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SURVEY OF CURRENT CONSTRUCTION PRACTICES AND RECOMMENDATION TO BUILDING INDUSTRY TO IMPROVE OF ENERGY EFFICIENCY IN GEORGIA

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Summary

A survey shows that there are very good opportunities to improve energy efficiency of buildings in Georgia by using new technologies. These technologies are already produced and in wide use in EU and also in Ukraine and Kazakhstan. The centralized heating supply system has been destroyed in Georgia in the 1990s. Many indoor spaces do not have even minimally acceptable thermal comfort during the winter. There is much new construction activity in Tbilisi – more than 2 mln sq.m is being erected each year. Sealed glass units in windows with single plastic or metal frames, instead of unsealed double-pane windows, heavy weight concrete in the external walls as well as decentralized heat supply systems, are beginning installed. These technologies can increase a building's energy efficiency up to about 20%, but minimal thermal comfort still cannot be achieved. The next step is to change heavy weight concrete blocks to light weight concrete blocks and double-pane windows into sealed glass units to a modern window with low-E coating, which together would improve energy efficiency up to about 40% and with thermal comfort. And at last (but not least) it would be desirable to use combination of window units with low-E coatings and modified polystyrene-concrete blocks, which would increase energy efficiency up to about 60% and to the level of energy efficiency of Germany (EnEV-2000) improving thermal comfort significantly. These recommendations will correspond to a new European Directive (Law) to save energy "The directive 2002/91/EC of the European Parliament and of the European Council on the Energy Performance of Buildings".

Introduction

The objective of this survey was to study current residential sector construction practice with regard to energy consumption during the heating season and to show ways for the Georgian buildings industry to improve energy efficiency and thermal comfort in new buildings in economically advancing ways.

Over the past decade, a new generation of building energy codes have taken effect in the EU, Russia and another CIS countries includingthe Ukraine and Kasakhstan. These codes, which mandate a reduction of at least 40 percent in energy consumption for heating, have led to the need for an increase in envelope thermal performance. Consequently, a fundamental transformation has taken place toward the production, sale, and use of energy-efficient construction materials and products, and changes in building design methods. To achive this a very important new European Directive to save energy "Directive 2002/91/EC of the European Parliament and of the European Council on the Energy Performance of Buildings" was implemented at the beginning of 2006.

New technologies and design approaches for building envelopes include design of widened buildings with a lower surface-area-to-volume ratio; energy-efficient windows with sealed glass units; use of light-weight thermal-insulation materials in exterior-wall systems; and others. Implementation of these new systems and technologies has run into problems both in design and in constuction: Because there is no requirment to use these new technologies in Georgia, technical support and the markets are not developed.

A survey and assessment of current residential-sector construction practice in Georgia[1], of energy efficiency of existing buildings is attached, to study of possible improvements to thermal performance of buildings and limitation of energy consumption by buildings during the heating season and recommendations to the Georgian buildings industry for future development.

1. Status of construction standardization -mandatory, voluntary

For the buildings sector in Georgia, new national construction standardization documents (codes) have not been developed and adopted yet. The primary importance during development and construction is given to structural stability, because the country is located in a seismically active zone. Old Soviet-style codes for structural stability of buildings are used for engineering calculations. The old Soviet Codes for thermal engineering of buildings are used on a voluntary basis.

2. Building Permits for construction of buildings

Building Permits for construction of new buildings are described based on the example of Tbilisi. To start construction, all that is required is to apply to the Urban Planning Department of Tbilisi City Hall. To obtaining permission to start construction it is necessary to pass through 3 stages:

Stage 1

Defines conditions for building in the city. It is required to submit the documents to the Urban Planning Department of Tbilisi City Hall. The required documents list includes:

1) An application which should include the description of the type of building activity you desire to start;

2) A document confirming the property (Public Registry Certificate and Cadastre Map);

3) Topography maps, 1:500 and 1:2000;

4) Photo materials on surrounding places;

5) Notarized agreement of the co-owner;

Stage 2

The second stage requires submittal of the application to the Urban Planning Department of Tbilisi City Hall within 30 days.

The second stage is necessary for acceptance of the project. The following materials are required by the Urban Planning Department of Tbilisi City Hall:

[1] Assessment of current construction practices and analysis of energy efficiency in Georgia is covered preliminary report written by experts Melikidze and Verulava

1) Cadastre map of the land area and a Public Registry Certificate;

2) Architectural-building design;

3) Administrative act on defining of town-building conditions;

4) Engineer-geological conclusion;

Stage 3

After the second stage is submitted the administrative act requires an appointment to be set up wit the Urban Planning Department of Tbilisi City Hall to gain acceptance of the architectural design.

Following acceptance of the plan the following documents have to be submitted to the Urban Planning Department of Tbilisi City Hall:

1) Architectural-building design;

2) Layout drawings;

3) Technical conditions obtained form the local utility suppliers, TELASI, Tbilisi Water and Kaztransgas;

4) Cadastre map of the land and the Public Registry certificate.

In case of a building of special importance a report on the suitability and compliance of the building is required to be submitted with the application.

After the third stage the building permit is issued within 10 days.

3. Building Indicators

Building indicators are controlled by the Urban Planning Department of Tbilisi City Hall. For starting the building process in Tbilisi it is highly required to calculate the coefficient for building up of the ground space.

There are 2 types of indicators: k1 and k2.

- k1 defines the foot print of the building in square meters as a proportion of total land area. After the calculation of the k1 coefficient the total area to be covered by the building is defined.
- k2 defines the number of floors and the size of the floors permitted to be constructed on the property excluding the balconies and terraces.

4. Licensing of Construction Activities

Under the new *Law on Licensing,* the licensing of construction companies has been abolished.

5. General Volume of Residential Stock and Distribution of these Resources into Groups: low (up to 3 stories) and multi-family buildings, 4-5, 6-8, 9-12 stories

According to the statistical data about 4.2 million people live in Georgia. Half of THE population lives in cities. About 1.2 million people live in the capital city, Tbilisi.

The Residential Sector of Georgia accounts about **103** million square meters, among them:

- single-family buildings - about **73** million square meters;
- multi-family - about **30** million square meters;
- 24.5 m^2/ per inhabitant average.

The amount of the single family buildings is about - 670 000-700 000.

It should be noted, that in Tbilisi, about 15 % of the population is living in single-family homes; in Kutaisi (the next-largest city of Georgia), 30 % of the population is living in single-family homes.

6. Energy efficiency in existing building stock.

The existing building stock of Georgia is characterized with very low efficiency. The thermal resistance to heat losses of the buildings, for instance in Tbilisi are 3 to 4 times less than recommended for energy efficiency for the Tbilisi climate zone. Georgia uses 40 to 50% more energy for heating per square meter of floor space, than the EU countries with the same climate conditions. Residential and commercial buildings in Georgia, with heavy concrete exterior walls and single glazing windows, consume more than 60% of the total primary energy consumed in Georgia. Buildings are Georgia's biggest energy (and money) wasters and largest sources of green house gas emissions.

7. Volume of residential building stock over the last 5 years and estimated building construction for the upcoming 5 years

According to information from the urban design department of the Tbilisi City Municipality, about 6.5 million square meters of multistory residential buildings were newly constructed over the last three years.

According to the Georgian State Department of Statistics, the country's construction sector had a turnover of 1.61 billion GEL (about $961.481 million) in 2006, compared to 243 million GEL (about $145 million) in 2001. Table. 1 below illustrates dynamic of growth in construction sector.

