MULTITRACES

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TITLE OF THE PROJECTS

SMART AND SUSTAINABLE GREENHOUSES IN THE CONTEXT OF CIRCULAR ECONOMY

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Table of Contents

1. Memory of the project 5
1.1 Executive summary 5
1.2 Introduction 7
1.3 State of the art 7
1.3.1 Historical framework of the context 7
1.3.2 Existing solutions 8
1.4 Description of the chosen solution 9
1.4.1 SWOT analysis 9
1.5 Conclusion 10
1.6 References 11
2. Calculation and design 13
2.1 Input data of the project 13
2.2 Calculation and design of the final solution 14
2.2.1 Greenhouse building 14
2.2.2 Utilization of natural resources 15
2.2.3 Automations 16
2.3 Benefits of the solution from point of view of Circular Economy 18
2.3.2 Impact on the environment 19
2.4 Conclusion 20
2.5 References 21
3. Investment cost and profitability analysis 22
3.1 Cost of the proposed solution 22
3.2 Benefit of the proposed solution 22
3.3 Net present value 23
3.4 Payback period 25
3.6 Conclusion 26
3.7 References 27
Annexes 28

1. MEMORY OF THE PROJECT

1.1 Executive summary

The purpose of this document is to showcase ways of either implementing or extending and improving already existing greenhouses in a sustainable way.

Greenhouses involve a great deal of manual labor. This project aims to provide a guideline and possible implementation that would remove the need of manual labor and, potentially, also provide tweaks on how to make greenhouses self-sufficient, sustainable and profitable.

Greenhouses have evolved greatly and nowadays, with the use of technology, we can see fully automated ones. Automated greenhouses are not a new concept and there is a long list of available preconfigured equipment that can be used to make a greenhouse into a smart one. However, the main question would be whether or not it is the best choice. What about tailoring the experience, the implementation of a greenhouse for a specific case? What would it look like, what features would it have? In this mindset, each and every greenhouse, in order to be self-sufficient and sustainable, should accommodate and be accommodated to its surroundings.

"Designing a sustainable greenhouse involves:

1. Selecting the right site
2. Designing the right structure
3. Building with sustainable materials
4. Implementing an eco-friendly watering system
5. Following the 3 R's: Reduce, Reuse, Recycle
6. Optimizing energy usage"[7]

The company's location for which this project proposal has been put together, facilitates the implementation of greenhouses through its natural resources such as running water from underground springs, the temperate climate and the soil type. What is left is to build, automate and cultivate. Those processes can be quantified and classified as capital investments.

In order to implement the greenhouse, the required external resources are building materials and construction workers (that if the chosen frame is not a prefabricated one. However, this project proposal makes use of a prefabricated model), IoT powered devices in order to automate simple and/or complex processes, the required seeds, plants for cultures and equipment for said cultures.

The return of investment can never be guaranteed on small-scale operations such as the proposed greenhouse but the vision of this project is to integrate greenhouses as part of the development direction on the current property in ways to offer experiences for the to-be visitor center and also as a food source for the potential clients.Taking the previous aspects into consideration, a greenhouse could prove to be valuable since the idea of a smart, sustainable greenhouse is to produce food on a minimum investment with minimum operating costs.

In the county of Bacau, Romania, most greenhouses are used for growing flowers, however. Some vegetable cultivators could also be found but those use mostly open-field techniques which are dependent on the weather conditions.

A list of all existing firms within the country of Bacau that have their activity listed as agriculture can be seen in Annex 1.1.

For marketing, the suggestion is to advertise the greenhouse(s) as an extra activity for the visitor experience sphere. Products from the greenhouse can be exploited as food, whereas the greenhouse can be used as a way for mostly urban-raised populations to learn about gardening.

The budget is calculated based on the costs of implementation of a single smart & sustainable greenhouse and is detailed in chapter 2.

Through the implementation of this project, the aim is to enhance the assets of the company with a modern, smart, sustainable greenhouse used within the scope of a circular economy. The strongest aspect of this greenhouse is that it aims to provide crops using minimum investments and maintenance while also acting as an activity center for future visiting members.

1.2 Introduction

"Greenhouse gardening is an efficient way to grow food on a relatively small piece of property without compromising soil quality. Greenhouses help keep surrounding areas undisturbed, preserving the ecosystems and wildlife that live there. Compared to conventional farming, growing in greenhouses is a more sustainable method of food production. But if designed without sustainability in mind, greenhouses can be quite energy and water intensive. From their construction to operation, sustainable greenhouses are designed to preserve resources and have a low environmental impact". [2]

Nowadays, sustainability should be a key factor in every decision taken whether it is personal or business related. This project aims to showcase ways in which greenhouses can be made into sustainable and smart additions to properties in order to enhance food production with minimal investments and maintenance while using existing by-products within the scope of the circular economy.

