DETERMINATION OF COST-EFFECTIVE PIPELINES INSULATION OF SOLAR THERMAL SYSTEM

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1. Abstract

Baltic States climate is colder than the average European climate, and solar radiation amount is less. This gives an increased need to optimize the overall solar thermal system for the Baltic States conditions.

Solar thermal system manufacturers and vendors emphasize attention to solar energy absorption unit, but the rest of the system components remain in consumer choice. The publication describes a method for selection of the more energy effective and cost profitable pipe insulation type in solar thermal systems.

A certain proportion of the solar thermal system generated energy is missed as the heat loss in pipes between the solar energy absorbing devices to the heat-accumulation tank.

Pipe isolation is necessary for both an outdoor and indoor pipes of solar energy heating system. Outdoor pipes insulation should conformed to outdoor climate conditions and indoor pipes insulation accordingly should conform to indoor conditions.

Amount of pipe heat losses mostly depends on pipe diameter, heat carrier temperature, air temperature of the room or environment. Solar systems heat carrier temperature depends on solar radiation intensity in a given period, and the outside air temperature changes throughout the year. Instantaneous pipeline heat losses are calculated according to the instantaneous heat carrier, outdoor and indoor air temperatures. Results of calculations using the average values are not correct. Therefore, it is necessary to use modeling programs with precise meteorological data.

The amount of pipeline heat energy losses in accordance with the pipeline isolation type of solar thermal system was determined with the PolySun simulation program models.

The most popular heat pipe insulation materials in Baltic region were inspected and compared. The amount of absorbing energy value and heat losses were calculated and displayed in the graphic form.

As a result the method was defined. The method helps determine most cost-effective solar thermal systems pipe insulation type.

2. Introduction

Solar radiation intensity in the Baltic region is lower in comparison with the average European values. The average solar radiation intensity reaches 1100 kWh/m^2 per year in Baltic region. And outdoor air temperature range is below average values in Europe. Range of outdoor air temperature in the Baltic region is -3 ^{o}C in winter and +16 ^{o}C in summer. Therefore, there is a particular need to optimize the solar thermal system in the Baltic region.

A significant part of the solar thermal system generated energy is consumed as heat losses in pipelines, in stage from the solar energy absorbing devices to the heat-accumulating tank. Pipe isolation is necessary for both an outdoor and indoor pipes of solar energy heating system. Outdoor pipes insulation reduces heat output to the environment. Indoor pipes insulation reduces an additional heat release in indoor in hot period.

Solar thermal system manufacturers and vendors emphasize attention to solar energy absorption unit, but the rest of the system components remain in your choice.The publication describes a method for selection energy-cost effective pipe insulation type in solar thermal systems.

Metrological data collect from Solar Energy Polygon, which located in the Institute of Physical Energetic in Latvia.

3. Description of the IPE Solar Energy Testing Polygon

The IPE is the leading institute for solar energy research and development in Latvia.

As shown by experimental studies in Institute of Physical Energetics in Latvia, the application of solar collectors in Latvia can give good results. The energy of solar radiation can be employed for 1700-1900 hours annually.

- The reasons that make the use of solar energy attractive and suitable in Latvian conditions in the last years are as follows: High consumption of cold water in summer time (typically taking place in dwelling houses and such public institutions as hospitals, hotels & camps, sportive and summer camps).
- Tendency for price increasing.
- Construction of new buildings in which solar collectors and PV could be built-in. Latvian's energy policy now provides use of RES, accordingly to the "Law of Energy Efficiency in Building" article 7 recommends use of RES in the new buildings and renovated buildings.

