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Application Potential of Gasification Technologies in Rural Settlement Areas

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ABSTRACT

The rural settlement area of Niğde Çukurkuyu was chosen as a model location in this study to support rural development and sustainability. In order to identify the feasibility of the technology; the population, energy consumption, available potential raw materials (household and agricultural waste amount depending on years) of the settlement have been determined and analyzed and an economic feasibility report has been prepared. According to the obtained data from the region, 30% of the agricultural land is used and annual average of generated agricultural waste is 32200 tons. Depending on the season, averagely 1080 tons of domestic waste potential is available at the settlement. According to these data, estimated installed power of the gasification/plasma gasification plant which use of household waste can be 3 MW. The planting of energy plants such as Switchgrass and Sweet sorghum into unused agricultural land can increase the installed power of the plant to up to 18.8 MW. 1.1% of the energy produced by the process can meet the electricity needs of a 1000 selected rural residential area. Plus, entire heating requirement of the site can be met by 35% of the energy of process. With the remaining energy generated can be used by the grid, so the national economy will be contributed. Finally, it is obviously that a significant energy potential is available for rural development and sustainable energy production

Keywords: Climate change mitigation, energy plants, renewable energy, rural life, waste management.

INTRODUCTION

World energy demand has been increased as parallel to population growth. Although urban area has higher demand to energy compared to rural areas, rural areas' energy demand is crucial for daily life, agricultural and livestock activities, which are farmers' main income. The context of Turkey's energy demand is as similar as other countries. Turkey's 80% of energy is outsourced; besides Turkey has a high-energy potential because it is an agricultural country. Though Turkey has various energy production plants, almost all of them cause environmental problems such as carbon dioxide emission or waste heat. On the other hand, Turkey has significant amount of renewable energy sources such as wind power, solar power or biomass energy. Even though biomass energy, such as municipal solid waste (MSW) or agricultural waste (AW), does not have widespread applications, electricity production from biomass can support the gap of fluctuation occurred the solar power and wind power sources (Öztürk, 2002; Ertürk et. al., 2006).

Since the technological revolution, the importance of energy security has increased dramatically because industrial production demands energy supply continuously. That's why developed and under developed countries are in competition, due to the energy and energy security are crucial and indispensable part of sustainable development. In order to reach sustainable development, sustainable energy production must be completed. That's why fossil fuel based energy sources have shifted to renewable sources, otherwise environment, which is the one the important element of the sustainably concept, could be destroyed (Seydioğulları, 2013).

Nowadays, the greatest impact on the environment is greenhouse gas emission, which could be prevented by the renewable energy sources such as solar power, wind power, biomass, geothermal etc. This context gives an ignition to improvement and investment to renewable energy technologies. In developed countries, biomass utilization in industry is highly improved. Although, the ratio of the biomass energy decreased to 3%, it is clear that the bioenergy utilization has important situation for many countries such as Finland, Sweden, and the USA whose biomass ratios are 15%, 9% and 4% respectively (Koç & Garip, 2008; The World Energy Council, 2016).

According to biomass gasification models, the efficient operation of a biomass gasifier depends on a number of complex chemical reactions, including fast pyrolysis, partial oxidation of pyrolysis products, gasification of the resulting char, conversion of tar and lower hydrocarbons, and the water–gas shift reaction. These complicated processes, coupled with the sensitivity of the product distribution to the rate of heating and residence time in the reactor, required the development of mathematical models. The main goals of these models are to study the thermochemical processes during the gasification of the biomass and to evaluate the influence of the main input variables, such as moisture content, air/fuel ratio, producer-gas composition and the calorific value of the producer gas (Arnava et. al., 2010). Recently, waste to energy technology development has increased rapidly. Especially, gasification and plasma gasification technologies are the promising ones. These technologies have higher efficiency capabilities than the other conventional systems and they are much suitable to utilize in and dispose the medical, municipal and agricultural wastes. All kind of raw materials that are derived from carbon base, have applied with the system. By gasification systems, the carbon-based-raw materials are converted to heat energy via partially oxidation process. Gasification generally has four steps, which are drying, piroliz, oxidation and reduction. There are some other kinds of gasification processes that have been used however; fluidized bed and plasma gasification is the most common types. Their some significant advantages are low emission, low amount of final inert material, usable by-products and low greenhouse gas footprint. In the Table 1.1 below, the content of the compounds after the gasification process is given (Klein, 2002).

Table 1.1. Syngas content after treatment process in gasification process (Marano, 2013).

