D3.3 Technoeconomic evaluation

THEGREEFA

Thermochemical fluids in greenhouse farming

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Document references

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Executive Public Summary

This report has been developed within the scope of TheGreefa EU-funded project, and it is providing results of the study performed within the *Task 3.3 Technoeconomic evaluation*, providing presentation of the cost analysis of the implementation of TheGreefa technology in greenhouses.

The study was based on the real data collected from TheGreefa Swiss demonstrator (new system implemented) and the Italian case study (simulations on the real greenhouse). The analysis considered long term operation of the greenhouses to calculate the return of investment periods and the costs of TheGreefa system to meet the most expected period for the return of costs.

The results obtained in the presented technoeconomic evaluation have shown that TheGreefa indoor climate control system for greenhouses is able to provide visible cost savings in greenhouses operation. However, the cost efficiency of the system has some limitations. The cost savings are closely related with the heat demand of a greenhouse, and the warmer the climate zone where a greenhouse is located, the lower is the heat demand and cost savings too.

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1. Document information

This deliverable comprises the actions undertaken in T3.3 Technoeconomic evaluation of WP3 of TheGreefa project. It includes the results of the study on the technoeconomic assessment performed analysing TheGreefa demonstrators and case studies. The presentation of the study and the results is preceded by a description of the demonstrators/case studies and the methodology of the study performed.

a. Purpose and goals

A study was carried out in T3.3 to determine the cost-effectiveness of implementing TheGreefa technology in greenhouses. The study is based on the two greenhouses included in the project. Data from TheGreefa demonstrators and case studies were collected to be analysed in terms of energy, water, fossil fuels consumption and production of the greenhouses to compare cost related with the greenhouses' operation before and after implementation of TheGreefa system based on real data (demonstrators) or simulations (case studies). The study helps to assess possible period for the return of the investment needed for adding the new system into the greenhouse.

b. Target audience

The deliverable *D3.3 Technoeconomic evaluation* is the public report therefore the target audience are all parties interested in the results of the study. Although the aim of the report is to present the economic evaluation of TheGreefa technology to the European Commission, other groups for whom the results presented may be of most interest are scientists and academics.

c. Relation to other activities

The activities of the technoeconomic evaluation performed within *WP3 Comprehensive assessment* are in relation with technical work packages WP1 and WP2. The two WPs are a source of data needed for the economic analysis – WP1 gives inputs about TheGreefa technologies and demonstrators, while WP2 gives inputs from case studies and simulations.

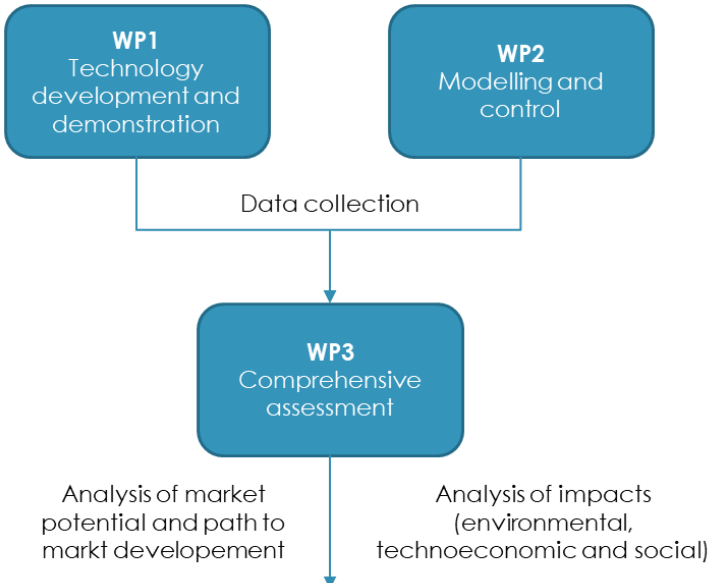


Figure 1. Relation between TheGreefa work packages in terms of technoeconomic evaluation.

2. Technoeconomic evaluation

The technoeconomic evaluation has been performed in close relation to the environmental assessment presented in the report *D3.4 Environmental assessment*. The same data about energy and fuels consumed in TheGreefa greenhouses were used in the economic study, additionally considering also information about costs related to the energy and fuels. The outputs of the study were supposed to be estimation of possible return of investment period for implementation of TheGreefa system, as well as suitable cost of the system itself offering acceptable return of investment. Another result of the analysis is evaluation of viability of implementation of the system in greenhouses in different climate zones.

a. Data collection

The collection of the inputs needed for the technoeconomic evaluation, as well as for the environmental assessment started with definition of the needed and available data. Templates were distributed to TheGreefa partners responsible for the demonstrators and the case studies of the project.

The data collected is information about electricity, biomass, water and fossil fuels used by a greenhouse in a season and their costs. Performing calculations for a greenhouse for two scenarios gives annual cost savings of a greenhouse comparing the greenhouse operation with and without TheGreefa system. To compare the greenhouses of the project, the collected data were processed for comparison of 1 ha area of the greenhouses.

