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Techno-economic, Social and Environmental Assessment of Biomass Based District Heating in a Bioenergy Village

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ABSTRACT

Bioenergy villages can be defined as villages, municipalities, settlements or communities, which produce and use most of their energy from local bioenergy and other renewable energy sources. A bioenergy village approach has not been applied in Macedonia yet, and it is at a nascent stage of implementation in other South-Eastern European countries. This work aims to integrate a techno-economic, social and environmental assessment and an implementation strategy into a bioenergy village concept, which is not often seen in works dedicated to bioenergy villages and biomass based heating systems. The assessment was conducted by means of energy audit and project-related tools, whilst the strategy was composed by bioenergy working group meetings. Results show that a biomass based district heating system is a more attractive solution for heating several public buildings instead of a fossil fuelled system, with numerous associated benefits. Such concepts can be replicated with variety of renewables, thus contributing to sustainable development pathways of small communities.

KEYWORDS

Bioenergy village, Bioenergy, Biomass, District heating.

INTRODUCTION

Villages and communities today support the idea of local energy supply and join the energy transition in their countries. In Germany, for instance, the energy transition comprises organizational innovations for providing sustainable energy to small communities, referred to as "bioenergy villages" [1]. A bioenergy village can be defined

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as a village, municipality, settlement or community, which produces and uses most of its energy from local bioenergy and other renewable energy sources [2]. Bioenergy, particularly biomass, could be given a role as one of the most important renewable energy sources for the future low carbon economy, whose increased domestic consumption, compliant to certain sustainability criteria, also positively contributes to the energy security. The biomass availability is highly correlated to the location and ecosystem [3]. Underutilised biomass shall be targeted [4] and long-term scenarios contextualized [5]. The utilization of biomass residues as a feedstock for renewable heating systems is increasing [6, 7]. Biomass residues from forests have great potential for energy use [8, 9] and are considered economically viable, e.g. in South-eastern European countries [10]. Harvesting the forest residues is in favour of forest management with an obligation to dispose them and leave a minimum biological amount for the ecosystem, but more importantly, to protect the forests from fires. Kasurinen *et al.* [11] highlights the complementarity of the ecosystem and the bioenergy businesses, meaning that the ecosystem is provided with services by the bioenergy businesses, while through the ecosystem, bioenergy businesses fulfil the heating as a basic human need. Heating with different biomass fuels, e.g. forest residues and wood-pellets in multi-fuel boilers [12], shall be fostered when planning the heating systems. The variety of biomass based technologies conduces to the actualization of sustainable development at the local level, and simultaneously, gives local communities the power to submit valuable contributions towards the global Paris agreement [13].

Bioenergy is even recognised as a socio-technical system, thus promoting social resources, leadership and collective action, transparency, social activities, and consistent networking [14]. A study on public acceptance of biomass, shows the positive feedback from population and key actors on its exploitation [15]. On the downside, Vad Mathiesen *et al.* [16] upholds the limitation of biomass dependence, due to rising challenges in renewable energy systems. However, as the fossil fuelled systems are still predominantly employed, creative approaches like the bioenergy village approach, would motivate the citizens to act and switch to renewables. The civic engagement transforms the energy systems through community-led innovations [17] or citizen-driven renewable energy cooperatives [18], and is able to largely reshape the local energy sector. A strong emphasis is placed on the social aspects and combining assessments and analyses with activities needed in the process of becoming a bioenergy village, such as workshops, meetings and study tours to best-practice examples [19]. Interviews and questionnaires can significantly help in the implementation of bioenergy villages and pinpoint the success factors [20, 21]. They can further indicate criteria decisive for households when selecting a heating system, such as easiness, comfort and affordability, and environmental awareness. On the supply side, through workshops and questionnaires, Kasurinen *et al.* [11] examined bioenergy operators' level of maturity of responsibility for sustainability, justifying the biomass production only if addresses urgent environmental and human challenges, both globally and locally. The means of bringing a low carbon energy supply for small communities into practice have their pros, and an expansion of biomass utilization for heat and power production is still recommended, due to a cost-efficient decarbonisation [22].

