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Rural houses heating costs

Abstract. Average full (including capital, operation and maintenance costs) annual heating costs in a standard family house with 180 m^2 of floor surface are compared for various heating systems under the Polish economic conditions. The compared heating technologies comprise water to water and ground loop heat pumps with both vertical and horizontal loops, a liquid gas combustion furnace, an earth gas combustion furnace, a coal combustion furnace, a straw combustion furnace, a wood combustion furnace and an electric stove. A sensitivity analysis with regard to the interest rate and the value of owner's work did not change the general conclusion that in most cases heat pumps were the cheapest, while oil and coal burning furnaces or an electric boiler the most expensive solutions. The cost of own labour was decisive for the appraisal of labour intensive systems.

Key words: house heating, annual cost, heat pump, electric boiler, coal burning furnace, oil fuelled boiler, straw burning furnace, wood burning furnace, liquid gas fuelled boiler, earth gas fuelled boiler

Introduction

Non-renewable sources of energy are being gradually depleted, and at a growing rate. Burning fossil fuels adds, according to widely shared opinions, to a climate change for warmer by adding carbon dioxide and other greenhouse gases to the atmosphere and in this way making it less permeable for the infrared eradiation of waste energy dissipated in the air into the outer space. Poland, thanks to its abundant deposits of coal and brown coal, appears as a particularly lavishing user of traditional non-renewable energy sources.

A switch to the use of alternative sources of energy is observed therefore on a global, and in many places also a local scale, including our country. As the most local scale the family house heating systems might be envisaged.

House heating plays an important role in the total energy consumption. Its distribution between various uses in Europe in 2000 was as follows: industry 28%, transportation 31%, in- and out-buildings and other constructions services 41%. In the household energy consumption in Poland 8% of this total was used by electric appliances, 31% by family cars, 8% by hot water heating and 53% by house heating [Dreger 2005].

In a recent study Manteuffel Szoege and Olesik [2008] compared full annual costs borne by an owner of a family house of 180 m^2 of floor surface for heating the house when using different energy sources. The study was limited to the energy supply cost and excluding the costs of warmth propagation inside the house, whose technology usually does not depend on the type of heat source, though some propagation systems are very often combined with a specific type of energy source.

The energy sources investigated were especially suited for country houses which can not be, because of the cost, connected to a communal central heating system. In the last years, however, local earth gas networks have become popular in the country and many rural houses can use earth gas as the energy carrier.

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In this study annual heating costs of this variant have been compared to some other solutions examined before.

Using various sources of thermal energy and different technologies of their utilization is connected with various costs. Eleven different energy sources for heating purposes, more or less popular in Poland, have been compared in this respect, applying the mid 2008 price level. Inflation is not very high in the last years in Poland, though it has grown recently and for the year ending July 2008 the CPI (Consumer Price Index) is estimated at 104.3%[2].

Most of the costs, estimated originally by using end of 2006 prices, have been updated using a CPI for the period of July 2008 to December 2007 multiplied by a CPI for the period of December 2007 to December 2006 [Ceny… 2008]. This product value amounted to 1.0691. The energy sources prices correspond to the mid 2008 level, the same applies to the earth gas system investment operation and maintenance costs.

The compared energy sources were: heat pump type water to water, heat pump using brine as media and equipped with a horizontal ground loop, heat pump using brine as media and equipped with a vertical ground loop, gasified wood fuelled boiler, straw bales fuelled boiler, wood pellets fuelled boiler equipped with a feeding screw, liquid gas fuelled condensation boiler, low temperature oil fuelled boiler, upper combustion coal fuelled boiler, electric boiler and earth gas fuelled boiler. Direct solar energy heating was not included in investigation as inadequate for all year heating under Polish weather conditions.