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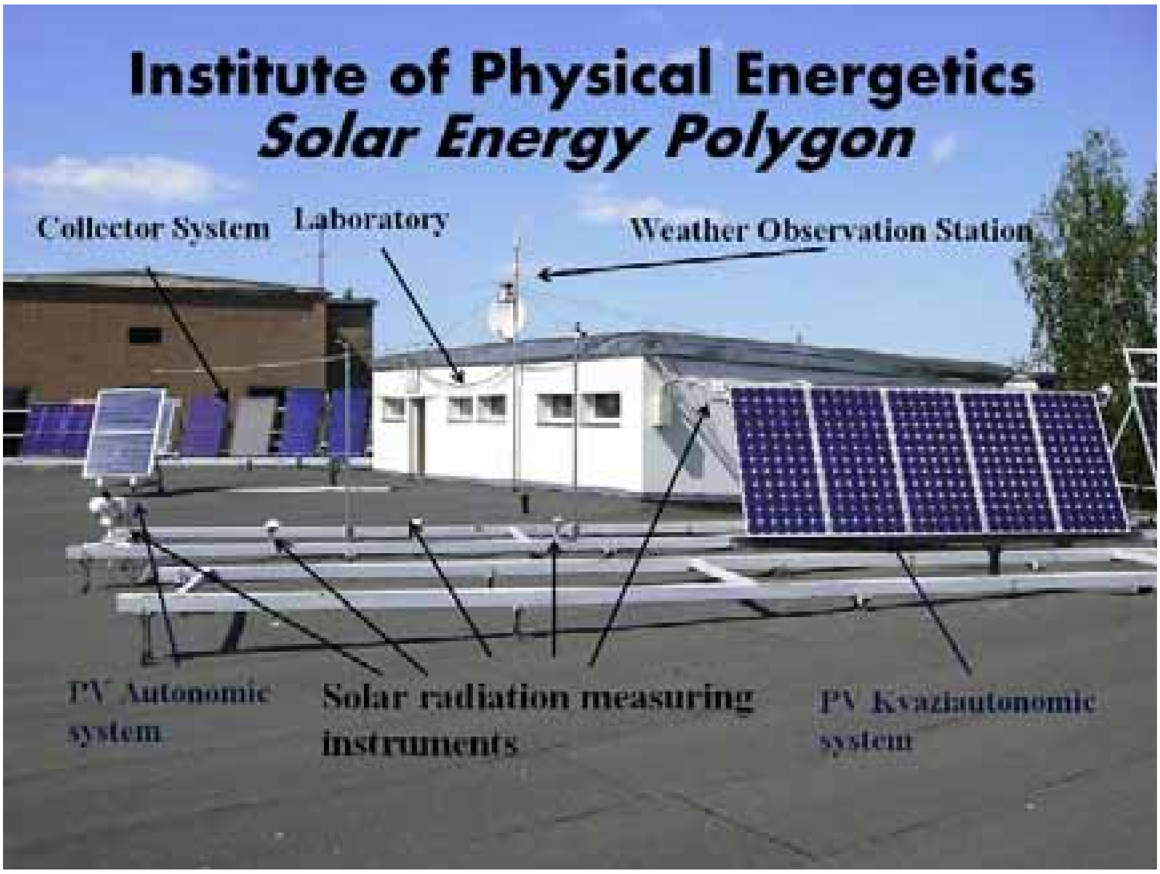

Fig.1. Solar Energy Polygon in the Institute of Physical Energetic

On the roof of the Institute of Physical Energetics a testing polygon for the devices using solar energy, which consists of the following four large parts (see Figure 1), has been created:

- An autonomous system for testing solar photo-voltaic (PV) elements.
- A quasi-autonomous system for testing PV elements.

- A system for testing solar collectors.
- Sensors of solar parameters and weather conditions.

The system for testing solar collectors consists of seven solar collectors, accessories, monitoring devices, control system's devices, and a heat accumulator. Each solar collector possesses its own separate frame capable of changing its slope to the horizon. The installed collectors are: five collectors of the popular producers and two self-made collectors. From each collector a pair of tubes is extended, which forms for it a separate heat carrying loop. A collector's loop contains a circulating pump, a heat meter, a bidirectional valve with drive, and a balance valve. For automatic pump operation, in the forward and backward directions of each collector's loop temperature sensors are arranged. Similar arrangement is provided for the meters and driven valves.

