MSc Program
Renewable Energy in Central & Eastern Europe

Feasibility analysis of construction of 3 storey residential and office building of the passive house standard in conditions of Stará Ľubovňa, North-Eastern Slovakia

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“Master of Science”

supervised by
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Affidavit

I, **Laura Martonová**, hereby declare

1. that I am the sole author of the present Master Thesis, "Feasibility study of construction of 3 storey residential & office building according to the passive house standards in conditions of Stará Ľubovňa, North-Eastern Slovakia", 68 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted this Master Thesis as an examination paper in any form in Austria or abroad.

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Abstract

Submitted work studies feasibility of construction of a 3 storey residential and office building in the passive house standard in climate conditions of Stará Ľubovňa, North-Eastern Slovakia and the analyses the sufficiency of renewable energy sources to supply the energy demand for heating, domestic hot water preparation and lighting.

The work included search for suitable location for the building, designing the dimensions and setting the energy-related parameters of its construction materials and components. Than a calculation of energy balance of the building has been done to analyse the possibility to reach passive house standards.

Calculations shown that it is feasible to construct the building of the design in the passive house standard although higher quality construction materials and components than minimum required must be used. Energy demand for heating can be fully supplied by air recovery and heat pump. Energy demand of the building can be fully covered from solar thermal system. Installing photovoltaic modules would suffice to cover electricity demand for lighting.

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List of Acronyms

(in alphabetic order)

CHP – combined heat and power

EC – European Community

EN – European norm

EPBD – Energy Performance of Buildings Directive

EPS – expanded polystyrene

EU – European Union

GPS – geo-positioning system

HVAC – heating, ventilation, air-conditioning

HW – hot water

IEA – International Energy Agency

kWp - (kilo Watt peak)

NGO – non-governmental organisation

PH – passive house

PHPP – Passive House Planning Package

PV – photovoltaics

STN – Slovak technical norm

I. Introduction

Recent global situation in depletion of fossil fuels resources, increase of energy prices and series of related environmental problems and climate change force the humankind to re-consider and change the ways of resources and energy management to more efficient and sustainable practices in all fields.

About 40% of the energy consumption in IEA-member countries is used for heating of buildings. Half of this is allotted to residential buildings. In the past, many buildings and heating systems were realized without considering their environmental impact. The most of the existing buildings are nor energy-efficient, considering available technologies. For European countries it is estimated that more than 30% of the energy demand in the building sector could be saved, without losses in the comfort. Especially building renovation is an important task to achieve a sustainable energy economy [6, pg 154].

Therefore there is high need for energy efficient management in the buildings, both administrative and residential sector. Research and testing of the new construction methods, materials, components and appliances has started decades ago and nowadays there are many proofed measures ready to be applied in practice to achieve higher energy efficiency of the buildings and preserving the comfort of living.

Besides of efficient use of energy produced there is raising importance and potential for producing the energy from alternative renewable energy sources.

The EU has the targets, legislation measures and methodologies set already and the energy efficiency is being put into everyday life. However, there is still lack of information, false beliefs, doubts and scepticism for new things amongst the public in some of the European countries, especially in former socialistic block. Unfortunately, the similar situation is amongst the professionals such as architects, planners, construction engineers and craftsmen, too. Also short-time thinking and considering only the costs of today hinder the broader application of the energy efficient measures in construction or retrofitting of existing buildings.

Therefore more awareness raising, information, promotion and consultancy for public are necessary.

I.1. Motivation

The motivation of this work is to support realization of a long-term goal of creating an information, promotion and consultancy centre for energy efficiency and renewables in Stará Ľubovňa, North-Eastern Slovakia which would be situated in a building constructed and operated according to the declared principles (passive house, using renewable energy sources, efficient energy use) and thus serve as a practical example of feasibility of projects of the kind.

Taking into account conditions in Slovakia, nature of people and long term experiences with public awareness campaigns there is a great need for a practical "really working" example to break the barrier of doubts and disinformation about energy efficiency, low-energy buildings, renewable energy sources and related issues, especially in colder climate regions such as Stará Ľubovňa region. Building an information centre according to the declared principles would give the promoted topic higher importance and trustworthiness.

Another important point is necessity of financial sustainability of the information centre itself. Reckoning with present and assumed future situation in grants (in relation mainly to The EU Structural Funds) the investment into the construction is possible to be financed of major part from external sources. However, the NGO must find the resources for further operation of such a centre. Considering the prices which could be charged for consultancy works there is need for raising the higher funds somewhere else, too. A solution might be renting the living and/ or office space in the new building.

There are only two passive houses built in Slovakia to the date (state of October 2008) and only a couple in preparation. All of them are family houses and situated in South-Western Slovakia region with warm climate. However the "economy of scale" (area to volume – ratio of the building) and longer heating periods indicate that a larger building in cold climate would be more reasonable, would bring more remarkable benefits and would be of higher importance in field of promotion of the energy efficient building.

I.2. Objectives

The main objective of this work is to analyse feasibility of construction of a building of given parameters according to the passive house criteria in climate conditions of Stará Ľubovňa, North-Eastern Slovakia.

Given parameters of the building are: 3 storey building, with residential part (living area at least 4 persons) and office part (including at least 2 office rooms, space for library and seminar room).

Primary **hypothesis** is that it is technically feasible. Derived major questions and tasks are:

1) Is there suitable location for the building?
2) Would the building designed with typical passive house parameters perform as passive house in test under local climate conditions? Or special construction material and/ or components must be used?
3) Is it possible to supply the whole energy demand for heating, hot water and lighting from renewable sources installed on the building?
4) What would be the investment costs of such a building?

I.3. Structure of work

The work consists of **theoretical part** describing the basic principles of passive houses planning, construction and operation and their parameters.

The following chapters describe the **conditions of the location** of the interest – town Stará Ľubovňa in North-Eastern Slovakia. This description consists of data, maps and tables on climate conditions, heating period information and detailed geomorphology of the particular supposed construction site.

Based on the theory on passive house and local conditions the **preliminary design of the building** has been created. The design consists of draft sketches in digital form and corresponding descriptions.

The main **results** of the feasibility consist of **calculations of energy balance** of designed building. The core text includes the basic equations and parameters used and particular result values. The calculation sheets are attached in Annexes.

Results are evaluated and particular findings are listed in **Conclusions** together with summarization and evaluation of fulfilment of the work's objectives.

II. Approach and methodology

Used **approach** was to prove the hypothesis by creating a preliminary design of the building and test it under local conditions and under passive house criteria.

Description of methodology applied (in time succession):

- research and documentation of basic passive house criteria, methodology, technical issues, norms and legislation applied
- search for available design tools, software, etc.
- search for, own observations and documentation of local climate data
- site search

The search for suitable building site and related climate data was realized from September 2007 until August 2008. It consisted mainly of observations of weather, sunshine duration and shading conditions. Further have been the potential sites compared to cadastre records and the sites available for sales have been selected. Then the comparison with spatial planning documentation of municipality of Stará Ľubovňa has been done.

- preliminary design of the building – setting the orientation, dimensions, volumes, composition, etc.
- testing the designed building - calculating the energy parameters of the building under local climate conditions
- adjustments of the first design to achieve the required parameters if needed
- calculation of the demand of heating, hot water and electricity for lighting and comparison with the calculated potential of energy production from renewables by the building itself and thus proving or disapproving the self-sufficiency

  Used calculation method is energy balance of the building.
- research of available materials, components and appliances with particular parameters
- listing the materials, components and appliances suitable for the designed building
- calculation of the approximate costs

III. Documentation of data and data collection

Collected data consist mainly from:

1. **legislation** concerning energy efficiency of the buildings which have an impact on planning, designing and construction of new buildings
2. **passive house** - standard parameters and requirements for used materials, components, appliances and construction
3. **climatic data** on particular location or data on climate of close region interpolated to local conditions
4. data on **local situation**, especially in terms of heating period

III.1. Strategic documents and legislation on energy efficiency

On European level there are several strategic documents which set commitments, framework and targets in field of energy efficiency of the buildings, energy saving and use of renewable energy sources. The strategic documents are then transposed into regulatory documents (directives, regulations etc.). Particular regulations must have been further adapted into national legislation, including Slovak one.

III.1.1. European level

III.1.1.1 Strategic documents

In the **Green Paper on energy efficiency – or "Doing more with less"** from June 2005, the Commission estimates that the EU could **reduce energy consumption** by 20% by 2020, which would increase amounts of money possible to be used for other investments, it would reinforce the competitiveness of European industry within the framework of the **Lisbon agenda** and could lead to the creation of a million jobs in related fields (transport management, high energy efficiency technologies, etc.). A 20% energy saving would also allow the EU to meet its **Tokyo commitments** by reducing CO_2 emissions in order to protect a healthy environment for the citizens of today and tomorrow and last but not least it would help to reduce Europe's dependency on fossil fuels import.

Series of targets and measures in transport and construction sectors and in buildings and households to fulfil the Paper's goal were stated in **Action Plan on Energy Efficiency: Realising the Potential** from October 2006.

The purpose of the Action Plan is to mobilise the general public, policy-makers and market actors, and to transform the internal energy market in a way that provides EU citizens with the most energy-efficient infrastructure (including buildings), products (including appliances and cars), and energy systems in the world.

In order to achieve substantial and sustainable energy savings, energy-efficient techniques, products and services must be developed and consumption habits must be changed so that less energy is used to maintain the same quality of life.

The Commission considers the biggest energy savings are to be made in the following sectors: residential and commercial buildings (tertiary), with savings potentials estimated at 27% and 30% respectively, the manufacturing industry, with the potential for a 25% reduction, and transport, with the potential for a 26% reduction in energy consumption. Another sector is energy production and transformation sector.

III.1.1.2. Legislation on energy efficiency of buildings on EU level

In 2000 has The European Council approved the EC **Action plan of energy efficiency** and required measures to be taken **in building/construction sector**. One of the main requirements is improvement of energy efficiency of the buildings.

Following was the **Directive** of European Parliament and European Council **2002/91/EC on energy performance of the buildings (EPBD).** The most important goal was the reduction of the energy demand and the CO_2 emissions of the building. Another goal was the European harmonization of standards for calculation and evaluation (certificates) of energy demand of the buildings. The directive requires several different measures to achieve rational use of resources and reduction of environmental impacts of the energy use both in new and the existing buildings.

One of the tools to achieve the goals is set of minimum requirements on the energy performance of the new buildings and for large existing buildings that are subject of major renovation (EPBD, Articles 4, 5 and 6) which must be applied by the Member States.

Other tools are certification of the buildings (Article 7), inspection of boilers (Article 8) and air-conditioning systems (Articles 9).

Systems of **energy certification and energy labelling** of the buildings provide easy, understandable and profound evaluation of the building in terms of its energy needs and enables comparison of individual buildings. Information provided can as well be used for economic purposes, pricing and evaluations.

So far the energy demand for heating is the main monitored parameter but it is expected that others will be added, too (e.g. energy demand for cooling, for hot water preparation, for building operation, for building construction).

Important assumption for application of Articles 4, 5, 6 and 7 is a general framework **methodology of calculation** of the total energy performance of the buildings ant that was set in Article 3 and Annex of the directive. Calculation is based on set of standards with specific aspects of calculation:

Table 1 – Technical norms related to energy efficiency of the buildings

Work item	EN number	Content
14	prEN ISO 13790	Net energy use for heating and cooling; taking into account the losses and the gains
4	prEN 15203	Energy use for heating, cooling, ventilation systems, hot water and lighting, including the system losses and auxiliary energy and definition of energy ratings
2	prEN 15315	Primary energy and CO_2 emissions
1 + 3	pr EN 15217	Ways of expressing the energy performance (for purposes of energy certificates) and the requirements (for purpose of regulations) Content and format of energy performance certificate
5	prEN 15378	Boilers inspections
6	prEN 15240	Air-conditioning systems inspections

III.1.1.3. Other energy efficiency related EU legislation

- Regulation (EC No 106/2008) requires EU institutions and central Member State government authorities to use energy efficiency criteria no less demanding than those defined in the ENERGY STAR programme when purchasing **office equipment**. The usual thresholds for public supply contracts apply.

- Directive 2006/32/EC of the European Parliament and of the Council of 5 April 2006 on **energy end-use efficiency and energy services** and repealing Council Directive 93/76/EEC
- Directive 2005/32/EC of the European Parliament and of the Council of 6 July 2005 establishing a framework for the setting of **ecodesign** requirements for energy-using products and amending Council Directive 92/42/EEC and Directives 96/57/EC and 2000/55/EC of the European Parliament and of the Council
- Directive 2004/8/EC of the European Parliament and of the Council of 11 February 2004 on the **promotion of cogeneration** based on a useful heat demand in the internal energy market and amending Directive 92/42/EEC
- Council Directive 92/75/EEC of 22 September 1992 on the indication by **labelling** and standard product information of the consumption of energy and other resources by **household appliances** (+ series of directives implementing the directive; on energy labelling of individual household appliances)

III.1.1.4. Energy efficiency related EU legislation in preparation

- energy labelling of tyres
- efficient lamps and lighting in households (expected in 2009)
- obligatory requirement for installation of passive heating and cooling systems in the buildings
- proposal of international treaty on energy efficiency

III.1.2. Slovak level

Slovak government has approved the new **Concept of energy efficiency of buildings** until year 2020 in accordance with Directive 2002/91/EC in June 2008. The document includes legal, institutional and technical framework for systematic reaching the energy efficiency of the buildings.

Unfortunately, the energy policy of the Slovak Republic is not very much in favour of alternative approach to energy management. Although declaring the trends towards energy efficiency and use of renewables there is major stress and importance put into nuclear power and there are many administrative and bureaucratic procedures disabling fast development of efficient technologies. Even this Concept has defined many barriers but without any further measures to be taken:

- existing tax system which does not apply any tax allowances for purchasing and using energy efficient technologies or appliances reducing use of fossil fuels and greenhouse gases emissions (except of biofuels)
- missing information on energy consumption and energy costs of products and services
- non-professional servicing and maintenance which results in mistrust in new technologies
- not taking into account future benefits and energy savings during decision making on investment

III.1.2. Legislation on energy efficiency of buildings in Slovakia

- Until beginning of year 2008 there was no certifying and/or labelling system implemented in force in Slovakia. To evaluate the energy demand of the buildings the **Slovak Technical Norm (STN) 73 0540-2/2002** was used only. It includes requirements for thermal protection and energy label of the building. However, the data it contains is theoretical only, not considering the way of heating, regulation and ventilation which are very important parameters for energy efficient buildings.
- **Act Nr. 555/2005 of 8 November 2005 on energy efficiency of the buildings** is in force from 1 January 2008. The Act is application of the Directive 2002/91/EC. It states obligatory energy certification of all new buildings and old buildings that are subject to major renovation in case of sale, rent or finalization of the new building; otherwise is voluntary. Doesn’t apply to historical buildings, churches, industrial buildings, housing buildings used less than 4 months in a year, buildings smaller than 50 m^2 of used area.

Further regulative, executive and methodology by-laws have been put into force to execute the act:

- **Executive notice Nr. 625/2006** of 22 November 2006 is in force from 1 January 2007. It states minimal requirements to all new and existing buildings:
  - Maximal U-values of building construction
  - Heat demand requirements
  - Maximal total energy supplied for m^2 of total floor area of operation permission issued after 1.1.2008.

  Besides that it states the calculation procedure of energy certificate, energy classes and CO_2 emissions; gives form of energy certificate for individual buildings and energy label for individual appliances.
- Series of applied **EN-norms** (listed in III.1.1.2. and others)

III.1.3. Other Slovak energy efficiency related legislation

- Act Nr. 17/2007 on regular control of boilers, heating systems and air-conditioning systems

III.2. Brief characteristics of passive house

The Passive House is the world's leading standard in energy efficient construction. The Passive House concept is a comprehensive approach to **energy and cost-efficient, high quality, healthy and sustainable construction**.

A passive house is a building in which a comfortable interior climate can be maintained without active heating and cooling systems [8]. The house heats and cools itself, hence "passive".

There are several approaches to the passive concepts amongst professional designers, architects, constructors and various technicians. Anyhow, the basic principle remains the same: to **decrease the net heat demand** of the building by means of minimizing the heat losses (from transmission and ventilation) by insulation and by maximizing the heat gains (mainly from solar radiation) and all

this concurrently with securing **high air quality and thermal comfort** for the people.
The standard has been named "Passive House" because the passive heat inputs – delivered externally by solar irradiation through the windows and provided internally by the heat emissions of appliances and occupants – essentially suffice to keep the building at comfortable indoor temperatures throughout the heating period.
The minimal heat requirement can be supplied by heating the supply air in the ventilation system – a system which is necessary in any case. Low energy demand allows use of renewable energy appliances. Energy demand for heating is ca 80% lower compared to conventional standards of new buildings [8].

