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Energy Planning in Small Municipalities Based on Monitoring Results and Demand Side Management

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Abstract: Recent estimates state that the European Union is on course to achieve only half of the 20% energy consumption reduction target by 2020. As the first governmental stakeholders involved in the implementation of energy saving initiatives, municipalities play a strategic role in the energy planning process. This paper focuses on establishment of an energy planning methodology for small municipalities with numbers of inhabitants in range of 1,000-10,000 which often face common problems associated with low efficient district heat supply systems and decreasing energy consumption in buildings. Particular attention is paid to DSM (demand side management) activities. DSM scheme includes legislative and financial flows with small investments from municipality side. Based on increased information and motivation it promotes reduction of energy consumption in all kinds of buildings. Practical experience has shown that application of DSM measures allows achieving 20% energy savings in municipal buildings during the first year.

Key words: Demand side management, energy efficiency, energy planning.

1. Introduction

EU's (European Union's) climate and energy package, presented in 2009, includes three key climate and energy policy objectives for 2020, known as the "20-20-20" targets. The latest evaluation shows that the EU is on the way towards achieving its targets of reducing greenhouse gas emissions whilst raising the share of renewable energy sources [1]. However, much greater effort is needed to improve energy efficiency. Recent estimates of the European Commission state that the EU is on course to achieve only half of the 20% objective by 2020 [2].

Buildings represent the greatest energy saving potential [2]. On March 8, 2011, the European Commission presented a new energy efficiency plan that aims to improve the energy performance of both public and private buildings and promotes the exemplary role of the public sector. Following on June 22, 2011, the Commission proposed for a new Directive on energy efficiency repealing directives 2004/8/EC and 2006/32/EC. The directive was adopted on October 25, 2012 and established a common framework for promoting energy efficiency in the EU to ensure achievement of agreed 20% primary energy savings target by 2020 [3]. For public sector, which is of the main interest in this paper, the directive makes provision that member states shall encourage public bodies to adopt their energy efficiency plans containing specific energy saving objectives and put in place energy management systems as part of the implementation of these plans. In addition, member states shall ensure that starting from 2014, 3% of the total floor area owned by public bodies is renovated each year to meet at least the minimum energy performance requirements.

1.1 The Role of Public Bodies in Increasing Energy Efficiency

According to Brandoni et al. [4] and Neves et al. [5], local authorities are the first governmental stakeholders involved in the implementation of energy saving

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initiatives. Municipalities therefore play a strategic role in the energy planning process being able to implement several schemes designed to fulfil their exemplary role: (1) develop building codes and issue construction permits responding to high energy efficiency criteria; (2) implement demonstrative energy efficiency initiatives in public properties; (3) launch informative campaigns to increase citizens' knowledge and awareness about energy and environmental issues; (4) adopt new "clean" technologies [4, 6].

A number of authors have discussed aspects of decentralized energy planning [7-9]. Hiremath et al. [7] state that decentralized energy planning is one of the options to meet the rural and small-scale energy needs in a reliable, affordable and environmentally suitable way. Shikha et al. [8] add that decentralized energy planning is in the interest of efficient utilization of resources and takes into account various available resources and energy needs of the region. Eventually Dzene et al. [9] choose decentralized energy planning on a regional level as the most appropriate way to promote renewable energy sources and to reduce negative environmental impacts of energy systems.

1.2 Energy Planning in Small Municipalities

Energy system of a small municipality differs from that of a large one. It is not only about the size but as well technological solutions, financial and management capacity.

Generally more interest has been paid on national and regional energy planning issues than on energy planning at municipal level. However, a number of examples on energy management in municipalities are reviewed in literature. Based on a review of 11 municipal energy plans, Sperling et al. [10] examined to what extent municipal energy planning matches national renewable energy strategies in Denmark. Nilsson and Martensson [11] performed similar study in Sweden analysing whether municipal energy plans have contributed to the development of local energy systems. Cai et al. [12-14] pay attention to long-term renewable energy management in communities within the context of local energy planning and Rezessy et al. [15] discuss the factors that govern local authorities to involve in the market for energy services and energy efficient equipment.

