Czech University of Life Sciences Prague

Faculty of Economics and Management
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Renewable energy as a concept for a family house

Bachelor Thesis

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BACHELOR THESIS ASSIGNMENT

Lukáš Sedlák

Economics and Management

Thesis title

Renewable energy as a concept for a family house

Objectives of thesis

The aim of the theoretical part is to introduce the issue of renewable energy sources and description of the concrete sources, that are suitable as a heating system for a family house. Another aim I will focus on in the theoretical part is to design and describe a concrete family house, which energy requirement will be solved in the practical part.

In the analytical part calculation of energy balance of the house will be made. The goal of this part is to evaluate all the calculations and chose the best option, out of the four renewable energy sources technologies, for the chosen family house.

Methodology

The theoretical part will be compiled on the basis of data collection and on study of scientific publications and other sources of Czech as well as English literature. The first part deals with explication of the specific words that are associated with the issue of renewable energy sources. All of the publications and sources used in this work will be listed in the list of references.

Calculation of the energy consumption of the house will be conducted as an input parameter for the analytical part. The calculating procedure will fully comply with provisions of the Decree No.78/2013 Coll. Energy performance of buildings. The calculated values of energy requirements for family house will be used as a default requirement for the designed house and for the assessment of the various energy sources options. In the practical part will be comparative and descriptive methods.

The proposed extent of the thesis

40 pages

Keywords

renewable resources, solar energy, initial cost, environment,

Recommended information sources

ČESKÁ ZEMĚDĚLSKÁ UNIVERZITA V PRAZE. PROVOZNĚ EKONOMICKÁ FAKULTA. KATEDRA ŘÍZENÍ, – ŘÍMOVSKÁ, P. *Metodické postupy v projektování podnikatelských projektů : Teoretické přístupy a praktické návody k aplikaci.* Praha: Česká zemědělská univerzita, 2008. ISBN 978-80-213-1828-1.

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Declaration

I declare that I have worked on my diploma thesis " Renewable energy as a concept for a family house" by myself and I have used only the sources mentioned at the end of the thesis. As the author of the diploma thesis, I declare that the thesis does not break copyrights of any third person.

In Prague, March 8, 2017

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Lukáš Sedlák

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Koncepce obnovitelné energie pro rodinný dům

Renewable energy as a concept for a family house

Koncepce obnovitelné energie pro rodinný dům

Abstrakt

Tato bakalářská práce je zaměřena na porovnání 4 typů obnovitelné energie, které je možné použit jako koncepci pro rodinný dům. Práce je rozdělena do tří částí. První část je zaměřena na stručné uvedení do problematiky důležitosti obnovitelné energie. Také jsou v této části popsány použité výpočetní metody. Teoretická část této práce popisuje obnovitelné zdroje energie, které mohou být využity pro rodinný dům. Poslední, praktická část je soustředěna na porovnání použitých typů energií, pořizovacích cen a zhodnocení všech vybraných obnovitelných zdrojů energie použitých pro rodinný dům. Cílem této práce je zjištění nejvhodnější technologie z ekonomického pohledu, která může být využita pro konkrétní rodinný dům.

Klíčová slova: Obnovitelné zdroje, solární energie, počáteční náklady, životní prostředí, čistá současná hodnota

Renewable energy as a concept for a family house

Summary

This bachelor thesis discusses the comparison of 4 types of renewable energy, that can be used as a concept for a family house. The thesis is divided into three parts. The first part is a brief introduction of the renewable energy importance, as well as the explanation of used methodology. The theoretical part of this bachelor thesis describes renewable energy sources, that can be used for family houses. The last, practical part is focused on comparison of used energy, purchase price and valorisation of all chosen renewable energy sources used in the model family house. The aim of this thesis is to find the best technology that can be used for family house from the financial and economical point of view.

Key words: Renewable resources, solar energy, initial cost, environment, net present value

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1. Introduction

Renewable energy is drawn from renewable sources, which have infinite quantity and are naturally replenished at a measurable rate and for a reasonable price. Unlike the traditional fossil or nuclear sources, these forms of energy are almost inexhaustible. The renewable sources of energy are wind, sunshine, geothermal energy, water, soil, air, biomass, landfill gas, sewer gas and biogas.

"The time will arrive when the industry of Europe will cease to find those natural resources, so necessary for it. Petroleum springs and coal mines are not inexhaustible but are rapidly diminishing in many places. Will man, then, return to the power of water and wind? Or will he emigrate where the most powerful source of heat sends its rays to all? History will show what will come." (Augustine Mouchot, 1873)

Due to the constant decrease of global reserves of fossil fuels and the trends to restrict nuclear programs, and on the other hand the rapid increase of power consumption Union has adopted a series of actions, that should lead to energy savings in all member countries. Based on that the European Commission has adopted several legislative standards, documents and actions for the member countries, including the Czech Republic, from energy labelling of building, to subsidy for user of renewable and sustainable sources of energy. Renewable sources of energy and their use is becoming more relevant topic. It is not an issue of big companies anymore. Recently we can see the use of renewable energy even in the private sector, especially in the construction and operation of a family house. The supply for renewable sources of energy is very wide. Nowadays the selection of a particular source of energy is only up to the concrete investor. Whether, under the actual circumstances, he will use solar panels, heat pump or for example biomass boiler. The possibilities for multilateral renewable energy use are enormous. Wide variety of different technical equipment may provide almost any amount of electricity, heat or fuel.

When we choose the renewable source of energy the things we are interested in, of course in addition to the environment and climate protection, is the return on investment in these facilities, which purchase costs tent to be higher. In this thesis, I examine the possibility of using renewable sources of energy and their combinations for specific family house. I will consider the particular conditions that are necessary for their installation and operation, purchase costs and maintenance costs, as well as durability, and I will make their comparison primarily from an economic perspective.

Economic return on investment, especially long-term, that the purchase of house and its energy security in the future undoubtedly belongs, is a current topic that concerns everyone who intends to reasonably and carefully manage their financial resources. The subject environmental and interest in renewable sources of energy were the main reasons for choosing this topic.

2. Thesis objectives and methodology

2.1 Thesis objectives

The aim of the theoretical part is to introduce the issue of renewable energy sources and description of the concrete sources, that are suitable as a heating system for a family house. Another aim I will focus on in the theoretical part is to design and describe a concrete family house, which energy requirement will be solved in the practical part.

In the analytical part calculation of energy balance of the house will be made. The goal of this part is to evaluate all the calculations and chose the best option, out of the four renewable energy sources technologies, for the chosen family house.

2.2 Methodology

The theoretical part will be compiled based on data collection and on study of scientific publications and other sources of Czech as well as English literature. The first part deals with explication of the specific words that are associated with the issue of renewable energy sources. All the publications and sources used in this work will be listed in the list of references.

Calculation of the energy consumption of the house will be conducted as an input parameter for the analytical part. The calculating procedure will fully comply with provisions of the Decree No.78/2013 Coll. Energy performance of buildings. The calculated values of energy requirements for family house will be used as a default requirement for the designed house and for the assessment of the various energy sources options. In the practical part will be comparative and descriptive methods.

2.2.1. Investment plan

The investment plan, according to (Římovská, 2014), we consider the default document processed, respectively typed by investor. It is a summary of the requirements with suggested solution that contains preliminary estimates of balance, consumption, cost estimates, the adequacy of the proposed settlement, estimated return on investment, etc. Before the actual investment plan there is primarily created the future development vision, followed by a corresponding identification of target. These targeted plans are gradually concretised in the form of a project.

2.2.2 Methods of technical and technological specifications

Four possible options for the energy security of the house will be suggested in this thesis. To assess the advantages and disadvantages of the proposed solution alternatives of investment plan, it should be alternatively assessed in particular:

- custom installation options and requirements for the operation of these devices in terms of our proposed family house
- verification of usability, design efficiency and capacity of the equipment in which to be invested
- verification of the technical know-how (if the installation and the operation of the future equipment would not be too difficult for the investor or house user

- How long will it take to purchase the house? Will we use the installation on stages? Any pre-installation adjustments?
- Will we require further structural adjustment? Chimney, electric and gas connection …
- Have I got enough space available on the location and operation of an equipment?
- Will any limitations arise from the installation in the future?
- Do I have enough cash to purchase or will I get a loan?
- Verify the economic or technical lifetime of the investment in the acquired technological equipment
- The possibility of variability for example an increase in the number of people in the house
- Will the installation of new equipment and related facilities require the need to increase (or savings) of energy, water and foreign services?
- Comfort, self-service, remote control, …
- inspection and need of a permission from the authorities
- transport, installation and training of operators in the purchase price

Solution of the points above will undoubtedly have an impact on effectiveness, profitability and return on invested capital.

2.2.3 Evaluation of investment performance and return on

Investment = "currently implemented cash outlay will in the future evaluate, i.e. converted into future cash income over a longer period" (Rosochatecká a kol, 2014).

