ECONOMICALLY OPTIMAL LEVEL OF THERMAL INSULATION FOR SINGLE-FAMILY HOUSES IN KYRGYZSTAN

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Abstract

Residential buildings in Kyrgyzstan consume a large amount of energy for space heating. This heat demand can easily be reduced by implementing efficiency measures such as thermal insulation of the building envelope. The aim of this paper is to find the most economical level of thermal insulation for a single-family house considering local conditions in Kyrgyzstan (continental climate, energy prices scenarios, availability of materials etc.). The thermal behavior of a typical single-family house was investigated by computer simulations in TRNSYS 17.1. The mathematical model of this house includes 3 thermal zones. Two different fuels for heating systems were considered: natural gas (imported) and electricity (from domestic hydro power). To identify the optimal insulation level, the insulation (polystyrene, basalt, glass fiber) thickness was changed step by step for external walls, ground floor and roof from 0 to 0.4 m. To obtain the optimal values a large quantity of possible combinations with intercorrelated impact of each of them on the heat demand was considered by simultaneously varying insulation thicknesses for these three construction elements. This complex calculation was carried out by coupling GenOpt, an optimization tool, with TRNSYS. Using combined Particle Swarm (PSO) and Hooke-Jeeves optimization algorithms (implemented in GenOpt), the optimal thicknesses of the insulation were determined. The investigation showed that insulation for the chosen single-family house is not always economically justified in Kyrgyzstan, especially in case of electrical heating. However, it is economically feasible if a gas heating system is installed. The results are discussed in detail in this paper.

1. Introduction

Kyrgyzstan, a small, mountainous country, is located in the heart of Central Asia (Fig. 1). About 95% of the entire area is covered by mountains; the elevation of 90% of the country is above 1500 m. It covers an area of about 198.000 km² with a population of 5.36 million people [1]. A continental climate with hot summers, cold winters and relatively little rainfall is typical for this region.

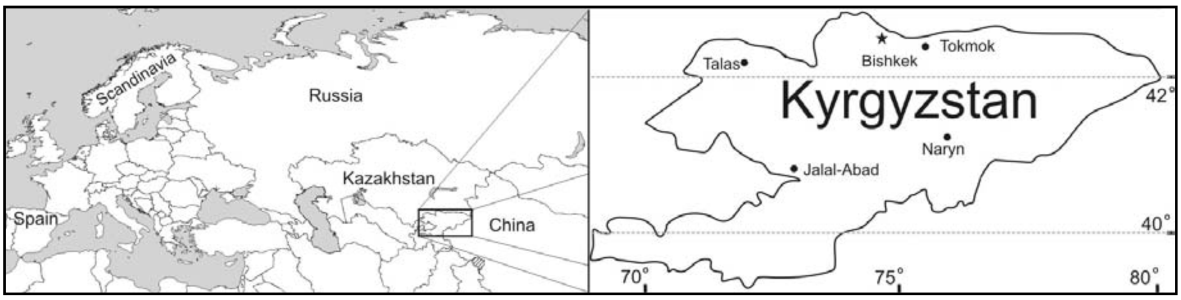

Fig. 1. Location of Kyrgyzstan on the map.

Most residential buildings were built during the former Soviet Union era. At that time, the priority of the urbanization was given to construction speed and constructed living space. This strategy was successfully applied, but had negative consequences such as a high energy demand for heating. Even today, the “old approach” – to build spending the minimal investments and using the cheapest materials – is predominated for constructing both, single- and multi-family houses. Therefore, residential buildings are currently the largest energy consumers in Kyrgyzstan, followed by industry and transportation [2]. Residential buildings consume the largest amount of energy for space heating. This heat demand can easily be reduced by implementing efficiency measures such as thermal insulation of the building envelope. The necessity to consider energy efficiency in residential buildings is increasing due to the raise of energy prices and, to a minor extend, due to environmental awareness. The aim of this paper is to find the most economical level of thermal insulation for a single-family house considering local conditions in Kyrgyzstan (continental climate, energy prices scenarios, availability of materials etc.).

2. Climate

The geographical location determines the specific climatic conditions in Kyrgyzstan. High mountains, remoteness from oceans, seas and deserts of the neighboring countries create a continental climate here. The seasons are clearly expressed with hot summers and cold winters. Meteorological data from Meteonorm 6.0 were used for the investigations. Meteonorm 6.0 has meteorological data for 5 cities in Kyrgyzstan: Bishkek, the capital, Talas, Tokmok, Jalal-Abad and Naryn, cf. fig. 1. Solar radiation data were interpolated by Meteonorm 6.0 from available data of stations in neighboring countries. Long-term monthly average values of the ambient temperature as well the monthly sum of global solar radiation on the horizontal surface is presented in Fig. 2. It shows a good solar potential for these cities. The coldest temperature can be observed in Naryn due to its location (elevation above 2000 m), whereas Jalal-Abad has the highest annual ambient temperature (appr. 14°C).

