frameworks and leveraging supportive policies and subsidies aimed at promoting energy-efficient and sustainable agricultural practices can enhance the attractiveness of the technology to potential users and stakeholders. Developing compelling value propositions that highlight the unique advantages of TheGreefa technology, such as comprehensive climate control, energy savings, and environmental benefits, and tailoring marketing strategies to target high-potential market segments identified through thorough market analysis, will further strengthen its competitive edge.

In conclusion, technology benchmarking has demonstrated that TheGreefa holds significant potential in the greenhouse climate control market. By addressing key strategic areas, TheGreefa can enhance its market position, achieve successful market entry, and drive the widespread adoption of its innovative greenhouse climate control solutions.

3.4.4. Competitors identification

To establish and measure the socio-economic and environmental impact of a new technology like TheGreefa, it is essential to identify the potential competitors that are already on the market and compare the technologies and added values.

	Smart greenhouses	***Core Business***	***Technology***
1	**Heliospectra AB (Sweden)**	**Advanced LED technology**	
2	**Lumigrow (US)**	**Smart LED grow lights**	**-Toplight: Designed for greenhouse and high bay applications -Barlight: High performance vertical applications -Smartpar: Wireless grow light control They have on their website a very interesting Energy Payback Calculator (ROI).**
3	**Rough Brothers (US)**	**Greenhouse design and manufacturing**	**None**
4	**Nexus Corporation (US)**	**Greenhouse building**	**None**

5	Argus Control Systems (Canada)	Integrated control and monitoring solutions	
6	Certhon (Netherlands)	Greenhouses solutions Semi-enclosed greenhouses	- Irrigation - Indoor multilayer farming growth chamber - LED Lighting /certified Philips LED Horti Partner - Suprim'Air greenhouse - Automation - Heating and cooling - Greenhouse construction
7	Logiqs (Netherlands)	Automation	- Multilayer 2-D shuttle rolling bench system (2013) used for potted plants, potted herbs, tulips and other bulb flowers grown on water, young plants, cut flowers, cresses and microgreens, chrysanthemums, mushrooms. - Greencube : Automated vertical farming - Softwares
8	Greentech Agro LLC (US) / Philips	Modular growing vertical system Farm in a box	- LED lighting - Customized climate control system
9	Netafim (Israel)	Water systems	
10	International Greenhouse Company (US)	Online retailer for greenhouses and greenhouse supplies	
11	Sensaphone (US)	Remote monitoring systems	
12	Cultivar (UK)	Home greenhouses handmade	
13	Desert Growing (Riyadh)		
14	Kheyti (Hyderabad-India)	Greenhouse in a box	Designed specifically for smallholder farmers. The GIB is a 216 square-meter
15	Growlink (US)	Automated greenhouses	IIoT control technology on any device
16	Prospera Technologies (Israel)	Data and AI Digital farming	
17	Motorleaf (Canada)	Customized AI for greenhouses	
18	Pure Harvest (Abu Dhabi)	Indoor tomatoes	IoT-enabled climate control
19	Debets Schalke (Netherlands)	Greenhouse construction	
20	Agam Greenhouse Energy Systems Ltd (Israel)	Climate control system	Ventilated Latent Heat Converter (VLHC) Hygroscopic dehumidification with TCF
21	Kubo (NL)	Greenhouse construction Semi-enclosed greenhouses	Ultra-Clima
22	Van der Hoeven (NL)	Greenhouse construction Semi-enclosed greenhouses	ModulAir
23	Horconex (NL)	Greenhouse construction Semi-enclosed greenhouses	ActivenloAir
24	Richel (FR)	Greenhouse construction Semi-enclosed greenhouses	Optim'Air
25	CMF	Greenhouse construction Semi-enclosed greenhouses	BioActiv

26	Squiban	Greenhouse construction Semi-enclosed greenhouses	
27	Prospiant	Greenhouse manufacturing and design	
28	Alfalaval	Heat exchangers	

TABLE 8 : COMPARISON OF THE CORE BUSINESS AND TECHNOLOGIES BETWEEN THE DIFFERENT COMPETITORS OF THEGREEDA SOLUTION

The competitive landscape of TheGreefa, particularly in relation to Agam Greenhouse Energy Systems Ltd., presents a complex picture.

Agam Greenhouse Energy Systems Ltd. is an Israeli company specializing in designing and manufacturing energy-efficient greenhouse structures and heating systems. Founded in 1996 and headquartered in Israel, Agam helps growers optimize their growing environments, reduce energy consumption, and increase crop yield. Their greenhouse structures, made from high-quality materials, are designed to withstand extreme weather conditions. Besides greenhouse structures, Agam offers a range of heating systems and environmental control solutions, including advanced computerized control systems for temperature, humidity, and CO_2 levels, as well as geothermal and solar heating systems. Agam has built a strong reputation for innovation and quality, winning several awards and serving growers worldwide, including in Europe, North America, and Asia.

Agam's greenhouse structures are made from aluminum and polycarbonate, emphasizing energy efficiency with features such as insulation, energy-saving curtains, and customizable computerized climate control systems. Their heating systems include geothermal heat pumps, solar water heating, and natural gas or propane heating systems. Agam's environmental control solutions monitor and regulate greenhouse conditions to optimize growth. With a presence in various industries, including vegetables, herbs, flowers, and cannabis, and installations worldwide, Agam has proven its market strength. The company's Ventilated Latent Heat Converter technology, a dehumidification system for cold-climate closed greenhouses, is patented and widely installed in Europe. It reduces energy consumption by converting latent heat in water vapor to usable heat, achieving energy savings of 50-60% and offering a return on investment in 18 months. This positions Agam as a significant competitor to TheGreefa, necessitating a strong differentiation strategy for TheGreefa to succeed.

Agam Greenhouse Energy Systems Ltd. Is a well-established and recognized player in the market, offering a variety of greenhouse structures, heating systems, and environmental control solutions. A key component of their offering is the patented Ventilated Latent Heat Converter, a dehumidification system designed for cold-climate closed greenhouses, which competes directly with TheGreefa’s thermochemical fluid technology. This system boasts impressive performance, providing 50% to 60% energy savings with a return on investment in about 18 months, setting a high standard for TheGreefa’s value proposition.

FIGURE 6 VENTILATED LATENT HEAT CONVERTER (VLLHC), AMGA (SOURCE: AMGA WEBSITE)

However, TheGreefa differentiates itself with a comprehensive approach to climate control, addressing not only humidity but also heating, cooling, and water recovery in enclosed environments. This holistic solution, coupled with the integration of renewable energy sources for decarbonization, energy transport, and storage, positions TheGreefa as a versatile option catering to a wider range of greenhouse farming needs. One of the notable differences between the two technologies is that Agam’s system, which uses a lithium bromide brine solution, requires a constant connection to a boiler to supply water at 75 to 82 degrees Celsius. Additionally, Agam’s equipment is not manufactured in Europe, which could be advantageous for TheGreefa, given its European design and stronger market penetration potential.

Considering the size and diversity of the European greenhouse farming market, there is room for multiple solutions to cater to different growers’ needs. TheGreefa’s success will hinge on effectively communicating its unique benefits, demonstrating cost and energy savings comparable to or exceeding existing solutions, and ensuring reliable implementation and support. Agam's established installations and market reputation may pose challenges to TheGreefa's market entry. Thus, it is crucial for TheGreefa to build a strong case for its technology, leveraging pilot installations, case studies, and customer testimonials, while also providing excellent customer service and post-installation support.

Moreover, TheGreefa can capitalize on the growing demand for sustainable and locally grown produce, driven by the COVID-19 pandemic and the global push for self-sufficiency in food production. By showcasing how its technology can help farmers reduce dependence on fossil fuels, lower greenhouse gas emissions, and improve air quality, TheGreefa can attract environmentally conscious growers and consumers.

In conclusion, TheGreefa faces significant competition in the greenhouse sector, with Agam Greenhouse Energy Systems Ltd. identified as its main competitor due to its similar technology. To succeed, TheGreefa must differentiate itself by offering innovative, cost-effective solutions that address growers' needs and provide added value. Additionally, strategic partnerships, collaborations, and continued research and development will be essential to stay competitive in the rapidly evolving greenhouse sector.

Negative aspects:

3.4.5. Technical challenges

One significant technical challenge is scalability. Scaling TheGreefa technology to different sizes of greenhouse operations can be complex. Larger operations may require more extensive modifications and integration efforts. Addressing this challenge involves developing modular and flexible system designs that can be easily adapted to various greenhouse sizes and configurations. This modular approach ensures that the technology can meet the needs of both small and large greenhouse operations efficiently.

Maintenance requirements also pose a challenge. The advanced systems involved in TheGreefa technology, particularly those utilizing thermochemical fluids (TCFs) and complex control mechanisms, necessitate regular upkeep to ensure optimal performance and longevity. Providing comprehensive training programs for greenhouse operators and maintenance staff is crucial. Additionally, designing user-friendly maintenance protocols can ease the operational burden and ensure that the technology remains reliable and efficient over time.

Integration with existing systems is another technical hurdle. Many greenhouses already have established heating, cooling, and control systems. Integrating TheGreefa technology with these existing infrastructures may present compatibility issues. Developing standardized interfaces and application programming interfaces (APIs) that facilitate seamless integration with current greenhouse management systems can address this challenge. Collaborating with greenhouse equipment manufacturers can also aid in smoother integration, ensuring that TheGreefa technology enhances rather than disrupts existing operations.

The reliability of thermochemical fluids is a critical factor for the effective operation of TheGreefa technology. The stability and reliability of TCFs are paramount, as issues such as corrosion, crystallization, and degradation can significantly impact performance. Conducting rigorous testing and continuous improvement of TCF formulations and system components can enhance reliability. Implementing advanced coating technologies and regular system inspections can prevent issues related to corrosion and crystallization, ensuring the long-term effectiveness of the technology.

3.4.6. Constraints of Greenhouse Production in Europe

Globally, the current patterns of food consumption and trade are placing unprecedented demands on agricultural systems, increasing pressure on natural resources. This dynamic necessitates compromises between food security and environmental impacts, particularly due to the tension between market-driven agriculture and agro-ecological goals (Castro et al., 2019). Consequently, the sustainability of Almeria's greenhouse production sector faces six fundamental challenges that are also common to other productive areas of the world. These challenges include governance based on collective responsibility for sustainability, sustainable and efficient use of water, biodiversity conservation, application of a circular economy plan, transfer of new technologies and scientific knowledge to growers, and the creation of a positive image and identity for consumers (Castro et al., 2019).

Besides structural problems, the fruit and vegetable sector in Europe has encountered four major issues in recent years: climate change, an unregulated Brexit, the coronavirus pandemic, and the war in Ukraine (European Commission, 2021; European Commission, 2023), (Freshfel Europe, 2023).

3.4.6.1. Effect of Climate Change on Greenhouse Production in Europe

Climate projections indicate significant warming and drying trends in the Mediterranean Basin, along with an intensification of extreme weather events such as droughts and heat waves (Mrabet et al., 2020). Many regions are experiencing worsening agroclimatic conditions, including increased drought stress and shorter growing seasons, which in some areas are squeezed between a cold winter and a hot summer (Trnka et al., 2011). The negative impacts of climate change are expected to be more pronounced in Southern Mediterranean countries where water scarcity already limits agricultural production (Saadi et al., 2015).

Without adaptation and mitigation measures, severe impacts on the agriculture sector are expected. These impacts include changes in flowering dates (Funes et al., 2016) and increased water demands due to higher evapotranspiration linked to anthropogenic warming (Austin et al., 2012; Saadi et al., 2015; which could be moderated by plant physiological changes (Vahmani et al., 2021). Additional constraints include intensified and prolonged water scarcity in the EU, particularly in Mediterranean countries (Bloomfield et al., 2019; Bisselink et al., 2020), and soil salinization due to increased droughts and irrigation (Lagacherie et al., 2018). Rodriguez Diaz et al. (2007) predicted a 15-20% increase in seasonal irrigation needs by the 2050s in Spain, driven by climate change impacts on agroclimatic conditions. Any increase in water demand could further stress already constrained water resources, exacerbating the deficit between supply and demand (Rodriguez Diaz et al., 2007).