Sulphur	**< 200 ppmw**
Alkali metals	< 1 ppmw
Valitile metals	1 ppmw
Halogens	1 ppmw
Particle	< 20 ppmw

Gasification processes produce slag as a by-product, which is an inert material that does not create any contamination to the soil or water. Plus, it can be used as an aggregate on concrete production. An example of slag content is given at Table 1.2.

Table 1.2. Slag content from gasification plant (Marano, 2013).

Compaund	Unit	Amount
Arsenic	mg/L	< 0.001
Cadmium	mg/L	< 0.001
Chrome VI	mg/L	<0.005
Chrome VI	mg/L	< 0.001
Mercury	mg/L	< 0.0001
Selenium	mg/L	< 0.001

In this study, to investigate sustainability of rural areas and solid waste management, Çukurkuyu town was chosen as a study area. Projected gasification plant can be utilized for solid wastes, agricultural wastes and medical wastes. Waste management and renewable energy production is indispensable part of the sustainability issue especially for rural areas. Çukurkuyu is a rural town and municipal solid waste and agricultural wastes are regularly produced at this town. In this study, energy potential of solid wastes was investigated. Plus, uncontrolled CO_2 emission from solid waste had prevented. Besides, thanks to energy from solid wastes CO_2 have been saved from the fossil fuels.

MATERIAL AND METHODS

Çukurkuyu town

Çukurkuyu is a town of Bor district at Niğde province. The town is at 37°52′N 34°20′E, it is situated in the plains of Central Anatolia. The distance between Bor and Çukurkuyu is 25 km and from Niğde city center to Çukurkuyu is 35 km. Çukurkuyu town has 7300 hectare unused agricultural field and 9800 hectare field which belong to Ministry of Treasury. Although household number of the Çukurkuyu is almost 1000, only 600 homes have permanent residents. Other 400 residents have used only summer season for a short time.

Çukurkuyu town energy consumptions

All houses are separate private house at the Çukurkuyu town. Permanently residence 600 house are consumed mid quality coal to heating purpose during winter season. Electricity consumption of Niğde province is equal to Turkey average consumption ratio which is 2565 KWH/year.person. But according to “Turkish Statistical Institute” the daily electricity consumption of one house is averagely 10 KWH/day and electricity consumption values of Çukurkuyu town is compatible with this standard value.

Çukurkuyu town agricultural data and numbers

Population of Çukurkuyu is 2367 and main economic income of the local people is agricultural activities which are livestock and farming activities. Especially sugar beet, tomatoes, apple, corn and water melon is primary agricultural products. The amount of agricultural products and their amount of seasonal wastes values are shown in the Table 2.1. As shown in Table 2.1. the ratio of agricultural waste are high because of unexpected frost weather or hail fail.

Table 2.1. The amount of agricultural products and their waste

Product	Decares/ year	Ton waste / year
Melon, Watermelon	6000	21000
Tomatoes	5000	10000
Sugar beat	1200	1200
Corn	1000	250

Nowadays cattle number have rose to over 7000 and the number of sheep and goat have reached over 9000. All animals are separated uniformly to the village area. This town is the highest number of animals compared to the population than the other towns of Bor.

Çukurkuyu town municipal solid waste amount

Although the amount of municipal solid waste can be seasonal fluctuations, averagely 1080 ton waste have been produces from town and then these solid waste have transferred to landfill area which is far away over 45 km from the town.

RESULTS AND DISCUSSION

Gasification Plant Estimation with Municipal Solid Wastes and Agricultural Wastes

The annual amount of MSW and agricultural wastes are 1080 and 32450 tons respectively. However, available waste amount from the region is up to 33530 tons per year as explained. For the calculation of the plant parameters, the studies from Tolay (2011) is used as references. While daily raw material amount is 91.86 T/day, expected syngas production amount is 5000Nm^3/h which is equal to 3688 GJ/year. That means to 3.3 MW installed capacity, if the plant is run 8000 hours per year. The plant consumes 10% of the produced energy. For thermal energy calculations, gasification plant can produce 6MW thermal energy but 50% of it should be used for internal purposes.

Electricity Fed-in tariff of Turkey is 0.133 $/kw, if energy is coming from renewable sources. As a result, the annual income of the electricity would be equal to 3192000 $. On the other side, some expenditure are indispensable. They are agricultural waste transfer from field to plant, some additional fuel for plant maintenance, official payments and salaries. If they are calculated, roughly they would cost 217500$, 218000$, 33000$, 17000$ and 390000$ respectively. Total amount of expenditure is about 617.000$. So, expected annual net profit would be almost 2600000$. The assumed first investment cost is approximately 10000000$ in which details are given at the Table 3.1.

Table 3.1. Economic indicators of the gasification plant.

