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Project of bioenergy village development in Kostojevići

There is no precise definition of term "bioenergy village". In the framework of three-year Bio-Vill project, supported by the European Union's Horizon 2020 programme [1], the term is described as follows: "A bioenergy village is a village, municipality, settlement or community which produces and uses most of its energy from local biomass and other renewables energies. Biomass from forestry, agriculture and waste is used in a bioenergy village to generate electricity and heat. This is usually im-plemented by several technologies of different sizes, such as: woodchip boilers, pellet stoves, logwood boilers, biogas plants, combined heat and power plants using woodchips etc. They usually supply a small district-heating (DH) grid of the village in order to distribute the heat to the consumers. The planning and installation of renewable energy technologies is often accompanied with energy efficien-cy measures. Besides supporting an increased use of renewable energies and its positive effects on climate and environmental protection, a central objective of a bioenergy village is to strengthen the local economy, as the expenses for energy remain in the region. The involvement and participation of a broad range of local stakeholders and consumers is crucial for the success of a bioenergy village. Ideally, biomass suppliers and energy consumers are shared owners of the necessary installations. The concept to set-up bioenergy villages was developed through concerned citizens' movements aiming to contribute in making the energy sector environmentally friendlier." These movements were especially strong in countries like Germany, Austria or Denmark [2].

1 Introduction

Kostojevići is the only village in Serbia with existing DH system, fuelled by heavy fuel oil. That was the reason to be selected for the case study in BioVill project, for the implementation of bioenergy village concept in Serbia. This activity is in line with a strategic goal of the Serbian energy sector to change the structure of fuels used in DH systems [3]. The goal is the reduction of the coal and liquid fuels share in heat production, and the increasing of biomass share to 12.1% by 2025. Currently, the share of biomass use in DH systems is less than 1% [4].

In this paper, the analyses of the viability of a fuel switch in existing DH system to locally avail-able biomass (wood chips) was done, as well as the assessment of the viability of the installation of a biomass CHP plant, which injects part of its heat produced into the existing grid of the DH plant. Be-sides, different business models for implementation bioenergy village concept in Kostojevići are con-sidered. These business models include issues and topics as the investments and ownership, biomass supply, system management, method of payment for delivered heat, etc.

The paper is organized, as follows: after the Introduction part, the current situation, concerning DH system in Kostojevići, and projections of development are presented in section 2; the opportunities to set up biomass based heat plant or CHP plant are considered in section 3; in section 4, different business models are discussed; short conclusions are in section 5.

2 District heating system in Kostojevići

The DH system in Kostojevići has been operating since 2007 as a part of the Public Utility Company "BB term" (hereafter PUC BB Term) from Bajina Bašta. There are two "Ivar" boilers with "Weishaupt" burners, each with a power of 750 kW. The system regularly operates with one boiler, while the second boiler is the reserve. The fuel that is now being used is heavy fuel oil. The DH net-work is 2.9 km long and it is made of insulated steel pipes.

The system was designed to operate as a water heating system in the 90°/70°C temperature regime. It is a direct system without any substation. The system is not equipped with any measurement devices, neither at the side of heat production, nor at the side of heat consumption. The only reliable measurement refers to the fuel consumption of the system. The maximum heating area was 3,474 m² in the period of 2008-2010, when 38 households, as well as the local school, the ambulance and some commercial facilities were connected to the grid. The maximum number of ever-connected consumers was 42. However, in the meanwhile some customers decided to switch to individual heating systems, mostly using their own firewood. Presently, only 25 households, with an area of 1,262.25 m², the local school and the ambulance use a centralized heating system.

From the above-presented data it is evident that the length of the grid is disproportionally high in comparison to the heat consumption. The current network heat utilization rate is unacceptably low and amounts 276 kWh/m/a. Moreover, the high price of heavy fuel oil adds to the fact that the operation of the DH system is unsustainable in financial terms. Right from the beginning of operation, this sys-tem has generated permanent financial losses [5]. An additional problem with using heavy fuel oil is its environmentally polluting impact.

A projection of further development of the DH system in Kostojevići includes, besides fuel switch and using biomass, reconnecting of all previously disconnected consumers to the system, and connecting additional consumers without further expansion of the network. This is a possible solution, since in the initial plan for the development of the DH system in Kostojevići, according to information obtained from PUC BB Term, 80 household connections were envisaged in total. To fulfil this plan, an additional connection of 38 consumers must be realized. Taking into account that the average size of dwelling per household is 97.1 m² [6] and that the survey conducted in the commercial sector identi-fied approximately 2,787 m² of space area that could be connected to DH system, additional 6,477 m2 could be connected to the grid.