The **energy demand for space heating** of the passive house should be **lower than 15 kWh/m²a**. Exceptionally efficient components achieve high energy savings without reducing the indoor thermal comfort, but on contrary - increasing it and besides they reduce the building's dependency on external energy suppliers and/or carriers.
Part of the Passive House philosophy is to implement other efficient technologies to minimize the other sources of energy consumption in the building, too. The **combined primary energy** consumption of living area of a European passive house may not exceed **120 kWh/m²a** for heating, hot water preparation and household electricity. Energy-efficient appliances for warm water preparation and electricity for lighting are used.
Through efficient electricity usage, the total end-use energy requirement incl. household electricity and domestic hot water is lower than 33 kWh/(m²a). [7, pg.3]

Under theses pre-conditions the energy requirements can be easily supplied by alternative renewable energy sources.
Passive houses are characteristic by the superior design and its components which must be optimized carefully and work in perfect mutual interaction:

- compact form and superinsulation
- passive use of solar energy
- ventilation with heat recovery and heating of supply air
- innovative heating & energy efficient technologies

III.2.1. Compact form and superinsulation

Passive house must have an exceptionally well insulated envelope **preventing heat losses** by transmission and ventilation. To secure that the thermal bridges and air leakages must be eliminated. Using simple and compact shape of the building reduces risks of thermal bridges at construction junctions.

Calculation of heat losses is mainly based on:

- Amount of heat losses by 1°K temperature difference between internal to external surface of transparent (glazed) and non-transparent areas of the building (walls, roof, bottom) represents the **U-value**. U-values are set for individual construction items and/or materials. Typical U-values in passive houses are: <0,15 W/ K.m^2 for the envelope; construction items; ≤ 0.75 W/ K.m^2 for windows glazing and ≤ 0.8 W/ K.m^2 for the frames.
- Building element junctions must be free of thermal bridges; characterised by Ψ **(heat bridge coefficient; linear thermal transmittance)** values <0.01 W/ K.m^2.
- Air tightness is characterised by **n_x ≤ 0,6** (**air rate change**; leakage of the air per hour at closed windows). Air leakage through unsealed joints must be less than 0,6 times the house volume per hour. Very air-tight houses have n_x = 0,5/h.
- Windows should have **g-value** minimum 0,5 (50% of the solar energy passes through the glass inside the building.

For the windows given parameters fulfil at least double pane or even better three pane gas (Ar, Kr) filled windows with low emissive coating and superinsulated frames. Because the heat losses through the windows increase with the surface area and temperature difference, optimization measures include minimizing the window on the northern side of the building.

Passive house parameters can be reached by using high quality building and insulation materials and their combinations, including alternative, natural and renewable building materials as wood, clay and straw.

III.2.2. Passive use of solar energy

Passive houses are usually solar houses, too. Solar gains are passive heat gains of the building from solar irradiation that passes into the building through the glazed surfaces.

Calculation depends on area of glazed surface, on windows parameters, on the shading and on the total irradiation that hits the windows in four world sides. Important window parameter is g-value - the solar heat-gain coefficient which represents the share of the total amount of solar energy that passes through the window glass.

The irradiation values vary with different climate conditions.

Solar heat gains can be maximized by:

- optimized building orientation to south
- elimination of shading
- higher share of glazed area on south side of the building
- internal heat storage

Windows (glazing and frames, combined) should have U-value not exceeding 0,80 W/(m²K), with solar heat-gain coefficients around 50%.

As heat source in passive house is used so called **thermal mass** – structural components (walls, floors) of the house which work as a heat accumulator and short time storages of heat. The thermal mass absorbs the heat when the space is heated up and gradually releases the heat back to the space when the space temperature falls below surface temperature of the thermal mass. Accumulating ability of particular materials is described by thermal capacity c_p, the density ρ_{Sp} and the thermal conductivity λ of the storage medium, as well as on the heating and heat dissipation time. Thermal mass is related to its surface, not thickness/volume. The thickness of wall plays a role until ca 15 cm only.

Good thermal mass materials have high thermal capacity, high conductivity and high density. For better heat absorption the surface is painted black (dark colour) or covered with absorber foil.

Important on the other hand is solar **shading** to stop overheating the building in the summer. Shading is made by structural elements, external shading devices or internal shading devices.

III.2.3. Ventilation with heat recovery and heating of supply air

Due to airtight house construction the air exchange from infiltration is not sufficient for supply of fresh air. Sufficient volume of fresh air is necessary for comfort as well as for hygienic and healthy living conditions. Ventilating by opening windows would mean heat losses in heating periods. Therefore **mechanical ventilation** is one of the key technologies in passive houses.

Ventilation secures a continuous and regulated supply of fresh air in quantities required for excellent indoor air quality and the occupants comfort. One person needs ca 30 m^3 of fresh air per hour. Exhaust air is extracted from rooms.

Ventilation systems are designed so that the mass flow does not increase; there is no recirculation of air, no noise and no drafts.

Besides the fresh air the ventilation system has a function of heating system - transporting the heated fresh air inside the building. This is only possible in case of superior thermal insulation; air tight envelope and **maximum heat load 10 W/m^2** which is a highest level of heat load the fresh air can carry.

Passive houses use the **heat exchangers and heat recovery systems.**

A high performance heat exchanger is used to transfer the heat contained in the exhaust indoor air to the incoming fresh air. The latent **heat recovery rate is $\eta \geq$ 80%.** The two air flows are not mixed.

On particularly cold days, the supply air can receive supplementary heating when required. Additional fresh air preheating in a subsoil, air or water heat exchanger is possible, which further reduces the need for supplementary air heating. E.g. the fresh air may be brought into the house through underground ducts that exchange heat with the soil. This preheats fresh air to a temperature 5 - 8°C (41°F), even on cold winter days.

Even though mechanical ventilation systems raise initial investment costs, if designed efficiently they will reduce the energy costs significantly, even paying off the initial cost.

Indoor temperature for residential buildings used in heat demand calculation is 20°C although there are tendencies for its increase. Today’s value is most usually ca 22°C. Increase of indoor temperature by 1 degree means increase of heat demand by ca 6%. [10, pg. 9].

III.2.3. Using innovative heating & energy efficient technologies

Although the dramatic reduction of energy demand for space heating significantly reduces the energy consumption and the costs; most of the new built passive houses use in addition other energy efficient measures and thus become more and more energy independent, environmentally friendly and climate neutral.

It is realised by energy rational behaviour of the occupants, by using energy efficient and energy saving appliances and by using the renewable energy sources.

III.2.3.1. Meeting the remaining energy demand with renewables

The low remaining energy demand can make possible implementation of technologies based on renewable energy sources which could have been unaffordable or insufficient before the energy demand reduction.

Most widely used are solar thermal systems, the heat pumps or biomass boilers for hot water preparation and additional heating. Photovoltaic modules or small wind turbines can be used for electricity supply. [*])

Well designed and optimized **solar thermal systems** can meet about 40–60% of the entire low-temperature heat demand of a passive house. Solar panels are either mounted or integrated in the roof and/or the wall. Optimal orientation and inclination for particular location should be considered. Shading of the panels must be avoided.

[*] *Note: External sources of heat and electricity (e.g. buying "green electricity" from the grid or heat from central heating system using biomass) are not considered here.*

Heat pumps are broadly used in passive houses. Different media combinations are available depending on local conditions – ground, water or air. The advantage is extremely high efficiency (300-700%), low maintenance; little space needed, low operation costs, stable capacity and comfort.

Biomass is usually used for heating and/ or hot water preparation in form of wood (pellets, briquettes, chips).

Photovoltaic modules can be installed on passive houses, too, to produce electricity. There can be on-grid and off-grid installations.

Small wind turbines (up to ca 5 kW output) can be installed on the roof or on the land adjacent to the passive house to produce electricity. However they are not used widely due to relatively high costs and low efficiency.

III.2.3.2. Using electricity-efficient appliances

Passive houses are equipped with efficient energy saving household/office appliances: refrigerators, freezers, washers, dryers, lighting, computers, copiers, etc. All building services (e.g. ventilation system) are designed to operate with maximum efficiency.

Connecting the washing machines and dishwashers to hot water pipes can save additional energy.

With all these measures the electricity consumption can be also reduced dramatically – even by 50% compared to the average building, without any loss of comfort or convenience.

High-efficiency appliances are often no more expensive than average ones and they usually pay themselves back through electricity savings during the lifetime.

III.2.3.3. Regulation & behaviour of the occupants

Operation and efficiency of the heating system, ventilation and hot water preparation of the passive house requires good controlling and regulation. Regulation is important in terms of securing the thermal comfort in every room of the house at every weather conditions and perfect co-operation of individual components and appliances connected to the system.

The everyday habits of the passive house occupants play a role in general performance of the building, too. Even highly efficient systems and appliances must be used in correct ways to perform with the declared efficiency.

III.2.4. Passive house examples

III.2.4.1. Passive house examples in EU

There are numbers of passive houses – one or more family houses, residential buildings, office buildings, industrial buildings – built in world. The leaders in Europe are Germany and Austria where development has been promoted also by specialized programmes.

- CEPHEUS (Cost Efficient Passive House as European Standard) [2]

Is a large project within the THERMIE Programme of the European Commission, Directorate-General Transport and Energy, which was realized in years 1998-2001. Ca 250 housing units to Passive House standards in five European countries have been construction, with in-process scientific back-up and with evaluation of building operation through systematic measurement programmes.

One of the subprojects was construction in Hannover-Kronsberg, Germany. 32 terraced houses in 4 rows have been built. Mixed construction was used: dividing walls, floor slabs and building-services-cum-staircase core are made of prefabricated concrete elements, insulating building envelope of prefabricated lightweight timber elements. Fitted with airing cabinets. Provision of financial incentives to purchase efficient household appliances. Fitted with thermal solar collectors. Supplementary heat supply from local district heat system fed by combined heat and power units. Climate neutral through Euro 1.250 share in wind energy facility integrated in house purchase price. One of the houses is used for seminars, guided tours and exhibitions. Some of the houses were used by the municipal utility, Stadtwerke Hannover AG, as EXPO 2000 guest houses [2].

- „Haus der Zukunft“ („Building of tomorrow“)[9]

It is one of the subprograms of The Austrian Program on Technologies for Sustainable Development developed by the Austrian Federal Ministry of Transport, Innovation and Technology. It initiates and supports trendsetting research and development projects and the implementation of exemplary pilot projects.

Over 60 projects realized during 5 years included construction of various types of new passive buildings as well as the reconstruction of existing buildings into passive standard and development of new materials, appliances or procedures.

The "Buildings of Tomorrow" are residential and office buildings which differ from current building practice in Austria by fulfilling the following criteria:

- higher energy efficiency throughout the whole life-cycle of the building
- greater use of renewable energy sources, especially solar energy
- greater use of sustainable raw materials, and efficient use of materials
- increased consideration of user needs and services.
- However, the costs are comparable with conventional building methods

The subprogram's goal is the development and market diffusion of components, prefabricated building parts and building methods which correspond to the above criteria and to the main principles of sustainable development.

Examplary projects:

- **Applying passive technologies in social housing**, 1140 Vienna; Utendorfgasse 7. Multi-storey social passive house construction with 39 units under adherence to the international passive house standard and simultaneous extremely low construction costs.
- **ENERGYbase** is a showcase project in terms of energy efficiency and use of renewable energies realized by the Vienna business agency. With 7.500 m^2 net floor area ENERGYbase provides space for innovative business and research and development on the field of green energy.

III.2.4.2. Passive house examples in Slovakia

- **Family house, Stupava** [13]

Prevailing natural building materials. Wooden construction with cellulose insulation filling. Installation plane made from clay bricks and clay coatings. Compact air-conditioning system with heat exchanger.
Year of construction: 2008
Project by: Createrra, s.r.o.
Energy related area (according PHPP): 172,3 m^2
MPT (according PHPP): 15 kWh/m2.a
Heat losses (according PHPP): 13 W/m2
Air tightness: 0,46 1/h
Primary energy demand: 79 kWh/ (m^2a). Calculation (according PHPP) includes primary energy demand for heating (24 kWh/m^2a), hot drinking water preparation and electricity.

- Family house, Pusté Úľany [19]

For construction has been used complete brick system from Wienerberger. The envelope has been constructed from specially designed and adapted bricks Porotherm Profi 38 which gives minimum gaps. Mineral thermal insulation has been used. Controlled ventilation with heat recovery and soil-to-air heat pump. Hot water from solar collectors.

Year of construction: 2006

Project by: Studio Projekt Štefancovci

III.2.5. Other environmental measures for buildings

Passive houses are environmentally friendly buildings. Due to dramatic reduction of energy demand and due to use of renewable energy sources mostly their operation means lower consumption of fossil fuels and thus fewer emissions of greenhouse gases, particularly CO_2. Not only the operation but the construction and disposal of the building can be evaluated and particular measures can be taken in aims to reduce the impact on the environment.

The good environmental value of the passive house can be emphasized by using environmentally friendlier building materials:

- renewable materials

are restored within short time periods and their use doesn't cause irreversible depletion of natural sources: e.g. wood, straw, clay

- materials produced with minimum of energy
- local materials

do not require transport over long distances and thus is reduced the consumption of fossil fuels

- recyclable/recycled

materials without using dangerous chemical compounds which do not produce dangerous waste during the construction and after the life time; possibly could be recycled and used somehow then, too

produced from waste material – reusing the natural resources: e.g. cellulose insulation from waste paper

Other measures:

- recycling of the “grey water” from bathrooms to be used for the toilets after some cleaning
- using own small water cleaning plants based on cleaning by roots of the plants

III.3. Calculation of energy balance of the building

Calculating the heating and cooling needed for maintaining the inner thermal comfort in the building involves many factors. While designing the optimal heating, cooling and air-conditioning system (HVAC) for the building one must reckon with ambient conditions, heat flows to and from the building, variation of energy demand during the day or year.

Important concept is calculation of **energy balance for the building** to show the relation between loads and energy and to be able to state the design and energy consumption.

To carry out an energy balance calculation of a building input data about the geometry of the building, about its physical qualities, about the outdoor climate and about the specific ways the building is used are necessary:

- Geometric building data:
    - The dimensions of all thermal relevant parts of the building, such as walls, roofs, floors, ceilings, windows.
    - The heated volume and the heated area of the building.
    - Construction elements dimension (window frames, etc).
- Thermal qualities of the building
    - U-Values (Heat transmission coefficient) of all main building components
    - Heat transmission coefficients for thermal bridges
    - Air-tightness of the building's envelope
    - Qualities, areas and orientation of transparent building elements
    - Shading of glazed elements
- Outdoor climate data
    - Monthly average outdoor air temperature
    - The duration of the heating period
    - The monthly sums of solar radiation
- Use of the building
    - Indoor air temperature
    - Number of inhabitants, number of technical equipment. Both usually estimated and resulting in a prediction of total internal gains.
    - If used: Quality of the mechanical ventilation system, including the air exchange rate.

Energy balance relates energy flows of losses and usable gains:

$$E_{\text{heating/cooling}} = Q_{\text{losses}} - Q_{\text{usable gains}}$$

Designing HVAC system means to specify the capacity of the heating and cooling units sufficient to maintain comfort under extreme conditions. That means to state the instantaneous rate of energy flow and the greatest loads the HVAC system will have to produce.

Heat losses are caused by transmission from building envelope and by ventilation losses. Heat gains include passive solar gains and internal gains produced by occupants and electric appliances.

The ***heating load*** is then reckoned as amount of heat needed when heat losses are maximal, there are no solar heat gains, no heat gains from occupants and appliances and to heat released from internal storage.

$$P_{\text{heating, design}} = P_{\text{losses, extreme design conditions}}$$

The ***cooling load*** calculation uses the opposite assumptions: the solar and internal heat gains are maximal, the ambient conditions are extreme in terms of warmth and the moisture load is taken in account in addition.

Heat demand is related to usable area which is needed to heat up.

Net heat demand of the building is calculated as sum of transmission losses and ventilation losses minus solar gains and internal gains.

$$Q_H = Q_T + Q_V - (Q_s + Q_i)$$

Q_H – net heat demand of the building

Q_T – heat losses by transmission

Q_V – heat losses by ventilation

Q_s – solar heat gains

Q_i – internal heat gains

III.4. Climate conditions

The area of interest is located in Eastern Slovakia, in its northern part, ca 30 km east-north from High Tatras mountains. It belongs to administrative region of Prešov, district of Stará Ľubovňa, cadastre of Stará Ľubovňa.