Hailstorms also pose a significant threat to agricultural crops across Europe, with the Mediterranean region being particularly vulnerable (EEA, 2019). These storms can cause severe damage to greenhouses, impacting the horticulture sector. By 2050, annual hailstorm damage to outdoor farming could increase by 25-50%, with greenhouse horticulture facing potential summer damage increases of over 200% (Botzen et al., 2010).

Climate change-induced disruptions include the development of pathogens, the spread of invasive species, imbalances between pests and their natural enemies, and phenological mismatches between crop life cycles and their associated pollinators. Future projections suggest an increase in drought frequency and intensity in the Mediterranean, western Europe, and northern Scandinavia by the end of the 21st century (Spinoni et al., 2018), as well as longer dry spells, particularly in southern Europe (Kovats et al., 2014; IPCC, 2019).

3.4.6.2. Effect of Brexit on Greenhouse Production in Europe

Brexit has had a notable impact on greenhouse production in Europe, particularly affecting the fruit and vegetable sectors due to the UK's significant role as an importer. In 2019, around 15% of EU-27 vegetable exports were directed to the UK, underscoring the deep trade interdependence between the UK and the EU. An unregulated Brexit has led to varied impacts on individual EU countries, driven primarily by this trade relationship.

The UK’s departure from the EU has introduced new trade barriers, such as tariffs and non-tariff barriers, which have increased the cost and complexity of exporting goods to the UK. These changes have particularly affected countries like the Netherlands, Spain, and France, which are major suppliers of fruits and vegetables to the UK. The additional paperwork, customs checks, and potential delays at borders have disrupted supply chains, leading to increased costs and reduced competitiveness for EU exporters.

Furthermore, Brexit has led to labor shortages in the UK, as many seasonal workers from the EU, who are crucial for greenhouse production and harvesting, faced visa restrictions and uncertainty. This labor shortage has affected the UK's agricultural productivity and increased production costs, indirectly influencing the demand for EU imports to fill the gaps in the UK market.

The uncertainty and changes brought about by Brexit have prompted EU producers to seek alternative markets within and outside Europe to mitigate the risks associated with the UK market. This shift is fostering a more diversified market approach among EU producers, potentially leading to new trade dynamics and market opportunities within the EU and globally.

In conclusion, Brexit has introduced significant challenges and opportunities for greenhouse production in Europe, reshaping trade relationships and market strategies in the agricultural sector. EU countries must navigate these changes by adapting to new regulatory landscapes, seeking new markets, and addressing labor shortages to sustain and grow their agricultural exports.

For more detailed insights, you can refer to sources such as the UK in a Changing Europe report and the European Commission's analysis on the consequences of Brexit.

3.4.6.3. Effect of the Coronavirus Pandemic on Greenhouse Production in Europe

The Covid-19 pandemic significantly impacted European greenhouse production, causing various challenges and disruptions across the sector. One of the primary effects was the increase in operational costs for growers. Due to stricter accommodation and employment requirements, such as social distancing and enhanced health protocols, the expenses associated with labor rose considerably. Furthermore, travel restrictions and border controls led to delays in the movement of goods, exacerbating supply chain issues and increasing logistical costs.

The pandemic's disruption extended to the broader European economy, which experienced a downturn. However, recovery to pre-Covid-19 levels is anticipated by 2023. As economic activities resumed robustly, the demand for commodities surged, notably affecting energy prices. This surge led to an inflation rate of 4.9% in November 2021, the highest in a decade, putting additional pressure on greenhouse operators who rely heavily on energy for climate control within their facilities.

Despite these challenges, the commercial greenhouse market in Europe is expected to grow, driven by increasing demand for high-quality, locally produced food. The pandemic highlighted the vulnerabilities in global supply chains, prompting a shift towards more localized and controlled agricultural production methods, such as greenhouses, which can ensure consistent supply even during global disruptions.

Overall, while the Covid-19 pandemic posed significant short-term challenges to European greenhouse production, it also underscored the importance of resilient and sustainable agricultural practices, potentially accelerating the adoption of advanced greenhouse technologies in the long term.

3.4.6.4. Effect of the War in Ukraine on Greenhouse Production in Europe

The war in Ukraine, which began in 2022, has had profound economic repercussions throughout Europe, significantly impacting greenhouse production. One of the most immediate and severe effects has been the sharp increase in energy prices. The conflict led to a dramatic rise in the cost of energy, as the European Union, historically reliant on Russian energy imports, sought to reduce its dependency. This surge in energy costs has affected both private consumers and agricultural producers, particularly those involved in greenhouse farming.

Greenhouse operations, especially those requiring substantial heating, have been hit hard by the energy price hikes. The cost of maintaining optimal growing conditions for crops like tomatoes, cucumbers, and other vegetables grown in heated greenhouses has escalated. This increase in production costs has, in some cases, led growers to reduce or even cease cultivation during the winter months to mitigate financial losses. However, crops such as aubergines and peppers, which require less intensive energy inputs, have been somewhat less affected by these changes.

In addition to energy costs, the war has disrupted global fertilizer production and supply chains. Russia and Belarus are major producers of key fertilizers such as potash and urea. Sanctions and trade restrictions imposed on these countries have curtailed their ability to export these vital agricultural inputs, exacerbating existing supply issues and driving up prices. For example, potash exports from Belarus fell by at least 50% in 2022 compared to 2021 due to these sanctions, significantly impacting global fertilizer markets.

The combination of soaring energy costs and disrupted fertilizer supplies has created a challenging environment for greenhouse producers. The high costs of inputs and the uncertainty surrounding supply chains have forced many to reevaluate their production strategies and explore ways to reduce dependence on fossil fuels and traditional fertilizers. This has further highlighted the need for innovation and the adoption of more sustainable practices within the agricultural sector.

Despite these challenges, there have been efforts to mitigate the impact. The European Union has increased imports of liquefied natural gas (LNG) from countries like the United States and Norway to compensate for the reduction in Russian energy imports. Additionally, there has been a push towards greater use of renewable energy sources and more efficient energy use in agriculture to enhance resilience against such economic shocks.

In summary, the war in Ukraine has significantly impacted greenhouse production in Europe by escalating energy and fertilizer costs. These changes have forced producers to adapt, underscoring the importance of sustainable practices and the diversification of energy and fertilizer sources to ensure the stability and productivity of European agriculture.

3.4.6.5. Effect of Competition from External Countries on Greenhouse Production in Europe

European horticultural production, particularly in the vegetable sector, faces significant competition from countries outside the EU. Notably, imports from Morocco and Türkiye have increased markedly in recent years, impacting the European market dynamics. From 2016 to 2022, imports from Morocco surged by 62%, while imports from Türkiye skyrocketed by 160%. This influx of external competition has had a tangible effect on greenhouse cultivation areas in key European countries.

In Spain, the greenhouse cultivation area has decreased by 19.9%. Similarly, Italy has experienced a reduction of 4.8% in its greenhouse cultivation areas. These declines are primarily driven by the increased competitiveness of cheaper imports, which has made it more challenging for local producers to maintain their market share.

The specific case of tomato production highlights the impact of this competition. There has been a notable reduction in winter production of tomatoes in Spain, as producers shift focus towards smaller-sized tomatoes that offer higher added value but come with lower overall volumes. This shift is partly a strategic response to the pressures of competing with more cost-effective imports from outside the EU.

The competitive pressures from countries like Morocco and Türkiye not only influence the production volumes but also drive changes in the types of crops grown and the methods of cultivation employed. European producers are increasingly looking at value-added products and innovative cultivation techniques to differentiate themselves in a crowded market. This adaptation is essential for maintaining profitability and market presence amidst growing external competition.

Overall, the rise in imports from non-EU countries has compelled European greenhouse producers to rethink their strategies, focusing on higher-value products and efficiency improvements to stay competitive. This evolving landscape underscores the need for continued innovation and strategic adjustments in European horticulture to counterbalance the competitive pressures from abroad.

3.4.6.6. Final remarks

TheGreefa technology presents a transformative approach to greenhouse farming, offering significant environmental, economic, and social benefits. However, its successful adoption and implementation face several drivers and barriers that must be carefully navigated.

The environmental benefits of TheGreefa technology are substantial. It significantly reduces CO2 emissions, achieving up to 54% energy savings in ideal scenarios. This translates into notable reductions in greenhouse gas emissions, aligning with global sustainability goals and enhancing the environmental appeal of the technology. Furthermore, TheGreefa technology offers considerable economic advantages, including improved production efficiency and added economic value to the auxiliary sector. The estimated increase in gross margins by 10-20% and the potential net economic value of €1000-€5000 per hectare highlight the financial benefits of the technology.

Supportive policies and subsidies also play a crucial role in driving the adoption of TheGreefa technology. The European Union's policy landscape, including the Green Deal, Farm to Fork Strategy, and Fit-for-55 package, provides a conducive environment for the adoption of sustainable technologies like TheGreefa. Financial incentives, grants for research and development, and subsidies for renewable energy installations significantly lower the barriers to entry for greenhouse operators. Additionally, TheGreefa technology's integrated climate control system, use of thermochemical fluids for energy management, and compatibility with renewable energy sources underscore its technological superiority. These innovations not only enhance energy efficiency but also support the transition to a low-carbon economy.

Stakeholder engagement has been another critical driver for TheGreefa project. The project has effectively engaged with a diverse range of stakeholders, including industrial agricultural producers, research centers, farmers, and policymakers. This engagement has provided valuable insights, helping to refine the technology and align it with market needs. Continuous communication and feedback loops have built trust and fostered a collaborative environment.

However, the high initial costs associated with TheGreefa technology represent a significant barrier to its adoption. The substantial upfront investment required for installation and equipment can deter greenhouse operators. To overcome this barrier, it is essential to provide financing options and incentives to demonstrate long-term cost savings. Technical challenges also pose a barrier. Scalability, maintenance requirements, and integration with existing systems can be complex. The advanced systems involved in TheGreefa technology, particularly those utilizing thermochemical fluids and complex control mechanisms, necessitate regular upkeep to ensure optimal performance and longevity. Developing modular designs, user-friendly maintenance protocols, and standardized interfaces are crucial to addressing these technical challenges.

Market resistance due to the perceived complexity of TheGreefa technology and uncertainty about its benefits is another potential barrier. Greenhouse operators may prefer simpler, more familiar systems. Demonstrating the technology's ease of use and tangible benefits through pilot projects and testimonials is essential to reduce this resistance. Regulatory hurdles also present a significant challenge. Compliance with environmental regulations and obtaining necessary certifications can be lengthy and complex. Early engagement with regulatory authorities and thorough documentation of the technology's safety and efficacy are vital to expedite approval processes and ensure market acceptance.

Social and cultural barriers can also hinder the adoption of TheGreefa technology. Resistance due to cultural perceptions and social norms, particularly in regions where traditional farming practices are deeply ingrained, can pose significant challenges. Engaging with local communities, demonstrating the benefits in a culturally sensitive manner, and providing comprehensive training can help build trust and encourage adoption.

In conclusion, while TheGreefa technology offers substantial benefits that can revolutionize greenhouse farming, addressing the financial, technical, market, regulatory, and social barriers is critical for its successful implementation. By leveraging supportive policies, engaging stakeholders, and continuously improving the technology, TheGreefa can overcome these challenges and achieve widespread adoption and market acceptance.

