ADAPTATION OF BIOENERGY VILLAGE CONCEPT IN SMALL TOWNS OF LATVIA

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Abstract. Energy policy is a significant component of the European Union (EU) sustainability policy. Along with transnational agreements, which determine the development of energy sector in accordance with the environmental, competition, availability, and supply aspects, local initiatives also exist, including bioenergy villages.
Bioenergy villages are an example of a sustainable policy implementation at the lowest level of administrative territories. The positive aspect of bioenergy villages appears in the support of local public as well as in the positive effect of a bioenergy village on agriculture and the environment. By establishing local residential places that are self-sufficient with bioenergy, sustainable development is stimulated not only at the local, but also national level. The aim of the present paper is to calculate, by means of a simulation model, the amount of resources needed for the establishment and operation of a bioenergy village and its effects on greenhouse gas (GHG) emissions and resource imports.
By developing and exploiting a simulation model for a bioenergy village, which was based on the authors' calculations on economic and environmental effects of biogas production as well as assumptions and calculations regarding the use of biomass and information on the output and consumption of energy in Auce town, it was found that establishing a bioenergy village would have the following positive affects: GHG emissions would decrease by 1 792.7 7 t CO_{2eq} a year, local agriculture would have to supply the necessary biogas substrate – 4 233.3 t of silage and 15 366.7 t of cattle liquid manure, imports of resources (energy and fertilisers) would decline by a value of LVL 199 060.69 a year, and the cost of thermal energy for residents would not change.
Key words: bioenergy village, biogas, biomass, energy self-sufficiency.
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Introduction

Presently, the dominant equipment for large-scale energy production may be characterised by high production efficiency and low per-unit cost. At the same time, large production capacity is an equivalent for relatively long distances for the delivery of resources and products (electricity and thermal energy) as well as huge quantities of resources harming the environment (Ayres et al., 2007). Manfred and his colleagues (Manfred et al., 2011) point to a change in the paradigm for establishing energy supply systems. In the future, an essential role will be played by micro-networks, information and communication technologies (virtual energy networks and intelligent power grids) as well as an integrated energy supply system.

Decentralised energy production is local energy production; it is located close to a consumer and it uses local resources. In the case of Latvia, the determinant factors have to be searched for in historical background, especially it relates to the location of a gas pipeline that determined the possibilities of a decentralised energy generation facility for using natural gas for cogeneration (Pelse et al., 2011). However, sustainable energy supply is associated not only with the location of energy production, but also with a more complete use of resources, which would also include waste recycling as well as active support of the public for changes in energy consumption. Actually, local regions, cities, towns, and villages try to enhance the flow of energy by consuming an energy mix characteristic of their potentialities and wishes, which would contain not only primary energy resources of high value (gas, oil, and wood), but also industrial and household wastes. Such a perspective is not new, as it actually reflects Wolman's idea on the metabolism of cities that suggests viewing cities as flows of energy and resources. The sustainable development of a 21st century city is not imaginable without GHG emissions and analyses of energy resources (Kennedy et al., 2011). An idea about the establishment of bioenergy villages is proactive, which actually is the result of developing the city metabolism idea. *Bioenergy villages are populated territories where energy needs are satisfied with local alternative energy biomass resources, thus increasing the economic, environmental, and agricultural sustainability of a local community*.

The research aim is to calculate, by means of a simulation model, the amount of resources needed for the establishment and operation of a bioenergy village and its effects on GHG emissions and resource imports. The research tasks are as follows: 1) to develop a model for energy production in a bioenergy village in order to obtain economic and environmental data for energy production; 2) to assess the gained results by comparing them with the alternative of fossil energy use. The research object is energy supply in Auce town, and the research subject is a possibility to establish a bioenergy village, based on the resources of Auce town.

Research results and discussion

R.Mangoyana and T.Smith (2011), when analysing several bioenergy village models worldwide, found that only one best bioenergy village model does not exist. It is