The data collection was available for one TheGreefa demonstrator – Meyer Orchideen's greenhouse in Switzerland, and one case study – Sfera Agricola's tomato greenhouse in Italy.

In the time of writing the report, the system in Tunis demonstrator is not in operation yet. However, having the data we have, it is possible to analyse the cost-effectiveness of the system in midcontinental and mediterranean climates.

b. Methodology

The performed technoeconomic evaluation of TheGreefa system was performed based on the consumption data from the greenhouses energy systems. The cost was calculated using the consumption data and the unit cost provided by the greenhouse operators from their invoices. Any specific tool was not used for the technoeconomic evaluation. The assessment was performed as an analysis of the long-term operational costs of the analysed greenhouses and their comparison depending on the use of the standard system and TheGreefa system. When the annual expenses for energy and fuels are known, the difference between the two cases is calculated giving the annual cost savings resulting from the implemented TheGreefa system.

To calculate the expected return of investment period (in years), the investment cost of implementing the new system in the greenhouse was subtracted from the savings achieved in the first year. This gave a negative cost value at the beginning. The cost savings from the next years were then added to the cost balance value checking in which year the balance will have a positive value. It means the

investment cost was paid back with the annual savings. In this way the possible time needed for the payback of the investment can be identified.

Another way, using the same strategy but different investment cost, the most suitable investment cost can be identified. Checking when the shortest payback period can be achieved the competitive cost of TheGreefa system can be identified.

c. Presentation of the greenhouses

In this part the study greenhouses and the data collected are presented.

i. Swiss demonstrator

The Meyer Orchideen greenhouse is TheGreefa demonstrator, where the real scale system is implemented and in operation. In the greenhouse of Meyer Orchideen AG in Switzerland, being close to the Zurich airport, there were demonstrated TheGreefa humidity control, heating and cooling in one system through a single process.

Meyer Ochideen AG is a very innovative enterprise, founded in 1937 and today produces 500,000 orchids annually on an area of 16,000 m^2 in ecologically and environmentally friendly way. Through the consistent implementation of energy-saving measures in recent years as the installation of a groundwater heat pump, a large woodchip heating system and 124 kWp photovoltaic system, energy consumption has been massively reduced.

Meyer Orchideen AG recognized the technology of TheGreefa as a huge potential to reduce further the energy consumption and increase the quote of renewable energy thanks to the possibility to have loss-free energy seasonal energy storages.

The sorptive greenhouse air-conditioning system is used to air-condition the greenhouse no. 12 of Meyer Orchideen AG in Wangen near to Dübendorf. The orchids in this greenhouse are in the flowering stage, which requires a constant indoor climate with a temperature range 18-22°C and a relative humidity between 50-70%.

The greenhouse in the analysis has the area of 600 m^2, where there are 9 air conditioning units (absorbers) implemented, each of the power of 8 kW as heat/cooling capacity, each supplying approximately 50 m^2 of planting tables. The air is distributed under the enclosed planting tables. Over the tables, there are evenly distributed air intakes at ceiling height. The heating circuit and the well water system of the temperature control of the Thermochemical Fluid (TCF) are integrated in the absorber. The TCF used in the project is $MgCl_2$. All the 9 systems are served by desorber installed outside the greenhouse, including and diluted TCF-tanks. The energy systems are integrated with the renewable system of the greenhouse, including wood boiler, ground-water heat pump, photovoltaic panels and well water. To protect the crops from solar radiation and to reduce thermal losses during the night the roof is equipped with shading screens, which are operated automatically. Solar energy is used for TCF regeneration and buffer storages are installed to store diluted and concentrated TCF.

The demonstrator is operated in full-automatic mode. The TCF regeneration is performed in the desorber by connecting it to CO_2-neutral heating system of the greenhouse (wood /oil boilers, ground-

water heat-pump and photovoltaic panels). Most of the water consumed is recycled, while the consumption from the water pipeline is required in the hottest period of the season. Some amount of tap water is needed to be consumed for the cooling process in TheGreefa system operating.

The heat energy for the greenhouse is delivered from an external company. The greenhouse owner pays the prices for delivered energy, as follows: €96/MWh of heat from oil and €45.12/MWh of heat from wood. The electricity cost is €197.76/MWh.

The data collected for the evaluation was supposed to allow to compare the economic impacts between the 600 m^2 greenhouse operating without TheGreefa system and with the system implemented in a long-term period of operation. The analysis has been performed for the 600 m^2, as well as for a reference unit of 1 ha of the analysed greenhouse. Therefore, the collected inputs required recalculation for 1 ha area.

The consumption data from the Swiss greenhouse has been measured or calculated based on the invoices for the energy consumption. The invoices were share by the greenhouse owner to the Zurich University of the Applied Sciences (ZHAW), which then performed the calculations. The data being the inputs are presenting a year of the greenhouse operation. However, in cases TheGreefa system was not in operation, the consumption has been interpolated using the measured data.

In terms of the investment cost relate to the implementation of TheGreefa system in the Swiss greenhouse, the cost was €153 600. Breaking down this cost into the cost of materials and labour, the ratio is estimated to be 50/50. In Switzerland, the labour cost used in the study is €120/hour. The investment cost represents implementation of the system in the 600 m^2 greenhouse.