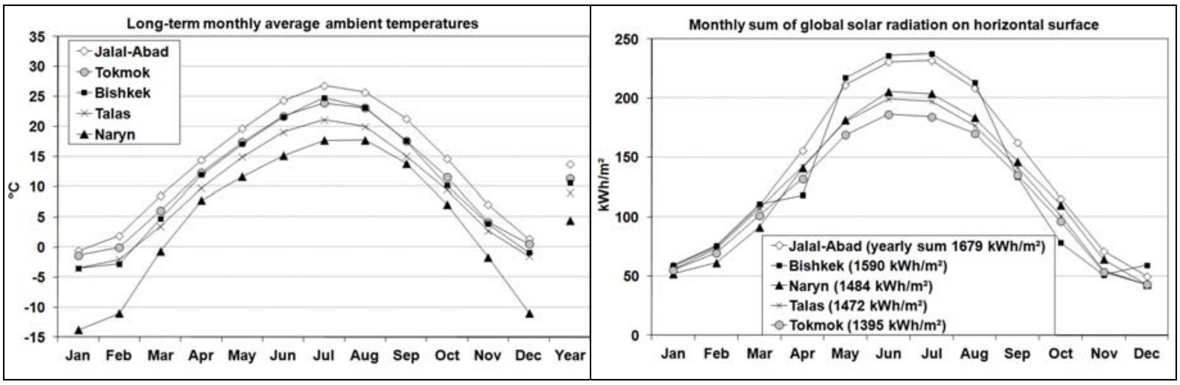

Fig. 2. Long-term monthly average ambient temperatures (left) and monthly sum of global solar radiation on horizontal surface (right) in some cities of Kyrgyzstan.

Another possibility to evaluate the climate in the region is to analyze the number of the heating degree days (HDD). There are different methods of calculating the heating degree days. For instance in the USA this is the difference between the baseline (18.3°C) and the actual outdoor temperature multiplied with the number of days[3]. In Germany, the so called “heating boundary temperature” (Heizgrenztemperatur) is additionally considered to the baseline temperature (20°C). Only outdoor temperatures below this boundary temperature (10°C according the German building code EnEV 2009) are accounted for in the calculation of heating degree days. In Kyrgyzstan, the heating period begins as soon as the daily mean outside temperature drops below 8°C for at least five consecutive days and finishes when the daily mean outside temperature will be above 8°C for at least five days as well. The number of heating degree-days is therefore calculated by the difference between the baseline temperature (20°C for residential buildings) and the average outdoor temperature during the heating period multiplied by the numbers of days in heating period. In Table 1 the heat degree days based on the Kyrgyz code [4] are presented and compared to our own calculations according to the same method but using the meteorological data (hourly mean values) from Meteonorm. Both data sets are in good agreement. Insignificant deviation is probably caused by the different periods that were used for the calculation of long term average values of the outdoor temperature.

Table 1. A comparison of heating degree-days from SNiP KR 23-02-00 and own calculation based on used meteorological data from Meteonorm.

City	Bishkek	Talas	Naryn	Jalal-Abad	Tokmok
SNiP KR 23-02: 2009, Kd	2970	3588	4992	2447	3212
Meteorological data from Meteonorm, Kd	3106	3328	4761	2248	2732
Deviation ((SNiP-Meteonorm)/SNiP), %	4.6	7.2	4.6	8.1	14.9

3. Single-family house model

3.1. Building description

There are many existing construction types of single-family houses in Kyrgyzstan (Fig. 3) [5]. On the one hand, in the rural places and some cities a historical technique of “clay walls” is still practiced, these are called “Gualak”, „Sokmo“, “Pasha”[1] etc. Pure clay or mixed with sand and/or straw was a universally available and 100% recyclable material for houses not only in Kyrgyzstan, but also in the whole Central Asia. On the other hand the materials as brick, foamed concrete are also used for wall construction. Particularly the new single-family houses in Bishkek are built from