Table 1

	Thousand m^2 of total floor area			Thousand apartments		
	Commissioned in total	of which by: State enterprises and organizations	Private clients	Commissioned in total	of which by: State enterprises and organizations	Private clients
1995	161	26	135	1.2	0.4	0.8
1996	148	34	114	1.1	0.4	0.7
1997	105	15	90	0.7	0.1	0.6
1998	92	21	71	0.8	0.2	0.6
1999	183	15	168	1.1	0.2	0.9
2000	213	22	191	1.4	0.2	1.2
2001	139	-	139	0.7	-	0.7
2002	222	19	203	1.1	0.2	0.9
2003	189	-	189	1.1	-	1.1
2004	139	-	139	0.7	-	0.7

Meanwhile, the cost for the new apartment buildings built by these companies continues to soar. The cost of the construction itself varies from 400 $ per m^2 up to 500 $ per m^2. The price for sell is reaching in average the level up to 2000 $ in central districts of Tbilisi. By comparison, Georgia's per capita gross national income in 2005 was estimated at $1,320, according to a World Bank (2007) analysis (table 2).

Table 2

Construction

	2002	2003	2004	2005	2006	2007 (9 month)
Turnover, mln. GEL	317.5	309.0	387.4	778.8	1125.3	989.1
Output, mln. GEL	322.2	297.9	377.1	746.1	1184.9	1048.3
Value added, mln. GEL	91.8	89.1	127.1	245.9	401.4	...
Intermediate consumption, mln. GEL	235.7	213.2	256.5	523.0	784.5	...
Fixed assets, mln. GEL	82.9	85.9	127.2	258.7	474.9	...
Number of employed persons, person	19963	18874	21344	38560	46681	36085
Average wages and salaries per employed persons, GEL	176.6	199.5	237.9	292.3	391.0	583.3

According to Ministry of the Economic Development officials, Arab businessmen are considering investing as much as $200 million in construction of elite residential complexes in Tabakhmela and Tsavkisi, two areas located close to the center of Tbilisi. Next to the Arab project, Israeli investors plan to spend some $100 million on residential construction, according information obtained from the Tbilisi City government. Another significant investment is expected by a Korean investors on Elia Mountain, a less populated area within walking distance of Tbilisi's historic center.

Zoning laws, introduced in 1970, expired in 2000, although the city continues to use them. Work is continuing on new regulations, including one that puts a three-story cap on new buildings in certain parts of old Tbilisi.

An overall construction development plan for the city was expected to come into force by the end of 2007. But how to balance investor demand with preservation concerns is a topic no official has mastered yet. Within the city government, officials say that they see no end in sight for the Georgian capital's construction boom, and concede that the building frenzy could well change the city's look. Outdated zoning laws mean that little legal basis exists for managing the building frenzy, though city government representatives contend that they are in fact controlling the process.

8. Production volume of construction materials and products. Volume of imported construction materials and products.

Georgia has sufficient local construction materials, such as cement and gravel. The country produces construction products for local needs such as block production, gypsum board, foam plastic, sandwich panels, perlite construction blocks/bricks. Many construction companies are producing construction products in small enterprises for their own business needs. Steel is mostly imported from Ukraine, finishing materials and glass for windows plastic frames mostly from Turkey and Iran. The prices for these major items influence the cost of construction. Thermal insulation materials aren't produced in the country.

9. Certification of construction materials and products, including sanitary assessment of safety of use and identification of operating characteristics.

Imported construction materials and products have certificates from foreign manufacturers which are part of the required documentation for importation to Georgia. Local construction products are certified by Georgian Certification Authority. About 1,200 certificates are given for exploration of construction materials i.e. sand, stone and etc.

It was learned that new window units are not tested after installation into the frame.

10. Commonly used building envelopes and their heat transfer resistance

Constructions companies in Tbilisi (in Georgia), are using the frame and block method of construction. Low-quality concrete blocks, or at best bricks, are used as building materials. The thickness of the exterior walls in new buildings in Tbilisi is: 250- 300mm, or at best, 400 mm.

The thermal conductivity of the above-mentioned materials widely distributed in Tbilisi is $\lambda = 0.6 - 0.7$ W/m ^{o}C. (This is an estimate, because there are no laboratories for measuring this very important index of construction materials in Tbilisi). Such low-quality concrete blocks are no longer used in any European countries. Even Eastern European countries are using light weight concrete blocks with the thermal conductivity 2-3 times lower.

From these figures, we can easily calculate that the thermal resistance to heat flow R – of Georgian new buildings is, at best, no more than 0.57 m^2 $^oC/W$ which is corresponding to sanitary requirements only. Heat loss through a wall is depended on thermal resistance – if thermal resistance is twice heat loss, is two times less (see Table 3). This means huge wastes of energy resources, wastes of money, and pollution of the environment by new buildings, not to mention existing buildings.

However, it is possible to improve energy performance of buildings - to cut building energy use in half in Georgia - trough simple measures such as thermal insulation in walls and installation of energy efficiency window units. Thermal insulation can be the most cost–effective way to turn Georgia's buildings from energy wasters into climate and money savers.

The company "Eurobuilding" is constructing a residential 7-story building in the center of Tbilisi. Exterior walls are made of pumice-concrete blocks, 400x300x200 in size. The density of such block is 1,000-1,200 kg/m^3 and the thermal conductivity approximately is 0.47 $W/(m \cdot ^oC)$. The walls are covered on the outside with outside 40 mm thick foamed polystyrene, produced by the Georgian company "Interplast". The density of this material is 18 kg/m^3, the thermal conductivity is 0,052 $W/(m \cdot ^oC)$. The thermal resistance of such walls is about 1.41 $m^2 \cdot ^oC/W$. This is a vast improvement if compared to conventional construction with a thermal conductivity of 0.57 $m^2 \cdot ^oC/W$.

11. Types of fenestration used in construction.

Double-glazed, single-sash windows are commonly used in new buildings. The common materials used for frames in such windows are metal and plastic. Metal-plastic window frame profiles and two panes units are produced by domestic companies, among them advanced companies like "Interplast" and others. Reduced thermal resistance a window of two panes unit in wooden and plastic frame is an average 0.35 $m^2 \cdot ^oC/W$. Such windows are not energy efficient. A modern window is an average 0.56 $m^2 \cdot ^oC/W$ that means a heat loss through such window 1.6 times less compare to past technologies (see Table 3).

No glass with low-E coating is available in the Georgian construction market. Surveying construction companies in Tbilisi, out of twelve questioned, only one construction manager was aware of the existance of low-E coated glass. This indicated a need to educate architects and engineers in modern construction methods and material availability.

High thermal resistance windows with two low E- coating panes in a wooden or plastic frame with an average of 0.56 $m^2 \cdot ^oC/W$ costs 5 to 8% more compare to a window without low-E coating. There are additional advantages to use low-solar-heat-gain low-E windows and overhangs to provide shade in the summer and prevent solar heat from entering the premises.

12. Heating systems for indoor climate conditions.

Up to the early 1990s, District Heating System (DHS), for supply heat and hot water, covered most of the urban areas. After the independency declaration as the supply of fuel diminished and finally ground to a halt, district heating boiler plants gradually stopped to operate. Now the entire central heating system of Georgia is damaged and abolished. At this time, the apartments in multi–family residential buildings in Tbilisi use inefficient, polluting and unsafe heating technologies that comes with considerable problems for users, such as visible smoke, increased humidity and associated health and environmental effects inside and outside buildings, and other safety hazards. To provide the urban population of with efficient, safe and economically viable residential heating is a top priority for social and economic and energy consumption reasons, health and environmental protection. The development of efficient residential heating systems is considered part of the general guidelines to improve building energy efficiency in Georgia. Buildings with more efficient heating systems can significantly improve the situation to reduce household heating bills and their share in household income.