Bioenergy villages involve small and medium scale individual and District Heating (DH) systems. DH systems with their great potential as highly efficient and economically viable ways of heat production have the possibility to penetrate larger amount of renewable energy in the existing energy systems. They contribute to developing the future sustainable energy systems or smart energy systems [23]. Comparison of modern heating systems and solutions against conventional ones is a major point of interest for customers as well as researchers [24, 25]. For that reason, benefits of biomass versus fossil fuel based DH system in a small community are investigated in this work as part of a H2020 project called BioVill (Bioenergy Villages – Increasing the Market Uptake of Sustainable Bioenergy), on a case of a small and densely populated settlement, in the Macedonian municipality of Kichevo, for which a bioenergy village concept was developed. The concept contains a small DH system and network, fuelled by local forest residues. A bioenergy village approach has not been applied under Macedonian conditions yet, although biomass seems to take up a serious role in Greenhouse Gases (GHG) emission reduction in the country [26]. The approach is at a nascent stage of implementation in other South-Eastern European countries as well, so the main goal is to scrutinize the feasibility and determine all the associated perks as well as to bring new knowledge to these countries.

Techno-economic [8], social [23] and environmental assessments [9, 25, 27], are fundamental for such bioenergy concepts and shed light on the viability for their realization. In order to succeed, the concepts shall primarily be economically feasible and affordable to the consumers [23]. Moreover, they shall address sustainability, increase the renewable energy share, mitigate the GHG emission, particularly CO_2 emission [7], generate cost savings and additional revenues, and create new jobs and value chains.

Campaigns, subsidies, policy measures and implementation strategies are suggested for replacement of fossil fuels with local biomass sources in DH systems [28]. An adequate implementation strategy is also developed in this work, taking into consideration the current local and national frameworks, similarly as in Kainiemi *et al.* [21]. Indeed, governance and regulatory frameworks strongly impact the transition towards sustainable energy systems [29]. In addition, economic and environmental uncertainties could lower the public acceptance of bioenergy applications [21] and hamper the overall process of becoming a bioenergy village. Bioenergy villages can often face these regulatory and economic changes and challenges, which shall be used to balance the interests of actors and promote close cooperation and coordination within the community [1]. Bottom-up civil society activities and the trust of local politicians in community-led projects are crucial, alongside the existence of funding opportunities [29].

Finally, this work aims to integrate the assessment and the strategy into one bioenergy concept, which is not often seen in works dedicated to bioenergy villages and small biomass based heating systems.

METHODS

In order to calculate the heat demand of buildings connected to a DH system, a heat demand survey that includes energy audit was carried out. The outcomes were used to conduct a techno-economic (pre-feasibility) assessment of the economic and technical viability of setting up a small DH network, while considering the actual costs and saving potentials. This techno-economic assessment is executed on the base of a tool named "B4B BioHeat Profitability Assessment Tool" [30], an Excel based tool developed by the Austrian Energy Agency for the H2020 project Bioenergy4Business (B4B). The tool incorporates a discounted cash-flow analysis founded upon the Association of German Engineers Guideline 2067 (VDI Guideline 2067). It can be used for comparison of the economic efficiency (pre-feasibility level) of small/medium scale, solid biomass and fossil fuel fired (district and in-house) heat-only plants. Furthermore, the calculator contains country-specific reference values for investment (of various plant components) and for outgoing and incoming payments of twelve European countries (price base 2015). Scopes of this tool are biomass heating plants with and without DH networks, in a capacity range from 0.1 to 20 MW. In this work, the tool is used to compare a fossil fuelled DH reference system as a reference scenario with biomass fuelled DH system as a proposed scenario for implementation.

Additionally, as an input needed for the B4B BioHeat Profitability Assessment Tool, the biomass fuel costs of the system are calculated by means of available biomass fuel price lists and the B4B Wood Fuel Parameter Calculator [31], developed by the Austrian Energy Agency. The calculator is based on the Austrian standards ÖNORM M 7132, 7133, and 7135 and ÖNORM B 3012, and on generally acknowledged empirical values. For this work, a mixture with equal contents of European beech and Turkey oak is used. Also, the fuel oil costs, as outgoing payments, are calculated based on average values for the twelve European countries incorporated in the B4B BioHeat Profitability Assessment Tool (price base 2015).