4. POLICY RECOMMENDATIONS AND REGULATORY FRAMEWORK

4.1. Policy recommendations

4.1.1. European policy framework for the use of thermochemical fluids in greenhouses

The use of thermochemical fluids is frequent in food production in the form of pesticides and herbicides and is therefore subject to a variety of laws and regulations to ensure their safety and minimize their impact on human health and the environment. It is because of that the regulations for using thermochemical fluids in greenhouses can vary across Europe, but here are some of the laws and regulations to consider.

Magnesium chloride ($MgCl_2$) has generally been recognized as safe for human consumption and is commonly used as a food additive.

However, to ensure that the interaction between MgCl2 and other TFCs do not require special measures, we must analyze the regulation of the TFCs and verify that they comply with the different regulations:

The Plant Protection Products (PPPs): REGULATION (EC) No 1107/2009 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 21 October 2009 concerning the placing of plant protection products on the market and repealing Council Directives 79/117/EEC and 91/414/EEC): This regulation sets out the rules for the authorization, marketing, and use of pesticides in the EU. The REGULATION (EC) No 1107/2009 requires that all pesticides must be approved for use by the European Food Safety Authority (EFSA) and member states before they can be marketed and used in the EU.

It is necessary to verify that there is no interaction between substances or phytosanitary products and the MgCl2, because it requires that plant protection products be safe for human health and the environment, and that they be effective in controlling pests.

DIRECTIVE 2009/128/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 21 October 2009 establishing a framework for Community action to achieve the sustainable use of pesticides: “The Sustainable Use of Pesticides Directive (SUD)”: This directive sets out the rules for the use of pesticides in agriculture and other areas, including greenhouses. It requires that users of pesticides take measures to minimize their impact on human health, the environment, and non-target organisms.

It is convenient to take into account the PROPOSAL for a Regulation of The European Parliament and of the Council on the sustainable use of plant protection products and amending Regulation (EU) 2021/2115. Brussels, 22.6.2022

The REACH Regulation: Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH), establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No 793/93 and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC: This regulation sets out the rules for the registration, evaluation, authorization, and restriction of chemicals in the EU. It requires that all chemicals be assessed for their potential risks to human health and the environment. As well, it requires manufacturers and importers to submit safety data and risk assessments for their products, as well as to register their products with the European Chemicals Agency (ECHA).

It applies to all chemicals, including TCFs as pesticides, and requires manufacturers and importers to submit safety data and risk assessments for their products. This Regulation is in force, with numerous minor modifications up to the present, and is the specific reference regulation applicable to chemical substances, mixtures and products such as thermochemical fluids.

On the other hand, Directive 2009/28/EC of European Parliament and of the Board, of 23 April 2009, on the promotion of the use of energy from renewable sources and amending and repealing Directives 2001/77/EC and 2003/30/EC): This directive sets targets for the use of renewable energy in all sectors, including heat and electricity. It also requires that renewable energy meet certain sustainability criteria, including those related to land use, biodiversity, and emissions. This Directive pays special attention to the protection of air, soil and water. It also deals with calculations of 'gross final consumption of energy' means the energy commodities delivered for energy purposes to industry, transport, households, services including public services, agriculture, forestry and fisheries, including the consumption of electricity and heat by the energy branch for electricity and heat production and including losses of electricity and heat in distribution and transmission; which has to do with the object of the project.

National regulations: Each EU member state may have its own regulations for the use of pesticides and other chemicals in greenhouses. These regulations may specify how and when chemicals can be used, as well as any restrictions on their use.

The specific regulations in every country or region must ensure the complying with all applicable laws and regulations when using thermochemical fluids in greenhouses.

4.1.2. Key regulations related to the use of thermochemical fluids and their residues in contact with food

The Food and Feed Hygiene and Safety Regulation: This regulation sets out the rules for the production, processing, and distribution of food and feed in the EU. It includes provisions related to the use of pesticides and other chemicals in food production and requires that food products be safe for consumption.

In addition to these regulations, each EU member state may have its own specific laws and regulations related to the use of thermochemical fluids in food production. It is important to comply with all applicable laws and regulations and to use these chemicals in a responsible and safe manner.

European Regulations and directives related to the use of thermochemical fluids in food:

- EU Plant Protection Products Regulation (PPPR)
- Sustainable Use of Pesticides Directive
- REACH Regulation
- Maximum Residue Levels (MRLs)
- EU Pesticide Residues Regulation
- Food and Feed Hygiene and Safety Regulation

- Regulation (EC) No 1935/2004 provides a harmonised legal EU framework. It sets out the general principles of safety and inertness for all Food Contact Materials (FCMs).
- Regulation (EC) No 1935/2004 was amended by Regulation (EU) 2019/1381 on the transparency and sustainability of the EU risk assessment in the food chain amended with effect from 27 March 2021

Maximum Residue Levels (MRLs): MRLs are the maximum amount of a pesticide or other chemical residue that is allowed to remain on or in food products. MRLs are set by the European Commission based on scientific assessments of the risks to human health and are enforced by member states.

The EU Pesticide Residues Regulation: This regulation sets out the rules for the maximum residue levels of pesticides in food products and requires that food products comply with these limits before they can be placed on the market. It also sets out rules for monitoring and enforcement of these limits.

In the absence of specific EU measures, EU Member State countries may maintain or adopt their own national provisions on FCMs in accordance with Article 6 of Regulation 1935/2004. National legislation is in place in the majority of EU Member States, setting out individual rules on different materials and substances. These may differ from one Member State to another.

4.1.3. Magnesium chloride ($MgCl_2$)

Magnesium chloride ($MgCl_2$) is generally recognized as safe for human consumption and is commonly used as a food additive, however the regulations and guidelines set by relevant authorities such as the European Food Safety Authority (EFSA) and national food safety agencies. should be considered:

Magnesium chloride is an ionic mineral compound based on chlorine, negatively charged, and magnesium, positively charged, which is stable, but we do not know how it reacts with water, with other TCFs (for example, phytosanitary products). or other substances present in greenhouse crops.

This is important because when combined with these other substances, it becomes a potentially toxic or dangerous mixture, or that requires protective measures for its handling or for contact with food.

Here are some general aspects to consider:

Maximum Residue Levels (MRLs): MRLs are the maximum allowable levels of residues of a particular substance, such as $MgCl_2$, in food products. These levels are established to ensure that the consumption of the food does not pose a risk to human health. The MRLs for $MgCl_2$ vary depending on the specific food commodity and are usually defined by the European Commission and implemented by individual member states.

Good Agricultural Practices (GAPs): Good Agricultural Practices encompass a set of guidelines and standards that promote the safe and sustainable use of agrochemicals, including $MgCl_2$. These practices include using appropriate dosages, adhering to application intervals, following label instructions, and respecting pre-harvest intervals to minimize residues in the final food product.

Food Additive Regulations: In some cases, $MgCl_2$ may be used as a food additive, primarily for its role as a nutrient and flavor enhancer. The usage of $MgCl_2$ as a food additive is subject to specific regulations, including maximum permitted levels and the foods in which it can be used.

For example, Magnesium Chloride hexahydrate $MgCl_26H_2O$ is not recommended for direct contact with food, as we verified in its voluntary safety data sheet, in accordance with Regulation (EC) No. 1907/2006 (REACH).) and registered as article 2189, despite the fact that they are not persistent, bio accumulative and toxic (PBT) or very persistent and very bio accumulative (vPvB) substances, according to annex XIII of REACH.1

For this reason, it is convenient to know technically if MgCl2 can be converted into $MgCl_26H_20$ in the absorption and desorption processes that are the object of TheGreefa project.

[1] **We attach the safety data sheet for the substance $MgCl_2$ 6 H $_2$O from ECHA article 2189 (REACH Registration No. 01-2119485597-19-xxxx)**

Labeling Requirements: Proper labeling of food products is essential to inform consumers about the presence of any additives or substances, including $MgCl_2$. Food manufacturers are typically required to accurately list all additives used in their products on the packaging.

4.1.4. ECHA

Magnesium chloride ($MgCl_2$) itself is not listed as a substance in the European Chemicals Agency's (ECHA) Registration, Evaluation, Authorization, and Restriction of Chemicals (REACH) regulation's Annex XIV, commonly known as the "Authorization List." The Authorization List includes substances of very high concern (SVHCs) that may have harmful effects on human health or the environment, and their use may be subject to authorization.

However, it is important to note that the absence of $MgCl_2$ from the Authorization List does not mean it is entirely without any potential hazards. $MgCl_2$ can still have certain health and safety considerations, and its specific classification and potential risks would depend on various factors, such as concentration, exposure, and application.

4.1.5. Exposure measurements

To ensure the safe use and handling of $MgCl_2$, it's recommended to consult safety data sheets (SDS) provided by the manufacturer or supplier, which contain information on the substance's properties, classification, and safety precautions. Additionally, following good practices, such as using personal protective equipment (PPE) and adhering to safe handling and storage protocols, is crucial when working with any chemicals, including $MgCl_2$.

When handling magnesium chloride ($MgCl_2$), it is important to take appropriate measures to minimize exposure and ensure worker safety. Here are some general guidelines for handling $MgCl_2$:

1. **Personal Protective Equipment (PPE)**: Wear suitable protective clothing, such as gloves, safety goggles, and a lab coat or protective clothing, to prevent direct contact with $MgCl_2$. The specific type of PPE required may depend on the concentration, form (solid or solution), and handling procedures involved. Refer to the safety data sheet (SDS) provided by the manufacturer for specific PPE recommendations.
2. **Engineering Controls**: Use adequate ventilation systems, such as local exhaust ventilation, to control airborne concentrations of $MgCl_2$ and prevent the inhalation of dust or aerosols. This is particularly important when working with $MgCl_2$ in powdered or granular form.
3. **Storage and Handling**: Store $MgCl_2$ in appropriate containers and keep them tightly sealed to prevent spills or leaks. Follow good handling practices to minimize the

generation of dust or aerosols. Avoid direct skin contact and inhalation of $MgCl_2$ particles or solutions.

4. **Hygiene Practices**: Wash hands thoroughly with soap and water after handling $MgCl_2$. Avoid touching your face, eyes, or mouth while working with the substance. Remove and wash contaminated clothing before reusing. Maintain good personal hygiene practices in the workplace.
5. **Training and Awareness:** Ensure that workers handling $MgCl_2$ are adequately trained on the safe handling procedures, potential hazards, and emergency response measures. Provide clear instructions and guidelines for safe use, storage, and disposal of $MgCl_2$.
6. **Emergency Procedures:** Establish emergency procedures in case of accidental spills, leaks, or exposure incidents. This includes having appropriate spill kits and eyewash stations readily available and ensuring that workers are aware of the correct response actions.

It's important to note that these are general recommendations, and specific safety measures should be determined based on the properties of the $MgCl_2$ being handled and the applicable regulations in your region. Always refer to the SDS and follow the guidance provided by the manufacturer for safe handling practices specific to the $MgCl_2$ product.