In each case a specific representative for the given type of heating system has been investigated. For the water to water heat pump it was the Stiebel Eltron WPF model powered 7.4 kW, for the heat pumps with both horizontal and vertical ground loops it was the Stiebel Eltron WPC model powered 7.9 kW, for the furnace burning gasified wood it was the Atmos DC18S model powered 18 kW, for the straw burning furnace it was the Metalerg Biowat S4 model powered 25 kW, for the pellets burning furnace the Eko-Vimar Orlean model powered 25 kW, for the liquid gas burner the Saunier Duval Thermaclassic model powered 23.6 kW, for the oil burner the Ferroli GTU 1203RS\V130 model powered 21 kW, for the coal burning furnace the Kotły Żywiec Vigas model 25 powered 25 kW, for the electric boiler the ACV E-TECH S160 model powered 21.6 kW, for the earth gas burning boiler Buderus UD54 with water heater F120/3, connector and temperature gauge AS16. The last solution requires also connecting the house installation with the local earth gas network.

The cost data have been collected from advertisement leaflets, literature [Laskowski 2006, 2007 and 2008; Małkowska 2006] and by interviewing the heating installations dealers. The valuation of own labour input in various cases has been obtained by surveying 50 house owners in the suburbs of Lodz city in Poland [Olesik 2007].

Annual heating costs

- **Energy source costs**

The energy consumption estimated for the investigated systems, as well as the energy prices and costs, are displayed in Table 1. Besides the energy purchase cost in some cases

[2] The CPI growth accelerated in the last months of 2007. In October the CPI was 102.2% for the previous 12 months while in November it grew to 103.6% annually and in 2008 as above [Money... 2007].

the fuel delivery costs must have been added, estimated for 2006 at 200 PLN per year. In the case of a gas burning device the cost of leasing a gas tank was 600 PLN per year[3]. For 2008 these costs have been updated by multiplying by the above mentioned inflation index, equal to CPI for the period between December 2006 and July 2008.

Table 1. Annual fuel or energy consumption and cost, PLN/year

Energy source	Unit	Consumption unit/year	Price, PLN/unit	Energy cost PLN/year	Additional cost PLN/year	Total cost PLN/year
electricity for a heat pump	kWh	2700	0,492	1329	200	1529
wood	m^3	22	150	3300	214	3514
straw	kg	9087	0,096	874	214	1088
pellets	tonne	4,5	850	3825	214	4039
liquid gas	l	2340	2,5	5850	641	6491
fuel oil	l	1603	3,43	5498	0	5498
coal	tonne	4,14	480	1987	214	2201
electricity for an electric boiler	kWh	11077	0,4924	5454	200	5654
earth gas	m^3	2500	1,561	3903	150	4053

Table 2. Life expectancy for energy supplying installations, investment and depreciation cost

Type of installation	Investment cost, PLN	Life span, year	Depreciation PLN/year
heat pump, type water-water	22345	35	638
heat pump, horizontal ground loop	20468	35	585
heat pump, vertical ground loop	31518	35	901
gasified wood fuelled boiler	4035	25	115
straw bales fuelled boiler	16043	25	458
pellets fuelled boiler with feeding screw	12829	25	367
liquid gas fuelled condensation boiler	3849	25	110
low temperature oil fuelled boiler	9510	30	272
upper combustion coal fuelled boiler	2293	15	66
electric boiler	10333	25	295
earth gas fuelled boiler	16370	15 and 50	576

- **Capital costs**

The value of investment outlays in various cases is displayed in Table 2. Annual capital costs have been calculated in the form of annuity (equal annual equivalent, EAE) corresponding to these outlays and are quoted in Table 3. The depreciation cost, for the sake of comparison, is inserted in Table 2, although not used in further calculations. Instead of it the EAE has been calculated by using the standard formula (1)

[3] Prevailing exchange rate in the end of 2006 was about 4 PLN/€, in the beginning of 2008 it was about 3.5 PLN/€.

$$EAE = CV * \frac{R * (1+R)^t}{(1+R)^t - 1} \qquad (1)$$

where CV stands for the capital value of installation, t for its life span and R for the interest rate, in decimals (not in percentages).