Closer to the topic of this paper, Fiaschi et al. [16] performed a comprehensive investigation on the energy consumption of public buildings and utilities and evaluated the most effective and feasible ways to save energy in a small Italian township with approximately 16,000 inhabitants and Dzene et al. [9] elaborated a screening method for identifying suitable options for improving energy system in an environmentally sound direction in a typical middle-sized rural region in Latvia.

1.3 Energy System of a Municipality

Energy system of a municipality is represented as a network of energy chains consisting of primary energy supply and conversion, energy transmission and distribution and finally the end-use.

The demand for space heating and hot water in buildings is still the major element of the total energy demand for many municipalities in countries with moderate to cold climates [17]. Although district heating offers a number of advantages compared to single house heating systems, the share of individual heating systems is usually larger, mainly due to low density of population in rural areas. Correspondingly, operation of individual heating systems is often associated with lower energy efficiency because of such reasons as technological limitations, lack of owners' knowledge, etc.

On the other hand, also the existing district heating systems face several problems, e.g., decreasing energy consumption due to such reasons as the implementation of energy efficiency measures in buildings, migration of people from rural to urban areas, and shift from district to decentralized renewable energy systems.

Recently an increasing number of studies have analysed possibilities to promote the use of district heating in the context of decreasing energy consumption in buildings. Thyholt and Hestnes [18] concluded that lowering space heating demand in buildings results in higher costs for district heating. Aberg and Henning [19] add that traditional district heating networks are not designed for low energy buildings because of relatively high distribution heat losses. Meanwhile, Sperling and Möller [17] find that in general substantial reductions of buildings' heat demand can go hand in hand with a continued expansion of the district heating system and can improve the overall efficiency of energy system in the short and long term.

The above mentioned case studies indicate that energy planning in municipalities is a topical question both from side of effective energy production and consumption. Despite the fact that, for example, in Sweden municipal energy planning has been part of energy policy for more than three decades, generally municipalities, especially small ones, lack experience, knowledge and resource to develop qualitative long-term energy plans in their territories. The aim of this paper is to propose a methodology for design of energy plans in small municipalities focusing on DSM (demand side management) measures. The established energy planning model was applied on a case study of Beverina region in Latvia.

2. Methodology

An algorithm for energy planning in municipalities is proposed in Fig. 1. It consists of 11 both directly and indirectly interrelated modules.

Evaluation of the current energy situation in the region is the starting point of energy systems' planning from which it is possible to set relevant objectives and elaborate an adequate action plan. The baseline review is based on existing data on energy system performance in the region and covers both quantitative (energy production and consumption) and qualitative (energy management, knowledge, etc.) aspects. Input data include information on space heating area (m^2), energy consumption for space heating and hot water preparation (MWh/year, kWh/m^2/year), and heat costs (EUR/year, EUR/m^2/year). Data are obtained both directly (from building inventories, accounting, and energy meters) and by calculations if only fuel consumption is measured (frequent for wood fuel applications). In case reliable data are not available several assumptions must be done, e.g., in regard to the length of heating season or energy content of fuels.