1.3 State of the art

1.3.1 Historical framework of the context

"The idea of growing plants in environmentally controlled areas has existed since at least Roman times. The cucumber was a favorite of Roman emperor Tiberius, who 'was never without it' (Pliny the Elder 77 C.E. in Bostock and Riley 1855). The Roman gardeners used artificial methods (similar to the greenhouse system) of growing to have it available for his table every day of the year. Cucumbers were planted in wheeled carts, which were put in the sun daily, then taken inside to keep them warm at night under special conditions (Pliny the Elder 77 C.E.). The cucumbers were stored under frames or in cucumber houses glazed with either oiled cloth, known as 'specularia,' or with sheets of mica.

The first modern greenhouses were built in Italy in the sixteenth century to house the exotic plants that explorers brought back from the tropics. They were originally called *giardini botanici* (botanical gardens). The concept of greenhouses soon spread to the Netherlands and then England, along with the plants."[3]

"Greenhouses arrived in America during the 1700s. Andrew Faneuil, a prosperous Boston merchant, built the first American greenhouse in 1737. George Washington built a greenhouse at his home in Mt. Vernon to serve pineapple to guests. The French botanist Charles Lucien Bonaparte, credited with constructing the first practical greenhouse in Leiden, Holland, during the 1800s, used it to grow tropical, medicinal plants. Initially, only the rich could afford greenhouses, but research potential spread to the universities where they began popping up."[6]

1.3.2 Existing solutions

In terms of sustainable and smart greenhouses, existing solutions revolve around the following concepts and directions:

- Greenhouses as CEA Solutions

CEA stands for Controlled Environment Agriculture.

In the classical sense, greenhouses use simple principles for design and operation: cardinal orientation, glass walls, insulation, etc. The main advantage of greenhouses is represented by the discreet use of solar light and heat, it being known that sunlight is the most beneficial for the optimal development of plants.

This aspect distinguishes the greenhouses from other CEA facilities.

Artificial cultivation lights are expensive, both from the point of view of the initial cost, as well as from the point of view of the operating cost. That's why, even if it requires a supply of moonlight in particular conditions, greenhouses represent the most sustainable and ecological option for growing plants.[5]

- Sustainable Greenhouse Design in Maximizing Energy Efficiency

When it comes to sustainable greenhouse design, key decisions influence the energy-efficiency of the structure.

Of course, one of the important aspects considered when building a greenhouse is, as previously mentioned, the positioning in relation to the east-west axis in the northern hemisphere, so that the glazed wall has exposure to the south, thus capturing most of the light and heat during a day. Extending the glazed surface to the south actually means a solar gain throughout the year, so that the additional light intake is as small as possible.[5]

Another key decision in designing a sustainable greenhouse and increasing energy-efficiency, would be insulation. Greenhouses are not inherently warm. Through their orientation and placement, greenhouses make use of the light from the sun but also collect its heat. Through adding insulation to the walls that are not required for sun collection, the heat can be trapped within the structure.

- Geothermal Heating and Cooling

"When it comes to smart greenhouse design, usage of natural resources needs to be optimized. If the budget permits, making use of geothermal energy should be encouraged. Since old times, greenhouses were heated during winter ,using wood stoves, in order to preserve the crops. As technology advanced, people moved towards electrical heaters but we can safely say that both solutions are quite resource intensive. Through employing natural resources such as geothermal heating/cooling, the issue of keeping the temperature regulated within the greenhouse can be solved in a sustainable way."[5]

1.4 Description of the chosen solution

1.4.1 SWOT analysis

"If you want to thrive in a competitive marketplace, you have to assess the condition of your business, inside and out. Internally, you have to understand what you're doing well, and where you could improve. Externally, you have to consider where to take your business next, and predict emerging market challenges you'll likely face." [4]

Through the implementation of the smart greenhouse, we wish to achieve yet another form of entertainment for the client that wishes to go into agroturism and also a stack of food created with minimum investments and maintenance costs. However, in order to determine whether or not the solution is feasible, one must do a SWOT analysis.

Strengths	**Weaknesses**
● Sustainable design ensures the quality and quantity of crops.	● From a touristic standpoint, there are other vendors facilitating the same type of experience. ● Technological improvements involve maintenance costs.
Opportunities	**Threats**
● Accessing European funds for	● The increase of costs for IOT equipment

development. ● State-funded projects.	combined with the impossibility of vendors providing the required amount of devices.

1.5 Conclusion

Greenhouses provide food while taking into account optimized resource consumption and, with the right automations, optimized maintenance costs.