As for the social and environmental assessment, the jobs potentially created are predicated on working hours per terajoule (TJ) primary energy input of biomass fuel transported and converted in a heating plant, empirically surveyed [32]. The job creation potential is presented in full-time job equivalents on basis of 1,720 working hours per year. The potential of the bioenergy concept to avoid carbon dioxide (CO_2) emission is calculated on basis of a fossil fuelled reference system. The difference between GHG emission of the bioenergy system and the reference system is estimated in CO_2 equivalents (CO_{2eq}) and represent the GHG emission savings, if implement a biomass based heating system instead of a fossil fuel based heating system. For that purpose, the European reference Life Cycle Assessment (LCA) emission factors (3.6 t CO_{2eq}/TJ for sustainable wood, 84.7 t CO_{2eq}/TJ for fuel oil) [33] are embedded in the B4B BioHeat Profitability Assessment Tool, referring to the overall cycle of the energy carrier, which covers not only the GHG emission due to fuel combustion but also emission of the entire energy supply chain – exploitation, transport, processing.

The major findings of the techno-economic, social and environmental assessment were used to outline an implementation strategy through establishing a bioenergy working group and organising bioenergy working group meetings. Aspects considered in the implementation strategy are: development of an individual business model, definition of a biomass and heat supply chain, duration of contracts and contractual agreements, investigation of financing opportunities, improvement of regulatory and policy framework, and realization of communication and dissemination activities.

THE CASE STUDY: BIOENERGY VILLAGE IN KICHEVO

Kichevo is located in the western part of the Republic of Macedonia, in a valley in the southeastern slopes of Bistra Mountain, with a total area of 814.3 km^2. Main challenges in Kichevo are the relatively high energy consumption, outdated energy infrastructure and high environmental pollution, along with the economic stagnation in the last decades. Common heating sources utilized in the residential sector in Kichevo are often untenable firewood and electricity deriving mainly from coal, whilst in the public and commercial sector (e.g. schools and kindergartens) fuel oil is used as well. In the public buildings, the municipality is dealing with inadequate indoor conditions due to old and inefficient heating systems that have incited protests of citizens and closure of schools in previous years. On the supply side, the coal based thermoelectric power plant Oslomej in Kichevo faces economic challenges due to shortage of fuel and high cost of energy production. Traditional industries like heavy industry have become mostly uneconomical and the main factories have been phased out. As a consequence, the majority of citizens now works in the public administration, small and medium-sized enterprises or abroad. Starting from such framework conditions, an urgent need to increase the utilization of local sources is evident, so as to overcome environmental, economic and social problems as well as to create jobs and to support the local economic growth. The first step for setting-up a bioenergy village in Kichevo is transforming the energy system in a densely populated settlement with a high heat demand called “Lozhionica”, comprising an area of around 0.5 km^2, thus affecting around 3,000 students and residents [34].

Techno-economic assessment

DH system. The DH system foresees woodchips from forest residues as biomass resources, and woodchip boilers and a heating network as technologies. It is planned to be realized in the following three phases:

- Phase 1: Implementing a DH system for 4 public buildings (3 schools and 1 kindergarten);
- Phase 2: Enlarging the system by connecting 7 old residential buildings (240 households);
- Phase 3: Connecting additional 2 new residential buildings (40 households).

Results from the conducted heat demand survey depict an annual space heat demand of 1,089 MWh for Phase 1. After finalisation of Phase 1, possibilities for extending the bioenergy village concept with Phase 2 and Phase 3, with annual space heat demand of 7,213 MWh and 540 MWh, respectively, are inspected. The total assumed annual space heat demand of all three phases sums up to 8,842 MWh (Table 1).

