A Conventional Goal Programming Model for the Optimization of Wet Garbage Biogas Production Facility

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Abstract: As cities are growing, the government-mandated the builders to construct recycling plants. These production plant uses organic wastes as raw material for the recycling process. Main objective of the optimization is to calibrate the actual state of a process about a certain property through regulated variation of influencing factors in such a way as to achieve definite goals. In this study, we concentrated on the production of biogas, quality of feed, improper maintenance of generators, temperature controls are the factors that affect the production of biogas, keeping all these in mind we took three different plants for the study, here we developed a goal programming model which minimize the underutilization of feeding to the plant, maximize the running hours of the generator, maximize the power supply to the grid, minimize the underutilization of utilization of produced electricity, and minimize the production of manure by calculating quantity of biogas produced.

Keywords: Wet Garbage, Biogas, Goal Programming (GP), Under achievements, Over achievements.

1. Introduction

In this mechanical world, the environment is facing a lot of issues of which the garbage problem is the predominant one. Due to poor management of solid waste pollution levels in water, air, soil are increasing drastically which is becoming hazardous and reducing the health of the environment. Also due to the excessive usage of non-renewable resources, we are on the verge of destroying mother nature by extensive and rapid growth in almost every field. As a result, the consumption of non-renewable resources is exponentially high due to which the available resource is diminishing. To reduce all these government has taken many measures to dispose of this garbage. Wet garbage can be converted into compost and biogas which acts as an alternate fuel and can be utilized as an alternative for non-renewable resources. The biogas can be produced using wet garbage instead of dumping in landfills. The biogas produced from household waste contains - 50-60 % of methane, wastewater treatment plants sludge contains 60-75% methane, Agricultural & Food wastes contain 60-75% methane gas. When we compare this with natural gas it has only 20-30% less methane as natural gas is composed of 90-95% of methane gas. Thus the production of biogas is the most suitable option for growing nations like India. But the management of the biogas facilities is facing lots of challenges which can be sorted out by proper budgetary allocation. The various possible solution can be achieved through goal programming as it gives a most satisfactory level of solution.

2. Literature review

[1] and [2] worked on the production of biogas by Anaerobic Digestion of organic waste. The current biogas potential can considerably reduce India's LPG imports and future energy independence in the country. Here [1] explains Challenges in Family-based models, Community based models, Market challenges while producing the biogas. Whereas [2] explains how biogas is produced by Hydrolysis or fermentation, acidogenesis, Methanogenesis, Acidogenesis. [3] applied AHP and GIS for Optimal allocation for the development of MSW treatment facilities by considering Cost, hydrology, Topography and soli, access to infrastructure. [4] has explained the Application of GP in budgetary allocation of garbage disposal unit by considering various factors like Expenditures such as Infrastructure cost, Landfill cost, Maintenance charges, personnel cost, assets of the unit, Revenue generated and Minimizing the Liabilities, Infrastructure cost, Sanitary landfill cost, maintenance charges, general expenses. [6] has applied Mixed Integer Goal Programming (MIGP) for the Proper management of paper recycling logistics. [1]. [7] gave A multi-objective optimization model based on the goal programming approach is proposed in this paper to assist in the proper management of hazardous waste generated by the petrochemical industry here the author has used Analytic Hierarchy Process (AHP), Goal Programming (GP) by considering the Hazardous waste removal, Transportation cost, funds, Utilizing the available resources, Recycling, energy production, waste minimization, waste recyclizing as constraints. [8] also worked on Hazardous Waste for the Sustainable collection system design for urban municipal solid waste. [8] done the Analysis of waste based on the area characteristics and mathematical projection of existing and future collection systems, data acquisition and evaluation by GIS, and identification of appropriate alternatives through comparative multi-criteria decision analysis. [9] applied CCP, fuzzy goal programming to Minimize the system cost and maximize income for the disposal facility by considering various constraints such as Landfill capacity, Incinerator capacity, Composting facility capacity, Material recycling facility, Waste disposal.

3. Model development

For this study, Data has been collected from three biogas plants as shown in Tables 1 2 & 3. These three periods represent the three seasons viz., summer rainy, and winter season.

