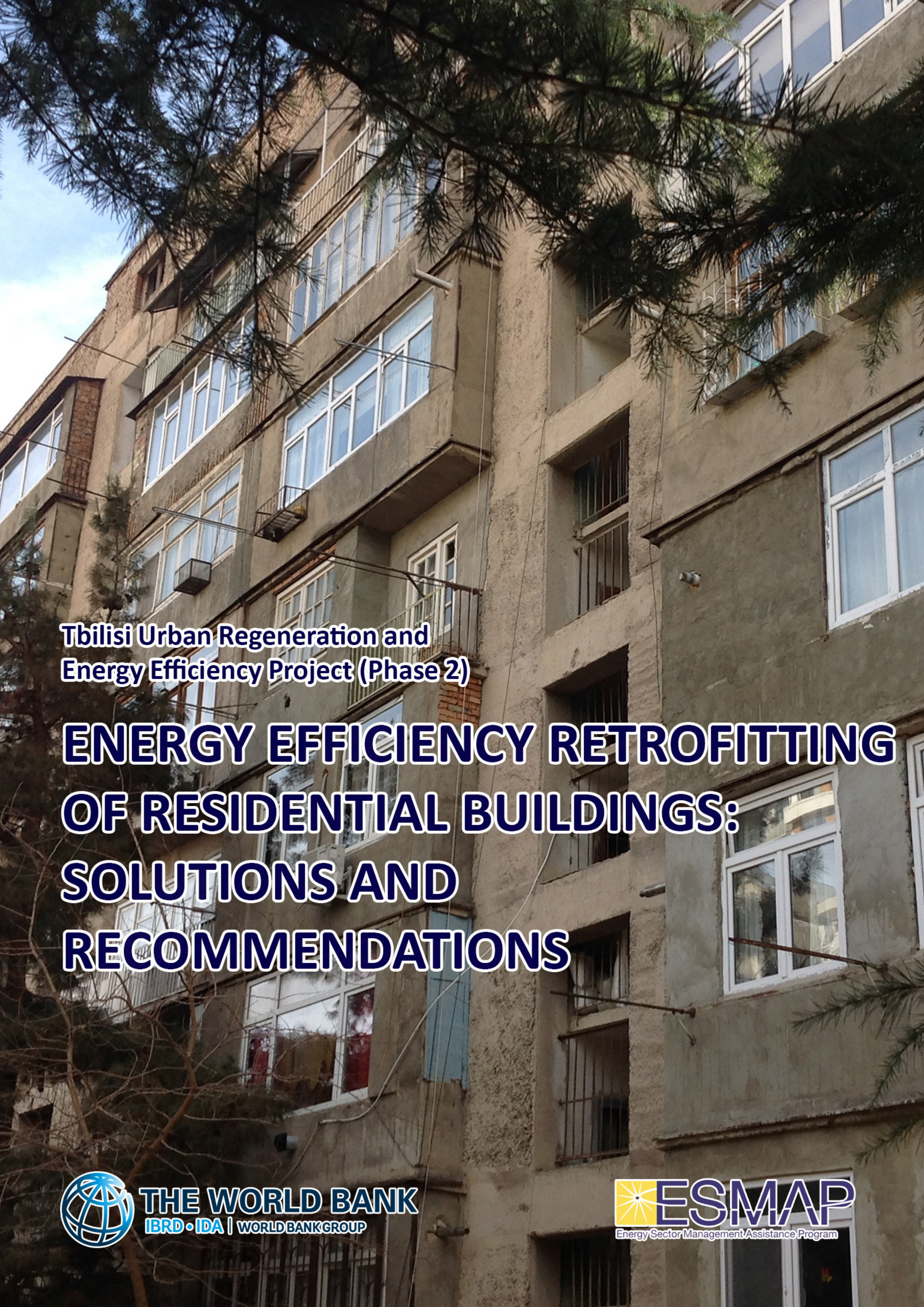

Tbilisi Urban Regeneration and Energy Efficiency Project (Phase 2)

ENERGY EFFICIENCY RETROFITTING OF RESIDENTIAL BUILDINGS: SOLUTIONS AND RECOMMENDATIONS

THE WORLD BANK
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ESMAP
Energy Sector Management Assistance Program

Executive Summary

For most commercial and residential buildings, energy is one of the largest operating expenses over a building's useful life. Energy consumption (and costs associated with such consumption) can be minimized through proactive, technical approaches during building design, construction, operations, and through retrofitting, when possible. Yet the historic and current construction market in Georgia rarely delivers buildings designed for energy efficient operations, and the energy performance of the building stock so far remains a challenge.