4.1.6. Regulatory and policies framework:

European Green Deal (COM (2019) 640 final 11.12.2019)
Farm to Fork Strategy
EU's common agricultural policy (CAP)
Biodiversity Strategy
Regulation (EU) 2021/1119 of the European Parliament and of the Council **of 30 June 2021 establishing the framework to achieve climate neutralit**y **("European Climate Law"**
EU Effort Sharing Regulation, also known as ESR - Regulation (EU) 2018/842 of the European Parliament and of the Council **of 30 May 2018 on binding annual greenhouse gas emission reductions by Member States from 2021 to 2030**
Paris Agreement and amending Regulation (EU) No 525/2013.)
Directive (EU) 2023/1791 of the European Parliament and of the Council, of 13 September 2023, on energy efficiency **and amending Regulation (EU) 2023/955 (recast), published in the Official Journal on 20 September 2023.**
The Directive 2010/31/EU of the European Parliament and of the Council **of 19 May 2010 on the energy performance of buildings**
Regulation (EU) 2018/842 of the European Parliament and of the Council **of 30 May 2018 on binding annual greenhouse gas emission reductions by Member States from 2021 to 2030**
Directive (EU) 2023/2413 of the European Parliament and of the Council of 18 October 2023 **amending Directive (EU) 2018/2001**

Regulation (EU) 2018/1999 and Directive 98/70/EC as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652.
REPowerEU
EU's Fit-for-55
Energy Taxation Directive (2003/96/EC, the European Union's framework for the taxation of energy products including electricity, motor and most heating fuels)
Revised Renewable Energy Directive
Revision of the Energy Performance of Buildings
European Commission Recommendation of 14 March 2023 **on Energy Storage – Underpinning a decarbonised and secure EU energy system (2023/C 103/01).**
Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy (Water Framework Directive - WFD) **recognizes**
REGULATION (EC) No 1907/2006 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL, **of 18 December 2006 concerning the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH), establishing a European Chemicals Agency**
REGULATION (EC) No 1272/2008 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL**, of 16 December 2008 on classification, labelling and packaging of substances and mixtures (CLP)**
Regulation (EC) No 1935/2004, OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL**, of 27 October 2004, on materials and articles intended to come into contact with food.**
The 1991 Waters Protection Act. **(Switzerland)**
The 1998 Federal Act on Agriculture. **(Switzerland)**
The Ordinance on Organic Farming and the Labelling of Organically Produced Products and Foodstuffs**. (Switzerland)**
Climate Act and the National Climate Agreement. (Netherlands)
Environment and Planning Act **(Netherlands)**
National Program to Reduce Nitrogen Greenhouse Gas Emissions in rural areas **(Netherlands)**
Law 7/2021, of May 20, on climate change and energy transition **(Spain)**
Royal Decree 149/2021, of March 9**, regulates the aid program for carrying out** energy efficiency actions in agricultural holdings**. (Spain)**
Royal Legislative Decree 1/2001, **of July 20, approves the consolidated text of the** Water Law**. (Spain)**
Royal Decree 656/2017, **of June 23, which approves the** Regulation for the Storage of Chemical Products and their Complementary Technical Instructions**. (Spain)**
Law on energy transition for green growth, promulgated on 17 August 2015**. (France)**
Law on the Future of Agriculture, Food and Forestry of 13 October. **(France)**
Legislation on the future of agriculture by 2040, known as PLOAA (**projet de loi d'orientation pour la souveraineté Agricole) (in discussion). (France)**
Renewable Energy Sources Act **(Eneuerbare-Energien-Gesetz) to support renewable energy sources. (Germany)**
"Commission for the Future of Agriculture" (Zukunftskommission Landwirtschaft, ZKL) in July 2020 and tasked it with making a proposal for an ecologically, economically and socially sustainability agriculture and food system. The Commission's final report, titled
"The Future of Agriculture. A common agenda" was approved on 29 June 2021. **(Germany)**

LEGGE 28 febbraio 2024, n. 24- **Disposizioni per il** riconoscimento della figura dell'agricoltore custode dell'ambiente e del territorio e per l'istituzione della Giornata nazionale dell'agricoltura. **(Italy)**
Decree published by the Ministry of the Environment and Energy Safety on February 13, 2024. **(Italy)**
Water Act of 2017 **and the** Strategy for Sustainable Rural Development, Agriculture, and Fishery 2030. **(Poland)**

4.2.Overview

Considering that TheGreefa is a novel technology, there is no evidence of any other similar experience, which is why we are going to focus on analysing the keys to European and national policies on energy efficiency and water saving.

European legal issues that must be considered when using thermochemical fluids in greenhouses to promote energy efficiency and sustainability. Here is a summary focusing on the relevant European legal aspects:

4.2.1. EU Regulations:

The EU's Fit-for-55 package addresses the double taxation of energy storage, encouraging the utilization of energy storage, including thermal energy storage, to enhance flexibility in the energy sector.

The Renewable Energy Directive promotes energy storage solutions, such as thermal energy storage, to support the integration of renewable energy sources and improve energy system flexibility.

4.2.2. Energy Labelling Framework:

Regulation (EU) 2017/1369 establishes a framework for energy labelling of energy-related products placed on the market or put into service. This framework aims to provide information on energy consumption during use, which is relevant for products like thermochemical fluids used in greenhouses.

4.2.3. Energy Efficiency Agreements:

Energy-efficiency agreements in countries like Spain and France focus on implementing sustainable heating methods in greenhouse horticulture, including the use of thermochemical fluids, to reduce energy consumption and emissions.

4.2.4. Environmental sustainability regulations:

Regulations in various European countries, such as France, emphasize the importance of promoting alternative agronomic techniques in greenhouse farming to optimize resource use, reduce waste, and enhance environmental performance.

These European legal issues underscore the significance of complying with energy efficiency regulations, promoting sustainable practices, and utilizing thermochemical fluids effectively in greenhouses to contribute to a more sustainable and environmentally friendly agricultural sector.

Encouraging the adoption of agro-ecological approaches, implementing energy-saving measures with a quick payback period, and supporting innovative heating methods are crucial for achieving sustainability goals in greenhouse agriculture.

By adhering to European regulations, implementing energy-efficient practices, and embracing sustainable agricultural techniques, greenhouse operators can enhance energy efficiency, reduce environmental impact, and contribute to a more sustainable and eco-friendly agricultural sector.

4.3. Review of the European strategic and regulatory framework

4.3.1. Agriculture

Regarding the European strategic framework in agriculture, it must be highlighted two elements of special interest:

Farm to Fork Strategy + Common agricultural policy.

4.3.1.1. Farm to fork strategy

Climate change and environmental degradation are an existential threat to Europe and the world. To overcome these challenges, the European Green Deal (COM (2019) 640 final 11.12.2019) aims to transform the EU into a modern, resource-efficient and competitive economy, ensuring no net emissions of greenhouse gases by 2050, economic growth decoupled from resource use, and no person and no place left behind.

The Farm to Fork Strategy is at the heart of the European Green Deal aiming to make food systems fair, healthy and environmentally-friendly. It promotes a more sustainable food system and it is among its main objectives to guarantee enough food, and that it is affordable and nutritious, without exceeding the limits of the planet.

A proposal for a legislative framework for sustainable food systems will be put forward to support implementation of the strategy and development of sustainable food policy.

4.3.1.2. Common agricultural policy

Launched in 1962, the EU's common agricultural policy (CAP) is a partnership between agriculture and society, and between Europe and its farmers, which, among other objectives, aims to help tackle climate change and the sustainable management of natural resources.

The CAP has evolved over the years to meet changing economic circumstances and citizens' requirements and needs. The CAP 2023-27 entered into force on 1 January 2023. The approved Plans are designed to make a significant contribution to the ambitions of the European Green Deal, Farm to Fork Strategy and Biodiversity Strategy, with the modernization of agriculture through the development of more sustainable agricultural practices, while protecting nature and fighting climate change.

Among the tools that will further promote sustainable farming practices throughout the EU, the future CAP includes conditionality, which links area and animal-based CAP payments to a range of obligations. In addition, it also introduces the new 'eco-schemes' that aim to reward farmers for going further in the implementation of sustainable agricultural practices. These practices could include the implementation of environmentally friendly production systems such as agroecology, agroforestry and organic farming. The rural development framework also includes environmental and climate management commitments, which aim to compensate farmers and other beneficiaries for voluntarily committing themselves to implement sustainable practices.

4.3.2. Energy

In the energy field, there are two proposed technologies at TheGreefa:

- Air humidity and temperature control integrated to seasonal thermal storage, this is, storing solar thermal energy in the summer months (when solar availability is greatest) for later use in the night when gets cooler.
- Low temperature drying processes for herbs and foods with renewable energy independent from weather conditions

Thus, we must approach the field of energy from a triple perspective: energy efficiency, renewable energies and storage, all of them advantages offered by the proposed technology, and also central to achieving the EU's climate neutrality ambition. We refer to all this in the following sections.

4.3.2.1. Climate neutrality

Regulation (EU) 2021/1119 of the European Parliament and of the Council of 30 June 2021 establishing the framework to achieve climate neutrality ("European Climate Law" establishes the following objectives, positioning the EU as a global leader in the fight against climate change:

- Article 2- Climate neutrality objective: Greenhouse gas emissions and removals will be balanced within the Union by 2050 at the latest
- Article 4- Intermediate climate objectives of the Union:
  - by 2030 a domestic reduction in net greenhouse gas emissions of at least 55% compared to 1990 levels
  - For 2040, a new climate target will be set by means of a legislative proposal to amend this Regulation, which will be presented within six months of the first global assessment.

Energy production and use account for more than 75% of the EU's greenhouse gas emissions. Therefore, it is impossible to achieve these objectives without decisive action in the energy field.

Agricultural Greenhouse gas emissions are covered by the EU Effort Sharing Regulation, also known as ESR - **Regulation (EU) 2018/842 of the European Parliament and of the Council of 30 May 2018 on binding annual greenhouse gas emission reductions by Member States from 2021 to 2030** contributing to climate action to meet commitments under the Paris Agreement and amending Regulation (EU) No 525/2013.), which sets annual targets for each Member State for the period 2021-2030, for sectors not covered by the EU Emissions Trading System (ETS) such as agriculture.

4.3.2.2. Energy efficiency

The European reference standard has been recently updated. This is **Directive (EU) 2023/1791 of the European Parliament and of the Council, of 13 September 2023, on energy efficiency** and amending Regulation (EU) 2023/955 (recast), published in the Official Journal on 20 September 2023.

It significantly raises the EU's ambition on energy efficiency, raising the EU energy efficiency target and making it binding for EU countries to collectively ensure an additional 11.7% reduction in energy consumption by 2030, compared to the 2020 reference scenario projections.

It also gives "energy efficiency first principle" a legal-standing for the first time, so that in practical terms, energy efficiency must be considered by EU countries in all relevant policy and major investment decisions taken in the energy and non-energy sectors. Indeed, the higher level of ambition requires a stronger promotion of cost-effective energy efficiency measures in all areas of the energy system and in all relevant sectors where activity affects energy demand, such as agriculture**. In this sector the Directive states that, advanced irrigation technologies, rainwater harvesting and water reuse technologies could substantially reduce water consumption.**

Additionally, under the revised Directive, EU countries will need **to ensure an appropriate level of competence for energy efficiency related professionals**, aligning them with market needs and enforcing clearer and stricter requirements for the necessary competencies. This includes energy service providers, energy auditors, energy managers and installers.

The Directive establishes project development assistance mechanisms at national, regional, and local levels to support energy efficiency investments and facilitate the attainment of the EU's ambitious energy efficiency targets.

In addition to this Directive which deals in general with energy efficiency, there are two other directives on energy efficiency at European level, one referring to buildings and another referring to products. Below we refer to them.

- The **Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings** sets the following legal definition of a building in its article 2.1: *"a roofed construction having walls, for which energy is used to condition the indoor climate*". The European Greenhouse standard. UNE-EN13031-1 defines a greenhouse as *"the structure used for the cultivation and/or protection of plants, which favors the transmission of solar radiation under controlled conditions in order to improve the development environment of the plants, presenting such dimensions that allows people to work within themselves for the development of agricultural activity".* Therefore, greenhouses may be included in the scope of Directive 2010/31/EU, but the proposed technology will not affect the greenhouse building as such, but rather the production process that takes place inside it, so the regulation to take into account is the one referred to products, which we analyze below.

