Multiobjective Optimization of Dairy Waste Management Superstructure in a Large-scale Farm

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This study introduces an energy superstructure for waste management in a large-scale farm. It selects the optimal technologies by optimizing the productivity factor and greenhouse gas (GHG) emission functions. The optimization results show that the optimal solution to maximize the efficiency factor is to use a biogas engine that produces a significant amount of 1695.825 GWh of electricity and 1893.11 GWh of heat in a year. Also, one of the advantages of this scenario is that it is economically feasible and has a justified return of investment, which attracts investors to it. On the other hand, the optimal solution to minimize GHG emissions do by using combined heat and power based on gas turbine and carbon capture storage; this scenario emits 114.585 Kton of carbon dioxide per year. It is worth noting that this amount, based on waste management, as well as electricity and heat production, reveals the high value of bioenergy potential.

keywords: *Multi-objective Optimization, Superstructure Model, Mathematical Programming, Dairy Waste Management, Bioenergy, Polygeneration.*

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NOMENCLATURE

AD	Anaerobic digestion
BE	Biogas engine
CCS	Carbon capture storage
CHP	Combine heat and power
COD	Chemical oxygen demand
GA	Genetic algorithm
GHG	Greenhouse gas
GT	Gas Turbine
IRR	Internal rate of return
NPV	Net present value
OS	Optimistic scenario
PP	Payback period
PS	Pessimistic scenario
SMR	Steam methane reformer
SOFC	Solid oxide fuel cell
VOCs	Volatile organic compounds

1. INTRODUCTION

The upward population trend has significantly impacted energy demand, food consumption, and global water consumption. For example, the world population has increased almost 12% from 6.84 billion in 2009 to 7.673 billion in 2019. Consequently, electricity consumption amplified dramatically, from 18516.6 TWh in 2009 to 25027.3 TWh in 2019 [1]. Besides, fossil fuels are a simple way to supply energy. One of the issues caused by the use of fossil fuels in the contemporary world is the concerns of climate change and global warming, so researchers pay a lot of attention to environmental issues and moving towards decarbonization and higher efficiency systems in various industries like the dairy industry, a prominent industry in terms of GHG emissions; therefore it has drawn the attention of researchers to the potential of using renewable energy (RE) in this industry, especially biomass energy, since power production alongside waste management is a big step toward solving the problems of climate change and global warming. In addition, predicted ways of reaching net zero emissions are long-term strategies, in which the amount of bioenergy supply will reach 102 EJ by

2050; hence, it shows that bioenergy will be one of the essential sources in the future [1].

Nowadays, most livestock farms are built near dairy factories, so livestock products like milk can use more efficiently, and there is no need for transportation and long-term storage. Which simultaneously makes the management of dairy and animal waste critical [2]. In the past, various methods have been used to manage dairy waste, but today researchers are looking for innovative ways that causes minimum damage to the environment; therefore, considering the potential of the waste produced by this industry, the purpose is not only managing and eliminating the waste, but to use them efficiently by converting them into bioenergy by designing adequate systems [3]. Another reason for the importance of this matter is the existing restrictions and prohibitions of disposing these wastes, such as whey, animal wastes, and dairy sludge, because executives of the dairy factories cannot release their wastes to the environment directly, so they must have an environmentally friendly plan to dispose of their wastes because they include methane, nitrogen oxide, and CO2 [4]. Nevertheless, there are different methods to eliminate these animal and dairy wastes but one of the crucial factors in determining the appropriate way and system of waste disposal, is the amount of the waste, and the size of the livestock or dairy industry [5].

The commonly used approaches include; selling the waste as a natural fertilizer to farmers or selling it to biomass power plants as fuel. On the other hand, it is inappropriate to release this waste on the land or dispose of them on the ground. Besides, the dairy industry needs electricity for various sectors, such as milk processing or thermal energy for sectors, such as pasteurization and heating the livestock environment. Eventually, the approach of selling to biomass power plants gives us the idea that livestock farms can manage their wastes themselves with the help of anaerobic digestion systems and a cogeneration system instead of selling them to a biomass power plant; in addition to waste management, electrical and thermal energy is obtained [6]. The dairy industry and animal husbandry have a high potential for polygeneration systems because they can use their wastes as an energy resource; in addition, they can produce some valuable substances like modified fertilizer. Nevertheless, there are numerous obvious reasons for using polygeneration systems in the dairy industry, for instance, to improve the system's productivity. In addition, one of the most important reasons is the reduction of energy consumption by this industry which will decrease the fossil fuel consumption greatly; so due to these reasons, many models have presented livestock farms with a modern system for waste management and power generation [7].