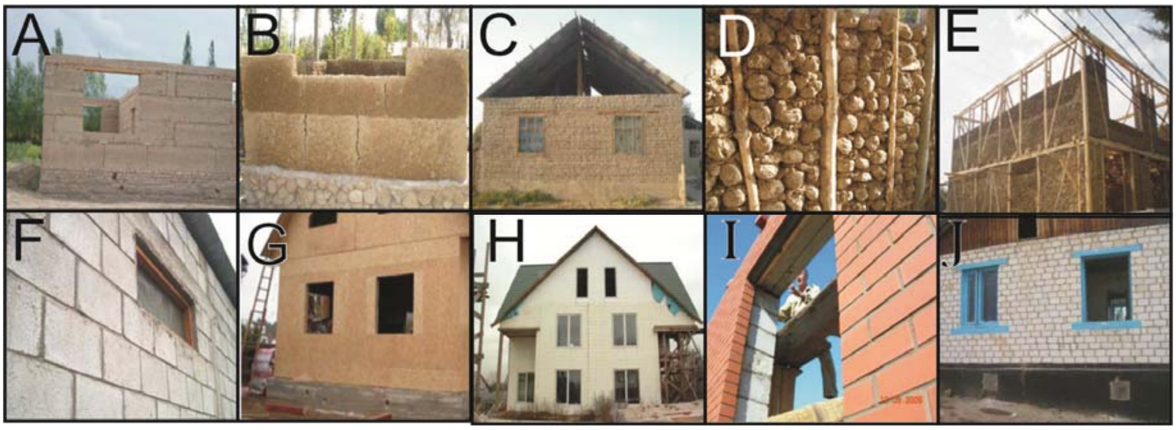

Fig. 3. Some types of existing construction techniques in Kyrgyzstan a) sokmo b) pahsa c) raw bricks d) gualak e) sinch - pre-cut method, f) sandblock g) panel board frame house h) styrofoam concrete i) burnt red bricks j) silicate brick.

bricks. It should be emphasized that a general feature in almost all single-family houses in Kyrgyzstan is the absence of thermal insulation.

[1] Gualak was used in the south of Kyrgyzstan, and represents a method where balls will be hand made from the mix of clay and straw and pressed in a timbering or a carcase. “Sokmo” is translated from kyrgyz language as “beating”. The mix is filled in in timberings, afterward it is stomped (beated) with special tool for compression.

For our investigation, a typical single-family house was chosen and modeled in TRNSYS 17.1. Due to the absence of a building typology for Kyrgyzstan, a typical building was selected based on own experience and based on the assessment of the local Center for Energy Efficient Building Central Asia (CEEBA). The selected house is a one-store building with approximately 90 m² living area. It has brick walls and no thermal insulation. The mathematical model of this house was simulated in TRNSYS 17.1 for analyzing its thermal behavior. The sketch of the chosen house with important dimensions is illustrated in Fig. 4. This building was divided into three thermal zones: the basement, first and attic floor. The applied materials and layer thicknesses describing the reference building are listed in Table 2. Double-glazed windows (g-Value = 0.755, frame 15% with U=2.27 W/(m²K)), were assumed for this house.

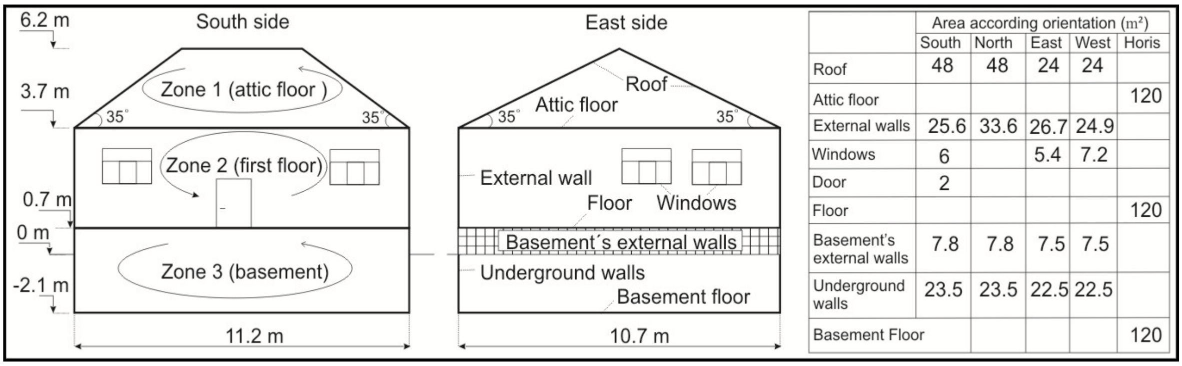

Fig. 4. The sketch of the single-family house divided into three thermal zones (left), the elements of construction (middle) as well as their area for each orientation (right).

Table 2. Construction of buildings elements of the chosen single family house.

