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Biomass district heating methodology and pilot installations for public buildings groups

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Abstract: The objective of the paper is to show how locally available biomass can support a small-scale district heating system of public buildings, especially when taking into account energy audit in-situ measurements and energy efficiency improvement measures. The step-by-step methodology is presented, including the research for local biomass availability, the thermal needs study and the study for the biomass district heating system, with and without energy efficiency improvement measures.

1. Problem

In Western Macedonia Region, a large number of mainly rural households use lignite for heating purposes, and due to the financial crisis lignite and fire wood are displacing heating oil also in urban areas. Moreover, in the same region, three operational district heating networks based on the nearby lignite-fired plants are active. The intense agricultural and forestry activities in the area provide an abundance of different types of biomass according to national statistical authorities [1]. The main idea behind the paper is to present a methodology for setting up a biomass district heating network for small public building groups that can later be evolved in the core of an extensive district heating network of a city. Such a network is considered a renewable energy resource system that can bring the following benefits to the rural and urban areas of the region:

1) The supply of firewood in bigger quantities and at central collection points is expected to reduce the supply cost, both for the local biomass, as well as for the biomass that is purchased by the market.

2) The efficiency of the burner-boiler system is controlled much more effectively, leading to even more savings in economical and energy resourcesterms.

3) The use of properly maintained filters contributes to the environmental conservation of the areas.

4) Increase of comfort indicators for the inhabitants of theareas.

2. Method

The methodology is adapted to the regional needs and is also based on the Greek National legislation on Energy Efficiency in Buildings. Therefore, the first step is the estimation of the local availability and supply of biomass. Then, the public buildings' thermal needs drive the study for the design and estimation of capacity and cost for the biomass unit and the district heating network. The next step is the energy efficiency study of the public buildings and the proposal for targeted energy efficiency improvements that will decrease the buildings' thermal needs. At this phase, the necessity to conduct in-site measurements during the energy audits of buildings, rather than rely on tables and statistics, is emerged. Then, the reduced thermal needs drive the study for the re-design and re-estimation of capacity and cost for the biomass unit and the district heating network. The methodology is applied to four public buildings at the Karpero village of the municipality of Deskati.

2.1. Local availability and supply ofbiomass

Since almost all of the inhabitants already use fire wood for heating purposes, due to the local rights on forest woods, the availability of biomass and the cost of supply are secured. Moreover, more extensive, quantified studies for the whole Grevena Prefecture [2]-[5] reveal that the available biomass of the prefecture is enough to cover also the entire city of Grevena. More specifically, if the residues of the local wood industries are taken into account and the availability of the dry lignite of the Western Macedonia region, it is deduced by Table I that the attempt of biomass district heating of the public buildings is possible, in terms ofresources.

Table 1. Available biomass for the Grevena prefecture.

Biomass type	**Availability in tons**
Wheat cultivation residues	30.000
Corn cultivation residues	10.000
Energy plants cultivation	500-1.000
Wood biomass	21.000
Forestry residues	2.000-4.000

At the following tables, the supply cost of biomass is also shown.

Table 2. Supply cost for the prefecture of Grevena (per ton).

Biomass type	**Cost (€/tn) (including transport, not VAT)**
Pellet	200,00
Wheat cultivation residue	60,00
Corn cultivation residue	40,00
Forestry residue	75,00 – 81,00

Table 3. Supply cost per energy resources (The boiler efficiency is assumed equal to 85 %) [5].

Biomass type	**Cost (€/MWh) (including transport, not VAT)**

Pellet	56,14
Wheat cultivation residue (**max cost**)	24,00
Corn cultivation residue	17,00
Forestry residue – (**max cost**)	23,00 – 24,50
Oil	76,00
Natural Gas	50,00
Lignite (Public Power Corp.)	16,00
Dry lignite	23,50

2.2. Design and estimation of the biomass unit and the district heating network for public buildings

The methodology is adapted to the needs of a Greek rural municipality, the Municipality of Deskati. More specifically, the village of Karpero is selected, since it already involves utilisation of wood for heating by the inhabitants. Five municipal buildings are indicated by the local authorities.
Their total surface is 3.100,00 m^2. The installed total capacity of the boilers is almost 700 kWs. According to the relative data sheets, the annual oil consumption for heating is 25,7 tns (306 MWh).
At the following table, the necessary collected data are broken down to each building.

Table 4. Collected data per building.