Smart greenhouses are designed to be highly efficient and sustainable, optimizing resource consumption such as water, energy, and nutrients. By using hydroponic systems, energy-efficient technology, automated nutrient delivery systems, advanced climate control, and sustainable waste management practices, smart greenhouses maximize plant yields while reducing waste and costs. These greenhouses not only contribute to a more efficient and cost-effective agricultural system, but also play a crucial role in creating a more sustainable future.

Additionally, automated greenhouses not only optimize energy consumption but also provide increased crop quality and quantity. For example:

1. Studies by researchers from the University of California conclude that using IoT to control temperature and humidity can increase crop yields by up to 30%.
2. Researchers from the University of Arizona reinforce the previous conclusion, arguing that soil moisture monitoring and automated irrigation systems can improve water use efficiency by up to 90%, which can increase crop yields by up to 50%. The researchers from the University of Florida included the CO2 level in the monitoring process, in addition to monitoring soil moisture and air temperature, with the help of IoT devices. Controlling these parameters contributes to increasing quality and productivity.

These studies and others demonstrate the potential for IoT to significantly improve crop quality and productivity, making it an important tool for the agricultural industry. However, it's important to note that while IoT has the potential to greatly benefit agriculture, it is only one of many factors that contribute to crop quality and productivity. Other factors, such as soil quality, plant genetics, and growing conditions, also play a critical role.

1.6 References

[1] Top 25 agriculture firms in the county of Bacau, Romania - available at https://www.clientsolutions.ro/firme-de-agricultura-din-judetul-bacau/, (20.06.2022).

[2] 6 Step Guide to design and create a sustainable greenhouse - available at https://greenbusinessbureau.com/industries/6-step-guide-to-design-and-create-a-sustainable-greenhouse/, (10.05.2022).

[3] Greenhouse, New World Encyclopedia - available at https://www.newworldencyclopedia.org/entry/greenhouse#:~:text=The%20first%20modern%20greenhouses%20were,England%2C%20along%20with%20the%20plants, (05.08.2022).

[4] SWOT Analysis examples - available at https://www.semrush.com/blog/swot-analysis-exam-ples/?kw=&cmp=EE_SRCH_DSA_Blog_MR_BU_EN&label=dsa_pagefeed&Network=g&Device=c&utm_content=573844374362&kwid=dsa-1584264071402&cmpid=12690580684&agpid=132042518837&BU=MR&extid=23623720033&adpos=&gclid=Cj0KCQjwxIOXBhCrARIsAL1QFCY6EN68egWPLgPJ_yOxfV1U6kBwT7lRqj1fkvgwbbdz-WslqSs3tF0aAvoXEALw_wcB, (05.08.2022).

[5] Advancing sustainability through smart greenhouse design - available at https://www.agritecture.com/blog/2020/10/15/advancing-sustainability-through-smart-greenhouse-design (15.10.2022)

[6] The History of Greenhouses - available at https://blog.growlink.com/the-history-of-greenhous-es#:~:text=The%20French%20botanist%20Charles%20Lucien,where%20they%20began%20popping%20up. (20.10.2022)

[7] 6 Step Guide to Design and Create a Sustainable Greenhouse - available at https://greenbusinessbureau.com/industries/6-step-guide-to-design-and-create-a-sustainable-greenhouse/ (10.11.2022)

2. Calculation and design

2.1 Input data of the project

The beneficiary of this project is the company ROMAGRIS SRL, 24997400 and its central point of work is located at Călugăreni, Dămieneşti, Nr. 1, County of Bacău, P.O 607136. The company has been registered in 2009 and its approved area of expertise is cereals (except for rice), vegetables and oleaginous plants cultivation.

	Cifra Afaceri - RON	Profit Net - RON	Angajati
2021	4.718.972	848.183	4
2020	2.624.455	-423.883	4
2019	5.518.641	5.551	4
2018	948.288	14.751	5
2017	3.565.368	1.086.863	5
2016	2.815.582	43.233	5
2015	2.018.394	-172.191	3
2014	2.654.536	16.388	3
2013	1.908.881	144.670	4
2012	1.316.820	26.392	4

fig. 2.1.a - Financial Data for the company for the past 10 years [3]

From the above attached financial information, and the on hands experience at the company site, it is obvious to the naked eye that the company mainly functions with a small number of employees and relies on technology upgrades and specialized machinery to facilitate farming. Hence, the suggestion of a smart & sustainable greenhouse.

2.2 Calculation and design of the final solution

In terms of timelines, the roadmap of the project, not taking into consideration possible delays, should be structured as it follows:

- preparing the terrain and utilities - up to 5 days for the greenhouse, not including bringing water from the nearby lake.
- acquiring materials - up to 30 days since the geopolitical conditions have created shortages of IoT devices.
- building - for prefabricated structures, building should not take more than 5 days to be put together.
- automating - up to 15 days for installing the system.
- creating and maintaining crops - this is dependent on the chosen cultures.