The projections of heat demand, heat load and heat area that should be relevant for the future, biomass fuelled DH system are presented in Table 1. Data about the commercial and public sector in Kostojevići was provided by a survey of current consumption of heat, while the annual heat load of households is adopted to be 140 kWh/m2 [7].

Table 1. Expected Development of the Heat Demand in Kostojevići DHS [6]

Sector:		2016	Projections
Households	Heat demand (MWh/a)	413	930
	Heat load (kW)	334	814
	Heating area (m^2)	2,230	5,920
Commercial and public facilities	Heat demand (MWh/a)	267	941
	Heat load (kW)	185	585
	Heating area (m^2)	1,231	4,335

By connecting all residential and commercial/public consumers, the total heat area would be over 10,000 m², with a total heat demand of 1,870 MWh per year, and a total connected consumer heat load of 1.4 MW. This leads to an increase of the network heat utilization rate to 645 kWh/m/a and represents the maximum that can be achieved without further extending of the grid length. It is im-portant to emphasize that a further extension of the existing grid length (2.9 km of grid trench length) is not an option, as sufficient potential new consumers with significant or whole year heat consump-tion were not identified to justify the necessary investments in a grid expansion.

3 Techno-economical assessment of a fuel-switch for biomass in an existing DH system

The accepted technical concept for the DH system basically focuses on a fuel switch in the ex-isting DH system, from heavy fuel oil to wooden biomass. Existing facilities would partly remain in operation (a 750 kW heavy fuel boiler and a 100 t fuel tank) for covering peaks in heat consumption and in the case of failure of the biogas boiler. It is expected that this boiler would require approximate-ly 9% of total fuel input per year. New biomass boiler station (500 + 200 kW wood-chip boilers) and 5-days biomass storage will be built in close proximity to existing facilities (land is available and be-longs to municipality) and will be connected to the existing DH network.

The necessary biomass resources for the operation of the proposed installation are available. The calculation was made with an assumption that the biomass would be provided by Public Company National Park Tara (hereafter NP Tara) and such solution is quite convenient. However, the inhabitants of Kostojevići own approximately 725 ha (of total forest area of 733.95 ha) that is located within the village's borders. Also, the significant amount of residues after agriculture production could also be transformed into wood chips. Therefore, it can be concluded that the significant amounts of biomass resource could be provided from local forests and local agriculture production.

The economic assessment of the project was done with the "B4B BioHeat Profitability Assess-ment Tool", developed by the Austrian Energy Agency [8]. The investment/cost/price data used for the assessment of the biomass DH system are based on Serbian conditions or, in the case where no relia-ble data are available, estimated values are accepted from B4B BioHeat Profitability Assessment Tool with adequate expert's modification.

The total investment for the whole biomass DH system was estimated to 280,000 EUR excl. VAT. For comparison (reference system) the investment for refurbishment of the existing fossil fuel system are considered. This investment includes only some minor improvements in electric, hydraulic and measurement installations. Therefore, the proposed investment for the fossil fuelled reference system amounts only 20,000 EUR (excl. VAT). Both, the normally higher up-front investments and re-investments of biomass based heating systems are offset by lower fuel costs or lower total annual payments. Investment subsidies, lowering the surplus upfront investment were not taken into consider-ation, as such subsidies in Serbia do not exist. The basic technical characteristics and related invest-ments of the biomass heating system and the fossil fuelled reference system are given in [6].

During annual biomass DH plant operation 1,870 MWh of heat will be delivered to the end con-sumers, while the total heat produced by the plant and injected to the heat grid will be 2,493 MWh/a. Taking into account the 83% of biomass boiler efficiency (for 91% of energy production), an amount of 2,734 MWh/a fuel equivalent woodchips is needed. The average annual full-load operating time of installed biomass boilers is 3,241 h. The annual energy efficiency of the whole heating plant (heat sold/fuel input) is 62%.

For the first year of operation, a heavy fuel oil purchase price (free heating plant excl. VAT) of 40 EUR/MWh and a corresponding wood-chip price of 15.6 EUR/MWh were set. Since a regular biomass market in Serbia does not exist yet, the wood-chip price was researched locally [9]. It is assumed that both fuel prices equally increase by 2% p.a. for the calculated service life.