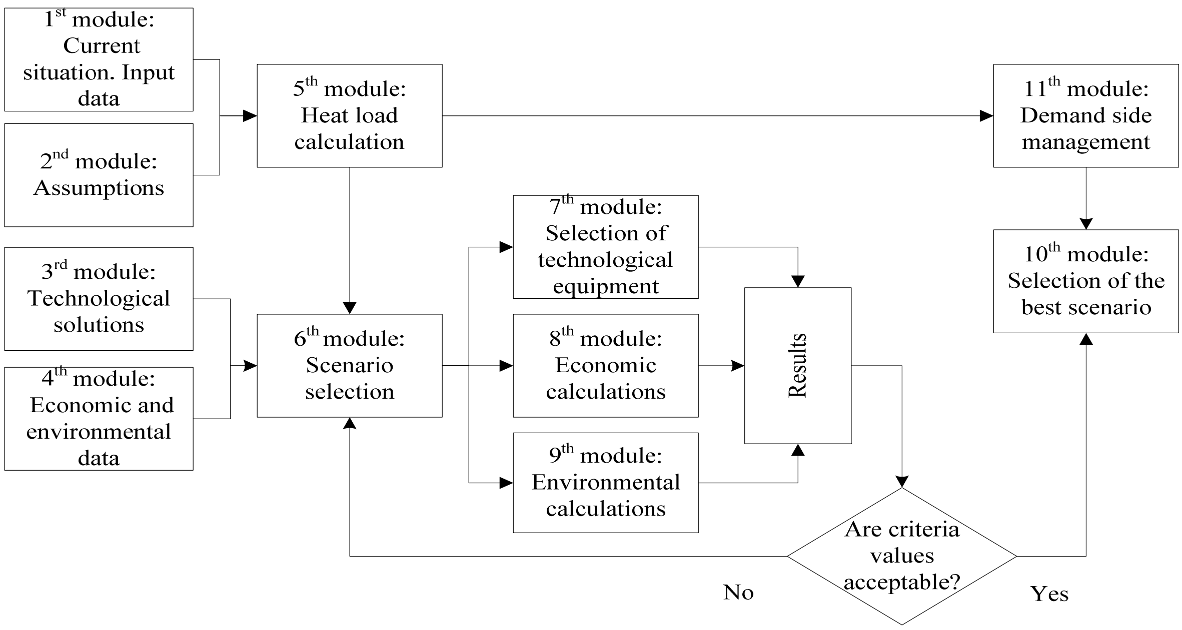

Fig. 1 Algorithm for energy planning in municipalities.

Collected data are further analysed and interpreted. Based on buildings energy consumption characteristics annual heat energy consumption graph is drawn to indicate base and peak loads. Determination of an appropriate heat load is important to ensure high-efficient systems performance.

Based on the data collected, hypothesis for future development of the regional energy system is established. Available technological solutions and economic and environmental considerations are taken into account in this step. Following detailed development scenarios are modelled including selection of technologies and corresponding economic and environmental calculations.

Based on findings of the different scenarios and taking into account specific needs of the region, municipality stakeholders determine the most promising scenario and select measures and actions to be implemented. Finally, implementation of the regional energy strategy is based on previously developed demand side management plan to ensure that planned efficiency improvement is achieved.

3. Results of the Case Study

The proposed algorithm for development of future energy systems was applied to a case study of a small municipality in Latvia. This chapter presents results of the case study.

3.1 Target Region Portrait

Beverina region with its 3,500 inhabitants is an example of a typical small rural area in Latvia, as approximately 70% of regional municipalities in Latvia have less than 10,000 inhabitants based on census data available in Ref. [20]. The municipal area is approximately 301 km^2, resulting in a density of 12 people per square kilometre.

Local administration is responsible for approximately 20 public buildings, including schools and kindergartens, libraries, cultural houses, several social offices and central administration. Household building stock is circa 170,000 m^2, of which 70% are single family houses. Space heating and hot water is mainly supplied by individual heating systems (stoves, furnaces, fire-places or electric heating units) [21].

Further in the paper the authors have chosen to analyse three problematic elements of the energy system of Beverina region:

- Murmuiza boiler house;
- multi-apartment house “Lazdas”;
- Trikata Primary School and sports hall.

3.2 Input Data

There is no single source of information on energy situation in Latvian municipalities. Therefore, a comprehensive research was performed to collect the necessary input data characterizing energy supply infrastructure, primary energy resources and energy consumers in Beverina region. All three specific cases covered by this research will be described below.

3.2.1 Murmuiza Boiler House

District heating in Murmuiza community, one of the largest settlements in Beverina region, is supplied by a 1 MW biomass boiler. Fuel consumption was 3,000 m^3 loose volume of wood chips and additional 200 m^3 loose volume of saw dust in 2011. Boiler efficiency is 61.0%.

Data characterizing energy consumers in Murmuiza are illustrated in Fig. 2. Energy consumption in eight monitored buildings varies in range 70 kWh/m^2/year -220 kWh/m^2/year. Building energy performance is the main cause explaining diverse energy consumption though also human factors play a crucial role.