Table 1. Calculated heat load and heat demand of three-phase project

Phase	Space heat load [kW]	Annual space heat demand [MWh]
1	830	1,089
2	4,285	7,213
3	321	540
Total	5,436	8,842

In accordance with the B4B BioHeat Profitability Assessment Tool, a total nominal biomass boiler capacity of 5 MW (1 MW for Phase 1) and a fuel oil boiler as backup and peak load boiler with nominal capacity of 3 MW are suggested. With regard to the fossil fuelled reference system, a total installed nominal heat capacity of 10 MW is proposed. The trench length of the heating grid is assumed with 1,220 m in both cases. This results in a relatively good heat load-length ratio [34].

Moreover, the average annual full-load operating hours of installed biomass boilers are taken to be 1,886 hours. During annual biomass DH plant operation, 8,842 MWh will be delivered to the end consumers. The total heat produced by the plant and injected to the DH network is 9,824 MWh, for which an amount of 11,363 MWh biomass fuel equivalent is needed (net calorific value). This equals an annual quantity of 10,230 m³ of loose (4,165 t – fresh, 2,500 t – absolute dry) woodchips. Seen from the perspective of available biomass feedstock, the feasibility of the three-phase project is secured. Indeed, the annual harvest of wood in Kichevo's is around 40,000 m^3, whereof 35,000 m^3 for energetic use (firewood) and 5,000 m^3 for material use (industrial wood), and additional 2,000-5,000 m^3 (depending on the seasonal conditions) are forest residues, which, converted into woodchips (around 10,000 m^3), are sufficient for the fuel demand of the three-phase project [35].

The annual energy use efficiency of the whole DH plant projected to be situated in one of the schools' backyards is 74.6%. The plant is planned to have enough space to accommodate the boilers for Phase 2 and 3. Also, the network should be ready to provide access to the buildings from Phase 2. Both interventions in the DH plant and network will slightly boost the initial investment, but will drastically decrease the future costs for expansion of the system towards the residential buildings. Further, this will increase the flexibility of the operator who can offer a more competitive price for heating, notably after the complete liberalization of the electricity market towards the residential sector in Macedonia, when the prices for electricity are predicted to rise and affordable alternatives will be sought by the households.

Economics. Investment, cost, and price data used for the design of the biomass DH system are based on Macedonian conditions, having in mind experts' opinion and the suggested values of the B4B BioHeat Profitability Assessment Tool. The total initial investment for Phase 1 of the biomass DH system, as the most achievable option at the moment in Kichevo, is around kEUR 688, which is about 56% higher than the fossil fuelled reference system, requiring a total initial investment of kEUR 442 (Table 2).

Table 2. Estimated investment costs for Phase 1 of Kichevo's concept

Item	Amount [EUR]	
	Biomass DH system	Fossil fuelled DH system
Boiler	277,000	166,000
Construction (boiler house, fuel storage, electric, hydraulic installations)	120,000	72,000
Heating grid investment	191,000	191,000
Project documentation (3% of the total investment in equipment and works)	20,000	13,000
Other initial investment (mobile wood chipper and truck)	80,000	-
Total	688,000	442,000

The profitability assessment is calculated for a service life of 25 years, since this period is sufficient to show whether the project is able to finance re-investments by itself. The calculations consider re-investments of plant components according to their technical service life, i.e. the replacement of the boilers and the related electric and hydraulic installations. In year 20 of operation, the re-investment is assumed to be kEUR 397 for the biomass DH system and kEUR 190 for the fossil fuelled reference system. Both, the normally higher up-front investment and re-investment of biomass DH systems are offset by the lower outgoing fuel or lower outgoing total payments. As illustrated in Figure 1, the total annual outgoing payments (operating and capital expenditures) are lower for the biomass DH system compared to the fossil fuelled reference system, i.e. 40.2% or kEUR 289 in year 4 of system operation.

