Biomass district heating methodology and pilot installations for public buildings groups

N Chatzistougiani¹, E Giagozoglou¹, K Sentzas², E Karastergios², D Tsiamitros¹, D Stimoniaris¹, A Stomoniaris¹ and S Maropoulos¹

¹Western Macedonia University of Applied Sciences, Koila Kozanis 1, Kozani, 50100, Greece
²Municipality of Deskati, Deskati, 51100, Grevena, Greece

E-mail: dtsiamit@teiwm.gr

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 firewood 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 resource terms.
3) The use of properly maintained filters contributes to the environmental conservation of the areas.
4) Increase of comfort indicators for the inhabitants of the areas.

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 of biomass

Since almost all of the inhabitants already use firewood 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 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 of resources.

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) |
|-------------------------------|-------------------------------------------|
Table 4. Collected data per building.

| Usage                  | A  | B   | C     | D    | E    |
|------------------------|----|-----|-------|------|------|
| 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] of the 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,m²] | 185 | 170 | 99 | 253 |
| Boiler capacity [kcal/h,m³] | 62 | 57 | 33 | 84 |
| Normalized energy consumption [KWh/m²,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/m²,a]. The only exception is building D.
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 | | | | | |
| Thermal needs | Mcal/h | | | | Optimistic scenario |
| Thermal needs | Mcal/h | | | | Pessimistic scenario |
| 154 | 58 | 72 | 9 | **293** |
| 232 | 62 | 88 | 10 | **392** |

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.**

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

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°C and Temperature difference: DT=30°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:
For the cost estimation of the building, the following main parts are considered:

- Installation of the biomass unit in a container 15Χ5m (including 500KW biomass boiler, pumps, biomass storage, ancillary equipment).
- 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     | Placement of heat...   | Upgrade cooling system | Placement of heat...   | No interventions       |
| interventions | in... nutshell      |                        | in... nutshell         |                        |
| the roo    | and the roo... building|                        | and the roo... building|                        |
| of the bu  |                        |                        |                        |                        |
| ilding     |                        |                        |                        |                        |
| 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/](http://biofoss-project.eu/).

[7] TEE-KENAK software, available at [www.tee.gr](http://www.tee.gr).

[8] Dimitrios Stimonyaris, Dimitrios Tsiamitros, V. Zacharaki, F. Dialynas, T. Kottas, S. Maropoulos, M. Stefanovski, Z. Stepanovski, I. Milosovsk, K. Micalevski, V. Karagiannis, T. Papotis, E. Dialynas 2014 *MedPower 2014 Conference*, Athens, Greece.