Several different values of the interest rate have been tried in a sensitivity analysis. Since the owners usually employ their own capital for financing the investment, the interest rate determining the opportunity cost of this capital has been set equal, as it is commonly being done in such cases, to the deposit rate in a bank. This rate has been reduced by 20% of income tax imposed on the deposit interest in Poland and then transformed to its real value, which meant eliminating the inflation factor. The standard formula for this operation is

$$R_{real} = \frac{1+R_{nom}}{1+R_{inf}} - 1 \qquad (2)$$

where R_{real}, R_{nom} and R_{infl} stand respectively for the real interest rate, the nominal rate and the inflation rate, the last set equal to the last year's CPI – 1. In this case an inflation rate for consumer goods for period January-July 2008 in relation to the period January-July 2007 has been employed, equal to 4.3%.

The average real deposit rate in the 20 biggest banks operating in Poland turned to be, as it frequently happens, negative and equal to -0.825%. Therefore a long-term regular deposit rate in a better paying bank was used, which meant practically zero real rate after tax (0.096%), and a special premium rate, which gave a real rate after tax of 1.438% [Getin... 2008]. The last two possibilities are usually available to better informed, though not professional, potential investors and therefore may be taken for a basis of the opportunity cost estimation. In three cases financing the investment from a bank credit has been assumed. An average rate in the 20 biggest banks applicable to a credit for house purchase (meaning usually mortgage credit) gave a real rate of 2.78% and that for a consumer credit gave a real rate of 9.204% [Ceny… 2008]. The consumer credit in the particular bank used for the deposit rate estimation had a real cost of 12.052%[4]. The last two rates denote a very high cost of capital which in reality may be applied only to a short initial period when the credit is still pending. Normally no private person lives permanently on borrowed capital. The moderate rates are more appropriate then.

- **Operation and maintenance costs**

Own labour costs

Various heating systems require different inputs of owner's own labour. This labour has its opportunity cost, otherwise defined as a disutility of effort. A standard procedure for its estimation consists of taking it as equal to the hourly earnings of the agent, on the grounds that he must at least value his effort at this level because otherwise he would not make it.

[4] Probably a sign of an economic recession from the times of two years ago, when both deposit and credit rates were about 2 percent points higher.

Table 3. Heating installations annual capital cost, PLN/year

Type of installation	Equal annual equivalent of capital value, interest rate =				
	-0,00096	0.01438	0,0278	0.09204	0.1205
heat pump, type water-water	627	817	1007	2156	2744
heat pump, horizontal ground loop	575	748	922	1975	2514
heat pump, vertical ground loop	885	1152	1420	3040	3871
gasified wood fuelled boiler	159	193	226	418	516
straw bales fuelled boiler	634	769	899	1660	2053
pellets fuelled boiler with feeding screw	507	615	719	1328	1642
liquid gas fuelled condensation boiler	152	184	216	398	492
low temperature oil fuelled boiler	312	393	472	942	1185
upper combustion coal fuelled boiler	152	171	189	288	338
electric boiler	408	495	579	1069	1322
earth gas fuelled boiler	668	808	947	1767	2176

Table 4. Operation times, minutes

Type of installation	Time per operation	Operation time per day	annually	Preparation & closing time, annually	Total time annually
heat pump, type water-water	0	0	0	0	0
heat pump, horizontal ground loop	0	0	0	0	0
heat pump, vertical ground loop	0	0	0	0	0
gasified wood fuelled boiler	5	5	915	1830	2745
straw bales fuelled boiler	10	30	5490	5490	10980
pellets fuelled boiler with feeding screw	20	5	915	458	1373
liquid gas fuelled condensation boiler	0	0	0	0	0
low temperature oil fuelled boiler	0	0	0	0	0
upper combustion coal fuelled boiler: loading	5				
light up	20				
deashing	20	34.9	6379	6483	12862
electric boiler	0	0	0	0	0
earth gas fuelled boiler	0	0	0	0	0

By surveying suburban inhabitants of Łódź city in central Poland was in 2006 an average valuation of 1 hour of own work estimated at 12 PLN, and the responses varied between 8 PLN and 15 PLN [Olesik 2007]. All these three values have been used in a sensitivity analysis multiplied by consumer iflation index for the period elapsed since the survey. Also 13.46 PLN/hour was used, which is a net correspondent to the 2951.36 PLN/month of an average gross salary in Poland in the second quarter of 2008 [Komunikat... 2008]. On a higher side a net equivalent of a university professor remuneration for one overtime teaching hour of 42.67 PLN and, still much higher, an hourly net equivalent of gross salary earned by a member of the state Council of Monetary Policy equal to 232.17 PLN/hour have been used.