Moreover, financing of both systems is based on 30% equity from own funds and 70% from a credit line. No investment subsidies are foreseen in the analysis. In 2019 (year of the initial investment), the biomass fuel costs are assumed with 17.5 EUR/MWh [36, 31], and the fuel oil costs are set at an average price of 50.1 EUR/MWh, as suggested in [30]. The biomass DH system would have heat generation costs of 44.9 EUR/MWh in 2020 (first year of operation), whereas the fossil fuelled reference system's heat generation costs would be 75.2 EUR/MWh, which makes the latter less attractive for the community.

With an assumed DH price of 46.5 EUR/MWh for both systems, which is comparable to the current energy prices in the country, and an annual growth of 2% over the calculated service life, the fossil fuelled reference system does not pay off (amortize) at all. As displayed in Figure 2, the planned biomass DH system amortizes (dynamically) within 4.5 years, leading to the conclusion that the biomass DH system is much more beneficial to the DH consumers, compared to the fossil fuelled reference system. Key indicators for the profitability of the biomass DH system are furthermore the Net Present Value (NPV) and the Internal Rate of Return (IRR). The NPV for the calculated lifetime of 25 years has a positive value of about kEUR 250 for the biomass DH system unlike the fossil fuelled reference system with a negative NPV (visualisation of the dynamic payback time is given in Figure 2). As for the IRR, the calculated value for the biomass DH system is 7.1%, which is more than twice as high as the present loan interest rate of 3% [34].

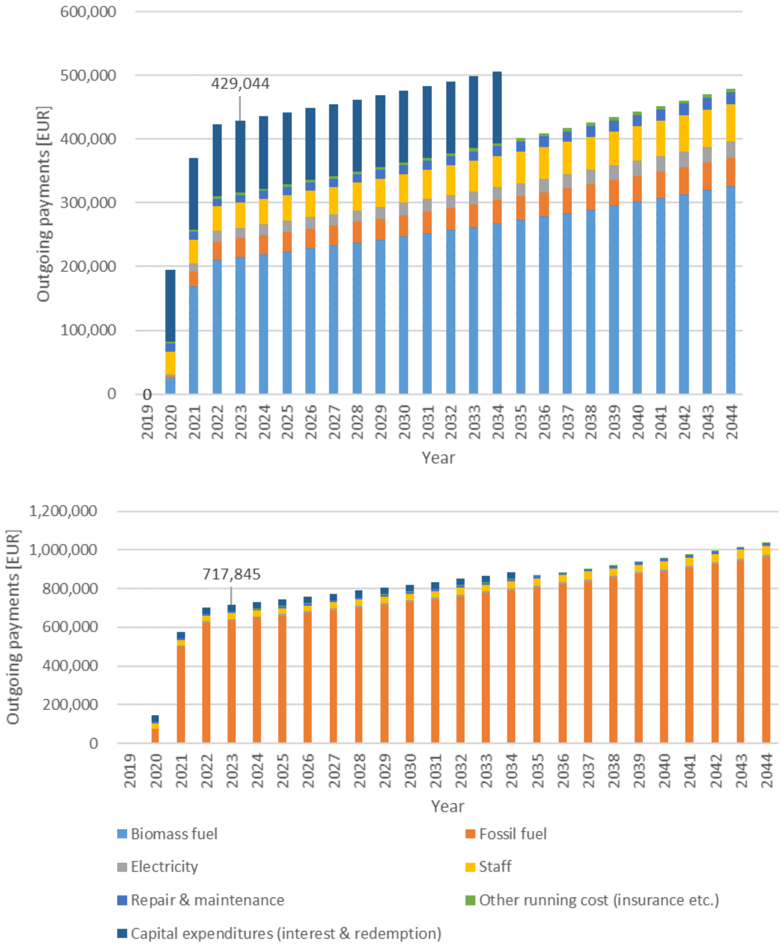

Figure 1. Development of outgoing payments for biomass DH system (up) and fossil fuelled reference system (down)

