WP 4 Energy Supply

Summary of the Concept for EER of buildings and modernization of the supply infrastructure in the target areas of Siauliai

2011.03.30

Summary of the Concept for EER of buildings and modernization of the supply infrastructure Lieporiai target area of Siauliai

Analysis of Alternative Ways to heat Buildings

In theory, heat can be supplied to quarter apartment buildings in a variety of ways: using district heating or decentralization of heat supply, using natural gas or liquefied gas, wood, electric power, and other fuels in individual boiler-houses for heating. Each of these methods will be discussed separately.

As an example, a typical 5 storey apartment building containing 45 apartments located at Krymo St. 44 has been selected. The total usable area of the house is 2325 m^2, the installed heating capacity is 244 kW, and power for hot water is 296 kW. Annual heat consumption in the apartment building is estimated at about 357.22 MWh per year. The options to disconnect from the current district heating scheme and install an autonomous boiler-house are considered.

The capacity of a boiler-house installed in the given block of flats shall cover the maximum needs of the consumers, 540 kW. It is assumed that the autonomous boiler-house financing is carried out on a 15-year loan with an 8% annual interest. Based on the formula for disconnecting heat consumer facilities from the heat supply system, presented in economic assessment methodology, Table 3: 60 000+295×P, where P is power [kW], the investment for a boiler-house with such a capacity would be around 220 thousand litas, and the total amount including the bank interest would make 385.5 thousand litas. The annual amount to be repaid (annuity) will be **25.7 thousand** litas. The life of the boiler-house shall be 15 years.

In each case, the price of heating energy produced in the autonomous boiler-house with different fuels will be measured. It is assumed that the boiler-house installation investments shall remain the same irrespective of the fuel used for heating: natural gas, liquid fuel or liquefied gas.

Natural gas. In proportion to the annual consumption of heat, 357.22 MWh, gas consumption will amount about 42541 Nm^3/year. The adopted average boiler-house efficiency is 90% and gas energy value is 9.33 kWh/Nm^3 (the average in 2009). Gas price is LTL 1560/1000Nm^3 (including VAT) plus a nonvolatile component of LTL 14.05 per month

Part-financed by the European Union (European Regional Development Fund and European Neighbourhood and Partnership Instrument).
Baltic Sea Region
Programme 2007-2013

(including VAT). The price has been withdrawn from the official quotation currently approved by “Lietuvos dujos” AB and valid until 31 December 2010. The monetary value of annual fuel consumption will be 66.53 thousand litas.

The total annual fuel and investment consumption will make:

66.53 +25.7 = LTL 92.23 thousand/year.

Based on these calculations, heat price for consumers will be:

92.230 [LTL/year] / 357.220 [kWh/year] = 0.2582 LTL/kWh or 25.82 ct/kWh.

The price of a fuel component makes 18.62 ct/kWh, while an investment component is 7.20 ct/kWh. We can see that the estimated total cost is 25.82 ct/kWh higher than a fixed monomial district heating price which equals 24.2 ct/kWh. It should be noted that the autonomous boiler-house costs will include additional operating expenditure for water, electricity, current repairs, and maintenance; moreover a potential rise in gas prices which will further increase the heat price has not been rated. Therefore, we can state that the autonomous boiler-house installation does not provide consumers with economic utility.

Analysing the case where a self-contained heating system is installed by every resident, the heat price would be still higher than in the event of a communal boiler-house since a gas tariff would increase to consumers in smaller groups. In addition, rules for installation of gas equipment lay down requirements for chimney connection: “Clause 75. Gas boilers of not more than three consumers are allowed to be connected to a single chimney. The distance between the attachment points of gas boilers and the chimney on different floors of the building must be at least 6.5 m. Where the distance between the attachment point of the communal chimney and the top of the chimney is less than 4 m, a separate chimney for the gas boiler has to be installed providing the necessary traction”. As we can see, these requirements are hardly technically feasible since the installation of gas facilities to all residents of the tower-block shall provide for more than one chimney, which significantly increases the total investment.

Liquefied gas. Use of liquefied petroleum gas in autonomous boiler-houses presents one of technical options however tanks shall be installed near heated buildings to this end. Such a solution is difficult to implement technically. The market price of liquefied petroleum gas (propane butane mix) quoted by “Orlen Lietuva”AB (as of 24 November 2010) is LTL 3419.87 per ton (including VAT). The gas phase density is 2.32 kg/Nm^3 and the calorific value is 104650 kJ/Nm^3. With the average 90% boiler-house efficiency, the fuel component would cost around 30.32 ct/kWh. It is much more expensive than the price of district heating, even before considering investment in the boiler-house installation. The cost of heating, investment included, would amount 37.52 ct/kWh. In this case, if consumers disconnect from the district heating system, they will suffer considerable losses instead of deriving economic benefit.

Liquid fuel. It is an option difficult to implement technically since, as in the case of a liquefied gas, special fuel facilities must be fitted next to residential houses. In addition, it is related to significant investment. The market price of diesel fuel quoted by “Orlen Lietuva” (as of 24 November 2010) is LTL 3210.12/1000 l. The calorific value is 42480 kJ/kg. With the average 90% boiler-house efficiency, the fuel component would cost around 36.38 ct/kWh. The cost of heating, the boiler-house installation investment included, would amount 43.58 ct/kWh therefore it can not compete with district heating prices.

Biofuels (woodchips, sawdust, wood). It is an option difficult to implement technically since special fuel hoppers or storages have to be fitted next to residential houses. The given option shall be rejected as technically impossible in densely built-up residential and public quarters. Biofuel use might be considered in sparsely built-up industrial areas.

Let us make preliminary assessments of the expected price of heat generated in a biofuel boiler-house. According to the data provided by the National Control Commission for Prices and Energy in October 2010, the average price of heat produced using biofuels is 63.09 LTL/MWh (where suppliers are paid for the quantity of heat produced). Thus, the fuel component for heating energy would cost about 6.3 ct/kWh.

The evaluation of investment in equipment purchase (admitting it is 20% higher than in the case of natural gas) and bank interest shows that the price of heating energy by burning wood could be around 14.94 ct/kWh.

This is the price of heating obtained where personal work on fuel handling, the boiler-house maintenance and burning (as done in individual houses) is excluded. Where the capacity of a boiler-house is bigger and larger objects such as multi-storey buildings, quarters, and companies are serviced, the boiler-house shall require service staff, controllers and stokers. It is assumed that four maintenance positions must be filled during the heating season and one position during the non-heating season. According to the Lithuanian Department of Statistics, average monthly gross earnings in economics amounted to LTL 2055.8 in the second quarter of 2010. These earnings equate to approximately LTL 2000 accordingly the annual total amount of remuneration will constitute:

4 x 2000 [LTL/month] x 7 [month] +1 x 2000 [LTL/month] x 5 [month] = LTL 66.000 per year

The remuneration portion per unit of the heat produced will be:

66.000 [LTL/year] / 357.220 [kWh/year] = 0.0185 LTL/kWh or 18.5 ct/kWh.

