Available online at www.ap.iauardabil.ac.ir **Islamic Azad University, Ardabil Branch**
Anthropogenic Pollution Journal, Vol 4 (2), 2020: 44-51
DOI: 10.22034/ap.2020.1903832.1069
ISSN: 2588-4646

Optimal location of electrical energy generation from municipal solid waste for biomass power plants

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Received: 7 February 2020 / **Accepted**: 15 August 2020/ **Published**: 31 September 2020

Abstract: Today, with the increase in population, the use of fossil fuels has also increased; On the other hand, this increase in population has led to the production of more municipal solid waste, which is itself the source of environmental pollution. One of the ways to reduce waste pollution is to use it to generate useful energy such as electricity, which reduces pollution and provides part of the required electrical load. In this study, the study area of Hamadan city is considered to have an average municipal solid waste production of about 420 tons/month. Homer software has been used to analyze the amount of electrical energy produced, and economic and environmental analysis has also been done. One of the outstanding results of the research is the production of 229,735 kW/year of electrical energy. Electrical energy generation with biomass resources will reduce Co2 and Co emissions by 77.2 and 7.96 kg/year, respectively. The cost of energy (COE) for this system is 0.177$/kWh.

Keywords: Municipal solid waste, electrical energy, environmental pollutants, optimization.

1. Introduction

The increasing population in the world has resulted in increasing use of fossil fuels and environmental pollution. Another consequence of over population is the high amount of urban waste production due to people consumption(Maanifar, and Fataei, 2015; Hemmati et al., 2019). One way to reduce emissions and reduce fossil fuel consumption is to use renewable energy (Kasaeian et al., 2015; Iniyan et al., 2020; Mortensen et al., 2020). The advantages of renewable energy include non-emission of environmental pollutants and availability (Wolde-Rufael et al.,2020). Urban waste is one of sustainable sources which can be used to generate energy in two ways. It can be as generator fuel after being converted to gas or after going through separation processes (Fataei and Seied Safaviyan, 2017; Situmorang et al. 2020; Zhang et al. 2020; Moreno et al. 2020), which have their own advantages and disadvantages. Several studies have been conducted on gas production from urban waste such as Noori et al. (2019), Díaz-Trujillo et al. (2019) , Khalil et al. (2019), Alayi et al. (2020), Al Afif et al. (2019). Another research that has been considered in the field of utilizing municipal waste as generator input fuel is Gao et al (2019) , Yuan et al. (2019), Torres et al. (2019), He et al. (2019), Hiloidhari et al. (2019). Also, a study proposed to Designing an integrated municipal solid waste management network (Yousefloo et al., 2020). Chambon et al.,(2020) also provided that Techno-economic assessment of biomass gasification-based mini-grids for productive energy applications: The case of rural India. In another study, Sustainable supply chain network design for the optimal utilization of municipal solid waste was studded (Mohammadi et al. 2019).

Optimal process design for integrated municipal waste management with energy recovery in Argentina was also studded (Morero et al. 2020). Solid fuel from oil palm biomass residues and municipal solid waste by hydrothermal treatment of electrical power generation in Malaysia: a review (Hamzah et al. 2019). Feasibility study of renewable energy sources for developing the hydrogen economy in Pakistan (Shah et al. 2020). In another study, it was proposed that Electrical Impacts of the Distributed Generation with Incineration of Urban Solid Waste (da Costa et al. 2019).

According to the above research, it can be seen that biomass technology is expanding. And it is inevitable to use this type of technology in big cities due to the high production of urban waste and it can be considered as a valuable source of energy. Most research has focused on methane production from waste. In this study, after the separation of waste and during the early stages, urban waste is similarly considered in generators to generate electricity. In addition, in this research, the amount of electricity generation by biomass power plant has been obtained in different months of the year and economic and environmental analysis have been done.

2. Materials and Methods

Data Collection

The selected location for this study is an in Hamadan, Iran. Urban solid waste of Hamadan city per day and per month is shown in Figure 1 and 2. According to the population located in the waste management basin in the region, each person produces an average of 765 gr/day of industrial and urban waste (Wolde-Rufael et al.2020).