Times necessary for operating and servicing the installations cover various activities. The most frequent is loading fuel to the furnace[5]. To the actual working time also the time needed for preparation and closing the operation, like for washing and changing clothes has been added. Then was it supplemented with the time necessary for contracting and reception of fuel deliveries. Also was it assumed that on the average 2 hours of owner's time was spent per 1 repair or inspection of the installations for contracting the repairman, supervision and making payments.

Table 5. Time spent for servicing and operation, minutes per year

Type of installation	Time for fuel supply reception	Time for managing repairs	Time for operation	Total time for operation & maintenance
heat pump, type water-water	0	12	0	12
heat pump, horizontal ground loop	0	12	0	12
heat pump, vertical ground loop	0	12	0	12
gasified wood fuelled boiler	90	180	2745	3015
straw bales fuelled boiler	90	180	10980	11250
pellets fuelled boiler with feeding screw	90	180	1373	1643
liquid gas fuelled condensation boiler	90	180	0	270
low temperature oil fuelled boiler	90	152	0	242
upper combustion coal fuelled boiler	90	264	12862	13216
electric boiler	0	24	0	24
earth gas fuelled boiler	20	144	0	164

Table 6. Own labour opportunity cost, PLN/year

Type of installation	Cost PLN/hour					
	8.55	13.46	12.83	16.04	42.67	232.17
heat pump, type water-water	2	3	3	3	9	46
heat pump, horizontal ground loop	2	3	3	3	9	46
heat pump, vertical ground loop	2	3	3	3	9	46
gasified wood fuelled boiler	430	677	645	806	2144	11667
straw bales fuelled boiler	1604	2524	2406	3007	8001	43532
pellets fuelled boiler with feeding screw	234	369	351	439	1168	6356
liquid gas fuelled condensation boiler	38	61	58	72	192	1045
low temperature oil fuelled boiler	34	54	52	65	172	936
upper combustion coal fuelled boiler	1884	2966	2826	3532	9399	51140
electric boiler	3	5	5	6	17	93
earth gas fuelled boiler	23	37	35	44	117	635

Estimates of operation times are shown in Table 4, of other times and the totals in table 5 and the costs of the owner's labour input in Table 6.

[5] In most of cost calculations this is the only own working time input counted in, if any.

Table 7. Annual servicing costs

Type of installation	Frequency interval, year			Unit cost, PLN/case			Annual cost, PLN/year			
	Over-haul or repairs	Inspect-ion & clean-ing	Spare parts replace-ment	Over-haul or repair	Inspect-ion & clean-ing	Spare parts replace-ment	Over-haul or repairs	Inspect-ion & clean-ing	Spare parts replace-ment	Total main-tenance
heat pump, type water-water	10	0	0	2138	0	0	214	0	0	214
heat pump, horizontal ground loop	10	0	0	2138	0	0	214	0	0	214
heat pump, vertical ground loop	10	0	0	2138	0	0	214	0	0	214
gasified wood fuelled boiler	2	1	0	214	160	0	107	160	0	267
straw bales fuelled boiler	2	1	0	214	160	0	107	160	0	267
pellets fuelled boiler with feeding screw	2	1	0	214	160	0	107	160	0	267
liquid gas fuelled condensation boiler	5	1	0	802	267	0	160	267	0	428
low temperature oil fuelled boiler	5	5	15	160	374	1604	32	75	107	214
upper combustion coal fuelled boiler	2	1	0	214	160	0	107	160	0	267
electric boiler	5	0	0	321	0	0	64	0	0	64
earth gas fuelled boiler	5	1	1	300	200	200	60	200	200	460