Table 1. Seasonal input for the Swiss greenhouse – 600 m^2.

	Standard greenhouse	**Cost**	**TheGreefa system**	**Cost**
Electricity consumption (pumps, fans and heat pump)	43.18 MWh	€8 539.02	39.95 MWh	€7 900.03
Oil consumption	1.35 MWh	€129.60	0.32 MWh	€30.72
Wood consumption	228.15 MWh	€10 294.13	54.08 MWh	€2 440.09

Table 2. Cost of implementation of TheGreefa system in the 600 m^2 Swiss greenhouse.

Materials cost	€76 800.00
Labour cost	€76 800.00
Total investment cost	€153 600.00

As mentioned, to be able to compare the results of the study with the 1ha Italian greenhouse, the costs and consumption of energy and fuels were calculated for 1 ha. Then the investment cost is €2 560 000.

Table 3. Seasonal input for the Swiss greenhouse – 1 ha.

	Standard greenhouse	**Cost**	**TheGreefa system**	**Cost**
Electricity consumption (pumps, fans and heat pump)	719.65 MWh	€142 317.98	665.79 MWh	€131 666.63

Oil consumption	22.50 MWh	€2 160.00	5.33 MWh	€511.68
Wood consumption	3 802.50 MWh	€171 568.80	901.33 MWh	€40 668.01

Table 4. Estimated cost of implementation of TheGreefa system in the 1 ha Swiss greenhouse.

Materials cost	€1 280 000.00
Labour cost	€1 280 000.00
Total investment cost	€2 560 000.00

ii. Italian case study

The greenhouse system of Sfera Agricola represents the high technology system and one of the new methods of high-quality agriculture production. It performs a case study with water recovery and energy efficiency in greenhouses. The greenhouse is located in South Toscany in Italy.

The case study of the Sfera company represents an ideal example of the challenges of intensive and high-quality Mediterranean agriculture, particularly in the important challenge areas of water and energy efficiency. Sfera's case study performed the analysis of the collected data in its company and shared them with partner universities and companies.

The aim of the case study activities is to analyse the data collected during the year, depending on the climatic variations and the cultural needs of the greenhouse, to define the best design needs to further reduce energy costs and improve quality and productivity.

The data collected for the environmental assessment are results of simulations performed by TheGreefa project partners. The consumption with TheGreefa system implemented was estimated by Sfera using the final efficiency of TheGreefa system. The data represents a full season of operation of 1 ha greenhouse area. The cost data was calculated by Sfera based on their invoices for energy and fuels.

The heat in the greenhouse is supplied by wood and oil boilers. The system has a power of 7 000 kW. The main types of wood used as fuels are fir, pine, holm oak and chestnut. The oil consumption is approx. 600 l/h. The heating system consumes about 28% of the electricity used by the greenhouse, mainly for auxiliary equipment, such as pumps. The unit costs of energy and fuels provided by Sfera are: €0.22 per 1 kWh of electricity, €1.05 per 1l of oil and €75 per 1t of wood. The estimated annual cost of transport of fuels is €5 000.

Table 5. Seasonal input for the Italian greenhouse – 1ha.

	Standard system	**Cost**	**TheGreefa system**	**Cost**
Electricity	90 330 kWh	€19 872.60	99 363 kWh	€21 859.86
Oil	34 350 l	€36 067.50	27 480 l	€28 854.00
Wood	631 t	€47 325.00	505 t	€37 860.00

In terms of the investment cost, it was estimated based on the cost in the Swiss greenhouse. The same ratio of materials and labour costs were used. In terms of the labour cost, it is cheaper in Italy compared

to Switzerland, and it is €40/hour. The €2 560 000 of the investment cost for 1ha Swiss greenhouse was taken as a base for calculation. It gives around €426 600 as the labour cost. Including materials, the total value of the investment cost for the Italian greenhouse is €1 706 600.

Table 6. Estimated cost of implementation of TheGreefa system in the 1 ha Italian greenhouse.

Materials cost	€1 280 000.00
Labour cost	€426 000.00
Total investment cost	€1 706 600.00

d. Results of the technoeconomic evaluation

In this part the results of the technoeconomic evaluation are presented with their interpretation. The analysis was based on the collected data presented in the previous points.

i. Swiss demonstrator

To be able to perform the technoeconomic evaluation of the TheGreefa system implementation, the Swiss demonstrator has been analysed in two scenarios:

- Standard system – The greenhouse operation before the implementation of TheGreefa system.
- TheGreefa system – The greenhouse operation with TheGreefa climate control system implemented.

In Table 7, the return of investment period simulation is presented considering annual expenses of the greenhouse operation (energy systems) with the standard system and with TheGreefa system. Calculated annual cost savings are €8 591.91. The return of investment presents the investment cost of €153 600 as a negative value plus the achieved savings. Then, it is checked when the return of investment value will be positive. Based on the simulation in Table 7, the return of investment period is 18 years. Such amount of time is acceptable and expected by both the owner of the Meyer greenhouse, as well as the Swiss Federal Office of Energy collaborating in the demonstration of the Swiss greenhouse.