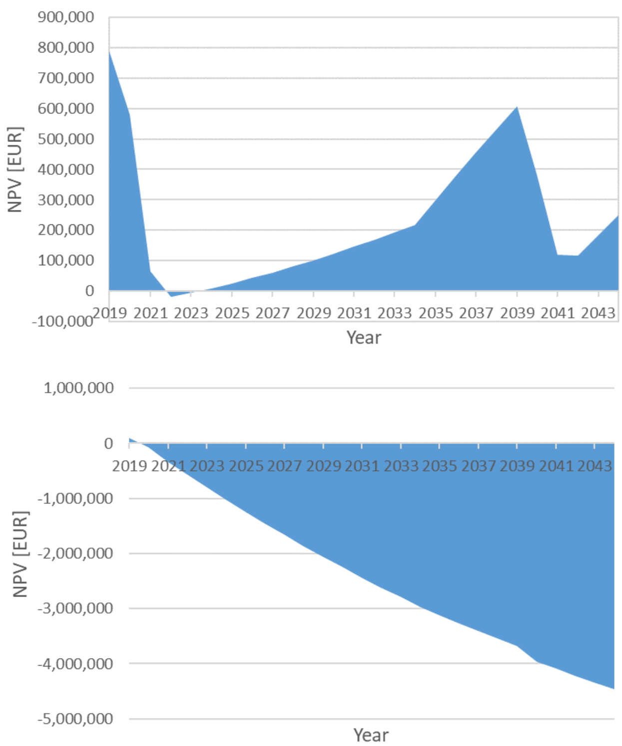

Figure 2. Development of NPV for biomass DH system (up) and fossil fuelled reference system (down)

Social and environmental assessment

In addition to the technical and economic key indicators of the bioenergy village concept, social and environmental effects have to be weighed. The most obvious effects of the concept in Kichevo are the additional revenues and incomes created along the new value chain. The operator of the new biomass DH plant can expect revenues of about kEUR 411 in the first year of operation. The most substantial cost factor for the operator will be the purchase of biomass fuels, which on the other side represent additional revenues for the wood supply chain. The annual revenue for the woodchip suppliers would be about kEUR 199 in full operation mode.

The realisation and maintenance of the DH system, and the reinvestment after 20 years are expected to create jobs in different sectors related to planning, construction and technical services. In the long run, the system will create and secure jobs preferably in the local wood supply sector and in the management of the DH system, thereby influencing the local craft sector. Directly required working hours and potential full-time jobs created can be estimated by using the empirically proven amount of 168.3 working hours per TJ [32]. Taking into account a primary energy input for the biomass DH system of 11,363 MWh or 40.9 TJ, the production of biomass and energy would require about 6,884 working hours per year, which results in four full-time jobs.

With reference to the environmental protection and climate change mitigation, the bioenergy village concept would raise the local share of renewable energy sources used for heat production by 8% and decrease the related GHG emission by 94.6%. The planned biomass DH system avoids the thermal utilization of 11.07 GWh of fuel oil and the emission of 3,334 t CO_{2eq} per year, compared to the fossil fuelled reference system [37].

Implementation strategy

Major findings of the techno-economic, social and environmental assessment that will help pave the way for the future realization of the three-phase project are summarized in Table 3.

Table 3. Findings of the techno-economic, social and environmental assessment

No.	Description	Indicator
1	Utilization of sustainable forest residues [m^3/year]	10,000
2	Increase of renewable energy share in the final energy consumption [%]	+8
3	Reduction of GHG emission [t CO_{2eq}/year]	3,334
4	Saving of costs compared to fossil fuelled DH system [%]	40
5	Addition of revenues for the system operator (a) and woodchip suppliers (b) [EUR/year]	(a) 411,000 (b) 199,000
6	Creation of new jobs (full-time)	4

The findings were used to develop an implementation strategy for the bioenergy village concept, which was a key action of the bioenergy working group initiated by the BioVill project in Kichevo and the municipality. Key stakeholders and members of the working group are the regional forest service and forest concessionaires, policy and decision makers and interested citizens, gathered at regular meetings. In their opinion, the realisation of Phase 1 is presently the most viable option for Kichevo's biomass DH system and several opportunities and models for operation and maintenance part of the concept are at hand.