In terms of the human resource, the implementing team should include:

- a product owner (representative from the company)
- a project manager (not recommended but can be the same as the product owner)
- a cross-disciplinary team (2-5 people)
- one long-term employee responsible for learning and later overseeing the aspects related to the technology added to the greenhouse

2.2.1 Greenhouse building

Greenhouses come in many shapes and sizes. Depending on the purpose there is a choice of going with a prefabricated one or building it independently. For this project, the proposal is to go with a prefabricated one which would range anywhere from 1000 Euro to 5000 Euro depending on the size and materials.

The proposed size is 19.30 x 52.55 meters (2 modules) and 9.70 x 52.55 meters (2 modules). It would cost around 11.000 Euro (2 x 3.5000 Euro + 2 x 2.000 Euro). The costs that might arise from preparing the terrain and actually putting together the pre-built greenhouse.

Later, should the proposed solution prove profitable, the solution can be scaled.

fig. 2.2.1.a Image of a market-available greenhouse structure [1]

2.2.2 Utilization of natural resources

Greenhouses are using natural resources by design and the most common design flaws in a greenhouse are to do with the watering system & the energy usage. However, since the proposed site for the greenhouse is near a natural water source, the resource should be exploited.

Sustainable greenhouses prioritize the utilization of natural resources in order to minimize waste and promote a closed-loop system. Here are a few ways in which sustainable greenhouses utilize natural resources:

1. Water: Sustainable greenhouses use hydroponic systems to conserve water by precisely measuring and distributing water to the plants, reducing waste and evaporation. They may also collect and reuse rainwater to further conserve this precious resource.

2. Energy: Sustainable greenhouses prioritize renewable energy sources such as solar and wind power to minimize their carbon footprint and reduce energy costs. They also use energy-efficient systems, such as LED lighting and advanced climate control, to min-

imize energy consumption.

3. Nutrients: Sustainable greenhouses use compost made from recycled organic waste to enrich the soil, reducing fertilizer costs and waste. Automated nutrient delivery systems further optimize the use of nutrients by monitoring plant health and adjusting nutrient levels accordingly.

4. Climate control: Sustainable greenhouses use advanced climate control systems to regulate temperature, humidity, and CO2 levels, creating optimal growing conditions while minimizing energy consumption.

5. Waste management: Sustainable greenhouses minimize waste by using a closed-loop system in which organic waste is recycled and transformed into compost, which is then used to enrich the soil.

By utilizing natural resources in a sustainable manner, greenhouses are able to maximize plant yields and reduce costs while also promoting a more sustainable future.

2.2.3 Automations

A greenhouse is a structure used to grow plants and even though it creates a perfect environment for plants, it needs human care. Automated greenhouses constitute a way to help people when they wish to grow plants through providing a set of tools that provides them monitor and control capabilities remotely.

For the implementation of this project, the project proposes automation of humidity control for plants as a starter pack with the possibility of automating lighting & ventilation.

In order to automate humidity control, the following solution is proposed: IoT Smart Garden Setup with MKR IoT Carrier. This solution is properly described and documented on the official vendor site [2] but also explained summarily below.

"The MKR IoT Carrier has built in relays that can let you control circuits that are powered separately. (...) and it can be used to create a sophisticated smart garden setup, capable of:

- Remote watering of a plant **(with a pump)**.
- Check the moisture of your plant **(with a moisture sensor)**.
- Check the temperature/humidity **(using the onboard HTS221 sensor)**."[2]

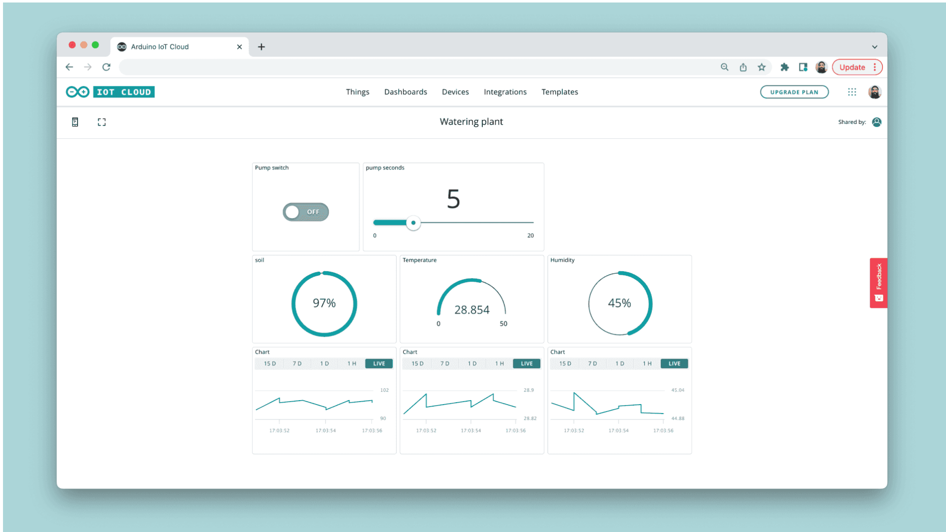


fig. 2.2.3.a - Image of the Automations Dashboard [2]