For the evaluation of the economic efficiency of investment, according to (Rosochatecká a kol, 2014), we must determine in particular:

- Total investment cost (purchase cost of equipment, installation costs, construction work, …)
- Determining the method of financing (own resources or a bank loan)
- Processing of the balance of revenues and expenses during the lifetime (comparing the volume of the invested capital and the time of its return)

For evaluating the economic efficiency of investment are used various evaluation methods. The goal of these methods is to use mathematical tools to quantify the economic effect that the investment brings, and based on the findings, decide which investment option is for the considered project the most economically advantageous.

Among the most commonly used terms for the division of the different methods is the time factor. Based on whether the methods consider the time value of money, we distinguish between statistic and dynamic methods.

Static methods - offer the advantages of simplicity and speed of calculation, neglect lack of time factor and its impact on the value of money. Use of static methods is usually for short-term investments. Even though, distortion may occur in resulting economic effect and an incorrect decision. Despite these shortcomings, we can use it for the first preliminary calculations. Among static methods are payback period or discounted payback period.

Dynamic methods - take into account the effects of time factor and partly the risk factor. These factors are reflected in the discount rate, which is used to update all the input data. Use of dynamic methods is primarily for evaluation of the investments with a longer economic life, when no major distortion of values occurs due time. The dynamic methods include, for example calculation of the net present value or internal rate of return.

The net present value will be used in this theses as one of the criteria, which will help us to choose the economically best option.

NPV (net present value cash flow from the investment)

If the investment includes revenues, we choose the option with the highest NPV. If we evaluate the investment on a cost basis, we are looking for the option with the lowest NPV. Net present value is nowadays one of the most appropriate criteria. The whole lifetime of the project and the possibility of investing in other equally risky project are included in it. NPV is calculated by the formula (1):

$$NPV = \sum_{t=1}^{T} \frac{C_t}{(1+r)^t} - C_o \qquad (1)$$

where Ct = net cash inflow during the period t
C_o = total initial investment costs
r = discount rate, and
t = number of time periods

In year 0 we calculate only with the initial investment. In the following year (which means in the year 1) is the device put into operation and we can count the first revenues, operating expenses, depreciation, etc.

2.2.4. Costing

The purpose of costing is the calculation of the total cost of each technology solutions.

Costs - perceived as monetary expression of substantiated use of resources and work on necessary, useful and desirable activity. (Schneiderová a kol. 2009)

We distinguish:
investment costs (acquisition):

- The cost of processing documents before purchase of equipment
- Costs for the purchase of equipment
- The cost of installation and commission
- The cost of training and, if necessary, functional tests and exams

And operating costs:

- The cost of fuel, energy
- Cost of services (maintenance and inspection of equipment)
- Control of equipment

This work will be focused on the calculation of the investment costs due to the overall life of the project and operation cost related to the selected period.

2.2.5 Analytic hierarchy process

The goal of mathematical tools in the role of optimisation is to determine the values of variables, to which the objective function becomes the minimum or maximum value. In analytic hierarchy process we work with two or more decision-making criteria when we search for the optimal solution.

According to (Šubrt,2011): "Analytic hierarchy process characterises almost every decision-making situation. Considering several criteria when evaluating it brings to the solution of a problem difficulties, conflicts, arising from a general controversy of criteria. If all the criteria indicated the same solution, only one of them would be enough to choose the most appropriate decision."

To assess each proposed version, I will use models of analytic hierarchy process of variations in the way, that a set of possible alternatives I will choose the option that is based on the specific criteria in some way the best and ideal. The ideal variant is a variant comprised of the best criteria values.

Elements of model analytic hierarchy process variants

Variants are the specific decision-making options, the subject of self-determination and they are realisable. In this thesis, I will compare different options of the designed energy security of the house.

Criterion is the aspect of evaluation of alternatives, it may be qualitative or quantitative. Criteria must be independent and should cover all aspects of the selection. My chose criteria, by which I will compare the individual variants, and which are enough for addressing the requirements in this work, are as follows:

- time of the technical and economic life of the machine
- the total amount of initial investment
- consumption, volume of variable and fixed costs of operation
- required level of service and the cost of maintenance and operation of facilities
- settings difficulty, effect on the operating and control comfort, respectively remote adjustment
- net present value of the investment

Decision matrix Y, where the element y_{ij} expresses rating "i variant" of the "j criteria", will have the following form (ŠUBRT, 2011):

$$Y = \begin{matrix} \\ a_1 \\ a_2 \\ \dots \\ a_m \end{matrix} \begin{pmatrix} f_1 & f_2 & \dots & f_n \\ y_{11} & y_{12} & \dots & y_{1n} \\ y_{21} & y_{12} & \dots & y_{1n} \\ \dots & \dots & & \dots \\ y_{m1} & y_{m2} & \dots & y_{mn} \end{pmatrix} \qquad (2)$$

Weights or preference of criteria, which determination is the starting step of the analytic hierarchy process of alternatives, they will be set by the applications of Saaty method of determining the scales.

Saaty method

As reported by (Šubrt, 2011) this method is used to determine the weights of criteria, if there is only one expert to asses. It is a method for the quantitative pairwise comparison criteria. To evaluate paired comparisons of criteria is used a nine-point scale, and it is possible to enjoy even intermediate steps (values 2, 4, 6, 8)
1- Equivalent criteria "i" and "j"
3- Slightly preferred criterion "i" before the "j"
5- Strongly preferred criterion "i" before the "j"
7- Very strong preference of criterion "i" before the "j"
9- Absolute preference of criterion "i" before the "j"

Expert compare each pair of request and the size preferences of the "i criteria" with respect to the "j criteria" will enter in, according to (Šubrt, 2011), Saaty matrix $S=(s_{ij})$:

Where also, according to (Šubrt, 2011) we assume the consistency of the matrix measured by the consistency index:

$$S = \begin{pmatrix} 1 & s_{12} & \dots & s_{1n} \\ 1/s_{12} & 1 & \dots & s_{2n} \\ \dots & \dots & \dots & \dots \\ 1/s_{1k} & 1/s_{12} & \dots & 1 \end{pmatrix} \qquad (3)$$

$$CI=(l^{max}-n)/(n-1) \qquad (4)$$

where "l^{max}" is the largest eigenvalue of Saaty matrix and "n" is the number of criteria.

Analytic hierarchy process allows us to evaluate a finite number of variants depending on the final number of different criteria (Šubrt, 2011.)

The work will evaluate four variants of the energy security of the house by six appropriately selected criteria.

3. Theoretical part

3.1 Renewable energy sources

Renewable energy sources are characterised by having the capability of partial or complete recovery. As examples of this sources we can name solar, wind, hydropower and biomass, as well as biogas, landfill and sewage gas. In some locations, you can also take advantage of the sea tide and geothermal energy, that comes from the bowels of the earth.

Globally, renewable sources cover around 16% of industrially produced energy. In terms of the European Union is the share of energy generated from renewable sources in total gross energy table (%), see Table 1.

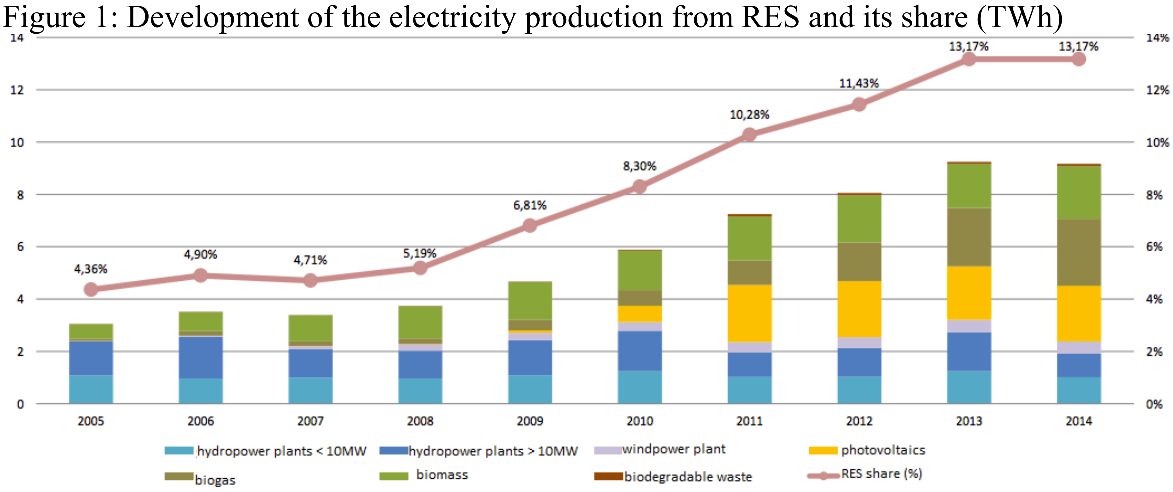
Table 1: Gross final consumption of energy from renewable source (%)

	2004	2007	2010	2014	2015	2020 (target)
European Union	8,48	10,42	12,82	15,96	x	20
Belgium	1,89	3,09	5,65	7,98	7,88	13
Czech republic	6,83	7,96	10,52	15,07	15,07	13
Germany	5,77	9,12	10,47	13,83	14,59	18
France	9,43	10,11	12,52	14,7	15,18	23
Latvia	32,79	29,61	30,38	38,65	37,56	40
Austria	22,56	27,19	30,36	32,76	32,96	34
Poland	6,92	6,94	9,25	11,94	11,78	15
Sweden	38,73	44,18	47,23	52,52	53,93	49
Great Britain	1,13	1,78	3,66	7,07	8,23	15
Norway	58,08	60,14	61,22	69,39	69,43	67,5

Source 1: Eurostat, Renewable energy in the EU 28, (2015)

On the domestic electricity production participate renewable sources by around 15%. Currently we use mostly water, solar and solid biofuels. Regionally, of course, it depends on the climate and geography.