In the current economical climate, the main effort should be focused on the low cost and short-pay back period heating system development, such as: decentralized system designed for one building or individual apartments to use gas fired boilers for heating and hot water supply.

13. Assessment of energy efficiency of existing buildings (old infrastructure) and new buildings built over the last five years.

The approach is to be based on requiring a value for specific energy demand for heating any building (see appendix 1). To calculate this value, thermal performance properties of the envelope assembly or building shell should be determined. The specific heating energy demand (for building heating and ventilating) is defined as the quantity of heat for space heating in the heating period per sq.m of the total heated floor area or per cub.m of the volume of a building, per degree-day, $W \cdot h/(m^2 \cdot {}^oC \cdot day)$ or $W \cdot h/(m^3 \cdot {}^oC \cdot day)$.

Under this new principle, requirements are set forth not for the separate components that affect the heat balance of the building (walls, floors, ceilings, windows, et al.), but rather for the energy performance of the building as a whole (see appendix 1). Energy performance is calculated as a function of envelope performance, building design and geometry, design and selection of heating and ventilation systems, additional heat gains, taking into account the efficiency of the heat supply system and climatic parameters.

Assessment of energy efficiency is calculated by the use of the concept of "Energy Passport" (see appendix 1). The Energy Passport of the building is a document that intends to verify energy performance in design, construction, and operation. The Energy Passports also provides information to potential buyers and residents on what they can expect regarding the building's energy efficiency and real costs, helping to stimulate market preferences for high-performance buildings.

To help ensure quality in energy-related aspects of building designs, the new Russian and other countries codes require the preparation of a special section of the building design, entitled "Energy Efficiency." This section must include summary parameters for energy performance for various parts of the building design. These parameters are presented side-by side with code-required values. To facilitate and standardize calculations, a PC version of the Energy Passport has been developed. This version enables quick calculations, iterative assessment of design variants, and comparison with code values at all stages of design, construction, and operation.

Calculations were made for the 7 different buildings for climatic conditions for Tbilisi. (Appendixes 3). The specific consumption during the heating season, taking into consideration of degree-days was calculated by electronic means for the Energy Passport. Sic variants were calculated for each building. For each variant the coefficient of efficiency ε = 0.65 for decentralized heating systems was used. This value is an average and very realistic. However a modern heating system has ε = 0.95.

The results of these calculations were compared with var.1 (the heavy weight concrete blocks and the single pane windows were named below as the simple blocks) which are customarily used for construction of buildings in Georgia. Results of these calculations are presented in the table 3.

Table 3

Vari-ants	R-Wall	R-Win-dows	10 st., 3 sec	8 st., 1 sec	7-8-9 st., 3 sec	9 st., 3 sec	10 st., 1 sec ZNIIEP	10 st., 1 sec ARCI	15 st., 2 sec Muza Venecia	Avera ge
	$m^2 \cdot {}^oC/W$		Specific Energy Consumption, $kW \cdot h/m^2$							
Var.1	0,57	0,18	103,4	92,3	124,0	123,3	138,8	140,4	153,1	125,0
Var.2	0,57	0,35	82,3	78,0	100,3	100,8	115,3	113,6	120,2	101,5
Var.2a	0,57	0,56	73,9	72,4	91,6	91,9	105,9	102,9	107,1	92,2
Var.3	1,0	0,35	60,3	57,1	72,4	72,3	80,8	79	81,4	71,9
Var.3a	1,0	0,56	53,9	53,0	63,2	63,4	71,5	68,4	68,3	63,1
Var.4	1,61	0,56	42,8	42,4	51,42	51,1	54,2	51	48,9	48,8
Vari-ants	Avera ge, $kW \cdot h/m^2$	Savings related to var.1, %								
Var.1	125,0	0								
Var.2	101,5	19								
Var.2a	92,2	26								
Var.3	71,9	42								
Var.3a	63,1	50								
Var.4	48,8	61								

The first variant includes the existing level of thermal properties of the construction performance for the buildings which were constructed during the Soviet era. The reduced U-value of the walls is 1.75 $W/m^2 \cdot {}^oC$. The reduced U-value for the single pane window is 5.55 $W/m^2 \cdot {}^oC$. The average specific energy consumption during heating season of 7 buildings is 125.0 $kW \cdot h/m^2$.

The second variant has two sub variants:

The first sub variant reflects improvement in the building construction during last few years. In this version the U-value of the walls was not changed, but new types of windows with single chamber units in plastic frames and sash that started to be implemented in buildings was considered. The U-value of such windows is 2.86 $W/m^2 \cdot {}^oC$. The average specific energy consumption of 7 buildings in this case will be 101.5 $kW \cdot h/m^2$ and 19 % savings over variant 1.

The other sub variant reflects possible improvements in windows with low-E coating. The U-value of such windows is 1.79 $W/m^2 \cdot {}^oC$. The U-value of the walls was not changed. The average specific energy consumption of 7 buildings in this case is 92.2 $kW \cdot h/m^2$ and 26 % savings related variant 1.

The third variant also has two sub variants:

The first sub variant can be proposed as a basic level in Georgia. The U value for windows was not changed and remains as it is proposed in the second variant. The walls should be improved up to the assigned baseline U-level: 1 $W/m^2 \cdot {}^oC$. The specific energy consumption for the heating period in this case is 71.9 $kW \cdot h/m^2$ representing a 42.4 % savings over variant 1. This variant is very realistic (see also economical calculation below).

The next variant reflects possible improvements in windows with low-E coating. The U-value of such windows is 1.79 $W/m^2 \cdot {}^oC$. The U-value of the walls was not changed. The average specific energy consumption of 7 buildings in this case will be 63.1 $kW \cdot h/m^2$ and 50 % savings related variant 1

The fourth variant can be proposed for future development for building envelopes in Georgia, but it is not realistic at this time. The windows would be improved using a selective coating in the same window as in the second. The reduced U-value of such windows is 1.78 $W/m^2 \cdot {}^oC$. Such windows are widespread in Ukraine and in Europe. The walls should be improved up to the assigned baseline level: 0.62 $W/m^2\ {}^oC$. The average specific energy consumption for the heating period of the 7 buildings in this case is increased to 48.8 $kW \cdot h/m^2$ and represents 61 % savings over variant 1.

The potential savings demonstrate good results. To achieve such reduced energy consumption results is possible through a combination of the following measures:

- improving thermal resistance values (**R**-values) for the whole building envelope;
- use of energy efficient fenestration (windows, glazed doors);
- reduction of air permeability of the building envelope;
- use of energy efficient heating system.

From thermal engineering point of view, to reach the high **R**-values for exterior walls like they are shown in Var.3 it is necessary to make a decision between two approaches: To use

a. single-layer walls consisting from light weight concrete blocks, or

b. multi-layer, basically double layer walls consisting from the structural construction material like concrete blocks or bricks and insulation layer.

The basic advantage of single-layer walls made of light weight aggregate concrete can be stated as its high thermal homogeneity, as well as an expected service life - not less than 100 years.