Zone	Assembly	Layer	Thickness [m]	Density [kg/m³]	Conductivity [W/(mK)]	Capacity [kJ/(kgK)]	U-value [W/(m²K)]
Attic Floor	Roof (0.02 m)	Roof tile	0.02	2200	0.96	0.92	5.24
		Wood construction	Ne -	glec -	ted		
	Attic floor (0.16 m)	Mix of clay and straw	0.08	300	0.1	0.9	0.49
		Straw	0.03	150	0.04	2.1	
		Pine wood	0.05	500	0.13	1.4	
First floor	External walls (0.44 m)	Plaster inside	0.03	1800	0.76	0.84	1.1
		Brick	0.38	1600	0.58	0.8	
		Plaster outside	0.03	1800	0.76	0.84	
	Windows						2.83
	Door	Pine wood	0.04	500	0.13	1.4	3.24
	Floor (0.3 m)	Concrete slab	0.22	2500	1.92	1.13	1.72
		Plaster	0.05	1800	0.76	0.84	
		Pine wood	0.03	600	0.13	1.7	
Basement	Basement´s external walls (0.52 m)	Plaster inside	0.05	1800	0.76	0.84	1.98
		Concrete slab	0.44	2500	1.92	1.13	
		Plaster inside	0.03	1800	0.76	0.84	
	Underground walls (0.47 m)	Concrete slab	0.44	1800	0.76	0.84	2.28
		Plaster	0.03	1800	0.76	0.84	
	Basement floor	Plaster	0.05	1800	0.76	0.84	4.24

It has to be noted, that the Kyrgyz building energy codes [4] contains requirements to the building's design for energy conservation and energy saving. For example, maximal U-values of the construction are required depending on the location (expressed via heating degree-days). However, the building codes are usually not considered in reality during the construction of buildings, so that most single-family houses, including the reference building, do not fulfill the requirements.

3.2. Air change rate

Besides transmission through the building-envelope, significant heat losses in houses occur due to ventilation, ex- and infiltration. The air-tightness of a building, which defines the ex- and infiltration rate, can be determined by a blower-door test. However, such tests have not been carried out in Kyrgyzstan and are currently not available there. The ventilation losses are difficult to estimate, because they depend mainly on the occupant's behavior. For instance, the frequency of windows and doors opening and its duration determine the heat losses in winter time. For this study, the following air change rates for different thermal zones were assumed based on preliminary results of the European project Tabula [6] (low air-tightness of the house, so called "leaky" house), cf. Table 3.

Table 3. Air change rates for the thermal zones.

	Zone 1 (attic floor)	**Zone 2 (first floor)**		**Zone 3 (basement)**
		Ex- and infiltration	ventilation	
Air change rate, 1/h	0.4	0.3	0.6	0.6

3.3. Internal gains

Internal heat gains from household appliances and occupants were considered. It was assumed that the single-family house was occupied by a family consisting of four persons. The heat dissipation from occupants to the surroundings was estimated in accordance with the ISO 7730 standard [7] for activity degree "seated at rest" at 100 Watt per person. The rough occupancy profile considered that the inhabitants are not at home from 8.00 to 17.00 every day. This leads to average internal gains by inhabitants of 6 kWh/day. The consumption of electricity not used for space heating was considered to be 300 kWh per month, which is a typical value in Kyrgyzstan. It was assumed that 60% of the electricity consumption (180 kWh per month or 6 kWh per day) remains inside the building as thermal energy. Based on these assumptions the total internal gains are estimated at 12 kWh/day.

3.4. Heat demand and expenses for heating

In order to achieve healthy and pleasant indoor conditions, the room temperature of the second thermal zone (first floor) was set to the constant level of 20 °C during the heating period. The heat demand of the house, considering heat losses through the walls, ventilation and internal gains including solar energy coming through the windows, were simulated with TRNSYS 17.1 for a typical year and presented in Table 4. The simulation time step was 1 hour.

Table 4. The heat demand of the reference house depending on location.

	Bishkek	**Talas**	**Naryn**	**Jalal-Abad**	**Tokmok**
Heat demand, MWh/a	32	35	48	25	30
Specific heat demand, kWh/(m²a)	350	390	530	275	330

The heat demand of single-family houses in Kyrgyzstan is usually covered by a conventional heating system that generates heat by combustion of imported fossil fuels such as coal and natural gas or by using electricity generated by local hydro power stations. The heating system itself was not modeled in this investigation. However, two energy carriers (electricity or natural gas) were considered to estimate energy costs. Due to local and large scale production, electricity is less than half as expensive as natural gas for residential consumers in Kyrgyzstan (1.5[2] US $ cent /kWh for electricity and 3.5 US $ cent/kWh for natural gas). Besides the current prices of heat carriers, the increase of the annual energy price should be taken into consideration. The historical trend of energy prices (natural gas and electricity) for consumers and the linear function trend that describes its development are shown in Fig. 5. On the left side, the energy price is presented in national