GPS coordinates: 49°18′34″ North 20°40′44″ East

Elevation: 545 m (540-600 m)

Figure 1- Location of Stará Ľubovňa on map of Slovakia (*Source: http://maps.google.com)*

The site of the interest lies on the hill northwards from the town centre. Total height of the hill is 605 m, the site lies on south-westwards oriented side in height ca 560 m.

Figure 2 - Relief map of Stará Ľubovňa and the site localization (*Source: http://maps.google.com)*

III.4.1. General climatic conditions

The area is generally considered as mild to cold climate typical for valleys of mountain regions.

It belongs to climatic region type M5 which is characterized as moderately warm, humid, with cool to cold winters and valley/basin climate.

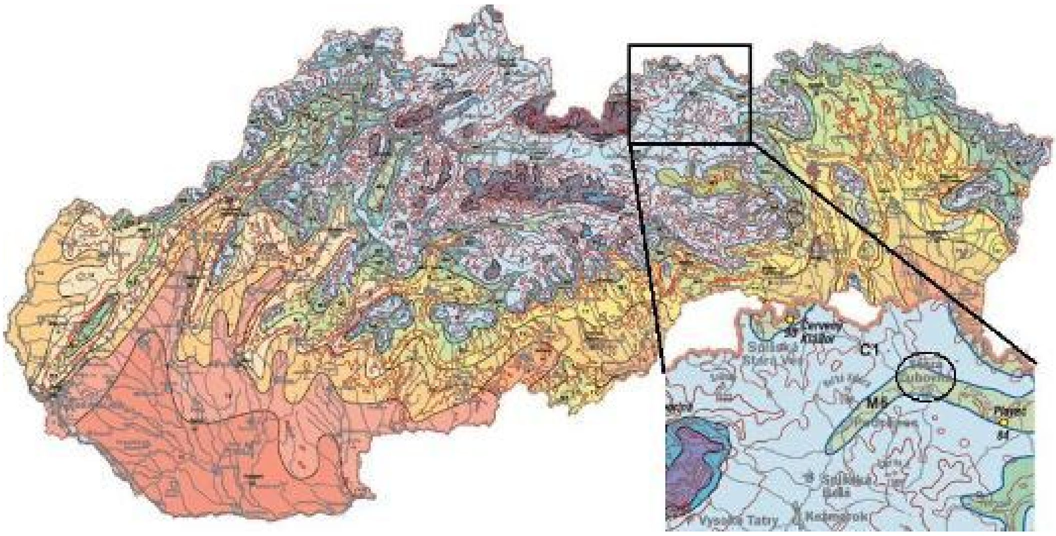


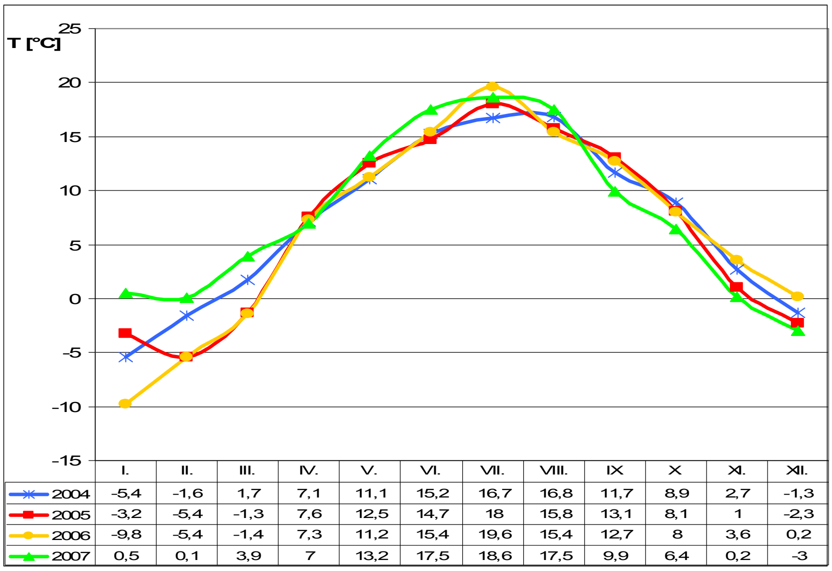
Figure 3 – Map of climate regions of Slovakia with detail of Stará Ľubovňa region (*Source: Landscape Atlas of the Slovak Republic, pg. 94, map 27.)*

Data of temperature measurements come from major heat supplying company – Slobyterm. There closest measuring station of national hydro meteorological network is ca 30 km far and the climatic conditions are not appropriate to use here. The measuring is done three times a day; at 7,00 a.m., 14,00 pm. and 21,00 p.m.. The average daily temperature is then average of sum of the three real temperatures plus temperature of 21,00 p.m..

Average number of days with snow cover is 100.

The lowest recorded temperature during monitored period was – 17°C.

The highest recorded temperature during monitored period was 32°C.



	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX	X	XI.	XII.
2004	-5,4	-1,6	1,7	7,1	11,1	15,2	16,7	16,8	11,7	8,9	2,7	-1,3
2005	-3,2	-5,4	-1,3	7,6	12,5	14,7	18	15,8	13,1	8,1	1	-2,3
2006	-9,8	-5,4	-1,4	7,3	11,2	15,4	19,6	15,4	12,7	8	3,6	0,2
2007	0,5	0,1	3,9	7	13,2	17,5	18,6	17,5	9,9	6,4	0,2	-3

Figure 4 – Development of average monthly temperatures during years 2004 – 2007 (*Source: Concept of town Stará Ľubovňa Development in Area of Heat Energy, 2006; pg. 42-43,+ internal data of Slobyterm, s.r.o.)*

Wind speed and directions:

Concerning the wind conditions the situation in Stará Ľubovňa is closest to the one in meteorological station in Plaveč nad Popradom, ca 30 km South-Eastwards. This station lies in the Poprad river valley, too, and the site has similar geomorphology. Prevailing wind direction there is South-North, with maximum wind speed not exceeding 8 m/s. The area has average inversion conditions. Inversions are typical for spring and autumn seasons.

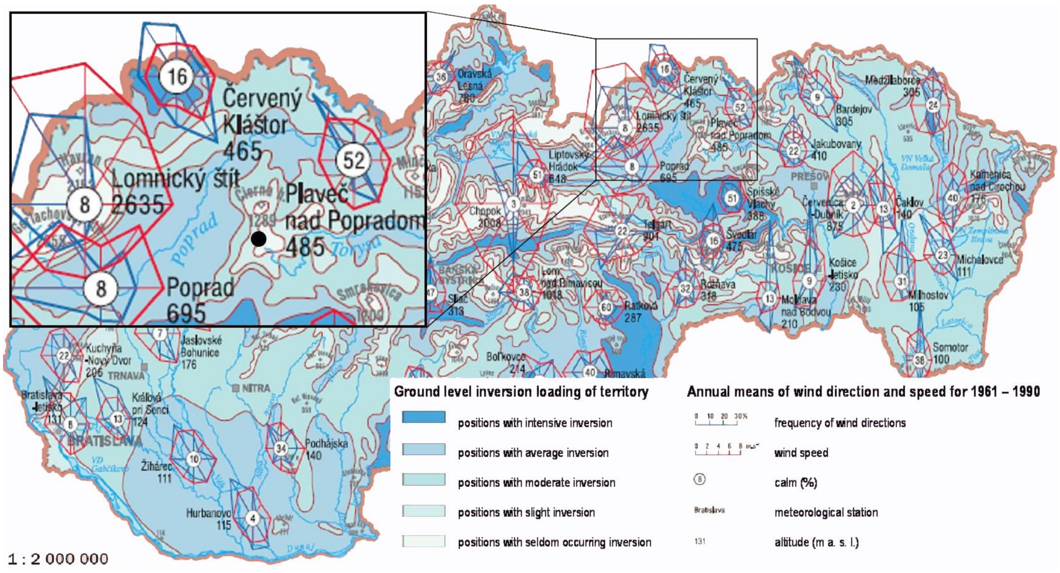


Figure 5– Map of wind speed and directions and ground level inversions of Slovakia with detail of Stará Ľubovňa region (*Source: Landscape Atlas of the Slovak Republic, pg. 100, map 58.)*

III.4.2. Solar radiation & shading

III.4.2.1. Solar radiation values

Area of interest is situated in region with mean global solar radiation 1100-1150 kWh/m^2 per year. Relative sunshine duration is around 40%. The data come from national measurements during years 1961-1990.

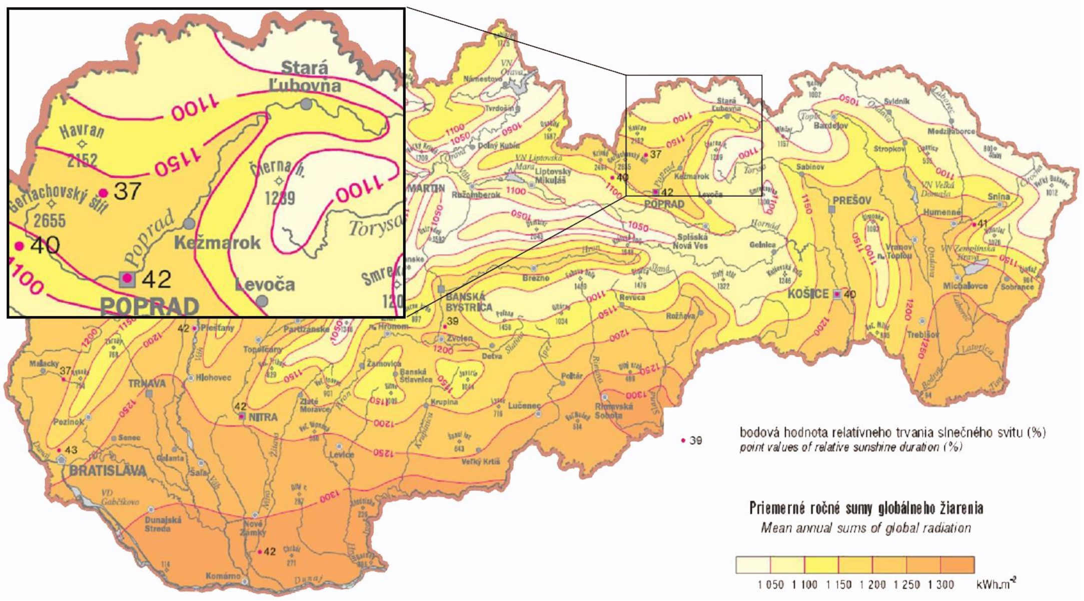


Figure 6 – Map of average annual sums of global solar radiation of Slovakia with detail of Stará Ľubovňa region (*Source: Landscape Atlas of the Slovak Republic, pg. 96, map 34.)*

However, there are several other sources claiming different values. The other national sources are those promoting use of renewable energy sources and they claim higher values (1175-1225 kWh/m^2.a). [3, pg. 36]

The European level source – Photovoltaic Geographical Information System of EC Joint Research Centre in Ispra (Italy) [4] provides data on solar radiation mainly focused on electricity production from PV modules. The solar radiation database was developed from climatologic data homogenized for Europe and available in the European Solar Radiation Atlas, using the *r.sun* model and the interpolation techniques *s.vol.rst* and *s.surf.rst*. The data generated for the location of interest give values of ca 1050 kWh/m^2.a of total annual solar irradiation. The advantage of this data source is better detail of the data – the data are available on monthly basis, too, which is not available from any source of the national level.

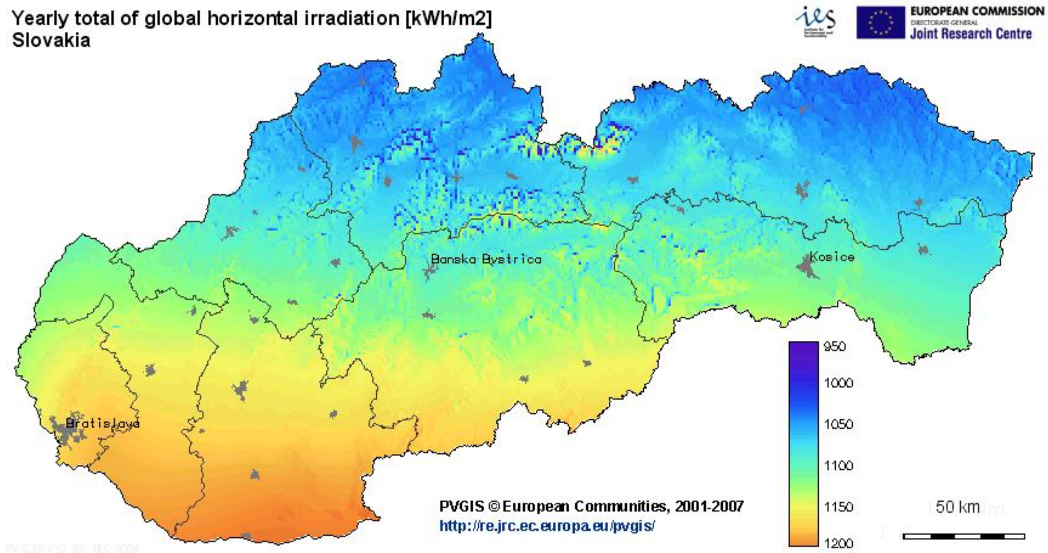


Figure 7 – Map of total annual global horizontal irradiation of Slovakia (*Source: PVGIS© European Communities, 2001-2007; http://re.jrc.europa.eu/pvgis/)*

The sources of solar irradiation data and the variations are discussed so much here because the results of the energy calculations of the designed building strongly depend on heat gains from solar radiation and different data input give different results.

III.4.2.2. Geomorphology and related shading situation

The site lies on a south-west facing side of a hill in height ca 560 m. The slope in this part has elevation ca 14,5 %.

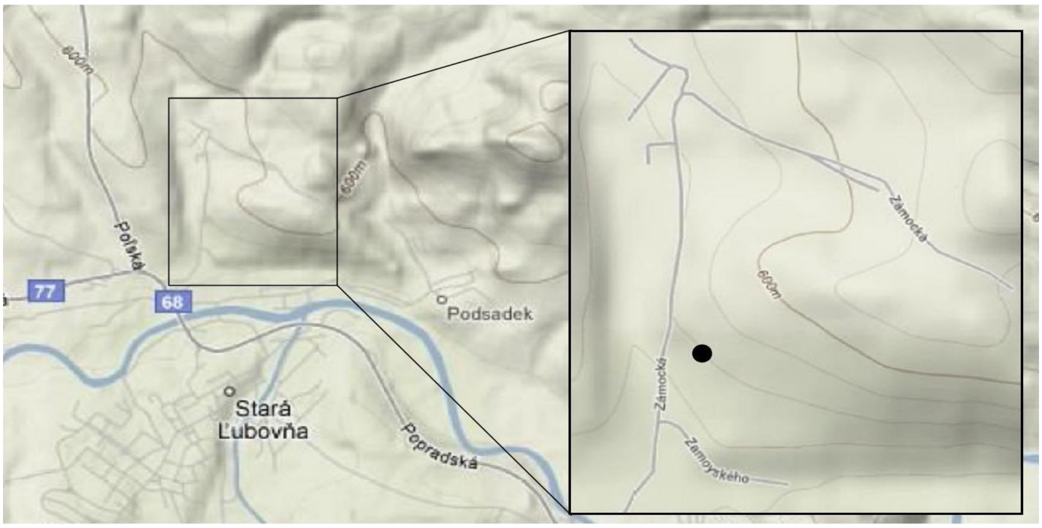


Figure 8- Terrain map of the site (*Source: created from maps at www.googlemaps.com)*

The hill is grass covered mostly; there is a pine forest to the north up the hill which is ca 30 m tall. The closest buildings are rows of family houses ca 20 westwards downhill. There is no access road to the site yet.