One of the presented models for the use of livestock wastes with a cogeneration system using anaerobic digestion (AD) and solid oxide fuel cells (SOFC) was investigated, by Corigliano et al. [8]. This model has focused more on energy analysis, which is one of the reasons for using the SOFC, which has a higher efficiency than other energy conversion technologies. Besides, this investigation presented a designed model, which combined the AD processes with an indirect internal reformer and SOFC. Moreover, one of the other models reviewed in England, was a recycling system to preserve the energy of biological waste (animal and agricultural waste), which was feasible in terms of the sustainability of the system for a small-scale dairy farm [2]. In addition, it designed a model of combined heat and power systems and AD processes in ECLIPSE to simulate biogas production with different waste samples. The following study did manage for these animal and agricultural wastes to feed a biomass cogeneration power plant. This model has been studied from an economic and technical view by Calise et al. [9]. Furthermore, the model investigated by Kozłowski et al. is the energy and economic analysis of a biogas plant using waste generated in the dairy industry [10]. One of the studies carried out in northeast Brazil presented an economic cogeneration model using commercially available technologies to supply the energy demands of a Brazilian dairy industry [11]. Baldinelli et al. have investigated a small-scale cogeneration model based on biomass energy and SOFC, in which the essay aims to find the opportunities and strengths of this model for the livestock industry [12]. In the article by Luqman et al. on the subject of a novel solution toward zero waste in dairy farms, which is a thermodynamic study of an integrated polygeneration approach [13]. Aghaei et al. investigated the technical factors of the trigeneration system on the subject of optimization of a combined cooling, heating, and power (CCHP) system with a gas turbine prime mover in a case study, which is in a dairy industry [14]. In addition, this article provided an accurate technical detail for the model. An article by León et al. on the optimal production of power in a combined cycle from manure-based biogas have done, which introduced a model to produce energy from livestock manure [15]. This investigation, in addition to solving a mixed integer nonlinear programming (MINLP) problem, solved two distinct nonlinear programming (NLP) problems with 1100 constraints in GAMS. Research on the current and future trends of biogas production from livestock waste by Wang et al. for China, one of the largest countries in the dairy and livestock industries, investigated in 2021, in which suggestions have been made to improve performance and increase productivity [16]. Furthermore, investigation has also been done in the field of combining renewable energy with the dairy industry by Kirim et al., in which a model of photovoltaics and biogas plant has been presented, which has been analyzed economically and technically [17].

Basically, in this article, a design has been made to propose a superstructure for waste management and energy supply for livestock farming alongside a dairy factory, which has three scenarios, using the data and information that exist for different technologies. Moreover, various environmental and economic assessments are implemented for the superstructure to provide a proper perspective for investors to make the best decision with their selected policies. Besides, in the objective functions assigned for optimization as well as the design of the superstructure, there is a lot of attention to environmental issues so that the presented model has proper justification and foresight with a concern for climate change. In addition, the polygeneration system has diverse technologies that include investigations in the field of clean energy, such as clean energy carriers like hydrogen, and a new energy conversion system, such as the biogas engine. Which is becoming more important every day because it is predicted that bioenergy will play a critical role in reaching the scenarios adopted to achieve net zero emissions in 2050.

2. METHODOLOGY

A. System Description

In this research, the feedstocks considered to use in the superstructure are divided into two categories of dairy and livestock waste. The case study is divided into two parts: a dairy factory and an animal husbandry next to each other. So the reason for considering these two sections is to provide the required milk through the dairy factory by animal husbandry; so that, the dairy

Table 1. Dairy and livestock waste used in the superstructure

Parameter	Daily production (ton/day)	Yearly production (ton/day)	Reference
Cow manure	18	6570	[1]
Cow sewage	22	8030	[1]
Whey	40	14600	[2]
Dairy sludge	2.6	949	[2]
Fatty sludge	0.08	29.2	[2]

factory does not need to buy milk or pay for milk transportation. Moreover, the case study included a livestock farm with 400 dairy cows next to a dairy factory; the information of the dairy factory was obtained from the article [10] that was done based on the milk production of 4000 dairy cows, that's the reason why, all the data of the dairy factory of article [10] has been divided by ten. The waste created in this case study, which are used in the superstructure, are summarized in Table 1.