14. Assessment of the thermal performance of the building envelopes

To verify which general energy efficiency approach for the selection of which type of wall system would be the most cost effective for Tbilisi climate conditions, an assessment of the life-cycle energy costs analysis for the 7 studied buildings was conducted:

- in the case of single–layer walls of lightweight perlite and aerated concrete (airocrete) blocks;
- in the case of double layer walls of pumice blocks with foam plastic insulation.

These options were selected on the basis of technical solutions defined from current advanced construction and development practices in Tbilisi.

Single layer walls of lightweight perlite and aerated concrete

The appropriate information about perlite construction blocks as coefficient of the thermal conductivity and the size of the blocks was obtained from the mining company "Paravanperlite".

The size of single block is 400 x 200 x 200 mm with a coefficient of thermal conductivity λ = 0,148 W/m·°C. The wall thickness would be 200 mm. The thermal resistance of the exterior walls built from the *perlite blocks* constitutes an **R**-value of 1,35 m^2·°C/ W.

The coefficient of thermal conductivity for the lightweight aerated concrete (airocrete) block was obtained from the "Porobeton Ltd." company and is λ = 0,154 W/m·°C. The size of each block is 600 x 300 x 200 mm, with 300 mm taken as a thickness of the exterior wall. Thermal resistance of the exterior walls built from the *light airocrete blocks* **R**-value is 1,95 m^2·°C/ W.

In comparison, the thermal resistance of the exterior walls built from the *simple blocks* (variant 1) has an **R**-value of 0,57 m^2·°C/ W.

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The main results of Energy Passport calculations for the walls of lightweight perlite and airocrete blocks of ARCI building and their comparison with the walls of simple concrete block are presented in the Table 4.

Table 4.

Variants of the walls, m^2·°C/W	Overall consumption of energy, kW·h	Specific energy demand for heating, kW·h/m^2	Savings related to var.1, kW·h/m^2	Savings related to simple block var.1, (%)
Simple block (var.1) $\mathbf{R_{wall}=0.57}$ $\mathbf{R_{win}=0.18}$	400145	144,2	0	0
Perlite block $\mathbf{R_{wall}=1.35}$ $\mathbf{R_{win}=0.35}$	196847	70,9	203298	51
Airocrete block $\mathbf{R_{wall}=1.95}$ $\mathbf{R_{win}=0.35}$	167854	60,5	232291	58

As it can summarize from the Table 4 figures confirm high energy saving potential (about 51%-58%) in the buildings with the exterior lightweight concrete single layer walls.

Multi-layer walls of pumice blocks with foam plastic insulation.

The appropriate information about pumice blocks with foam plastic layer was obtained from the company "Eurobuilding"(see p.9).

The results of the Energy Passport calculations for walls of pumice blocks with foam plastic layer from ARCI building and its comparison with the walls of simple block are presented in the Table 5 below.

Table 5.

Variants of walls $m^2 \cdot {}^oC/W$	Overall consumption of energy, kW·h	Specific energy demand for heating, $kW \cdot h/m^2$	Savings related over var.1, $kW \cdot h/m^2$	Savings related to simple block var.1, (%)
Simple block (var.1) **R_{wall}=0.57** **R_{win}=0.18**	400145	144.2	0	0
Pumice blocks with foam plastic layer **R_{wall}=1.41** **R_{win}=0.35**	192.837	69.5	207308	52

Multi-layer energy efficient exterior walls also prove high energy saving potential as it follows from the Table 5.

For clarification of the cost-effectiveness of the single and multi-layered exterior walls a cost/benefit analysis is given below:

15. Economical calculations to use light weight blocks in the wall construction.

Economical calculation was done for the different construction of the walls of ARCI building compare to the var.1 (the simple blocks). Total wall area in ARCI residential building project constitutes **F**=2057 m^2. The load of the heating system based on information obtained from the energy passport for the var.1 will constitute for the whole winter period: Q= 400145.2 kW·h..

For economic calculation the following basic formula was used:

$$TC = CI + RC \quad (1)$$

where: TC - total cost;
CI - capital investment;
RC – running cost (energy needed for heating of building during the whole winter period)

For simplification purposes, the formula does not take into account to increase in future the cost of building materials and products or increases in heating fuel costs.

Single layer walls of perlite blocks.

For **F** = 1.2 m^2 of the wall area, 15 perlite blocks are needed if the thickness of the wall is to be 300 mm resulting in a cost of 3.3 x 15 = 49.5 GEL.

For the same wall area **F**=1.2 m^2 will be needed 15 simple blocks the cost would be 18 GEL. Accordingly price of 1 m^2 of wall area constructed from perlite blocks can be calculated as 41.25 GEL and from the simple block as 15 GEL.

The Capital cost for the walls of ARCI building in Tbilisi, for example, perlite blocks will be: $\mathbf{CI_1}$= 2057 x 41.25 = 84,851.25 GEL compared to simple block construction, were the cost would be $\mathbf{CI_2}$= 2057·15=30,855 GEL.

The heating system load based on information obtained from the energy passport for the perlite block variant would be: Energy consumption, Q = 167,854 kWh for the entire winter period. Taking into consideration that 1m^3 of natural gas generates the equivalent of 10.33 kW·h of heat, 19,055.9 m^3 of gas will be burned costing 19,055.9 x 0.51 = 9,718.5 GEL in the case of perlite blocks. In the case of simple blocks 38,736.2 m^3 of gas will be needed costing 38,736.2 x 0.51 = 19,755.5 GEL per heating season.

As it is shown by calculations presented below the simple payback period for the additional investment in perlit blocks will be 5.5 years, assuming no future escalation in natural gas prices. This means that after 5.5 years of operation of the heating system the capital investment of the perlite blocks will become profitable thus load of the heating system in this case is much lower than in the case of the simple blocks. Total cost is calculated

$$\mathbf{TC_1} = 84{,}851.25 + 5.5 \times 9{,}718.5 = 13{,}830.3 \text{ GEL}$$
$$\mathbf{TC_2} = 30{,}855 + 5.5 \times 19{,}755.5 = 13{,}9510.3 \text{ GEL}$$

Thus, it can be summarized that the higher capital investment in perlite blocks will be compensated by operational costs of the low load heating system after 5.5 years operation during the heating season.

Single layer walls of lightweight airocrete blocks

For **F** = 1.2 m^2 of wall area, 10 light weight blocks are needed if the thickness of the wall is assumed to be 300 mm at a cost of about 50 GEL. For the same **F** = 1.2m^2 wall area, 15 simple blocks costing 18 GEL are required. Accordingly for 1 m^2 of wall area the price of the light blocks would be 41.7 GEL compared to the cost of simple blocks, 15 GEL.

Thus, the cost of light weight blocks would be: $\mathbf{CI_1}$ = 2,057 x 41.7 = 85,776.9 GEL; for simple blocks, $\mathbf{CI_2}$ = 2,057 x 15 =30,855 GEL.

The energy consumption during the heating period Based on information obtained from the Energy Passport for light weight blocks will constitute for the heating season would be: **Q** = 167,854 kW·h requiring 16,249.2 m^3 of gas which, at current prices, would cost 16,249.2 x 0.51 = 8,287.1 GEL.

The payback period for light weight blocks would be 5 years:

$$\mathbf{TC_1} = 85{,}776.9 + 5 \times 8{,}287.1 = 85{,}776.9 + 41{,}435.5 = 12{,}7212.4 \text{ GEL}$$
$$\mathbf{TC_2} = 30{,}855 + 5 \times 19{,}755.5 = 30{,}855 + 98{,}777.5 = 129{,}632.5 \text{ GEL}$$

Thus it can be assumed that the higher capital cost for the light weight blocks will be recaptured from operational costs savings of the low load heating system after 5 years operation during the heating season.