Figure 9 – Satellite map of the site ***(Source: created from satellite maps provided by Town Stará Ľubovňa, Department of Regional Development)***

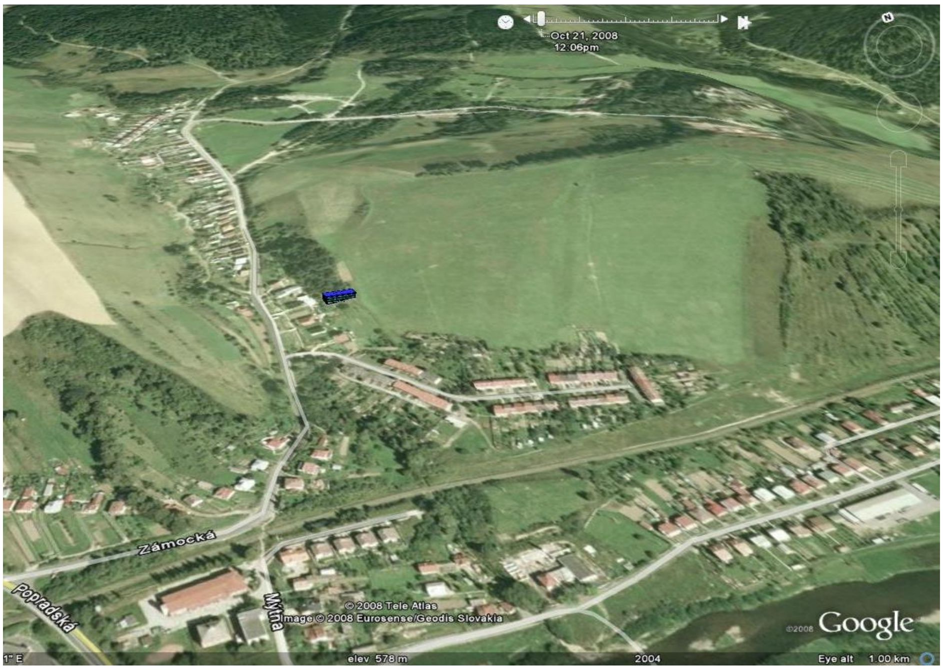


Figure 10 – Localization of the building ***(Source: created from maps at www.googlemaps.com)***

The sun on the site is in highest position on June 21st; the altitude angle is 65°. The lowest position is on December 21st when altitude angle is 18° (values for noon time).

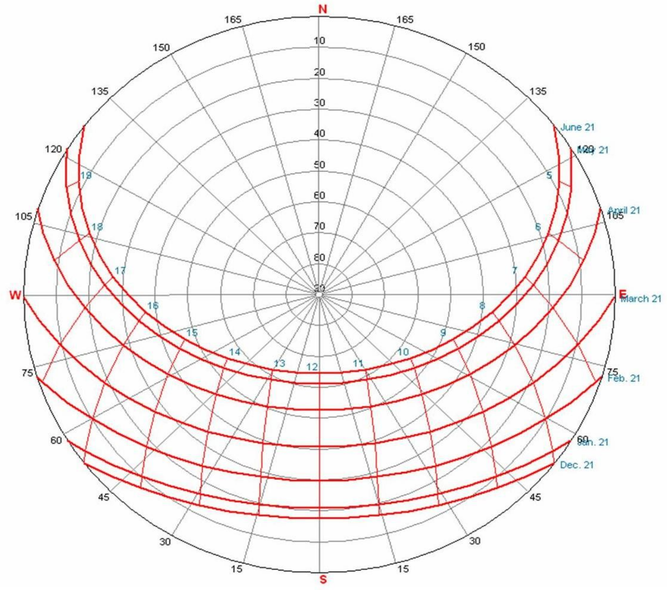


Figure 11 – Sun path diagram of the site *(Source: created by Shading Analyser 1.0.0, MBS Lab, School of architecture, USC 1999)*

Due to no buildings or other objects the site is not shadowed from the south and west, there is minor shadowing from the east by the hill itself. The forest would provide a shelter from wind from the north.

III.4.3. Heating & cooling period

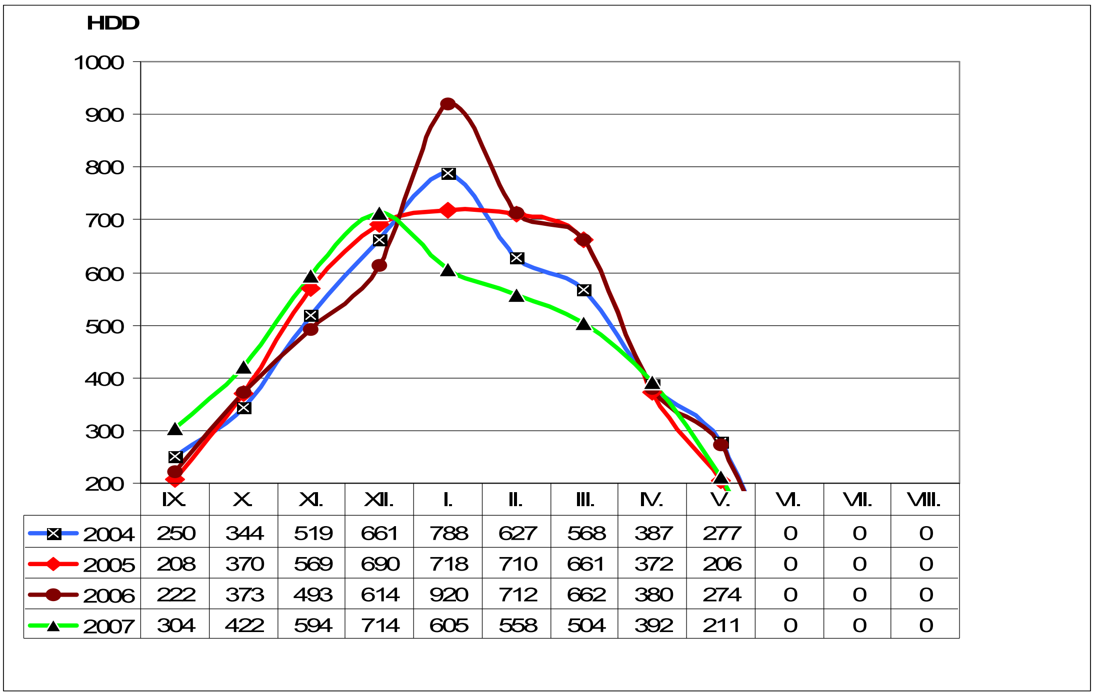
III.4.3.1. Heating period

Due to very cold winters the heating is the major energy demanding period. Cooling is not of very high importance though the climate warming up has been observed and hot tropical days occur more often. Heating degree days vary around 4000 but cooling degree days are ca 100 only.

As discussed in solar radiation the sources concerning the ambient temperature and thus the heating period are different, too. The local source is the central heating system supplier's – the company Slobyterm, s.r.o. Their data originate from measurements of outside temperatures (3 times a day) compared to standard indoor temperature 20°C.

Heat and hot water in the town is supplied by three sources depending on type of end user:

- most of the households (in blocks of flats) are supplied by major heat supplier via central heating system from 3 boiler-houses burning natural gas
- ca third of the households in blocks use own gas boilers
- family houses have own boiler-rooms, using natural gas at the most; burning coal is diminishing; socially weaker households use wood



	IX.	X.	XI.	XII.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
2004	250	344	519	661	788	627	568	387	277	0	0	0
2005	208	370	569	690	718	710	661	372	206	0	0	0
2006	222	373	493	614	920	712	662	380	274	0	0	0
2007	304	422	594	714	605	558	504	392	211	0	0	0

Figure 12 – Development of number of heating degree days during years 2004 – 2007 (*Source: data provided by Slobyterm, s.r.o., Stará Ľubovňa)*

Total sum of averaged monthly heating degree days varies between 4200 and 4700. Long term average used in further calculations in this work is 4470.

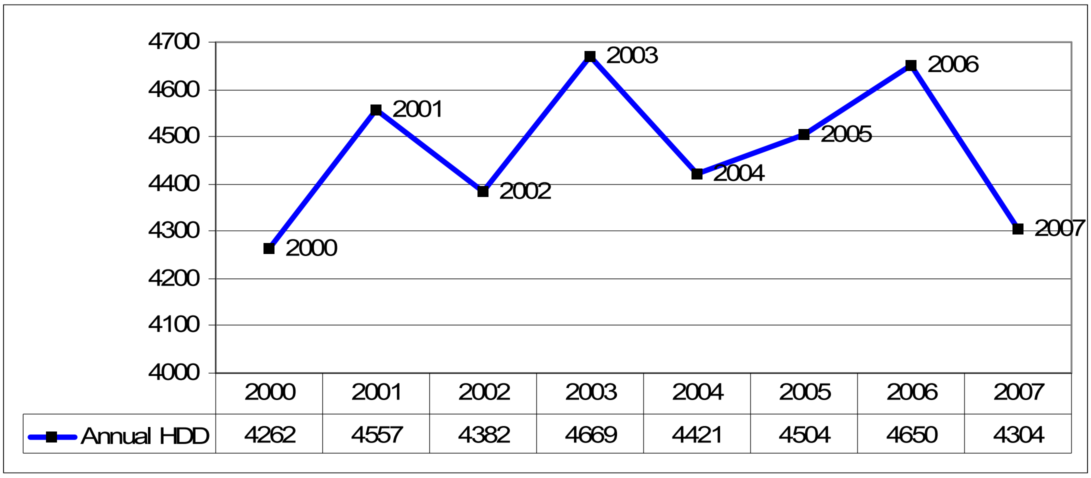


Figure 13 – Sum of averaged heating degree days per year, development of years 2000-2007 ***(Source: years 2000-2004: Concept of town Stará Ľubovňa Development in Area of Heat Energy, 2006, pg. 43; years 2005-2007: data provided by Slobyterm, s.r.o., Stará Ľubovňa)***

The international sources are either the PVGIS Database of EC JRC or RETScreen© [14] using measurements of NASA and then interpolated. They both state lower values of HDD than the reality is. JRC states 3812 heating degree days and RETScreen© states 3873 heating degree days for location of Stará Ľubovňa.

III.4.3.2. Cooling period

As mentioned above there is not a high need for cooling yet in the particular location. The cooling systems are relatively rare and almost exclusively installed in office buildings only. Therefore there are no local sources of data on cooling demand available.

However the climate warming up and demand for higher comfort will most probably raise the importance of cooling systems in the buildings.

International source of information is RETScreen© (based and interpolated from NASA measurements). It states 118 cooling degree days per year for particular location.

IV. Description of results – Concept of the building

IV.1. Shape, dimensions and orientation

The building concept has been created according to the basic rules of passive house, planned use of the building, as well as in accordance with local spatial distribution and visual aspects and after consultation with architect [18].

Its shape is compact and simple to reduce thermal bridges. It has lying cuboid shape with north-inclined roof.

The dimensions have been set according to the planned use of the building and space needed.

Dimensions:

Length: 31,6 m
Width/depth: 12,1 m
Height- south: 9,6 m
Height- north: 8,1 m

Built area of surface: 382,36 m^2

Built volume: 3 383,89 m^3

Table 2 – Calculation of areas of the building

			SOUTH	NORTH	EAST	WEST
TOTAL WALL AREA	**773,49**	**m^2**	**303,36**	**255,96**	**107,09**	**107,09**
WINDOWS AREA						
1st floor	39,00	m^2	36,00	0,00	1,00	2,00
2nd floor	80,65	m^2	60,00	1,00	9,40	10,25
3rd floor	82,65	m^2	60,00	3,00	9,40	10,25
windows area total	**202,30**	**m^2**	**156,00**	**4,00**	**19,80**	**22,50**
area of frame	60,69	m^2	46,80	1,20	5,94	6,75
area of glazing	141,61	m^2	109,20	2,80	13,86	15,75
share of windows on wall area	26%		51%	2%	18%	21%
WALL AREA (without windows)						
	571,19	**m^2**	**147,36**	**251,96**	**87,29**	**84,59**
FLOOR AREA						
1st floor	382,36	m^2	base on the ground			
2nd floor	382,36	m^2	ceiling of the 1st floor			
3rd floor	385,52	m^2	ceiling of the 2nd floor			
floor area total	**1147,08**	**m^2**				
HEATED FLOOR AREA brutto						
1st floor	office 18x8 m			144,00	m^2	
	corridor 18x3 m			54,00	m^2	
2nd floor	office 10x8 m			80,00	m^2	
	apartment 10x11,8 m			118,00	m^2	
	flat 10x11,8 m			118,00	m^2	
	corridor 10x3 m			30,00	m^2	
3rd floor	apartment 10x11,8 m			118,00	m^2	
	flat 10x11,8 m			118,00	m^2	
	flat 10x8 m			80,00	m^2	
	corridor 10x3 m			30,00	m^2	
	heated floor area total			**890,00**	**m^2**	
ROOF AREA						
roof	385,52	m^2	3rd floor ceiling; 12,2x31,6 m			

It is three storey building; the longest side oriented to the south, upright the slope of the hill. Due to the slope setting the northern wall and part of the eastern wall would be built into the side of the hill where some earth will need to be removed. Thus the northern wall and part of the eastern wall of the first/ground floor will be adjacent directly to the earth. On the western side the ground would be increased by levee formed of the earth from the eastern side to balance the ground horizontally.

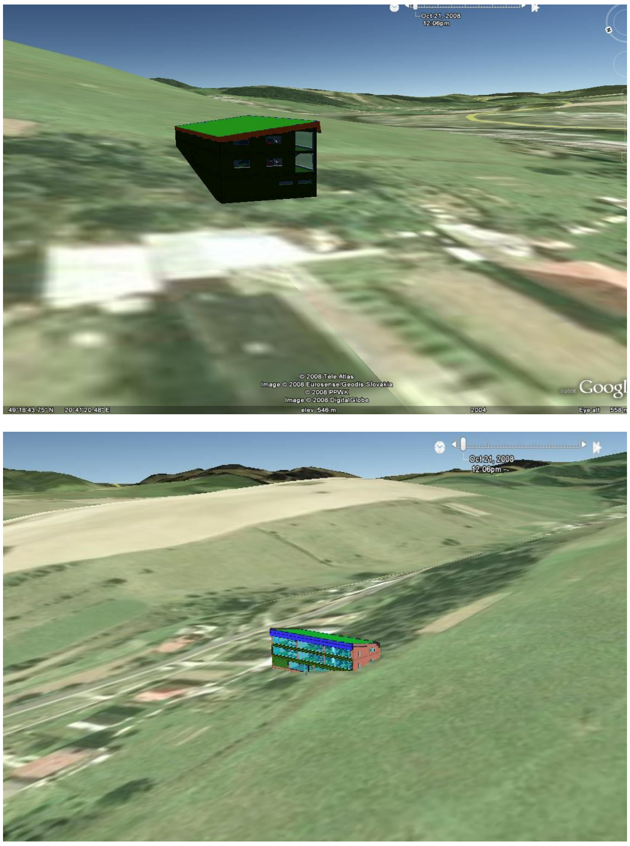


Figure 14, Figure 15 - Localization of the designed building - western and eastern views

IV.2. Planned use and composition of the floors

The building is supposed to be a combination of office and residential building.

two flats of ca 118 m^2, one flat of 80 m^2 and one apartment of ca 236 m^2 and office spaces of 144 and 80 m^2.

The office space should be primarily used as information and promotion centre for renewables and energy efficiency including library and seminar room.

The residential part includes apartment for an average sized family of the staff and 3 smaller rental flats.

Non-heated spaces include technical and storage room and garage.

Figure 16 – Front view of the designed building

Figure 17 – Western front view of the designed building

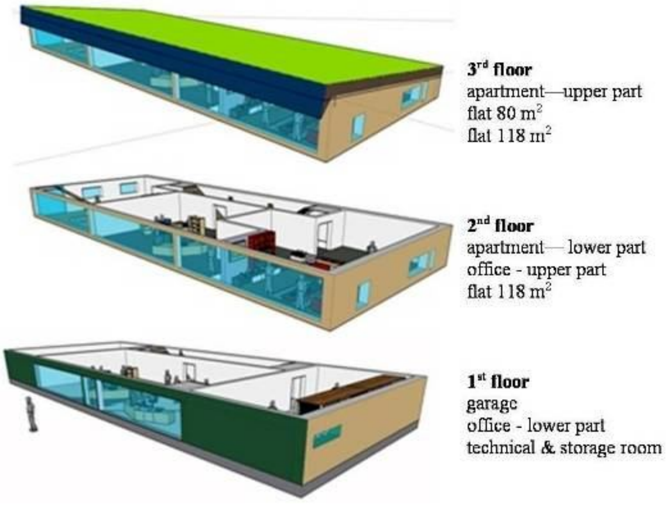


Figure 18 – Composition of the floors of the designed building

Distribution of the rooms:

- Frontal (southern) zones – living space
- Back (northern) zones – servicing zones (corridors, staircases)

IV.3. Passive solar use & shading

The building is designed to maximize the passive solar heat gains: the long front façade is oriented to the south; the southern walls are glazed on 51% and internal design of rooms according to the thermal zones.