Table 7. Return of investment simulation for the 600 m² greenhouse.

Years	Standard system expenses	TheGreefa system expenses	Savings	Return of investment
Y1	€ 18 962.75	€ 10 370.84	€ 8 591.91	-€ 145 008.09
Y2	€ 18 962.75	€ 10 370.84	€ 8 591.91	-€ 136 416.18
Y3	€ 18 962.75	€ 10 370.84	€ 8 591.91	-€ 127 824.27
Y4	€ 18 962.75	€ 10 370.84	€ 8 591.91	-€ 119 232.36
Y5	€ 18 962.75	€ 10 370.84	€ 8 591.91	-€ 110 640.45
Y6	€ 18 962.75	€ 10 370.84	€ 8 591.91	-€ 102 048.54
Y7	€ 18 962.75	€ 10 370.84	€ 8 591.91	-€ 93 456.63
Y8	€ 18 962.75	€ 10 370.84	€ 8 591.91	-€ 84 864.72
Y9	€ 18 962.75	€ 10 370.84	€ 8 591.91	-€ 76 272.80
Y10	€ 18 962.75	€ 10 370.84	€ 8 591.91	-€ 67 680.89

Y11	€ 18 962.75	€ 10 370.84	€ 8 591.91	-€ 59 088.98
Y12	€ 18 962.75	€ 10 370.84	€ 8 591.91	-€ 50 497.07
Y13	€ 18 962.75	€ 10 370.84	€ 8 591.91	-€ 41 905.16
Y14	€ 18 962.75	€ 10 370.84	€ 8 591.91	-€ 33 313.25
Y15	€ 18 962.75	€ 10 370.84	€ 8 591.91	-€ 24 721.34
Y16	€ 18 962.75	€ 10 370.84	€ 8 591.91	-€ 16 129.43
Y17	€ 18 962.75	€ 10 370.84	€ 8 591.91	-€ 7 537.52
Y18	€ 18 962.75	€ 10 370.84	€ 8 591.91	€ 1 054.39
Y19	€ 18 962.75	€ 10 370.84	€ 8 591.91	€ 9 646.30
Y20	€ 18 962.75	€ 10 370.84	€ 8 591.91	€ 18 238.21
Y21	€ 18 962.75	€ 10 370.84	€ 8 591.91	€ 26 830.12
Y22	€ 18 962.75	€ 10 370.84	€ 8 591.91	€ 35 422.03
Y23	€ 18 962.75	€ 10 370.84	€ 8 591.91	€ 44 013.94
Y24	€ 18 962.75	€ 10 370.84	€ 8 591.91	€ 52 605.85
Y25	€ 18 962.75	€ 10 370.84	€ 8 591.91	€ 61 197.77
Y26	€ 18 962.75	€ 10 370.84	€ 8 591.91	€ 69 789.68
Y27	€ 18 962.75	€ 10 370.84	€ 8 591.91	€ 78 381.59
Y28	€ 18 962.75	€ 10 370.84	€ 8 591.91	€ 86 973.50
Y29	€ 18 962.75	€ 10 370.84	€ 8 591.91	€ 95 565.41
Y30	€ 18 962.75	€ 10 370.84	€ 8 591.91	€ 104 157.32

The achieved return of investment period is acceptable for the greenhouse owner. However, in market study of TheGreefa project, it was identified the most expected and acceptable time for most of greenhouses is 7-10 years. The Figure 2 below, the results of simulation are presented where other investment cost's values, and their return of investment periods were checked.