Multi-layer walls of pumice blocks and foam plastic insulation

For **F** = 1.2 m² of the wall 15 pumice blocks, 400mm in long 300 mm wide will be needed. The cost would be: 2.6 x 15 = 39 GEL. 1 m² of the wall area will cost 32.5 GEL for the basic construction structural layer plus 45 GEL for the insulation layer for a total cost of 77.5 GEL.

Thus, the capital cost for pumice blocks with foam plastic insulation can be calculated as: $\mathbf{CI_1}$ = 20,57 x 77.5 = 159,417.5 GEL as compared to simple block construction: $\mathbf{CI_2}$ = 2,057 x 15 = 30,855 GEL.

The energy consumption during the heating season based on information obtained from the Energy Passport in the case of pumice blocks would be **Q** = 192,837.5 kW·h for the whole winter period utilizing 18,667.7 m³ of gas at a cost of 18,667.7 x 0.51 = 9,520.5 GEL.

.

Payback period for capital investment is defined as 13 years. Pumice blocks by themselves are not as expensive but they don't have high energy efficient characteristics. Energy efficiency in this case is reached by the combination of basic structural components, pumice blocks for the walls plus an expensive foam plastic layer. Total cost is calculated as follows:

$\mathbf{TC_1}$ = 159,417.5 + 13 x 9,520.5 = 159,417.5 + 123,766.5 = 283,184 GEL
$\mathbf{TC_2}$ = 30,855 + 13 x 19,755.5 = 30,855 + 256,821.5 = 287,676.5 GEL

The results of economic calculations are presented in the Table 6. It can be see that both variants of the single layer walls have cost benefit compare to multi-layer walls under Georgian climatic conditions.

Table 6.

Type of exterior wall	Investments [GEL]	Gas savings related to the var.1, [m³]	Gas savings in monetary terms [GEL/yr]	Payback period (PB) [yr]
single layer perlite block wall	84,851.25	19,680.3	10,037	5.5
single layer airocrete block wall	85,776.9	2,2487	11,468.4	5
multi layer pumice block wall with foam plastic insulation	159,417.5	20,068.5	10,235	13

16. Recommendations to the Construction Industry

The result of the work has shown that there are very good opportunities and relatively simplicity to improve energy efficiency of buildings in Georgia through the implementation of most cost effective practices: by using light weight concrete blocks and modern efficient windows with low-E to achieve at least 40 % savings of energy for heating. The most profitable measures can be taken by changing the building envelope to improve energy performance of buildings in Georgia as follow:

- Installation of light concrete blocks with low thermal conductivity for single layer exterior walls of buildings;
- Installation of modern, energy efficient windows;
- We urgently recommended development of a Georgian national standard for building energy and thermal performance and energy efficiency on the voluntary basis by construction companies;
- We also recommended for companies to organize a certification process for building materials and products in Georgia and use only those materials and products which are certified to meet Georgian standards.

That standard should regulate a building's construction and demonstrate to investors and clients the best or worst practice. Such standard may recommended the required energy efficiency levels as achieved in Variant 3 or higher level like EU standards, or lower levels like Variant 2. The standard can be proposed and adopted by professional engineering and architectural societies for implementation by the Ministry of Economic development.

It is very important to know that the opportunities for the future development of the above indicated two basic standards to improve building energy performance already exist in the Georgian construction market. The market is currently represented by small enterprises manufacturing different types of light concrete blocks and two types of windows. They will need support to further develop such advantageous technologies.

Local manufacturing of high-quality light concrete blocks will have a very positive impact on the process improvement of energy performance of the new buildings in Georgia. Furthermore, increased demand and production will create new businesses and new jobs, in the construction sector and the industries supplying the sector.

Light concrete blocks are an excellent construction material under Georgian climatic conditions. Use of lightweight concrete blocks for exterior walls, as single layer insulation material (with energy efficient windows) has the potential to satisfy the increased energy efficiency requirements, and as an economically visible method, to achieve a market success in Georgia. Light weight concrete blocks are environmental friendly materials. The materials used in light weight blocks are inorganic.

Beside energy savings, use of light concrete blocks has the potential to reduce investment cost of the construction works in Georgia. The following brief analysis confirms the correctness of the above conclusions:

- Use of light weight concrete blocks will decrease weight of the walls. This, in turn, will significantly reduce construction costs for ground and foundation works of buildings;
- Using light weight concrete blocks with higher dimensional accuracy are easier to install without the thick mortar; also will significant reduce the thickness and cost of plasters;
- As a result of the improved size/weight ratio, constructing with light concrete blocks is easier, reducing the construction time;
- Light concrete blocks reduce transportation costs of the material; and,
- Reduce labour costs. .

This report is focuses on building thermal performance. Improvements in heating system, like the use of ground source heat pumps are not included discussed here. However, it is understood that to optimize energy efficiency measures and to further reduce the life-cycle costs of the building, a combination of measures including the building envelope, as well as the in-house thermal engineering systems should be considered. In cases of poor insulation of the walls, the roof, inefficient windows, even if there is efficient heating system in the room, energy consumption will be inefficient and operating costs will be high. Buildings with higher efficiency due to efficient heating facilities can significant decrease in household heating bills and their share of household income.

Conclusion

1. It can be concluded that higher U-values can be achieved easily in Georgia for the walls as it can be seen from the above options.

2. The specific building energy consumption is reduced related to these Variants: 125 kW·h/m^2, 101 kW·h/m^2, 72 kW·h/m^2 and 49 kWh/m^2 or in percentages related to the first variant: 19 %, 42 % and 61 %.

   In the German normative standards document, EnEV-2002, there is a requirement for specific energy consumption of no more than 40 kW·h/m^2 for a 10 story building, or 32 kW·h/m^2 calculated for the climatic condition of Tbilisi. This specific energy consumption can be achieved using 200 mm of the modified polystyrene-concrete concrete blocks and the modern window with chamber units and low-E selective coating in a single frame.

3. It should be noted that improving thermal properties of windows and walls in the variants 3a and 4 is very realistic. Walls with those thermal properties are easy to achieve using polystyrene concrete blocks 200 mm thick with 50 mm light insulation covered by a thin plaster layer. The last option does not have an economical advantage compare to light weigh block. Also a price of the modern energy efficient windows is a little higher than those used traditionally, but well worth the investment.

4. Constructing new buildings in accordance with the three energy saving Variants discussed above, and assuming the same amount of new buildings will be constructed in Georgia in the coming years, total natural gas demand would increase by 21, 16 or 12, 8 mln m^3. This, however, would also represent a very realistic saving of 9 mln m^3 natural gas each year for Georgia.

5. Progressive construction companies in like "Delphti" are already achieving this level of the wall by the use of pumice blocks with density 625 kg/m^3 and thickness 400mm. Other companies like Interplast plan to produce polistirol concrete blocks in the near future.

6. Variants 2 and 3 suggest that the cost of the construction will be increased about 7-10 %, which justifies the idea that it isn't so expensive. As it was estimated from the assessment the cost of the construction varies from 400 \$ per m^2 up to 500 \$ per m^2. The price for sell is reaching in average the level up to 2000 \$ in central districts of Tbilisi. However, the increased construction costs and higher sales prices will easily be paid back during the first 5 to 6 years of building

operation and, with energy costs ever increasing, will result in significant life of building energy savings to the owners.

