TECHNIUM

Technium Vol. 14, pp.22-25 (2023)
ISSN: 2668-778X
www.techniumscience.com

Case studies about biomass district heating efficiency in Romania

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***Abstract*—Biomass became the perfect choice for heating in Romanian cities while the geopolitical situation remains still complicated. A selection of cases is presented with several cities using this fuel for heating. A cogeneration with steam boilers, new boilers for warm water or obsoleted ones are all investigated from technical and economical perspectives. The article includes correlations with number of inhabitants, buildings connected to the grid, economical aspects. Conclusions are obtained about the efficiency of biomass district heating for different sizes cities, for different technologies and opportunity to implement modernization projects. The results can enhance the local efforts for a better use of biomass in municipal heating without greenhouse gas emissions. Statistical data about Romanian district heating performance indicators have been used and approved tariffs against average revenues of the population were considered.**

Keywords— Biomass; District heating; Energy Cost

I. INTRODUCTION

Biomass reached a major importance in energy balance, in the actual geopolitical context. Energy crisis has determinate fossil fuels prices escalation. Mainly natural gas tariff shows in the last years incredible evolution based on market scarcity. Consecutively, biomass ready systems for heat generation offered a special resilience to their clients against gas market influences. One the most important properties of 4th generation DH system is the capacity to recycle heat and integrate renewable sources. [1,2]. Large-scale heat storage in district heating enables better integration of renewables, which reduces cost and adds flexibility to the coupled electric system [3].

In Bucharest, heat supply cost increased from 490 Ron/Gcal (100 euro/Gcal) in September 2020 to 860 Ron/Gcal (175 euro/Gcal) in October 2022. For biomass heated municipalities the corresponding cost is now 540 Ron/Gcal (110 euro/Gcal).

Electricity price evolution on the market was an advantage for cities where cogeneration is installed. Biomass use in cogeneration was the winning combination for those who invested smart in the past.

The use of biomass plants for generating heat and electricity suppose more effort than gas fueled sources. In addition, demanded areas for temporary biomass storage are considerable. Distance to biomass sources is one of the most important conditions to start an opportunity analysis for a new plant.

This element is also considered for natural gas plants where the proximity to a transport grid is suitable if acceptable economic indicators are in target.

Greenhouse gases emission associated with biomass use are much smaller than in the case of natural gas use. Green certificates prices increased from 20 euro in 2019 to 100 euro in 2022. The cost of each fossil fuel generated heat unit will be more and more affected by this evolution.

Hydrogen doesn't appear as a real solution of urban heating. Water consumption for green hydrogen generation, high cost, warries about the domestic use for heating made this fuel less suitable for a large scale in cities.

Heat pumps represents an interesting and accepted solution, mainly combined with green electricity [4]. Large scale use of it demands important spaces often unavailable in urban areas. Additionally, heat pump use cannot represent an immediate solution for existing building heating [5, 6].

In cities where district heating systems are installed biomass is an option to be considered. New context of natural gas prices, green certificates taxes, access on large agricultural farms residues and green heavy transports lead to reconsider biomass as fuel for heat generation [7].

Investments in urgent rehabilitation of district heating systems in the next period is the key factor to avoid new gas burners in future disconnected apartments. Actual legislation in great Romanian municipalities stopped new natural gas burners in apartments. Networks with large populations densities were shown to have significantly shorter pipe lengths, resulting in reduced heat losses and installation costs [8].

Thermal rehabilitation of residential buildings cannot lead fast to heat demand reduction, considering the present stage of the program. The future smart thermal grid necessitates heat distribution among low-energy buildings via the DH network, i.e. two-way DH [9].

Opportunity frame for heat supply decarbonization is one of the most important in Romania. Huge amount of money is available, a team of experts in district heating and a complicated fossil fuel market are part of this favorable context. Next 7 years will be critical for multiplying number of municipalities to eliminate carbon emissions on heat generation, supply, and use.