With increased urbanization, energy consumption in the residential sector will continue to increase in the near future. Electricity consumption in the housing sector globally has doubled between 1980 and 2000 and is expected to increase by another 50% by 2025 (EIA 2005a.) New buildings are added to the national building stock faster than old buildings are retired.

As part of the Association Agreement with the EU, Georgia has committed to improve energy efficiency (EE) in its housing stock, increase the country's use of renewable energy sources, and reduce its greenhouse gas emissions. This initiative has already led to significant changes in the country's construction sector. NIRAS engineering consultancy company, Environment and School Initiatives (ENSI) and Sustainable Development and Policy Center (SDAP) consortium, with the support from the Danish International Development Agency (DANIDA), worked closely with the Government and developed the regulations on minimum energy performance requirements for the buildings. In recent years, several projects addressing energy efficiency have been completed in Georgia, including the European Commission-funded project on *Retrofitting Three Kindergartens in Rustavi* and the Nordic Environment Finance Corporation financed project on *Energy Efficiency Rehabilitation of 25 Public Buildings* nationwide.

The objectives of this report are to improve Tbilisi Municipality's and its district units' technical capacity in energy efficiency retrofits of housing stock and offer a set of standards and guidelines for such retrofits. This report offers a comprehensive approach for promoting energy efficiency, and includes a discussion of the regulatory and legislative framework, provides an overview of residential building stock of Tbilisi, offers energy modeling results, and proposes standards and technical solutions (including detailed engineering design and bill of quantities for the selected apartment building).

The structure of this document is:

1. Chapter 1 describes the energy efficiency legislative framework applicable to the construction sector in Georgia.
2. Chapter 2 summarizes experts' analysis on residential structure, composition and energy consumption of residential building stock of Tbilisi City.
3. Chapter 3 provides an analysis of energy modeling of reference dwelling with an assessment of energy-saving potential and identification of energy efficiency measures for the selected focus group of 8-floor dwellings.
4. Chapter 4 presents guidelines of technical solutions and recommendations for energy efficiency retrofit designs for dwellings, to enable local governments to implement energy efficiency retrofit projects.
5. Annexes cover the energy audit and the proposed intervention measures for the selected residential building, supported with the technical documentation package.

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Acknowledgments

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Abbreviations

CDD	Cooling Degree Days
cm	Centimeter
DANIDA	Danish International Development Agency
DHW	Domestic Hot Water
DSM	Demand Side Management
EE	Energy Efficiency
EED	Energy Efficiency Directive
EPBD	Directive on Energy Performance of Buildings
ESCO	Energy Services Company
EU	European Union
GEL	Georgian Lari
GHG	Greenhouse Gas
GoG	Government of Georgia
HOA	Homeowners Association
HDD	Heating Degree Days
KWh	Kilowatt-hour
m	Meter
mm	Millimeter
MoESD	Ministry of Economy and Sustainable Development
MWh	Megawatt-hour
NEEAP	National Energy Efficiency Action Plan of Georgia
NEFCO	Nordic Environment Finance Corporation
SEAP	Sustainable Energy Action Plan
SNiP	Building Norms and Rules (СНиП – Строительные нормы и правила)
USD	United States Dollar
$W/(m^2)(K)$	Thermal transmittance of a material

Introduction

The city of Tbilisi has more than 500 Khrushovkas, multi-family residential buildings originally constructed in the late 1950s and early 1960s in response to the Soviet initiative "living space for all citizens." These Khrushovkas, which are now quite deteriorated, are home to more than 12,000 families.

During Soviet times, apartment buildings were owned by the city administration. Following independence in the early 1990s, these apartments were privatized and ownership transferred to the tenants, as part of the state privatization program. With no investments in major capital upgrades and low-quality maintenance (e.g. roof replacement, doorways and common space maintenance, etc.), the buildings started to deteriorate, and many face serious structural issues.

In response to the widespread problem of deteriorated housing stock, the City started to invest public funds in reconstruction and rehabilitation of the Khrushovkas. However, the reconstruction designs have been rather basic and have not followed construction standards, including any standards for promoting energy efficiency. Low-quality engineering designs have resulted in low-quality construction, contributing to increased GHG emissions and ongoing high energy consumption.