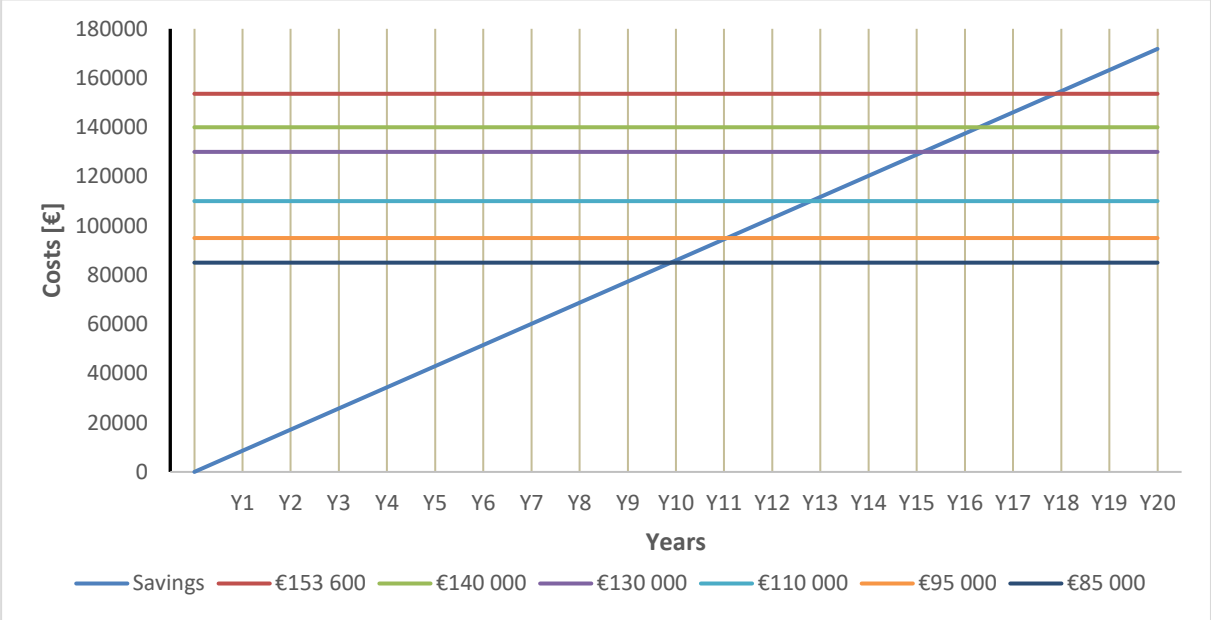


Figure 2. Return of investment period simulation for different investment costs – 600 m² Swiss greenhouse.

The goal is to find what should be the investment cost to meet the mentioned range of the expected time for the investment return. The initial value is €153 600 giving the period of 18 years. Limiting the cost to €110 000, the return of investment can be achieved in 13 years. However, only if the cost is almost 2 times lower than the initial value, meaning €85 000 the expected time of 10 years is achieved. The simulation is also presented in numbers in Table 8.

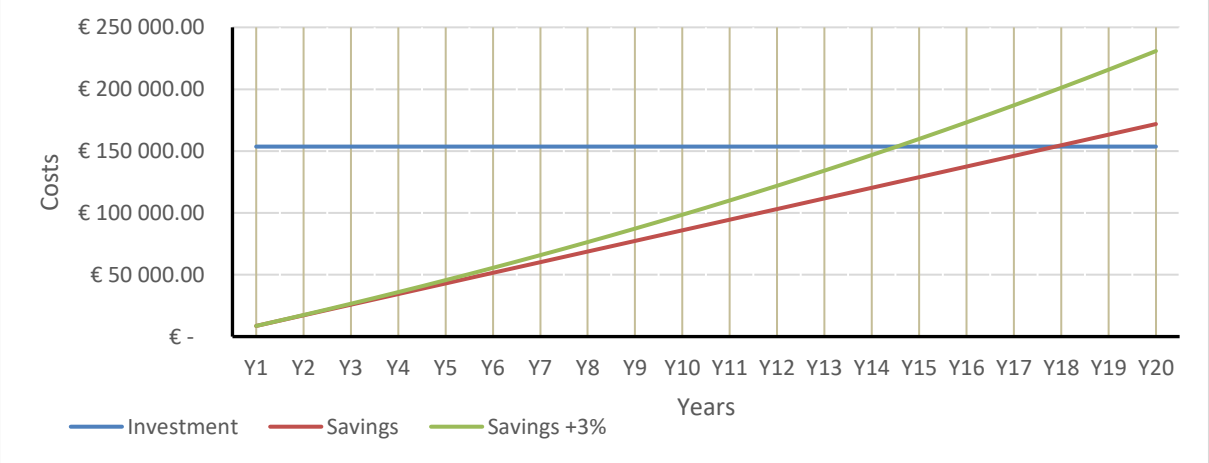
Table 8. Return of investment simulation for the 600 m² greenhouse for the investment cost of €85 000.

Years	Standard system expenses	TheGreefa system expenses	Savings	Return of investment
Y1	€ 18 962.75	€ 10 370.84	€ 8 591.91	-€ 77 008.09
Y2	€ 18 962.75	€ 10 370.84	€ 8 591.91	-€ 68 416.18
Y3	€ 18 962.75	€ 10 370.84	€ 8 591.91	-€ 59 824.27
Y4	€ 18 962.75	€ 10 370.84	€ 8 591.91	-€ 51 232.36
Y5	€ 18 962.75	€ 10 370.84	€ 8 591.91	-€ 42 640.45
Y6	€ 18 962.75	€ 10 370.84	€ 8 591.91	-€ 34 048.54
Y7	€ 18 962.75	€ 10 370.84	€ 8 591.91	-€ 25 456.63
Y8	€ 18 962.75	€ 10 370.84	€ 8 591.91	-€ 16 864.72
Y9	€ 18 962.75	€ 10 370.84	€ 8 591.91	-€ 8 272.80
Y10	€ 18 962.75	€ 10 370.84	€ 8 591.91	€ 319.11
Y11	€ 18 962.75	€ 10 370.84	€ 8 591.91	€ 8 911.02
Y12	€ 18 962.75	€ 10 370.84	€ 8 591.91	€ 17 502.93
Y13	€ 18 962.75	€ 10 370.84	€ 8 591.91	€ 26 094.84
Y14	€ 18 962.75	€ 10 370.84	€ 8 591.91	€ 34 686.75
Y15	€ 18 962.75	€ 10 370.84	€ 8 591.91	€ 43 278.66