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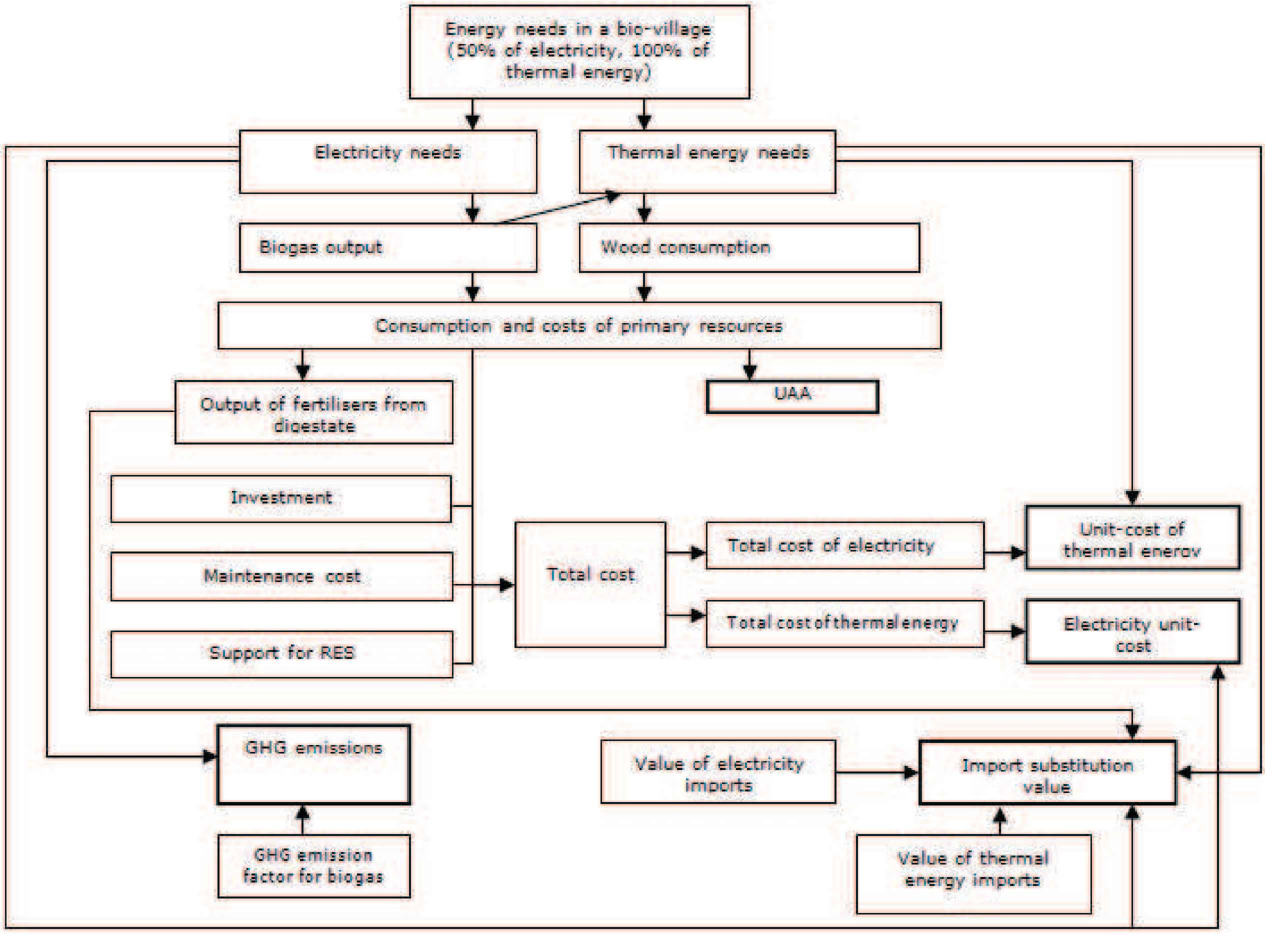

Source: authors' construction

Fig.1. **Block scheme for calculations for the model of energy production in a bioenergy village**

due to different ways of energy production, different uses of products, different kinds of energy sources, different amounts of output, different target groups of consumers as well as different forms of cooperation. Success is based on synergy among support for the consumption of energy resources, financial resources, technological knowledge, national support policies and the readiness of institutions for cooperation, as well as direct gains, mainly economic, and a great role is played by the support and participation of local public. German researchers Andre Wuste and Peter Schmuck (2012) carried out interviews and ascertained the opinions of initiators in 25 bioenergy villages to find out the motives that drove them to establish a bioenergy village. In short, a successful bioenergy model depends on several factors: development prospects for a village or small town, available resources and infrastructure, public support and common regional and environmental government policies.

In the present paper, the authors elaborated a bioenergy village model based on the example of Auce town. Such a choice was made owing to the fact that a biogas cogeneration power plant (capacity of 0.26 MW) is presently operated in Auce. Previously, this town had no natural gas infrastructure; therefore, the town already now partially provides itself with energy from renewable sources. A model for energy production in a bioenergy village contains the following energy production components:

— biogas cogeneration (electricity and thermal energy is produced);
— wood is used to generate thermal energy.