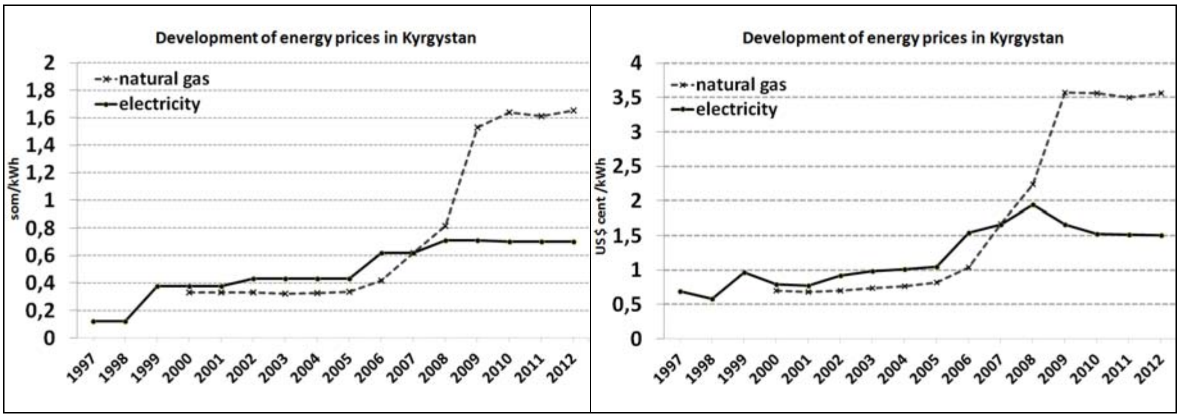

Fig. 5. The development of final energy prices for population in national currency (left) and US dollar (right).

currency, on the right side in US dollar. It is visible that prices for natural gas and electricity are not constant. The price changes depend on the period and currency considered. Generally, the annual electricity price increases during the last 15 years is 4% in the local currency (Som, KGS), whereas it increases over 8% in the same period if expressed in US dollars. The average annual raise of tariff for natural gas over the last 12 years is 13% for trend development in local currency and 30% in US dollar. As a correct estimation of future price development is not possible, therefore following scenarios of price increases of 5%, 10% and 15% will be considered in this paper.

4. Optimal level of thermal insulation

4.1. Methodology

It is well known that the efficiency of “additional centimeters” of insulation is decreasing. This tendency is reflected in the simulation results that show the specific annual energy savings of one square meter of insulation for the single family house in Bishkek and Naryn in Fig.6. The energy savings of insulation on different construction elements are calculated assuming an implemention only on the one respective element. The largest energy saving potential in our case is the insulation of external walls and the floor. An insulated area of one square meter can save about 60 kWh of thermal energy for a single-family house in Bishkek yearly, while in Naryn this value is 80kWh, 30% higher.

[2] The annual excange rate for June 2012 were taking from National Bank of Kyrgyz Republic 1 US $ = 47.20 Som

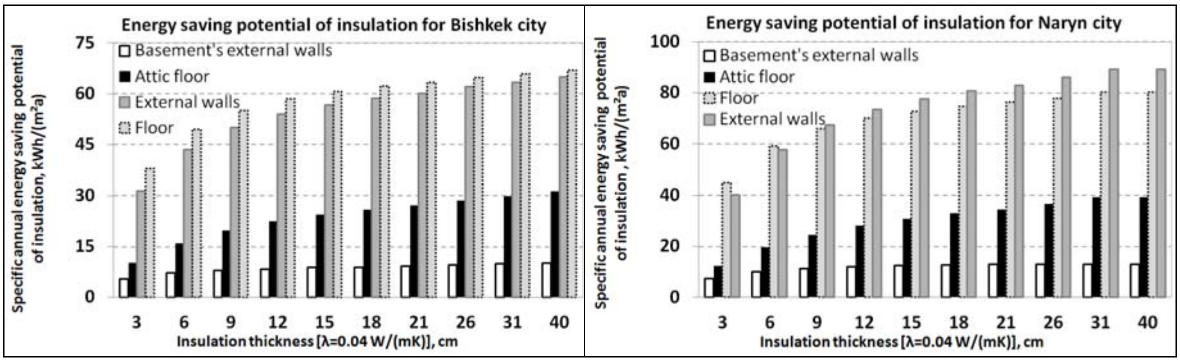

Fig. 6. Specific energy saving potential of insulation for Bishkek city (left) and Naryn city (right).