One of the wastes produced by the dairy factory is whey, which has a more significant amount than other wastes. Due to the high level of some properties such as chemical oxygen demand (COD), whey cannot be released directly into the environment; so there should be a plan to dispose of it, commonly using it as animal feed or transferring it to the biogas power plant. In this article, the conversion of it alongside other wastes into biogas is done inside the dairy factory to reduce transportation costs. Furthermore, dairy sludge is another produced waste from a dairy factory. Which is a side product of the white water produced in dairy factories and has sufficient energy to be used as input waste for biogas plants. Ultimately, the last produced waste in the dairy factory is fat sludge, which has an insignificant amount compared to the other two wastes; however, it can provide considerable amounts of energy [2]. Animal waste management is a fundamental problem for livestock farms. Standard methods used to dispose of and manage them are [3]; using and selling them as fertilizer for agricultural land, releasing them in open areas, remove in leak-proof pits, and transfer to biogas power plants. In this article, livestock and dairy wastes are used as input feed to a superstructure to convert into energy and generate power, in addition to disposing them. In the following parts, we will elaborate more on precise information about the systems used in the superstructure and the motivation behind selecting this system.

B. Superstructure

The concept of a superstructure includes three general steps [4]. Firstly, a primary cycle and structure design must be created by using the information. In an optional step, according to the valid public systems, we can evaluate the designed superstructure and achieve a valid superstructure. Secondly, we implement the designed superstructure with our knowledge of mathematical modelling and mathematical programming. Eventually, according to the desired objective function, we solve the mathematical model of the previous step using appropriate algorithms like a genetic algorithm (GA) to achieve an optimal structure and model [4].

According to the input feedstock to the system, biomass-to-biogas conversion technologies have been used in the superstructure, the most common of which is the AD system. Besides, with the research done on AD systems to increase the performance of these systems, the use of pre-treatment will be pretty useful; thus, before AD systems, thermal hydrolysis pre-treatment were used [5]. Moreover, these pre-treatment systems improve the performance of AD processes in the range of -3.4% to 31.48% [6]. Behind the conversion of biomass into biogas and modified fertilizer, desulfurization is done on the resulting biogas to make it ready to use in power and heat production sections [7]. In the designed superstructure, three scenarios (polygeneration systems) were used, and the selection of these used technologies were made to specific perspectives.

As noticed in Fig. 1, technologies such as SOFC, GT, CCS, steam methane reformer (SMR), and BE were used in the superstructure for energy conversion [8]. In addition, there are three paths to generate power and heat, and each of which has a reason to be chosen. The first scenario is using hydrogen (H2) as an energy carrier, which has been operated in SOFC technology. The reason for choosing this scenario in this article is to include technology with a highly suitable efficiency and low emission rate; however, this scenario has other reasons for being chosen as well, such as the importance of H2 in economy in the future years [9]. In the second scenario, a common system is used for energy conversion. In this manner, a GT-based cogeneration system has been used [10]. In addition, CCS has been considered as flue gas in the system [11]. In the last method, a new technology was used, a BE, an internal combustion engine with oxidative catalysts. In these engines, according to the used catalyst and appropriate methods, the amount of emission of substances such as HCl, H_2O, CO, NO_x, $SO2$, and $VOCs$ is reduced significantly; therefore, this is one of the main reasons for this technology to be chosen [12].

Furthermore, in this superstructure, some systems are not entered in detail, and these systems, such as CHP are presented as a black box. On the other hand, the flue gas of SOFC has a high temperature of about 900-1000°C [13]. In addition, SMR requires steam with a temperature of around 500-600°C [14], so it is rational that the exhausted gases of SOFC provide it. In this superstructure, some technologies such as pre-treatment, (AD), desulfurization, and CCS perform their process by consuming electricity and heat; hence, we provide these electricity and heat demands by the output of the superstructure. One of the main advantages of this superstructure is the polygeneration of products and energy. Nowadays, polygeneration systems have become significant as they produce beneficial chemical substances and power. Besides, these systems have suitable productivity, so high productivity means less fuel consumption; hence, GHG emission reducuction.