Technium Vol. 14, pp.22-25 (2023)
ISSN: 2668-778X
www.techniumscience.com

In this paper, an analysis of 3 Romanian cities is made. Biomass fueled district heating are present and different cases are considered for investigating the opportunity of this technology in Romania.

II. RELATED WORK

Subject of biomass district heating is largely presented in scientific papers. A comprehensive review on the integration of biomass-powered combined heat and power (BCHP) in district heating systems is presented in [10]. Some preliminary conditions for reaching an acceptable level of efficiency are listed:

- high density for populated targeted areas;
- high loading factors for the cogeneration;
- lower supply temperatures for buildings;
- integration of heat storage.

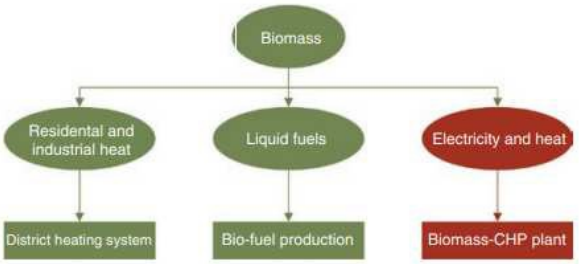

Fig. 1. Main application of biomass as a source of energy and the focus of the cited sources [10]

Distance to biomass source has the most important impact to the plant economy. Storage of the fresh biomass demands spaces and residual heat for drying (or long time for natural drying process) but less fuel cost could be considered.

Interesting case study of small scale biomass district heating system is presented in [11]. It is about 600 kW biomass plant and a small grid (670m length) for heating 4 municipal buildings with substations in Greece. About 200,000euro investment would produce dramatic reduction of emissions associated to the heating process. Fuel storage is also included in the project.

Amindeo District Heating from Western Macedonia Region covers approximately 2,000 public and residential buildings with a thermal load up to 25 MWth. A biomass thermal plant fueled by a mixture of wood chips and corn stover (60%) and lignite (40%) has ben installed. The heat source became a real support to develop local supply chain by agricultural residues. Detailed results are presented in [12].

One of the best environmental impact audit of biomass use for district heating in urban area is realized in [13]. Annual consumption considered for schools and hospitals was about 3,700 MWh/year. District heating associated pollution has been compared to domestic heat generation emissions for a clear and professional analyze of how an urban area became greener when biomass is involved.

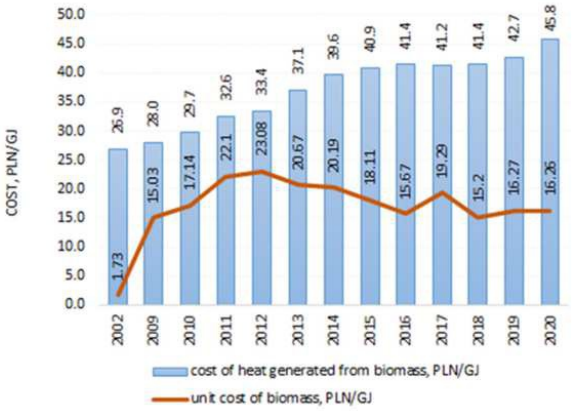

Fig. 2. Variation in the mean purchase cost and production cost of biomass generated heat [14] .

An interesting study performed for Polish market [14] offers complete data about cost of heat generated using biomass. The level for 2020 was 43 PLN/MJ (31.2 euro/MWh). Optimal range for biomass transport for heating purposes was in the range 10-20km. Logistics effort properly organized will determine an increase in the ratio of biomass use in heat production, which will allow farmers to organize the markets.

3 Municipalities in Spain was under study of BioUnviDH [15] with yearly heat demand in the range 10,000 – 15,000 MWh/year and biomass consumption 6,000 – 9,300 tons/year. Price for biomass considered in the study is 73.79 euro/tone. The massive application of the biomass fuel district heating system concept proves a high potential for energy and CO_2 emissions savings, creation of new direct incomes for municipalities and new jobs.