7. At this time heating systems for multi family buildings used in Georgia are individual apartment heating systems of differing designs. Installing centralized, whole building heating systems will result in additional significant energy expense savings.

8. In the current economical situation, the main effort should be focused on the low cost and short-pay back period of heating system, such as: decentralized system designed for one building or individual, apartment natural gas–boilers for heating and domestic hot water supply.

9. We urgently recommended for business to develop national energy efficiency standards on a voluntary basis. The standard should regulate a building construction and show the investors and clients the best or worst practice. Such standard may recommended the level as Variant 3 and higher level like in EU and lower levels like Variant 2. The standard can be adopted as recommendations by professional societies and/or the responsible ministry as regulation through a normative act.

10. We recommended also for the business to organize a certification process for building materials and products in Georgia and use materials in construction which are independently certified to meet the recommended standards.

11. Like is already required in most European countries, Georgia should require the provision of an Energy Passport for each building, to be supplied to the now owners of buildings and apartments within those buildings for the new owner to have a realistic understanding of his or her energy consumption and expense. Construction companies are using Energy Passports as effective marketing tools.

12. Public awareness needs to be increased to implement energy conservation measures in the building to stop the waste of energy. It will decrease household energy consumption and thus reduce the burden of utility payments for families, without sacrificing comfort. These measures will also contribute a reduction in the projected demand of imported natural gas and a reduction of CO_2 emissions.

The analysis shows a building's thermal insulation has the potential to be the most cost effective way to turn Georgia's buildings from energy wasters into climate and money savers. There are many tangible benefits to be achieved through the development of energy efficiency in Georgia's construction sector:

- reduced dependence on energy imports leading to improved national and energy security,
- improved air quality, particularly in urban areas,
- ongoing financial savings to the energy consumers and potentially to the builders,
- new job creation and market stimulus,
- improved quality of living standards in the country.

The construction industry survey and the recommendations to the industry were written by Matrosov Y., Melikidze K. and Verulava N.

November, 2008

Appendix 1

The new principles assessment of energy efficiency of the buildings

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Calculation of thermal properties of buildings with efficient energy use under the assumption that a building presents a single energy system makes it possible to design the building with balanced thermal properties and to reduce heat losses maintaining the same comfort conditions. Energy bases of thermal, air and humidity regimes of the building as a single unit have been developed; methods of estimating optimal parameters and orientation of buildings, based on the minimization of heat losses during cold period and heat gains during warm period of the year allowing for effects of solar radiation and wind; estimation and rating of energy characteristics of the building; establishment of thermal requirements to the building as a whole in addition to element by element rating of envelope structures and methods of estimation of air permeability resistance of enveloping structures and transition to rating air permeability of the building.

In thermal design of buildings and in implementation of energy saving measures, energy parameters are very important as they show the quality of design decisions. It is reasonable to choose such parameters which would most fully characterize the building as a single energy system. Highly important is to determine the optimal relationship between the capacity of the heating system and heat protective properties of the building. The same parameters will also help yield an opportunity to compare the quality of different design options and their selection for a building.

The most common way to calculate these are specific parameters related to a square meter of living, useful or total square meter area of the building. For rating the following energy parameters have been chosen:

- an index of compactness of the shape of the building K ;
- overall heat transfer coefficient of the entire building K , W/(m^2·°C);
- specific energy consumption for heating the building during the heating season based on degree-days, q, kW·h/(m^2·°C day).

Another feature on an Energy Passport of the building is its use in quality control of the design and subsequent construction and operation. The Energy Passport is a simple instrument for the development of the building design, and in the verification of that design's compliance with the requirements of the regional code. Moreover, it provides potential building buyers and residents with concrete information on what they can expect regarding the energy performance of the building. More energy efficient buildings may be given preference in comparison with less efficient ones that would lead to higher energy costs, which in turn are associated with non-compliance with the real energy-consumption implications of code requirements. Consequently, the Energy Passport is a fundamental document for economic incentives for energy efficiency (tax breaks, credits, subsidies, et al.) and informed assessments in the market for residential and commercial building space.

It has several purposes:

1. To allow building designers to conveniently calculate the expected energy consumption of a building;

2. To demonstrate whether the building complies with energy-code requirements;

3. To allow building owners and other stakeholders to rate and compare energy performance of various buildings, using a uniform system;

4. To serve as a permanent, easily retrievable record of building energy performance, with a form that is consistent across all buildings.

Calculation Example of the Energy Parameters of Energy Passport for "ARSI" 10 storey building

En-pass

Energy passport of residential building

Designer - NIISF RASSN *Matrosov Yu.A.* 7(495)4823710

	Georgia
Regions (towns, settlement	Tbilisi new_date_clim

General Project Information		***Date***	***27.09.2008***
Address of Building		Tbilisi new_date_clim	
Type of Building		Residential stay alone	
Storey of Building	10, 11 st.	10 story bldg	***single section***
High of Building		33	
Type of construction			
Address of Building			
Address and Phone of Designer			
Year of Design			
Project Code		ARCI	
Calculation amount of residens		140	

	Parametrs	Variable name	Units	Value	Notes
	1	2	3	4	
	1. Normative thermal performance parameters of bldgs				
1.1.	*Normative thermal resistance*	R_{req}	$m^2 \cdot °C/W$		
	- external walls	R_w^{req}	$m^2 \cdot °C/W$	2,212	
	- windows and balcony doors	R_F^{req}	$m^2 \cdot °C/W$	0,324	
	- roofs (combined)	R_c^{req}	$m^2 \cdot °C/W$	3,361	
	- attic floors (cold attic)	R_c^{req}	$m^2 \cdot °C/W$	2,945	
	- overlapping over passages and under bay windows	R_f^{req}	$m^2 \cdot °C/W$	3,361	
	- floors above unheated cellars and crawlspaces	R_f^{req}	$m^2 \cdot °C/W$	2,945	
	- entry doors and gates	R_{ed}^{req}	$m^2 \cdot °C/W$	0,517	
	Normative air permeability:	G_N	$kg/(m^2 \cdot h)$		
	- windows and balcony doors	In plastic and alum.casement		5	
	- entry doors			7	
1.2	*Normative building conpactness of res.bldg*	k_e^{req}	10-15 st.	0,29	
1.3	*Normative air exchange rate of res.bldg*	n_a	1/h	0,658 0	

1	2	3	4
2. Design indices and parameters of the building			
2.1. *Building geometry*			
Building volume (heated)	V_h	m^3	10442,6
Area of residential appartment (without summer premises) (for public buildings - useful area)	A_l	m^2	2775,6
Area of living spaces	A_h	m^2	1943
Total external envelope area of heated part of bldg including	A_e^{sum}	m^2	2819,15
- walls, including windows, balcony and entry doors into bldg здание, витражи	A_{w+F+ed}	m^2	*2509,66*
- walls	A_w	m^2	2057
- windows and balcony doors	A_F	m^2	445,56
among them windows and balcony doors in staircase and elevator	A_{FA}	m^2	54,4
- витражей	A_F	m^2	0
- skylight	A_F	m^2	0
- entry doors and gates	A_{ed}	m^2	7,1
- roofs (combined)	A_w	m^2	316,45
- attic floor (cold attic)	A_c	m^2	0
- attic floor (warm attic) including roofs	A_c	m^2	0
- floors above warm cellars	A_f	m^2	0
- floors above unheated cellars and crawlspace	A_f	m^2	316,45
- overlapping over passages and bay windows	A_f	m^2	0
- floors built on the ground	A_f		0
Fenestration coefficient A_F / A_{w+F+ed}	p	--	*0,18*
Building compactness index A_e^{sum}/V_h	k_e^{des}		*0,27*
Does k_e^{des} comply to the norm?			*YES*