Figure 1: Development of the electricity production from RES and its share (TWh)



Source 2: Energy regulatory office, (2014)

The Czech Republic in 2014:

Energy production from renewable sources: 9,17 TWh. This amount was gained by: water 1,9 TWh, gases 2,57 TWh, solar 2,12 TWh, biomass 2 TWh, wind 0,48 TWh, waste 0,09 TWh. Electricity consumption: 69,62 TWh, share of RES: 13,17 %. The Figure 1 Development of the electricity production from RES and its share in gross domestic consumption. Source: Energy regulatory office – annual report 2014 and the Table 2 Development of the electricity production from RES during 2006-2014. Source: Energy regulatory office – annual report 2014 contains statistical values of the development of renewable electricity generation in 2006-2014.

Table 2: Development of the electricity production from RES during 2006-2014

Renewable source	2006 in MWh	2007 in MWh	2008 in MWh	2009 in MWh	2010 in MWh	2011 in MWh	2012 in MWh	2013 in MWh	2014 in MWh
Hydropower plants < 10 MW	946 400	1 001 845	966 884	1 082 683	1 238 819	1 017 878	1 026 254	1 236 978	1 011 674
Hydropower plants > 10 MW	1 586 330	1 077 493	1 057 451	1 346 937	1 550 655	945 276	1 102 912	1 497 762	897 549
Biomass	728 526	933 360	1 231 210	1 436 848	1 511 911	1 682 563	1 802 591	1 670 327	2 007 039
Biogas	172 589	182 699	213 632	414 235	598 755	932 576	1 472 142	2 241 300	2 566 699
Biodegradable waste	11 260	11 260	11 260	11 684	10 937	35 580	90 190	86 686	83 842
Windpower plant	49 375	125 098	244 661	288 067	335 493	397 003	415 817	480 519	476 544
Photovoltaics	170	1 754	12 937	88 807	615 702	2 182 018	2 148 624	2 032 654	2 122 869
Total generation from RES	3 512 650	3 393 509	3 738 459	46 698 514	5 886 915	7 247 504	8 055 026	924 382	9 169 709
Gross electricity consumption in the Czech republic	71 729 500	72 045 200	72 049 267	68 600 000	70 691 700	70 516 541	70 453 278	70 177 356	69 622 096
Share of RES on gross el. Consumption	4,9%	4,71%	5,19%	6,18%	8,3%	10,28%	11,43%	13,17%	13,17%

Source 3: Energy regulatory office, (2014)

From an economic point of view, the subsidy on renewable energy sources and the possible grants from the program: "Green savings", which is a program of the Ministry of the Environment administered by the State environmental fund of the Czech Republic focused on energy savings and efficient use of energy resources, is important factor for the choice of energy sources.

3.2 Green savings

One of the options when acquiring energy sources significantly save money is the participation in the subsidy program of the Czech Republic for the support of RES use "green savings". Currently it is possible when meeting the conditions for drawing from the program to cover a significant portion of the cost of that particular source.

3.2.1 Conditions of the subsidy program

Subsidy program "Green savings" refers to technical standards information TNI 730329 and TNI 730330, which quite clearly define how to proceed in evaluating the energy performance of house with low energy consumption. Although these documents are primarily focused on calculations of low-energy and passive energy buildings, but their use to other houses to uniquely define many of fundamental data, as stated in the Ministry of environment on its website, for example:

a) boundary conditions for the calculations

Both TNI consider united climate data for the whole country. They always work with average monthly temperatures of air and the total monthly energy of solar radiation. The result of the calculation then is not “real” energy performance of a house in specific locality, but some reference value with which it is possible to directly compare the various houses and flats,

b) Internal gains

Internal gains from people, appliances and lightning are derived in both TNI from anticipated number of buildings and persons in the building. The minimum floor space required for one person is clearly defined, that it would not be possible to artificially increase the influence of internal gains in the calculations.

c) The heat for hot water and other consumption

Heat needed for water during a year is also derived by both TNI from the anticipated number of people. The same procedure is followed in determining the annual energy consumption for lighting. Other auxiliary energy consumption (pumps, fans, control) are dependent on the number of buildings and the method of heating, ventilation etc., and are again clearly numerically defined in the TNI

d) Ventilation

Fresh air flow rate in both TNI methodology is derived from the number of people and it is considering equally for natural or forced ventilation. (Green savings 2015, Ministry of environment).

3.3 Sources of energy for family house

This chapter will be focused on sources of energy suitable for a family house and its brief description

3.3.1 Fireplace

In terms of heating efficiency, the traditional fireplaces are not very effective. Well-built fireplace efficiency ranges between 15 % and 20 %, primarily because the radiant heat heats up only around the fireplace and the rest of the room does not.

If you want to drown effectively, choose a fireplace with built-in fireplace insert. Most of these types of fireplaces are designed to burn wood, we can use wooden or other pellets, briquettes and wooden chips. Such a fireplace is closed fireplace system which leads to more efficient combustion and the efficiency increases up to 80 %. This makes the fuel consumption decrease by 2/3, while decreasing the amount of waste and thus the elimination of environmentally harmful emissions. If you want to heat up even more rooms, choose a double-walled inserts with hot air distribution. In the second part, which acts as a heat exchanger, air circulates through the vertical flow. Due to the acceleration of air flow are some provided with fans.

Underfloor storage heating - uses the excess heat from the fireplace. Vacuum air flow from the fireplace into the chambers in the floor provides a fan with filter located in the technical room. Heat recovery unit can take over its function and the system can be supplemented by air exchange.

3.3.2 Gas boiler

From a structural perspective, there are several types of boilers - hanging boilers or stationary, combined with tank less water heaters or with a possibility of a connection indirectly heated tank or boiler with integrated hot water tank. Furthermore, the boilers are divided by type of exhaust flue system. We can choose a classic conventional (hot water) boiler or condensing boiler. In conventional boilers, the efficiency ranges from 90 to 93%, however the condensing boilers efficiency is up to 100%. Choosing the boiler also depends on the exhaust flue system. If there is not an option of fume outflow to the chimney, should be chosen boiler turbo, in which the flue is solved either by a special double or triple piping, which is designed for air intake and fume outflow or by a divided smoke extraction system.

3.3.3 Electric boiler

It is possible additional source during bivalent operation, mainly used in the cold season when the primary source of energy is not sufficient. Electric boilers not exactly electric heaters. The hydronic heating system with pipes, radiators, pumps, heating water is the heat transfer medium which flows past the heating rods and is heated. It is then transported by a pump to the radiators in the individual rooms. The advantage of electric versus gas boiler is that the high initial investments are eliminated, which is at the gas sources of heat needed, such as gas line or chimney. Additionally, the user receives form the electricity company conveniently low rate "tariff D45d" up to 20 hours a day, that he consumes also for other electrical appliances and thereby he compensates higher operating costs for electric heating.

3.3.4 Radiant heating

Modern alternative of heaters. The advantage is the possibility of installation on the ceiling and the design of attractive paintings or mirrors. For the radiant heating of interiors, as stated in [PETRÁŠ. D a kol, 2008] is used mainly radiant premises heating flow of the heating surface, which directly heat up the surrounding interior constructions, and only a very small part is given directly to the air in the heated interior by the conventions of radiating area. Heat rays that are emitted by the radiant heating surfaces are in fact electromagnetic waves of wavelength 0.78 to 400 μm, i.e. in the range of infrared part of electromagnetic waves spectre, spreading at the speed of 300,000 km/sec. Radiant heating surface can be placed either directly in the building structure (large-heating system built into the floor, walls, ceiling), or as separate heating surfaces located in the space (radiant heaters, heating panels, infrared heaters). Radiant panels are self-heating surface freely located in space. They offer high efficiency of power transmission, easy adjustment of performance and silent operation, with no swirling of dust, mites and dirt, making them ideal for premises in which allergy sufferers and asthmatics can live.

3.3.5 Heat pump

Heat pumps use energy of the environment and geothermal energy. The source of heat for a heat pump use is the earth, water and air.