It is obvious that one of the products with high value is modified as fertilizer, which has multiple benefits [15]. In addition, modified fertilizer is the product produced by the AD system, which is considered a valuable product due to its applications in residential gardening, which can be one of the salable products for the dairy and animal husbandry industries [18]. Finally, according to the acquaintance with the designed superstructure, we implement a mathematical model that we can optimize with the help of MATLAB software.

C. Objective Function

In general, researchers can adopt different objective functions for optimization; for instance, some researchers opt for the objective function based on the amount of GHG emissions, and others choose economic indicators for optimization. In this article, two objective functions have been selected; also, their results will be economically analyzed [19]. The first objective function is to

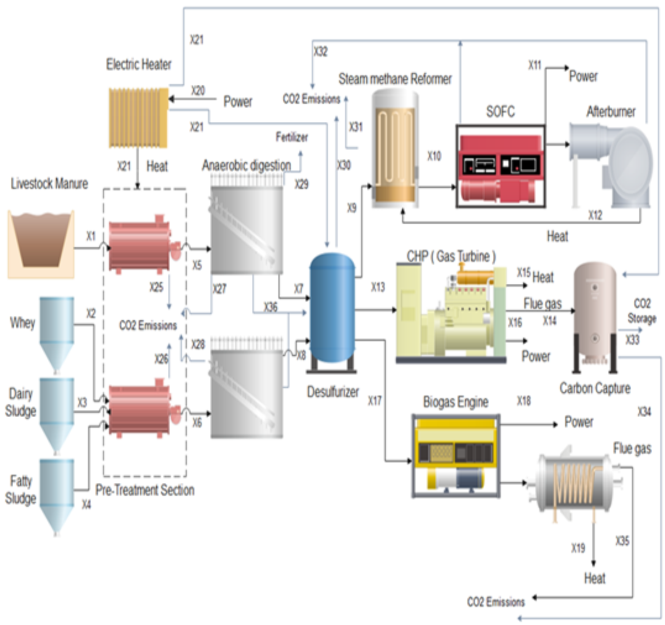

Fig. 1. Superstructure designed for case study

maximize the productivity coefficient of the superstructure. The productivity coefficient for cogeneration systems is defined as follows [20].

$$\epsilon = \frac{\dot{W}_{net} + Q_{process}}{Q_{in}} \tag{1}$$

Besides, calculating the calorific value of the input feeds is not an easy task because there was no calorific value or any specific information to calculate them in the articles; consequently, we cannot provide their calorific value without any chemical examinations, also this calorific value is fixed and cannot be changed, so it is enough to maximize the amount of electricity and heat output. Therefore, the first objective function according to the numbered streams in the superstructure is as follows.

$$ObjectiveFunction(1) = \dot{W}_{net} + Q_{process} \tag{2}$$

$$= X_{11} + X_{15} + X_{16} + X_{18} + X_{19} - X_{20}$$

The second goal is minimizing GHG emissions, which is excessively crucial for the contemporary world. In this section, for a better understanding, GHG emissions have been converted into CO2 equivalents [21]. Therefore, the second objective function according to the numbered streams in the superstructure is as follows.

$$ObjectiveFunction(2) = GHGemissions \tag{3}$$

$$= X_{25} + X_{26} + X_{27} + X_{28} + X_{30} + X_{31} + X_{32} + X_{34} + X_{35} + 0.15X_{36}$$

D. Assumptions governing technologies

In this part, the results of various sources have been used to write the equations governing the technologies used in the superstructure. The details of each technology have not been entered separately, so the assumptions given in Table 2 were used to write the constraints. Additionally, the black box mode was considered for the technologies to write more simple constraints.