Table 1: Details of Biogas plant 1

Period	1	2	3
1. Waste feed (in KGs)	90390.00	83900.00	97450.00
2. Generator running (in hours)	299.00	303.40	321.40
3. Power supplied (in units)	2517.00	2572.50	2416.00
4. Electricity utilized (in KWh)	260.50	256.00	232.00
5. Manure generated (in KGs)	8135.00	7551.00	8771.00

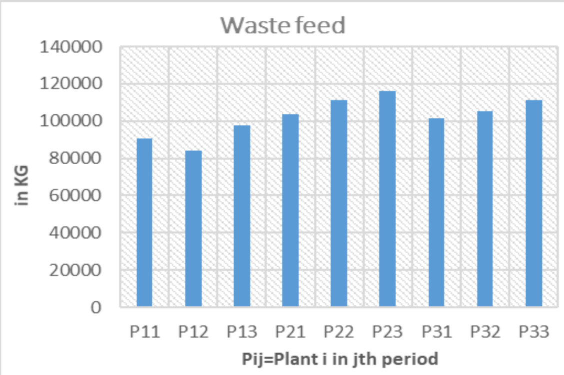
Table 2: Details of Biogas plant 2

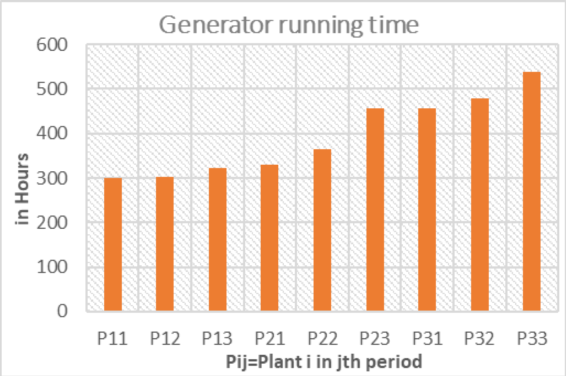
Period	1	2	3
1. Waste feed (in KGs)	103448.00	111518.00	116204.00
2. Generator running (in hours)	330.60	364.70	456.20
3. Power supplied (in units)	3283.90	3472.80	4700.30
4. Electricity utilized (in KWh)	278.00	295.00	319.50
5. Manure generated (in KGs)	9310.00	10037.00	10458.00

Table 3: Details of Biogas plant 3

Period	1	2	3
1. Waste feed (in KGs)	101695	105175	111400
2. Generator running (in hours)	455.6	477.7	538.6
3. Power supplied (in units)	5149.1	4781.5	6168.7
4. Electricity utilized (in KWh)	339	299.5	355.2
5. Manure generated (in KGs)	9153	9466	10026

The major aim of these plants to dispose of the wet garbage and to produce biogas so that it can be utilized to generate electricity for the streetlights. Due to various factors such as improper maintenance of biogas generator, poor quality of waste feed, excess water levels in the waste feed, temperature of the waste the in anaerobic digestor, improper maintenance of Ph levels inside the anaerobic digestor, etc., affects the production of electricity.





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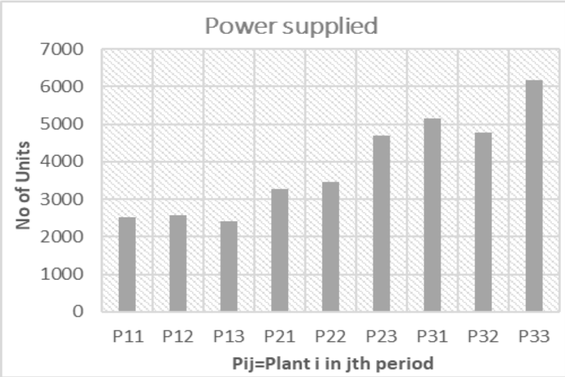

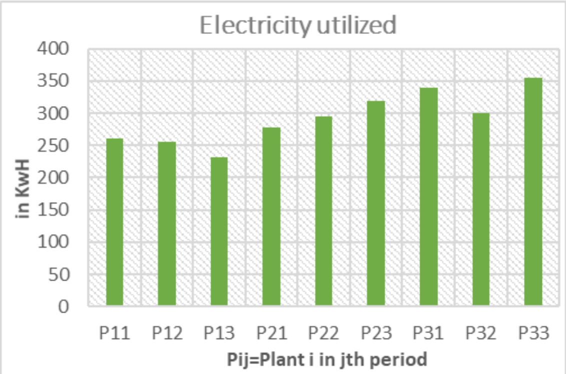

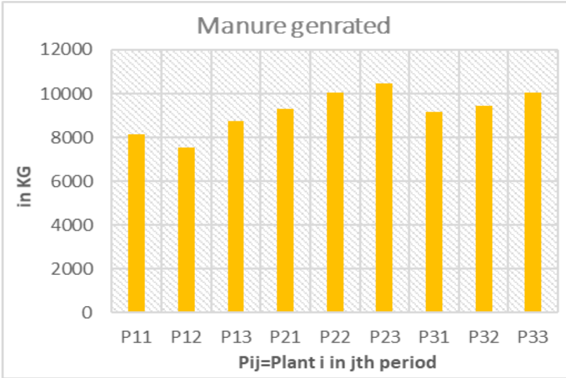

The decision maker they wanted to check which plant running optimally in the production of biogas and, which is not working up to the mark so that they can increase the performance of that plant. The current performance of the 3-plant combined is shown in the graphs.