The first one is an establishment of a public enterprise by the municipality, which will have the main role in distributing heat to the public buildings. Main advantage of this model is that the municipality is the investor, operator and owner of the system, which will result in an acceptable price for distribution of heat to the public buildings. Additionally, the enterprise will have to devise its own strategy in order to encompass the residential buildings planned for Phase 2 and Phase 3. This enterprise shall follow the trends of modern DH companies that are advised to formulate strategies in order to heighten flexibility, to adopt new services, and to invest in marketing and communication.

The municipality can also assign the responsibility to an existing public enterprise, i.e. the public enterprise for communal affairs. Prospects for establishing new public enterprise merely to distribute heat to the public buildings are very low, due to complicated establishment procedures. Nevertheless, if the project extends, as planned, towards the residential buildings from Phase 2 and 3, an establishment of a public enterprise will be legally binding.

In case the creditworthiness of the municipality is low and direct financing from the municipal budget is not manageable, the financial obligation can be transferred to a private company, by that establishing a public-private partnership. The private partner can be a shareholder in a newly created municipal company or can just sign a contract with the municipality to provide technical and financial services based on agreed costs for distribution of energy. Pursuant to the legal framework conditions in the country, currently possible is the second option where the private partner provides technical expertise and financial investments towards the municipality. If the municipality succeeds in operating the system with its own staff and will not need a technical expertise for operation of the system, the final costs for distribution of energy will decrease, which should be considered when drafting a contractual agreement with a private partner. However, the model will be designed in a way that the financial investments are still an obligation of the private partner and most of the risks (delivery of fuel, delivery of heat, technical malfunctioning and maintenance) are attributed to the private partner. After the expiration of the public-private partnership contract, the ownership of the system will stay with the municipality. The main advantage of this model is the financial capacity and flexibility of the private partner.

Last and most attainable model, starts from the fact that every public building within Phase 1 of the project has got a technical expert who operates the existing individual heating systems in the buildings. Bearing in mind that they have technical capacity and knowledge to maintain heating systems, with additional training they should be able to operate and maintain the prospective DH system as well. Besides, one or two engineers can be employed or transferred from another sector in the municipality and can form a subsector responsible for the operation of the plant.

Unfortunately, energy cooperatives as social innovation [29], still cannot be found in the country. Regardless of the selection of the model, as Kasurinen *et al*. [11] argued, it should be held responsible for sustainability.

Concerning the woodchip supply, potential woodchip suppliers are the local foresters. They lack a production unit (mobile wood chipper) and a transportation unit (truck). Having these units purchased by the municipality (investments given in Table 2) can serve as a convincing tool for signing long-term contracts (10 or 15 years) for production and distribution of woodchips at a lower price. The suppliers would produce the woodchips in the forests and transport them directly to the storage room within the DH plant. The storage room should enable drying of woodchips (floor heating or natural ventilation) to the adequate water content prescribed by the installed biomass boilers. Since this will be a duty of the future operator of the DH system and not the woodchip suppliers, it will further impact the negotiation process and determine a reduced price of woodchips. Furthermore, a suitable de-risking strategy could be the application of two running modes of the biomass boilers – woodchip mode as a primary mode and pellet mode as a secondary mode.

The most sensitive matter for the implementation strategy is the involvement of the residential sector, and the highest priority must be given to the creation of an enabling environment for signing long-term contracts (10-15 years) with future heat consumers for distribution of heat. The contracts will rely on a DH price, that shall be competitive to the affordable firewood and electricity prices in the country and a price adaption clause should be included therein. According to a survey with citizens of Kichevo, prepared by the BioVill project, 61% of respondents are willing to connect their house to a future biomass DH system, which demonstrates the citizens' positive attitude towards DH [38].

Therefore, key factors for the inclusion of the residential sector are the communication, dissemination and popularization of the results achieved in Phase 1, e.g. through BioVill project activities, such as set-up of a local information point, organisation of information days for the citizens, facilitation of a dialogue process with local, regional and national authorities and politicians, signing letters of commitment, etc. as well as further activities beyond the project.

Regarding the financing of the concept, there exist several financial opportunities so far, e.g. credit lines from international financing institutions offered directly or via local commercial banks, national funds and programmes, e.g. Programme for financial support of the rural development and Programme for financial support of the agriculture [39].