Table 2. Dairy and livestock waste used in the superstructure

Items	Technologies	Conversion factor (%)	Refernce
Pre-Treatment	Thermal Hydrolysis	100	[6]
Anaerobic Digestion	Mesophilic	-	[16]
Desulfurizer	Dry Desulfurizer	98.505	[6]
Steam Methane Reformer	SMR-85% CC	33.33	[16]
Fuel Cell	SOFC	61	[17]
CHP	Based on Turbine	8.22 (Energy) 48.92 (Heat)	[18]
Carbon Capture Storage	Monoethanolamine (MEA)	85	[19]
CHP	Based on Biogas Engine	40.4 (Energy) 45.1 (Heat)	[20]
Heater	Electric	100	[6]

E. Environmental constraints

In Fig. 1, technologies, which have a significant emission rate, are marked with numbered streams. Moreover, the pretreatments section releases GHG into the environment, so according to the pre-treatments technology, which is thermal hydrolysis, the amount of emissions depends on the input feedstocks; consequently, the constraints of pre-treatments are as follows [22].

$$X_{25} = 0.06X_1 \quad ton \quad emissions/year \tag{4}$$

$$X_{26} = 0.06X_6 \quad ton \quad emissions/year \tag{5}$$

Furthermore, AD's constraint for the animal husbandry section according to the type of digester used, which is mesophilic, so the range of methane emissions in this technology are between 6.56 to 7.6 kg of methane per number of livestock in a year in the available data of various articles. We chose the average of this interval, which is 7, so according to the case study, the amount of AD emissions in the animal husbandry sector is as follows [23].

$$X_{27} = 70 \quad ton \quad emissions/year \tag{6}$$

According to knowing the amount of input feedstock and the same type of digester, the amount of digester emissions in the dairy factory section is as follows.

$$X_{28} = \frac{70X_6}{14600} \quad ton \quad emissions/year \tag{7}$$

For the SMR section, the SMR-85% type is used; according to the data and information available for this model, the GHG emissions are equivalent to 1.98 kg of CO2 per kg of produced H2; the constraint is as follows [24].

$$X_{30} = 1.98X_{10} \quad ton \quad emissions/year \tag{8}$$

$$X_{32} = (1.81 \times 10^{-7})X_{11} \quad ton \quad emissions/year \tag{9}$$

For the CHP section, considering that the exhausted gas is entered into a CCS system instead of being released into the environment if we assume that this system and the pipelines used in them do not have any leaks; therefore, the amount of emissions is assumed nil, and all exhaust gases go to CCS and are calculated in that part [25]. For the CCS section, we can consider the inputs and outputs according to the data and conditions that exist and use those data to write the constraint of this section. As seen in Fig. 2, it is possible to absorb CO2 in CCS with an efficiency of approximately 85%. We can implement the equation of this part, but the issue is that we should be aware of the amount of CO2 in the exhaust gas stream entering the CCS [26]. According to Fig. 2, the constraints can be written as followed.

$$X_{33} = 0.85X_{14} \quad ton \quad emissions/year \tag{10}$$

$$X_{34} = 0.15X_{14} \quad ton \quad emissions/year \tag{11}$$

Ultimately, to calculate the exhaust gas and its contents that exit the CHP system, it is necessary to dip into the system's insides and be aware that the commonly used CHP system has a combustion chamber where input fuel, such as methane, burns, so it is enough to consider the equation of burning methane with 20% of additional air that is usually given to the chamber (for complete combustion) and using the obtained molar data, we can calculate the amount of CO2 in the exhaust gas. The combustion equation in the combustion chamber with 20% excess air is as follows [27].

$$CH_4 + 1.2 \times 2(O_2 + 3.76N_2) \rightarrow CO_2 + 2H_2O + 0.4O_2 + 9.024N_2 \tag{12}$$

Nevertheless, a kilo mole of CO2 is produced per kilo mole of methane, which, according to their molar mass, means that 44 kg of CO2 is produced per 16 kg of methane. To calculate the content of exhaust gas from the CHP system, we should calculate pure methane and CO2 exiting the AD section. In addition, we have not included other trace gases in the output streams of X7 and X8, and then all the available CO2, which we have put in the flow of X36, which does not enter the reaction in combustion reactions. Eventually, in terms of CO2 emission, the equation is as follows.

$$X_{14} = \frac{44X_{13}}{16} \quad ton \quad emissions/year \tag{13}$$

For the BE section, the process is still combustion, while assuming complete combustion; thus, the process be done again as in the previous section. The difference between these two parts is the emission of local gases such as NOx, CO, and SO2. In a traditional CHP system, there is usually no solution to prevent the production of these harmful gases, which are not GHG, and they are produced and released into the environment. Besides, nowadays, due to the importance of climate change and environmental issues, BE is becoming more and more popular [28].