	A	B	C	D	E
Usage	Gymnasium	Municipality	Primary school	Kindergarten	Medical center
Construction date	1980	2003	1972	1996	1997
Thermal Isolation	NO	YES	NO	YES	YES
Type of transparent parts	Aluminum (double glass) 2000	Aluminum (double glass)	Aluminum (double glass) 2010	Aluminum (double glass)	Aluminum (double glass)
Number of	2	2	2	1	1
Heating surface	1605,08	748,09	603	100,8	50
Installed capacity	350	150	70	30	0
Oil consumption 2010-2014 [tn]					
2010					
2011	14-15 t	2,5	-	2,5 - 3,0 t	
2012	14-15 t	2-2,5 t	6,7 t	2,5 - 3,0 t	
2013	14-15 t	2-2,5 t	5,0 t	2,5 - 3,0 t	
2014	14-15 t	2-2,5 t	5,2 t	2,5 - 3,0 t	
Normalized installed capacity [kcal/h,m2]	*218*	*201*	*116*	*298*	-

Due to the occasional use of building E, this building is excluded from the study.
As shown from Table 4, the Normalized installed capacity [kcal/h,m2] oft he four buildings varies between 116 and 298 [kcal/h,m2].
Assuming an efficiency rate of 85 % of the existing boilers, the following table is derived:

Table 5. Normalized characteristics of the four public buildings.

Building	A	B	C	D
efficiency	85%	85%	85%	85%
Boiler capacity [kcal/h,m^2]	185	170	99	253
Boiler capacity [kcal/h,m^3]	62	57	33	84
Normalized energy consumption [KWh/m^2,a]	95	34	87	**302**

Comparing these buildings with similar from the same climate zone (Zone D, according to the National Regulation for buildings energy efficiency – KENAK), the normalized energy consumption is similar. E.g. a building with similar building envelope and usage has normalized energy consumption equal to 107[KWh/m^2,a]. The only exception is buildingD.
For the calculation of the thermal needs of the buildings and then for the calculation of the nominal proposed installed capacity, the local thermal conductance coefficients are considered. Then the thermal conductance coefficients of the National Regulation (KENAK) for old buildings without thermal isolation are considered. Consequently, two scenarios were developed: the optimistic / realistic evaluation and the pessimistic evaluation scenarios.
For both cases, the real thermal needs of all the buildings are expected to be lower than 700 kWs, as shown in the following table:

Table 6. Total thermal needs.

Building	A	B	C	D	**Total**	
	Gymnasium	Municipality Hall	Primary school	Kindergarten	Mcal/h	
Thermal needs Mcal/h	154	58	72	9	**293**	Optimistic scenario
Thermal needs Mcal/h	**232**	**62**	**88**	**10**	**392**	Pessimistic scenario

For the calculation of the losses of the district heating network, the relative manuals have been used.
The efficiency of the biomass boiler is again assumed equal to 85%.
Considering the district heating network losses and the thermal needs, the following table is derived:

Table 7. Proposed installed capacity of the biomass unit.

	Optimistic		Pessimistic	
	MCAL/H	KW	MCAL/H	KW
Buildings thermal needs	**293**	**340**	**392**	**456**
Losses	15	18	16	18

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Total	308	358	408	474
Boiler efficiency	85%	85%	85%	85%
Installed boiler capacity	362	**421**	480	**558**

Of course, it is proposed that the 420-558 kW capacity should be covered by at least two boilers with 200 kW and 300 kW, in order to use only one boiler during the periods with low heating demand.
The configuration of the system is shown in Figure 1.

Figure 1. Configuration of the biomass district heating system of Karpero.

For the network, the installation of underground preinsulated EN253 pipes is proposed, as in the cases of the Kozani, Ptolemais and Amyntaio. The network involves 670 m of excavation works, if the boiler unit is installed close to the Gymnasium, as shown in Figure 1. For the primary heating network, the following temperatures of operation are proposed: Inlet: 90^{o} C and Temperature difference: DT=30^{o} C (primary circuit).

For the easier management and automated supply of the unit with biomass, the biomass material should be supplied as wood chips. Consequently, enough space should be available next to the boiler for storing of the biomass.

The 26 tns that are consumed for space heating needs, will be now replaced with wood based biomass, leading also to the following environmental benefits:

Table 8. Comparison of emissions between the oil and biomass for the specific buildings.

Emissions [$\lambda_{\kappa,\nu}$] (g/kg) for 26 tns of OIL					
CO2	**SO2**	**CO**	**NOx**	**HC**	**Particles**
3142	0.7	0.572	2.384	0.191	0.286
Emissions (tn) for wood-based biomass					
CO2	**SO2**	**CO**	**NOx**	**HC**	**Particles**
81.69	0.02	0.01	0.06	0.00	0.01

For the cost estimation of the building, the following main parts are considered:

- Installation of the biomass unit in a container 15X5m (including 500KW biomass boiler, pumps, biomass storage, ancillaryequipment).
- Underground network of EN253 pipes of approximately 670m of length.
- Thermal substations for the consumers (totally 4).