These two components were combined in a single bioenergy village model. To compare the obtain results with the presently dominant energy supply in towns, the authors included also a component of fossil resources:

— fossil energy option.

A bioenergy village, in accordance with the basic prerequisites for establishing a bioenergy village, has to provide itself with half of the electricity and the whole amount of thermal energy consumed by its residents. In Auce town, 3867 people resided (2011 data), consuming annually 6805 MWh of thermal energy and 3765 MWh of electricity.

A block scheme for calculations for the model of energy production in a bioenergy village is presented in Figure 1.

A biogas production facility providing a bio-village with electricity and partially with thermal energy is considered a priority. The remaining amount of thermal energy is supplied by a boiler house running on wood. The necessary amount of energy determines the necessary amount of primary resources that compose

Table 1

Characteristics of the wood exploitation component in the bioenergy model for a small town

Indicator	Kind and amount of primary resources (firewood) m³, (woodchips) bulk m³		Value of fuel resources, LVL	Total cost (including support for investment), LVL, a year	Import energy substitution effect, LVL, a year
	firewood	woodchips			
Total for a bioenergy town	3 367	4 761	78 573.00	138 543.39	117 946.92
Per MWh of thermal energy	0.9896	1.3996	11.55	20.36	17.33

Source: authors' calculations

Table 2

Characteristics of biogas cogeneration in the bioenergy model for a small town

Indicator	Kind and amount of primary resources, t		Total cost (including support for investment), LVL, a year	Necessary UAA, ha, for		Import energy substitution effect, LVL, a year	GHG emissions produced, t CO_{2eq}
	Silage	Liquid manure		Silage	Forage		
Total for a bioenergy town	4 233.3	15 366.7	244 476.00	84.7	683.4	106 822.00	93.5
Per MWh of electricity	2.85	26.08	117.54	0.0407	0.3286	51.36	0.0449

Note: an amount of energy produced from substrates is equal to 1 484 655 kWh for silage and 599 300 kWh for liquid manure

Source: authors' calculations

the component of energy costs. Besides, these primary resources determine the necessary utilised agricultural area (UAA) as well as the amount of fertilisers saved owing to using digestate as a fertiliser in agriculture. The saved amount of fertilisers increases the import substitution value that is affected by the amount of energy generated in a bioenergy village and the value of a unit of imported energy. Total cost is affected by investment and maintenance costs as well as financial support for renewable energy. Based on the exergy method, total cost is divided into the cost of electricity and the cost of thermal energy, which, depending on the amount of energy generated, determines the cost of a unit of energy. GHG emissions are determined by the amount of biogas energy and the GHG emission factor for biogas. GHG emissions caused by burning wood are not included in the calculations, as it is assumed that the use of wood in energy production does not affect the potential of global warming.

Use of wood for generating thermal energy. Thermal energy production, based on using wood, is characterised by full (100%) self-sufficiency with thermal energy in Auce town. Half of the necessary amount of thermal energy is produced from firewood and half from woodchips. Actually, it is a heat supply option that is widespread in small towns and villages of Latvia. Characteristics of the wood exploitation component are presented in Table 1.

According to the data, the proportion of primary resources is quite high. The heat production cost is relatively low – 20.36 LVL/MWh, yet, it has to be taken into consideration that, in this case, additional taxes are not included in the calculations and this cost may not be considered a tariff for consumers. The import substitution value is equal to 17.33 LVL/MWh, i.e. the production of a MWh of thermal energy from wood improves foreign trade balance by LVL 17.33, compared with the situation if this energy is produced from natural gas. The GHG emissions are assumed to be neutral, thus causing no pollution.

Biogas cogeneration. The calculations for biogas exploitation are not orientated towards fully meeting the demand for thermal energy in the small town, but towards the production of electricity. The selected biogas cogeneration power plant exploits maize silage and manure as inputs. As any cogeneration power plant, the biogas cogeneration power plant produces several kinds of energy, in this particular case – electric and thermal energy. Different periods of demand for heat and electricity have to be taken into account. The demand for electricity lasts all year long and changes insignificantly, whereas the demand for heat is explicitly seasonal. It is assumed in the calculations that the main product is electricity, and the operating hours of a cogeneration power plant total 8 000 a year. Characteristics of biogas cogeneration are presented in Table 2.

If comparing the characteristics of the biogas production component (Table 2) with those of wood exploitation for heat production (Table 1), the complexity and capital-intensiveness of biogas production become explicitly apparent.