As far as we can see, remunerations for the boiler-house maintenance workers make up a large portion consequently the final cost of heat production from relatively low-priced biofuels shall rise to 33.4 ct/kWh.

Wood pellets. They present a technically realizable version with an easily automated combustion process. Underground hoppers for fuel supplies can be installed. However, such an option shall be rejected as technically impossible in densely built-up residential and public quarters due to the lack of storage space.

Let us make preliminary assessments of the price of heat generated in a pellet boiler-house. Pellet price is around LTL 485 per ton (bulk purchase). The average calorific value of fuel is 4.84 kWh/kg. With the average 80% boiler-house efficiency, the fuel component would cost around 12.5 ct/kWh.

After making an assessment of investments (20% higher than in the case of natural gas) and bank interest, assuming that one position of the boiler-house maintenance worker shall suffice all year round (process automation), the average cost of heating could rise to 27.85 ct/kWh.

Electric power. Heating and hot water preparation using electric power is technically quite easy to be implemented but this requires additional investment in the reconstruction of the existing system. Under the current rate structure, residents would have to pay 45 ct/kWh for the consumed electricity alone. Even by taking ultimate advantage of the reduced rate of 34 ct/kWh applicable at night and on weekends, the average cost of heating would be around 40 ct/kWh, i.e. considerably higher than the price of district heating. The given price will still increase following an assessment of investments consequently electric heating installation in multi-storey residential and other buildings is not economically viable.

Electric power is appropriate to be used in thermoaccumulative networks equipped with heat pumps. However current investments in such a network are significant and the final calculated price of heating energy is quite high.

Cost comparison of heating energy generated from various fuels in different types of boiler-houses is presented in Table 1.

Table 1. Heating Cost Comparison for Individual Boilers

Energy Source Used	Fuel Component (ct/kWh)	Investment Component (ct/kWh)	Total Cost (ct/kWh)	Comments
District heating	-	-	24.2	
Natural gas	18.62	7.20	25.82	Technically realizable. The price of heating energy is competitive to the price of district heating.
Liquefied gas	30.32	7.20	37.52	Technically realizable but the price of heating energy is considerably higher than the price of district heating.
Diesel fuel	36.38	7.20	43.58	Technically realizable but the price of heating energy is considerably higher than the price of district heating.
Biofuel (woodchips, wood)	6.3	Investment 8.64 remuneration 12	33.4	The price is higher than that of district heating. Moreover, the given way is difficult to implement in the case of apartment houses because of the shortage of fuel storage area, maintenance inconveniences, and pollution.
Wood pellets	12.5	Investment 7.65 remuneration 4.37	27.85	Technically realizable. The price of heating energy is competitive to the price of district heating. Easily automated fuel supply to the boiler.
Electric power	40	-	40	Technically realizable but the price of heating energy is considerably higher than the price of district heating.

As far as we can see from the data, the price of district heating is the lowest among the given alternatives. In addition, other risks and factors affecting the decision whether or not to disconnect from the district heating system could be isolated:

- the lack of an alternative heating source. In case of disruption in the supply of natural gas, for instance, consumers would remain without heating for a while. Electrical wiring is not included in heating needs, and maintenance of heat reserved in the existing district heating system would impose additional costs that reduce the appropriateness of the investment;
- heat consumer insolvency: not all residents are able to pay (on time) for services, and it can rebound on other residents of the apartment building;
- an increase in the costs of heating owing to a compensation for other users of the system whereas the compensation fee must be assessed for disconnected consumers to offset an increase in the costs for other users of the system under the Law on Heating Sector;
- the loss of the aesthetic look of the building and the surroundings caused by appearance of a boiler-house, chimney, etc. In particular, a negative effect occurs where chimneys protrude from the walls resulting from the installation of a self-contained heating system. This spoils the aesthetic look of the building and affects the living environment adversely. Often smoke is sucked up into the residential premises;

• the absence of options to control energy consumption for heating and lack of the accounting system in individual apartments. After disconnection from the district heating system without replacing the heat supply system of the apartment building, the possibility of the residents' abuse of the system failures persists.

Feasibility Study for Heat Cost Allocation System Installation on Apartment buildings

Taking into account consumer interests, the easiest way to reduce bills for heating is the opportunity to reduce heat consumption oneself. To this end, thermostats (Fig. 1) should be mounted on radiators in the flats of the apartment building and the heat cost allocation system (Fig. 2) should be installed allowing individual measurements of the quantity of heat consumed in the apartment. The system must be installed throughout the house.

The implementation of the heat cost allocation system in the apartment building provides a number of benefits:

- the opportunity to individually control heat consumption according to needs;
- motivation to conserve heat and to take care of the apartment thermal insulation (to change the windows, to insulate the walls);
- elimination of a heat excess and abuse possibility when some residents put in too many heating sections without leave;
- remote data retrieval prevents manipulation in meter reading;
- the computer program adjusts the reading of the heat cost allocators by the ratios of the apartment position, temperature transmission and type of the radiator (its design and materials it is made from), therefore the residents of corner, top floor and bottom floor apartments will not incur higher heating costs for the specific position of their apartments;
- residents can keep the daily track of alterations in their bills and limit needs beyond their financial capabilities;
- the heat cost allocation system allows reducing heating bills by 20-30%.

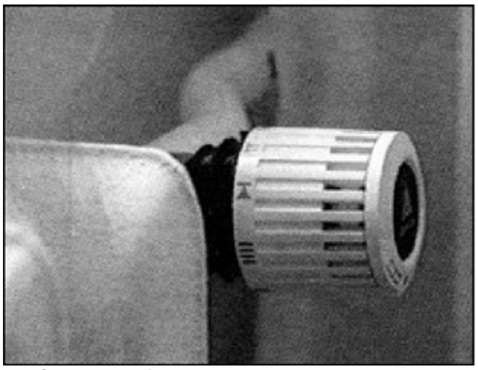


Fig. 1. Thermostat

Fig. 2. Heat Cost Allocator

A few years' experience in the system operation in apartment buildings all over the country has shown that despite all the benefits, the heat cost allocation system has a shortfall which is a disagreement among the residents of the apartments about heat consumption accounting methods.