2.2. *Level of thermal performance*			
Reduced thermal resistance			
- walls	R_w^r	$m^2 \cdot °C/W$	1,00
- windows and balcony doors	R_F^r	$m^2 \cdot °C/W$	0,35
- витражей	R_F^r	$m^2 \cdot °C/W$	0,00
- skylight	R_F^r	$m^2 \cdot °C/W$	0,00
- entry doors and gate	R_{ed}^r	$m^2 \cdot °C/W$	1,20
- roofs (combined)	R_w^r	$m^2 \cdot °C/W$	3,16
- attic floors (cold attic) *n* 0,9	R_c^r	$m^2 \cdot °C/W$	0,00
- attic floors (warm attic) including roofs	R_c^r	$m^2 \cdot °C/W$	0,00
- floors above warm cellarsперекрытий над техподпольями	R_f^r	$m^2 \cdot °C/W$	0,00
- floors above unheated cellars and crawlspaces *n* 0,9	R_f^r	$m^2 \cdot °C/W$	1,55
- overlapping over passages and under bay windows	R_f^r	$m^2 \cdot °C/W$	0
- floors built on the ground	R_f^r	$m^2 \cdot °C/W$	0
Overall transmission heat transfer coefficient of the building	K_m^{tr}	$W/(m^2 \cdot °C)$	*1,284*
coefficient of influence the heat recovery in windows 0,8	k	--	*0,8*
Conditional hear transfer index of building taking account the heat losses of infiltration and ventilation	K_m^{inf}	$W/(m^2 \cdot °C)$	*0,590*
Overall heat transfer coefficien of the building	K_m	$W/(m^2 \cdot °C)$	*1,874*

1	2	3	4	
2.3. ***Thermal energy parameters of building***				
Heat losses throught envelope during heating season	Q_h	MJ	*1059401*	
Heat gains to the building during heating season:				
- specific internal heat gain	q_{int}	W/m²	12	
- internal heat gain to the building	Q_{int}	MJ	*294117*	
- heat gain incident solar radiatiation during heating season:	Q_s	MJ	*164091*	
Light transparent construction Orientation of the building N/S	Area A, m²	Orienation of the facades (I)	$A * I$, MJ	
Windows on the facades:	*445,56*			
- first	222,78	*N(437)*	*97354,86*	
- second	0	*E(690)*	*0*	
- third	222,78	*S(1268)*	*282485,04*	
- forth	0	*W(690)*	*0*	
zenit sky-lights	0	*0*		
- shading coefficien of windows	τ_F	11в-Д,ПВХ,АЛ	*0,8*	
- shading coefficient of zenit sky-lights	τ_{scy}	--	--	
- solar coeficient of windows	k_F	--	*0,54*	
- shading coefficient of zenit sky-lights	τ_{scy}	7-зенит.двойн	*0,9*	
- solar coeficient of zenit sky-lights	k_{scy}		*0,9*	
Consumption of heat energy for heating the building:		Tower		
- coeficient taking account additional heat consumption of heat supply system	β_{hl}	--	*1,11*	
- consumption of heat energy	Q_h^y	MJ	*789391*	
Specific heat energy consumption for heating the building	q_h^{des}	MJ/m²	*284,40*	
Specific heat energy consumption for heating the building related to degree-day	q_h^{des}	kJ/ (m²·°C·day)	*122,51*	Up to the norml 79,00 kWh/m²
Coeficient of efficiency autocontrol of heat to the heating system	two pipes with thermostats with central co			
	ζ		*0,95*	
Design efficiency coefficient of distric heating system, starting at the heat source	ε_o^{des}		*0,5*	
Design efficiency coefficient of decentaraze heating system, starting at the heat source	ε_{dec}	0,65	*0,65*	
3. Comparison with required levels				
Normative specific heat energy consumption for heating the building	q_h^{req}	kJ/ (m²·°C·day)	*93,6*	60,36 kWh/m²
Does design comly to the Code?	two pipes with thermostats with central co			

4. Design conditions			
Design indoor air temperature	t_{int}	°C	20
Specific weight of indoor air	γ_{int}	N/m³	11,82
Design outdoor air temperature	t_{ext}	°C	-10
Specific weight of outdoor air	γ_{ext}	N/m³	13,17
Design warm attic temperature	t^{c}_{int}	°C	15,5
Design warm cellar temperature	t^{c}_{int}	°C	2
Duration of heating season	z_{ht}	day	146
Avg. outdoor air temperature during heating season	t_{ht}	°C	4,1
Degree-day in heating season	D_d	°C·day	2321
Max. from avg. wind velosity by rumb on January	v	m/s	0

Passport completed by	
Organization	NIISF
Address and Phone of Organization	Lokomotivny pr., 21, Moscow 7(095) 4823710
Responsible party	Matrosov Yu.A.

ENERGY PASSPORT OF BUILDING

Appendix D SNIP 23- 02-2003

General Projec Information

pages 5-8

Date	27.09.2008
Address of Building	Tbilisi new_date_clim
Designer	0
Address and Ohone of Designer	0
	0
Project number	ARCI

Design condition

	Design parameters	Variable name	Units	Value
1	Design indoor air temperature	t_{int}	°C	20
2	Design outdoor air temperature	t_{ext}	°C	-10
3	Design warm attic temperature	t_c	°C	15,5
4	design warm cellar temperature	t_c	°C	2
5	Duration of heating season	z_{ht}	day	146
6	Avg outdoor air temperature during heating season	t_{ht}	°C	4,1
7	Degree-days in heating season	D_d	°C.day	2321

Function, type, and construction of building

8	Use type	Residential
9	Site	stay alone
10	Type	10 story bldg
11	Construction	0

NN.	Design parameter	Variable name of parameter	Normative value of parameter	Design value of parameter	Measurement value of parameter
1	2	3	4	5	6
	Building geometry				
12.	Total external envelope area including:	A_e^{sum}, м²	--	2819,15	
	walls	A_w, м²		2057	
	windows and balcony doors	A_F, м²		445,56	
	stain glass windows	A_F, м²		0	
	skylight	A_F, м²		0	
	entry doors and gate	A_{ed}, м²		7,1	
	roofs (combine)	A_c, м²		316,45	
	attic floors (cold attic)	A_c, м²		0	
	attic floors (warm attic) including roofs	A_c, м²		0	
	floors above warm cellars	A_f, м²		0	
	floors above unheated cellars and crawlspaces	A_f, м²		316,45	
	overlapping over passages and under bay windows	A_f, м²		0	
	floors built on the ground			0	
13	Area of heated space of appartment	A_h, м²		2775,6	
14	Useful area (public building)	A_l, м²		--	
15	Area of living space of appartment	A_l, м²		1943	
16	Design are (public building)	A_l, м²			
17	Heated volume	V_h, м³		10442,8	
18	Fenestration coefficient	f		0,18	
19	Building compactness index	k_e^{des}, м⁻¹	0,29	0,27	