Unit	Price	Unit	Price
Fuel accept, Storage and Feed	150000$	Syngas Compressors	450000$
Biomass Drying Units	250000$	Waste Heat Storage	300000$
Gasification Reactor	1100000$	Gas Turbine and Gas Engine	1500000$
Oxygen Production Unit	500000$	Steam turbine	500000$
Syngas Cleaning	1000000$	Power Building	150000$
Syngas Pipe System	150000$	Support Systems And Emission Control Systems	600000$
Pipes and Valves	50000$	Electric Systems	800000$
Thermal Isolation and Personal Protection	50000$	Installation	110000$
Ash Storage and transfer system	50000$	Licenses and Engineering	750000$
PLC System	100000$	**TOTAL**	**9550000$**

Gasification Plant Estimation with Energy Plants

If the 8550 ha area, which is equal to 50% of public land, in the town were used for energy plant growing and assuming annual yield would be roughly 6-25 ton/ha plus, the amount would be averagely up to 200000 tons per year. According the report from Soylu (2009), the amount of dry matter per hectare is 12.8 tons and total amount is 109440 ton. The calculations showed that the installed capacity is almost 18.80 MW, that’s equal to 150400 MWH electricity energy per year. Moreover, although 50% of it has to be utilize by the process, 320000 MWH excess thermal energy can be produced from the system.
The hourly feed stock needed for the system is 12.60 ton and according to the reference plant from report (Tolay, 2011) some important components and the values are given at the Table 3.2.

Table 3.2. The important components of the gasification process and the values

Component	Value	Unit
Feed Fuel amount	12.60	Ton/hour
Total energy inlet to reactor	47880000	kcal/hour
%93 **pure oxygen to reactor**	3.80	Ton/hour
Ash from the reactor	1.10	Ton/hour
Raw syngas amount from reactor	16512	kg/hour
Treated and dry syngas amount	13799	kg/hour
Calorific value of clean sygas	2660	kcal/kg
The energy of final syngas	36701.11	kcal/hour
Gasification efficiency	76.65	%

For energy production conventional solid waste disposal methods are one of the most efficient method. It's known that much more energy gain is available with gasification systems than the conventional systems with the same amount of solid wastes. Moreover, these plants create less waste gases, so air pollution control units are much smaller and more economic than the conventional systems. The form of ash from the gasification systems has inert structure that's why toxic waste management is not necessary.

The feasibilities of plants, which are designed for Çukurkuyu town with two different installed capacities, are shown that they are available to perform. This gasification plant can utilize both municipal solid wastes and agricultural wastes of the town. In this way energy production can be done from these wastes whose transfer effort to landfill site is non-economic. Plus, utilization of these wastes can help to prevent the random solid waste storage and uncontrolled burning of the stubble.

CONCLUSIONS

Biomass is taken into account to be the important form of energy and having a significant share (10-14 %) in the global energy load, while it has major participant of 90% of total energy supply in the remote and rural areas of the developing world. It is probable to remain the main source of primary energy feedstock for the developing countries in the near future as around 90% of the world population is expected to reside in the developing countries by 2050 (Kucuk & Demirbaş, 1997; Pathak et. al., 2013; Sansaniwala et. al., 2017).

It is supposed that 3 MW installed capacity of the gasification plant is enough to utilize both municipal solid wastes and agricultural wastes at the same time. It also supports the economic development of the town. According to the calculation, expected net profit of the plant is approximately 2.5 M $ and the investment cost of the gasification plant with 3 MW capacity is around 10 M $. This means, rate of return time of the plant is almost 4 years. Furthermore, waste heat from the gasification plant is equal to heating energy need of the 1000 households. Çukurkuyu town has less than 1000 households, that's why excess heat can be perfectly utilized for greenhouses of the town. In general view this gasification plant can utilize annually 34.000 tons waste and can produce electricity which is equal to 6500 household need.

This plant creates net zero greenhouse gas emission, especially when it is compared to coal or natural gas electricity production plants. That means, this is an eco-friendly way to manage whole waste from the town.

The construction phase of the planned plant is expected to reach up to 14 month. In this time period wastes can be stored. When we consider the economic income of the town is agricultural and livestock, unused 8550 ha area may be used for growing energy plants which means that the installed plant capacity can be increased up to 6 fold which is equal to 18.8 MW. So that would support the annual income of the town, thus farmers can get extra income. As a result of this, migration to big cities may be prevented and agriculture application may be performed effectively and much more modern. This situation can allow agricultural development.

Especially in the middle Anatolian region, to support the agricultural and livestock applications, to make value added solid wastes, a pilot gasification plant should be constructed to prove this study.

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