The calculated heat demand and the overall U-value of construction elements of the single-family house are shown in Fig. 7 as a function of the insulation[3] thickness for Bishkek city. The heat demand and also the U-value are decreasing significantly when the insulation thickness increases from 0 to 15 cm. Further increasing of the insulation thickness from 15 cm has less intensive influence on both values. In spite of drastically reducing the U-value of the basement's external walls; the heat demand does not decrease; it remains on the same level of 32 MWh/a. Obviously, insulation of the house elements (walls) lying on perimeter of the second thermal zone (first floor) have the largest impact on the heat demand, while the remaining construction elements are less influential. Based on this analysis, the calculation of optimal thicknesses of the insulation for three house elements: floor, external walls and attic floor will be carried out.

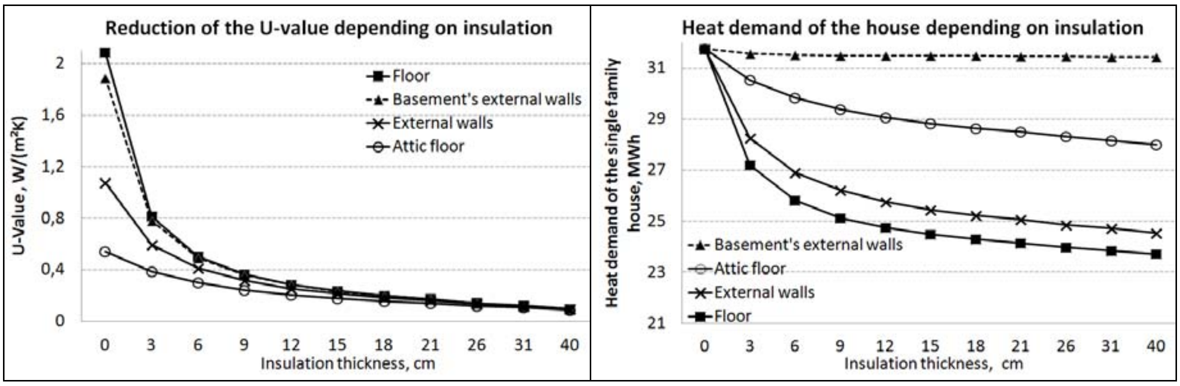

Fig. 7. The reduction of the overall U-value (left) and the heat demand (right) depending on insulation level.

Normally, the optimal thickness of insulation is determined with respect to economic indicators. Then, not only energy savings, but also cost savings, required investment for insulation and energy tariffs should be considered. It is easy to vary the insulation's thickness and to determine its optimal level for one construction element. The optimal value of the insulation thickness is determined by the maximal difference of the cost energy saving for heating and the investment for insulation over its lifetime. If the optimal thickness of the insulation should simultaneously be calculated for several construction elements, a large quantity of combination should be considered. Such an investigation requires an optimization technique, without which the simultaneously determination of optimal thicknesses for several construction's elements seems to be impossible.

The optimization program GenOpt was applied to determine the optimal level of thermal insulation for three intercorrelated construction elements of a typical single-family house in Kyrgyzstan. GenOpt is a tool for the minimization of a function that is evaluated by an external simulation

[3] The heat conductivity of the insulation is assumed with 0.04 W/(mK)

program, in our case TRNSYS 17.1. A combined Particle Swarm (PSO) and Hooke-Jeeves optimization algorithm, which was implemented in GenOpt, was coupled with annual building simulations in TRNSYS 17.1. This means that GenOpt sets the values of insulation thicknesses for three construction elements and starts the TRNSYS 17.1 program. TRNSYS 17.1 simulates the thermal behavior of the house, calculates the value of so called "objective function" and reports the results back to GenOPT. Based on this result the three key variables are simultaneously changed (from 0 to 0.4 m) again by the optimization algorithm in GenOPT and the next simulation is started etc. These repetitive processes are proceeded until the optimal thicknesses of insulation will be obtained.

4.2. Objective function

The objective function to be minimized by the optimization algorithm is the difference between investment costs for the thermal insulation of the building envelope I and the cost savings over the lifetime C_{sav} (both in US $)(eq.1) [1]. The positive value of the objective function means that this measure is economically not feasible, because the expenses for insulation are higher than the cost saving potential.