In order to achieve the aforementioned capabilities, besides the MKR IoT Carrier board, other components are needed such as:

- “MKR WiFi 1010
- 5V submersible pump.
- 1 meter watering pipe.
- Water container.
- USB adapter with at least 2 USB ports.
- Micro-USB cable.
- Open ended USB Cable.
- Soil moisture sensor.”[2]

As one can easily see, the presented solution is for a small scale project, but taking into consideration the proposed structure (8x4 meters) we could scale the above accordingly. The focus should, however, be on the way the automation should function and the following is proposed:

1. Sensors: Install sensors for measuring humidity and moisture levels in the greenhouse soil. These sensors should be connected to the Arduino MKR IoT Carrier.

2. Data Collection: The sensors will collect data on humidity and moisture levels and send this data to the Arduino MKR IoT Carrier.
3. Data Analysis: The Arduino MKR IoT Carrier will analyze the data received from the sensors and make decisions based on the data. For example, if the humidity levels are too high, the Carrier will activate a ventilation system to reduce humidity. If the moisture levels are too low, the Carrier will activate a watering system to provide water to the plants.
4. Actuators: Install actuators, such as fans and water pumps, that can be controlled by the Arduino MKR IoT Carrier.
5. Communication: The Arduino MKR IoT Carrier should be connected to the internet so that it can communicate with other devices and systems, such as smartphones and web-based monitoring systems.
6. Monitoring and Control: A user should be able to monitor and control the humidity and moisture levels in the greenhouse from a remote location, such as a smartphone or computer, using a web-based monitoring system.
7. Alarms and Notifications: The system should be able to send notifications or alarms if the humidity or moisture levels reach a critical level, alerting the user to take action.

This logical scheme provides a basic framework for an Arduino MKR IoT Carrier for humidity and moisture control in a greenhouse. The specifics of the implementation, such as the type and number of sensors, actuators, and communication systems, will depend on the specific requirements of the greenhouse.

2.3 Benefits of the solution from point of view of Circular Economy

When one hears of the Circular Economy, the main idea left behind by this concept is a way to achieve a sustainable future. Through the implementation of the smart and sustainable greenhouse, the project aims to make use of the key points of Circular Economy.

On the company's current land, there are a couple of old constructions that can serve as the starting point for the greenhouses. Repurposing old buildings as greenhouses is a sustainable solution that aligns with the principles of the circular economy. The existing structure of an old building, being close to natural resources such as sunlight and water, can be utilized to enhance the efficiency of the greenhouse. This can help to create a closed-loop system where resources are conserved and waste is minimized. By using the existing structure, the need for new construction and the use of new materials is eliminated. The construction industry is known for its significant environmental impact, therefore, repurposing an existing building can greatly reduce the carbon footprint and environmental impact of a new greenhouse.

Additionally, incorporating sustainable practices such as using rainwater harvesting and recycling greywater, and installing energy-efficient systems such as solar panels and geothermal heating can make the greenhouse even more sustainable. This can help to reduce the greenhouse's dependence on external energy sources and make it more self-sufficient. The use of natural resources in conjunction with energy-efficient systems can make the greenhouse more efficient, and therefore, more sustainable.

Furthermore, repurposing an old building as a greenhouse can also have socio-economic benefits. It can provide jobs in the local community and provide fresh produce for the local population. This can help to improve the livelihoods of the local population and promote food security. Overall, repurposing old buildings as greenhouses is a sustainable solution that aligns with the principles of the circular economy and can have multiple benefits for the environment, economy and society.

2.3.2 Impact on the environment

Since the greenhouse aims to be both smart and sustainable, the impact on the environment is estimated to be minimal.

Smart greenhouses can also incorporate ecological and smart farming methods to enhance their sustainability and efficiency. Ecological farming is an approach to agriculture that emphasizes the use of natural processes and biodiversity to enhance crop production and soil health. This can include techniques such as crop rotation, companion planting, and natural pest control methods. Incorporating these methods into smart greenhouses can help to reduce the dependence on chemical inputs and create a more sustainable and resilient ecosystem.