Fig. 2 shows a satisfactory correlation between two variables – normalized energy consumption (converted to standard degree days) in buildings connected to the network of Murmuiza boiler house and heated area of these buildings. In case DSM measures are applied, an empirical equation characterized by a linear function can be used as a benchmark to determine building energy consumption by Eq. (1):

$$Q = -0.083 \times F + 222.66 \quad (1)$$

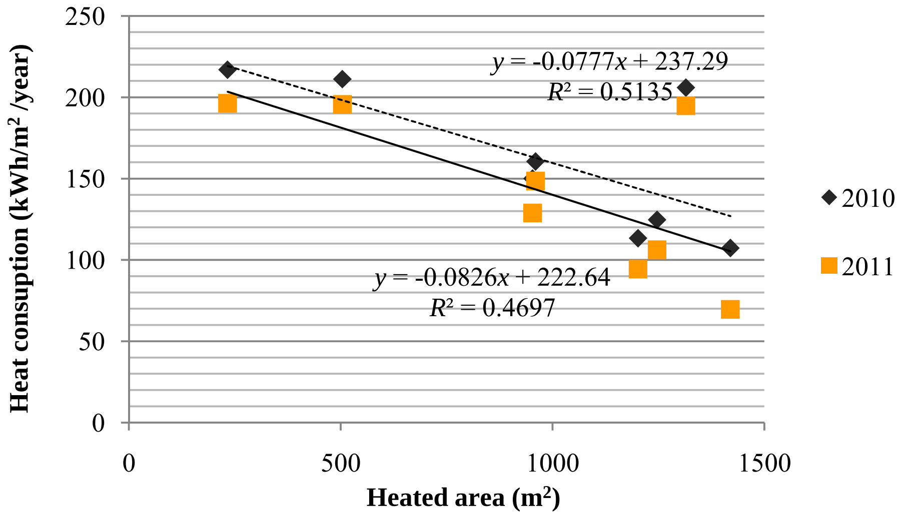

Fig. 2 Specific energy consumption of buildings in Murmuiza community.

where,

Q—annual specific heat consumption, kWh/m^2/year;

F—heated area of the building, m^2.

The benchmark is adjusted each year according to the level of achieved energy savings. Position and slope of the lines describes processes occurring in buildings. Data correlation should improve in line with increased knowledge and awareness of inhabitants about opportunities to reduce heat consumption.

3.2.2 Multi-Apartment House "Lazdas"

Multi-apartment house "Lazdas" in Cempi Community (another settlement area in Beverina region) represents a typical multi-family house in Latvia. Heating area of the building is 1,080 m^2 and specific heat energy consumption is 175 kWh/m^2/year. Heat and hot water is provided by electric heaters.

3.2.3 Trikata Primary School and Sports Hall

Trikata Primary School was built in 1938. A new sports hall next to the school was finished in 2005. Heating space of the school is 2,310 m^2 and of the sports hall—1,075 m^2. In 2007, several energy efficiency measures were implemented in the school including installation of ground heat pumps. Annual electricity consumption to power heat pumps is 144 MWh/year. Annual light fuel oil consumption for heat supply in sports hall is 6.5 t/year.

3.3 Development of Alternative Scenarios

Based on evaluation of current situation, alternative scenarios for each case study were developed. The scenario description are in Table 1 (Murmuiza Boiler House), Table 2 (multi-apartment house "Lazdas"), and Table 3 (Trikata Primary School and sports hall).

4. Discussion

Results of the research have highlighted the main energy management problems in Beverina municipality associated with primary energy purchase, lack of appropriate training of energy operators and building energy management policy. This has led to proposal of a municipality DSM system further applicable for integration in regional level energy planning process. A self-financing scheme can be applied to implement proposed energy efficiency measures (in Fig. 3).

The scheme involves development of a municipality energy management division that is responsible for implementation of energy efficiency related initiatives in the municipality. This includes development of a single documentation for fuel purchase tenders, energy training of building managers and implementation of energy efficiency measures in public buildings. Municipality financing for energy efficiency related projects is secured from two sources: state grants and energy savings. This

Table 1 Alternative scenarios for energy efficiency measures in Murmuiza boiler house.

Alternative	Service	Costs, 1,000 EUR	Payback time, years
A: establishment of an energy management programme	Experts consultation and energy managers salary	3-6	< 1
	Measuring equipment and engineering service purchase	7-10	< 1
	Equipment installation	14-21	< 1
B: installation of effective biomass boilers with flue gas condensing units	Wood pellet boiler (0.4 MW)	57	10
	Wood chips boiler with a flue gas condensing unit (0.4 MW)	71	7
	Wood pellet boiler (0.2 MW) and wood chips boiler (0.2 MW) with a condensing unit	85	10
	Biomass cogeneration unit (0.3 MW_e and 0.4 MW_{th})	1,423	10
C: heat supply decentralization	This is an alternative solution in case installation of new district heating boiler is not technologically and economically feasible. Installation of a pellet boiler in each multi-family house is proposed.		

