Choosing the type of floor heating to install

When creating an energy-efficient, economical and environmentally-acceptable project, it is useful to prepare an analysis of these aspects specially for the given building.

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Because primary sources of energy are non-renewable, it is crucial to utilise them in an efficient and economical manner. The subject of this paper is the energy, economic and environmental analysis of the energy systems used in warm water floor heating as well as direct heating via resistance cables. This analysis is carried out for a specific detached house.

Figure 1 The studied example detached home

Thermal and technical parameters

The following parameters were considered while analysing the detached house and its surroundings:

- average outdoor air temperature $\theta_{m,e}$ = 9.9 °C,
- outdoor design temperature θ_e = –11°C,
- number of heating days: 202,
- design heating wattage: 16 kW,
- yearly heat demand: 30 MWh,
- yearly heat demand for hot water production: 3.8 MWh,
- yearly fuel consumption: 3 022 m³.

Hot water production using a solar powered system

Investment costs for a solar powered system are displayed in *Tab. 1*.

Types of floor heating

The aim of this article is to compare warm water floor heating and direct heating via electric resistance cables. If the composition of an interior floor contains a heat register, this indicates that low-temperature floor heating is being used.

Table 1 Investment costs for a solar powered system

Equipment	No. of items	Price per item (in €)	Total price (in €)
Solar collector	3	528	1 584
DN20 connecting pipes	1	69	69
Set for the attachment of collectors on a roof	1	296	296

Solar expansion vessel	1	78	78
Solar set + storage tank heater	1	2 770.32	2 770.32
Storage tank anode	1	154	154
Total			4 951.32

At present, this type of floor heating application is rather popular, particularly in family homes. However, such an application depends on the thermal and technical parameters of the building itself - its average heat loss must be less than 20 W/m³. It is clear that the building itself needs to have minimum energy consumption and that the use of a heating application offering the possibility of heat storage in the floor, where the thermal inertia is approximately 4 to 8 hours, and with a high level of self-regulation, is dependent on the building having such low consumption. When warm water floor heating is used, an almost optimum thermal state can be attained for interior areas, with an almost ideal vertical and horizontal temperature gradient.
In the case of electric floor heating, electrical energy is transformed into heat in one compact unit directly in the heated room, and therefore this type of floor heating is classified as a local heating system. The efficiency of the transformation of electrical energy is almost 100%. This type of heating is ecological; it takes place at the location where it is consumed, and it doesn´t pollute the air at the given location. There is no need for a chimney, fuel storage space, a boiler room or a boiler. The electricity distribution system is significantly simpler and cheaper compared to other warmth-conveying material, and it requires smaller alterations to building structures, with lower requirements as regards space. Another advantage is that it is easier to control the performance of the heating system by interrupting the electricity supply via room thermostats, or the use of room thermostats with weekly or monthly programming. On the one hand, the advantages of this system make it very attractive, though on the other hand, the overall comfort is reflected in the higher operating costs [1].

Floor heating construction types

Low-temperature floor heating

- gas tariff D3: 1kWh = 0.0461 € + fixed tariff 7.75 €/month
- standard tariff DD2: 1kWh = 0.1379472 €
- boiler inspections and chimney cleaning are necessary
- the following are required: expansion vessel, safety valve, chimney, boiler, distributors, collectors, fittings, gas connection
- the system takes longer to heat up
- it is essential to regulate the system
- higher investment costs are required
- air is polluted (CO_2) in the area of consumption

Direct heating using electric resistance cables

- use of the more advantageous DD5 tariff: 1kWh = 0.1123872 €
- this variant is more ecological – heating occurs at the place of consumption
- convenient for the user
- chimney cleaning is unnecessary as no chimney is required
- the system starts producing heat quickly
- easy to regulate
- markedly lower investment costs
- the system aids in achieving resultant savings in operating costs
- the floor heats up fast

Table 2 Yearly consumption of electricity by appliances

Electric circuit	Wattage P_1 (kW)	Wattage per day P_{day} (kWh)	Price for electricity DD2 (kWh/year)	Price for electricity DD5 (kWh/year)
Lighting circuit	3	18	917.2	738.4
Wall socket circuit	12	72	3 668.6	2 953.5
Automatic washing machine	2.8	16.8	856	689.2

Motor-driven appliance circuit	2	1	51	41
Electric oven	2.8	1.4	71.3	57.4
Dishwasher	2.8	2.8	142.7	114.9
Electric cooker	5	15	764.3	615.3
Other	7	3.5	178.3	143.6
Simultaneity	0.4	0.4	0.4	0.4
Total simultaneous wattage	15	52	2 660	2 141

Energy analysis

In order to determine operating costs it is necessary to calculate the energy requirements for both alternative heating systems. The calculation is performed according to the degree day method [2].

$Q_{y,heat} = 24 \times 3\,600 \times \varepsilon \times Q_{max,(elec)} \times (\theta_i - \theta_{avg}) / (\theta_i - \theta_e) \times d$(J/year) (1)

where ε is the correction factor for simultaneity
(0.765) (–),
Q_{max} – the maximum design heating wattage (of the building) (W),
Θ_i – the required calculated internal temperature (°C),
θ_{avg} – the average temperature, the outside air temperature during the heating season (°C),
θ_e – the calculated (lowest) external air temperature (°C),
d – the length of the heating season (days).

Heat demand of low-temperature floor heating

$Q_{y,heat} = 24 \times 3\,600 \times 0.765 \times 15\,800 \times (20 - 4.3)/(20 - (-11)) \times 202 = 106\,836\,977\,400$ J/year
$Q_{y,heat} = 106\,837$ MJ/year = 29 677 kWh/year = 30 MWh/year

After adding the appropriate values to the formulathe heat demand value for heating is determined to be 30 MWh/year.