It should be noted that the apartment-level heat accounting in an apartment building is economically feasible in newly constructed houses or houses undergoing complex renovations. In the matter of non-renovated old buildings, there is no point in the apartment-level heat accounting due to a high heat demand of the given apartments for heating. Owners of apartments in old blocks of flats are deprived of the heat conservation opportunity because to ensure comfort within their apartments, the maximum amount of heat must be constantly supplied. It is therefore advisable to improve thermal properties of partitions in an old block of flats in the first place, and afterwards (or simultaneously if the building is undergoing complex renovations) to invest in the installation of heat meters for each apartment.

Let us assess the implementation costs of the heat cost allocation system in a standard old 5 storey apartment building containing 45 apartments. The system is worth to be installed exclusively in a renovated house. The renovation of the typical old 5 storey apartment building containing 45 apartments, which includes: substituting old windows, insulating walls, the plinth and the roof, and installing the heat cost allocation system, would cost about 900 thousand litas. Implementation of these measures would save about 40-50% consumption of thermal energy in the building. The approximate payback period would be 25 years. Below assessed are the investments in the heat cost allocation system implementation alone.

Where the heating unit in a house has been renovated (e.g., Gegužių St. 29, Sevastopolio St. 1, Krymo St. 4, etc.), stands and radiators in apartments shall be reconstructed: thermofication water pressure compensation controllers shall be installed in separate stands of the heating system to ensure an equal heating of the entire house premises and piping insulation shall be arranged. Thermostats and heat meters, allocators, shall be mounted on radiators.

According to “Vilniaus energija” UAB, the installation price of the heat cost allocation system is about LTL 29.5 per square meter of apartment space. The useful floor area of the standard five storey house containing 45 apartments approximately equals 2325 m^2. Thus, the installation of the heat control and accounting system in such a house would cost about LTL 68.588.

The payback period for the heat cost allocation system installation in the standard five storey house containing 45 apartments has been estimated for several cases (Table 2). It should be noted that the investment does not include the costs of the house walls (partitions) thermal insulation and the heating unit renovation.

Table 2. Economic Indicators of Heat Control & Accounting System for Five Storey Apartment Building

Amount of Heat Conserved %	Amount of Heat Conserved kWh	Funds Saved LTL/year	Payback Period in Years
30	107166	25934	2,6
25	89305	21612	3,17
20	71444	17289	3,97
15	53583	12967	5,29
10	35722	8645	7,93
5	17861	4322	15,87

The experience in project implementation shows that the reconstructed heating unit with reorganized heat and hot water supply systems reduces heat consumption by 15-20% while the investment pays off in 3-5 years. It should be noted that the installation of thermostats with heat cost allocators merely enables residents to regulate the room temperature themselves. Heat can be conserved by residents who are often absent or do not live throughout or maintain the room temperature below +18 ° C, in other words, who save at the expense of comfort.

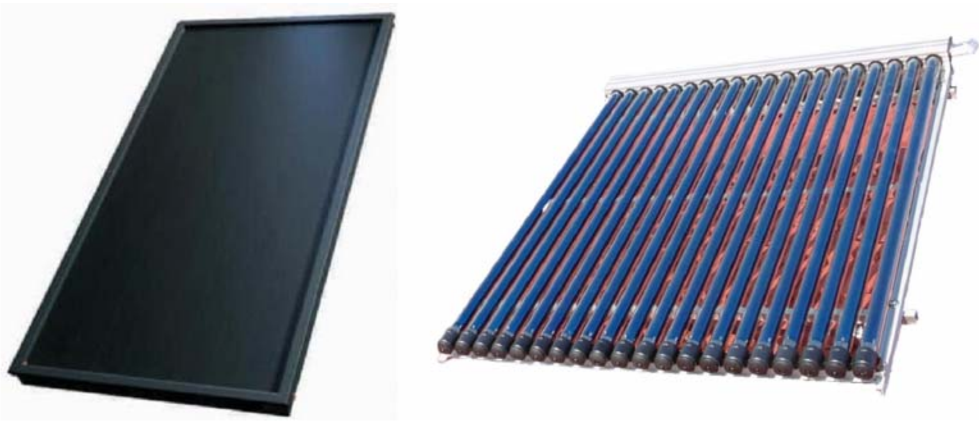
It should be noted that the installation of the heat cost allocation system has been recently included in a list of recommended home renovation measures consequently residents can expect 15 percent compensation for costs. In this case, the payback period would be even shorter.

Feasibility Study for Usage of Renewable Energy Sources in Apartment Buildings

The analysis of the potential for using a renewable energy source for heat generation in an apartment building can include two options: solar energy or wind energy. Wind power plants and solar photocells are designed to produce electric power. The possibility of using electric power as the source of heat production is technically feasible but in order to produce, for example, the annual quantity of heat consumed by the apartment building, a 250-300 kW wind turbine or a 450 kW solar photo-thermal power plant occupying an area of some 3000 m^2 of space is required which technically is an impracticable task for a single block of flats. For the above reasons, these options shall be rejected as technically impossible.

Solar collectors are designed for heat production from renewable energy sources. Depending on the production technology of sunlight-absorbing units, there are basically two types of solar collectors: flat plate and evacuated tube. A less efficient flat plate collector consists traditionally of an insulated metal box with a glass cover (the glazing) and a metal absorber plate. The other type is evacuated tube solar thermal collectors which are equipped with high efficiency vacuum elements (Fig. 3).

The advantages of evacuated tube solar collectors gained over flat plate collectors manifest themselves under our latitude climate conditions. The efficiency of evacuated tube solar collectors is higher than the efficiency of flat plate collectors at low ambient air temperatures. Also, the former are more efficient when exposed to high temperatures (~100 degrees) in summer. Typically, the life of such a tube ranges from 25 to 30 years. Manufacturers provide a guarantee to achieve performance up to 10 years. The rate of heat loss from a vacuum container is very low so the heat carrier can be heated to 120-160˚.



a b

Fig. 3. Types of Solar Collectors: Flat Plate (a) and Evacuated Tube (b)

The advantages of evacuated tube solar collectors gained over flat plate collectors manifest themselves under our latitude climate conditions. The efficiency of evacuated tube solar collectors is higher than the efficiency of flat plate collectors at low ambient air temperatures. Also, the former are more efficient when exposed to high temperatures (~100 degrees) in summer. Typically, the life of such a tube ranges from 25 to 30 years. Manufacturers provide a guarantee to achieve performance up to 10 years. The rate of heat loss from a vacuum container is very low so the heat carrier can be heated to 120-160°.