4. Methods and Results

Companies of Solar collector installation were interviewed to determine pipe insulation types used in Solar thermal systems. Questionnaire was determined that Stone wool insulation types with different thickness are most used in solar thermal systems. As well as, special for solar thermal systems, pre- insulated copper pipes are used in some cases. 20 mm and 30 mm Stone wool insulation types are most often used for solar collector circuit in indoor part, and 30 mm Stone wool insulation type the most commonly used in outdoor part. 4, 5, 6, 8 and 10 cm thick rock wool insulation types were included in the research list for deeper and wider issues research.

Amount of pipe heat losses mostly depends of pipe diameter, heat carrier temperature, air temperature of the room or environment. Solar systems for heating temperature depends on solar radiation intensity in a given period, and the outside air temperature changes throughout the year. Instantaneous pipeline heat losses are calculated according to the instantaneous heat carrier, environment and room air temperature. Calculation of average values is not correct. Therefore, it is necessary to use modeling programs with accurate meteorological data.

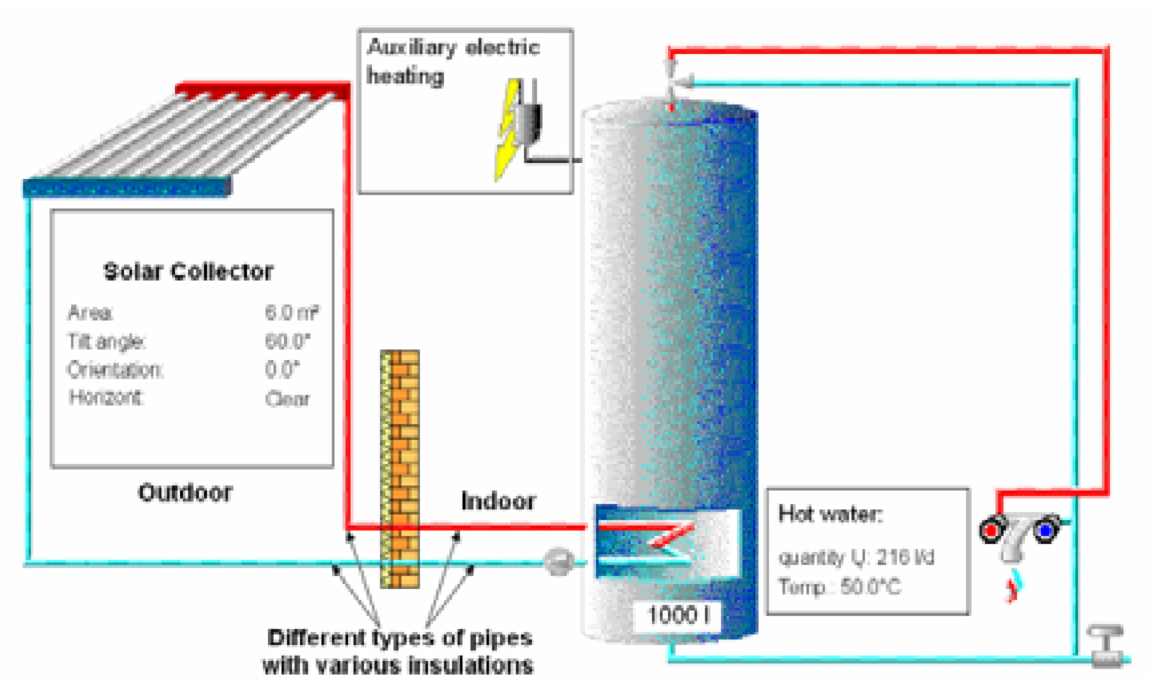

Fig. 2. Principal scheme of Solar thermal system.

Values of pipe heat losses were determined with the PolySun program modules for each type of pipe insulation and for three diameter dimensions. Model was created for hot water pre-heating with Solar thermal system in typical single-family house. The main elements of the Solar thermal system: 6 m2 area of absorbent (2 vacuum tube Solar collectors); 1m^3 accumulation tank; 15, 18 and 22 mm diameter dimension pipes. Hot water consumption was created with inconstant daily water demand and without the breaks in holidays. Hot water is heated from 10 to 50 ºC in this model. Solar collectors can provide about 65% of the hot water heats on consumption in the Baltic States under the climatic conditions, it is therefore necessary in addition to the heater. Hot water have extra heating with electricial heater. Electric heater placement does not affect the pipe heat losses in Solar collector contour.