Smart farming, also known as precision agriculture, is the use of advanced technologies such as IoT, sensors, and automation to optimize crop production and improve resource efficiency. By using sensors to monitor various environmental factors, such as temperature, humidity, and light levels, smart farming can help to optimize the growing conditions for plants and increase the overall yield. Additionally, by using automation to control irrigation systems, it can help to conserve water and reduce the greenhouse's overall water usage.

Combining ecological and smart farming methods in smart greenhouses can lead to a more sustainable and efficient use of resources. It can also help to create a closed-loop system where resources are conserved, waste is minimized, and the overall yield is increased.

In summary, incorporating ecological and smart farming methods into smart greenhouses can help to enhance their sustainability and efficiency. By using natural processes and biodiversity to enhance crop production and soil health, as well as advanced technologies such as IoT, sensors, and automation to optimize crop production and improve resource efficiency, it can lead to a more sustainable and efficient use of resources.

2.4 Conclusion

In conclusion, we believe that the proposed solution would bring value to the business on minimal investments and maintenance costs through providing entertainment, food and jobs.

IoT technology in smart greenhouses is a sustainable concept that can help to optimize crop productivity and improve resource efficiency. By automating various functions and monitoring environmental factors, IoT can help to create a more conducive environment for plant growth and reduce the greenhouse's dependence on external resources.

The use of IoT technology in smart greenhouses can help to conserve resources such as water by automating irrigation systems and adjusting the amount of water used according to the soil moisture levels. Additionally, IoT technology can be used to reduce the greenhouse's energy consumption and carbon footprint by controlling temperature, light and humidity levels to optimize the environment and by monitoring energy usage.

IoT technology can also be used for pest management, by detecting pests early and using natural pest control methods instead of harmful pesticides. This helps to protect the natural ecosystem and promote biodiversity.

Overall, by using IoT technology in smart greenhouses, it can help to create a closed-loop system where resources are conserved and waste is minimized, resulting in a more sustainable and efficient use of resources. This concept aligns with the principles of the circular economy, which aims to keep resources in use for as long as possible and reduce waste.

2.5 References

[1] Professional greenhouse for vegetables, https://www.semplus.ro/sera-profesionala-pentru-legume-si-flori-gata-pentru-montat-4-metri-latime-x-8-metri-lungime?gclid=CjwKCAjwkaSaBhA4EiwALBgQaK4ZGDwQtMz2CCzR28EHJ0p0BZ58lmpCLOYo1bjYBlAQDr-AeIOzoxoCAugQAvD_BwE (1.12.2022)

[2] Smart garden project using Arduino, https://docs.arduino.cc/tutorials/mkr-iot-carrier/smart-garden-project (5.12.2022)

[3] Romagris SRL on RISCO, https://www.risco.ro/verifica-firma/romagris-cui-24997400 (5.12.2022)

3. Investment cost and profitability analysis

3.1 Cost of the proposed solution

On the assumption that available land, water and electricity is already present within the property, and also since the main area of activity of the company is agriculture, the following calculation does not reflect costs needed for buying land, hiring horticulturists or costs involving creating a connection to the main power grid or general water supply (which can prove to be quite an expensive and time consuming process in Romania).

Identified costs for the proposed solution can be categorized into costs for building, costs for automation, costs for cultivating.

3.2 Benefit of the proposed solution

Through the implementation of the proposed solution, the following benefits could be identified:

- Creating farm-like experiences as an activity for students/visitors in the context of agro-tourism.
- Vegetable cultivation with a low investment and few maintenance costs.
- Usage of otherwise unused farm space.
- Usage of existing by-products as fertilizers.

The above benefits can also be achieved with a standard Greenhouse. Therefore, in the context of smart and sustainable greenhouses, the benefit would be the lack of human intervention needed to operate the structure. If humidity & ventilation are taken care of, weeds, depending on the way of cultivation chosen and the available budget for investments, can also be taken care of using robots, herbicides or human labor.

Also, in the context of possible agro-touristic development, a greenhouse can also act as an activity for future visitors.

fig. 3.2.a Greenhouses as a touristic activity [5]

3.3 Net present value

"Net present value is a capital budgeting analysis technique used to determine whether a long-term project will be profitable. The premise of the NPV formula is to compare an initial investment to the future cash flows of a project."[3]

$$NPV = \sum_{t=0}^{T} \frac{C_t}{(1+r)^t} \quad (1)[4]$$

The net present value (NPV) of a greenhouse depend on a number of factors, including the initial investment, operating costs, revenue, and the discount rate used to calculate the NPV.