The outgoing annual fuel payments are calculated to be 54% lower for the biomass DH system than for the fossil fuelled reference system. Although biomass DH systems involve higher personnel, service, maintenance and other running costs, the total annual outgoing payments are also lower for the biomass DH system, by 23.5%.

The heat sales price was assumed to be 50.3 EUR/MWh (excl. VAT) in the 1st year of operation and was set to increase by 2% p.a. to compensate at least for the inflation rate. That means that the development of incoming payments (from DH sales) is exactly the same for both systems compared.

The profitability assessment is based on a discounted cash-flow analysis (based on cost catego-ries according to VDI Guideline 2067) with a calculated service life of 25 years. The main assump-tions and results can be seen in the Table 2. The calculations take care of re-investments in plant com-ponents according to their technical ser-

Discounted Cash-flow analysis (based on VDI Guideline 2067) - Assumptions overview			
Cost of Equity Capital (interest rate) - pre-tax	5,88 %	Cost of Equity Capital (interest rate) - pre-tax	5,88 %
Long term Loan - effective interest rate (pre-tax)	2,50 %	Long term Loan - effective interest rate (pre-tax)	2,50 %
Tax rate	15,0 %	Tax rate	15,0 %
Average heat sales price (excl. VAT), in year 1	50,30 EUR/MWhsold	Average heat sales price (excl. VAT), in year 1	50,30 EUR/MWhsold
Calculated service life (t)	25 a	Calculated service life (t)	25 a

Discounted Cash-flow analysis (based on VDI 2067) - Results			
Biomass Heating System		**Fossil Fuelled Reference System**	
Discounted Payback Time	**10,5** a	**Discounted Payback Time**	**> 25,0** a
Net Present Value (NPV, t=25 yrs.)	**55.932** EUR	**Net Present Value (NPV, t=25 yrs.)**	**-490.953** EUR
Internal Rate of Return (IRR, t=25 yrs.)	**8,66** %	**Internal Rate of Return (IRR, t=25 yrs.)**	**#НУМ!** %
Calculatory Heat Generation Cost	**48,42** EUR/MWhsold	**Calculatory Heat Generation Cost**	**66,76** EUR/MWhsold
Energy and greenhouse gas related impacts of the bioheat plant		**Reduction compared to fossil fuelled Ref-System**	
Annual fossil fuels subsituted by bioheating system	***2.649,3 MWh/a***	*Reduction compared to fossil fuelled Ref-System*	***90,3 %***
Annual greenhouse gas savings (LCA, CO2-equivalent)	***798,2 t CO_2-eq/a***	*Reduction compared to fossil fuelled Ref-System*	***89,2 %***
Annual energy savings (total fuel input, NCV)	*-84,4 MWh/a*	*Reduction compared to fossil fuelled Ref-System*	*-2,9 %*

Figure(s): Development of the NPV for a calculated service life of 25 years - visualization of the dynamic payback time.

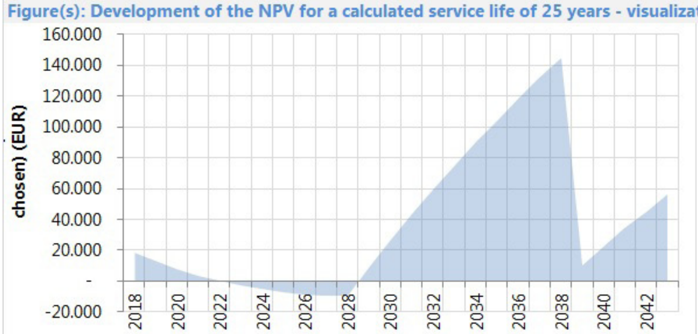

Table 2: Cash-flow analysis and energy and greenhouse gas related impact of the bio-heat plant

vice life and in line with VDI Guideline 2067. Basically, these are a replacement of the boilers and the related electric and hydraulic installations. In year 21 of op-eration, re-investment is assumed to be 200,000 EUR for the biomass DH system and 80,000 EUR for the fossil fuel reference system. Theoretically, the technical service life of the plant would be extend-ed for another 20 years because of the re-investment. However, the calculated service life is only 25 years. This period is sufficient to show whether the project is able to finance re-investments by itself or not.