Latvian meteorological data of several years entered into the program. PolySun Program results were compared with results from Solar Energy polygon. Program results can be suitable for other neighboring countries, such as Lithuania and Estonia.

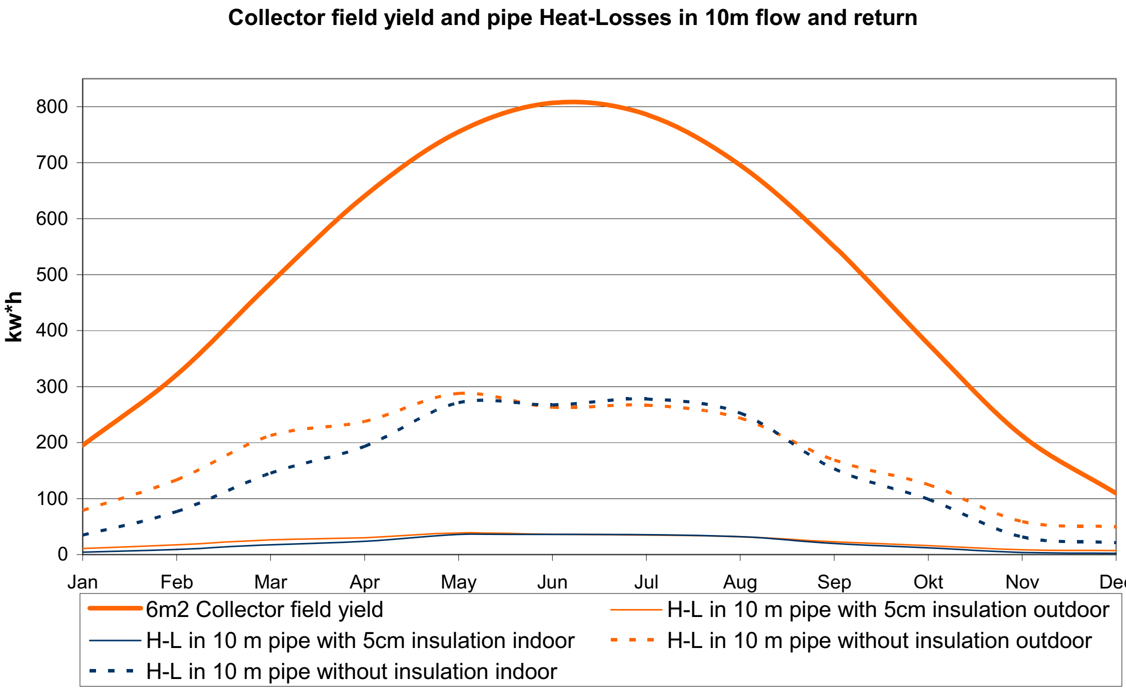

Fig.3. Monthly comparison of amount of absorbing energy with heat losses (H-L) in Dn18 pipelines.

Pipe diameters adopt after solar thermal systems hydraulic calculations. 15, 18 and 22 Dn pipes can be used in this case. 2 types of materials are used for pipe insulation in program models. The first is the rock wool with a coefficient of thermal conductivity λ= 0,039W/m*K. The second is the porous material of synthetic rubber with thermal conductivity λ=0,037W/m*K for pre-insulated pipes.

Table 1. Heat loses in pipe per year.

Insulation Type		Non insulation	Pre- insulated			Stone wool						
Thickness			14 mm	19 mm	26 mm	20 mm	30 mm	40 mm	50 mm	60 mm	80 mm	100 mm
	Pipe Ø	kWh/m*year										
Outdoor pipe	15mm	90.72	18.31	15.08	13.39	16.43	14.14	12.83	11.98	11.35	10.49	9.92
	18mm	103.37	21.37	17.59	15.59	19.11	16.37	14.87	13.87	13.16	12.19	11.54
	22mm	117.97	25.49	21.11	18.73	22.78	19.54	17.72	16.54	15.73	14.61	13.86
Indoor pipe	15mm	77.58	15.35	12.57	11.15	13.77	11.79	10.66	9.92	9.38	8.64	8.14
	18mm	88.24	17.81	14.58	12.82	15.83	13.48	12.20	11.36	10.74	9.90	9.34
	22mm	100.45	21.03	17.26	15.20	18.70	15.88	14.35	13.32	12.63	11.67	11.03

Table 1 shows pipe insulation main effect on the system from viewpoint of energy consumption. This table displays average value of flow and return heat losses for each pipeline meters.