The question which type of solar collectors should be used for an apartment building cannot be answered unambiguously. High-quality evacuated tube collectors are twice as expensive as flat plate collectors of the same capacity. From October to February, an increase in the amount of energy converted is small accordingly flat plate collectors have been chosen for feasibility assessment in order to reduce investment spending.

Let us evaluate the potential for using evacuated tube solar collectors for an apartment building's hot water production. The 9 storey building No. 11 in Sevastopolio Street, which consumes a lot of heat energy, has been chosen for calculations. The calculations were done using the EnergyPro program.

According to perennial observation data, the average annual total solar radiation incident upon horizontal surface in Lithuania is about 1000 kWh/m^2. The amount is almost the same as in Denmark and larger than in Sweden where the use of solar energy is especially popular. About 88 percent of annual solar energy received on the Earth's surface perpendicular spans over seven months: March, April, May, June, July, August, and September. Such distribution of the amount of solar energy allows adjusting the operation of solar collectors to heating of buildings from one season to the next: in winter, hot water is supplied by the individual home heating systems meanwhile during the non-heating season, it comes from the sun.

A solar water heating system shall be installed by mounting the solar collectors on the roof (Fig. 4) therefore the system is calculated according to the roof area measurements.

Fig. 4. Roof of Apartment Building No. 11 in Sevastopolio Street

The roof area is 452 m^2 and the total roof area applicable for installation of the solar collectors is 410 m^2. The capacity of the solar collector system being installed is determined by the configuration of the apartment building roof applicable for use. The preliminary assessed collector area feasible to install is up to 300 m^2. The collector tilt angle is 35° and the collectors are directed towards the south.

The solar output would be stored in a water container with a volume calculated from the residents' daily hot water usage. The assumptions are made that daily hot water consumption is about 30 l per capita and 135 residents live in the 54 apartments of the apartment building. Then their demand for hot shall approximately total 4 m^3/day. Taking into account variations in demand, the water volume shall be increased to 5 m^3.

Such a system of solar collectors will produce about 71.5 MWh per year. In 2009, the apartment building No. 11 in Sevastopolio Street consumed 167.466 kWh of energy for heating water. The result is that the solar collector system would supply 43% of the total heat demand in the apartment building’s hot water supply network, and approximately 96 MWh/year or 57% of the heat should be additionally supplied by the district heating network.

The price of German 300 m^2 flat plate collectors is LTL 187.740 (Terma UAB Price List). The guide price for a hot water storage tank of 5 m^3 in volume is LTL 16.200 (Terma UAB Price List). The guide price for mounting materials is LTL 35.000 and the guide price for installation is about LTL 50.000. Total guide investment in the solar collector system installation is LTL 288.940. It should be noted that the price depends on the quality of equipment and technology.

The calculations show that the usage of the solar water heating system would result in the annual savings of about LTL 17.300. This means that the system’s simple payback period would be 16-17 years which is beyond the life of the solar collectors. The EU support for the project implementation would shorten the payback period, and create an opportunity to use higher quality equipment.

Generalization: Alternative Ways to Produce Heat & Heat Saving Opportunities

Partial or complete decentralization of the existing district heating system in the quarter is technically feasible. A sufficiently well-developed low-pressure natural gas network ensures gas supply for household needs.

The examination of alternative ways to heat apartment buildings aims to find a solution to ensure a reliable supply of heat, which would be environmentally and economically optimal to an entire urban community. After completing the analysis of potential individual heat supply options, it was found that under the current costs of gas and other energy resources, it is economically inappropriate for consumers to disconnect from the district heating system. In all cases, the measured price of heat was higher than the price of district heating. This means that in the long term, heating costs for consumers would be higher than in the district heating case. This is at variance with a low consumption concept.

The economic evaluation of the heat control and accounting system implementation has shown that this is one of the best ways to bring lower heating bills for residents. Also, the payback period is directly proportional to the amount of heat conserved therefore residents are interested in saving heat and looking to the thermal characteristics of their house. Given heat savings of 15-20%, investments would pay off in 3-5 years. The economic evaluation of the solar water heating system installation has shown that the project is not sufficiently viable in terms of the technical life of solar collectors, and it will not produce substantial economic benefits for the short term. Subsidies received would have a substantial impact on the project performance.

Evaluation of Main Heat Supply Network Modernization

About 3 km of main networks have been laid out in the area in question. According to preliminary estimates, the heat loss from the main pipelines in question is 2954 MWh/year during a normative year. Notice should be taken that the bulk of the main pipelines laid out in the area (approximately 684 meters) perform the encircling function of the city’s central heat transfer network therefore, even after complete abandonment of the district heating scheme within the given area, these mains will have to be preserved and continue to function. The main pipeline scheme is presented in Figure 5.

Fig. 5. Main Heat Pipeline Scheme

Based on the pipeline hydraulic simulation results, the capacity of the existing main pipelines is, in places, greater than that required by the existent heat energy consumers, which means that during the reconstruction of pipelines, diameters of some sections can be replaced with smaller-diameter pipes.

The lengths of the main pipelines before and after the reconstruction are summarised in Table 3.

Table 3. Summary Table of Main Pipeline Lengths

Nominal Pipe Diameter	Present Lengths of Main Pipes (m)	Lengths of Main Pipes after Reconstruction (m)
DN150	460	
DN200	964	1424
DN250	410	
DN300	539	579
DN350		213
DN400		157
DN500	214	214
DN600	470	470

After the replacement of all main pipes, heat loss from the given pipelines will be cut by half to approximately 1550 MWh/year, i.e. the reconstruction will result in the savings of 1404 MWh/ year, or under the current cost of heat energy production it will amount LTL 161.46 thousand a year. Aggregate construction cost indices were employed to estimate that the reconstruction of overall main networks will amount LTL 6648 thousand wherefore a simple payback period will be 6648/161.46 = 41 years.

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Analysis of Alternative Ways to heat Buildings

In theory, heat can be supplied to quarter apartment buildings in a variety of ways: using district heating or decentralization of heat supply, using natural gas or liquefied gas, wood, electric power, and other fuels in individual boiler-houses for heating. Each of these methods will be discussed separately.

As an example, a 5 storey stone house containing 22 apartments has been selected. The total usable area of the house is 1213 m^2, the installed heating capacity is 128.86 kW, and power for hot water is 214 kW. Annual heat consumption in the apartment building is estimated at about 238.48 MWh per year. The options to disconnect from the current district heating scheme and install an autonomous boiler-house are considered.