At the request of Tbilisi Municipality, the World Bank team was tasked to provide support to the City's Infrastructure Department to help:

1. Define the required technical measures for EE retrofit designs, and
2. Provide capacity building for the department staff on incorporating EE measures into building designs and construction standards.

This report will support the City's Infrastructure Department with the development of EE standards, which in turn, shall inform detailed engineering designs for rehabilitation and reconstruction of multi-family residential buildings. The report is based on the applicable EE standards and incorporates them into a sample engineering design for rehabilitation/reconstruction of deteriorated housing stock.

The assignment also included knowledge sharing and capacity building at the technical level of the City government, involving the City Infrastructure Department and district-level staff. While the original plan was to conduct a face to face workshop, the office closures caused by COVID-19 pandemic prompted the team to shift instead to engage in virtual learning sessions with the City's technical staff. Topics that were covered, to help them increase their awareness on the cycle from design stage to construction supervision, included:

1. Recommended EE standards and how they can contribute to the decreased Greenhouse Gas (GHG) emissions triggered by reduced energy consumption;
2. How to prepare Terms of Reference, when putting together tender documentation to procure the next batch of detailed designs for rehabilitation/reconstruction of deteriorated housing stock;
3. How to ensure the adequacy of the proposed detailed designs with the EE retrofit guidelines when reviewing and inspecting the designs;
4. How to conduct monitoring for compliance of the EE retrofitting guidelines during the construction phase.

Legislative framework of the construction sector of Georgia

Overview of the construction regulatory documents and technical standards currently used in Georgia

On March 7, 2013, the Government of Georgia issued Decree №50 and approved the use of Technical Regulations of member-states of the European Union and the Organization for Economic Cooperation and Development for construction activities in Georgia. The Decree allows the use of regulations from 37 countries.

On January 14, 2014, the Government of Georgia issued Decree №521 on validity of operation and recognition of technical regulations of construction in Georgia. This decree establishes the rule which regulates the existing technical regulations of Georgia. In particular, it recognizes the existing technical regulations that are not contrary to the applicable legislation and/or the international treaties to which Georgia is a party, within the time period remained from the former Soviet Union till 1992 and thereafter.2 To this end, the old Soviet building codes, called "SNiPS", as well as their later modifications, are fully or partially recognized in Georgia and will remain applicable until relevant national technical regulations are adopted.

The list of the buildings codes and other regulations related to the construction sector activities recognized in Georgia, covers 5 main parts of the codes, namely:

1. Part 1 - Management and Economics;
2. Part 2 - Design Standards;
3. Part 3 - Management, Implementation and Acceptance Works;
4. Part 4 - Cost estimation standards;
5. Part 5 - Standards, Materials and Labor Costs

Whilst the industry follows the SNIPs and mandatory regulations, the following design standards are providing additional guidance on architectural solutions for buildings and engineering systems:

1. Law of Georgia on Construction Activities #577, 2000
2. Law of Georgia on Architectural Activities #1335, 1998
3. Law of Georgia on Spatial Management and Urban Planning Principles #1506, 2005
4. Law of Georgia on License and Permits #1775, 2005
5. Decree of the Government of Georgia #57 of 2005 on Issuing construction permits and construction permit requirements
6. Decree of the Government of Georgia #41 of 2016 on Technical Regulation on Approving Rules of Safety of Buildings
7. Decree №14-39 of the Tbilisi Municipal Council of May 24, 2016-Tbilisi Municipal Land Use and Development Regulations Approval;
8. Residential Apartment Building- SNIP 01/31/2003 (updated edition)
9. Heating, ventilation and conditioning standards and rules -SNIP 01/41/2003 (updated edition);
10. Domestic water supply and drainage systems in buildings-SNIP2.04.01-85(updated edition);
11. Boiler equipment - SNIP II/35/1976 (updated edition);
12. 2009 International Building Code;
13. 2009 International Mechanical Code.

The absence of the consolidated building regulations at the national level leaves its footprints on construction activities. Although, the industry can follow the codes of other countries, they usually tend to apply the former Soviet construction practices (comfort factor), bypassing the energy efficiency measures.

Recently, only a few advanced companies and developers started to construct residential buildings with enhanced energy performance of the building envelope. However, they don't provide customers with any kind of energy passports and/or energy performance certificates so far. Energy efficiency in such buildings is usually introduced fragmentarily and the overall energy performance of these assets is much lower, if compared to the advanced energy efficiency indicators.