- The **Regulation (EU) 2017/1369 of the European Parliament and of the Council of 4 July 2017 setting a framework for energy labelling** and repealing Directive 2010/30/EU lays down a framework that applies to energy-related products placed on the market or put into service, considering that 'energy-related product' or 'product' means **"a good or system with an impact on energy consumption during use"**. It provides for the labelling of those products and the provision of standard

The TheGreefa has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 101000801.

product information regarding energy efficiency, the consumption of energy and of other resources by products during use and supplementary information concerning products, thereby enabling customers to choose more efficient products in order to reduce their energy consumption. Its article 7.2 establishes that where Member States provide incentives for a product specified in a delegated act in accordance with Article 17 in order to supplement this Regulation by establishing detailed requirements relating to labels for specific product groups, **those incentives shall aim at the highest two significantly populated classes of energy efficiency, or at higher classes as laid down in that delegated act.**

4.3.2.3. Renewable energies

The Renewable Energy Directive is the legal framework for the development of clean energy across all sectors of the EU economy, and it has also been recently revised: **Directive (EU) 2023/2413 of the European Parliament and of the Council of 18 October 2023** amending Directive (EU) 2018/2001, Regulation (EU) 2018/1999 and Directive 98/70/EC **as regards the promotion of energy from renewable sources**, and repealing Council Directive (EU) 2015/652.

It raises the share of renewable energy in the EU's overall energy consumption to 42.5% by 2030 with an additional 2.5% indicative top up to allow the target of 45% to be achieved. Each member state will contribute to this common target.

4.3.2.4. Energy storage

Energy storage is a crucial technology to provide the necessary flexibility, stability, and reliability for the energy system of the future. System flexibility is particularly needed in the EU's electricity system, where the share of renewable energy is estimated to reach around 69% by 2030 and 80% by 2050.

The EU's current policy framework for storage facilitates the development and deployment of energy storage as a key technology to support the decarbonisation objectives of the European Green Deal:

- The REPowerEU plan specifically highlights the importance of energy storage in ensuring flexibility and security of supply in the energy system by: (i) facilitating the integration of renewable generation; (ii) supporting the grid; and (iii) 'shifting' energy so that it is available when it is most needed. The REPowerEU plan also recognizes the role of energy storage in reducing the use of gas power plants in the energy system.

- The EU's Fit-for-55 package contains relevant provisions on energy storage. For example, as part of the package, there is a proposal to revise the Energy Taxation Directive (2003/96/EC, the European Union's framework for the taxation of energy products including electricity, motor and most heating fuels) which includes a **specific provision to end the double taxation of energy storage**, in line with the consideration of energy storage as a substantial contributor to climate-change adaptation and mitigation in the EU taxonomy.
- The revised Renewable Energy Directive also contains specific provisions encouraging energy storage as a source of flexibility, including for thermal energy storage.
- The revised Energy Efficiency Directive also encourages energy storage to increase efficiency.
- The revision of the Energy Performance of Buildings Directive which encourages: the effective control, storage, and use of energy.
- Finally, the **European Commission Recommendation of 14 March 2023 on Energy Storage – Underpinning a decarbonised and secure EU energy system (2023/C 103/01)** sets out a list of recommendations to ensure greater deployment of energy storage.

4.3.3. Water

If we analyse the origin of the water used in greenhouses, we find that 10% is tap water or desalinated water, and the remaining 90% comes from either stored rainwater or an underground well, normally requiring a prior permission from the competent public authority that enables its use.

The proposed technology offers significant advantages in terms of water savings, thanks to water recovery through evapocondensation strategies, including sorptive drying and evaporative cooling with saline water. As we will see in this section, it is in line with the strategies and regulations on the matter.

Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy (Water Framework Directive - WFD) recognizes that waters in the Community are under increasing pressure from the continuous growth in demand for sufficient quantities of good quality water for all purposes, and that it is necessary to achieve a further integration of protection and sustainable management of water into Community policy areas such as agriculture.

Taken it into account, the WFD has the purpose of establishing a framework for the protection of inland surface waters, transitional waters, coastal waters and groundwater which, among other things, (b) promotes **sustainable water use** based on a long-term protection of available water resources.

The hydrological planning process is crucial to achieve this goal. WFD establishes a series of criteria that govern this hydrological planning process throughout the EU whose primary element is the integrated planning of water resources management by basins or hydrographic districts. According to article 13.1, member states shall ensure that a river basin management plan is produced for each river basin district lying entirely within their territory. It shall be reviewed every six years and it must make the achievement of environmental objectives for the bodies of water and associated ecosystems compatible with attention to the demands for the different uses of water, both in sufficient quantity and quality.

Also, article 11 of WFD states that a program of measures must be established in order to achieve the environmental objectives established in its article 4, and its Annex VI, part B, specifies a non-exclusive list of supplementary measures which Member States within each river basin district may choose to adopt as part of the programme of measures, among which we can find*: "ix) demand management measures, inter alia,* ***promotion of adapted agricultural production such as low water requiring crops in areas affected by drought"***

On the other hand, we must refer to the economic-financial regime for water, based on the principle of cost recovery established in the WFD and which refers to the fact that the cost of investments made by public authorities to enable the provision of water by individuals is recovered through payment for the use of water by the different end users. The application of this principle must be done in a way that encourages the efficient use of water and, therefore, contributes to the environmental objectives pursued, with an adequate contribution from the various uses, in accordance with the polluter pays principle, and considering at least supply, agricultural and industrial uses. Under this principle, the competent public administrations must establish mechanisms to pass on costs, which normally include **bonuses for agricultural use when the application of good agricultural practices is demonstrated.**

4.3.4. Chemicals

TheGreeFa project is based on an innovative use of absorption processes in the greenhouse air-conditioning, achieved using the hygroscopic properties of a fluid salt solution, here called thermo-chemical carrier fluid (TCF). More concretely, an aqueous magnesium chloride solution (MgCl2), has been found as the more appropriate. This means that, among others, we have to take into account the regulations on chemicals.

The European chemicals regulation is based on REACH and CLP regulations.

• REGULATION (EC) No 1907/2006 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL, of 18 December 2006 concerning the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH), establishing a European Chemicals Agency

• REGULATION (EC) No 1272/2008 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL, of 16 December 2008 on classification, labelling and packaging of substances and mixtures (CLP)

Both of them are based on the principle that the burden of correctly managing the risks of the substances and mixtures used in industrial processes and the obligation of ensuring their secure use towards human health and the environment belongs to industry itself (before these regulations it belonged to public authorities)

They are directly binding in all member states without the need of transposition, which means that there is no need for the member states to adopt any regulation at a national level, and they affect to all companies that use chemicals, not only to the ones that produce or import chemicals.

4.3.5. According to REACH and CLP:

- ‘substance’ means a chemical element and its compounds in the natural state or obtained by any manufacturing process, including any additive necessary to preserve its stability and any impurity deriving from the process used, but excluding any solvent which may be separated without affecting the stability of the substance or changing its composition;
- ‘mixture’ means a mixture or solution composed of two or more substances;
- ‘downstream user’ means any natural or legal person established within the Community, other than the manufacturer or the importer, who uses a substance, either on its own or in a mixture, in the course of his industrial or professional activities.

Therefore, if we apply these legal definitions to our project we find that magnesium chloride solution ($MgCl_2$) is a mixture because it is composed of two substances, and it is a mixture which is pretended to be used in professional activities in greenhouses by different downstream users all over Europe.

The main obligations for downstream users under REACH and CLP regulations are:

1. Not to use any substance that is not registered or pre-registered, unless the reason why it is not derives from the application of one of the many exceptions established in the REACH Regulation. The obligation to register belongs to manufacturers or importers, but

downstream users have to ask their suppliers for the register number, no matter the mixture is hazardous or not.

2. To only use substances in accordance with the identified uses and risk control measures reported in the Safety Data Sheet. This means that the downstream user has the right to receive different information from his supply chain:
    - if the substance or mixture is not hazardous he has the right to receive the register number, authorization o restriction data, and information for risk management
    - if it is hazardous he has the right to receive the Safety Data Sheet (SDS)
3. To ensure that workers have adequate information about the substances or mixtures they use or may be exposed to in the course of their work.
4. Not to use any substance subject to authorization (listed in Annex XIV of the REACH Regulation) unless having obtained authorization to do so (MgCl2 is not included)
5. Not to use any substance subject to restriction (listed in Annex XVII of the REACH Regulation) unless it meets the conditions of the restriction (MgCl2 is not included)

The legal obligations will depend not only on the role of the company, but also on the classification of the mixture. According to article 3 of CLP Regulation, *"A substance or a mixture fulfilling the criteria relating to physical hazards, health hazards or environmental hazards, laid down in Parts 2 to 5 of Annex I is hazardous and shall be classified in relation to the respective hazard classes provided for in that Annex."*

The main information found about this mixture in the ECHA webpage is the following (https://echa.europa.eu/substance-information/-/substanceinfo/100.029.176):

4.3.5.1. Magnesium chloride:

- Substance identity: EC / List no.: 232-094-6, CAS no.: 7786-30-3, Mol. formula: Cl2Mg
- Hazard classification & labelling: According to the notifications provided by companies to ECHA in REACH registrations **no hazards have been classified.**
- How to use it safely: ECHA has **no data from registration dossiers on the precautionary measures for using this substance.** Guidance on the safe use of the substance provided by manufacturers and importers of this substance: https://echa.europa.eu/es/information-on-chemicals/registered-substances/-/disreg/substance/100.029.176

4.3.6. Food safety

The regulation to take into account in this area is **Regulation (EC) No 1935/2004, OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL, of 27 October 2004, on materials and articles intended to come into contact with food**, which provides a harmonized legal EU framework, setting out the general principles of safety and inertness for all Food Contact Materials (FCMs). This Regulation was amended with effect from 27 March 2021 by Regulation (EU) 2019/1381 on the transparency and sustainability of the EU risk assessment in the food chain.

The purpose of this Regulation is to ensure the effective functioning of the internal market in relation to the placing on the market materials and articles intended to come into contact directly or indirectly with food, whilst providing the basis for securing a high level of protection of human health and the interests of consumers. It shall apply to materials and articles, which in their finished state are intended to be brought into contact with food or are already in contact with food and were intended for that purpose, or can reasonably be expected to be brought into contact with food or to transfer their constituents to food under normal or foreseeable conditions of use.

The proposed use of magnesium chloride in greenhouse crops in TheGreefa avoid specifically by its design the direct contact with the crops. The potential risks could be more probably associated with scenarios of storage and handling of the mixture by workers. For example, it is necessary to verify that there is no interaction between magnesium chloride and water or soil and also with phytosanitary products used in the greenhouse.

4.4. Review of national regulatory frameworks of special interest

4.4.1. Switzerland

Overall, greenhouse farming regulations in Switzerland emphasize sustainable and **environmentally conscious practices** in greenhouse farming. The key requirements center around organic and sustainable production methods, efficient resource use, and voluntary participation in additional quality assurance programs. Among these regulations we can highlight the following:

- **The 1991 Waters Protection Act**, which aims at safeguarding water quality, maintaining adequate residual flows and preventing harm to waters.
- **The 1998 Federal Act on Agriculture**, which requires the Confederation to ensure that the agricultural sector makes a significant contribution towards among others the reliable provision of the population with foodstuffs and preserving natural resources through sustainable and market orientated production.
- **The Ordinance on Organic Farming and the Labelling of Organically Produced Products and Foodstuffs.**

On the other hand, Switzerland has set ambitious targets to reduce its overall greenhouse gas emissions, including the ones from the agricultural sector. The country's Long-Term Strategy submitted to the UNFCCC in 2021 targets a 40% reduction in agricultural emissions by 2050 compared to 1990 levels. However, Switzerland has not yet assigned a specific emissions reduction target for agriculture in legislation. The government is expected to propose it as part of an upcoming revision of the CO_2 Act.