The capacity of a boiler-house installed in the given block of flats shall cover the maximum needs of the consumers, 342.86 kW. It is assumed that the autonomous boiler-house financing is carried out on a 15-year loan with an 8% annual interest. Based on the formula for disconnecting heat consumer facilities from the heat supply system, presented in economic assessment methodology: 60 000+295×P, where P is power [kW], the investment for a boiler-house with such a capacity would be around 161 thousand litas, and the total amount including the bank interest would make 282 thousand litas. The annual amount to be repaid (annuity) will be **18.8 thousand** litas. The life of the boiler-house shall be 15 years.

In each case, the price of heating energy produced in the autonomous boiler-house with different fuels will be measured. It is assumed that the boiler-house installation investments shall remain the same irrespective of the fuel used for heating: natural gas, liquid fuel or liquefied gas.

Natural gas. In proportion to the annual consumption of heat, 238.48 MWh, gas consumption will amount about 28400 Nm^3/year. The adopted average boiler-house efficiency is 90% and gas energy value is 9.33 kWh/Nm^3 (the average in 2009). Gas price is LTL 1560/1000Nm^3 (including VAT) plus a nonvolatile component of LTL 14.05 per month (including VAT). The price has been withdrawn from the official quotation currently approved by “Lietuvos dujos” AB and valid until 31 December 2010. The monetary value of annual fuel consumption will be 44.47 thousand litas.

The total annual fuel and investment consumption will make:

44.47 +18.8 = LTL 63.27 thousand/year.

Based on these calculations, heat price for consumers will be:

63.270 [LTL/year] / 238.480 [kWh/year] = 0.2653 LTL/kWh or 26.53 ct/kWh.

The price of a fuel component makes 18.6 ct/kWh, while an investment component is 7.93 ct/kWh. We can see that the estimated total cost is 26.53 ct/kWh higher than a fixed monomial district heating price which equals 24.2 ct/kWh. It should be noted that the autonomous boiler-house costs will include additional operating expenditure for water, electricity, current repairs, and maintenance; moreover a potential rise in gas prices which will further increase the heat price has not been rated. Therefore, we can state that the autonomous boiler-house installation does not provide consumers with economic utility.

Analysing the case where a self-contained heating system is installed by every resident, the heat price would be still higher than in the event of a communal boiler-house since a gas tariff would increase to consumers in smaller groups. In addition, rules for installation of gas equipment [Construction Technical Regulations STR 2.08.01:2004 "Gas Systems in Buildings" approved by Order No. 702 of 24 December 2003 of the Minister of Environment of the Republic of Lithuania ("Valstybės žinios", 2004, No. 21-653)] lay down requirements for chimney connection: "Clause 75. Gas boilers of not more than three consumers are allowed to be connected to a single chimney. The distance between the attachment points of gas boilers and the chimney on different floors of the building must be at least 6.5 m. Where the distance between the attachment point of the communal chimney and the top of the chimney is less than 4 m, a separate chimney for the gas boiler has to be installed providing the necessary traction". As we can see, these requirements are hardly technically feasible since the installation of gas facilities to all residents of the tower-block shall provide for more than one chimney, which significantly increases the total investment.

Liquefied gas. Use of liquefied petroleum gas in autonomous boiler-houses presents one of technical options however tanks shall be installed near heated buildings to this end. Such a solution is difficult to implement technically. The market price of liquefied petroleum gas (propane butane mix) quoted by "Orlen Lietuva"AB (as of 24 November 2010) is LTL 3419.87 per ton (including VAT). The gas phase density is 2.32 kg/Nm^3 and the calorific value is 104650 kJ/Nm^3. With the average 90% boiler-house efficiency, the fuel component would cost around 30.32 ct/kWh. It is much more expensive than the price of district heating, even before considering investment in the boiler-house installation. The cost of heating, investment included, would amount 38.21 ct/kWh. In this case, if consumers disconnect from the district heating system, they will suffer considerable losses instead of deriving economic benefit.

Liquid fuel. It is an option difficult to implement technically since, as in the case of a liquefied gas, special fuel facilities must be fitted next to residential houses. In addition, it is related to significant investment. The market price of diesel fuel quoted by "Orlen Lietuva" (as of 24 November 2010) is LTL 3210.12/1000 l. The calorific value is 42480 kJ/kg and density is 0.84 t/m^3. With the average 90% boiler-house efficiency, the fuel component would cost around 35.98 ct/kWh. The cost of heating, the boiler-house installation investment included, would amount 43.86 ct/kWh therefore it can not compete with district heating prices.

Biofuels (woodchips, sawdust, wood). It is an option difficult to implement technically since special fuel hoppers or storages have to be fitted next to residential houses. The given option shall be rejected as technically impossible in densely built-up residential and public quarters. Biofuel use might be considered in sparsely built-up industrial areas.

Let us make preliminary assessments of the expected price of heat generated in a biofuel boiler-house. According to the data provided by the National Control Commission for Prices and Energy in October 2010, the average price of heat produced using biofuels is 63.09 LTL/MWh (where suppliers are paid for the quantity of heat produced). Thus, the fuel component for heating energy would cost about 6.3 ct/kWh.

The evaluation of investment in equipment purchase (admitting it is 20% higher than in the case of natural gas) and bank interest shows that the price of heating energy by burning wood could be around 15.76 ct/kWh.

This is the price of heating obtained where personal work on fuel handling, the boiler-house maintenance and burning (as done in individual houses) is excluded. Where the capacity of a boiler-house is bigger and larger objects such as multi-storey buildings, quarters, and companies are serviced, the boiler-house shall require service staff, controllers and stokers. It is assumed that four maintenance positions must be filled during the heating season and one position during the non-heating season. According to the Lithuanian Department of Statistics, average monthly gross earnings in economics amounted to LTL 2055.8 in the second quarter of 2010. These earnings equate to approximately LTL 2000 accordingly the annual total amount of remuneration will constitute:

4 x 2000 [LTL/month] x 7 [month] + 1 x 2000 [LTL/month] x 5 [month] = LTL 66000 per year

The remuneration portion per unit of the heat produced will be:

66.000 [LTL/year] / 357.220 [kWh/year] = 0.0185 LTL/kWh or 18.5 ct/kWh.

As far as we can see, remunerations for the boiler-house maintenance workers make up a large portion consequently the final cost of heat production from relatively low-priced biofuels shall rise to 34.26 ct/kWh.

Wood pellets. They present a technically realizable version with an easily automated combustion process. Underground hoppers for fuel supplies can be installed. However, such an option shall be rejected as technically impossible in densely built-up residential and public quarters.

Let us make preliminary assessments of the price of heat generated in a pellet boiler-house. Pellet price is around LTL 485 per ton (bulk purchase). The average calorific value of fuel is 4.84 kWh/kg. With the average 80% boiler-house efficiency, the fuel component would cost around 12.52 ct/kWh.