Y16	€ 18 962.75	€ 10 370.84	€ 8 591.91	€ 51 870.57
Y17	€ 18 962.75	€ 10 370.84	€ 8 591.91	€ 60 462.48
Y18	€ 18 962.75	€ 10 370.84	€ 8 591.91	€ 69 054.39
Y19	€ 18 962.75	€ 10 370.84	€ 8 591.91	€ 77 646.30
Y20	€ 18 962.75	€ 10 370.84	€ 8 591.91	€ 86 238.21
Y21	€ 18 962.75	€ 10 370.84	€ 8 591.91	€ 94 830.12
Y22	€ 18 962.75	€ 10 370.84	€ 8 591.91	€ 103 422.03
Y23	€ 18 962.75	€ 10 370.84	€ 8 591.91	€ 112 013.94
Y24	€ 18 962.75	€ 10 370.84	€ 8 591.91	€ 120 605.85
Y25	€ 18 962.75	€ 10 370.84	€ 8 591.91	€ 129 197.77
Y26	€ 18 962.75	€ 10 370.84	€ 8 591.91	€ 137 789.68
Y27	€ 18 962.75	€ 10 370.84	€ 8 591.91	€ 146 381.59
Y28	€ 18 962.75	€ 10 370.84	€ 8 591.91	€ 154 973.50
Y29	€ 18 962.75	€ 10 370.84	€ 8 591.91	€ 163 565.41
Y30	€ 18 962.75	€ 10 370.84	€ 8 591.91	€ 172 157.32

There was also simulation performed to check how an increase of energy and fuels prices can affect the return of investment. In the simulation 3% increase of the prices each year was included. It was compared with the first calculation checking when the investment cost of €153 600 will be met. In this case the return of investment period is 15 years. Also, the lower investment cost will allow to repay the system implementation faster.

Figure 3. Return of investment period simulation considering annual 3% increase of energy and fuels prices – 600 m² Swiss greenhouse.



In Table 9, the simulation is presented for the Swiss greenhouse but for 1 ha area of such greenhouse. The estimated investment cost for such case is €2 560 000. In this case the return of investment period is also 18 years. The data is proportional for the 600 m² greenhouse, but it is needed for the purpose of comparison with the 1ha Italian greenhouse.

Table 9. Return of investment simulation for the 1 ha greenhouse.

Years	Standard system expenses	TheGreefa system expenses	Savings	Return of investment
Y1	€ 316 046.78	€ 172 846.32	€ 143 200.46	-€ 2 416 799.54
Y2	€ 316 046.78	€ 172 846.32	€ 143 200.46	-€ 2 273 599.07
Y3	€ 316 046.78	€ 172 846.32	€ 143 200.46	-€ 2 130 398.61
Y4	€ 316 046.78	€ 172 846.32	€ 143 200.46	-€ 1 987 198.14
Y5	€ 316 046.78	€ 172 846.32	€ 143 200.46	-€ 1 843 997.68
Y6	€ 316 046.78	€ 172 846.32	€ 143 200.46	-€ 1 700 797.22
Y7	€ 316 046.78	€ 172 846.32	€ 143 200.46	-€ 1 557 596.75
Y8	€ 316 046.78	€ 172 846.32	€ 143 200.46	-€ 1 414 396.29
Y9	€ 316 046.78	€ 172 846.32	€ 143 200.46	-€ 1 271 195.82
Y10	€ 316 046.78	€ 172 846.32	€ 143 200.46	-€ 1 127 995.36
Y11	€ 316 046.78	€ 172 846.32	€ 143 200.46	-€ 984 794.90
Y12	€ 316 046.78	€ 172 846.32	€ 143 200.46	-€ 841 594.43
Y13	€ 316 046.78	€ 172 846.32	€ 143 200.46	-€ 698 393.97
Y14	€ 316 046.78	€ 172 846.32	€ 143 200.46	-€ 555 193.50
Y15	€ 316 046.78	€ 172 846.32	€ 143 200.46	-€ 411 993.04
Y16	€ 316 046.78	€ 172 846.32	€ 143 200.46	-€ 268 792.58
Y17	€ 316 046.78	€ 172 846.32	€ 143 200.46	-€ 125 592.11
Y18	€ 316 046.78	€ 172 846.32	€ 143 200.46	€ 17 608.35
Y19	€ 316 046.78	€ 172 846.32	€ 143 200.46	€ 160 808.82
Y20	€ 316 046.78	€ 172 846.32	€ 143 200.46	€ 304 009.28

ii. Italian case study

To be able to perform the technoeconomic evaluation of TheGreefa system implementation, the Italian greenhouse of Sfera has been analysed in two scenarios:

- Standard system – The greenhouse operation before the implementation of TheGreefa system.
- TheGreefa system – The greenhouse operation with TheGreefa climate control system implemented.

In Table 10, the return of investment period simulation is presented considering annual expenses of the greenhouse operation (energy systems) with the standard system and with TheGreefa system. Calculated annual cost savings are €14 691.24. The return of investment presents the investment cost of €1 706 600 as a negative value plus the achieved savings. Then, it is checked when the return of investment value will be positive.