As we know, one of the available solutions to solve climate change is the use of bioenergy, which will play a significant role in the global energy supply in the future. The importance of this issue in recent years brings this idea to the minds of researchers to create a technology that can use biogas energy directly with proper energy efficiency and minimal local gas emissions; hence this matter has led to the movement toward particular engines for biogas fuel, which are known as BE. In addition, in these engines using catalysts like oxidative catalysts, and methods such as chemical scrubbers and thermophilic biofilters are used to reduce local gas emissions; eventually, if we consider the ignition assuming completeness, the constraint becomes as follows [29].

$$X_{35} = \frac{44X_{17}}{16} \quad ton \quad emissions/year \tag{14}$$

Another assumption to improve this superstructure is to transfer stream 36, which carries CO_2, to CCS.

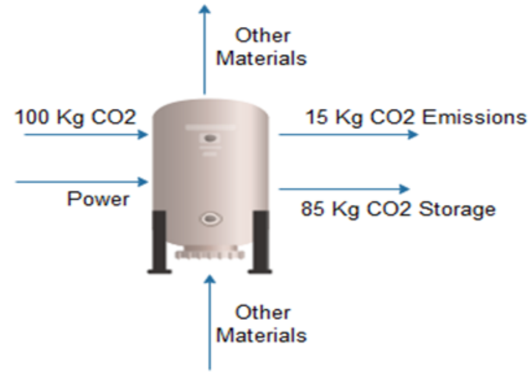

Fig. 2. Inputs and outputs to a CCS-85%

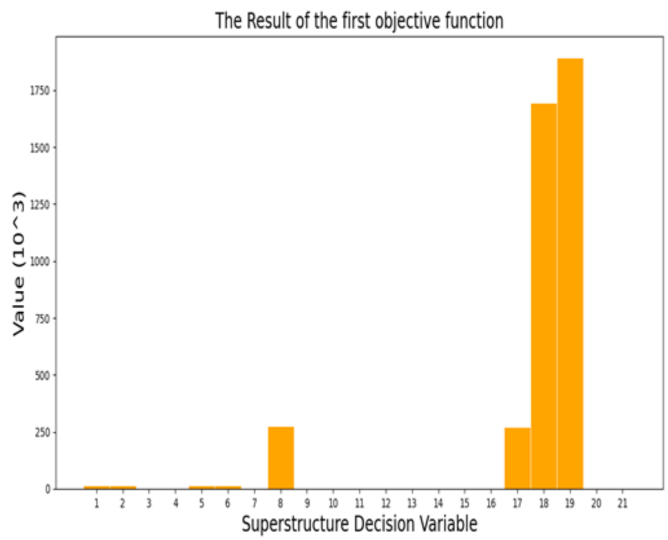

Fig. 3. Results of optimization of the first objective function

3. RESULTS AND DISCUSSION

A. Optimization results

The mathematical model obtained for the objective functions is analyzed separately, and then, with the help of the genetic algorithm, the optimal state for both objective functions is obtained simultaneously. First, according to Fig. 3, the result of optimization to maximize the productivity factor can be seen. The most optimal possible mode is to use the BE, showing that BE should be promote intensely in the future.

The results obtained to minimize GHG emissions are shown in Fig. 4, which shows that the best way to achieve the most optimal emission mode is to use the CHP cogeneration system using CCS; which shows that CCS is one of the most important technologies in the contemporary world. The result of multi-objective optimization on two objective functions with the help of a genetic algorithm are also shown in Fig. 5 and Fig. 6.