$$y = I - C_{sav} \quad \text{(eq.1)}$$

The required investment I (in US $) is the sum of capital expenditures (incl. installation costs) for insulation of the external walls (façade) I_{ew} , floor I_{gf} and the attic floor I_{af} (eq.2):

$$I = I_{ew} + I_{gf} + I_{af} \quad \text{(eq.2)}$$

The following insulation materials polystyrene λ=0.04 W/(mK), basalt wool λ=0.04 W/(mK) and glass fiber Isover λ=0.039 W/(mK) were considered. Based on the market research conducted by the authors and supported by CEEBA in Bishkek city, the following simple cost functions for insulation costs have been developed (eq.3).:

$$I_{ew} = A_{ew}\left(I_{fix,ew} + i_{ew} \cdot d_{ew}\right),\ \ I_{gf} = A_{gf}\left(I_{fix,gf} + i_{gf} \cdot d_{gf}\right),\ \ I_{af} = A_{af}\left(I_{fix,af} + i_{af} \cdot d_{af}\right) \quad \text{(eq.3)}$$

A_{ew}, A_{gf}, A_{af} [m²] –the total external walls, ground floor and roof areas
d_{ew}, d_{gf}, d_{af} [m] – the thickness of the insulation on façade, ground floor and the attic floor
$I_{fix,ew}$, $I_{fix,gf}$, $I_{fix,af}$ [US $/m²] –installation costs and costs of additional materials
i_{ew}, i_{gf}, i_{af} [US $/m³] –material price of the insulation for façade, ground floor and roof areas

The linear cost functions (I_{ew}, I_{gf}, I_{af}) consist of fixed costs ($I_{fix,ew}$, $I_{fix,gf}$, $I_{fix,af}$) and costs that are proportional to the insulation thickness (i_{ew}, i_{gf}, i_{af}). Depending on installation technology, work complexity and required additional materials the fixed cost coefficients were defined as the sum of the expenses for work and the cost of additional materials. The entire coefficients for different insulation materials are presented in Tab. 5.

Table 5. The applied coefficients for insulation materials for cost function based on market research.

Insulation	Specific costs for installation and additional materials, US $/m²						Specific insulation material cost, US $/m³		
	$I_{fix,ew}$ (façade)		$I_{fix,gf}$ (floor)		$I_{fix,af}$ (attic floor)		i_{ew} (façade)	i_{gf} (floor)	i_{af} (attic floor)
	work	material	work	material	work	material			
Basalt wool	8	8.5	5.3	10.5	1.5	2.7	119.7	33.5	33.5
Polystyrene	8	8.5	5.3	8.5	3.0	1.2	74.2	33.9	33.9
Glass fiber	8	8.5	5.3	10.5	1.5	2.7	317.8	36	36

For instance, the costs for installation and finishing work for polystyrene on the façade is in the range of 8 US $/m² (column "work" in Tab.4), the additional materials for 1 m² area (beside insulation) as glue, plaster, grid, etc. can be obtained for 8.5 US $/m² (column "material" in Tab.4) on a local market. Thus, $I_{fix,ew}$ equals 16.5 US $/m². The second component of the cost function is specific insulation cost, which depends only on applied insulation volume. The glass fiber (isover OL-E-50) for the façade is currently the most expensive material on the market 317.8 US $/m³, whereas it costs 36 US $/m³ (Isover KT-40-TWIN-50) for the floor or the attic roof almost as much as polystyrene or basalt wool. It can be seen that the fixed costs for the three types of insulation is almost the same. Some differences occur due to a small variation of technology by installation. The cheapest insulation material on the local market in Bishkek is polystyrene, but the cost difference with basalt wool is not large.

The cost savings over the lifetime are defined as (eq.4):

$$C_{sav} = E \cdot P\left(\frac{1+s}{i-s}\right) \cdot \left(1 - \left(\frac{1+s}{1+i}\right)^n\right) \qquad \text{(eq.4)}$$

E [kWh/a] – annual thermal energy saving for space heating after insulation
n [years] – the lifetime of the insulation, was assumed to be 20 years
i [%/a] – interest rate , 6%/a[4]
s [%/a] –annual energy (electricity and gas) price increase rate, e.g. 5 %/a
P [US $/kWh] – the present cost for the electricity or gas

The cost savings over the lifetime depend on many factors like thermal energy savings after insulation, the cost of the energy carrier for heating and pricing trends as well as on interest rate on capital. Some parameters as interest rate on capital or pricing trends are difficult to estimate accurately. The following boundary conditions are used further calculations: interest rate on capital s=6%/a, lifetime of the insulation n=20 years; the pricing trends 5%/a, 10%/a and 15%/a. According these price scenarios, the electricity price in 20 years will be either 3.8 (5%), 9.2 (10%) or 21.3 (15) $ cent/kWh, that seems to be reasonable. For natural gas the price in 20 years increases up to 8.8 (5%/a), 21.5(10%/a) and 50 (15%/a) $ cent/kWh. At least the first two scenarios seem to be realistic.