Results of Table 1 show that heat losses from 1m non insulated pipelines are equal to heat losses from 9m good insulated pipelines.

Negligible change of Solar heat systems structure may affect the total energy production. But it not much effect values of pipeline heat losses in solar collector contour. Therefore, it can be used also in similar projects.

50 mm is the maximum thickness of the standard stone wool insulation for copper pipes with 15 mm diameter dimensions, and 60 mm for copper pipes with 18 and 22 mm diameter dimensions. It is difficult to find the stone wool pipe insulation with a higher thickness in this case, so it should be rendered on order.

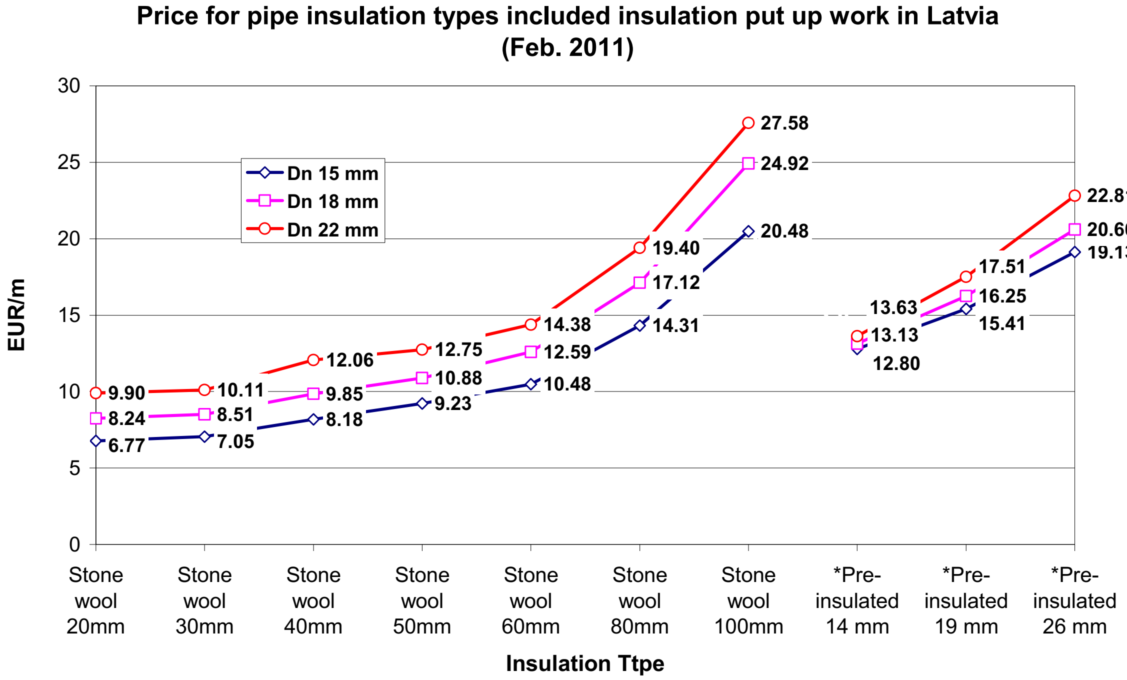

Fig. 4. Price for pipe insulation types included insulation put up job in Latvia (Feb. 2011)

***prices for pre- insulated pipes are without cupper pipe and put up prices.**

As previously mentioned, the solar thermal systems require an additional heat source in Baltic state conditions. It makes hot water after heating. The more energy is spent on the pipeline in the form of heat loss, the more energy it takes to further heating of the water. Therefore, heat losses energy prices are equal to the energy prices from auxiliary heat source.