B. Cost Analysis

Animal husbandry and large-scale dairy industries should pay special attention to the economic aspect [30]. Today, financial problems are critical, so before a system is implemented, an economic analysis should be done on it. In addition, we investigate the optimal scenarios in terms of economic feasibility

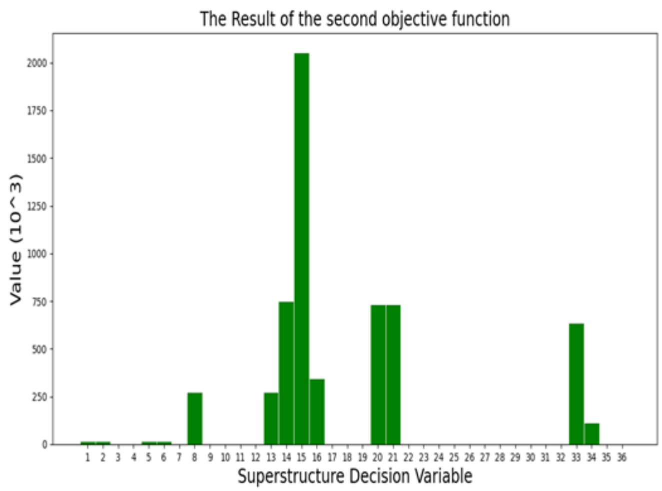

Fig. 4. Results of optimization of the second objective function

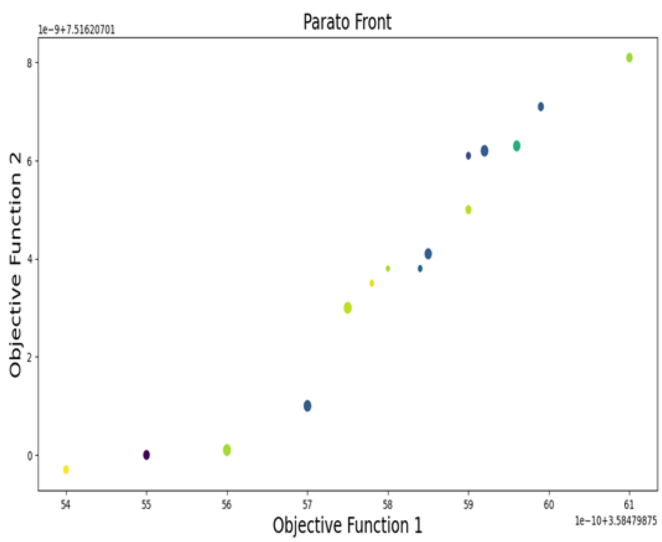

Fig. 5. The result of Parato Front (Genetic algorithm)

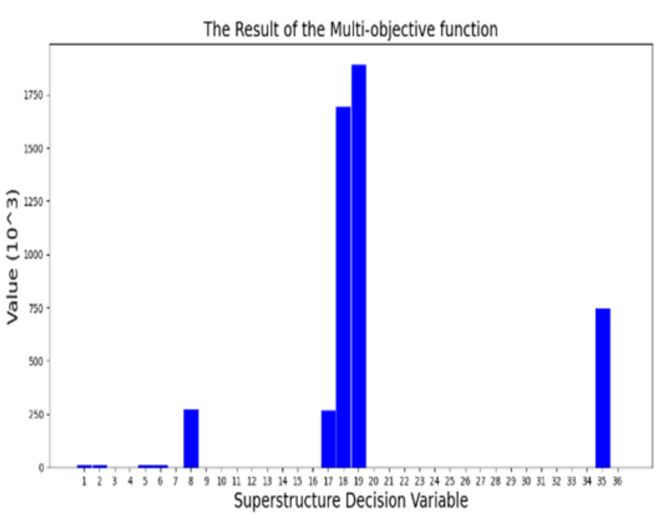

Fig. 6. Results of optimization of multi-objective assessment

Table 3. Summarize the assumptions and data used to analyze economically [32] [2]

Parameter	Value	Unit
Electricity price	82-179	$/MWh
Heat price	49.5	$/MWh
Discount rate	12	%
Euro exchange rate	1.13	$/Eur
Operation period	20	yr
Tax rate	15-30	%
CO2 emissions penalty	50	$/(ton CO_2)
Annual operating costs (Q&M)	10	% of total investment

Table 4. Results of cost analysis for the optimal scenario of the first objective function

Items	Optimistic scenario (OS)	Pessimistic scenario (PS)
NPV (M$)	1600.25	486.5
IRR (%)	73	31
Simple payback period (year)	1.363	3.162

[31]. A summary of the data and assumptions necessary for the economic analysis is given in Table 3.