Table 10. Return of investment simulation for the 1ha Italian greenhouse.

Years	Standard system	TheGreefa system	Savings	Return of investment

Y1	€ 108 265.10	€ 93 573.86	€ 14 691.24	-€ 1 691 908.76
Y2	€ 108 265.10	€ 93 573.86	€ 14 691.24	-€ 1 677 217.52
Y3	€ 108 265.10	€ 93 573.86	€ 14 691.24	-€ 1 662 526.28
Y4	€ 108 265.10	€ 93 573.86	€ 14 691.24	-€ 1 647 835.04
Y5	€ 108 265.10	€ 93 573.86	€ 14 691.24	-€ 1 633 143.80
Y6	€ 108 265.10	€ 93 573.86	€ 14 691.24	-€ 1 618 452.56
Y7	€ 108 265.10	€ 93 573.86	€ 14 691.24	-€ 1 603 761.32
Y8	€ 108 265.10	€ 93 573.86	€ 14 691.24	-€ 1 589 070.08
Y9	€ 108 265.10	€ 93 573.86	€ 14 691.24	-€ 1 574 378.84
Y10	€ 108 265.10	€ 93 573.86	€ 14 691.24	-€ 1 559 687.60
Y15	€ 108 265.10	€ 93 573.86	€ 14 691.24	-€ 1 486 231.40
Y20	€ 108 265.10	€ 93 573.86	€ 14 691.24	-€ 1 412 775.20
Y25	€ 108 265.10	€ 93 573.86	€ 14 691.24	-€ 1 339 319.00
Y30	€ 108 265.10	€ 93 573.86	€ 14 691.24	-€ 1 265 862.80
Y35	€ 108 265.10	€ 93 573.86	€ 14 691.24	-€ 1 192 406.60
Y40	€ 108 265.10	€ 93 573.86	€ 14 691.24	-€ 1 118 950.40
Y45	€ 108 265.10	€ 93 573.86	€ 14 691.24	-€ 1 045 494.20
Y50	€ 108 265.10	€ 93 573.86	€ 14 691.24	-€ 972 038.00
Y55	€ 108 265.10	€ 93 573.86	€ 14 691.24	-€ 898 581.80
Y60	€ 108 265.10	€ 93 573.86	€ 14 691.24	-€ 825 125.60
Y65	€ 108 265.10	€ 93 573.86	€ 14 691.24	-€ 751 669.40
Y70	€ 108 265.10	€ 93 573.86	€ 14 691.24	-€ 678 213.20
Y75	€ 108 265.10	€ 93 573.86	€ 14 691.24	-€ 604 757.00
Y80	€ 108 265.10	€ 93 573.86	€ 14 691.24	-€ 531 300.80
Y85	€ 108 265.10	€ 93 573.86	€ 14 691.24	-€ 457 844.60
Y90	€ 108 265.10	€ 93 573.86	€ 14 691.24	-€ 384 388.40
Y95	€ 108 265.10	€ 93 573.86	€ 14 691.24	-€ 310 932.20
Y100	€ 108 265.10	€ 93 573.86	€ 14 691.24	-€ 237 476.00
Y105	€ 108 265.10	€ 93 573.86	€ 14 691.24	-€ 164 019.80
Y110	€ 108 265.10	€ 93 573.86	€ 14 691.24	-€ 90 563.60
Y111	€ 108 265.10	€ 93 573.86	€ 14 691.24	-€ 75 872.36
Y112	€ 108 265.10	€ 93 573.86	€ 14 691.24	-€ 61 181.12
Y113	€ 108 265.10	€ 93 573.86	€ 14 691.24	-€ 46 489.88
Y114	€ 108 265.10	€ 93 573.86	€ 14 691.24	-€ 31 798.64
Y115	€ 108 265.10	€ 93 573.86	€ 14 691.24	-€ 17 107.40
Y116	€ 108 265.10	€ 93 573.86	€ 14 691.24	-€ 2 416.16
Y117	€ 108 265.10	€ 93 573.86	€ 14 691.24	€ 12 275.08
Y118	€ 108 265.10	€ 93 573.86	€ 14 691.24	€ 26 966.32
Y119	€ 108 265.10	€ 93 573.86	€ 14 691.24	€ 41 657.56
Y120	€ 108 265.10	€ 93 573.86	€ 14 691.24	€ 56 348.80

Based on the simulation in Table 10, the estimated return of investment period is 117 years. Such long period is totally unacceptable and unachievable in real life. The long period is caused by proportionally small cost savings compared to the Swiss greenhouse analysed earlier. In case of the indoor climate control system for greenhouses in TheGreefa project it aims to reduce the heat losses and reduce the