Most energy- cost profitable type of insulation can be calculated having regard: price for pipe insulation with put up job; annual amount of energy consumption in the form of heat losses; and energy price volatility for auxiliary heater in calculated time period.

The cost of certain type of insulation and operating costs in calculated time period is:

$$P_{i,j} = p_{0i} + E_i \times \sum_{n=1}^{j} f_{(j)} \quad \text{(eq. 1)}$$

i – type of pipe insulation;
j – a calculation time period;
E0i – pipe insulation price;
bi – annual amount of energy consumption in the form of heat losses;
f(j) – energy price volatility for auxiliary heater.

Most energy- cost effective insulation type has the smallest amount spent in a certain time.

Example: Ø 18 mm copper pipe; fixed energy prices (f(j) =const), and it is equal with Latvenergo enegy price (Apr 2011g. with VAT) 152.77 EUR/MWh [9]; 20 -year time period.

$$P_{Dn18i,20} = p_{0Dn18i} + E_{Dn18i} \times \sum_{n=1}^{20} 152.77 \text{ EUR/MWh} \quad \text{(eq. 1)}$$

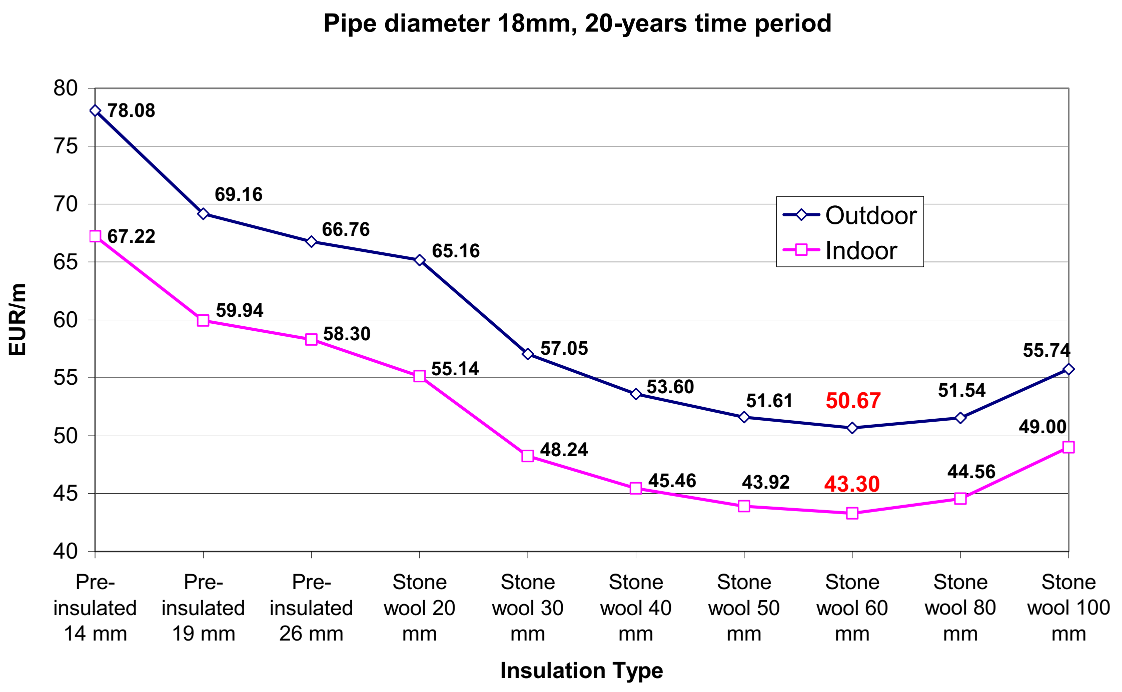

Fig 5. Amount of consumed money for different type of insulation and operating costs in 20-years time period.

It can be concluded from figure 5, that 60mm stone wool insulation type is the most energy- cost profitable in this case for outdoor and indoor copper pipes with 18 mm diameter dimension.