Fuel requirement for low-temperature floor heating

The calculation method was selected in accordance with STN EN 832-3 [2].

$B_{heat} = E_{heat} \times 1\,000/H \times \eta_c$ (m³/year) (2)

where E_{heat} is the yearly consumption for heating (GJ/year),
H – heating capacity of the fuel (natural gas) (MJ/m³),
η_c – boiler efficiency (–).

$B_{heat} = 106.8 \times 1\,000/35 \times 1.01 = 3\,022$ m³/year

Heat demand of direct heating using electric resistance cables

ε – correction factor for simultaneity (0.4) (–),
Q_{elec} – output of electric resistance cables (kW),

$Q_{y,heat} = 24 \times 3\,600 \times 0.4.\ 15\,800 \times (20 - 4.3)/31 \times 202 = 55\,862\,471\,850$ J/year
$Q_{y,heat} = 55\,862.5$ MJ/year = 15 517.36 kWh/year = 15.52 MWh/year

The duration of direct heating using electric floor heating is 4 to 6 hours [2].

Energy requirements for other appliances in a detached house

When using low-temperature floor heating, the gas consumed by the boiler is calculated according to the gas supplier, SPP, according to tariff D3: 1 kWh = 0.0461 €. Also, every month a fixed sum of 7.75 € is paid along with the consumption of electrical energy according to tariff DD2: 1 kWh = 0.1395984 €. When using direct heating via electric resistance cables, no gas connection is required, and it is possible to agree with electricity suppliers on the application of the DD5 double tariff for an electric cooker. The high tariff applies from 7:30 to 8:30, from 9:30 to 10:30, from 20:30 to 21:30 and from 22:30 to 23:30, and is 0.3179472 € per 1 kWh. For the other 20 hours the low tariff is charged, which is 0.1123872 € per 1 kWh. The tariffs for electrical energy consumption were obtained from the Slovak electrical energy supplier Západoslovenské elektrárne (ZSE).

Economic analysis

For the economic evaluation of heating alternatives it is necessary to determine the investment costs for all types of floor heating.

Investment costs for low-temperature floor heating

The prices of the individual components in *Tab. 3* were determined according to the price lists published by individual companies. The price for a standard metre of floor heating pipe is 1.96 €.

Investment costs for a direct heating system with electric resistance heating cables

The prices of the individual components in *Tab. 4* were determined according to company price lists.

Table 3 Prices of components for low-temperature floor heating

Component	Quantity	Price with VAT (in €)
Condensing boiler	1	2 024.4
Chimney	1	1 044
Safety valve	1	18
Expansion vessel	1	29
Gas connection	1	2 300
Heating pipes	1 189 m	2 330.1
Heating ladders	3	552
Heating rod	3	396
Installation box and regulation valve	4	642.7
Distributor/collector	4	1 026.8
Fittings	48	254.4
Ball valve	8	160
Floor convector	1	497
Total price for all components	Σ	1 1274

Table 4 Prices of components for an electric cable-based heating system

Component	Quantity	Price with VAT (in €)
Electric convector heater	1	74.7
Heating ladders	2	471
Heating rod	2	270
Analogue thermostats	21	259.8
Electric resistance cables	1 457 m	2 512.8
Total price for all components	Σ	3 588

Evaluation of economic advantages

The economic advantages of selected types of floor heating can be clearly evaluated from Figures 2 and 3. The total investment and operating costs for the specific building studied here are higher in the case of warm water floor heating than in the case of electric floor heating.

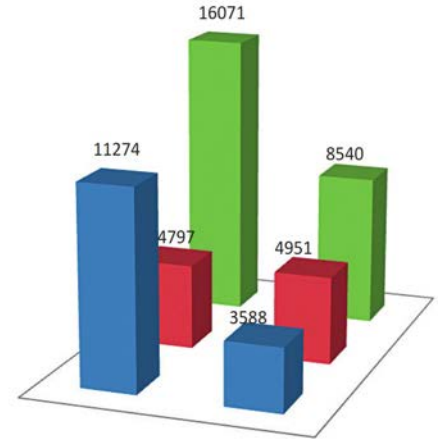

Figure 2 Investment costs (€)
heating hot water production
total investment costs

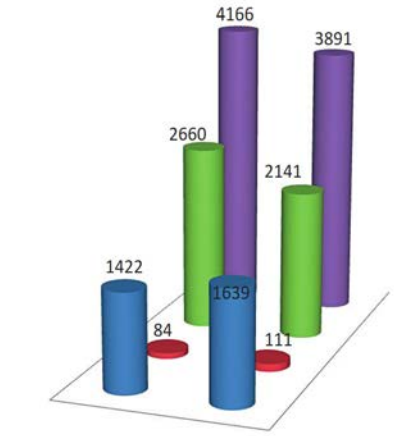

Figure 3 Operating costs (€)
heating hot water production
appliances
total operating costs

Conclusion

Based on the economic and energy analysis above it can be seen that the investment costs for electric heating are lower by 46.8% and the operating costs by 6.6% in comparison with warm water floor heating. Even though, when taken in isolation, the operating costs of heating are lower in the case of warm water floor heating, the total operating costs of electric floor heating were lower after the application of a more advantageous electricity consumption tariff. On the basis of these facts, it would be more advantageous to install floor heating with direct heating via electric resistance cables in this family home.

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Figures: From the authors' archives

Literature

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