TABLE I. DATA AND RESULTS FOR BIOMASS ANALYSE IN SPAIN [15]

	Town A	**Town B**	**Town C**
Habitants	1,502	1,919	1,998
Fuel Poverty Index [%]	48.58	50.28	21.29
First houses	530	745	770
Second houses	294	305	775
Thermal Power [MW]	7.91	10.11	10.53
Degree Days 20 based [C/year]	3,439	4,133	3,359
Energy [MWh/year]	10,090	15,063	13,281
Biomass required [t/year]	6,312	9,306	8,316
Biomass available [t/year]	15,969	8,830	8,799
Network length [m]	4,792	8,465	11,905
Linear heat density [MWh/y m]	230.52	192.58	122.25
Invest [Meuro]	2.9	4.2	5.0
Biomass Price 20% RH[euro/t]	73.79	57.74	67.00
Biomass cost [keuro/year]	373	430	446

All information converge on the same conclusion: biomass is part of the future energy mix for urban heat supply. It is important to understand the real need in investment for enhancing the present district heating systems, transferring best results in other areas, making the green heat dream possible for maximal populations.

III. CASE STUDIES

According to [16], Romania has a considerable energy potential in biomass, evaluated at 318 x 10^9 MJ/year, about

20% of total energy resources of the country. In most cases, when biomass is used for heating the efficiency is poor and no modern installations are in place.

For the study, 3 Romanian cities were selected using biomass as main fuel for heat (and electricity) generation. Different district heating network sizes and technical conditions were considered as a frame for multicriterion analyse. The aim of the research is to better understand which factor is more important for reaching an affordable heat price. The size of the system, pipes condition, boilers efficiency could be targeted indicators for our investigation.

Suceava is situated in the south-western part of the Suceava County, in a moderately hilly area, and is an important commercial town and regional transport hub with Ukraine to the north, on the one hand, and with Transylvania to the west on the other hand. The town of Suceava covers two types of geographical areas, the hills (of which the highest is Zamca Hill) and the meadows of the Suceava river valley.

According to the 2011 census data, Suceava had a population of 92,121, making it the 23rd largest city in Romania.

Bioenergy Suceava is the largest biomass cogeneration plant in Romania with an annual capacity of 270,000 Gcal/year. It operates on biomass and natural gas using 4 biomass steam boilers, a hot water biomass boiler and 3 natural gas boilers.
In 2021, district heating system for Suceava supplied heat for about 16,000 apartments 100 houses, 450 small business and 30 municipal buildings. Total delivered heat was 85,000 Gcal/year with total transport and distribution losses reaching 74,000 Gcal/year. Heat is generated in cogeneration using a steam turbine and biomass boilers. About 73,000 tons of biomass were used to produce heat and about 134,000 MWh/year electricity.
Heat transport system lenght is 54 km pipes, 86% underground located. Half of these pipes are replaced with isolated ones in the last years. Distribution system is based on 322 km underground old pipes. An important amount of losses is recorded every year during district heating system operation.

First case is interesting for having a new and performant cogeneration plant owned by a private company. After some turbulences when biomass prices increased, in the last years (when natural gas price exploded), Suceava has been considered one of the lucky cities where heat was affordable for the population. Cogeneration of green heat for population and precious electricity for a hot prices market was amasingly profitable. Unfortunatelly the heat transport and distribution losses are still important and unacceptable. A reduction potential of 60,000 Gcal/year is waiting for investment in 3rd or 4th generation district heating elements. Simple calculation using 50 euro/Gcal shows that 3,000,000 euro/year saving could be obtained. It is clear that public funds has to be used for district heating reabilitation in the future.


Fig. 3. Image of biomass cogeneration plant in Suceava

Vatra Dornei is a small city north Romania. It is situated in the hystorical region of Bucovina, the 5th largest urban settlement in the county, with a population of 14,429 inhabitants, according to the 2011 census.

The district heating system in Vatra Dornei supplied heat for about 2,000 apartments and houses and 100 municipal buildings. Total delivered heat was 7,500 Gcal/year with total transport and distribution losses 5,485 Gcal/year. Pipes system lenght is 11,5 km for transport and 20 km for distribution. Heat generation is located in a biomass boiler plant using about 8,300 tons/year.