In the meantime, Switzerland is implementing other policies to mitigate agricultural greenhouse gas emissions, which include promoting sustainable and **resource-efficient agricultural practices**, such as through the Proof of Ecological Performance requirements that nearly all farmers comply with, providing direct payments to farmers who adopt ecological measures and services, and investing in research and advisory services to help farmers reduce their environmental impact.

4.4.2. The Netherlands

The Netherlands is world leader in agricultural innovation and world's second largest exporter of agricultural products despite its size and weather conditions. This has only been possible using new technology and knowledge that has allowed them to obtain twice as much food using half as many resources.

The Netherlands has implemented various regulations and initiatives to reduce greenhouse gas emissions and promote sustainable agriculture, including greenhouse farming.

When it comes to climate policy in general, the Dutch government aims to reduce greenhouse gas emissions by 49% by 2030 and by 95% by 2050 compared to 1990 levels. This is laid down in the **Climate Act and the National Climate Agreement**. The National Climate Agreement contains agreements with the sectors on what they will do to help achieve these climate goals. Agriculture is a participating sector, and these are some of the measures:

- The government promotes the use of **sustainable heating methods** in greenhouse horticulture to reduce energy consumption and emissions, mainly **residual heat and geothermal energy**.
- Energy-efficiency agreements have been made to implement next-generation cultivation methods in horticulture, with a focus on achieving **climate-neutral greenhouses by 2030**.

The agreement contains a specific section titled "C4.6 Greenhouse horticulture. On the road to sustainable, economically attractive & climate-neutral production" of which it is interesting to highlight the following agreements: The Greenhouse as a Source of Energy transition programme, Residual heat and geothermal energy and Flower bulbs and bulb flowers, the latter with an express mention of a specific commitment to the energy-neutral drying and preservation of flower bulbs in sheds, and the recognition that innovations in the flower bulb sector have a spin-off to other agricultural sectors where storage plays a key role, such as for potatoes and fruit.

There is also an **energy saving obligation** for greenhouses, **set out by the Environment and Planning Act** which requires large commercial energy consumers to invest in energy-saving measures. They have to take energy-saving measures with a payback period of five years or less. This obligation applies to large commercial energy consumers, this is, businesses using 50,000 kWh of electricity or 25,000 cubic meters of natural gas per year. 2023 update now includes greenhouses and horticultural businesses. The Environment and Planning Act came into force on January 1, 2024. Therefore, Dutch greenhouse growers are now obligated to save energy, with technologies like DryGair offering up to 70% energy savings with a return on investment (ROI) of 1-3 years. This obligation is crucial due to the significant energy consumption of greenhouses, which consume nine percent of the natural gas in the country.

There is also **a water-saving obligation** outlined by the Environment and Planning Act, which includes strict requirements for water use efficiency. Greenhouses are mandated to reuse drain and drainage water to a certain extent, with an obligation to store rainwater and reuse it (rainwater storage of 500 m3 per year per hectare of greenhouse is obligatory), emphasizing the importance of efficient water management. Additionally, the Environment and Planning Act encourages the development and application of innovations that enable water-saving practices, such as optimizing climate control and adopting closed greenhouse systems.

Lastly, the Dutch government has also presented a **National Program to Reduce Nitrogen Greenhouse Gas Emissions in rural areas,** with the Dutch Provinces being responsible for developing measures to achieve the reduction targets (in the agricultural sector, greenhouse gas emissions are mainly methane and nitrogen dioxide).

4.4.3. Spain

Greenhouse farming in Spain is subject to various regulations and initiatives aimed at promoting environmental sustainability and addressing climate change. The country's dynamic agro-food sector has been making efforts to tackle environmental challenges, with new policies and regulations supported by substantive funding from the 2023-27 Common Agricultural Policy (CAP) and the EU-wide COVID-19 recovery funds. Spain has also approved its first Law against Climate Change, which aims to achieve climate neutrality before 2050, with all sectors, including farming, required to contribute to the economy’s decarbonization. Additionally, the Spanish government offers various subsidies and loans to promote greenhouse farming as a viable and sustainable form of agriculture. These measures reflect a commitment to regulating and supporting greenhouse farming in Spain to ensure its long-term environmental sustainability.

More specifically, **Law 7/2021, of May 20, on climate change and energy transition,** seeks to respond to the commitment assumed by Spain at the international and European level regarding climate change. The Law establishes four minimum national objectives for the year 2030:

- Reduce GHG emissions of the Spanish economy as a whole by at least 23% compared to 1990.
- Achieve a penetration of renewable energies in final energy consumption of at least 42%.
- Achieve an electrical system with at least 74% generation from renewable energies.
- Improve energy efficiency by reducing primary energy consumption by at least 39.5%

Likewise, the law establishes that before 2050, Spain must achieve climate neutrality and the electrical system must be based exclusively on renewable generation sources.

These objectives, furthermore, will be reviewable, without implying a decrease in the level of environmental ambition and must reflect the greatest possible ambition. Energy efficiency and the progressive penetration of renewable energies in the Spanish energy mix are considered the main levers of economic reactivation in the short term, as well as the pillars of decarbonization.

Royal Decree 149/2021, of March 9, regulates the aid program for carrying out energy efficiency actions in agricultural holdings.

Regarding water, **Royal Legislative Decree 1/2001, of July 20, approves the consolidated text of the Water Law.** Its article 60 establishes the order of preference of uses that must be observed in the granting of concessions, determining that it will be that established in the Hydrological Plan of the corresponding basin, and failing that: 1. Population supply, 2 .º Irrigation and agricultural uses, 3.º Industrial uses for the production of electrical energy, 4.º Other industrial uses not included in the previous sections, 5.º Aquaculture, 6.º Recreational uses, 7.º Navigation and water transport and 8. Other uses, adding in paragraph 4 a provision of special interest such as that, within each class, in case of incompatibility of uses, those of greater public or general utility **will be preferred, or those that introduce technical improvements that result in lower water consumption** or in maintaining or improving its quality.

Finally, in what concerns to Spanish chemicals storage regulation, it is based on **Royal Decree 656/2017, of June 23, which approves the Regulation for the Storage of Chemical Products and their Complementary Technical Instructions** MIE APQ 0 a 10, which is adapted to REACH and CLP regulations, and it only applies to substances or mixtures classified as hazardous according to CLP, which is not our case.

4.4.4. France

Greenhouse farming in France is subject to strict government regulations aimed at reducing greenhouse gas emissions, promoting sustainable agriculture, ensuring food safety, and protecting the environment. Farmers engaging in greenhouse farming must adhere to various regulations, including obtaining environmental permits, following water usage regulations to encourage water-saving technologies, complying with pesticide and chemical use regulations, obtaining organic certification for crops grown without synthetic chemicals, meeting labor and safety standards for workers' well-being, managing waste properly, and ensuring quality control and traceability of crops. These regulations are crucial for maintaining sustainable practices, food safety, and environmental protection within the greenhouse farming sector in France.

The **Law on energy transition for green growth, promulgated on 17 August 2015**, aims to reduce French GHG emissions by 40%, reduce fossil fuel consumption by 30% and increase the share of renewable energy to 32% by 2030. This law includes measures to combat food waste and encourage the production of biogas from agricultural waste.

In terms of greenhouse farming specifically, the French government has implemented regulations to promote the use of **alternative agronomic techniques**, such as optimizing the use of fertilizers and pesticides, recovering and transforming agricultural residues into bioenergy, improving irrigation systems, and combating agricultural losses and food waste. This way, France is committed to promoting agro-ecology, which aims to make environmental performance an element of competitiveness in agriculture. Thus, the **Law on the Future of Agriculture, Food and Forestry of 13 October 2014** set the objective of ensuring that 50% of French farms implement agro-ecological approaches by 2025. At the international level, France has initiated a cooperation programme with the FAO for this purpose and is already cooperating at the scientific level with many countries to identify agronomic solutions that will enable agriculture to be better adapted to the consequences of climate change and to make it more carbon efficient.

Furthermore, the French government is discussing **legislation on the future of agriculture by 2040, known as PLOAA** ***(****projet de loi d'orientation pour la souveraineté Agricole*), in a bid to ensure that new generations are able to adapt to climate change and to the agroecological transition. The text presented to the Council of Ministers on Wednesday, April 3 (2024) is the text revised after the latest events, including the recent protests by farmers, but remains about modernizing the production model to regain competitiveness, while adapting it to the constraints imposed by climate change.

Finally, we will point out that France also expects the development of biomethane to help reduce the sector's emissions. By transforming organic waste into energy, dependence on fossil fuels is reduced and contributes to the reduction of greenhouse gas emissions. This allows farmers to actively participate in the energy transition, opening new avenues of income, improving their competitiveness in the market and promoting a circular economy in the primary sector.

4.4.5. Germany

As in other European countries, greenhouse farming regulations in Germany aim to promote sustainable agricultural practices, reduce environmental impacts, and support the transition to greener farming methods. Financial support, subsidies, and tax credits are available to farmers who invest in green technologies, while regulations are in place to ensure the development of biomethane and address environmental challenges in the agricultural industry. Additionally, Germany promotes organic farming and energy-efficient greenhouse facilities.

In 2000, Germany adopted the **Renewable Energy Sources Act** (Eneuerbare-Energien-Gesetz) to support renewable energy sources. Subsequent revisions have further refined the Act, which now sets ambitious targets, including generating 80% of electricity from renewable sources by 2030 and achieving a GHG-neutral electricity supply by 2050.

Also, to define a long-term strategy allowing Germany to meet national greenhouse gas mitigation targets, the German government adopted the Climate Action Plan 2050 in late 2016, setting a goal of reducing greenhouse gas emissions in 2050 by 80-95 % as compared to 1990.

To promote climate-friendly farming practices, the German government has implemented measures to reduce emissions from agriculture, improve resource efficiency, and transition towards organic farming. These measures include reducing nitrous oxide emissions from nitrogenous fertilizers, establishing incentive systems for optimizing nitrogen efficiency, and promoting organic farming through research, innovation, and increased productivity.

Finally, we have to mention that the German government established a "Commission for the Future of Agriculture" (Zukunftskommission Landwirtschaft, ZKL) in July 2020 and tasked it with making a proposal for an ecologically, economically and socially sustainability agriculture and food system. The Commission's final report, titled **"The Future of Agriculture. A common**

agenda" was approved on 29 June 2021. The key outcomes of the report include the need for a transformation in agriculture towards increased climate protection, environmental conservation and animal welfare, the need for ecological action to be translated into economic success and receive the appropriate financial support, and the need for the transformation to be supported by society as a whole.

4.4.6. Italy

The regulations for greenhouse agriculture in Italy focus on reducing greenhouse gas emissions. Italy has set reduction targets for NH3 emissions, aiming for a 5% reduction by 2020 and a 16% reduction by 2030 compared to 2005 levels. The country emphasizes the importance of **energy-efficient measures** in greenhouse agriculture, such as greater insulation, reducing heat loss, and using **renewable energy sources** like geothermal, biomass, and solar technologies.

We also have to mention that Italy has very recently passed a new law, **LEGGE 28 febbraio 2024, n. 24- Disposizioni per il riconoscimento della figura dell'agricoltore custode dell'ambiente e del territorio e per l'istituzione della Giornata nazionale dell'agricoltura,** that establishes farmers and agricultural cooperatives as guardians of the land and defines agriculture's role in protecting the environment, promoting economic activities in at-risk areas, and reversing rural depopulation. Under this law, farmers are deemed responsible for promoting "rural biodiversity", promoting growth of native plant species, and using sustainable farming practices, local authorities are encouraged to deploy projects and protocols to support farmers as custodians of the land, and the government will award a yearly prize of €20,000 to farmers using innovative, **environmentally-friendly farming techniques.**

In Italy there are also capital contributions and an incentivizing tariff for agrivoltaic systems (combining solar panels and agriculture) which represent a concrete solution for achieving Italy's energy transition goals, offering advantages to both the agricultural and energy sectors. This has been recognized from regulatory perspective in a recent **Decree published by the Ministry of the Environment and Energy Safety on February 13, 2024.**

4.4.7. Poland

The environmental regulations for greenhouse farming in Poland aim to address greenhouse gas emissions, biodiversity conservation, and climate stabilization.