After making an assessment of investments (20% higher than in the case of natural gas) and bank interest, assuming that one position of the boiler-house maintenance worker shall suffice all year round (process automation), the average cost of heating could rise to 32.04 ct/kWh.

Electric power. Heating and hot water preparation using electric power is technically quite easy to be implemented but this requires additional investment in the reconstruction of the existing system. Under the current rate structure, residents would have to pay 45 ct/kWh for the consumed electricity alone. Even by taking ultimate advantage of the reduced rate of 34 ct/kWh applicable at night and on weekends, the average cost of heating would be around 40 ct/kWh, i.e. considerably higher than the price of district heating. The given price will still increase following an assessment of investments consequently electric heating installation in multi-storey residential and other buildings is not economically viable.

Electric power is appropriate to be used in thermoaccumulative networks equipped with heat pumps. However current investments in such a network are significant and the final calculated price of heating energy is quite high. Cost comparison of heating energy generated from various fuels in different types of boiler-houses is presented in Table 1.

Table 1. Heating Cost Comparison for Individual Boilers

Energy Source Used	Fuel Component (ct/kWh)	Investment Component (ct/kWh)	Total Cost (ct/kWh)	Comments
District heating	-	-	24.2	
Natural gas	18.6	7.93	26.53	Technically realizable. The price of heating energy is competitive to the

				price of district heating.
Liquefied gas	30.32	7.89	38.21	Technically realizable but the price of heating energy is considerably higher than the price of district heating.
Diesel fuel	35.98	7.88	43.86	Technically realizable but the price of heating energy is considerably higher than the price of district heating.
Biofuel (woodchips, wood)	6.3	Investment 15.76 remuneration 12.2	34.26	The price is higher than that of district heating. Moreover, the given way is difficult to implement in the case of apartment houses because of the shortage of fuel storage area, maintenance inconveniences, and pollution
Wood pellets	12.52	Investment 9.46 remuneration 10.06	32.04	Technically realizable. The price of heating energy is competitive to the price of district heating. Easily automated fuel supply to the boiler.
Electric power	40	-	40	Technically realizable but the price of heating energy is considerably higher than the price of district heating.

As far as we can see from the data, the price of district heating is the lowest among the given alternatives. In addition, other risks and factors affecting the decision whether or not to disconnect from the district heating system could be isolated:

- the lack of an alternative heating source. In case of disruption in the supply of natural gas, for instance, consumers would remain without heating for a while. Electrical wiring is not included in heating needs, and maintenance of heat reserved in the existing district heating system would impose additional costs that reduce the appropriateness of the investment;
- heat consumer insolvency: not all residents are able to pay (on time) for services, and it can rebound on other residents of the apartment building;
- an increase in the costs of heating owing to a compensation for other users of the system whereas the compensation fee must be assessed for disconnected consumers to offset an increase in the costs for other users of the system under the Law on Heating Sector;
- the loss of the aesthetic look of the building and the surroundings caused by appearance of a boiler-house, chimney, etc. In particular, a negative effect occurs where chimneys protrude from the walls resulting from the installation of a self-contained heating system. This spoils the aesthetic look of the building as well as adversely affects the living environment. Often smoke is sucked up into the residential premises;
- the absence of options to control energy consumption for heating and lack of the accounting system in individual apartments. After disconnection from the district heating system without replacing the heat supply system of the apartment building, the possibility of the residents' abuse of the system failures persists.

Taking into account consumer interests, the easiest way to reduce bills for heating is the opportunity to reduce heat consumption oneself. To this end, thermostats (Fig. 1) should be mounted on radiators in the flats of the apartment building and the heat cost allocation system (Fig. 2) should be installed allowing individual measurements of the quantity of heat consumed in the apartment. The system must be installed throughout the house.

The implementation of the heat cost allocation system in the apartment building provides a number of benefits:

- the opportunity to individually control heat consumption according to needs;
- motivation to conserve heat and to take care of the apartment thermal insulation (to change the windows, to insulate the walls);
- elimination of a heat excess and abuse possibility when some residents put in too many heating sections without leave;
- remote data retrieval prevents manipulation in meter reading;
- the computer program adjusts the reading of the heat cost allocators by the ratios of the apartment position, temperature transmission and type of the radiator (its design and materials it is made from), therefore the residents of corner, top floor and bottom floor apartments will not incur higher heating costs for the specific position of their apartments;
- residents can keep the daily track of alterations in their bills and limit needs beyond their financial capabilities;
- the heat cost allocation system allows reducing heating bills by 20-30%.

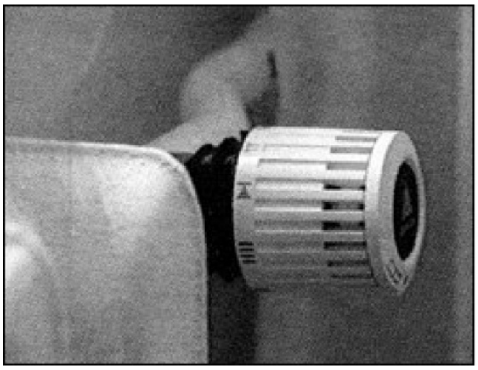


Fig. 1. Thermostat

Fig. 2. Heat Cost Allocator

A few years' experience in the system operation in apartment buildings all over the country has shown that despite all the benefits, the heat cost allocation system has a shortfall which is a disagreement among the residents of the apartments about heat consumption accounting methods.

It should be noted that the apartment-level heat accounting in an apartment building is economically feasible in newly constructed houses or houses undergoing complex renovations. In the matter of non-renovated old buildings, there is no point in the apartment-level heat accounting due to a high heat demand of the given apartments for heating. Owners of apartments in old blocks of flats are deprived of the heat conservation opportunity because to ensure comfort within their apartments, the maximum amount of heat must be constantly supplied. It is therefore advisable to improve thermal properties of partitions in an old block of flats in the first place, and afterwards (or simultaneously if the building is undergoing complex renovations) to invest in the installation of heat meters for each apartment.

Let us assess the implementation costs of the heat cost allocation system in a 5 storey stone house containing 22 apartments. As mentioned in the previous section, the renovated house specifically shall be worth to be equipped with the system accordingly only investments in the heat cost allocation system implementation will be assessed.

Let us assume that the heating unit in the house has been renovated. Stands and radiators in apartments shall be reconstructed then: thermofication water pressure compensation controllers shall be installed in separate stands of the heating system to ensure an equal heating of the entire house premises and piping insulation shall be arranged. Thermostats and heat meters, allocators, shall be mounted on radiators.