The function of the heat pump may be described as follows: compressed liquid heat transfer medium (usually water) expands in the expansion valve and in the evaporator, it changes its state of matter into gas. By this procedure, it is cooled to a low temperature and thus can more easily take over heat from its ambience (water, earth, air) and thereby it is heated. Gaseous heat transfer medium passes through the pipe system into the ground, water, or removes air heat and is sucked in and compressed by the compressor back. By the compression of the gas it will increase the gas temperature, which is liquefied in the condenser and raises the temperature of the condenser (usually over 50%). The condenser is constructed as a heat exchanger in which the obtained energy is transmitted to water, which may already heat up central heating radiators, pool, or boiler with water.

<u>Heat pumps earth/water</u>

The most widely used systems using two different installation methods:
Natural borehole - ensures by the dry boreholes implemented technologies for wells. Boreholes may reach a depth of 30m to 150m (there is a constant temperature of 8-12 °C) with minimum pitch of 10m to avoid interference. The area around the borehole is cooled by the exchanger loops of polyethylene pipes. The advantage is the absolute independence on the influence of the environment, disadvantage is the relatively high purchase price.

Subsurface collectors - have relatively lower heating factor than natural boreholes, but more favourable purchase price. The disadvantage of subsurface laying is the impossibility of further area utilization into the depth due to pipeline frost-free depth installation of about 1-1.5m below the surface.

<u>Heat pumps water/water</u>

Groundwater - subject to installation of this technology is the excavation of two wells that between them will be a space of 15 m, of which the first well has a minimum annual yield of about 40 -50 l/min for a pump of power 10kW. Ground water is withdrawn from the first, source well and after cooling is discharged into the second, return well.

Surface water - works on the principle of cooling water in a pond or a stream. This principle is however only used sporadically due to frequent fouling of the exchanger by polluted water.

<u>Heat pumps air/water</u>

The ambient air - pump uses the ambient air temperature, but in winter only up to a certain temperature (-20 °C). This type of pump is simple to install with lower acquisition costs, the drawback is fan noise.

The exhaust air - this method uses air from technological processes and furthermore exhausted ventilated air produced through the forced ventilation.

Heat pumps earth/water are usually dimensioned on the performance, that corresponds to the 60-80% of heat loss (for bivalent operation) or 100% of the heat losses (monovalent operation). Heat pumps air / water are dimensioned on the performance that corresponds to the 70-90% of heat loss (for bivalent operation). Bivalence point at earth pumps is chosen in the temperature range -5 °C to -8 °C, for the air pumps it is in the temperature range of -3 °C to -5 °C. (Karlík, R., 2010)

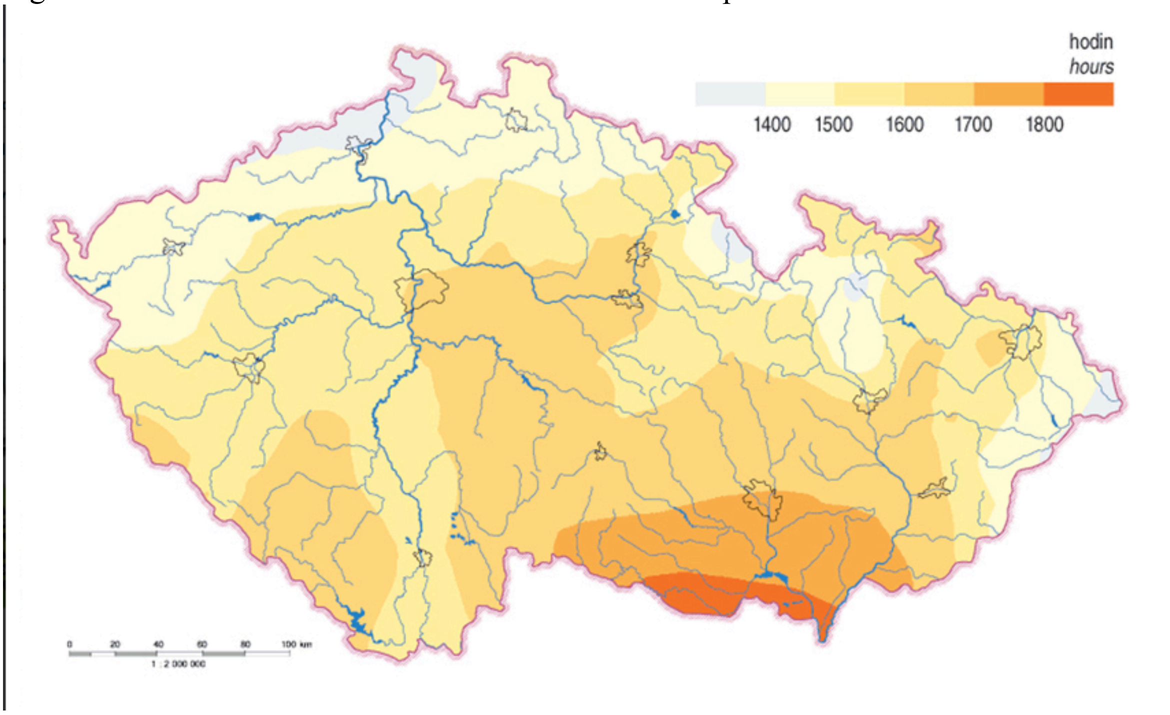
3.3.6 Solar, photovoltaic, photothermic system

Solar energy that heats the surface of our planet is practically inexhaustible, easily available, performance-stable and supply is totally reliable (Velfel a kol., 2010).

The annual total of incident solar energy particularly affects the geographical location, the orientation of the system in relation to the sun, total hours of sunshine, altitude, and finally, air quality.

Conditions for the use of solar energy in the Czech Republic are relatively good. The total duration of sunshine (no clouds) is from 1 400 to 1 700 hours per year, see Figure 2.

Figure 2: The total duration of sunshine in the Czech Republic

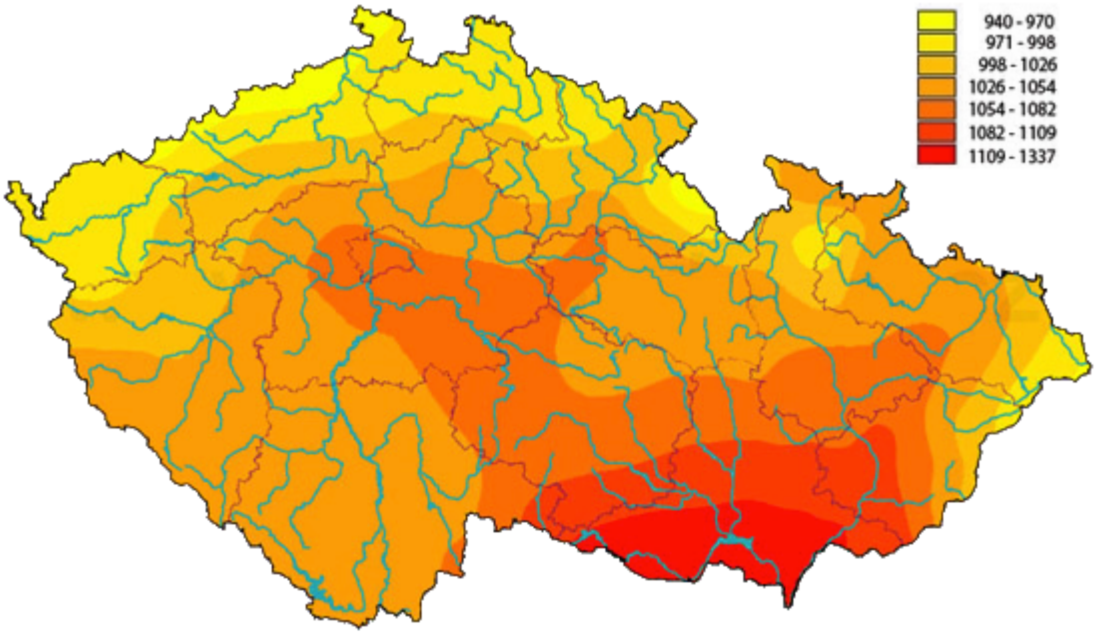


Source 4: ISOFEN ENERGY, s. r. o.,(2014) available from: http://www.isofenenergy.cz/Slunecni-zareni-v-CR.aspx

Suitability of the locations for the use of solar energy is best described in the map of the annual total global solar radiation in the Czech Republic, which is based on long-term meteorological measurements. In the Czech Republic will fall on one square meter about 950 to 1340 kWh of solar energy of which the largest part (about 75%) is during the summer. The intensity of sunshine enables to completely cover the energy needs for water heating from approximately the beginning of April to September, for the rest of the year the sun offers about 60% of the required energy.