Besides, the economic analysis was done in two optimistic and pessimistic views; for the optimistic view, the maximum price for selling electricity is considered, and the tax rate is considered as the minimum value. As of the pessimistic perspective, opposed to the optimistic view, all prices and rates are considered in the worst economic conditions. The result of the economic analysis obtained for the optimal scenarios is summarized in Table 4 and Table 5 [33, 34].

Sensitivity analysis is one of the most critical processes that must carry out in any project. Researchers implement sensitivity analysis in different parts of the mathematical model or superstructure, for example, on the capacities of technologies, the costs of components, and many other cases [14]. In this article, sensitivity analysis was carried out on the economic aspects. In this direction, the project will fail if the conditions for the sale of electricity and heat do not go well or if the cost of implementation and purchase of equipment exceeds the estimations [35]. The results obtained from the sensitivity analysis are summarize in Table 6 and Table 7, which show all the possible conditions for the existing economic possibilities. The importance of the results obtained from the sensitivity analysis is to increase the reliability and risk tolerance of the investors of this project [36].

The obtained results show that the scenario, which is environmentally friendly, can be profitable and appropriate in the case of the optimistic view; eventually, this project represents a big step in moving towards bioenergy use.

Table 5. Results of cost analysis for the optimal scenario of the second objective function

Items	Optimistic scenario (OS)	Pessimistic scenario (PS)
NPV (M$)	163.798	-100.3
IRR (%)	18	8
Simple payback period (year)	5.464	9.634

Table 6. Results of sensitivity analysis for the optimal scenario of the first objective function

Items	NPV (M$)	IRR (%)	Simple payback period (year)
A 20% increase in investment costs	1528.82 (OS)	61 (OS)	1.635 (OS)
	415.075 (PS)	26 (PS)	3.794 (PS)
A 20% increase in Q&M costs	1546.9 (OS)	71 (OS)	1.401 (OS)
	433.15 (PS)	29 (PS)	3.375 (PS)
A 20% decrease in profits	1208.77 (OS)	59 (OS)	1.703 (OS)
	317.77 (PS)	25 (PS)	3.952 (PS)

Table 7. Results of sensitivity analysis for the optimal scenario of the second objective function

Items	NPV (M$)	IRR (%)	Simple payback period (year)
A 20% increase in investment costs	74.512 (OS)	14 (OS)	6.557 (OS)
	-189.585 (PS)	6 (PS)	11.56 (PS)
A 20% increase in Q&M costs	30.415 (OS)	13 (OS)	6.993 (OS)
	-233.682 (PS)	2 (PS)	15.673 (PS)
A 20% decrease in profits	41.752 (OS)	13 (OS)	6.83 (OS)
	-169.525 (PS)	5 (PS)	12.042 (PS)

4. CONCLUSION

The obtained consequences reveal that the technologies used in the optimal model can be different according to the investor's point of perspective, so if the perspective is only waste management and converting it into energy, we can achieve this goal by using BE. However, this scenario releases significant amounts of GHG emissions and is not environmentally friendly, so it can only be an economical and profitable choice along with dairy industry waste management. However, the obtained results from the minimization of emissions illustrate that the optimal scenario should be a CHP cogeneration system with the CCS technology to achieve the lowest emissions. The cost analysis shows that the optimal path to maximize the productivity factor is an economical solution. On the other hand, the optimal approach to minimize GHG emissions is not economical if you have a pessimistic view, but if an optimistic outlook is used to implement this optimal scenario, it becomes economically feasible; eventually, it is evident that if governments support the low-carbon emission technologies, it can encourage investors to pay more attention to environmental issues.

Ultimately, according to the results obtained from the amount of electricity and heat produced by this superstructure in one of the industries with bioenergy potential, we realize the importance and high potential of this type of renewable energy. This article was done on a large-scale of the dairy and animal husbandry industry; although, if taken to a larger scale, such as at the level of a country or the world, we may be able to find out more about the importance of this type of renewable energy. Finally, a suggestion for future investigation is that researchers dip more into technical details such as technical parameters of the technologies in order to optimize the superstructure.

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