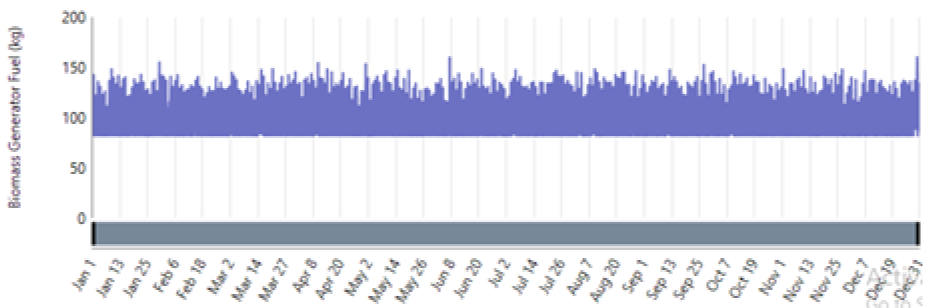

Fig.1- Urban solid waste of Hamadan city per day [source: wm. hamedan.ir]

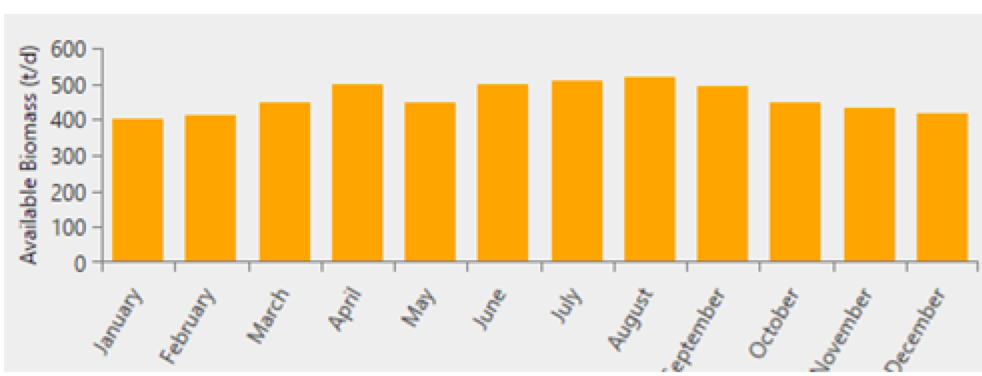

Fig.2- Urban solid waste of Hamadan city per month [source: wm. hamedan.ir]

Load Profile

The electrical load demand is intended for a village near Hamadan, Iran. It is considered as an electrical load demand for residential buildings and public uses such as street lighting. In Figure 3, the electrical load demand can be seen in different days of the year, and in Figure 4, the amount of electrical load demand can be seen in different hours of the day.

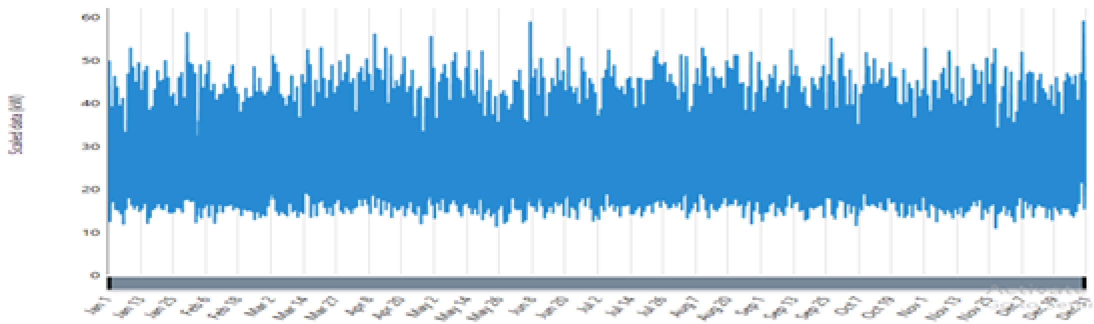

Fig.3- Daily electrical load profile

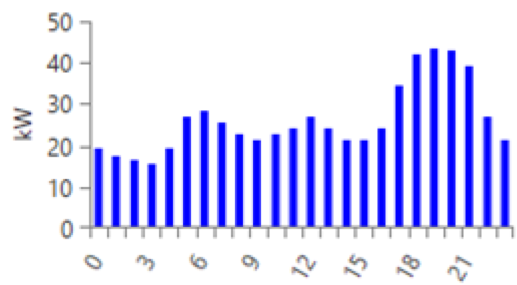

Fig.4- hourly electrical load profile

According to Figure 3, the maximum and minimum daily electrical load demand is 1.7 MW and 0.8 MW, respectively. It can also be seen that the maximum and minimum hourly electrical load demand is 41 kW and 17 kW, respectively. Meanwhile the average maximum load demand is 57 kW, while the average minimum load demand is 27kW and the load factor is 0.44.

System Model

HOMER was used to determine the feasibility of biomass system installation on-site. At its core, HOMER is a simulation model. It will attempt to simulate a viable system for all possible combinations of the equipment that you wish to consider. Depending on how you set up your problem, HOMER may simulate hundreds or even thousands of systems. HOMER Pro features our new optimization algorithm that significantly simplifies the design process for identifying least-cost options for micro-grids or other distributed generation electrical power systems. The software tool is expected to show the technical and economic parameters for the optimal system configurations. (www.homerenergy.com).