Indication of the annual total global solar radiation is very important for calculations of the future energy balance of a photovoltaic system and thus the return on investment. If we know how much solar radiation annually will fall on one square meter of photovoltaic systems and photovoltaic panel conversion efficiency, which is approximately 14%, we get from this area about 133-188 kWh of electricity power per year. Yearly global solar radiation in the Czech Republic is shown in Figure 3 Annual total global solar radiation in the Czech Republic [W/m^2].

Figure 3: Annual total global solar radiation in the Czech Republic (W/m^2)



Source 5: ISOFEN ENERGY, s. r. o., (2014) available from: http://www.isofenenergy.cz/Slunecni-zareni-v-CR.aspx

There are obviously far more renewable energy sources, in this chapter I mention only those sources that are suitable for a family house. I will use these sources and their specifications for the energy security of the projected house in the next chapters of this work.

4. Analytical part

4.1 Project of a house

House, which technical parameters and specifications I will use for this bachelor theses is following. It is a proposal of new single-storey house, which will be built in the Královéhradecký Region in the village Očelice. House is designed as a single-storey (bungalow) without a basement totalling 4+1. Inside the building is layout of the apartment 4+1 with other accessories. In the single floor is entrance hall and hallway, kitchen with dining room and living room, study, children's room, guest room, one larger and one smaller bathroom each with toilet, bedroom, cloakroom and technical room. I have chosen this location because I live in Očelice for 23 years and I know the all conditions needed for calculations used in this thesis. According to (ENERGIASTAV CZ, s. r. o. and MS HOUS, s. r. o.) in this region is this type of house (bungalow, 4+1) most requested for a four-member family.

4.1.1 Basic information about the facility:

The length of the building	18,70 m
The width of the building	11,75 m
Height (spot height roof top)	5,25 m
Built up area	201,0 m^2
Area of land	1170 m^2

The main roofed entrance to the family house is on the northwest side, another direct exit is from the living room by a glass door to the outdoor terrace situated on the opposite side of the house.

The living room is oriented to the southwest with the southern wall. Cladding works are brickwork Heluz thickness 380 mm + facade EPS 70 thickness 100 mm. The ceiling to the attic space will be provided with mineral wool insulation Rockwooll thickness 260 mm. The floor will be fitted with insulation made of PS thickness 100mm + system board for floor heating thickness 30 mm. The windows are new plastic, according to the assignment from building designer UN = 1.2 W/m^2.K. Entrance doors are new wood, according to the assignment from building designer UN = 1.4 W/m^2.K.

Heat transmission coefficient of building constructions according to data of the building designer meet the CSN 730540-2:

Outside peripheral wall	UN = 0,174 W/m^2K
Floor	UN = 0,226 W/ m^2K
Ceiling to the attic space	UN = 0,175 W/ m^2K
Windows, French doors	UN = 1,2 W/ m^2K
Entrance doors	UN = 1,4 W/ m^2K
Interior doors	UN = 3,5 W/ m^2K
Interior masonry construction	UN = 0,62 – 1,61 W/ m^2K

4.1.2 Energy performance of the house

The total energy requirement of the building during the various time periods and a summary during the entire year consists of the energy requirements for:

Heating
Ventilation
Cooling
Hot water heating
Lighting

In the house will be installed a low temperature heating system. The planned number of occupants is 4. For consumption of hot water, we consider 50 litres person/day. Furthermore, we will consider installation of controlled ventilation using heat recovery units.

4.1.3 Characteristics and specifics for the calculation of costs of sources

Table of consumption of household appliances, which will be used in the house and their consumption derived from the frequency of its use.

Table 3: Consumption of household appliances

Appliance	Power (W)	Working hours (hours/day)	Annual consumption (kWh)	Heat recovery (kWh)
Electric stove	2000	1	730	371
Electric oven	2000	0,5	365	186
Kettle	2000	0,12	88	45
Microwave	600	0,3	66	33
Refrigerator	120	6	263	134
Dishwasher	650	1,5	356	181
Air recovery	25	24	219	111
Washing machine	600	1,5	329	167
Lightning 1	18	8	53	27
Lightning 2	12	4	18	9
Television	70	6	153	78
Personal computer	80	6	175	89
Internet (modem,…)	10	24	88	45

Source 6: own procedure

Substrates for the processing of Table 3 have been drawn from the Web site TZB.INFO, approximate value of electricity for home appliances. Available from: http://www.energetickyporadce.cz/cs/kalkulacky-energie/domaci-spotrebice/posouzeni-provoznich-nakladu-domacich-spotrebicu/

Total electricity consumption for household appliances is in the sum 2,901 kWh/year. Internal heat gains from appliances are in total 1,476 kWh.

4.2 Variants of renewable energy sources concepts

When designing the options there were chosen different primary sources and that for variant I gas, version II and IV electricity and biomass and for variant III electricity and the external ambience. For all variants is a primary assumption the installation for low-energy house with a low temperature heating and hot water heating. Overall energy balance includes use of energy for heating, hot water heating, the operation of technical equipment, lighting and household appliances.

4.2.1 Variant I: Gas condensing boiler + solar panels

The heat source for heating the building will be wall-mounted condensing gas boiler. The boiler will be from Viessmann company, type Vitodens 343-F with a rated output of 1.9 - 19 kW with a solar integration and a reservoir of 220 liters. Designed boiler is based on long-term research on world technical level because of its high efficiency, by that can secure at even 40% of nominal performance, low incidence of harmful exhaust emissions, particularly NOx, operating reliability and long service life. In terms of the occurrence of harmful exhaust emissions, these boilers meet the most stringent standards of Western European climate protection. On the boiler will be equipped a controller Vitotronic 200. The regulation will be controlled by the outside temperature - euthermic regulation. In the boiler will be prepared heating water with temperature gradient of 40/35 °C, in case of hot water heating may be a temperature of a heating water up to a temperature gradient of 80/60 °C. For installation of Viessmann equipment it is necessary to observe the installation and operating instructions that came with the device from the manufacturer. Putting the boiler into operation is performed by a service technician from Viessmann company.

The heating element is a low temperature floor heating system Ivar TH30P, ALPEX - THERM XS the heating surface of 125.3 m^2. Individual heating surfaces for the rooms are divided as follows:

Heating surface 75 R 16x2 16.9 m^2, heating surface R 150 16x2 48.5 m^2, heating surface R 225 16x2 6.5 m^2, heating surface R 300 16x2 53.4 m^2.

Table 4: Components of variant I

Source + accessories	Type	Price without VAT	Price with VAT
Gas condensing boiler	Viessmann, Vitodens 343-F, 1,9 – 19 kW	134075	**162240**
Chimney	Schiedel ABSOLUT	27233	**32954**
Assembly, revision	ČEZ RWE	34998	**42350**
Hot water distribution systém	Ivar system TH30P, ALPEX - THERM XS heating surface 125,3m	5177	**6265**
	ALPEX - THERM XS 16x2 mm, 200 m		
	- 809 m	20225	**24270**
	Compression fittings for ALPEX pipeline		
	TA4420 16x2 Alu-EK - 24 pieces	1190	**1440**
	Manifold assembly CS 553 VP 7-way		
	- 1 piece	8360	**10116**
	Manifold assembly CS 553 VP 8-way		
	- 1 piece	8950	**10830**
	Electrothermal propulsion 230V TE 3040 230V		
	- 12 pieces	6981	**8448**
	Room thermostat T 6360 A 1079 - Honeywell		
	- 1 piece	702	**849**
	Central apartment unit Vitotronic 200-H,HK3B		
	– 1 piece	23419	**28338**
Solar panels - solar collectors	JUNKERS FKC1-1S 2 piecestotal absorption area 1300x2100, 4,46m2, set	57525	**69609**
	Pipeline Cu 18x1,0 izol 20m	420	**508**
Total			**398217**

Source 7: own procedure

Assumptions for the calculation:
Hot water boiler connected to a system of low temperature heating
The system is a low temperature - floor heating surfaces (40/35 °C)
Control of room temperature is euthermic
Annual efficiency of heat production 98%
Dimensioned for 120% heat loss

Table 5: Strengths and weaknesses of variant I

Strengths	**Weaknesses**
- lower operation costs (price of gas)	- dependence on the supply of natural gas
- lower CO_2 emissions	- the need to build a chimney
- excellent control - adjusts the system needs	- difficult to operate
- quality burning of fuel in condensing mode	- necessity of revision
- proven solution	- high investment cost
Opportunities	**Threats**
- reduction of primary energy consumption	- increasing gas prices

Source 8: own procedure

4.2.2 Variant II Electric boiler + Fireplace stoves with heat exchanger

For this variant will be a source of heating in the building hanging electric boiler THERM EL 9 with a touchscreen and a heat output 1,0 - 9,0kW, from the Czech manufacturer THERMONA. As an additional secondary heat source will be installed fireplace with a fireplace insert. The heat exchanger in the fireplace insert will be suitable to the specific type of fireplace (e.g. Scandigue, Kago, Romotop etc.). The best way is to buy a fireplace insert already with a fireplace. In the storage tank will be accumulated potential heat from the fireplace insert while burning wood in the fireplace in the living room. In the storage tank will be prepared warm water for underfloor heating. At the time of heat accumulation from the fireplace insert this temperature will be higher than is required for the floor heating.