Table 8. Costs in the basic case, interest rate 1.438%, own labour cost equal to 12.83 PLN/hour, PLN/year

Type of installation	Capital costs (EAA)	Fuel/ energy	Own labour, operation & servicing	Servicing	Total O&M costs	Total costs
heat pump, type water-water	817	1529	3	214	1745	2562
heat pump, horizontal ground loop	748	1529	3	214	1745	2494
heat pump, vertical ground loop	1152	1529	3	214	1745	2898
gasified wood fuelled boiler	193	3514	645	267	4426	4619
straw bales fuelled boiler	769	1088	2406	267	3761	4530
pellets fuelled boiler with feeding screw	615	4039	351	267	4657	5272
liquid gas fuelled condensation boiler	184	6491	58	428	6977	7161
low temperature oil fuelled boiler	393	5498	52	214	5764	6156
upper combustion coal fuelled boiler	171	2201	2826	267	5294	5465
electric boiler	495	5654	5	64	5723	6218
earth gas fuelled boiler	808	4053	35	460	4548	5356

Installation servicing costs

These costs are equivalent to the average annual expenditure on inspection, routine spare parts replacements, repairs and overhauls of the installations. Their estimates, based on their frequency and unit cost information acquired from the branch dealers, are shown in Table 7.

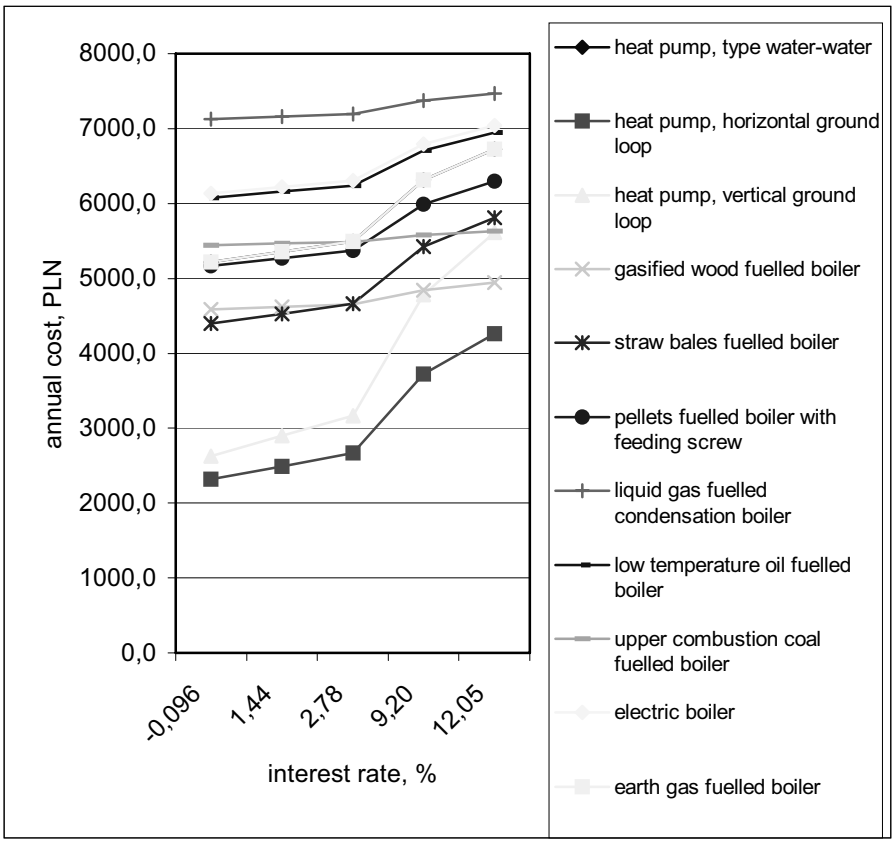

Fig. 1. Annual house heating costs depending on the cost of capital, own labour cost set at 12.83 PLN/hour[6]

- **Total annual costs**

Total costs in the basic case envisaging the most common interest rate and the average labour cost are shown in Table 8.