1 http://www.economy.ge/?page=ecoleg&s=21&lang=en
2 economy.ge/?page=ecoleg&s=21&lang=en

In the meantime, the Georgian Parliament has adopted the new umbrella code called *Georgian Space Planning, Architectural and Construction Activity Code*, that was brought into force on June 3, 2019. It was developed under request of the Ministry of Economy and Sustainable Development (MoESD) with the assistance from the German Agency for International Cooperation - GIZ. The above code has two special articles No 87 on *Building's Energy Efficiency* and No 88 on *Application of renewable energy technologies in the buildings* that set up requirements for development of high energy performance buildings and application of renewable energy technologies3.

This document introduces the Georgia's innovative vision on the construction sector activities emphasizing promotion and implementation of energy efficiency as well as application of renewable technologies in buildings.

Overview of legislative framework for improvement of energy efficiency in the buildings

In 2014, Georgia signed the Association Agreement with the EU, committing to align the national laws and regulations with the EU legislation. In 2015, the Government of Georgia (GOG) amended the energy policy document *The Main Directions of the State Energy Policy of Georgia*. Such approach aimed to emphasize the country's vision of the new energy policy, in order to facilitate implementation of EE and utilization of renewable energy sources in the energy sector in Georgia.

After signing the agreement with the EU, Georgia has been actively seeking financial support to improve the situation with GHG, reduction of carbon emissions and improvement of energy efficiency within its existing building stock. There are a few estimates4 at the national level of financing requirements for Georgia to meet its sustainable development and climate change targets. Estimates include the following:

1. USD 8.3 billion for 2017-30 for energy efficiency (National Energy Efficiency Action Plan) (NEEAP Expert Team, 2017)
2. USD 10.6 billion between 2017-30 for energy efficiency, non-energy greenhouse gas (GHG) and land use, land-use change, and forestry emission reduction (Low Emission Development Strategy) (Winrock and Remissia, 2017)
3. USD 2.4 billion for hydropower 2017-30 (Third National Communication of Georgia to the United Nations Framework Convention on Climate Change) (Government of Georgia, 2015)
4. USD 1.5-$2.0 billion for climate change adaptation over 2021-30 (Intended Nationally Determined Contribution) (Government of Georgia, 2015)

It is clear from the energy balance reports of the National Statistics Office of Georgia, that the country's building sector is one of the most energy consuming sectors5. Therefore, for the improvement of energy efficiency in the building sector of Georgia, the Annex XXV of the EU Georgia Association Agreement highlights obligations on transposition of the EU Directives as follows:

- Directive on Energy Performance of Buildings (EPBD 2010/31/EU) [3]
- Energy Efficiency Directive EED (EED 2012/27/ EU) [4]

Building sector of Georgia falls under the main focus for Government from the energy consumption reduction standpoint, thus many international donor projects including the European Commission, DANIDA, NEFCO, EBRD, and the World Bank are supporting the government to address this issue. Georgia has already fulfilled its obligations related to transposition of the both Directives and has even submitted the draft version of laws to the Parliament of Georgia for its further adoption, With the support of the energy community.

3 Georgia: Space Planning, Architectural and Construction Activity Code https://policy.asiapacificenergy.org/sites/default/files/Georgian%20Space%20Planning%2C%20Architectural%20and%20Construction%20Activity%20Code%20%28GE%29.pdf

4 https://www.oecd-ilibrary.org/sites/920b1670-en/index.html?itemId=/content/component/920b1670-en

5 Energy Balance of Georgia, 2019 National Statistics Office of Georgia https://www.geostat.ge/media/28553/ENERGY-BALANCE-of-GEORGIA_2018.pdf

State Construction Regulations of Georgia on minimum energy performance requirements for buildings (draft)

Requirements for design and construction of building elements of all categories and subcategories of new buildings/units and major renovations of existing buildings/units are set in the regulation at two levels:

- Level 1 - requirements for building fabric elements[6];
- Level 2 - requirements on aggregated elements for thermal building envelope.

The maximum allowed thermal transmittance U values [W/m²K] for individual elements of the building fabric for all categories of buildings are specified. Requirements on aggregated elements at Level 2 present the maximum allowed thermal transmittance $\bar{U}_{max}$ of aggregated elements of thermal building envelope as illustrated in Table 2 below.