Created sketches show the different penetration of the sun rays into the building in winter and in summer for the building without the front inclined roof. The winter sun rays hit the surface in angle ca 16° and through the glazing penetrate 7,2 m deep into the house (fig.19).

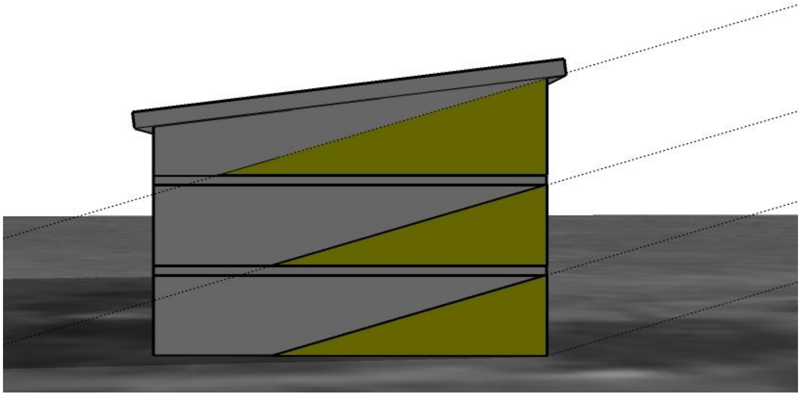


Figure 19 – Solar radiation in winter time (December 21st)

The summer sun rays hit the surface in angle ca 60° and penetrate 1,1 m deep into the house through the glazed surface (fig.20).

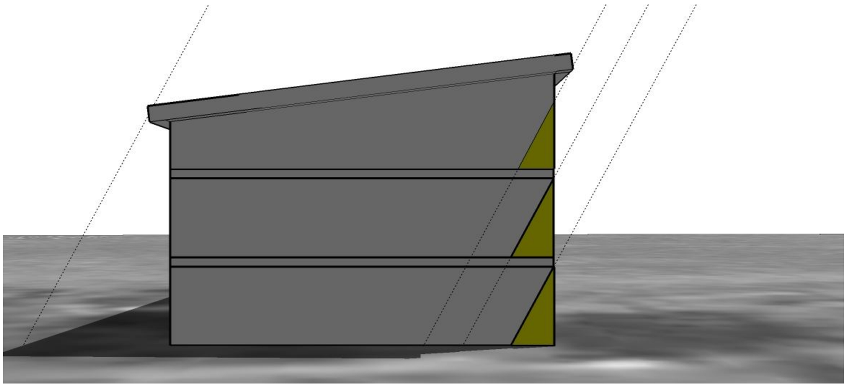


Figure 20 – Solar radiation in summer time (July 21st)

Although the penetration is not great these rays could cause overheating of the indoor space. Therefore shading measures need to be taken to prevent it.

The first measure taken was implementing the front roof inclined in 37°. This part of the roof would be covered with PV modules and this is the best inclination for PV for the particular location [4]. This roof would provide complete shading of the indoor space of the third floor in summer, too (fig.23).

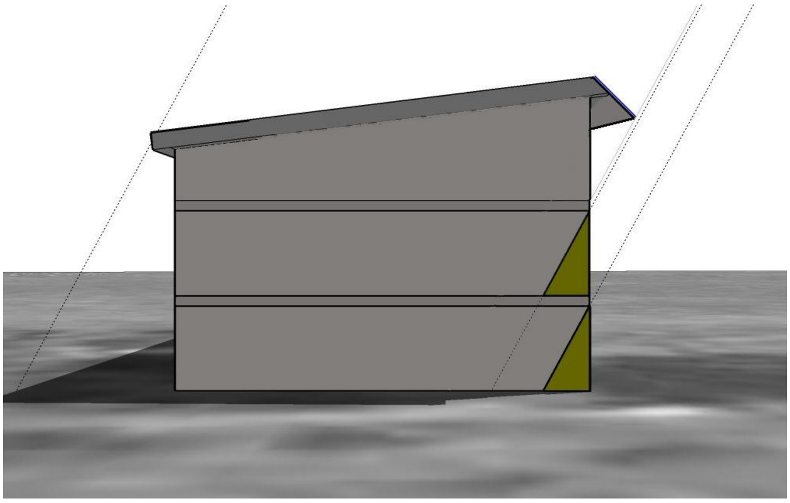


Figure 21 - Situation of the shading of the front roof in summer (July 21st)

The shading by the roof would as well mean ca 90 cm shorter penetration of sun rays into the space of the third floor in the winter (fig.22).

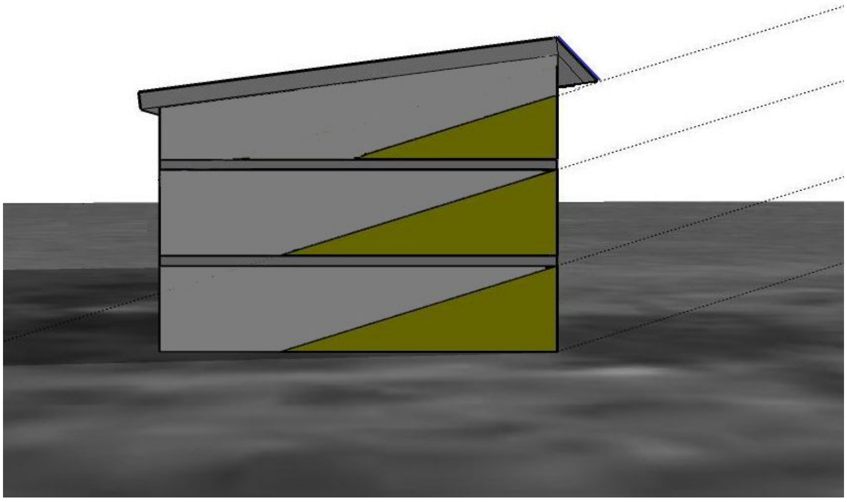


Figure 22 – Situation of sunshine and shading of the front roof in winter (December 21st)

Shading for the first and the second floor must be realized, too. The easiest is sizing and positioning of the windows. If the windows reach to the height 2 m only and the rest of the storey height (0,5 m) was non-transparent wall, the inside would be completely shaded in summer.

Another alternative is installation of shading device; preferably external. Internal shading is not efficient because it stops the sunlight but not the heat which has already passed through the glass into the room.

Calculation of usable amount of passive solar heat follows in chapter IV.6.2.1. Solar gains.

IV.4. Energy supplying technologies

As already mentioned, the building energy demand will from major share be supplied by renewable energy sources:

- heating will be supplied by ventilation system with heat recovery; in winter heating will be assisted by ground heat pump
- hot water will be supplied by solar thermal façade collectors
- PV module on the front part of the roof will supply some share of electricity demand

These technologies are dimensioned according to the need and the existing potential; calculations are in chapter IV.8. Design of energy appliances.

IV.5. Visual aspects, exterior design

The solar thermal façade collectors mounted on the front façade will have green colour to fit better the appearance of the surrounding on the castle hill which is a dominant of the town Stará Ľubovňa.

Covering the roof with grass will reduce the negative visual impact of the building to its environment especially in terms of the view on the hill from the top from the castle. Besides that the green roofs have other advantages [1]:

- economics benefits (ca double lifespan than conventional roofs)
- green roof improves the thermal parameters of the roof
- improvement of the microclimate: absorbing the heat of the air in summer, improving the humidity, water catchment
- good sound insulation
- improvement of the air quality: oxygen production, CO2 reduction, filtration of airborne particulates

IV.6. Calculation of energy balance of the building

For energy balance calculation have been used the simplified equations [10] and minimal parameters of materials, construction and operation (such as U-values, heat bridge coefficient, air exchange rates, etc.) which should the passive house have.

The calculation has been elaborated with use of real data for particular location, e.g. heating period duration and amounts of solar irradiation. These data are available on monthly basis.

Crosscheck of calculation results has been executed by using the averaged standardized data given by Notice Nr. 625/2006 on energy efficiency of the buildings, Attachment Nr.1. However, these standard data are average for whole Slovakia and they differ a lot from the local conditions of Stará Ľubovňa, especially in sum of the heating days, heating degree days and solar radiation. Besides that, there are annual data available only.

Depending on the final results of heat demand and energy consumption influencing the project's feasibility there may be a need to adjust the parameters of materials and components to fulfil the passive house criteria as described in chapter IV.6.3.2. Adjustments of building parameters to passive standard. Example materials and construction components with particular parameters are listed in chapter IV.7. Material and components – examples.

One of important energy demand related parameters of the buildings is the so called A/V- ratio depending on the shape of the building. It is a ratio of built area to built volume of the building where the lower the value is the better energy performance of the building is due to high volume but lower area and lower transmission losses and less heat bridges.

A/V-ratio for designed building:
area =1 538,21 m^2
volume = 3 383,89 m^3
A/V-ratio = 1538,21 m^2 / 3383,89 m^3 = 0,45.

IV.6.1. Heat losses

IV.6.1.1. Transmission losses

The losses through the building envelope are calculated for non-transparent (walls, basement slab, ceilings, roof) and transparent areas (windows and glazed doors) and heat bridges (construction junctions):

- L_T of non-transparent areas = 258,21 W/K; at max. U-value of the envelope = 0,15 W/K.m^2
- L_T of transparent areas = 157,45 W/K; at glazing U-value = 0,75 W/K.m^2 and frame U-value= 0,8 W/K.m^2
- L_T of heat bridges = 41,57 W/K; ≈ 10% (L_T non-transparent areas + L_T transparent areas); at total area of the building A= 1 538,21 m^2 the Ψ = 0,027 W/K.m^2

  This Ψ value is above minimal required by passive house standard therefore particular measures must be taken, e.g. using construction components of better parameters (lower U-values).

L_T total = 457,23 W/K

HDD – 4470 average of real data from years 2004-2007

- 3422 standard sum according to the Notice Nr. 625/2006 on energy efficiency of the buildings, Attachment Nr.1

Table 3 – Transmission losses of the designed building

Real conditions	January: 8 315,20 kWh February: 7 152,01 kWh March: 6 570,41 kWh April: 4 200,12 kWh May: 2 655,60 kWh June –August: 0 kWh September: 2 699,49 kWh October: 4 139,77 kWh November: 5 966,87 kWh December: 7 349,53 kWh ***Q_T = 49 049,00 kWh per year***
Notice Nr. 625/2006	***Q_T = 37 551,47 kWh per year***

Calculation sheets are in Annex 1

IV.6.1.2. Ventilation losses

Calculation of heat losses caused by ventilation is based on:

- netto volume of the building (= ca 75% of volume brutto)
- standardized ventilation rate value $\mathbf{n_v}$ = 0,4 (40% of air is exchanged within 1 hour)
- $\boldsymbol{\eta_v}$ - heat recovery efficiency of heat exchanger; 80%
- $\mathbf{n_x}$ - leakage rate; air exchange rate through the not tight building envelope at closed windows and doors; assuming very air-tight building: 0,05/h

calculated energy equivalent air exchange rate n=0,13/h

L_V = 108,88 W/K

HDD – 4470 average of real data from years 2004-2007

- 3422 standard sum according to the Notice Nr. 625/2006 on energy efficiency of the buildings, Attachment Nr.1

Table 4 – Ventilation losses of the designed building

Real conditions	January: 1 980,03 kWh February: 1 703,05 kWh March: 1 564,56 kWh April: 1 000,14 kWh May: 632,35 kWh June –August: 0 kWh September: 642,81 kWh October: 985,77 kWh November: 1 420,84 kWh December: 1 750,08 kWh ***Q_V = 11 679,62 kWh per year***
Notice Nr. 625/2006	***Q_V = 8 941,81 kWh per year***

Calculation sheets are in Annex 2.

IV.6.2. Heat gains

IV.6.2.1. Solar gains

For calculation of solar gains the average glazing area 70% of total window/door area has been used.

Other parameters:

- Solar heat gain coefficient g=50%;
- Shading factor f_s= 80%; (due to little shading by surrounding objects, considering the shading from dust and dirt)
- Solar irradiation

As discussed in chapter III.4.2.1. Solar radiation values the data on solar radiation differ a lot depending on a source and so do the results (tab.5).

Table 5 – Solar radiation on location according to data from Slovak Notice Nr. 625/2006 on energy efficiency of the buildings, Attachment Nr.1

south	320	kWh/m^2
north	100	kWh/m^2
east, west	200	kWh/m^2
south-west, south-east	260	kWh/m^2
north-east, north-west	130	kWh/m^2

Table 6 – Solar radiation on location according to data from Photovoltaic Geographical Information System, EC JRC

south	618,90	kWh/m^2
north	161,23	kWh/m^2
east	336,10	kWh/m^2
west	367,10	kWh/m^2

Note: These amounts represent the share of solar radiation for the heating period only (June-August excluded). Particular data sheets are in Annex 3.

Table 7 – Solar heat gains of the designed building

Data source	**Efficient solar heat gains***	
	per side	**per month**
Real conditions	South: 27 033,55 kWh North: 180,58 kWh East: 1 863,34 kWh West: 2 312,73 kWh ***ηQ_s =28 400,87 kWh/a***	January: 2 118,12 kWh February: 2 787,32 kWh March: 4 034,22 kWh April: 3 931,69 kWh May: 4 023,77 kWh June –August: 0 kWh September: 3 800,85 kWh October: 3 856,25 kWh November: 2 187,53 kWh December: 1 661,11 kWh
Notice Nr. 625/2006	South: 13 977,60 kWh North: 112,00 kWh East: 1 108,80 kWh West: 1 260,00 kWh ***Q_s =16 458,40 kWh/a***	

*In real life the efficiency of these heat gains is little lower; ηQ_s = ca 90%. [10, lecture notes]

Calculation sheets are in Annex 4.

IV.6.2.2. Internal gains

Internal gains are sum of the energy produced by people and appliances at operation in the building. One person produces ca 3 W per m^2 of heat from his biological functions and from using average electrical devices [10, lecture notes]. The internal gains are related to the total heated area S_{brutto} = 890 m^2. List of heated rooms is in the chapter IV.1. Shape, dimensions and orientation.

Again, the total number of the heating days in real heating season differs from the standard set in the Notice on energy efficiency of the buildings:

a) Real conditions: 273 days/year
b) Notice Nr. 625/2006: 212 days/year

Table 8 – Internal heat gains of the designed building

	Efficient internal heat gains*
Real conditions	January: 1 787,83 kWh February: 1 614,82 kWh March: 1 787,83 kWh April: 1 730,16 kWh May: 1 787,83 kWh June –August: 0 kWh September: 1 730,16 kWh October: 1 787,83 kWh November: 1 730,16 kWh December: 1 787,83 kWh ***Q_s= 15 744,46 kWh/a***
Notice Nr. 625/2006	***Q_s = 12 226,46 kWh/a***

*In real life the efficiency of these heat gains is little lower; ηQi = ca 90%. [10, lecture notes]

Calculation sheets are in Annex 5.

IV.6.3. Energy demand for heating

IV.6.3.1. Heat demand

Summarization of heat losses and heat gains:

$$Q_H = (Q_T + Q_V) - (\eta Q_s + \eta Q_i) \ \ [\mathrm{kWh/a}]$$

$$q_H = Q_H / S_{\mathrm{brutto}}$$

$S_{\mathrm{brutto}} = 890\ \mathrm{m}^2$

Table 9 – Heat demand of the building

Real conditions	January: -6 389,28 kWh February: -4 452,92 kWh March: -2 312,92 kWh April: 461,59 kWh May: 2523,65 kWh June –August: 0 kWh September: 2 188,71 kWh October: 518,54 kWh November: -3 470,01 kWh	

	December: -5 650,68 kWh ***Q_H = 16 583,30 kWh/a***	***qH = 14,46 kWh/m^2.a***
Notice Nr. 625/2006	***Q_H = 19 545,26 kWh/a***	***qH = 16,96 kWh/m^2.a***

Calculation sheet is in Annex 6.

Maximum heat demand of passive houses is 15 kWh/m^2.a. The designed building calculated according the real location data fulfils the criteria of passive house. It is due to high solar gains. However, the limit has been fulfilled very hardly only.

The result according to the legislation act is over the passive house limit.

It is obvious that using the construction materials and components of the minimal requirements for the passive houses is not sufficient therefore adjustments in materials and components must be done.