Table 6: Components of variant II

Source + accessories	Type	Price without VAT	Price with VAT
Electric boiler	THERM EL 9 THERMONA	20899	**25289**
Hot water distribution system	Ivar system TH30P, ALPEX - THERM XS heating surface 125,3m	5177	**6265**
	ALPEX - THERM XS 16x2 mm, 200 m		
	- 809 m	20225	**24270**
	Compression fittings for ALPEX pipeline		
	TA4420 16x2 Alu-EK - 24 pieces	1190	**1440**
	Manifold assembly CS 553 VP 7-way		
	- 1 piece	8360	**10116**
	Manifold assembly CS 553 VP 8-way		
	- 1 piece	8950	**10830**
	Electrothermal propulsion 230V TE 3040 230V		
	- 12 pieces	6981	**8448**
	Room thermostat T 6360 A 1079 - Honeywell		
	- 1 piece	702	**849**
Fire place stoves with heat exchanger	HAAS+SOHN mantova AL	17869	**21622**
	Instalations	7000	**8470**
Chimney	Schidel absolut	27235	**32954**
Storage tank	Dražice NADO 1000/100v2	9835	**11900**
	Isulations SYMBIO II 80mm	3967	**4800**
	Expansion tank REGULUS HS025 (25l)	736	**890**
Pump, central apartment unit		45000	**54450**
Total			**222593**

Source 9: own procedure

Assumptions for the calculation:
Hot water boiler connected to a central heating system
The system is a low temperature - floor heating surfaces (40/35 ° C)
Control of room temperature is euthermic
The boiler output is controlled stepwise
The location of the stove in each heated room, respectively. one stove for interconnected rooms

What affects the actual fuel consumption:
Fuel consumption for firing
A high proportion of not burnt fuel ash residues
Imperfect combustion control - unstable performance of the source

Table 7: Strengths and weaknesses of variant II

Strengths	**Weaknesses**
- possibility of heating only by fireplace stove during winter	- dependence on the supply of electricity
- acceptable investment cost	- the need to build a chimney
- excellent control - adjusts the system needs	
Opportunities	**Threats**
- reduction of primary energy consumption	- increasing electricity prices
- when heating by fireplace stove independence of energy supply	

Source 10: own procedure

4.2.3 Variant III Heat pump air / water + solar panels

The heat pump from Viessmann, type Vitocal 242-S, with a rated power of 5.6 kW. This is a heat pump air-water as a compact device in performance "Split" for heating, cooling and heating of potable water with integrated solar function. The system has an integrated 220 liters' water tank and built-in circulation pump with 3-way valve.

Table 8: Components of variant III

Source + accessories	Type	Price without VAT	Price with VAT
Heat pump air-water	Vitocal 242-S, 5,6kW, AWT- AC 241.A07	142835	**172840**
Storage tank	Dražice NADO 1000/100v2	9835	**11900**
	Isulations SYMBIO II 80mm	3967	**4800**
	Expansion tank REGULUS HS025 (25l)	736	**890**
Hot water distribution system	Ivar system TH30P, ALPEX - THERM XS		
	heating surface 125,3m	5177	**6265**
	ALPEX - THERM XS 16x2 mm, 200 m		
	- 809 m	20225	**24270**
	Compression fittings for ALPEX pipeline		
	TA4420 16x2 Alu-EK - 24 pieces	1190	**1440**
	Manifold assembly CS 553 VP 7-way		
	- 1 piece	8360	**10116**
	Manifold assembly CS 553 VP 8-way		
	- 1 piece	8950	**10830**
	Electrothermal propulsion 230V TE 3040 230V		
	- 12 pieces	6981	**8448**
	Room thermostat T 6360 A 1079 - Honeywell		
	- 1 piece	702	**849**
Solar panels - solar collectors	JUNKERS FKC1-1S 2 piecestotal absorption area 1300x2100, 4,46m2, set	57525	**69609**
	Pipeline Cu 18x1,0 izol 20m	420	**508**
Total			**322765**

Source 11: own procedure

<u>Assumptions for the calculation:</u>

The heat pump is connected to the central heating system

The system is a low temperature - floor heating surfaces (40/35 ° C), respectively in combination with heating bodies designed as a low temperature

Fuel factor indicated in the entry field for the parameters A2/W35 (Air temperature/the heating water temperature)

Output of the heat pump is rated at 70% - 80% of heat loss of the building, the rest covers electric boiler

Control of room temperature is euthermic

Part of the heating system is the storage tank 200 l

What affects the actual fuel consumption:

Increased energy consumption of the operation of electric boilers at low temperatures

Low temperature heating system allows you to set a lower temperature in heated rooms, due to seemingly higher emotional temperature.

The high inertia of the system slightly increases the energy consumption due to the slower response to an immediate need for heat

Operating expenses in the amount of 2% of the initial investment cost

One of the main factors that affect the amount of savings of heat pumps system is control system which is included in the heat pump.

Table 9: Strengths and weaknesses of variant III

Strengths	**Weaknesses**
- lower operation costs	- dependence on the supply of electricity
- remote control	- high investment cost
- excellent regulation	- demanding service
Opportunities	**Threats**
- reduction of primary energy consumption	- too low temperatures can reduced pump efficiency

Source 12: own procedure

Underfloor heating system

Advantages:

Heats the room by a larger area than the conventional elements while saving energy

The heating water in the system is colder than in conventional elements

Uniform heating of space increases humidity without unwanted condensation - is invisible thus does not interfere with the aesthetics of the room.

Disadvantage:

Invisibility and finality prevents major changes in the interior layout

4.2.4 Variant IV Radiant panels - infrared heaters

Radiant panels from PION which installation is expected in seven rooms. Installed glass infra panels PION Thermoglass contain the heating plates of perfectly transparent glass with nanotechnology in the aluminum frame on the brackets that are designed to be mounted on the ceiling or on the walls. Brackets for attachment on the construction of the frame are included in the price.

Table 10: Components of variant IV

Source + accessories	Type	Price without VAT	Price with VAT
radiant panels - living room	3x PION PT 11	24544	**29700**
radiant panels - bedroom	1x PION PT 11	8182	**9900**
radiant panels - children's room	1x PION PT 11	8182	**9900**
radiant panels - workroom	1x PION PT 06	6198	**7500**
radiant panels - bathroom 1	1x PION PT 04	5620	**6800**
radiant panels - bathroom 2	1x PION PT 11	8182	**9900**
radiant panels - hall	1x PION PT 11	8182	**9900**
whireless thermostat	PION PT21	909	**1100**
electric heater for hot water	Dražice OKCE 200 S	6229	**7537**
Total			**92237**

Source 13: own procedure

Radiant panels offer an interesting option of heating system that is easy to install and very simple to operate. The following Table. 11 presents possible pros and cons of this investment.

Table 11: Strengths and weaknesses of variant IV

Strengths	**Weaknesses**
- each panel is seperately controllable	- high operation costs
- possibility of remote management system	- dependence on electricity supply
- design of panels properly fit into interior	
- panels are maintenance-free, without the need for regular servicing	
- heated surface, not only air	
- suitable for allergy sufferers and asthmatics	
Opportunities	**Threats**
	- increasing electricity prices
	- power outage

Source 14: own procedure

5 Evaluation of results

5.1 Analysis of the Energy Performance of chosen house

For the calculations in the next part, the data and specifications listed in the previous chapters will be processed.

5.1.1 Calculation of expected changes in annual costs of electricity

Input variables for the calculation were drawn from EUROSTAT database on the website of the Czech Statistical Office. Prices of electricity, according to the type of consumer incorporation. See the Table 12 below available from: http://apl.czso.cz/pll/eutab/html.h?ptabkod=ten00117.

Table 12: Electricity prices of mid-sized housholds (EUR/KWh)

year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Price EUR/kWh	0,087	0,099	0,107	0,14	0,146	0,15	0,166	0,166	0,168	0,139	0,139	0,14

Source 15: own procedure

Electricity prices in individual years are given in EUR/kWh, which will not affect the resulting values because we concentrate on the calculation of the expected changes and it does not matter whether the change will be calculated in EUR or CZK.

Table 13: Average annual increase of electricity prices

year	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016
Development of a price/year	13,40%	8,30%	31,30%	3,85%	2,80%	10,90%	0,30%	1,00%	-18,30%	-0,20%	2,50%
Average annual increase	**5,08%**										

Source 16: own procedure

The above Table 13 of electricity prices development year by year, of the Mid-sized households type, shows that the average annual increase of electricity prices is 5%. I will use this average annual increase as an expected increase for the following years.