Showing the calculations for the other cases would take too much space, therefore the results are synthesized, also not for all variants, in Figures 1 and 2.

Numerically the most probable variants are compared in Tables 9 and 10.

[6]Unfortunately some of the lines cover each other and are hardly visible, e.g. that for the heat water-water pump and the earth gas boiler..

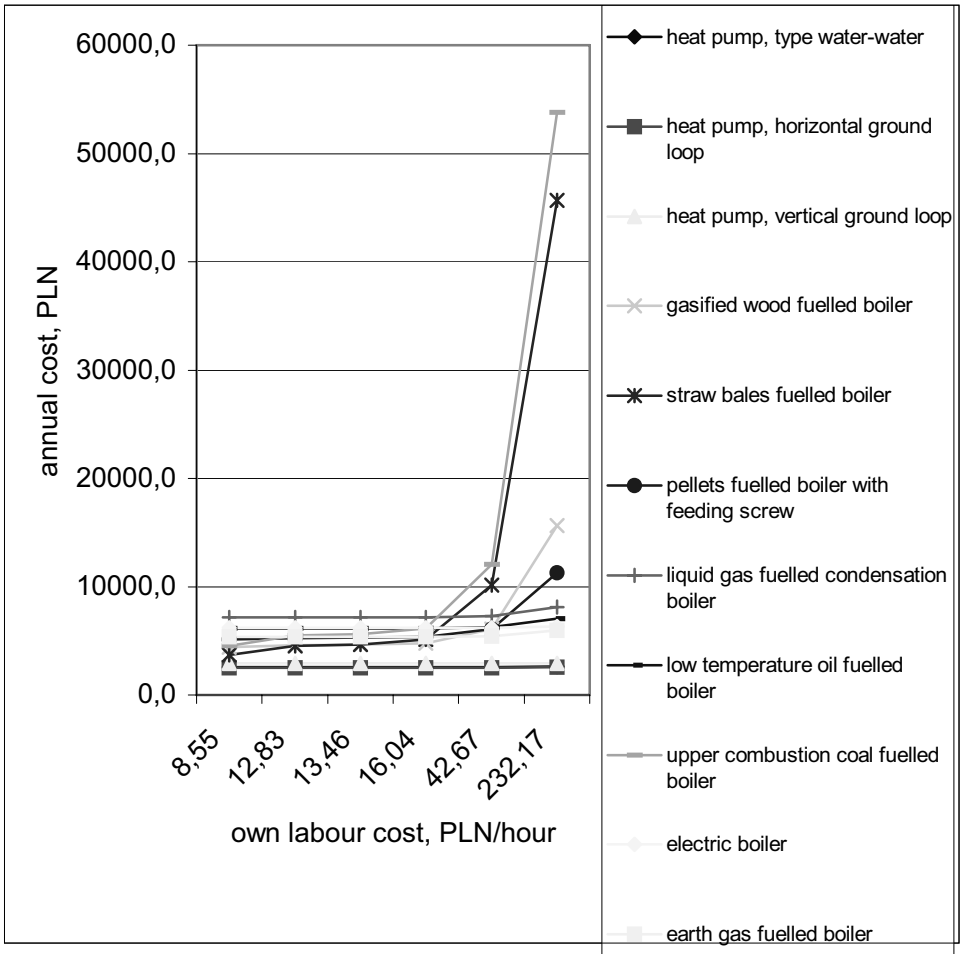

Fig. 2. Annual house heating costs depending on the own labour valuation, interest rate on capital set at 1.44%[7]

Conclusions

The costs, and therefore the choice of heating system, depend to a large extent on the amount of work required for the operation and maintenance of the system. The valuation of labour input varies significantly depending on the affluence of the owner and, probably, his fitness.

Operation and maintenance costs are by far much more important than the capital costs of the installations (e.g. Table 8). In the labour intensive solutions the labour costs play a significant role even in the case of their low valuation.