Additionally, Poland aims to increase organic farming by 2030 through eco-schemes under the EU's Common Agricultural Policy (CAP) that incentivize farmers to adopt environmentally friendly practices, promoting a transition to more sustainable agricultural methods. Farmers participating in these schemes will receive incentives, including direct payment contributions, for adopting soil preservation and sustainable production techniques.

The **Water Act of 2017 and the Strategy for Sustainable Rural Development, Agriculture, and Fishery 2030** outline specific measures to mitigate water contamination and promote sustainable agricultural practices in Poland.

4.4.8. Tunisia

Tunisia has established a regulatory framework covering food safety, plant health, seeds, and also environmental protection. On this last case, Tunisia requires environmental impact assessments, risk assessments, and **energy audits for agricultural projects** to prevent pollution and environmental degradation. The Investment Law, approved in 2016, also provides incentives for sustainable development.

However, implementation and enforcement of these regulations appears to be an ongoing challenge. For example, when it comes to water use, there are reports that Tunisia prioritizes water allocation to hotels over farmers for irrigation, which can negatively impact greenhouse farming.

We also have to mention REFAT "Renewable Energies for Agricultural and Rural Development in Tunisia", a cooperation project that is part of the international effort to fight against climate change by mitigating greenhouse gases to achieve the objective of staying below 2 degrees Celsius of increased temperaturesand adapting to the adverse effects of these changes.

4.5. Policy recommendations

As we have been able to verify by the analysis we have carried out at European and state level, the proposed technology is closely aligned with the strategic recommendations and the regulations that govern the areas affected by the project. Nevertheless, we can identify the following policy recommendations to facilitate the deployment of the technology proposed by the project:

1. Training professionals dedicated to energy efficiency to ensure that they know the proposed technology and understand the advantages it offers in terms of energy efficiency, in line with the new mandate of the Directive (EU) 2023/1791 of the European Parliament and of the Council, of 13 September 2023, on energy efficiency, to ensure an appropriate level of competence for energy efficiency related professionals.

2. The adoption by the Commission of a delegated act in accordance with Article 17 of the Regulation (EU) 2017/1369 of the European Parliament and of the Council of 4 July 2017 setting a framework for energy labelling, in order to supplement this Regulation by establishing detailed requirements relating to labels for the proposed technology, so that Member States can provide incentives for it according to article 7.2.

3. Prevent energy storage from being subjected to double taxation, so that charges are not applied both when storing the energy coming from the network as when returning it, in line with the proposal to revise the Energy Taxation Directive (2003/96/EC)

4. In river basin districts affected by drought, incorporation by Member States into the program of measures of the promotion of crops that require little water, not because of the type of cultivation itself, but because of the technology used.

5. Consideration of the proposed technology by the competent public authorities as a good agricultural practice deserving of a bonus in the economic and financial water regime, as well as generally deserving of incentives as an environmentally conscious farming practice.

6. Training the users in the safe use of magnesium chloride.

4.6. Final Recommendations

Financial Incentives: Provide financial support, subsidies, and tax credits to greenhouse operators who invest in energy-efficient technologies like thermochemical fluids. This can help offset initial investment costs and incentivize the adoption of sustainable heating methods.

1. The adoption by the Commission of a delegated act in accordance with Article 17 of the Regulation (EU) 2017/1369 of the European Parliament and of the Council of 4 July 2017 setting a framework for energy labelling, in order to supplement this Regulation by establishing detailed requirements relating to labels for the proposed technology, so that Member States can provide incentives for it according to article 7.2
2. Prevent energy storage from being subjected to double taxation, so that charges are not applied both when storing the energy coming from the network as when

returning it, in line with the proposal to revise the Energy Taxation Directive (2003/96/EC)

3. Consideration of the proposed technology by the competent public authorities as a good agricultural practice deserving of a bonus in the economic and financial water regime, as well as generally deserving of incentives as an environmentally conscious farming practice.

Regulatory Framework: Develop clear regulatory frameworks that support the use of thermochemical fluids in greenhouses, ensuring compliance with energy efficiency standards and environmental regulations. This can create a conducive environment for the widespread adoption of these technologies.

1. Consideration of the proposed technology by the competent public authorities as a good agricultural practice deserving of a bonus in the economic and financial water regime, as well as generally deserving of incentives as an environmentally conscious farming practice.

Capacity Building: Offer training programs and workshops for greenhouse operators on the benefits and proper utilization of thermochemical fluids. Increasing awareness and knowledge about these technologies can encourage their uptake in the agricultural sector.

1. Training professionals dedicated to energy efficiency to ensure that they know the proposed technology and understand the advantages it offers in terms of energy efficiency, in line with the new mandate of the Directive (EU) 2023/1791 of the European Parliament and of the Council, of 13 September 2023, on energy efficiency, to ensure an appropriate level of competence for energy efficiency related professionals.
2. Training the users in the safe use of magnesium chloride.

Public-Private Partnerships: Foster collaborations between government entities, research institutions, industry stakeholders, and technology providers to promote the use of thermochemical fluids in greenhouses. Public-private partnerships can facilitate knowledge sharing, technology transfer, and joint initiatives to drive adoption.

4.6.1. Annex ECHA data sheet example

There goes an example of a data sheet from the European Chemicals Agency (ECHA) as a reference for handling and safety information specifically related to thermochemical fluids.

Voluntary safety information following the Safety Data Sheet format according to Regulation (EC) No. 1907/2006 (REACH)

Magnesium chloride hexahydrate ≥99 %, p.a., ACS

article number: **2189**
Version: **3.0 en**
Replaces version of: 2020-08-20
Version: (2)

date of compilation: 2016-10-05
Revision: 2022-02-18

SECTION 1: Identification of the substance/mixture and of the company/ undertaking

1.1 Product identifier

Identification of the substance	**Magnesium chloride hexahydrate** ≥99 %, p.a., ACS
Article number	2189
Registration number (REACH)	01-2119485597-19-xxxx
EC number	232-094-6
CAS number	7791-18-6

1.2 Relevant identified uses of the substance or mixture and uses advised against

Relevant identified uses:	Laboratory chemical Laboratory and analytical use
Uses advised against:	Do not use for products which come into contact with foodstuffs. Do not use for private purposes (household).

1.3 Details of the supplier of the safety data sheet

Carl Roth GmbH + Co KG
Schoemperlenstr. 3-5
D-76185 Karlsruhe
Germany

Telephone:+49 (0) 721 - 56 06 0
Telefax: +49 (0) 721 - 56 06 149
e-mail: sicherheit@carlroth.de
Website: www.carlroth.de

Competent person responsible for the safety data sheet: :Department Health, Safety and Environment

e-mail (competent person): sicherheit@carlroth.de

1.4 Emergency telephone number

Name	Street	Postal code/city	Telephone	Website
National Poisons Information Service City Hospital	Dudley Rd	B187QH Birmingham	844 892 0111	

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SECTION 2: Hazards identification

2.1 Classification of the substance or mixture

Classification according to Regulation (EC) No 1272/2008 (CLP)

This substance does not meet the criteria for classification in accordance with Regulation No 1272/ 2008/EC.

2.2 Label elements

Labelling according to Regulation (EC) No 1272/2008 (CLP)

not required

2.3 Other hazards

Results of PBT and vPvB assessment

According to the results of its assessment, this substance is not a PBT or a vPvB.

SECTION 3: Composition/information on ingredients

3.1 Substances

Name of substance	Magnesium chloride hexahydrate
Molecular formula	$MgCl_2 \cdot 6 H_2O$
Molar mass	203,3 $^{g}/_{mol}$
REACH Reg. No	01-2119485597-19-xxxx
CAS No	7791-18-6
EC No	232-094-6

SECTION 4: First aid measures

4.1 Description of first aid measures

General notes

Take off contaminated clothing.

Following inhalation

Provide fresh air. In all cases of doubt, or when symptoms persist, seek medical advice.

Following skin contact

Rinse skin with water/shower.

Following eye contact

Rinse cautiously with water for several minutes. In all cases of doubt, or when symptoms persist, seek medical advice.

Following ingestion

Rinse mouth. Call a doctor if you feel unwell.

4.2 Most important symptoms and effects, both acute and delayed

Symptoms and effects are not known to date.

4.3 Indication of any immediate medical attention and special treatment needed

none

SECTION 5: Firefighting measures

5.1 Extinguishing media

Suitable extinguishing media

co-ordinate firefighting measures to the fire surroundings
water, foam, alcohol resistant foam, dry extinguishing powder, ABC-powder

Unsuitable extinguishing media

water jet

5.2 Special hazards arising from the substance or mixture

Non-combustible.

Hazardous combustion products

In case of fire may be liberated: Hydrogen chloride (HCl)

5.3 Advice for firefighters

In case of fire and/or explosion do not breathe fumes. Fight fire with normal precautions from a reasonable distance. Wear self-contained breathing apparatus.

SECTION 6: Accidental release measures

6.1 Personal precautions, protective equipment and emergency procedures

For non-emergency personnel

No special measures are necessary.

6.2 Environmental precautions

Keep away from drains, surface and ground water.

6.3 Methods and material for containment and cleaning up

Advice on how to contain a spill

Covering of drains. Take up mechanically.

Advice on how to clean up a spill

Take up mechanically.

Other information relating to spills and releases

Place in appropriate containers for disposal.

6.4 Reference to other sections

Hazardous combustion products: see section 5. Personal protective equipment: see section 8. Incompatible materials: see section 10. Disposal considerations: see section 13.

SECTION 7: Handling and storage

7.1 Precautions for safe handling

No special measures are necessary.

Advice on general occupational hygiene

Keep away from food, drink and animal feedingstuffs.

7.2 Conditions for safe storage, including any incompatibilities

Store in a dry place. Hygroscopic solid.

Incompatible substances or mixtures

Observe hints for combined storage.

Protect against external exposure, such as

high temperatures, humidity

Consideration of other advice:

Specific designs for storage rooms or vessels

Recommended storage temperature: 15 – 25 °C

7.3 Specific end use(s)

No information available.

SECTION 8: Exposure controls/personal protection

8.1 Control parameters

National limit values

Occupational exposure limit values (Workplace Exposure Limits)

This information is not available.

Environmental values

Relevant PNECs and other threshold levels

End-point	Threshold level	Organism	Environmental compartment	Exposure time
PNEC	3,21 mg/l	aquatic organisms	freshwater	short-term (single instance)
PNEC	0,32 mg/l	aquatic organisms	marine water	short-term (single instance)
PNEC	90 mg/l	aquatic organisms	sewage treatment plant (STP)	short-term (single instance)
PNEC	288,9 mg/kg	aquatic organisms	freshwater sediment	short-term (single instance)
PNEC	28,89 mg/kg	aquatic organisms	marine sediment	short-term (single instance)
PNEC	662,8 mg/kg	terrestrial organisms	soil	short-term (single instance)

8.2 Exposure controls

Individual protection measures (personal protective equipment)

Eye/face protection

Use safety goggle with side protection.

Skin protection

• hand protection

Wear suitable gloves. Chemical protection gloves are suitable, which are tested according to EN 374.

• type of material

NBR (Nitrile rubber)

• material thickness

>0,11 mm

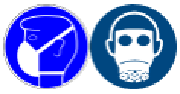
• breakthrough times of the glove material

>480 minutes (permeation: level 6)

• other protection measures

Take recovery periods for skin regeneration. Preventive skin protection (barrier creams/ointments) is recommended.