According to "Šiaulių energija" UAB, the installation price of the heat cost allocation system is about LTL 29.5 per square meter of apartment space. The useful floor area of the five storey house containing 22 apartments approximately equals 1213 m^2. Thus, the installation of the heat control and accounting system in such a house would cost about LTL 35.790.

The amount of heating energy each house saves is different therefore the payback period for the heat cost allocation system installation in the five storey house containing 22 apartments has been estimated for several cases (Table 2). It should be noted that the investment does not include the costs of the house walls (partitions) thermal insulation and the heating unit renovation.

The experience in project implementation shows that the reconstructed heating unit with reorganized heat and hot water supply systems reduces heat consumption by 15-20% while the investment pays off in 3-5 years. It should be noted that the installation of thermostats with heat cost allocators merely enables residents to regulate the room temperature themselves. Heat can be conserved by residents who are often absent or do not live throughout or maintain the room temperature below +18 ° C, in other words, who save at the expense of comfort.

Table 2. Economic Indicators of Heat Control & Accounting System for Five Storey Apartment Building

Amount of Heat Conserved %	Amount of Heat Conserved kWh	Funds Saved LTL/year	Payback Period in Years
30	71544	17313	2,1
25	59620	14428	2,5
20	47696	11542	3,1
15	35772	8657	4,1
10	23848	5771	6,2
5	11924	2886	12,4

It should be noted that the installation of the heat cost allocation system has been recently included in a list of recommended home renovation measures consequently residents can expect 15 percent compensation for costs. In this case, the payback period would be even shorter.

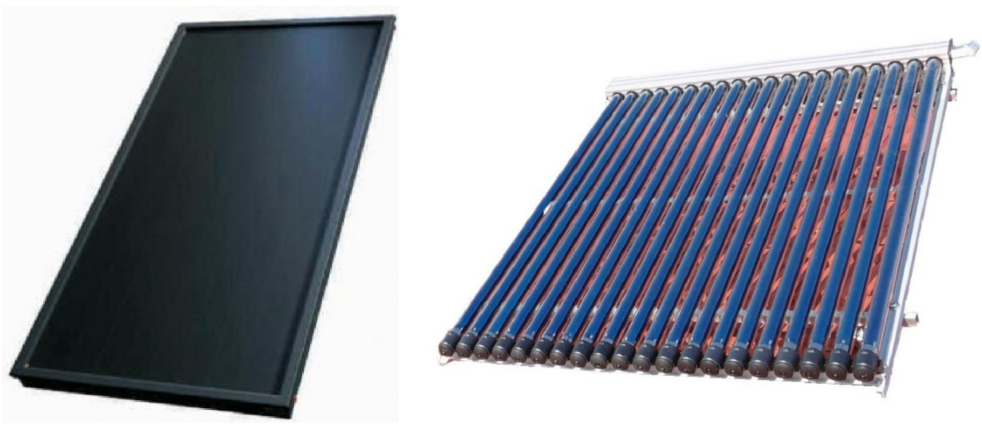
Feasibility Study for Usage of Renewable Energy Sources in Apartment Buildings

The analysis of the potential for using a renewable energy source for heat generation in an apartment building can include two options: solar energy or wind energy. Wind power plants and solar photocells are designed to produce electric power. The possibility of using electric power as the source of heat production is technically feasible but in order to produce, for example, the annual quantity of heat consumed by the apartment building containing 22 apartments, a 100-150 kW wind turbine or a 300 kW solar photo-thermal power plant occupying an area of some 2000 m^2 of space is required which technically is an impracticable task for a single block of flats. For the above reasons, these options shall be rejected as technically impossible.

Solar collectors are designed for heat production from renewable energy sources. Depending on the production technology of sunlight-absorbing units, there are basically two types of solar collectors: flat plate and evacuated tube. A less efficient flat plate collector consists traditionally of an insulated metal box with a glass cover (the glazing) and a metal absorber plate. The other type is evacuated tube solar thermal collectors which are equipped with high efficiency vacuum elements (Fig. 3).

The advantages of evacuated tube solar collectors gained over flat plate collectors manifest themselves under our latitude climate conditions. The efficiency of evacuated tube solar collectors is higher than the efficiency of flat plate collectors at low ambient air temperatures. Also, the former are more efficient when exposed to high temperatures (~100 degrees) in summer. Typically, the life of such a tube ranges from 25 to 30 years. Manufacturers provide a guarantee to achieve performance up to 10 years. The rate of heat loss from a vacuum container is very low so the heat carrier can be heated to 120-160°.

The question which type of solar collectors should be used for an apartment building cannot be answered unambiguously. High-quality evacuated tube collectors are twice as expensive as flat plate collectors of the same capacity. From October to February, an increase in the amount of energy converted is small accordingly flat plate collectors have been chosen for feasibility assessment in order to reduce investment spending.



a b

Fig. 3. Types of Solar Collectors: Flat Plate (a) and Evacuated Tube (b)

Let us evaluate the potential for using evacuated tube solar collectors for an apartment building's hot water production. The 5 storey building No. 156 in Vytauto

Street, which consumes a lot of heat energy, has been chosen for calculations. The calculations were done using the EnergyPro program.

According to perennial observation data, the average annual total solar radiation incident upon horizontal surface in Lithuania is about 1000 kWh/m^2. The amount is almost the same as in Denmark and larger than in Sweden where the use of solar energy is especially popular. About 88 percent of annual solar energy received on the Earth's surface perpendicular spans over seven months: March, April, May, June, July, August, and September. Such distribution of the amount of solar energy allows adjusting the operation of solar collectors to heating of buildings from one season to the next: in winter, hot water is supplied by the individual home heating systems meanwhile during the non-heating season, it comes from the sun. A solar water heating system shall be installed by mounting the solar collectors on the roof (Fig. 4) therefore the system is calculated according to the roof area measurements.

Fig. 4. Roof of Apartment Building No. 156 in Vytauto Street

The roof area is 307.26 m^2 and the total roof area applicable for installation of the solar collectors is 280 m^2. The capacity of the solar collector system being installed is determined by the configuration of the apartment building roof applicable for use. The preliminary assessed collector area feasible to install is up to 210 m^2. The collector tilt angle is 35° and the collectors are directed towards the south.

The solar output would be stored in a water container with a volume calculated from the residents' daily hot water usage. The assumptions are made that daily hot water consumption is about 30 l per capita and 60 residents live in the 22 apartments of the apartment building. Then their demand for hot shall approximately total 1.8 m^3/day. Taking into account variations in demand, the water volume shall be increased to 2.5 m^3.