IV.6.3.2. Adjustments of building parameters to passive standard

Series of measures can be proposed to adjust the parameters of the building in aim to reach the passive house standard.

Decreasing the heat losses is the most efficient measure and it is the crucial principle of the passive house construction. Due to stable values of parameters influencing the ventilation losses there is possibility to reduce the transmission losses only. It can be done by improving the envelope parameters, which means reducing the U-values of materials and components. In practice it means using more and/or better insulation material and using better windows. Heat losses from transparent areas can be reduced by using less glazed areas which is on the other hand contra productive because the natural daylight would be reduced, too and need for artificial lighting would increase electricity consumption. Reducing the glazed area would dramatically decrease the passive solar heat gains, too, which is not desired, either.

For proposing the better parameters existing materials and components and composed structural elements of existing passive house projects have been used and tested under the conditions of design. Their detailed list is in chapter IV.7. Materials and components – examples.

Adjusted parameters:

Walls – reducing the U-value from 0,15 W/K.m^2 to **0,101 W/K.m^2**

Basement – reducing the U-value from 0,15 W/K.m^2 to **0,1 W/K.m^2**

Ceilings – reducing the U-value from 0,15 W/K.m^2 to **0,135 W/K.m^2**

Roof – reducing the U-value from 0,15 W/K.m^2 to **0,1 W/K.m^2**

Windows – reducing the U-value of glazing from 0,75 W/K.m^2 to **0,59 W/K.m^2** (with g-value remaining stable 0,5)

Table 10 – Transmission losses of the designed building - original values and values after adjustments of the parameters

Parameter	**Using materials and components of the minimal required parameters**	**Using adjusted (improved) materials and components with better parameters**
Transmission conductance of non-transparent areas	258,21 W/K	186,10 W/K
Transmission conductance of transparent areas	157,45 W/K	134,79 W/K
Transmission losses through heat bridges	41,57 W/K	32,09 W/K
Transmission losses total	37 551,47 kWh/a	28 989,39 W/K* 37 865,38 W/K**

* Calculated according to the Slovak Notice Nr. 625/2006)

** Calculated according to the real local climate data

Calculation sheet with adjustments is in Annex 7.

Reduction of heat losses by transmission cause change in the final heat demand:

Table 11 – Reduction of heat demand after adjustments (calculated according to the data from the Slovak Notice Nr. 625/2006)

	Using materials and components of the minimal required parameters	**Using adjusted (improved) materials and components with better parameters**
Heat demand	19 454,26 kWh/a	10 892,18 kWh/a
Specific heat demand	16,96 kWh/a.m^2	**9,50 kWh/a.m^2**

Calculation sheet with adjustments is in Annex 8.

Table 12 – Reduction of the heat demand after adjustments (calculated according to the real local climate data)

	Using materials and components of the minimal required parameters	**Using adjusted (improved) materials and components with better parameters**
Heat demand	January: -6 389,28 kWh February: -4 452,92 kWh March: -2 312,92 kWh April: 461,59 kWh May: 2523,65 kWh June –August: 0 kWh September: 2 188,71 kWh October: 518,54 kWh November: -3 470,01 kWh December: -5 650,68 kWh Q_H = **16 583,30 kWh/a**	January: -4 493,34 kWh February: -2 822,20 kWh March: -814,80 kWh April: 1 419,26 kWh May: 3 129,15kWh June –August: 0 kWh September: 2 804,22 kWh October: 1 462,45 kWh November: -2 109,51 kWh December: -3 974,92 kWh Q_H = **5 399,68 kWh/a**
Specific heat demand	***qH = 14,46 kWh/m^2.a***	***qH = 4,71 kWh/m^2.a***

Calculation sheet with adjustments is in Annex 9.

Result: After applying the adjustments the specific heat demand is lower than 15 kWh/a.m^2 in both of the calculations and the designed building can be considered as a passive building.

Besides that it can be seen that reducing the heat losses led to reduction of the heating period: the heat gains in April, May, September and October are higher than the heat losses (positive value of monthly Q_H). Thus is the heating period reduced from 9 to 5 months a year.

IV.6.3.3. Heat load

Thermal size of the heating system is determined by the heat load calculated at extreme conditions and without taking into account the heat gains from solar radiation and internal heat gains:

$Q = L_T * \delta T$ [W] = [W/K] * [K]

preconditions: Qs = 0, Qi =0

L_T - transmission conductance; = 352,98 W/K

δT - temperature difference; $\delta T = T_i$ - min T_e

min T_e - lowest recorded outdoor (external) temperature-17°

T_i - indoor (internal) temperature; standard: 20°

δT= 20 -(-17) ° = 37°

Q= 13 060 W

Heat load=14,67 W/m^2

Maximal level of heat load for heating with ventilation system is 10 W/m^2. Due to occurring of extremely low temperatures in winter this **value was not reached**. The ventilation system will not be able to cover whole demand for heating in cold winter days.

Solution is either try:

- to decrease even more the heat losses from transmission by improving the insulation of the building envelope (better and more of insulation material, better windows)
- or to build an extra heating system to supply the missing heat in winter time. The output of the system would be ca 5 kW. Heat pump or solar thermal system could by used.

IV.6.4. Energy demand for cooling

Due to climate with relatively mild summers the cooling demand is not remarkable. Interpolated value stated by RETScreen© is 118 degree days (2832 cooling degree hours) at indoor temperature 20°C. At this level the ventilation system is able to provide the needed cooling. The energy demand is then the electricity needed for the system operation.

IV.6.5. Energy demand for hot water preparation

Calculation of energy demand for hot water (HW) preparation is based on normative need of hot water per person per day of medium standard assigned for HW demand calculation by the Notice 625/2006.

Residential HW need: 60 l/day/person

Office HW need: 5 l/day/person

Number of persons of designed building:

residential part: 3 flats with 1 person + 1 apartment for 3 persons = 6 persons

office part: 2 persons

Total HW demand in the building:

Residential part: 6* 60 l/day * 365 days/year; **$V_{res.}$*=131 400,00 l/year***

Office part: = 2* 5 l/day * 250 working days/year; **$V_{off.}$*= 2 500,00 l/year***

Total: $V=133,90\ m^3$/year

Energy demand for preparation of hot water: $Q = \rho * V * c_p * \delta t$

[kWh/a = (m3 * kWh/m3.K) * K]

ρ - water density; $\rho \approx 1000\ kg/m^3$

V - volume of water to be heated up; $V=133,90\ m^3/a$

cp - specific heat capacity of the water; =4,2 kJ/kg.K (≈ 1,16 $kWh/m^3.K$)

δt – temperature difference; $\delta t = (t_{HW} * t_{CW})$

t_{HW} - temperature of hot water; desired temperature; =60°C

t_{CW} - temperature of cold water; standard temperature in distribution pipes = 10°C

$\delta t=50°C$

energy demand for hot water preparation: Q=7 810,90 kWh/a

specific energy demand for HW per m^2 of floor area: 8,78 $kWh/m^2.a$

IV.6.6. Electricity demand

The electricity in the building is used for ventilation, lighting and electric appliances (office and household appliances).

Average household electricity consumption in Slovakia is a little lower than the EU average – ca 500 kWh/a per person [5].

For designed building 5 persons in residential area and 2 persons in office area are calculated. Assuming that office consumption of electricity is maximum 50% of that in household due to reduced electricity appliances, only 1 additional person for office area is calculated to 5 persons in the residential part.

Electricity demand $_{\text{6 persons}}$: 3 000 kWh/a

Specific electricity demand per treated floor area = 3000 kWh.a^{-1} / 890 m^2

Specific electricity demand: 3,37 kWh/a.m^2.

IV.6.7. Total end-energy demand

The heating demand of passive house must lower than 15 kWh/m^2.a. Through efficient electricity usage and other energy efficient measures, the total end-use energy requirement including heating, household electricity and domestic hot water of the passive house should be **lower than 33 kWh/(m²a).**

Table 13 – Total end-energy demand of the designed building

	Heating [kWh/a.m^2]	**Hot water [kWh/a.m^2]**	**Electricity [kWh/a.m^2]**	**Total end-energy [kWh/a.m^2]**
According to the real climate data	4,71	8,87	3,37	**16,95**
According to Notice Nr.625/2006	9,5	8,87	3,37	**21,74**

The total end-energy demand of the designed building fulfills the passive house criteria in both calculation cases.

IV.7. Materials and components – examples

This chapter contains examples of materials and components which can be used for construction of the designed building. For designed building the renewable and natural materials have been preferred.

IV.7.1. Construction, walls and insulation

Example construction[13] **:**

- **Construction type:** timber construction
- **Exterior wall:** diffusion open plasters/oak wood facade/woodchip board 50 mm/35 mm/ clay plaster Picas 60 mm
- **Insulation:** blown cellulose in wooden skeleton U*Psi 360 mm, air-tight OSB-boards 12 mm

U-value = 0,101 W/K.m^2

Air-tightness: n50 = 0,46/h

- **Integrated façade collectors:**

Façade collectors will be a part of the front (southern) wall therefore their U-values are discussed here although the effect of solar façade collector on U-value of the walls has not been taken into account. Façade collectors are usually available in wooden frames as large-scale installation panels. Collector panel is directly mounted on insulation envelope of building façade, there is no thermal separation between absorber and insulation envelope in the form of ventilation gap.

The integration brings several essential advantages in comparison with solar collectors mounted separately from building envelope (in the front of the envelope or on the flat roof). Additionally to the basic function of solar collector, façade collector serves also as protection shield against atmospheric effects (weather protection) and improves the thermal properties of the building with respect to passive solar gains. The U-value of the solar thermal collector is 0,8 and decreases with higher temperatures (fig.23).

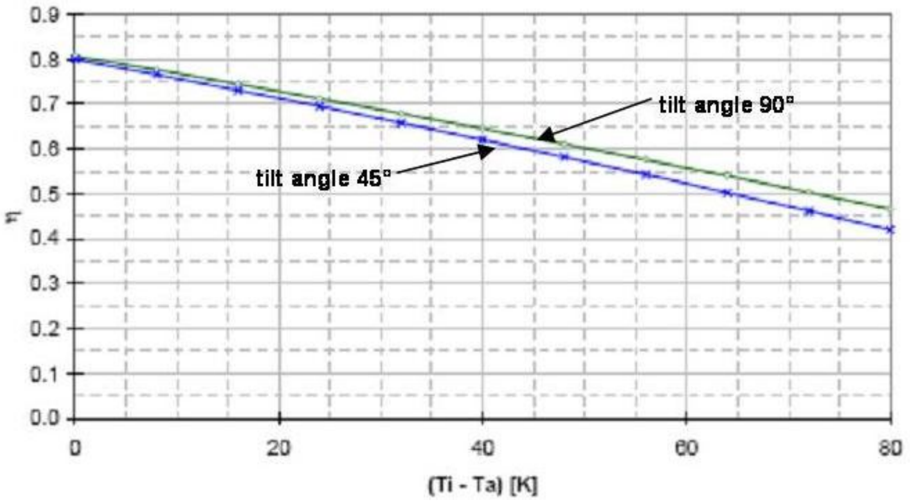


Figure 23 - Influence of the tilt angle on the efficiency curve for a collector with selective absorber at an irradiance level of 800 W/m^2, and no wind (*Source: Bergmann Irene, Meir Michaela, Rekstad John, Weiss Werner: "Architectural integration of collector arrays", in Solar Heating Systems for Houses - A Design Handbook for Solar Combisystems, deliverables of IEA SHC Task 26, 2002; pg.15)*

IV.7.2. Basement, ceilings and roof

Example basement floor [15]: Wolf-Thermo base plate, 30 cm EPS-insulation under the ground floor

U-value = 0,1 W/K.m^2

Example (green) roof [16]: double light wooden T-girders with in-blown mineral wool insulation of total thickness 44,5 cm

U-value = 0,1 W/(K. m^2)

IV.7.3. Windows

Example windows [13]: wooden windows, Janosik Softline 92; insulation covered wooden frames 92 mm, U-value = 0,89 W/K.m^2), tripple glazing Clima Guard Premium with Argon filling

U-value = 0,59 W/K.m^2

g-value 50%

IV. 8. Design of energy appliances

IV.8.1. Ventilation system

Example ventilation system [17]: ventilation unit THERMOS 300 DC, from company PAUL Wärmerückegewinnung (Austria), recuperation with aluminium channel cross-flow heat exchanger; ventilated air volume 50-400 m^3/h (380 m^3/h at 100 mPa), acoustic pressure 35 dB (at 58% rate of ventilation) – 42 dB (at 100% rate of ventilation)

Efficiency:

- ca 97 -99% according to DIBT, measured intake air flow by VEW Dortmund
- 92%, measured exhaust air, according to Passivhausinsitut Darmstadt

IV.8.2. Heating system

Heat load of the designed building is higher than 10 W/m^2 and thus extra heating system is needed. =15,18 W/m^2.

Example heating system [12]: ground or subsoil heat pump IVT Greenline C6 Plus, 5,9 kW, output temperature of hot water 65°C, hot water tank 225 l, electric boiler, equithermal regulation

Space distribution of heat: low temperature floor heating

IV.8.3. Hot water preparation

Example HW preparation by the solar thermal system of façade collectors: Collectors would be integrated to the southern façade of the building. Considered are green-coloured selective-coated liquid flat-plate collectors.

Dimensioning of the solar thermal system for hot water preparation:

- **Collector area:** There are many more or less complicated calculations for dimensioning

the solar system but for the appraisal the general rule of the thumb may be sufficient: For hot water preparation ca 1,5 m^2 of collector area per person is needed [3]. Considering lower efficiency of coloured collectors (ca 10% less than black ones for green one) [1, figure 2.10., pg.11] the required area of coloured collectors is ca 25-40% larger [1, pg.5] – ca 2 m^2 per person.

Calculating with 7 persons (6 occupants of residential part + 2 “half-persons” in office part) times 2 m^2/person there is **ca 14 m^2 of collector area needed** (at standard size of a collector ca 2 m^2 it will be 7 collectors) to supply the hot water demand.

The total front façade available for collector integration is:
1st floor – 51,28 m^2
2nd floor – 41,08 m^2
total – 92,36 m^2

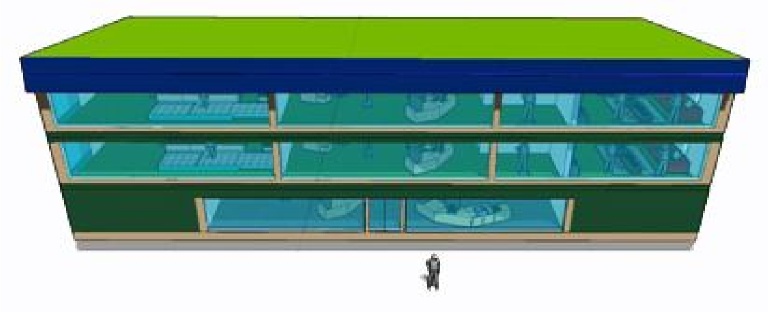


Figure 24 – Frontal facade area available for solar collectors (dark green)

Result: Total façade area available is more than sufficient to cover the hot water demand by installing the green integrated façade solar collectors.

- **Size of the solar storage tank:** The hot water is stored in storage tank. The volume of

the storage should be ca 2-2,5 fold the daily demand for regions with lower solar radiation (central and northern Europe). [21]

Using the 2,5 fold-size, the hot water storage tank volume is $\mathbf{V_{storage\ tank} = 0{,}92\ m^3}$

IV.7.4. Lighting

Electricity will be from major part delivered from the grid. Although not renewable it is still the cheapest to have electricity from the grid due to regulated energy prices in Slovakia. The own supply of electricity for lighting in the designed building is considered only.

Average household electricity consumption in Slovakia is ca 500 kWh/year per person [5]. Electricity for lighting is ca 10% of total electricity [20] - ca 50 kWh/year per person.

For designed building 5 persons in residential area and 2 persons in office area are calculated. Assuming that office consumption of electricity is maximum 50% of that in household due to reduced electricity appliances, only 1 additional person for office area is calculated to 5 persons in the residential part (chapter IV.6.6. Electricity demand). Reckoning than with 6 persons equivalent to household occupants the electricity demand for lighting in the designed building is ca 300 kWh/year.

Power output of photovoltaic modules in central and eastern European regions (with solar irradiation ca 1000 kWh/m^2) is 1000 kWh/kWp (kilo Watt peak). One kWp output is produced by ca 8 m^2 of PV modules [20].

To cover the electricity demand for lighting of the designed building ca 0,3 kWp would be needed. That **requires PV modules area of ca 2,5 m^2**.