Based on the assumptions shown in detail in [6], for the biomass DH system heat generation costs of 48.46 EUR/MWh were calcu-lated, compared to 66.76 EUR/MWh for the fossil fuel reference system. This corresponds to (dynamic) discounted payback times of 10.5 years (biomass DH system) and over 25 years (fossil fuelled reference system). The net present value (NPV) of the biomass DH system is 55,900 EUR and the internal rate of return is 8.66%. The graphs (Figure 1) show the devel-opment of the cumulated NPV for a calculated service life. It is evident that relatively high investment and debt capital conditions take the NPV in slightly negative values for the period of debt return. Therefore, even a small percentage of investment subsidies would significantly reduce the payback period. However, also without subsidies, constant revenues would enable necessary re-investments after 20 years of operation.

Further positive aspect of the biomass DH system is lower green-house gas emissions. The bio-mass DH system saves 90.3% of the fossil energy input and therefore avoids 798.2 t CO_2-eq/a com-pared to the fossil fuel DH system (Table 2).

The reduction/ avoidance of greenhouse gas emissions and other positive effects of a biomass fuelled DH system (e.g. on the local economy, energy system security and energy system resilience) are not considered in the economic calculations to establish a level play-ing field (e.g. by investment subsidies, CO_2-taxes) with a fossil fuel DH system.

The installation of a CHP plant was considered as a possible way to upgrade the district heating system in the future. For such a sys-tem, it is necessary to provide heat continuously to the consumers during the whole year. Such consumers in Kostojevići exist, but the analysis of their position and technical characteristics has shown that they are not suitable for CHP installation and connection to a centralized DH system. However, the village Kostojevići is positioned as a well-known fruit produc-tion region with the possibilities for development of the food industry. This fact has been used for consideration of investment in a CHP for adequately situated in a new industrial facility (e.g. pro-cessing line that could be used for jam or marmalade production, installation for fruit or vegetable drying, wood processing plant, etc.). Such process line and CHP could work together for 6.000 h/y to 8.000 h/y at nominal working regime. The proposed CHP plant would use a wood chip boiler with steam turbine and ORC module. Considered electric power was 130 kWel, with heat capacity of 630 kWth.

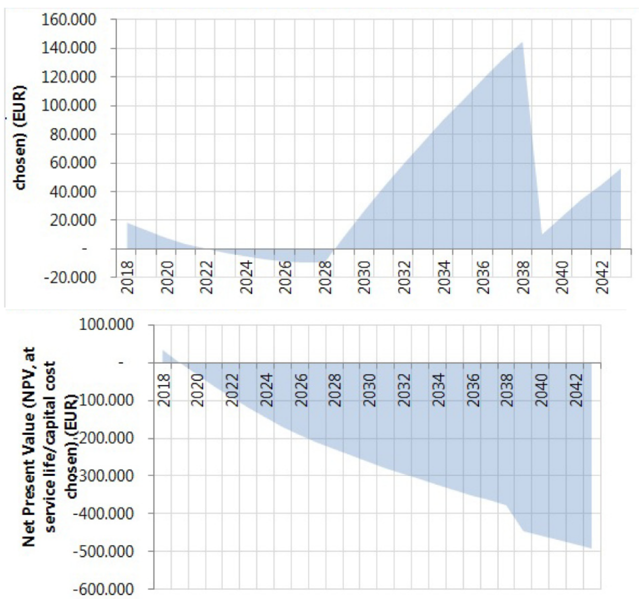

Figure 1: Development of the NPV for calculated service life of 25 years – visualization of dynamic payback time

4 Possible business models for bioenergy village in Kostojevići

Citizens, entrepreneurs, local authorities, NP TARA as the owner of biomass, private forest-owners are interested in implementing the project of using biomass in the DH system in Kostojevići. The choice of the financial model according to which the project will be realized, depends on the mu-tual relations and the strength of the motives of these stakeholders.

According to the laws of the Republic of Serbia, district heating is a communal activity and local governments are obliged to organize communal activities and have a regulatory role in determining the price of heat and defining the rules of operation of the district heating system. Traditionally, all district heating systems in the Republic of Serbia are owned by local governments (public property). The same case exists in the Kostojevići. New legal solutions allow that both entrepreneurs and private companies can be the owners of district heating and to distribute and to supply heat, with the prior acquisition of a license issued by the municipality. Besides municipality i.e. the PUC BB TERM that was established by municipality to develop, manage and operate of the DH system, investors can be also private part-ners, for example: energy cooperatives, entrepreneurs and companies. According to the PPP (public private partnership) model, a municipality with a private partner can establish a new legal entity that will produce heat and contract other activities such as distribution and supply of heat to the end users.