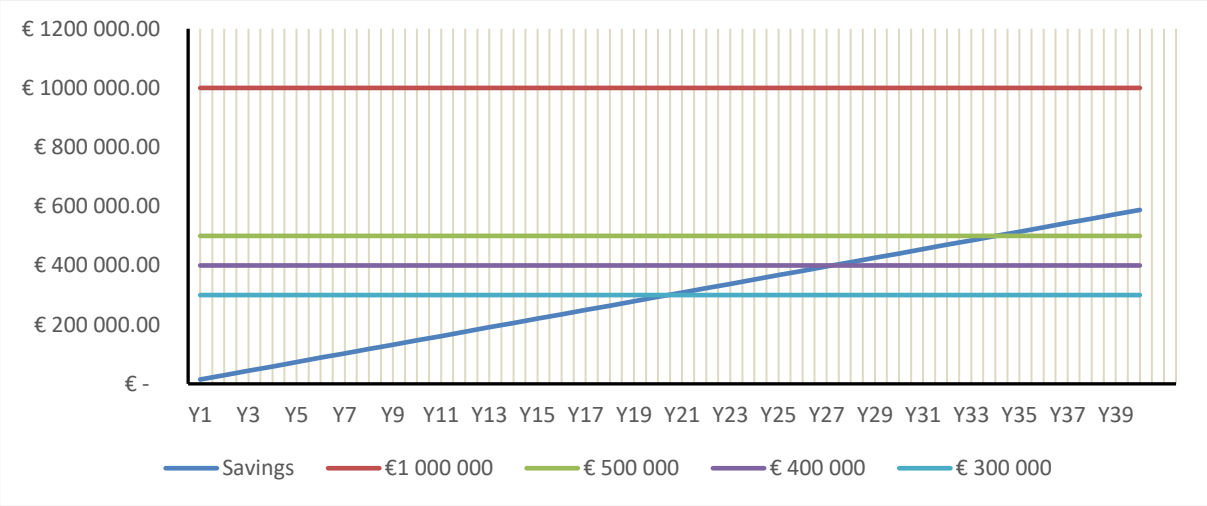
electricity and fuels consumption for providing the heat demand of the greenhouse. The higher is the heat demand of the greenhouse, the higher the savings resulting from the system implementation. It was identified during analysis of both Swiss and Italian greenhouses, the heat demand of the Italian case is 10 lower than of the Swiss case. The difference is of course caused by the location in different climate zones. The proportion is also visible comparing the cost savings. For 1 ha greenhouse in Switzerland the cost saving is €143 200.46 each year, while for 1 ha Italian greenhouse it is only €14 691.24.

It results in conclusion, the implementation of TheGreefa system for heating purposes in such areas as Italy will not be viable, at least considering the current cost of the system.

The Italian greenhouse used in TheGreefa project does not have a cooling system. Only heating is used with very small consumption of electricity during summer months. Unfortunately, it was not possible to test the efficiency of TheGreefa system for cooling purposes in warm climate. It was not possible to set the Tunisian demonstrator in operation by the end of the project. Therefore the focus of the study performed was on the use of TheGreefa for heating of the greenhouse.

The simulation was also performed to see what the cost of the system should be to have comparable return of investment period as the Swiss greenhouse. The results presented in Figure 4 below shows only if the cost of the system implementation is €300 000, then the return of investment period is 21 years. However, for now such cost is not possible to be achieved for 1 ha greenhouse.

Figure 4. Return of investment period simulation for different investment costs – 1 ha Italian greenhouse.



3. Conclusions

The technoeconomic evaluation performed has shown that TheGreefa indoor climate control system for greenhouses is able to provide visible cost savings in greenhouses operation. However, the cost efficiency of the system has some limitations. The cost savings are closely related with the heat demand of a greenhouse, and the warmer the climate zone where a greenhouse is located, the lower is the heat demand and cost savings too.

The evaluation gave promising results in case of the Swiss greenhouse of TheGreefa project located in Mid-continental climate. The investment cost of the implementation of the project's technology will give estimated return of investment period of 18 years. It is the period acceptable for the greenhouse owner and for the Swiss Federal Office of Energy which also contributed to demonstration of the technology in the greenhouse. Simulated 3% increase of prices of electricity and fuels each year can shorten the period to 15 years. If the cost of implementation of TheGreefa system would be almost half lower (€85 000 for 600 m^2 greenhouse and €1 416 000 for 1 ha greenhouse), it could give the return of investment period of 10 years or lower.

As for the Italian greenhouse, the study has shown TheGreefa system with its current cost cannot offer acceptable return of investment period. The greenhouse heat demand is too low to cause the cost saving able to cover the cost of implementation of the new system. The Italian greenhouse does not have a cooling system and the Tunisian demonstrator representing the use of TheGreefa in warm climate for cooling was not in operation within the project's duration. Therefore, the collection of inputs required for the assessment was not possible. The raw estimation which would be not based on any measured data or invoices from real greenhouse is not reliable and the focus of the evaluation was on TheGreefa's use for heating purposes only.

As TheGreefa system is still not ready to enter market as a product, there is still a chance, and attempts will be made to reduce the cost of the system. Also, it should be considered to analyse possible limitations in terms the requirements of the greenhouses where the system could be implemented. Firstly, the heat demand of the greenhouse should be analysed. The study of the Swiss greenhouse can be used then as a baseline for classification of possible implementation options. Adding renewable energy sources can also increase the cost savings, but it needs to be underlined that such modifications will also increase the investment cost.