Table 2 Energy efficiency measures in multi-apartment house "Lazdas".

No.	Measure	Costs, 1,000 EUR
1. District heat supply system		
1	Creation of a new heating system	24
2	Creation of a new hot water supply system	17
3	Creation of a heating unit	7
Total		48
2	Building energy performance improvement	
4	Energy efficiency measures in buildings	171
3	Heat source	
5	Installation of a fully automatized pellet boiler (70-100 kW)	28
Total		248

NB! Repayment time of the alternative is 10.5 years.

Table 3 Alternative energy efficiency measures in Trikata Primary School and sports hall.

No.	Measures at heat supply unit	Costs, 1,000 EUR	Repayment time, years
1	Development of a DSM programme	9	2
2	Development of a DSM programme and installation of a wood pellet boiler in sports hall	33	4.2
3	Development of a DSM programme and installation of a wood pellet boiler to cover the base load	38	3.9

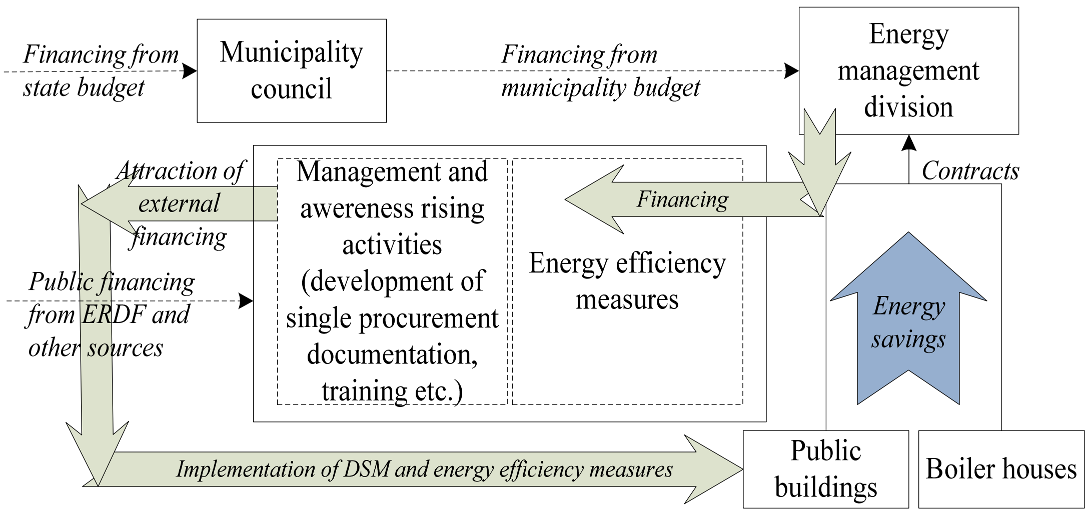

Fig. 3 A partial self-financing scheme for implementaion of energy efficiency and DSM measures in municipalities.

means that municipality invests in both direct energy saving measures in public buildings and in regulatory and awareness rising initiatives that allows achieving maximum planned energy savings. Municipality benefits include reduced fuel purchase and energy costs as well as improved quality of public infrastructure.

5. Conclusions

This study covered three problems typical for small municipalities in Latvia:

• existence of complex heat supply systems consisting of district or partly district heating in community centres and decentralized heat sources in single family houses;

• high energy consumption because of low energy performance of buildings and energy consumers' behavioural traits;

• inability (lack of knowledge, awareness and resource) of local authorities to manage the energy system.

Based on a case study, alternative scenarios were proposed mainly focusing on DSM measures. First results show that introduction of DSM in combination with simple energy efficiency measures in Beverina region has resulted in 20% energy consumption reduction in a half year.

Proposed energy efficiency measures and financing scheme can be considered a representative case study in Latvian scenario and can be applied to other municipalities of a similar size.

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