Figure 25 – Total front roof area available for PV modules (dark blue)

The front roof area which is meant for PV modules installation has dimensions 31, 6 * 1,7 m. Total **area available** for installation of PV is **53,72 m^2**.

Result: Total front roof part area available is more than sufficient to cover the demand of electricity for lighting by installing the photovoltaic modules.

IV.8. Investment costs

Until now there is no financial scheme (in form of grant or allowance) in force in Slovakia although many discussions are held on the topic.

The costs for building a house in passive standard are generally considered to be ca 10-15% higher than for construction of the same sized building in the conventional standard [11] although this refers mostly to foreign projects due to very little experience from Slovakia.

The costs increase is due to use of the very high quality materials, components and

- careful planning, designing and projecting
- continuous crosscheck and control of parameters during the construction process

- using very high quality materials, components
- using more insulation materials
- very high quality of work assumes need for professionals in designing, construction and continuous control and supervision

On the other hand, some of the costs can be reduced by using the local and renewable materials such as wood, straw and due to lower price of work in the Northern Slovakia region.

Due to lack of Slovak references the calculation of **costs for design and construction** of the designed building is based on rough figures from Austria [18]:

- construction costs of conventional standard building vary around 1500 €/m^2

  Reckoning with ca increase 10% due to higher quality of materials and components to reach the passive house standard for the designed building of ca 1150 m^2 built area the construction costs ≈ 1 897 500 €.
- design costs are ca 22% of the construction costs (+ 19% VAT in Slovakia + 10% profit)

  For designed building the design costs ≈ 34 558 €

The **costs of technologies** are based on existing market prices

- ventilation system with heat recovery [17] ≈ 2 000 €
- heat pump [12]: 17 790 € + 19% VAT ≈ 21 170 €

  (technology: 8300 € + hot water storage tank 1000 l: 3520 € + subsoil collector or borehole: 3300 € + installation: 2670 €)
- solar thermal system: 3 500 € including installation + 19% VAT ≈ 4 165 €
- PV system [20] ≈ 2 000 €

Total estimated costs for construction of the designed building are 1 961 393 € (1 705 €/m^2).

V. Conclusions

This work proves by means of rough design and parameter analysis of the building that it is feasible to construct the building of given dimensions in climate condition of Stará Ľubovňa, North-Eastern Slovakia.

Suitable location for the building in terms of solar conditions and shading has been found. The building has been designed according to the general rules of solar architecture and passive house design: with orientation to the south and minimum shading, compact shape and distribution of glazed areas to maximize solar heat gains.

However, the energy balance of the designed building has shown that it is not possible to reach passive house standard of the building by using construction materials and components with the lowest required parameters. Due to colder climate higher quality materials and components must be used to reduce the heat losses from the building.

Climate conditions cause higher heat load than the maximum load for the ventilation system is. Therefore it is necessary either to decrease the heat losses from transmission even more or install additional heating system. Further reduction of heat losses would mean using the super quality materials and components which may not be economically reasonable. Detailed analysis should be executed in future development of the project. This work has focused on dimensioning and proposing the extra heating system based on renewable energy source – the heat pump.

The building dimensions allow the installation of the solar thermal system and photovoltaic modules which would suffice to cover the whole calculated demand of domestic hot water and electricity for the lighting.

The rough calculation of costs of the construction resulted in ca 1700 €/m^2 which corresponds with experiences in Austria and Germany and with preliminary appraisals of Slovak professionals. Due to lack of existing projects of the kind in Slovakia any more detailed comparisons were not made.

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Annexes

Annex 1 - Calculation sheet - Transmission losses of the designed building
Annex 2 - Calculation sheet - Ventilation losses of the designed building
Annex 3 - Calculation sheet - Solar radiation on location according to data from Photovoltaic Geographical Information System, EC JRC
Annex 4 - Calculation sheet - Solar heat gains of the designed building
Annex 5 - Calculation sheet - Internal heat gains of the designed building
Annex 6 - Calculation sheet - Heat demand of the building
Annex 7 - Calculation sheet - Transmission losses after adjustments
Annex 8 - Calculation sheet - Reduction of heat demand after adjustments (calculated according to the data from the Slovak Notice Nr. 625/2006)
Annex 9 - Calculation sheet - Reduction of the heat demand after adjustments (calculated according to the real local climate data)

ANNEX 1

TRANSMISSION LOSSES

NON-TRANSPARENT AREAS

	A	**U**	**f**	**L_T**
	[m2]	[W/K.m2]	[-]	
basement	382,36	0,15	1	57,35
ceiling 1/2	382,36	0,15	0,5	28,68
ceiling 2/3	382,36	0,15	0,5	28,68
roof	385,52	0,15	1	57,83
wall S	147,36	0,15	1	22,10
wall N	251,96	0,15	1	37,79
wall E	87,29	0,15	1	13,09
wall W	84,59	0,15	1	12,69
Transmission conductance of non-transparent areas				**258,21 [W/K]**

$L_T = A * U * f$

f - correction factor fo different types of unheated rooms
connected to heated areas

U-values from PH in Stupava, Slovakia

TRANSPARENT AREAS

	A	**A_f**	**A_g**	**l_g**	**U_f**	**U_g**	**Ψ_g**	**L_T**
	[m2]	[m2]	[m2]	[m]	[W/K.m2]	[W/K.m2]	[W/mK]	[W/K]
south	156,00	46,80	109,20	54,60	0,80	0,75	0,038	121,41
north	4,00	1,20	2,80	1,40	0,80	0,75	0,038	3,11
east	19,80	5,94	13,86	6,93	0,80	0,75	0,038	15,41
west	22,50	6,75	15,75	7,88	0,80	0,75	0,038	17,51
Transmission conductance of transparent areas							**[W/K]**	**157,45**

$L_T = (A_f * U_f) + (A_g * U_g) + (l_g * \Psi_g)$

Af – area of the window frame = ca 30% of total window area

Ag - area of the window glass = ca 70% of total window area

l_g - length of glass gap; the heat bridge junction

U_f - U-value of window frame

U_g - U-value of window glazing

Ψ_g - heat bridge coefficient of the windows

HEAT BRIDGES

Transmission conductance of heat bridges 41,57 [W/K]

L_T heat bridges ≈ 10% (L_T non-transparent areas + L_T transparent areas)

total area of the building A= 1538,2 m2

heat bridge losses per m2 0,02702 [W/K.m2]

L*T* TOTAL

L*T* non-transparent areas	258,21	
L*T* transparent areas	157,45	
L*T* heat bridges	41,57	
Total transmission conductance	**457,23**	[W/K]

TRANSMISSION LOSSES

Q*T* = L*T* * HDD * 0,024 [kWh/a]=[W/K]*[K.day/a]*[kilohours/day]

HDD - Heating degree days: 4470 average of years 2004 -2007

3812 according to http://re.ec.europa.au/pvgis/

	IX.	X.	XI.	XII.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	year
2004	250	344	519	661	788	627	568	387	277	0	0	0	**4421**
2005	208	370	569	690	718	710	661	372	206	0	0	0	**4504**
2006	222	373	493	614	920	712	662	380	274	0	0	0	**4650**
2007	304	422	594	714	605	558	504	392	211	0	0	0	**4304**
4-years average HDD	**246**	**377**	**544**	**670**	**758**	**652**	**599**	**383**	**242**	**0**	**0**	**0**	**4470**
transmission losses	**2 699,49**	**4 139,77**	**5 966,87**	**7 349,53**	**8 315,20**	**7 152,01**	**6 570,41**	**4 200,12**	**2 655,60**	**0,00**	**0,00**	**0,00**	**49 049,00**
													K.day

Transmission losses Q*T* = 49 049,00 [kWh/a]

TRANSMISSION LOSSES according Notice Nr. 625/2006

$Q_T = L_T$ * HDD * 0,024 **[kWh/a]=[W/K]*[K.day/a]*[kilohours/day]**

HDD-Heating degree days:	**3422**	**Notice Nr. 625/2006 on energy efficiency of the buildings, Attachment Nr.1**
	4470	real data - average of years 2004 -2007
	3812	according to http://re.ec.europa.au/pvgis/, particular data for Stará Ľubovňa

Transmission losses Q_T = 37 551,47 [kWh/a]

ANNEX 2

VENTILATION LOSSES

VOLUMES

V_{brutto} = (8,1*12,1*31,6)+(12,1*1,5*31,6)/2 [m^3]

V_{brutto} = 3 383,89 m^3

V_{netto} = 75%V_{brutto}

V_{netto} = 2 537,91 m^3

$V_{vent} = V_{netto} * n$ [m3/n] = [m3] * [1/h]

V_{vent} = 329,93 [m3/h]

AIR EXCHANGE RATE

$n = n_v * (1-\eta_v) + n_x$ [1/h]

n - energy equivalent air exchange rate

n_v - ventilation rate [1/h] 0,4 1/h

η_v - heat recovery efficiency of heat exchanger; min 0,8

n_x - leakage rate; air exchange rate through the not tight building envelope
at closed windows and doors
assuming very air-tight building: n_x= 0,05 1/h

energy equivalent air exchange rate n= 0,13 1/h

VENTILATION LOSSES

$L_V = V_{vent} * \rho * c_p$ [W/K] = [m3/h] * [W.h/m3.K]

cp - specific heat needed for heating 1 kg of air by 1°K

$\rho * c_p$ - specific heat needed for 1 m^3 of air to change temeperature by 1°K;
= 0,33

L_V = 108,88 [W/K]

$Q_V = L_V * HDD * 0{,}024$ [kWh/a] = [W/K] * [K.day/a]*[kilohours/day]

HDD - Heating degree days: 4470 average of years 2004 -2007

3812 according to http://re.ec.europa.au/pvgis/

	IX.	X.	XI.	XII.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	year	
2004	250	344	519	661	788	627	568	387	277	0	0	0	**4421**	
2005	208	370	569	690	718	710	661	372	206	0	0	0	**4504**	
2006	222	373	493	614	920	712	662	380	274	0	0	0	**4650**	
2007	304	422	594	714	605	558	504	392	211	0	0	0	**4304**	
4-years average HDD	**246**	**377**	**544**	**670**	**758**	**652**	**599**	**383**	**242**	**0**	**0**	**0**	**4470**	**K.day**
ventilation losses Qv	**642,81**	**985,77**	**1 420,84**	**1 750,08**	**1 980,03**	**1 703,05**	**1 564,56**	**1 000,14**	**632,35**	**0,00**	**0,00**	**0,00**	**11 679,62**	**kWh**

Ventilation losses Q_V = 11 679,62 [kWh/a]

VENTILATION LOSSES according Notice Nr. 625/2006

$Q_V = L_V * HDD * 0{,}024$ **[kWh/a] = [W/K] * [K.day/a]*[kilohours/day]**

HDD - Heating degree days:

3422	**Notice Nr. 625/2006 on energy efficiency of the buildings, Attachment**
4470	average of years 2004 -2007
3812	according to http://re.ec.europa.au/pvgis/

Ventilation losses Q_V = 8 941,81 [kWh/a]

ANNEX 3

Irradiation on vertical surface (all windows are vertical) [kWh/m^2]

	South	**North**	**East**	**West**	
Jan	48,90	7,89	17,30	17,90	
Feb	63,00	11,40	27,80	28,30	
Mar	88,00	20,30	52,00	52,00	
Apr	81,60	28,60	65,20	65,20	
May	80,20	41,30	77,80	77,80	
Jun	70,40	43,90	72,40	72,80	
Jul	81,10	45,20	82,40	82,40	
Aug	84,50	33,90	71,00	71,00	
Sep	81,90	21,40	52,50	52,50	
Oct	86,70	15,00	40,60	40,60	
Nov	50,10	8,80	19,30	19,90	
Dec	38,50	6,54	13,60	12,90	
Year:	*854,90*	*284,23*	*591,90*	*593,30*	*kWh/m^2*
Heating season:	**618,90**	**161,23**	**366,10**	**367,10**	**kWh/m^2**

EUROPEAN COMMISSION

Photovoltaic Geographical Information System

European Commission
Joint Research Centre
Ispra, Italy

Performance of Grid-connected PV

PVGIS estimates of solar electricity generation

Location: 49°18'7" North, 20°41'25" East, Elevation: 530 m a.s.l.,
Nearest city: Stara Lubovna, Slovakia (1 km away)

Nominal power of the PV system: 1.0 kW (crystalline silicon)
Estimated losses due to temperature: 5.0% (using local ambient temperature)
Estimated loss due to angular reflectance effects: 4.2%
Other losses (cables, inverter etc.): 14.0%
Combined PV system losses: 21.7%

	Fixed system: inclination=90 deg., orientation=0 deg.			
Month	**Ed**	**Em**	**Gd**	**Gm**
Jan	1.33	41.2	1.58	48.9
Feb	1.87	52.3	2.25	63.0
Mar	2.29	71.1	2.84	88.0
Apr	2.11	63.3	2.72	81.6
May	1.94	60.0	2.59	80.2
Jun	1.73	51.8	2.35	70.4
Jul	1.92	59.4	2.62	81.1
Aug	2.03	63.0	2.73	84.5
Sep	2.11	63.3	2.73	81.9
Oct	2.23	69.2	2.80	86.7
Nov	1.37	41.1	1.67	50.1
Dec	1.04	32.2	1.24	38.5
Year	1.83	55.7	2.34	71.2

Ed: Average daily electricity production from the given system (kWh)
Em: Average monthly electricity production from the given system (kWh)
Gd: Average daily sum of global irradiation per square meter received by the modules of the given system (kWh/m2)
Gm: Average sum of global irradiation per square meter received by the modules of the given system (kWh/m2)

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Performance of Grid-connected PV

PVGIS estimates of solar electricity generation

Location: 49°18'7" North, 20°41'25" East, Elevation: 530 m a.s.l.,
Nearest city: Stara Lubovna, Slovakia (1 km away)

Nominal power of the PV system: 1.0 kW (crystalline silicon)
Estimated losses due to temperature: 12.5% (using local ambient temperature)
Estimated loss due to angular reflectance effects: 5.3%
Other losses (cables, inverter etc.): 14.0%
Combined PV system losses: 28.8%

	Fixed system: inclination=90 deg., orientation=180 deg.			
Month	**Ed**	**Em**	**Gd**	**Gm**
Jan	0.18	5.56	0.25	7.89
Feb	0.29	8.17	0.41	11.4
Mar	0.47	14.6	0.65	20.3
Apr	0.67	20.2	0.95	28.6
May	0.95	29.4	1.33	41.3
Jun	1.05	31.5	1.46	43.9
Jul	1.03	31.8	1.46	45.2
Aug	0.76	23.6	1.09	33.9
Sep	0.50	15.0	0.71	21.4
Oct	0.34	10.5	0.48	15.0
Nov	0.20	6.04	0.29	8.80
Dec	0.15	4.49	0.21	6.54
Year	0.55	16.7	0.78	23.7

Ed: Average daily electricity production from the given system (kWh)

Em: Average monthly electricity production from the given system (kWh)

Gd: Average daily sum of global irradiation per square meter received by the modules of the given system (kWh/m2)

Gm: Average sum of global irradiation per square meter received by the modules of the given system (kWh/m2)

Performance of Grid-connected PV

PVGIS estimates of solar electricity generation

Location: 49°18'7" North, 20°41'25" East, Elevation: 530 m a.s.l.,
Nearest city: Stara Lubovna, Slovakia (1 km away)

Nominal power of the PV system: 1.0 kW (crystalline silicon)
Estimated losses due to temperature: 6.5% (using local ambient temperature)
Estimated loss due to angular reflectance effects: 4.3%
Other losses (cables, inverter etc.): 14.0%
Combined PV system losses: 23.0%

	Fixed system: inclination=90 deg., orientation=-90 deg.			
Month	**Ed**	**Em**	**Gd**	**Gm**
Jan	0.43	13.5	0.56	17.3
Feb	0.79	22.0	0.99	27.8
Mar	1.33	41.3	1.68	52.0
Apr	1.69	50.7	2.17	65.2
May	1.92	59.5	2.51	77.8
Jun	1.83	54.8	2.41	72.4
Jul	2.00	62.1	2.66	82.4
Aug	1.73	53.6	2.29	71.0
Sep	1.34	40.2	1.75	52.5
Oct	1.01	31.4	1.31	40.6
Nov	0.49	14.8	0.64	19.3
Dec	0.33	10.3	0.44	13.6
Year	1.24	37.9	1.62	49.3

Ed: Average daily electricity production from the given system (kWh)