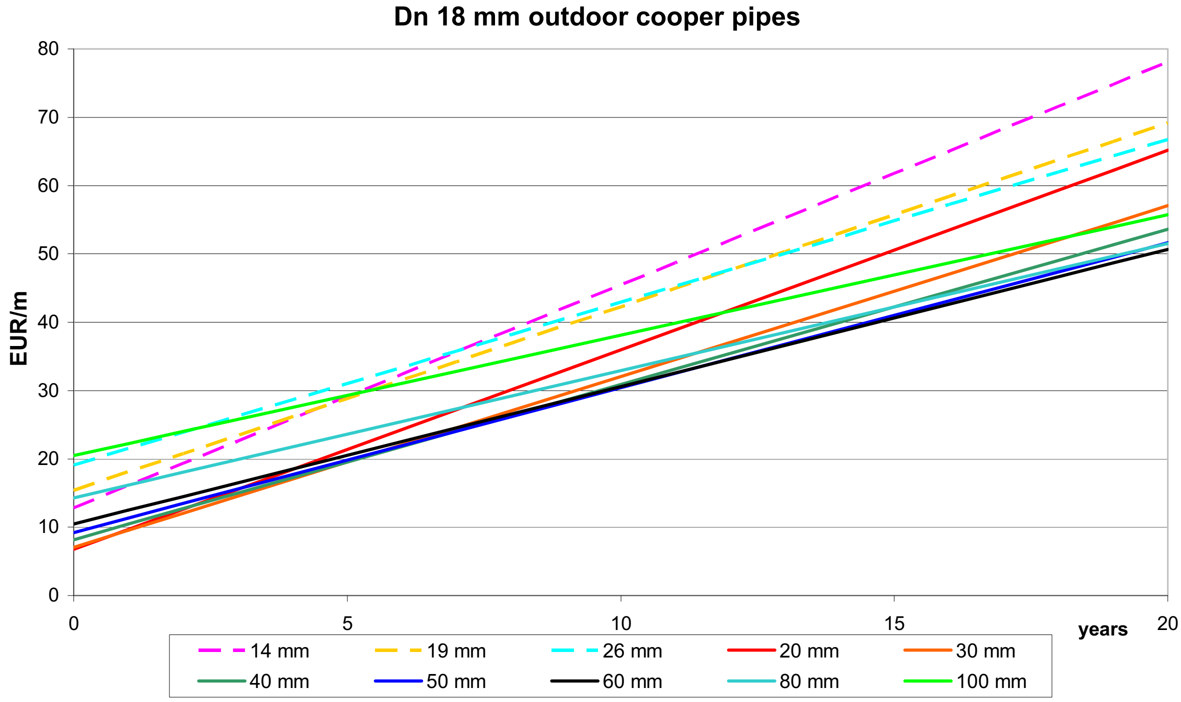

Fig. 6. Price and operating costs for different type of insulation

Figure 3 describe flow of money for each type of pipe insulation in 20 years. Insulation Selection can affect the repayment more than 25 Euro per pipe meter in this example. It can be conclude from Figure 5 and 6. Pipe is flow and return. Therefore repayment increases two times for each double pipeline meter.

Double pipe line length is up to 20 m for standard Solar thermal system. Amplitude of repayment different can reach 1100 Euro in 20-years.

5. Conclusion

There is increased need to optimize the overall solar thermal system for the Baltic States conditions. It is due to colder climate than the average European climate value and lower amount of solar radiation intensity in Baltic States.

Balancing investments and operating costs can increase reimbursement system within a specified period.

Most energy- cost profitable type of insulation can be calculated with this method. This method takes into account important factors:

1) Heat losses energy prices are equal to the energy prices from auxiliary heat source. And energy prices are volatility for auxiliary heater;

2) Prices of Insulation type can vary depending on supplier;

3) But values of heat losses not change over the time.

Calculation results show that heat losses from 1m non insulated pipelines are equal to heat losses from 9m good insulated pipelines.

This Method, for calculation of most energy- cost profitable type of pipe insulation, is useful for all Solar thermal systems designer, manufacturers and vendors.

6. References

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