The total cost of biogas production is much higher if calculated per MWh. Yet, it is important to note that these indicators may not be compared in a direct way because:

Table 3

Comparison of the alternatives for producing bioenergy and fossil energy in the bioenergy model for a small town

Indicators	Unit of measure	Fossil energy option	Bioenergy town
Thermal energy needs	MWh	6804.60	6804.60
Electricity needs	MWh	3765.10	3765.10
Needs for resources	t m^3 ber.m^3	239 695 m^3 of liquefied gas	4233.3 t of silage 15366.7 t of liquid manure 2636.4 m^3 of firewood, 3728.6 bulk m^3 of woodchips
Value of fuel resources	LVL/kWh	0.064	0.021
Thermal energy output	MWh	6 804.60	6 804.60
Electricity output	MWh	0	2 080.0
Thermal energy self-sufficiency, %	%	100	100
Electricity self-sufficiency, %	%	100*	55.2
Investment in equipment	LVL, a year	14 666.67	82 410.00
Maintenance cost	LVL, a year	44 709.69	125 810.39
Substrate cost	LVL, a year	433 847.95	190 458.36
Total cost	LVL, a year	493 224.31	398 678.75
Support for investments	LVL, a year	-	32 964.00
Support for production (electricity)	LVL/kWh	-	0.10 - 0.149
Total cost, including support	LVL, a year	493 224.31	365 714.75
Thermal energy cost	Ls/kWh	0.072	0.030
Electricity cost	Ls/kWh	0.035*	0.076
Amount of emissions produced	t CO_{2eq}	1886.24	93.5
Import substitution value	LVL, a year	-1825.31	199 060.69

*it is assumed that the public producer provides it at a tariff set by the PUC

Source: authors' calculations

1) regardless of energy unit, the amount of energy actually is different, as electricity is a higher level energy;
2) in the summary on biogas production, investment is expressed per MWh of electricity, yet, the thermal energy produced has to be also considered.

The use of heat is not included in the calculations, as these coefficients are employed in determining the effect of establishing a small bioenergy town.

Bioenergy village (a combination of biogas and wood). Based on the prerequisites for a bioenergy village regarding energy self-sufficiency, which require to supply at least half of the electricity and 100% of the thermal energy by exploiting energy generated locally, a combination of biogas and wood that actually meets these prerequisites is found. Biogas production generates additional large gains to ensure agricultural sustainability; therefore, it is used as a basis and is integrated in the bioenergy model for a small town. Owing to a synergy between energy produced from biogas and energy produced from wood, in the calculations, the demand for heat from wood is reduced by the amount of heat produced from biogas. The amount of heat to be produced from wood, in addition to the heat generated at the biogas power plant, is equal to 5325.4 MWh, accounting for 78.3% of the total amount of heat.

Fossil energy option. The authors calculated the option of energy supply from fossil resources, which may be considered a partial alternative, as in this case it is envisaged that the heat supply system will shift to liquefied gas. A large proportion of towns in Latvia have no natural gas pipeline in their region, therefore, the only real alternative for fossil resources is liquefied petroleum gas. The assumption is interesting in relation to the planned construction of a liquefied gas terminal in the Baltic region. In certain periods, liquefied gas would be able to compete quite well with natural gas for heat production. The calculations are important as an intermediate stage for transition to the use of biogas in heat production on the condition that the electricity market price is not able to cover the cost of energy and the public abandons the support policy for biogas production. The duty of the public producer is to supply electricity to households, which are not market participants, at a tariff set by the Public Utilities Commission (PUC) (in the calculations – tariff plan T1 Basic).

The results are presented in Table 3; at the same time, it is compared with the bioenergy village alternative. It has to be taken into consideration that the alternatives are not fully comparable, as there is no single energy amount standard with which the present options may be compared.

After analysing the results (Table 3), one can conclude that the model of energy supply for a bioenergy village is competitive in general. To establish a bioenergy village, two facilities, a boiler house running on wood, and a biogas cogeneration power plant are necessary. Such an option can fully satisfy the demand for heat and supply more than half of the electricity needed, and the basic prerequisites for energy self-sufficiency are met. The production of energy in a bioenergy village is closely integrated with agriculture, as a part of primary energy resources are agricultural products. To meet the need for resources, 4 233.3 t of silage, 15 366.7 t of cattle liquid manure as well as 2 636.4 m^3 of firewood and 3 728.6 bulk m^3 of woodchips are necessary. To produce the silage, an agricultural area of 84.7 ha is necessary, and one can say that, to a certain extent, such an area needs to change its kind of use from food production to energy production. It has to be noted that there are 3179 ha of unfarmed agricultural land in Auce municipality. At the same time, it has to be mentioned that such an area of land provides a more optimal substrate obtained from biogas production and, as a result, the necessary investment is saved. Every year, a small bioenergy town will produce a GHG emission of 93.5 t CO_{2eq}. If compared with the use of liquefied gas in energy production, it is an annual saving of 1792.74 t CO_{2eq}. At the national level, LVL 199 060.69 will be saved, which would otherwise be spent on imported energy resources.