5.1.2 Calculation of the costs of heating, hot water and electricity appliances

For the calculations have been used a web application for cost calculation on the web page TZB.INFO. A comparison of the heating costs TZB-INFO. Available from: http://vytapeni.tzb-info.cz/tabulky-a-vypocty/138-porovnani-nakladu-na-vytapeni-tzb-info

Table 14: Annual costs of individual variants

Fuel primary heat source efficiency	fuel price (CZK) connection fee	fuel consumption in year^{-1}	Annual costs (CZK)						without initial investment
			Heating	Hot water	Other appliances	The fee payment	Investment and maintenance	total	
Natural gas condensing boiler 98%	1.18273/kwh 259/month	1 330 m^3 14033 kWh	11 432	5 165	12 707	4 920	16083	**50 307**	**34 224**
Electricity electric boiler 95%	NT 2.14624/kWh VT 2.62338/kWh 443/month	13 910 kWh	21 224	8 630	7 009	5 316	7900	**50 079**	**42 179**
Heat pump air-water 3,2 heating facto	NT 2.22029/kWh VT 2.36798/kWh 381/month	5 010 kWh	8 474	2 650	7 193	4 572	25417	**48 306**	**22 889**
Electricity radiant panels 99%	NT 2.14624/kWh VT 2.62338/kWh 443/month	13 253 kWh	20 163	8 281	7 009	5 316	2333	**43 102**	**40 769**

Source 17: own procedure

5.1.3 Calculation of the net present value of the investment

Among the economic instruments that are suitable for the return on investment was chosen as the best the calculation of the net present value of the investment. For this calculation, we have sufficient input data. Since none of the variants showed during the lifetime any profit, its values are negative, as shown in Table 15.

The calculation of the net present value of investment is made by the formula (1), the discount rate of 3%.

Table 15: Calculation of net present value of the investment

Variant	Initial investment	annual costs	lifetime of investment	Percentage change in annual costs	Net present value (CZK)
variant 1	398217	34224	15	5%	**-970416**
variant 2	222593	42179	15	5%	**-927794**
variant 3	322765	22889	20	5%	**-859588**
variant 4	92237	40769	17	5%	**-840524**

Source 18: own computation

From the calculation of the net present value of the investment perspective it, according to Table 15, seems like the best option is variant 4, which has the lowest negative value.

5.2 Comparison of the designed variants

Mutual comparison of individual options based on multiple criteria analysis of variants will be performed with the use of scales elections through Saaty method.

5.2.1 Criteria comparison of the options

Based on the above materials of the previous chapters can be compiled following Saaty matrix. The goal is to determine which of the proposed alternatives of energy security will be the best for the sample house. The following table lists the various options and criteria on which the options will be evaluated. Based on the subjective point of view I have chosen the following criteria: lifetime of investment, initial investment, annual operating costs, difficulty of settings and regulation, demands for service and maintenance, and net present value.

Table 16: Saaty matrix

Variant/ criteria	Lifetime of investment (K1)	Initial investment (K2)	Annual costs (K3)	Difficulty of setting and regulation (K4)	Demands for service and maintenance (K5)	Net present value (K6)
Variant 1	15	398217	34224	complicated	demanding	**-970416**
Variant 2	15	222593	42179	easy	little challenging	**-927794**
Variant 3	20	322765	22889	difficult	little challenging	**-859588**
Variant 4	17	92237	40769	easy	undemanding	**-840524**
	max	**min**	**min**	**min**	**min**	**max**

Source 19: own computation

Since we have in the matrix some maximizing criteria and some minimizing, the next step of the calculation is to convert all the criteria into minimizing. Criteria matrix job is to transfer maximization criteria into minimizing using the transformation $y'_{ij} = -y_{ij}$.

Table 17: Criteria matrix

	Lifetime of investment (K1)	Initial investment (K2)	Annual costs (K3)	Difficulty of setting and regulation (K4)	Demands for service and maintenance (K5)	Net present value (K6)
Variant 1	-15	398217	34224	3	4	**970416**
Variant 2	-15	222593	42179	1	2	**927794**
Variant 3	-20	322765	22889	4	2	**859588**
Variant 4	-17	92237	40769	1	1	**840524**

Source 20: own computation

Now the matrix itself is ready to execute the calculation. In the first step of calculation we choose weights of individual criteria and verify the consistency of matrix at selected scales. The weights are determined by Saaty method.

Table 18: Determination of the weights of Saaty matrix

	K1	K2	K3	K4	K5	K6	Geometric mean	Standardized criterion weight
K1	1	1/5	1/4	2	1/2	1/7	0,43885	**0,045458124**
K2	5	1	3	6	5	1/4	2,26493	**0,234611982**
K3	4	1/3	1	5	4	1/5	1,37189	**0,142106746**
K4	1/2	1/6	1/5	1	1/3	1/8	0,29758	**0,03082472**
K5	2	1/5	1/4	3	1	1/7	0,63293	**0,065561833**
K6	7	4	5	8	7	1	4,64776	**0,481436595**
total	19,5	5,9	9,7	25	17,67	1,84	9,65394	1
		I_{max} =	6,464018		CI=	**0,092804**		

Source 21: own computation

The consistency of the matrix is measured by consistency index by formula (4) is equal to 0.092804, so the matrix can be considered as consistent.

From the results shown in column "Standardized criterion weight" is visible the priority given to the individual criteria. As the strongest criterion is evaluated criterion K6 (net present value), the smallest weight has the criterion K4 (Difficulty of settings and regulation).

The values of the weights of other criteria, can be easily read from the table. Their ranking is as follows:

Net present value
Initial investment
Annual costs
Demand for service and maintenance
Lifetime of investment
Difficulty of settings and regulation

The next step is the comparison of the proposed variants from the specific criteria point of view. This will set weights for the relationship of variants to the criterion for all six selected criteria. It is necessary for all the matrices to verify the consistency by consistency index.

Saaty matrix for criterion "Lifetime of investment":

From the table 19 can be seen that the criterion "lifetime of investment" affects individual variants. Because the sources in the proposed variants have different life spans, from 15 to 20 years, it was necessary to take this fact into account for the calculation. From the table 19 can be seen that the best variant from the lifetime of investment point of view is the variant number 3.

Table 19: Saaty matrix for criterion "Lifetime of investment"

Standardized criterion weight = 0,045458124	**Variant 1**	**Variant 2**	**Variant 3**	**Variant 4**	**Geometric mean**	**Standardized criterion weight**
Variant 1	1	1	1/8	1/6	0,37992	**0,05989151**
Variant 2	1	1	1/8	1/6	0,37992	**0,05989151**
Variant 3	8	8	1	3	3,72242	**0,58681132**
Variant 4	6	6	1/3	1	1,86121	**0,29340566**
total	16	16	1,58	4,33	6,34347	1
	l_{max} =	4,11414		CI=	**0,038046**	

Source 22: own computation

The consistency of the matrix is measured by consistency index by formula (4) is equal to 0.038046, so the matrix can be considered as consistent.

Saaty matrix for criterion "Initial investment":

Initial investment is a value involving a total amount required for the acquisition of the source and all its components (pipe, beams, chimney), installation (installation by a company, user training) and commissioning (permission of the local authority). Usually it is the largest investment in the equipment and significantly increases the budget, especially if the purchase of equipment is financed by a loan. As shown in Table 20, the lowest initial cost will have the variant number 4.

Table 20: Saaty matrix for criterion "Initial investment"

Standardized criterion weight = 0,234611982	**Variant 1**	**Variant 2**	**Variant 3**	**Variant 4**	**Geometric mean**	**Standardized criterion weight**
Variant 1	1	1/2	4	1/7	0,73111	**0,113359175**
Variant 2	2	1	6	1/5	1,24467	**0,192987053**
Variant 3	1/4	1/6	1	1/9	0,26085	**0,040444996**
Variant 4	7	5	9	1	4,21287	**0,653208776**
total	10,25	6,67	20,00	1,45	6,4495	1
	l_{max} =	4,205208		CI=	**0,0684026**	

Source 23: own computation

The consistency of the matrix is measured by consistency index by formula (4) is equal to 0.0684026, so the matrix can be considered as consistent.

Saaty matrix for criterion "Annual costs":

Annual operational costs include the estimated annual consumption multiplied by the price of fuel, as well as fixed fees (connection), maintenance and servicing of equipment and other payments associated with the operation of the equipment, see Table 14. From the table 21, it is clear, that the lowest annual operating costs will have equipment from the option 3.

Table 21: Saaty matrix for criterion “Annual costs”

Standardized criterion weight = 0,142106746	Variant 1	Variant 2	Variant 3	Variant 4	Geometric mean	Standardized criterion weight
Variant 1	1	2	1/5	4	1,12468	**0,178644552**
Variant 2	1/2	1	1/7	2	0,61479	**0,097653452**
Variant 3	5	7	1	9	4,21287	**0,669173697**
Variant 4	1/4	1/2	1/9	1	0,34329	**0,0545283**
total	6,75	10,5	1,45	16	6,29563	1
	I_{max} =	4,073967		CI=	**0,024656**	

Source 24: own computation

The consistency of the matrix is measured by consistency index by formula (4) is equal to 0.024656, so the matrix can be considered as consistent.