The graphic analysis (Fig. 1 and Fig. 2) has given a certain insight into the possible preferences of owners of different affluence. These preferences stay relatively constant for lower income (low own labour valuation) owners, but for those having higher or high incomes some labour intensive solutions become clearly unacceptable. For poorer owners (who need to use consumer credit for financing the investment, Fig.1) the capital intensive solutions (like heat pumps) become comparable to, or even dearer than, some of the less capital consuming solutions, otherwise much more expensive.

[7] Unfortunately some of the lines cover each other and are hardly visible, e.g. those for heat pumps.

The heat pumps seem to stand apart from the other solutions in most of the cases and represent the lowest cost alternative. Only if financed by a very expensive consumer credit combined with a mediocre or low own labour valuation they can be, with respect to costs, placed close to the other systems. This outcome can be appraised positively also from the environmental point of view, since these pumps use relatively small amounts of dirty energy produced from non-renewable resources (electricity). Unfortunately the devices using exclusively the renewable sources, like straw or wood burning furnaces, become much cost inefficient, in particular for the more affluent owners who value high their labour (Table 10).

Table 9. Annual total cost relations, the cheapest solution set equal to 100%, own labour valued at 12.83 PLN/hour, variation of interest rate, %

Type of installation	Interest rate, %				
	-0.10	1.44	2.78	9.20	12.05
heat pump, type water-water	102	110	119	168	193
heat pump, horizontal ground loop	100	107	115	160	184
heat pump, vertical ground loop	113	125	136	206	242
gasified wood fuelled boiler	198	199	200	209	213
straw bales fuelled boiler	189	195	201	234	251
pellets fuelled boiler with feeding screw	223	227	232	258	271
liquid gas fuelled condensation boiler	307	309	310	318	322
low temperature oil fuelled boiler	262	265	269	289	299
upper combustion coal fuelled boiler	235	236	236	241	243
electric boiler	264	268	272	293	304
earth gas fuelled boiler	225	231	237	272	290

Table 10. Annual total cost relations, the cheapest solution set equal to 100%, interest rate set at 1.44%, variation of own labour value, %

Type of installation	Hourly cost of own labour, PLN/hour					
	8.55	12.83	13.46	16.04	42.67	232.17
heat pump, type water-water	103	103	103	103	103	105
heat pump, horizontal ground loop	100	100	100	100	100	102
heat pump, vertical ground loop	116	116	116	116	116	118
gasified wood fuelled boiler	177	185	187	192	245	627
straw bales fuelled boiler	150	182	186	206	406	1831
pellets fuelled boiler with feeding screw	207	211	212	215	244	452
liquid gas fuelled condensation boiler	286	287	287	288	293	327
low temperature oil fuelled boiler	246	247	247	247	252	282
upper combustion coal fuelled boiler	181	219	225	248	483	2157
electric boiler	249	249	249	249	250	253
earth gas fuelled boiler	214	215	215	215	218	239

The investigated heating systems might be divided, because of the type of energy source used and its renewability, into sustainable[8] (wood, straw and pellets burning), non-sustainable (gas, oil or coal burning or electrically heated) and partially sustainable (heat pumps using electricity for pump propulsion). Out of these three groups the partially sustainable solutions are the cheapest in all cases, while in general the sustainable ones can compete with unsustainable solutions only in the case of a relatively low own labour valuation, i.e. in poorer households (Table 9 and 10). However these relations look different in different cases and can not be simply generalized.

The now most popular heating system using earth gas stays under the 2008 price conditions and with an average labour and capital valuation in the range of medium cost solutions, though some other variants using renewable energy sources look cheaper. Therefore its popularity seems reasonable, providing the heat pumps are excluded. Heat pumps are still a novelty combined with a high initial investment cost and therefore they do not arise a confidence among country inhabitants. The fast growing gas price will probably reverse this attitude in the near future. The choice of the earth gas as an energy source may also indicate that the own labour valuation in the rural areas is higher than the tentative 12.83 PLN/hour and therefore discourages implementation of the renewable, labour intensive but sustainable solutions. .

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[8] Their sustainability appears a little dubious if the life cycle of fuels is taken into consideration. For their acquisition and distribution usually quite considerable amounts of unsustainable energy resources are being used.