On 18 December 2008, the Regional PUC set a tariff of 41.95 LVL/MWh, VAT excluded, for thermal energy, although in practice the heat supply enterprise used a lower tariff of 37.09 LVL/MWh. (Par SIA Auces….); (Informacija par siltumenergijas ..., 2012). The cost of heat at a bioenergy village is 30 LVL/MWh, excluding heat transportation cost. By assuming that administration and marketing costs contribute to a price increase of approximately 30%, the tariff is 39 LVL/MWh, VAT excluded, for a bioenergy village, which is less than the existing tariff.

An opposite situation is observed for electricity, as its cost in the case of a small bioenergy town is much higher than the average cost for the public producer. The cost of electricity produced at a biogas power plant is equal to 0.072 LVL/kWh without any profit included. The price of electricity sold by the public producer is 0.035 LVL/kWh or more than two times cheaper. Yet, the price of electricity contains some more components, such as electricity transportation and distribution costs, compulsory purchase component cost, electricity marketing cost, and VAT. In a situation, when a bioenergy village wishes to consume locally produced electricity, another price formation mechanism is required, which excludes high voltage services, as they are not consumed; besides, the cost of compulsory purchase component (CPC) should not be included in total cost, as the CPC is actually a compensation for services paid by a bioenergy village directly to the producer. Namely, these services include the construction of new base load capacities, the expansion in the use of renewable sources, and the reduction of GHG emissions. Such an approach could equalise the real prices of fossil and green energy. Presently, electricity is purchased in accordance with the CPC procedure, which covers the cost of electricity at a greater extent than it is needed.

Conclusions

After comparing the model for a bioenergy village with the fossil energy option, one has to conclude that using liquefied gas in heating is expensive and significantly increases the cost of heat as well as increases energy imports. If compared with the alternative option, GHG emissions also increase. The fossil energy option does not affect the economic activity of local residents, and local resources, including agricultural land, are not exploited.

Bibliography

1. Ayres, R.U., Hal T., Casten T. (2007). Energy Efficiency, Sustainability and Economic Growth. In: *Energy*. Volume 32, Issue 5 (May 2007). pp. 634. - 648.
2. Informacija par siltumenergijas tarifa izmainam (2012) *(Information on Changes in the Tariff for Thermal Energy)*. Auces Novada Vestis, Nr. 7 (35).
3. Kennedy, C., Pinceti, S., Bunje, P. (2011). The Study of Urban Metabolism and its Applications to Urban Planning and Design. In: *Environmental Pollution,* Volume 159. Issues 8-9, pp.1965-1973
4. Manfred, M., Caputo, P., Costa, G. (2011). Paradigm Shift in Urban Systems through Distributed Generation: Methods and Models. In: *Applied Energy*, Volume 88, Issue 4, pp.1032-1048.
5. Mangoyana, R.B., Smith, T.F. (2011). Decentralised Bioenergy Systems: A Review of Opportunities and Threats. In: *Energy Policy.* Volume 39, Issue 3, pp. 1286.-1295.
6. Par SIA „Auces komunalie pakalpojumi" siltumenergijas tarifa apstiprinasanu (2008): Jelgavas regionalas SPR padomes lemums Nr.36 *(On Setting a Tariff for Thermal Energy for „Auces komunalie pakalpojumi" Ltd (2008): Jelgava Regional PUC decision No.36)*. Retrieved: http://www.sprk.gov.lv/doc_upl/Auces_ komunalie _pakalpojumi,_ SIA.pdf. Access: 5 March 2011.
7. Pelse, M., Leikucs, J., Naglis-Liepa, K., (2011). Abatement Factors for Renewable Energy Production in the Baltic States. In: *Energy solutions for a sustainable world*: Proceedings of the Third International Conference on Applied Energy. Italy, Perugia, pp. 255.-272.
8. Wüste, A., Schmuck, P. (2012). Bioenergy Villages and Regions in Germany: An Interview Study with Initiators of Communal Bioenergy Projects on the Success Factors for Restructuring the Energy Supply of the Community. In: *Sustainability*, Volume 4(2), pp. 244.-256.

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