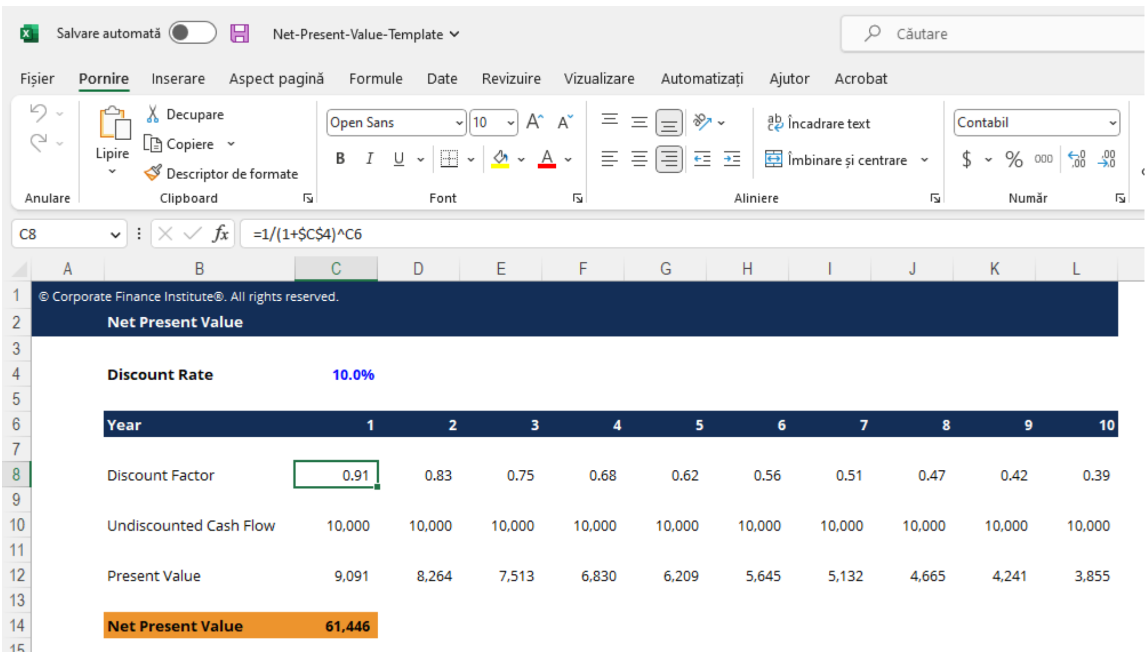
The initial investment consists of:

- irrigation systems: 2.000 Euro;
- heating system: 2.000 Euro;
- 4 vegetable greenhouse modules (including their equipment) - 11.000 Euro:
  - ➢ 2 Modules (double module), dimensions in plan 19.30 x 52.55 m.
  - ➢ 2 Module (simple module), dimensions in plan 9.70 x 52.55 m.
- humidity control solution (IoT Smart Garden Setup with MKR IoT Carrier): 600 Euro

Total initial investment = 15.600 Euro

With an initial investment of 15.600 euro and operating costs of 6.000 euro per year, the NPV would depend on the revenue generated by the greenhouse and the discount rate used to calculate the NPV.

Assuming a moderate revenue of 10,000 euro per year and a discount rate of 10%, the NPV of the smart and sustainable greenhouse over 10 years would be approximately 61.464 euro (without taking into account the cost of the initial investment):



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Net Present Value

Discount Rate 10.0%

Year	1	2	3	4	5	6	7	8	9	10
Discount Factor	0.91	0.83	0.75	0.68	0.62	0.56	0.51	0.47	0.42	0.39
Undiscounted Cash Flow	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
Present Value	9,091	8,264	7,513	6,830	6,209	5,645	5,132	4,665	4,241	3,855
Net Present Value	**61,446**									

If we take into account the cost of the initial investment, than: NPV = 61.466 Euro – 15.600 Euro = 45.866 Euro.

It's important to note that this is a rough estimate and the actual NPV could vary depending on the actual revenue generated by the greenhouse and the discount rate used in the calculation. Additionally, this calculation does not take into account the potential income from other forms of environmental benefits (discounts offered through various programmes for sustainable businesses), which could increase the NPV.

It's also worth noting that this calculation does not take into account the uncertainty that might come with the assumptions and projections of future cash flows. It's advisable to conduct a detailed financial analysis including a sensitivity analysis to obtain a more accurate NPV calculation. The sensitivity analysis would allow us to identify the variables that have the most impact on the NPV and to evaluate the uncertainty of the results.

3.4 Payback period

Considering the small investment sum needed for a greenhouse, the payback period is relatively short. However, to better understand the cash flow that can be achieved using greenhouses, it is necessary to study the already existing models.

"Depending on the scale of the greenhouse, the average amount of money generated from vegetables, for a single greenhouse, can range anywhere from 3-6.000$'[1] to "50-100.000$"[2]. Unfortunately there was no such data available for Romania.