In this case, heat source has new equipments and district heating is ready to be modernized in 2 phases of rehabilitation. Problem is no cogeneration was implemented and performance of the system remains modest. A saving potential about 250,000 euro/year could help to implement a small cogeneration unit if an application on public fund will be made.

Gheorgheni is located in Haghita county in center Romania. As of 2011, the city had a population of 17,705 inhabitants.

Delivered heat was about 29,000 Gcal/year for apartments and municipal buildings. Recorded losses were 8,900 Gcal/year for transport and distribution. District heating systems is based on 5.3 km transport pipes and 30 km distribution pipes. Heat generation is located in a biomass plant using 10,000 tons/year and 36,000 MWh/year additional natural gas. In this third case, the biomass plant is in a very poor condition and feasibility studies have been conducted for a necessary rehabilitation project. About 20,000 Gcal/year saving potential meaning 1 mil euro/year is a reason to continue the implementation of the plan for having a new biomass plant in 2 years horizont.

IV. ANALYSIS AND DISCUSSION

All cases need investment to make systems more efficient. Spoken about heat generation or transport/distribution, there is an important saving potential to be exploit. Table 2 shows data about the cost benefit analysis of modernization projects.

Biomass rehabilitation projects reveal good returns of investment due to an increasing cost of fuels and environmental taxes.

TABLE II. OPPORTUNITIES TO INVEST IN BIOMASS SYSTEMS MODERNISATION AND RESULTS

	Suceava	Vatra	Gheorgheni
Heat generation	Good/ Cogeneration	Good/No Cogeneration	Bad/No cogeneration
Transport Distribution	Poor	Medium	Good
Projects in generation	No need	Small Cogeneration	Medium Cogeneration
Projects in District Heating	Pipes rehabilitation Monitoring	Pipes rehabilitation Monitoring	Pipes rehabilitation Monitoring
Investment in heat generation	No need	1.5 mil euro	4 mil euro
Investment in transport/ distribution	15 mil euro	3 mil euro	2 mil euro
Savings in heat generation	-	0.25 mil euro	1.0 mil euro
Saving in transport/ distribution	3 mil euro	0.30 mil euro	0.20 mil euro
Total investment	15 mil euro	4.5 mil euro	6 mil euro
Total savings	3 mil euro	0.55 mil euro	1.20 mil euro

Several national and European funding programs are ready to finance these projects, but some technical documentations have to be made in advance. A payback period of 5 years seems to be the commun result of analysing projects.
Municipalities has no chance to avoid starting a rehabilitation road. With no action, technical parameters will became worse and heat cost to the population will increase. An important issue will be the availability of specialized work force. Many projects are already develloping in Bucharest for the next years and important expertise concentration is recorded in place. Not only thermal rehabilitation is fighting for workers, highways are critical issue for Romania also and an important number of people are concentrated on it.
Continous increasment of electricity price on the market will positively impact cogeneration implementation rezults. Internal use of generated heat for biomass drying can be a solution for better profit while more fuel humidity is accepted. Building rehabilitation with public funds should be restricted for a mandatory connection to district heating grid. In this way, a critical mass of heat Clients could be a base for future development to a smart city concept. Major cities have best chances for a perfect biomass cogeneration project if located close to a forrest area. Extension to trigeneration is not suitable while the climate is quite cold where biomass is abundand.

V. CONCLUSION

There are projects to be implemented in Romanian biomass district heating systems. With 5 years payback period and investment support available, it is no reason to non-action in the further period. Big amount of savings is possible and attractivity for not connected houses will increase in time. Present wasted fuel could be used for heating more houses, environmental effect will multiply. Potential of district heating systems rehabilitation with biomass cogeneration plants is important in Romania. The feasibility became more attractive, while fossil fuel has price and availability problems. Dedicated funds are ready to be used for financing mature projects, but thermal experts seem to be fully booked for the next years. There is no alternative than starting the design part, concentrate local resources and make rehabilitation one of the main goals. This approach would let think people to a future smart city.

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