Total Cost: ~160.000 - 190.000 € (no VAT included), ~210.000-240.000€ (VAT included).

2.3. Energy efficiency improvements of public buildings and recalculation of the thermal needs.

In order to further improve the efficiency of the whole system (biomass district heating system and buildings), detailed energy audit for the four buildings is conducted. According to each building's weakness, targeted improvements are applied, like external thermal isolation, building energy management systems, etc and the new classification is produced. The new classification leads to revised thermal needs of the buildings and a revised study for the biomass district heating network and the biomass boiler.

The results of the energy audit of each building and the targeted proposed improvements are shown in the following tables:

Table 9. Results of the energy audits (according to the KENAK software)

Building	A	B	C	D
	Gymnasium	Municipality Hall	Primary school	Kindergarten
Thermal needs kWh/m2	**194,1**	**65,6**	**221,1**	**243,2**
Total needs kWh/m2	**255,2**	**256,6**	**281,1**	**367,4**
Energy class	**Z**	**E**	**Z**	**E**

If the results of Table 9 are calculated in terms of consumed heating oil, the results show great differences than the actual consumed fuel. For example, for the case of building A (Gymnasium), a simple calculation gives:

194,1 KWh/m2*1605m2=311.530 kWh=311,53MWh

which equals to almost 30 tns of heating oil per annum. However, the consumed oil, as shown in Table 4, is 14-15 tns/a. This deviation is justified only partly due to the assumptions made at the KENAK software. However, these deviations also highlight the need of conducting in-site energy audit measurements and not rely exclusively on theoretical values from tables, since the construction uncertainties may lead to different results in energy classification [8].

Table 10. Targeted interventions at the four buildings and gains.

Building	A	B	C	D
	Gymnasium	Municipality Hall	Primary school	Kindergarten
energy interventions	Placement of heat insulation in the nutshell and the roof of the building	Upgrade cooling system	Placement of heat insulation in the nutshell and the roof of the building	No interventions
Total cost of interventions (euros)	80.000	4.000	36.000	The problem in this building is in its heating system.
% saving of primary energy	**51,6**	**10,1**	**52,8**	
damping of cost (years)	**4,6**	**5,2**	**4,8**	

Based on the percentage savings in primary energy from Table 10, the thermal needs of the four buildings are revised, leading to respective revision of the biomass district heating system. The comparison between the previous biomass district heating system and the revised one is outlined in the following results section.

3. Results

3.1 Comparative analysis after the re-design and re-estimation of the biomass unit and the district heating network for public buildings.

The application of the energy interventions described above will decisively contribute to energy savings for the proposed buildings. Therefore it is expected that the building's installed thermal load and the biomass boiler capacity will be reduced, compared to the initial estimations presented above.
Taking into consideration the thermal insulation to be applied on the shell and roof of the buildings, it is estimated that the actual buildings thermal demand will be reduced to 280KW, therefore the biomass boiler nominal capacity is estimated to 350KW.
The district heating system installation cost is estimated to 150,000€ (no VAT incl.), consisting of the boiler and boiler house cost, the preinsulated network cost and the district heating substations cost.

4. Conclusions

A proposed methodology of energy improvements in public buildings and their support with biomass district heating systems is described in this paper. The benefits for rural municipalities are impressive, in terms of operation cost and the environment, whereas the installation costs are not very high. Moreover, the results of the energy efficiency studies point out the need for detailed energy audits with in-situ measurements at the buildings.

References

[1] Reference to webpage: http://www.statistics.gr/ .
[2] Giagozoglou Eythymios,*Utilisation of biomass for district heating networks: The case of Grevena –MSc Theses*.
[3] Technical report of the project PROARES – Larisa University of Applied Sciences.

[4] Laspopouloy Tarina, *District heating study for the Grevena city with biomass,Graduate Theses,* National Technical University of Athens.
[5] Final report of ALTENER project 2002: *Concerted Actions to accelerate the district heating of Grevena city by Biomass Investment*, ANKOSA.
[6] Reference to webpage: BIOFOSS project:http://biofoss-project.eu/ .
[7] TEE-KENAK software, available atwww.tee.gr.
[8] Dimitrios Stimoniaris, Dimitrios Tsiamitros, V. Zacharaki, F. Dialynas, T. Kottas, S. Maropoulos, M. Stefanovski, Z. Stepanovski, I. Milosovska, K. Micalevski, V. Karagiannis, T. Papotis, E. Dialynas 2014 *MedPower 2014 Conference*, Athens, Greece.