Here decision maker wanted to feed all the garbage collected which was the primary goal of the construction of the biogas plant. They wanted to utilize the biogas in the production of electricity which has been utilized by streetlights by running biogas generators. Also, they wanted to minimize the production of manure which is considered as the least priority as it is difficult to control.

3.1. Goal Constraints:

To optimize this problem, we have formulated the following goal constraints as per the need of the decision-maker.

3.1.1. Goal 1: Minimize the underutilization of feeding to the plant.

$$\sum a_i x_i + U_a = T_a$$

Where, x_i = Quantity of biogas generated per day in a plant i; a_i = Average daily waste feedings to the biogas plant i; T_a = Target feeding to the biogas plant; U_a = Under Achievement

3.1.2. Goal 2: Maximize the running hours of the generator.

$$\sum b_i x_i + U_b - O_b = T_b$$

Where, x_i = Quantity of biogas generated per day in a plant i; b_i = Average daily generator running hours of the biogas plant i; T_b = Target generator running hours of the biogas plant; U_b = Under Achievement; O_b = Over Achievement.

3.1.3. Goal 3: Maximize the power supply to the grid.

$$\sum c_i x_i + U_c - O_c = T_c$$

Where, x_i = Quantity of biogas generated per day in a plant i; c_i = Average daily power supply to the grid from the biogas plant i; T_c = Target power supply to the grid from the biogas plant; U_c = Under Achievement; O_c = Over Achievement.

3.1.4. Goal 4: Minimize the underutilization of utilization of electricity.

$$\sum d_i x_i + U_d - O_d = T_d$$

Where, x_i = Quantity of biogas generated per day in a plant i; d_i = Average daily utilization of electricity produced from the biogas plant i; T_d = Target utilization of electricity produced from the biogas plant; U_d = Under Achievement; O_d = Over Achievement.

3.1.5. Goal 5: Minimize the production of manure.

$$\sum a_i x_i + U_e - O_e = T_1$$

Where, x_i = Quantity of biogas generated per day in a plant i; e_i = Average daily production of manure from the biogas plant i; T_e = Target production of manure from the biogas plant; U_e = Under Achievement; O_e = Over Achievement.

3.2. Priorities:

According to the decision-maker the priorities are given as follows.

P_1	P_2	P_3	P_4	P_5
Goal 1	Goal 4	Goal 3	Goal 2	Goal 5

Also, the priorities can be modified and reassigned to desired goals according to our needs.

3.3. Objective Function

$$\text{Min } Z = P_1 U_a + P_2 U_d + P_3 U_c + P_4 U_b + P_5 U_e$$

4. Result and discussion

4.1. **Case 1:** The Goal programming model has been developed and in the first run using Excel Solver as per direction from the direction of decision-maker and the priorities given by them for we got the following results as

Solution	0.00	77.73	201.90	0.00	0.00	0.00	296.44	0.00	6010.68	0.00	0.00	0.00	1.31	Min Z	26.22
Vairiables	x1	x2	x3	Ua	Oa	Ub	Ob	Uc	Oc	Ud	Od	Ue	Oe		Target
Objective Function	**0**	**0**	**0**	**100**	**0**	**40**	**0**	**60**	**0**	**80**	**0**	**0**	**20**		
1. Waste feed	3019.33	3679.67	3536.33	1	-1									=	1000000
2. Generator running	10.26	12.79	16.35			1	-1							=	4000
3. Power supplied	83.39	127.30	178.88					1	-1					=	40000
4. Electricity utilized	8.32	9.92	11.04							1	-1			=	3000
5. Manure generated	271.74	331.17	318.28									1	-1	=	90000

Figure 1:Case 1

shown in Figure 1. which represents that we have achieved Goal 1 with Priority 1, Goal 4 with Priority 2, Goal 3 with Priority 3, Goal 2 with Priority 4 and Goal 5 with Priority 5 is not achieved which is acceptable as the Oe value is very close to zero and least priority. Hence, we have obtained the most optimum solution.

4.2. **Case 2:** For the given developed goal programming model we have added the hard constraints as follows with the minimum production capacity.

$$x1 \geq 50;$$

$$x2 \geq 50;$$

$$x3 \geq 50;$$

Here we have imposed the restriction to produce biogas with a minimum quantity of 50units and run the model using Excel Solver with the same priorities which are given by the decision-maker we have achieved the following result as shown in Figure 2. which represents that we have achieved Goal 1 with Priority 1, Goal 3 with Priority 3,