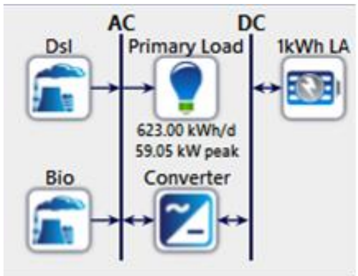

Fig.5- System Model in HOMER software

The system model is presented in Figure 5. Both biomass power plant and Diesel generator systems are connected to the AC bus. As the figure shows, two sources of power generation have been used to supply the required electric load. In this study, the main source of waste incinerator and diesel generator has been used as a backup. And the battery is used as a storage of excess electrical energy produced. The systems' technical and economic parameters are presented in Table 1.

Energy Management System

Technical and economical parameters for biomass power plant and Disel generator can be seen in Table 1. Table 2 shows waste generator specifications.

Table1: Technical and economic parameters.

No	Components	Specifications
1	Biomass	
	Size considered (kW)	0 to 250 kW with 50 kW step size
	Capital cost ($/kW)	1,000
	Replacement cost ($/kW)	833
	Operation and maintenance cost ($/hr)	0.12
	Lifetime (Hours)	15,000
2	Disel	
	Size considered (kW)	0 to 250 kW with 50 kW step size
	Capital cost ($/kW)	358
	Replacement cost ($/kW)	333
	Operation and maintenance cost ($/hr)	0.05
3	Site specific input	
	Minimum load ratio (%)	30
	Project life time (year)	25
4	Battery	
	Size considered (kW)	0 to 250 kW with 50 kW step size
	Capital cost ($)	300
	Replacement cost ($)	300
	Operation and maintenance cost ($/hr)	0.03
5	Convertor	
	Size considered (kW)	0 to 250 kW with 50 kW step size
	Capital cost ($/kW)	320
	Replacement cost ($/kW)	290
	Operation and maintenance cost ($/hr)	0.01

Table2: waste generator specifications.

Quantity	Value	Units
Fuel consumption	1,224	kg
Specific Fuel consumption	3.73	Kg/kWh
Fuel energy input	1,309,270	kWh/year
Mean electrical efficiency	17.5	%

3. Results

Table 3 shows the results for optimizing the study system by considering different scenarios. The first scenario is related to the diesel generator system and the second scenario is related to the biomass system. The table includes energy and economic analysis parameters.

Table3: Optimization results.

Rank	Dsl (kW)	Bio (kW)	Convertor (kW)	Battery (kWh)	Dispatch Strategy	Initial capital ($)	NPC ($)	COE ($/kW)	RF
1	60	-	0.116	1	LF	21,500	591,588	0.165	0
2	-	60	0.116	1	LF	60,000	632,687	0.177	100
3	-	100	0.116	1	LF	100,000	1.05M	0.294	100

According to the firs scenario, to provide the required load, considering the diesel generator, a size of 60 kW is required, and the cost of energy with this system is 0.165 $/kWh. In the second scenario, the purpose is to provide the required electric charge with biomass energy from municipal solid waste, so a 60 kW waste incinerator is needed to provide electrical energy. For the second scenario, net present cost and initial capital and the cost of energy (COE) is 63268 $ and 60000 $ and 0.177 $/kWh, respectively. Figure 6 shows the amount of electricity generated by the biomass system.

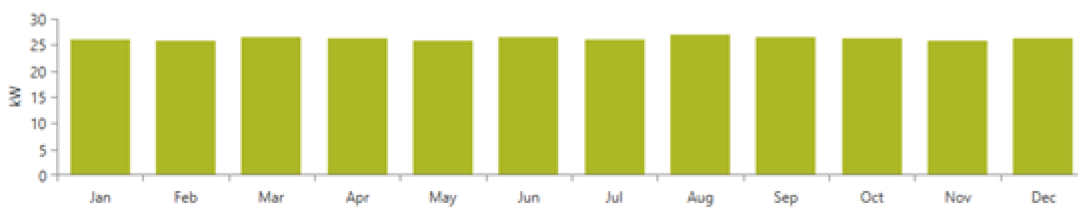

Fig.6- Monthly average electrical production by biomass power plant

According to the Figure 6, it can be seen that electricity generation is 229,735 kW/year, with an average electrical output of 26.2 kW and a maximum electrical output of 59.1 kW and a minimum electrical output of 18 kW. For this case, the amount of renewable fraction by the system is 100%. In some cases, too excess power is generated, which can be seen in Figure 7 and monthly average excess electrical energy production can be seen in figure 8.