Em: Average monthly electricity production from the given system (kWh)

Gd: Average daily sum of global irradiation per square meter received by the modules of the given system (kWh/m2)

Gm: Average sum of global irradiation per square meter received by the modules of the given system (kWh/m2)

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Photovoltaic Geographical Information System

European Commission
Joint Research Centre
Ispra, Italy

Performance of Grid-connected PV

PVGIS estimates of solar electricity generation

Location: 49°18'7" North, 20°41'25" East, Elevation: 530 m a.s.l.,
Nearest city: Stara Lubovna, Slovakia (1 km away)

Nominal power of the PV system: 1.0 kW (crystalline silicon)
Estimated losses due to temperature: 7.2% (using local ambient temperature)
Estimated loss due to angular reflectance effects: 4.3%
Other losses (cables, inverter etc.): 14.0%
Combined PV system losses: 23.6%

	Fixed system: inclination=90 deg., orientation=90 deg.			
Month	**Ed**	**Em**	**Gd**	**Gm**
Jan	0.45	13.9	0.58	17.9
Feb	0.80	22.3	1.01	28.3
Mar	1.32	41.0	1.68	52.0
Apr	1.67	50.2	2.17	65.2
May	1.90	59.0	2.51	77.8
Jun	1.82	54.7	2.43	72.8
Jul	1.99	61.6	2.66	82.4
Aug	1.71	53.1	2.29	71.0
Sep	1.33	39.8	1.75	52.5
Oct	1.01	31.2	1.31	40.6
Nov	0.51	15.3	0.67	19.9
Dec	0.31	9.76	0.42	12.9
Year	1.24	37.6	1.63	49.5

Ed: Average daily electricity production from the given system (kWh)

Em: Average monthly electricity production from the given system (kWh)

Gd: Average daily sum of global irradiation per square meter received by the modules of the given system (kWh/m2)

Gm: Average sum of global irradiation per square meter received by the modules of the given system (kWh/m2)

ANNEX 4

SOLAR HEAT GAINS

	A [m2]	A_g [m2]	g [-]	f_s [-]	I [kWh/m2]
south	156,00	109,20	0,50	0,80	618,90
north	4,00	2,80	0,50	0,80	161,23
east	19,80	13,86	0,50	0,80	336,10
west	22,50	15,75	0,50	0,80	367,10

Q_s [kWh/a]

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	year	heating period	
	2 135,95	2 751,84	3 843,84	3 564,29	3 503,14	3 075,07	3 542,45	3 690,96	3 577,39	3 787,06	2 188,37	1 681,68	37 342,03	**27 033,55**	
	8,84	12,77	22,74	32,03	46,26	49,17	50,62	37,97	23,97	16,80	9,86	7,32	318,34	**180,58**	
	95,91	154,12	288,29	361,47	431,32	401,39	456,83	393,62	291,06	225,09	107,00	75,40	3 281,49	**1 863,34**	
	112,77	178,29	327,60	410,76	490,14	458,64	519,12	447,30	330,75	255,78	125,37	81,27	3 737,79	**2 312,73**	
Q_s	**2 353,47**	**3 097,02**	**4 482,46**	**4 368,55**	**4 470,86**	**3 984,27**	**4 569,02**	**4 569,85**	**4 223,17**	**4 284,72**	**2 430,59**	**1 845,67**	**44 679,65**	**31 390,20**	**kWh/a**
ηQ_s	**2 118,12**	**2 787,32**	**4 034,22**	**3 931,69**	**4 023,77**	**3 585,84**	**4 112,12**	**4 112,87**	**3 800,85**	**3 856,25**	**2 187,53**	**1 661,11**	**40 211,69**	**28 400,87**	**kWh/a**

$$Q_s = I * f_s * g * A_g \quad [\mathrm{kWh/m2\,a}] = [\mathrm{kWh/m2}] * - * - * [\mathrm{kh/a}]$$

g- g-value, solar heat gain coefficient of the glazed part of the window; the share of solar energy that passes through the window glass into the building

f_s - factor of shading by trees, buildings, dust, dirt; standard ≈ 75-80%

I - solar irradiation that hits the windows

ηQ_s - efficient solar heat gains

Solar heat gains Q_s = 31 390,20 kWh/a

efficiency in practise ηQ_s = 90%

Efficient solar heat gains ηQ_s = 28 251,18 kWh/a

SOLAR HEAT GAINS according Notice Nr. 625/2006

	A [m2]	A_g [m2]	g [-]	f_s [-]	I [kWh/m^2]	Q_s [kWh/a]
south	156,00	109,20	0,50	0,80	320,00	13 977,60
north	4,00	2,80	0,50	0,80	100,00	112,00
east	19,80	13,86	0,50	0,80	200,00	1 108,80
west	22,50	15,75	0,50	0,80	200,00	1 260,00
					Solar heat gains	**16 458,40 kWh/a**

$Q_s = I * f_s * g * A_g$ [kWh/m^{2}a] = [kWh/m^2] * - * - * [kh/a]

g- g-value, solar heat gain coefficient of the glazed part of the window; the share of solar energy that passes through the window glass into the building

f_s - factor of shading by trees, buildings, dust, dirt; standard ≈ 75-80%

I - solar irradiation that hits the windows

Notice Nr. 625/2006 on energy efficiency of the buildings, Attachment Nr.1

	kWh/m
south	320
north	100
east, west	200
south-west, south-east	260
north-east, north-west	130

Solar heat gains Q_s = 16 458,40 kWh/a

efficiency in practise ηQ_s = 90%

Efficient solar heat gains ηQ_s = 14 812,56 kWh/a

ANNEX 5

INTERNAL GAINS

$Q_i = q_i * S * HD * 24$ **[kWh/a] = [kW/m^2] * [m^2] * [day/a] * [h/day]**

q_i - average heat flow density of internal heat sources; internal heat from occupants and appliances; standard = 0,003 kW/m2 (1 person produces 3 W/m2 by biological activity and by using electrical appliances

S - brutto heated floor area S= **890,00** **m2**

qi= **0,003 kWh/a**

HD - heating days

	HD	Qi	ηQi
January	31	1 986,48	1 787,83
February	28	1 794,24	1 614,82
March	31	1 986,48	1 787,83
April	30	1 922,40	1 730,16
May	31	1 986,48	1 787,83
June	30	1 922,40	1 730,16
July	31	1 986,48	1 787,83
August	31	1 986,48	1 787,83
September	30	1 922,40	1 730,16
October	31	1 986,48	1 787,83
November	30	1 922,40	1 730,16
December	31	1 986,48	1 787,83
year	**365**	**23 389,20**	**21 050,28**
heating period	**273**	**17 493,84**	**15 744,46**

Internal gains Q_i = 23 389,20 kWh/a

efficiency in practise ηQ_i = 90%

Efficient internal gains ηQ_i = 21 050,28 kWh/a

INTERNAL GAINS according Notice Nr. 625/2006

HD - heating days 212 **days/year** according to the Notice Nr. 625/2006
on energy efficiency of the buildings, Attachment Nr.1

qi= 0,003 kWh/a
Internal gains Q*i* = 13 584,96 kWh/a
efficiency in practise ηQ_i = 90%
Efficient internal gains ηQ*i* = 12 226,46 kWh/a

ANNEX 6

HEAT DEMAND

$Q_H = (Q_T + Q_V) - (\eta Q_s + \eta Q_i)$ [kWh/a]

Q_T - transmission losses Q_T = 49 049,00 [kWh/a]

Q_V - ventilation losses Q_V = 11 679,62 [kWh/a]

ηQ_s - solar gains ηQ_s = 28 400,87 [kWh/a]

ηQ_i - internal gains ηQ_i = 15 744,46 [kWh/a]

	IX.	**X.**	**XI.**	**XII.**	**I.**	**II.**	**III.**	**IV.**	**V.**	**VI.**	**VII.**	**VIII.**	**year**	**heating period**
HDD	246	377	544	670	758	652	599	383	242	0	0	0	4470	4470
QT	2 699,49	4 139,77	5 966,87	7 349,53	8 315,20	7 152,01	6 570,41	4 200,12	2 655,60	0,00	0,00	0,00	49 049,00	49 049,00
QV	642,81	985,77	1 420,84	1 750,08	1 980,03	1 703,05	1 564,56	1 000,14	632,35	0,00	0,00	0,00	11 679,62	11 679,62
ηQ_s	3 800,85	3 856,25	2 187,53	1 661,11	2 118,12	2 787,32	4 034,22	3 931,69	4 023,77	3 585,84	4 112,12	4 112,87	40 211,69	28 400,87
ηQ_i	1 730,16	1 787,83	1 730,16	1 787,83	1 787,83	1 614,82	1 787,83	1 730,16	1 787,83	1 730,16	1 787,83	1 787,83	21 050,28	15 744,46
heat demand	2 188,71	518,54	-3 470,01	-5 650,68	-6 389,28	-4 452,92	-2 312,92	461,59	2 523,65	5 316,00	5 899,95	5 900,70	533,34	-16 583,30

Heat demand Q_H = **16 583,30 [kWh/a]**

$q_H = Q_H / S$ [kWh/m2 .a]

specific heat demant q_H = **14,46 kWh/m2 .a**

HEAT DEMAND according Notice Nr. 625/2006

$Q_H = (Q_T + Q_V) - (\eta Q_s + \eta Q_i)$ [kWh/a]

Q_T - transmission losses $Q_T =$ 37 551,47 [kWh/a]

Q_V - ventilation losses $Q_V =$ 8 941,81 [kWh/a]

ηQ_S - solar gains $\eta Q_S =$ 14 812,56 [kWh/a]

ηQ_I - internal gains $\eta Q_I =$ 12 226,46 [kWh/a]

Heat demand $Q_H =$ 19 454,26 [kWh/a]

$q_H = Q_H / S$ [kWh/m2.a]

$q_H =$ 16,96 kWh/m2.a

ANNEX 7

TRANSMISSION LOSSES after adjustments

NON-TRANSPARENT AREAS

	A [m2]	U [W/K.m2]	f [-]	L_T
basement**	382,36	0,1	1	38,24
ceiling 1/2*	382,36	0,135	0,5	25,81
ceiling 2/3*	382,36	0,135	0,5	25,81
roof ***	385,52	0,1	1	38,55
wall S*	147,36	0,101	1	14,88
wall N*	251,96	0,101	1	25,45
wall E*	87,29	0,101	1	8,82
wall W*	84,59	0,101	1	8,54
	Transmission conductance of non-transparent areas			**186,10 [W/K]**

$L_T = A * U * f$

f - correction factor fo different types of unheated rooms connected to heated areas

* U-values from PH in Stupava, Slovakia

** U-value from PH Rheinland - Pfalz, Germany

*** U-value from PH in Darmstadt-Kranichsten, Germany

TRANSPARENT AREAS

	A [m2]	A_f [m2]	A_g [m2]	l_g [m]	U_f [W/K.m2]	U_g [W/K.m2]	Ψ_g [W/mK]	L_T [W/K]
south	156,00	46,80	109,20	54,60	0,80	0,59	0,038	103,94
north	4,00	1,20	2,80	1,40	0,80	0,59	0,038	2,67
east	19,80	5,94	13,86	6,93	0,80	0,59	0,038	13,19
west	22,50	6,75	15,75	7,88	0,80	0,59	0,038	14,99
			Transmission conductance of transparent areas				**[W/K]**	**134,79**

$L_T = (A_f * U_f) + (A_g * U_g) + (l_g * \Psi_g)$

Af - area of the window frame = ca 30% of total window area

Ag - area of the window glass = ca 70% of total window area

l_g - length of glass gap; the heat bridge junction

U_f - U-value of window frame

U_g - U-value of window glazing

Ψ_g - heat bridge coefficient of the windows

HEAT BRIDGES

Transmission conductance of heat bridges 32,09 [W/K]

L_T heat bridges ≈ 10% (L_T non-transparent areas + L_T transparent areas)

L_T TOTAL

L_T non-transparent areas	186,10	
L_T transparent areas	134,79	
L_T heat bridges	32,09	
Total transmission conductance	**352,98**	**[W/K]**

TRANSMISSION LOSSES

$Q_T = L_T * HDD * 0,024$ **[kWh/a]=[W/K]*[K.day/a]*[kilohours/day]**

HDD - Heating degree days: 4470 average of years 2004 -2007

3812 according to http://re.ec.europa.au/pvgis/

	IX.	**X.**	**XI.**	**XII.**	**I.**	**II.**	**III.**	**IV.**	**V.**	**VI.**	**VII.**	**VIII.**	**year**
2004	250	344	519	661	788	627	568	387	277	0	0	0	**4421**
2005	208	370	569	690	718	710	661	372	206	0	0	0	**4504**
2006	222	373	493	614	920	712	662	380	274	0	0	0	**4650**
2007	304	422	594	714	605	558	504	392	211	0	0	0	**4304**
4-years average HDD	**246**	**377**	**544**	**670**	**758**	**652**	**599**	**383**	**242**	**0**	**0**	**0**	**4470**
transmission losses	**2 083,98**	**3 195,86**	**4 606,37**	**5 673,77**	**6 419,26**	**5 521,29**	**5 072,30**	**3 242,46**	**2 050,10**	**0,00**	**0,00**	**0,00**	**37 865,38**
													K.day

Transmission losses Q_T = 37 865,38 [kWh/a]

TRANSMISSION LOSSES after adjustments according Notice Nr. 625/2006

$Q_T = L_T * HDD * 0{,}024$ [kWh/a]=[W/K]*[K.day/a]*[kilohours/day]

HDD-Heating degree days:	3422	**Notice Nr. 625/2006 on energy efficiency of the buildings, Attachment Nr.1**
	4469	real data - average of years 2000 -2007
	3812	according to http://re.ec.europa.eu/pvgis/, particular data for Stará Ľubovňa

Transmission losses Q_T = 28 989,39 [kWh/a]

ANNEX 8

HEAT DEMAND after adjustments according to the Notice Nr. 625/2006

$Q_H = (Q_T + Q_V) - (\eta Q_s + \eta Q_i)$ [kWh/a]

Q_T - transmission losses $Q_T =$ 28 989,39 [kWh/a]
Q_V - ventilation losses $Q_V =$ 8 941,81 [kWh/a]
ηQ_s - solar gains $\eta Q_s =$ 14 812,56 [kWh/a]
ηQ_i - internal gains $\eta Q_i =$ 12 226,46 [kWh/a]

Heat demand $Q_H =$ 10 892,18 [kWh/a]

$q_H = Q_H / S$ [kWh/m2.a]

$q_H =$ 9,50 kWh/m2.a

ANNEX 9

HEAT DEMAND after adjustments

$Q_H = (Q_T + Q_V) - (\eta Q_s + \eta Q_i)$ [kWh/a]

Q_T - transmission losses Q_T = 37 865,38 [kWh/a]

Q_V - ventilation losses Q_V = 11 679,62 [kWh/a]

ηQ_s - solar gains ηQ_s = 28 400,87 [kWh/a]

ηQ_i - internal gains ηQ_i = 15 744,46 [kWh/a]

	IX.	**X.**	**XI.**	**XII.**	**I.**	**II.**	**III.**	**IV.**	**V.**	**VI.**	**VII.**	**VIII.**	**year**	**heating period**
HDD	246	377	544	670	758	652	599	383	242	0	0	0	4470	4470
QT	2 083,98	3 195,86	4 606,37	5 673,77	6 419,26	5 521,29	5 072,30	3 242,46	2 050,10	0,00	0,00	0,00	37 865,38	37 865,38
QV	642,81	985,77	1 420,84	1 750,08	1 980,03	1 703,05	1 564,56	1 000,14	632,35	0,00	0,00	0,00	11 679,62	11 679,62
ηQs	3 800,85	3 856,25	2 187,53	1 661,11	2 118,12	2 787,32	4 034,22	3 931,69	4 023,77	3 585,84	4 112,12	4 112,87	40 211,69	28 400,87
ηQi	1 730,16	1 787,83	1 730,16	1 787,83	1 787,83	1 614,82	1 787,83	1 730,16	1 787,83	1 730,16	1 787,83	1 787,83	21 050,28	15 744,46
heat demand	2 804,22	1 462,45	-2 109,51	-3 974,92	-4 493,34	-2 822,20	-814,80	1 419,26	3 129,15	5 316,00	5 899,95	5 900,70	11 716,96	-5 399,68

Heat demand Q_H = 5 399,68 [kWh/a]

$q_H = Q_H / S$ [kWh/m2.a]

specific heat demand q_H = 4,71 kWh/m2.a