Solution	50.00	50.00	188.06	0.00	0.00	0.00	228.59	0.00	4175.47	11.92	0.00	0.00	1.52	Min Z	983.94
vairiables	x1	x2	x3	Ua	Oa	Ub	Ob	Uc	Oc	Ud	Od	Ue	Oe		Target
Objective Function	**0**	**0**	**0**	**100**	**0**	**40**	**0**	**60**	**0**	**80**	**0**	**0**	**20**		
1. waste feed	3019.33	3679.67	3536.33	1	-1									=	1000000
2. Generator running	10.26	12.79	16.35			1	-1							=	4000
3. power supplied	83.39	127.30	178.88					1	-1					=	40000
4. electricity utilized	8.32	9.92	11.04							1	-1			=	3000
5. manure genrated	271.74	331.17	318.28									1	-1	=	90000
	1.00													>=	50
		1.00												>=	50
			1.00											>=	50

Figure 2: Case 2

Goal 2 with Priority 4 and Goal 4 with Priority 2, Goal 5 with Priority 5 are not achieved which is acceptable as we have achieved 3 of our goals. Hence, we have obtained the most optimum solution.

4.3. **Case 3:** For the given developed goal programming model we have added the hard constraints as follows with the minimum production capacity.

$$x1 \geq 50;$$

$$x2 \geq 75;$$

$$x3 \geq 100;$$

Solution	50.00	75.00	162.05	0.00	0.00	0.00	123.02	0.00	2704.68	51.22	0.00	0.00	1.23	Min Z	4122.14
vairiables	x1	x2	x3	Ua	Oa	Ub	Ob	Uc	Oc	Ud	Od	Ue	Oe		Target
Objective Function	**0**	**0**	**0**	**100**	**0**	**40**	**0**	**60**	**0**	**80**	**0**	**0**	**20**		
1. waste feed	3019.33	3679.67	3536.33	1	-1									=	1000000
2. Generator running	10.26	12.79	16.35			1	-1							=	4000
3. power supplied	83.39	127.30	178.88					1	-1					=	40000
4. electricity utilized	8.32	9.92	11.04							1	-1			=	3000
5. manure genrated	271.74	331.17	318.28									1	-1	=	90000
	1.00													>=	50
		1.00												>=	75
			1.00											>=	100

Figure 3:Case 3

Here we have imposed the restriction to produce biogas with a minimum quantity of 50units, 75units, 100units respectively based on the performance according to the data collected. Now we run the model using Excel Solver with the same priorities which are given by the decision-maker we have achieved the following result as shown in Figure 3. which represents that we have achieved Goal 1 with Priority 1, Goal 3 with Priority 3, Goal 2 with Priority 4 and Goal 4 with Priority 2, Goal 5 with Priority 5 are not achieved which is acceptable as we have achieved 3 of our goals. Hence, we have obtained the most optimum solution.

5. Conclusion

The quality of feed, improper maintenance of generators, temperature controls are the factors that affect the production of biogas, keeping all these in mind we took three different plants for the study, here we tried to develop a goal programming model to minimize the underutilization of feeding to the plant, maximize the running hours of the generator, maximize the power supply to the grid, Minimize the underutilization of utilization of produced electricity, and minimize the production of manure. In this study, we considered the decision variable for the production of biogas by considering three different cases with the same priorities as given by the decision-maker. And we got the following result as mentioned in Table 4.

Table 4: Comparative study

Variables	Solution		
	Case 1	Case 2	Case 3
Min Z	**26.22**	**983.94**	**4122.14**
x1	0.00	50.00	50.00
x2	77.73	50.00	75.00
x3	201.90	188.06	162.05
Ua	0.00	0.00	0.00

Oa	0.00	0.00	0.00
Ub	0.00	0.00	0.00
Ob	296.44	228.59	123.02
Uc	0.00	0.00	0.00
Oc	6010.68	4175.47	2704.68
Ud	0.00	11.92	51.22
Od	0.00	0.00	0.00
Ue	0.00	0.00	0.00
Oe	1.31	1.52	1.23

In case 1 we got the objective value Min Z value 26.22 and we achieve 4 goals and 1 goal is not satisfied. Here model shows not to produce biogas from Plant 1 as it is a very low performer. By this decision-maker can work on plant 1 so that it can be improved. In case 2 and case 3 we imposed the minimum restrictions for the production of biogas, and we have achieved the 3 goals and 2 goals respectively achieved but we have got acceptable results as they are very close to zero. In case 2 and case 3 model says there is the underutilization of electricity which must be taken care of. And in all three cases, we can see that minimization of the generation of manure is not achieved as control over it very difficult.

6. Future Scope

The current study gives several unique theoretical and managerial insights for practitioners working in production sector. The given model can be slightly modified according to the need of decision maker of the various manufacturer based on the product produced. It also helps the new entrepreneurs in manufacturing field to take proper decision even before establishing the company. Also, with different priorities and current scenario they can get various solution and can take proper discission for the establishment of the production setup.

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