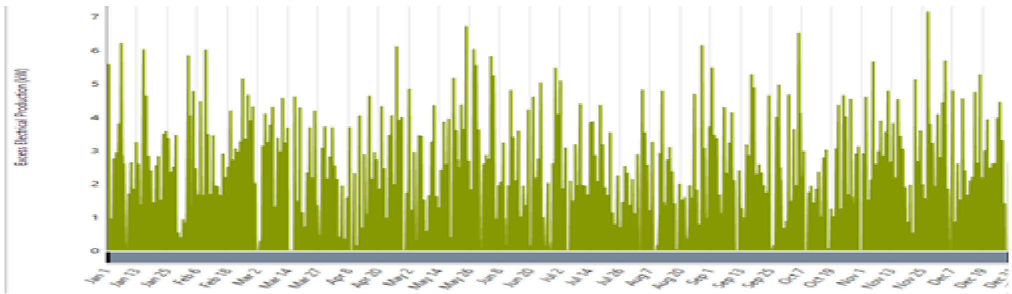

Fig.7- Excess electrical energy production (daily average)

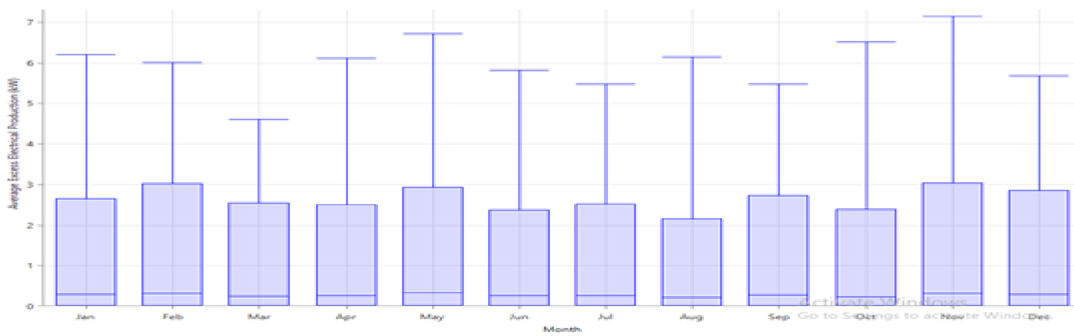

Fig.8- Excess electrical energy production (monthly average)

Figure 7 shows that, the highest and lowest excess electrical energy production by biomass power plant are related to the December 4th and March 2th which were 7.3 kW/day and 0.1 kW/day, respectively. Additionally, the highest and lowest monthly average excess electrical energy production by biomass power plant occurred in the November and August which were 3 kW/day and 2.1 kW/day, respectively. Table 4 shows the results for Reduction of environmental pollutants by biomass power plant.

Table4: Reduction of environmental pollutants.

Quantity	Value	Units
Co_2	77.2	Kg/year
Co	7.96	Kg/year
No_x	71	Kg/year
Unburned hydrocarbons	0.88	Kg/year

4. Discussion

Using the municipal solid waste in large cities, which can be the source of environmental pollution, can be a good solution to reduce environmental pollution and generate revenue.

This research, based on economic and environmental analysis techniques. In this research to realize this opportunity, Design of biomass was considered for the production of electrical energy. The required electrical energy load of the studied building is 626.25 kWh/d. To supply electrical energy load, it needs 3.35 tons/day of urban waste. The amount of municipal solid waste is taken from Hamadan municipality waste management organization, which is 460 tons/day. Due to the high volume of municipal solid waste, more electrical energy is produced than the amount of electrical load. excess electrical energy generation from biomass power plant is 2,340 kW/year, which is about 1% of total energy produce. On other hand a highest excess electrical energy production of 7.5 kW and a lowest excess electrical energy production of 0.1 kW. To supply this amount of electrical load, it needs 3.35 tons/day of urban waste. The overall efficiency of the system is 17.5%. In pollution indicators, the greatest reduction is related to Co2 with a 77.2 kg/year.

5. Conclusions

In this research, Modeling has been done with Homer software to estimate the amount of electrical energy production. For this modeling, the two function of minimum cost and pollution production were considered. The results showed that the amount of electrical energy is more than the required load and significantly prevents the release of environmental pollutants. Therefore, the generated electrical energy can be sold to the grid and earn income. Therefore, this type of technology is suitable for cities with large populations.

6. ADDITIONAL INFORMATION AND DECLARATIONS Funding

I thank Germi Branch, Islamic Azad University, Germi, Iran for funding.

Grant Disclosures

There was no grant funder for this study.

Competing Interests

The author declares there is no competing interests, regarding the publication of this manuscript.

Author Contributions

Reza Alayi: Purposed the plan, conceived the experiments, analyzed the data, authored or revised drafts of the paper, approved the final draft.
Hossein Monfared: analyzed the data.
Mehdi Jahangiri: Purposed the plan, conceived the experiments, analyzed the data.

Ethics Statement

The authors of the article would like to thank Hamadan municipality waste management organization.

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