4.3. Results and discussion

In this paper the optimal thickness of the thermal insulation for a single-family house was determined by coupling GenOpt, an optimization tool, with TRNSYS. The model of this house, applied meteorological data, developed cost function for thermal insulation were in detail described in this work. Different scenarios for energy prices development were considered for the following cities: Bishkek, the warmest city Jalal-Abad, and the coldest one Naryn, (see Table 6). Scenarios 1 and 2 show the application of basalt wool and fiber glass (Isover) by an annual increase in tariffs of 10% for the house with electrical heating. In the further three scenarios 3,4,5 polystyrene as insulating material, electrical heating in the house and an increase in energy costs of 5, 10 and 15 percent respectively were assumed. The scenarios 6, 7 and 8 include the same insulation material polystyrene and increase in tariffs, but natural gas is combusted for heating.

As expected, the growth rate of the energy prices for heating or lower specific cost for insulation increase the values of the optimal thicknesses of insulation. The optimal thickness of insulation for the single-family house with gas heating is larger than for a house with electrical heating under identical boundary conditions. The thermal insulation is mandatory and economically justified for Naryn city regardless of the heating system.

A surprising result was obtained by optimization of the single-family house with electrical heating for the climate zones with HDD < 3000 Kd, Bishkek and Jalal-Abad. As it can be seen from table 6 the economically optimal values of insulation's thickness for about half of the scenarios with

[4] http://www.nbkr.kg - the ineterst rate of the National Bank of Kyrgyzstan in June 2012.

electrical heating system is zero. An optimal thickness of insulation of zero means that the total investments cost for thermal insulation exceeds the cost saving for the single-family house. In common words the insulation is not economically justified for houses with electrical heating.

Based on this result, the policies and other attempts to foster the energy efficiency measures as thermal insulation will "not be effective" as long as this measure is economically not favorable! Under this condition it is preferable to construct the new single-family house without insulation and with low investment, because the future operation cost for heating is neglectable. In this context it is to see that the current electricity price is the significant obstacle for the promotion of energy conservation in the Republic.

Table 6. Economically optimal thickness of insulation for single-family house for nine different scenarios (n=20 years, p=6%/a interest rate on capital).

Scenarios			**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Energy heat carrier			electricity					natural gas		
s-energy price increases		%/a	10	10	5	10	15	5	10	15
Insulation			Basalt	Isover	Polysterene					
Jalal-Abad	Floor	cm	0	0	0	12	17	14	20	26
	Façade	cm	0	0	0	8	12	10	14	20
	Attic floor	cm	0	0	0	11	17	14	20	30
Bishkek	Floor	cm	14	0	0	14	20	16	22	29
	Façade	cm	7	0	0	10	14	12	16	23
	Attic floor	cm	23	0	0	13	20	16	24	34
Naryn	Floor	cm	16	16	12	16	23	20	25	34
	Façade	cm	9	4	10	13	18	15	21	29
	Attic floor	cm	18	18	12	18	27	22	31	39

5. Conclusions

It is common view that the thermal insulation is mandatory for energy conservation, in Kyrgyzstan and elsewhere. Depending on insulation thickness, about 50 – 80 kWh of thermal energy can be saved annually per one square meter of insulated area of the single-family houses in Kyrgyzstan. In this investigation, the economically optimal thickness of different insulation materials for several scenarios was determined. The local available insulation materials polystyrene, basalt wool and glass fiber (Isover) were considered. Special linear cost functions for above mentioned materials were developed by a market research. The applied meteorological data from Meteonorm are shown to be in a good agreement with data from local building codes [4]. This paper demonstrates that the total investments cost for thermal insulation exceeds the cost savings for a single-family house with electrical heating in most parts of Kyrgyzstan for scenarios with relatively moderate energy price increases. This means that the thermal insulation is not economically feasible in these cases, although high annual energy savings up to 60 kWh can be reached by insulating 1 m^2 of the single-family house. For gas heating, the installed insulation is economically justified with the assumption of further increase of the gas prices in the country. For mountainous regions (Naryn city), the economic efficiency of insulation is justified for single-family house with both electrical and gas heating. The general conclusions for Kyrgyzstan are:

- A high energy saving potential exists due to the low energy standards of the buildings

- Transformation towards “low energy buildings” becomes economically significant by higher annual energy price increases
- The cheapest insulation material is polystyrene, although the cost difference with basalt wool is not large
- The optimal thickness of the insulation decreases with increasing of insulation cost
- Current electricity tariff does not promote energy efficiency measures such as insulation and makes its implementation not viable

The results of the optimal level of thermal insulation and its economical feasibility can be only partly transferred to other sites of Central Asia due to different climate, energy prices and building standards.

Acknowledgements

The authors would like to express their gratitude to the local NGO “CEEBA” and DAAD.

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