With the support of the mayor and the local self-government, the concept shall be incorporated in the future energy efficiency programme and sustainable energy action plan of the municipality. Pursuant to the new legislation expected to enter into force as of 2019, the municipalities in the country will be obliged to prepare programmes and plans, based on a specific methodology. On a national level, already enacted policy measure is the increased threshold of previous 1 MW to 10 MW for energy producers who do not need to obtain additional construction authorization. Another recommendation for a measure, that stems directly from stakeholders and policy makers, is to legislate 100% utilization of forest residues in the country. One could argue that like in the case of the county of Marburg-Biedenkopf [29], the establishment of a bioenergy village is led by a variety of measures and policies or a complex policy mix, an interplay between those policies on different levels, and a combination of policies from different sectors.

CONCLUSIONS

The development of a bioenergy village is a lasting planning process and varies from region to region or even village to village. The complementarity of national and local political support, the funding opportunities, the decisions of mayors to be guarantors for credits, participation of authorities in new local decision-making procedures that reallocate the power to the local community, are necessary preconditions for the creation of the bioenergy village [29].

Through the bioenergy village case study in this work, a biomass DH system has shown to be a feasible option for heating the public buildings from Phase 1 of the planned three-phase project in Kichevo with a number of determined additional benefits. Phase 1 of the project is a stepping-stone towards realization of the complete three-phase project. It includes the connection of 4 public buildings to a DH system with a thermal capacity of 1 MW and a network length of about 1,220 m. The investment needed is about EUR 700,000 and the main investor and operator would be the municipality. Also, the municipality should take the responsibility for the management of the system, by using the experience of workers dealing with heating issues. In the future, the municipality can form a public enterprise that will take over the management of the system and intend to expand the network, not just on the selected site, but also on the entire territory of the municipality. The latter should come as a result of the successful realization of the planned project phases [35].

Inclusion of the residential buildings from Phase 2 and Phase 3 is desirable, albeit highly dependent on the DH price. To substantiate a hopefully attractive DH price in such concepts, an investor has to be identified, communication with potential consumers has to be intensified, an in-depth heat demand survey has to be conducted and, finally, an optimized technical planning and reliable cost surveys have to be performed. As soon as the actual heat demand and the cost figures are settled, the heat generation costs and the heat sales price applicable to DH consumers can be defined. This is when DH consumers can take a decision on a long-term connection. As it can be the case, that fewer consumers connect than expected, Phase 2 and 3 of the project can fail even at the advanced status. Basically, key success factors for the biomass DH system are a large proportion of energy sold and an effective biomass supply chain management.

Despite biomass, further work on this concept could possibly introduce another renewable energy technology into the DH system, e.g. combination with solar thermal collectors on the high school rooftop, as done with prosumers in [40], a process also known as hybridisation of a DH system. Also, Kichevo's concept itself can be replicated with a variety of bioenergy and other renewable energy sources, thus contributing to sustainable development pathways of other communities in the country. Within the BioVill project, the concept has been transferred to three follower communities – Kriva Palanka, Chashka and Delchevo. The relevant stakeholders from these communities have already started to develop similar project concepts utilizing as a fuel the biomass residues from greenhouse farming (Chashka) and from wood processing industry (Kriva Palanka). In general, Macedonia has a significant potential for utilization of agricultural residues for energy production, although, numerous projects/studies have not been implemented from various reasons yet, and residues stay untapped in rice fields and vineyards.

To sum up, raising awareness on renewable energy sources and energy efficiency and tackling social barriers like lack of knowledge, are essential for the success of bioenergy concepts. Core part in these concepts is also formulating an adequate implementation strategy where the local citizens, stakeholders, and policy and decision makers are the key drivers on the way to using local resources, impeding money outflow and contributing to sustainable development of local communities. Creation of jobs and business opportunities are important challenges as well. In combination with a strong public participation, bioenergy concepts are suitable to improve the social and environmental conditions and induce economic growth in small communities.

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