Теплоэнергетические показатели

	Теплотехнические показатели				
1	2	3	4	5	6
20	Reduced thermal resistance of envelope elements:	R_o^r, m²·°C/W			
	walls	R_w^r	2,21	1,00	
	window and balcony door	R_F^r	0,32	0,35	
	stain glass window	R_F^r	0,32	0,00	
	skylight	R_F^r		0,00	
	entry doors and gate	R_{ed}^r	0,52	1,2	
	roofs (combine)	R_c^r	3,36	3,16	
	attic floors (cold attic)	R_c^r	2,94	0,00	
	attic floors (warm attic) including roofs	R_c^r	3,36	0,00	
	floors above warn cellars	R_f^r	1,77	0,00	
	floors above unheated cellars and crawlspaces	R_f^r	2,94	1,55	
	overlapping over passages and under bay windows	R_f^r	3,36	0,00	
	floors built on the ground	R_f^r		0,00	
21	Overall thermal transmission coefficient	K_m^{tr}, W/(m².°C)	--	1,284	
22	Air exchange rate during heating season Air exchange rate under testing (50 Pa)	n_a, 1/h $n50$, 1/h	0,658	0,658	
23	Conditional hear transfer index of building taking account the heat losses of infiltration and ventilation	K_m^{inf}, W/(m².°C)	--	0,590	
24	Overall thermal transmission coefficient of the building	K_m, W/(m².°C)	--	1,874	

Heat energy parameters

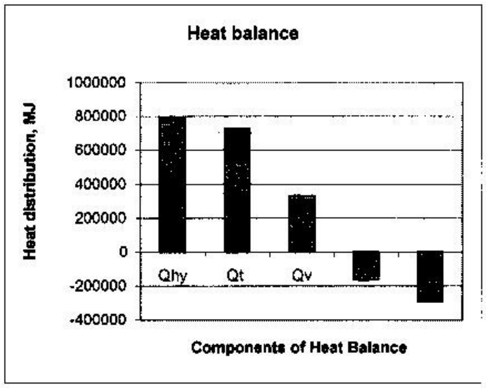
25	Heat losses through envelope during heating season	Q_h, МДж	--	1059401	
26	Specific internal heat gain in building	q_{int}, W/m^2	≥ 10	12	
27	Internal heat gain in building during heating season	Q_{int}, MJ	--	294117	
28	Heat gain incident solar radiation in building during heating season	Q_s, MJ	--	164091	
29	Consumption of heat energy of the building during heating season	Q_h^y, MJ	--	789391	
	Coeficients				
30	Design efficiency coefficient of distric heating system, starting at the heat source	ε_o^{des}		0,5	
31	Design efficiency coefficient of decentaraze heating system, starting at the heat source	ε_{dec}		0,65	
32	Coeficient of efficiency autocontrol of heat to the heating syst	ζ		0,95	
33	Coefficient of influence the heat recovery in windows	k		0,8	
34	Coef. taking account addit. heat consumption of heat supl.syst	β_h		1,11	
	Complex indexes				
35	Specific heat energy consumption for heating the building	q_h^{des}, kJ/(m^2·°C·day) [kJ/(m^3·°C·day)]	-- --	122,51	
36	Normative specific heat energy consumption for heating the building	q_h^{req}, kJ/(m^2·°C·day) [kJ/(m^3·°C·day)]	-- --	93,6	
37	Class of energy efficiency				
38	Does design comlyto the Code?			NO	
39	Revision necessary?			YES	

Class of Buildings for Energy Efficiency

	Class for Energy Efficiency ranges, kJ/(m^2.°C.day)		Class kJ/(m^2·°C·day)	Recommendation
	New and renovated buildins			
A	<46	*Very high*		Recommendation for financial incentive payments or credits
B	47-84	*High*		The same
C	85-98	*Normal*		-
	Operating buildings			
D	99-164	*Low*	**<= *D*** *122,51*	Renovation desirable
E	>165	*Very low*		Renovation recommended in near future

Components of Heat Balance MJ

Q_h^y	789391
Q_t	726026
Q_v	333375
Q_s	-164091
Q_i	-294117



Recommendation for increasing energy efficiency

35.	We recommended

36.	Passport completed	
	Organization	NIISF
	Address and phone	Lokomotivny pr., 21, Moscow 7(095) 48237
	Responsible party	Matrosov Yu.A.

Appendix 3

Climatic data

1 Distribution Degree-Days

	DD < 2 000
(yellow)	DD = 2 000-3 000
(orange)	DD = 3 000-4 000
(purple)	DD = 4 000-5 000
(cyan)	DD > 5 000

2 Georgia's climate is characterized with very high diversity from subtropics to rigorous continental climate. Below in Table. 1 is given calculation of degree days for most important cities and settlements of Georgia. Data for calculation is obtained from Georgian Scientific Applied Reference Book of Georgia. Part I. Separate Climatic Description. Developed by Ministry of Environmental Protection and Natural Resources of Georgia (Department of Hydrometeorology), and Institute of Hydrometeorology of the Academy of Sciences of Georgia (2004).

Calculations are based on data from Georgian Scientific Applied Reference Book of Georgia. Part I. Separate Climatic Description

Place	**THS**	**HS**	**18**	**20**	**22**
			Degree-days		
1 .Batumi	6.9	72	780	944	1088
2. Poti	6.5	83	955	1121	1287
3. Sukhumi	5.8	85	1037	1207	1377
4. Kutaisi	5.8	90	1098	1278	1458
5. Zugdidi	6.2	101	1192	1394	1596
6. Ozurgeti	5.3	106	1347	1559	1770
7. Tbilisi / Rustavi	4.1	146	2030	2322	2614
8. Telavi	3.1	141	2101	2383	2665
9. Marneuli	2.7	139	2127	2405	2683
10. Ambrolauri	2.5	145	2248	2538	2828
11. Gori	1.9	148	2383	2679	2975
12. Tskhinvali	1.5	163	2690	3016	3342
13. Akhaltsikhe	0.7	165	2855	3185	3515
14. Borjomi	1.1	179	3025	3384	3742
15. Akhalkalakhi	-1.2	207	3975	4389	4803
16. Bakuriani	-0.7	221	4133	4575	5017
17. Gudauri	-1.4	263	5103	5629	6155

3 For the calculation of the heating system conventionality is considered to divide the country's territory on following six Climate Zones**:**

Climate Zone	I	II	III	IV	V	VI
Design Heating Temperature,	**-2^{0}C**	**-4^{0}C**	**-8^{0}C**	**-13^{0}C**	**-16^{0}C**	**-18^{0}C**

°C						
Duration of the heating season, day						
Average outdoor air temperature of the heating season, °C						
Degree-Days of Heating Period, °C·day						

4. Solar radiation under cloud conditions during heating season, MJ/m²

Tbilisi

Month	Gorizontal surface	Orientation on the							
		N	NE	E	SE	S	SW	W	NW
I	178	74	75	118	190	249	206	118	75
II	235	96	98	147	213	261	219	147	98
III	382	146	153	225	281	319	283	225	155
IV	487	170	205	274	309	298	301	266	202
V	621	191	268	337	344	293	330	315	260
VI	679	176	291	353	335	273	335	331	278
VII	703	186	294	384	353	303	362	366	289
VIII	628	163	249	335	363	339	367	335	245
IX	468	129	176	264	341	350	335	258	173
X	331	101	120	197	295	351	291	189	116
XI	186	67	71	116	199	253	203	116	70
XII	150	59	59	94	171	225	171	94	59
For the heating season	1120	437	454	691	1028	1268	1054	690	455