Different business models for biomass-based DH system in Kostojevići have been considered.

The first considered option was the establishment of an energy cooperative of district heating customers in Kostojevići. The energy cooperative would include district-heating customers from the household sector, as they are in the same time the owners of the forests – the biomass resources. Dur-ing the meetings with potential members for the energy cooperative this solution wasn’t recognized as achievable. Reasons are different, from lack of experience in biomass business, inexistence of mech-anization for providing adequate quantity biomass, bad forestry roads, etc. A general, unfavorable economic situation and low and insecure households’ incomes additionally lower the motivation of some people for personal involvement in such kind of joint venture. Private companies located in Kostojevići showed interest to be connected to the DH network, but did not show any interest to invest in new facilities.

Presently, the PUC BB Term (founded by municipality of Bajina Bašta) is the owner and opera-tor of the district heating system in Kostojevići. Considering the limited financial resources of this company and municipality of Bajina Bašta, as well as their priorities regarding the reconstruction of district heating in the city of Bajina Bašta, it was concluded that the only real option for the investment is through the use of subsidies or especially favorable grants, with the BB Term (or municipality of Bajina Bašta) as the main investor.

The last considered option is including a private partner or partners in the investment process and establishing a PPP. In this option, the municipality of Bajina Bašta and the private partner would establish a partnership for producing heat by using biomass. This contracting model includes different activities such as distribution and heat supply to the end users. From the private investor would be expected to invest in new facilities, while the municipality would contribute the existing DH network and other facilities. The significant increase in the number of consumers would enable relatively low costs of heating due to reduction of the fixed operating costs (including costs of investment). That will make the district heating more attractive than any kind of local heating. The preliminary heat contracts would be signed with all customers for at least 15 years and these contracts would be used as basis for the sale of heat to customers in Kostojevići. Customers would pay monthly for the heat – based on a fixed price and per kWh of delivered heat.

5 Conclusions

The economic efficiency of district heating plant with wood-chips as a main fuel that should re-place the existing heavy fuel oil fired heating plant is analyzed in this paper. A key assumption for the calculation was the significant increase in the number of consumers and heat consumption. Without increasing of consumption, any investment in biomass based DH system is absolutely unsustainable.

The existing system supplies 25 households, a local school and an ambulance. To make the sys-tem sustainable, the new biomass fired district heating system should supply 93 heat consumers. The existing grid is used. The total investment costs for the biomass district heating system is 280 thousand EUR excl. VAT. Higher up-front investment and re-investment of bio-heat systems (compared to existing fossil fuelled system) are offset by lower biomass fuel price and lower outgoing total payments.

A regular biomass market in Serbia does not exist, thus for the calculation a wood-chips price was used from literature. This is a very important fact, since before a company will make an investment decision, the biomass supply chain must be clearly defined, and the wood-chips price must be exactly determined. Biomass can be supplied from the NP Tara, from local forests owner or from both. The biomass price should be defined in a long-term supply contract between DH owner and NP Tara or the local forest owners. The contracts have to be tailored to the requirements of the different suppliers.

For the acceptance of whole bioenergy project, it would be useful to oblige the DH system oper-ator to purchase some part of biomass from local forest owners or at least of the DH consumers.

The profitability assessment was based on a discounted cash-flow with a calculated service life of 25 years, and obtained results are, as follows: discounted payback times was 10.5 years, the NPV was 55.9 thousand EUR and internal rate of return was 8.66%. Analyses of development of the net present value shows that relatively high costs of investment and debt capital conditions take NPV in slightly negative values for the period of debt return. Even a small percentage of investment subsidies should significantly reduce the payback period and significantly improve overall profitability of pro-ject.

Therefore, the general conclusion is that the inexistence of state subsidies for investments in a biomass (and others RES) project for heat production is a significant barrier for this type of project.

The issue of investment is the main reason, why the final decision on the investment and opera-tor at this point has still not been decided. The municipality of Bajina Bašta will undertake activities in finding subsidies or investment grants, and in promotion of this project to ESCO companies in Serbia and the region. Also, the municipality of Bajina Bašta will consider feasible opportunities to make PPP with some of local entrepreneurs with the experience in energy services business (HVAC installation).

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