Now, to calculate the payback period we can use the following mathematical formula:

Payback Period = Initial investment / Cash flow (Annual income) per year

Let's presume that we can settle for the standard prefabricated greenhouse, the seeds and basic automations such as ventilation and humidity control and exclude one-time costs, usable for multiple greenhouses such as, e.g. bringing a duct from the water source.

Total initial investment = 15.600 Euro

Annual income:

Product	***Price/kg***	***Quantity produced / year***	***Total***
Pepper	1 Euro	2.000 kg	2.000 Euro
Eggplant	0,8 Euro	2.000 kg	1.600 Euro
Tomatoes	0,5 Euro	5.000 kg	2.500 Euro
Cucumbers	0,5 Euro	7.000 kg	3.500 Euro

Total revenue/income per year: 9.600 Euro

Annual profit = income per year - operating cost per year = 9.600 Euro – 6.000 Euro = 3.600 Euro

The payback period = Total initial investment / Annual profit = 15.600 / 3.600 = 4,33 year

3.6 Conclusion

Greenhouses have always been profitable and, with proper planning, more than profitable, greenhouses can be sustainable.

The profitability analysis of the smart and sustainable greenhouse has resulted in positive conclusions. The use of innovative technology in the greenhouse has proven to be a profitable investment, as it has led to increased efficiency and production. Adopting sustainable practices not only resulted in cost savings, but also improved the brand image of the greenhouse. The profitability analysis showed a positive return on investment and long-term financial viability, indicating the success of the project. This highlights the potential for further investment in smart and sustainable agriculture, as it has proven to be a profitable and responsible approach to agriculture.

3.7 References

[1] How much does a small family greenhouse business make? - available at https://krostrade.com/blog/how-much-does-a-small-family-greenhouse-business-make/ (12.09.2022)

[2] How to start a greenhouse business - available at https://howtostartanllc.com/business-ide-as/greenhouse#:~:text=How%20much%20profit%20can%20a,%2450%2C000%2D%24100%2C000%20per%20year. (5.11.2020)

[3] Calculating the Net Present Value - available at https://www.investopedia.com/ask/answers/032615/what-formula-calculating-net-present-value-npv.asp. (1.12.2022)

[4] NPV Calculator https://www.calculatestuff.com/financial/npv-calculator (20.12.2022)

[5] Farm Tours in Da Lat attract tourists - available at https://vir.com.vn/farm-tours-in-da-lat-attract-tourists-50003.html (18.12.2022)

3. Annexes

Annex 4.1 - A list with the top 25 agriculture oriented firms in the county of Bacau, Romania. Annex obtained from [1].

Nr.	Denumire	CUI	Reg. Com.	Localitate
1	INTERAGROALIMENT SRL	5845723	J04/850/1994	Filipesti
2	AGRICULTORUL SRL	10187705	J04/1203/1997	Barsanesti
3	AGROTEHNOGRUP SRL	959280	J04/746/1991	Onesti
4	SILVASERV TRANS SRL	26679119	J04/268/2010	Cotumba
5	AVICOLA NEAMT SRL	26725720	J04/296/2010	Traian
6	SUINPROD SIRET SRL	16458790	J04/983/2004	Bacau
7	AICBAC SA	945055	J04/925/1991	Serbesti
8	COMFERT AGRICULTURA SRL	26371304	J04/2/2010	Bacau
9	MOLDOVA FARMING SRL	30543505	J4/783/2012	Bacau
10	YOUR FRIEND SRL	12430214	J04/716/1999	Bacau
11	EURO RIN SRL	14668965	J04/356/2002	Sascut
12	FIDOLO COM SRL	5243124	J04/182/1994	Carligi
13	ROMAGRIA SRL	975170	J04/510/1992	Bacau
14	OCOLUL SILVIC LIGNUM SRL	18636087	J04/608/2010	Darmanesti
15	ZOOTECNIC INVEST SRL	9918720	J04/1022/1997	Filipesti
16	BRADATEL SRL	978702	J04/1403/1991	Apa Asau
17	C.M.A. VIP PRODUCTION SRL	30979700	J4/1262/2012	Onesti
18	PROD-SAG SRL	18423194	J04/305/2006	Bacau
19	AGROLEX PROD SRL	31103375	J4/43/2013	Bacau
20	MERTUR TRANS SRL	4670941	J04/1544/1993	Onesti
21	ROLEX SRL	955474	J04/856/1991	Radomiresti
22	DISTIVIN SRL	9694801	J04/758/1997	Targu Ocna
23	MIGAGRO IMPEX SRL	28057031	J04/189/2011	Motoseni
24	BOR IMPEX SRL	15032060	J04/820/2002	Sascut-Sat
25	AGROTOF SRL	18299240	J04/91/2006	Bacau