Such a system of solar collectors will produce about 37.5 MWh per year. In 2009, the apartment building No. 156 in Vytauto Street consumed 81.11 kWh of energy for heating water. The result is that the solar collector system would supply 46% of the total heat demand in the apartment building's hot water supply network, and approximately 43.6 MWh/year or 54% of the heat should be additionally supplied by the district heating system.

The price of German 210 m^2 flat plate collectors is LTL 131.470 (Terma UAB Price List). The guide price for a hot water storage tank of 2.5 m^3 in volume is LTL 9140 (Terma

UAB Price List). The guide price for mounting materials is LTL 24.000 and the guide price for installation is about LTL 35.000. Total guide investment in the solar collector system installation is LTL 199.610. It should be noted that the price depends on the quality of equipment and technology.

The calculations show that the usage of the solar water heating system would result in the annual savings of about LTL 9100. This means that the system's simple payback period would be 20 years which is beyond the life of the solar collectors. The EU support for the project implementation would shorten the payback period, and create an opportunity to use higher quality equipment.

Generalization: Alternative Ways to Produce Heat & Heat Saving Opportunities

Partial or complete decentralization of the existing district heating system in the quarter is technically feasible. A sufficiently well-developed low-pressure natural gas network ensures gas supply for household needs.

The examination of alternative ways to heat apartment buildings aims to find a solution to ensure a reliable supply of heat, which would be environmentally and economically optimal to an entire urban community. After completing the analysis of potential individual heat supply options, it was found that under the current costs of gas and other energy resources, it is economically inappropriate for consumers to disconnect from the district heating system. In all cases, the measured price of heat was higher than the price of district heating. This means that in the long term, heating costs for consumers would be higher than in the district heating case. This is at variance with a low consumption concept.

The economic evaluation of the heat control and accounting system implementation has shown that this is one of the best ways to bring lower heating bills for residents. Also, the payback period is directly proportional to the amount of heat conserved therefore residents are interested in saving heat and looking to the thermal characteristics of their house. Given heat savings of 15-20%, investments would pay off in 3-5 years. The economic evaluation of the solar water heating system installation has shown that the project is not sufficiently viable in terms of the technical life of solar collectors, and it will not produce substantial economic benefits for the short term. Subsidies received would have a substantial impact on the project performance.

Evaluation of Main Heat Supply Network Modernization

About 0.68 km of main networks have been laid out in the area in question. According to preliminary estimates, the heat loss from the main pipelines in question is 727.4 MWh/year during a normative year. Notice should be taken that the bulk of the main pipelines laid out in the area (approximately 491 meters) perform the encircling function of the city's central heat transfer network therefore, even after complete abandonment of the district heating scheme within the given area, these mains will have to be preserved and continue to function. The main pipeline scheme is presented in Fig. 5

Based on the pipeline hydraulic simulation results, the capacity of the existing main pipelines is, in places, greater than that required by the existent heat energy consumers, which means that during the reconstruction of pipelines, diameters of some sections can be replaced with smaller-diameter pipes. The lengths of the main pipelines before and after the reconstruction are summarised in Table 3.

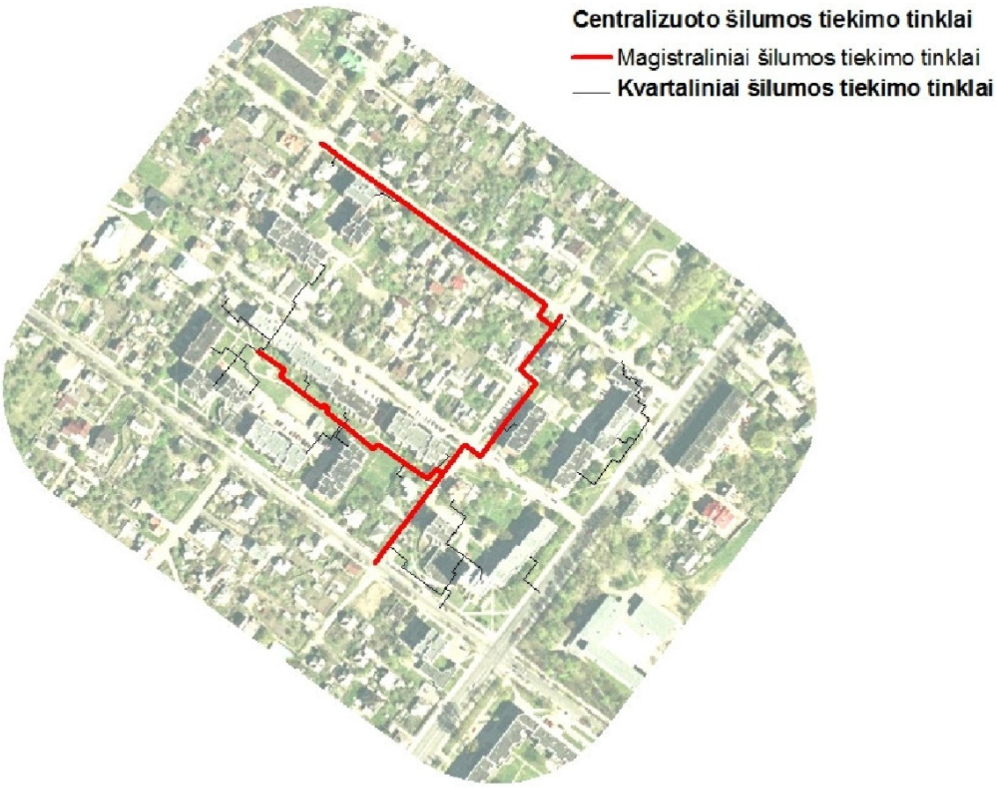


Fig. 5. Main Heat Pipeline Scheme

Table 3. Summary Table of Main Pipeline Lengths

Nominal Pipe Diameter	Present Lengths of Main Pipes (m)	Lengths of Main Pipes after Reconstruction (m)
DN100	95.89	
DN200		191.60
DN250	230.69	230.69
DN300	9.98	9.98
DN600	250.14	250.14
DN65	51.13	
DN80	44.58	

After the replacement of all main pipes, heat loss from the given pipelines will be cut by half to approximately 394.1 MWh/year, i.e. the reconstruction will result in the savings of 333.3 MWh/ year, or under the current cost of heat energy production it will amount LTL 45.32 thousand a year. Aggregate construction cost indices were employed to estimate that the reconstruction of overall main networks will amount LTL 1479.5 thousand wherefore a simple payback period will be 1479.5/45.32 = 32.6 years.