Respiratory protection



Respiratory protection necessary at: Dust formation. Particulate filter device (EN 143). P1 (filters at least 80 % of airborne particles, colour code: White).

Environmental exposure controls

Keep away from drains, surface and ground water.

SECTION 9: Physical and chemical properties

9.1 Information on basic physical and chemical properties

Physical state	solid
Colour	whitish
Odour	odourless
Melting point/freezing point	>100 °C (Release of crystal water)
Boiling point or initial boiling point and boiling range	not determined

Flammability	non-combustible
Lower and upper explosion limit	not determined
Flash point	not applicable
Auto-ignition temperature	not determined
Decomposition temperature	>100 °C
pH (value)	4,5 – 7 (in aqueous solution: 50 $^g/_l$, 20 °C)
Kinematic viscosity	not relevant
Solubility(ies)	
Water solubility	468,7 $^g/_l$ at 20 °C (ECHA)
Partition coefficient	
Partition coefficient n-octanol/water (log value):	not relevant (inorganic)
Vapour pressure	not determined
Density and/or relative density	
Density	1,57 $^g/_{cm^3}$ at 20 °C
Relative vapour density	information on this property is not available
Particle characteristics	No data available.
Other safety parameters	
Oxidising properties	none

9.2 Other information

Information with regard to physical hazard classes:	hazard classes acc. to GHS (physical hazards): not relevant
Other safety characteristics:	There is no additional information.

SECTION 10: Stability and reactivity

10.1 Reactivity

This material is not reactive under normal ambient conditions.

10.2 Chemical stability

The material is stable under normal ambient and anticipated storage and handling conditions of temperature and pressure.

10.3 Possibility of hazardous reactions

No known hazardous reactions.

10.4 Conditions to avoid

Keep away from heat. Decompostion takes place from temperatures above: >100 °C.

10.5 Incompatible materials

There is no additional information.

10.6 Hazardous decomposition products

Hazardous combustion products: see section 5.

SECTION 11: Toxicological information

11.1 Information on hazard classes as defined in Regulation (EC) No 1272/2008

Classification according to GHS (1272/2008/EC, CLP)

This substance does not meet the criteria for classification in accordance with Regulation No 1272/ 2008/EC.

Acute toxicity

Shall not be classified as acutely toxic.

Acute toxicity					
Exposure route	Endpoint	Value	Species	Method	Source
oral	LD50	>5.000 $^{mg}/_{kg}$	rat	anhydrous	ECHA
dermal	LD50	>2.000 $^{mg}/_{kg}$	rat	anhydrous	ECHA

Skin corrosion/irritation

Shall not be classified as corrosive/irritant to skin.

Serious eye damage/eye irritation

Shall not be classified as seriously damaging to the eye or eye irritant.

Respiratory or skin sensitisation

Shall not be classified as a respiratory or skin sensitiser.

Germ cell mutagenicity

Shall not be classified as germ cell mutagenic.

Carcinogenicity

Shall not be classified as carcinogenic.

Reproductive toxicity

Shall not be classified as a reproductive toxicant.

Specific target organ toxicity - single exposure

Shall not be classified as a specific target organ toxicant (single exposure).

Specific target organ toxicity - repeated exposure

Shall not be classified as a specific target organ toxicant (repeated exposure).

Aspiration hazard

Shall not be classified as presenting an aspiration hazard.

Symptoms related to the physical, chemical and toxicological characteristics

• If swallowed

diarrhea, vomiting, nausea, gastrointestinal complaints

• **If in eyes**

Data are not available.

• **If inhaled**

Data are not available.

• **If on skin**

Data are not available.

• **Other information**

none

11.2 Endocrine disrupting properties

Not listed.

11.3 Information on other hazards

There is no additional information.

SECTION 12: Ecological information

12.1 Toxicity

Shall not be classified as hazardous to the aquatic environment.

Aquatic toxicity (acute)

Endpoint	Value	Species	Source	Exposure time
LC50	541 mg/l	fish	ECHA	96 h

Aquatic toxicity (chronic)

Endpoint	Value	Species	Source	Exposure time
EC50	>900 mg/l	microorganisms	ECHA	3 h

Biodegradation

The methods for determining the biological degradability are not applicable to inorganic substances.

12.2 Process of degradability

Data are not available.

12.3 Bioaccumulative potential

Data are not available.

12.4 Mobility in soil

Data are not available.

12.5 Results of PBT and vPvB assessment

Data are not available.

12.6 Endocrine disrupting properties

Not listed.

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12.7 Other adverse effects

Data are not available.

SECTION 13: Disposal considerations

13.1 Waste treatment methods

Consult the appropriate local waste disposal expert about waste disposal.

Sewage disposal-relevant information

Do not empty into drains.

13.2 Relevant provisions relating to waste

The allocation of waste identity numbers/waste descriptions must be carried out according to the EEC, specific to the industry and process. Waste catalogue ordinance (Germany).

13.3 Remarks

Waste shall be separated into the categories that can be handled separately by the local or national waste management facilities. Please consider the relevant national or regional provisions.

SECTION 14: Transport information

14.1	**UN number or ID number**	not subject to transport regulations
14.2	**UN proper shipping name**	not assigned
14.3	**Transport hazard class(es)**	none
14.4	**Packing group**	not assigned
14.5	**Environmental hazards**	non-environmentally hazardous acc. to the dangerous goods regulations

14.6 Special precautions for user

There is no additional information.

14.7 Maritime transport in bulk according to IMO instruments

The cargo is not intended to be carried in bulk.

14.8 Information for each of the UN Model Regulations

Transport of dangerous goods by road, rail and inland waterway (ADR/RID/ADN) - Additional information

Not subject to ADR, RID and ADN.

International Maritime Dangerous Goods Code (IMDG) - Additional information

Not subject to IMDG.

International Civil Aviation Organization (ICAO-IATA/DGR) - Additional information

Not subject to ICAO-IATA.

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SECTION 15: Regulatory information

15.1 Safety, health and environmental regulations/legislation specific for the substance or mixture

Relevant provisions of the European Union (EU)

Restrictions according to REACH, Annex XVII

not listed

List of substances subject to authorisation (REACH, Annex XIV)/SVHC - candidate list

Not listed.

Seveso Directive

2012/18/EU (Seveso III)			
No	Dangerous substance/hazard categories	Qualifying quantity (tonnes) for the application of lower and upper-tier requirements	Notes
	not assigned		

Deco-Paint Directive

VOC content	0 % 0 g/l

Industrial Emissions Directive (IED)

VOC content	0 %
VOC content	0 g/l

Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS)

not listed

Regulation concerning the establishment of a European Pollutant Release and Transfer Register (PRTR)

not listed

Water Framework Directive (WFD)

List of pollutants (WFD)				
Name of substance	Name acc. to inventory	CAS No	Listed in	Remarks
Magnesium chloride hexahydrate	Metals and their compounds		a)	

Legend

A) Indicative list of the main pollutants

Regulation on the marketing and use of explosives precursors

not listed

Regulation on drug precursors

not listed

Regulation on substances that deplete the ozone layer (ODS)

not listed

Regulation concerning the export and import of hazardous chemicals (PIC)

not listed

Regulation on persistent organic pollutants (POP)

not listed

Other information

Directive 94/33/EC on the protection of young people at work. Observe employment restrictions under the Maternity Protection Directive (92/85/EEC) for expectant or nursing mothers.

National inventories

Country	Inventory	Status
AU	AICS	substance is listed
CA	DSL	substance is listed
CN	IECSC	substance is listed
EU	ECSI	substance is listed
EU	REACH Reg.	substance is listed
JP	CSCL-ENCS	substance is listed
KR	KECI	substance is listed
MX	INSQ	substance is listed
NZ	NZIoC	substance is listed
PH	PICCS	substance is listed
TR	CICR	substance is listed
TW	TCSI	substance is listed
US	TSCA	substance is listed

Legend

AICS	Australian Inventory of Chemical Substances
CICR	Chemical Inventory and Control Regulation
CSCL-ENCS	List of Existing and New Chemical Substances (CSCL-ENCS)
DSL	Domestic Substances List (DSL)
ECSI	EC Substance Inventory (EINECS, ELINCS, NLP)
IECSC	Inventory of Existing Chemical Substances Produced or Imported in China
INSQ	National Inventory of Chemical Substances
KECI	Korea Existing Chemicals Inventory
NZIoC	New Zealand Inventory of Chemicals
PICCS	Philippine Inventory of Chemicals and Chemical Substances (PICCS)
REACH Reg.	REACH registered substances
TCSI	Taiwan Chemical Substance Inventory
TSCA	Toxic Substance Control Act

15.2 Chemical Safety Assessment

No Chemical Safety Assessment has been carried out for this substance.

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SECTION 16: Other information

Indication of changes (revised safety data sheet)

Alignment to regulation: Regulation (EC) No. 1907/2006 (REACH), amended by 2020/878/EU

Restructuring: section 9, section 14

Section	Former entry (text/value)	Actual entry (text/value)	Safety-relevant
2.2	Signal word: not required		yes
2.3	Other hazards: There is no additional information.	Other hazards	yes
2.3		Results of PBT and vPvB assessment: According to the results of its assessment, this substance is not a PBT or a vPvB.	yes

Abbreviations and acronyms

Abbr.	Descriptions of used abbreviations
ADN	Accord européen relatif au transport international des marchandises dangereuses par voies de navigation intérieures (European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways)
ADR	Accord relatif au transport international des marchandises dangereuses par route (Agreement concerning the International Carriage of Dangerous Goods by Road)
CAS	Chemical Abstracts Service (service that maintains the most comprehensive list of chemical substances)
CLP	Regulation (EC) No 1272/2008 on classification, labelling and packaging of substances and mixtures
DGR	Dangerous Goods Regulations (see IATA/DGR)
EC50	Effective Concentration 50 %. The EC50 corresponds to the concentration of a tested substance causing 50 % changes in response (e.g. on growth) during a specified time interval
EC No	The EC Inventory (EINECS, ELINCS and the NLP-list) is the source for the seven-digit EC number, an identifier of substances commercially available within the EU (European Union)
EINECS	European Inventory of Existing Commercial Chemical Substances
ELINCS	European List of Notified Chemical Substances
GHS	"Globally Harmonized System of Classification and Labelling of Chemicals" developed by the United Nations
IATA	International Air Transport Association
IATA/DGR	Dangerous Goods Regulations (DGR) for the air transport (IATA)
ICAO	International Civil Aviation Organization
IMDG	International Maritime Dangerous Goods Code
LC50	Lethal Concentration 50%: the LC50 corresponds to the concentration of a tested substance causing 50 % lethality during a specified time interval
LD50	Lethal Dose 50 %: the LD50 corresponds to the dose of a tested substance causing 50 % lethality during a specified time interval
NLP	No-Longer Polymer
PBT	Persistent, Bioaccumulative and Toxic

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Abbr.	Descriptions of used abbreviations
PNEC	Predicted No-Effect Concentration
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
RID	Règlement concernant le transport International ferroviaire des marchandises Dangereuses (Regulations concerning the International carriage of Dangerous goods by Rail)
SVHC	Substance of Very High Concern
VOC	Volatile Organic Compounds
vPvB	Very Persistent and very Bioaccumulative

Key literature references and sources for data

Regulation (EC) No 1272/2008 on classification, labelling and packaging of substances and mixtures. Regulation (EC) No. 1907/2006 (REACH), amended by 2020/878/EU.

Agreement concerning the International Carriage of Dangerous Goods by Road (ADR). Regulations concerning the International Carriage of Dangerous Goods by Rail (RID). International Maritime Dangerous Goods Code (IMDG). Dangerous Goods Regulations (DGR) for the air transport (IATA).

Disclaimer

This information is based upon the present state of our knowledge. This SDS has been compiled and is solely intended for this product.

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