Saaty matrix for criterion “Difficulty of setting and regulation”:

Difficulty of setting and regulation involves, as the name itself suggests how the device is user-friendly, i.e. Is it necessary for every manipulation use manual or call the online help desk, or is a digital manual part of the device, or can the device be remotely operated, for example by using a mobile phone? etc. Even though this criterion does not have in the table of weights a great value, it will certainly be significant for users.

Table 22: Saaty matrix for criterion “Difficulty of setting and regulation”

Standardized criterion weight = 0,03082472	Variant 1	Variant 2	Variant 3	Variant 4	Geometric mean	Standardized criterion weight
Variant 1	1	1/6	3	1/6	0,53728	**0,086488157**
Variant 2	6	1	9	1	2,71081	**0,436370163**
Variant 3	1/3	1/9	1	1/9	0,25328	**0,040771517**
Variant 4	6	1	9	1	2,71081	**0,436370163**
total	13,33	2,28	22,00	2,28	6,21218	1
	I_{max} =	4,03971		CI=	**0,0132361**	

Source 25: own computation

The consistency of the matrix is measured by consistency index by formula (4) is equal to 0.0132361, so the matrix can be considered as consistent.

Saaty matrix for criterion “Demand for service and maintanance”:

Demands for service and maintenance includes in particular: Is there a possibility of simple repairs and service by yourself? Or is it necessary to call a professionally trained technique for any manipulation? Does it include the need for regular revision and time-consuming maintenance? According to Table 23 the least demanding device on the service and maintenance is option 4.

Table 23: Saaty matrix for criterion "Demand for service and maintanance"

Standardized criterion weight = 0,065561833	Variant 1	Variant 2	Variant 3	Variant 4	Geometric mean	Standardized criterion weight
Variant 1	1	1/6	1/6	1/9	0,23570	**0,041983428**
Variant 2	6	1	1	1/3	1,18921	**0,211824827**
Variant 3	6	1	1	1/3	1,18921	**0,211824827**
Variant 4	9	3	3	1	3,00000	**0,534366918**
total	22	5,17	5,17	1,78	5,61412	1
	I_{max} =	4,06508		CI=	**0,0216924**	

Source 26: own computation

The consistency of the matrix is measured by consistency index by formula (4) is equal to 0.0216924, so the matrix can be considered as consistent.

Saaty matrix for criterion "Net present value":

Net present value of the investment is economically one of the most important criteria when calculating the economic return on investment. The table 24 shows that the variant number 4 meets this criterion most.

Table 24: Saaty matrix for criterion "Net present value"

Standardized criterion weight = 0,481436595	Variant 1	Variant 2	Variant 3	Variant 4	Geometric mean	Standardized criterion weight
Variant 1	1	1/4	1/6	1/9	0,26085	**0,044369866**
Variant 2	4	1	1/2	1/5	0,79527	**0,135273236**
Variant 3	6	2	1	1/3	1,41421	**0,240553224**
Variant 4	9	5	3	1	3,40866	**0,579803674**
total	20	8,25	4,67	1,64	5,87899	1
	I_{max} =	4,07766		CI=	**0,0258877**	

Source 27: own computation

The consistency of the matrix is measured by consistency index by formula (4) is equal to 0.0258877, so the matrix can be considered as consistent.

Now the calculation of weights is complete and after substitution into the original matrix, Saaty matrix will look as see Table 25 Entry weights of individual criteria.

Table 25: Entry weights of individual criteria

Variant/ criteria	Lifetime of investment	Initial investment	Annual costs	Difficulty of setting and regulation	Demands for service and maintenance	Net present value
Standardized criterion weight	0,0454581	0,2346120	0,1421067	0,0308247	0,0655618	0,4814366
Variant 1	0,0598915	0,1133592	0,1786446	0,0864882	0,0419834	0,0443699
Variant 2	0,0598915	0,1929871	0,0976535	0,4363702	0,2118248	0,1352732
Variant 3	0,5868113	0,0404450	0,6691737	0,0407715	0,2118248	0,2405532
Variant 4	0,2934057	0,6532088	0,0545283	0,4363702	0,5343669	0,5798037

Source 28: own computation

After multiplying the mutual weights of variants with the weights of individual criteria, we get the result table (Table 26 Final evaluation of the various options by certain criteria). There is a comparison of individual variations and the result is displayed in the column “Total”.

Table 26: Final evaluation of the various options by certain criteria

Variant/ criteria	Lifetime of investment	Initial investment	Annual costs	Difficulty of setting and regulation	Demands for service and maintenance	Net present value	Total
Standardized criterion weight	0,0454581	0,2346120	0,1421067	0,0308247	0,0655618	0,4814366	
Variant 1	0,0027226	0,0265954	0,0253866	0,0026660	0,0027525	0,0213613	**0,0814843**
Variant 2	0,0027226	0,0452771	0,0138772	0,0134510	0,0138876	0,0651255	**0,1543409**
Variant 3	0,0266753	0,0094889	0,0950941	0,0012568	0,0138876	0,1158111	**0,2622138**
Variant 4	0,0133377	0,1532506	0,0077488	0,0134510	0,0350341	0,2791387	**0,5019609**

Source 29: own computation

From the Table 26 Final evaluation of the various options by certain criteria is clear that the best option is the variant number 4, radiant panels.

5.2.2 Final evaluation

For the calculations, Saaty method of quantitative paired comparison criteria have been used. This method of evaluation is used to determine the weights of the criteria and is especially useful in the evaluation with only one expert. Setting weights and preferences of individual criteria is burdened with a relatively large part of subjectivity. Nevertheless, this method is relatively accurate and is suitable for fulfillment of the objectives of this work.

As the best option based on the specified criteria is a variant number four, radiant panels. This is primarily due to the rate of initial investment and relatively maintenance-free operation with a simple adjustment. Even though the annual operational costs are quite high, due to the assumption that the price of energy will not rise too steeply, the radiant panels are, as investment of all the proposed options, by far the best.

6. Conclusion

The thesis is divided into three mutually systematically connected parts. In the introduction is a theoretical description of the topic and introduction to the topic. This part is followed by the objectives of the work, which the author aims to fulfill and by a methodology, which is a specifically described mathematical tool used in the analytical part. The theoretical part titled Literature review discusses the issue of renewable energy sources, with emphasis on sources suitable for house heating. Thesis also mentioned subsidy program of the Ministry of Environment "Green Savings", which supports the concept of renewable energy sources and provides significant subsidies for these projects.

The aim of this work was the design and description of a particular house and a solution of its energy security through renewable energy sources. The chosen house is located in the village Očelice, in the thesis are extensively described its proposition, as well as technical specifications.

For energy security of the chosen house, the theoretical part of the work designed and developed four variants of renewable energy concept, each based on a different power source. At the proposal has been considered the number of persons who will use the building, climatic area and the expected equipment of the house. Individual variants are developed including the design of individual devices available on our market and their price range. Author own experience and user reviews were considered when designing the house. A description of strengths and weaknesses is made for all variants.

Individual variants of energy security, as outlined in the theoretical part were compared to each other through multiple criteria analysis. To adjust the weights of individual criteria have been used Saaty method. The criteria were selected based on actual user requirements for energy sources. The resulting values are burdened with a relatively large weight of subjectivity in particular because of setting of the weights only by one subject nevertheless the use of this method, which is based on pairwise comparisons of the importance of objects is much more accurate than using e.g. Metfessel evaluation model. Based on the calculations and overall evaluation of the various options by certain criteria is for the chosen house most appropriate implementation of energy concept number four, where the primary source of heating, radiant panels are installed in each room of the house. This is given primarily by low initial investment in this technology. As it results from the comparison of different variants, for low-energy houses it will primarily depend on the initial investment, secondarily on operational costs, since the amount of energy required is minimized, especially by the technology of construction and materials used.

For the economic evaluation of concepts was chosen as the most appropriate method the calculation of net present value of the investment. This dynamic method is suitable mainly because the investment in the energy security of the house does not exhibit during its lifetime any profit. At selected uniform discount interest rate comes as the most economically advantageous variant number four as well, radiant panels, which has significantly the lowest initial cost.

Due to the relatively massive expansion of energy sources such as gas boiler, the results of the comparison of the various options were rather surprising. The advantage of securing heating of the house with this energy source type, is especially the low heat loss of the house and low acquisition cost of the source. From an economic point of view, the lowest amount of investment is wanted for the acquisition of source. For energy security of the chosen house is, based on selected criteria, especially economic advantage, the optimal variant heating by radiant panels and water heating through electric boiler.

If the user has chosen other priorities in the selection of criteria, or other criteria, for example. "Independence on electric power" or "maximum environmental friendliness," then the best option could be something completely different.

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