Requirements for design and installation of technical building systems in new buildings/units and for major renovations of existing buildings/units illustrate obligatory provisions for heating, domestic hot water, ventilation and air conditioning systems with the emphasis on:

- Minimum energy efficiency indicator;
- Minimum requirements for insulation of the pipes for reduction of heat losses;
- Obligatory performance of the new technologies such as a heat recovery for operation of ventilation systems

In December 2018, the draft law for State Construction Regulations of Georgia on minimum energy performance requirements for buildings was submitted to MoESD. It was developed with the intention to fulfill Georgia's aspirations to the EU.

As of today, it is considered as one of the most comprehensive work carried out with the purpose of development of energy efficiency standards for buildings in Georgia. The above-mentioned regulation is fully in line with the framework requirement of EPBD on the secondary legislation act regarding *Establishing minimum energy performance requirements for buildings or building units and building elements*.

The objective of the State Construction Regulations is to set up the minimum energy performance requirements for buildings' elements and technical building systems. This is in order to ensure improved energy efficiency and cost-effectiveness and reduction of greenhouse gas emissions by buildings. Following the EPBD, this regulation shall be obligatory for application to all new buildings and building units, as well as to existing buildings and building, that undergo major renovations.

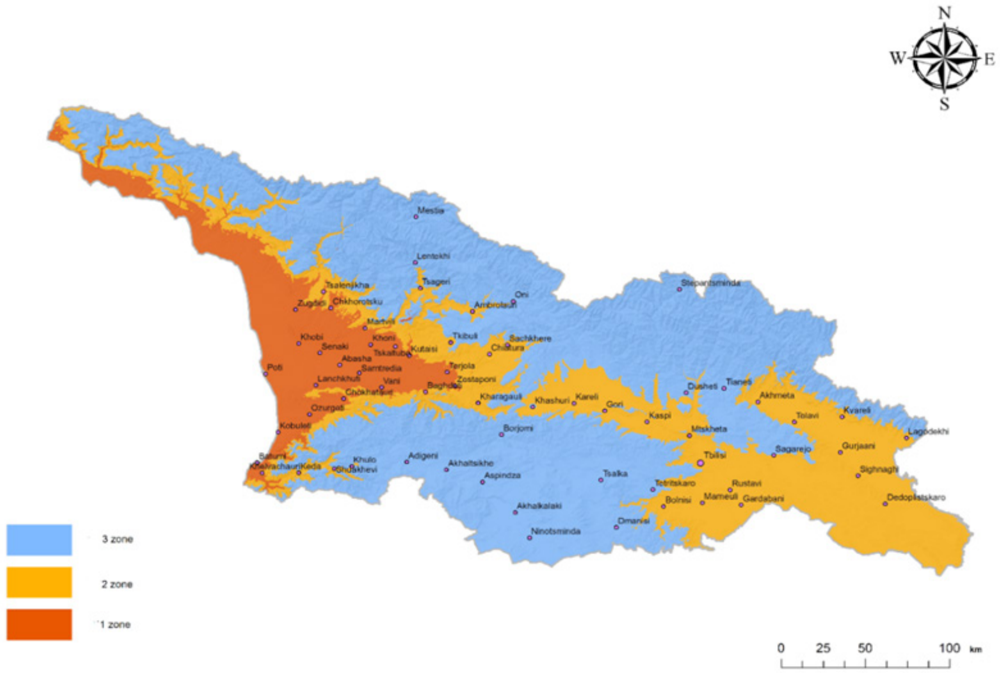
The scope of the work on the draft regulations of Georgia on minimum energy performance requirements was based on the building analysis evaluated together with the climate conditions of Georgia. The updated climate database (with daily measured climate parameters from 85 metrological stations) was obtained from the National Environmental Agency (NEA) of Georgia.

Methodology of mapping the climate zones for Georgia was based on evaluation of measured climate data. For that purpose, calculations of the Heating Degree Days (HDD) and Cooling Degree Days (CDD), as well as their averaged and weighted values were processed in connection with population and building stock of Georgia. Deviations from weighted averaged HDD and CDD for settlements were calculated and accounted as well. The results of analysis allowed to specify the 3 climate zones for Georgia as follows:

1. Climate zone 1- with the representative city Batumi. This zone covers mostly coastal area, with some parts of inland territory. This zone covers -30.4% of Georgian population. The HDD and CDD for this zone were calculated as: HDD=1697, CDD=623;
2. Climate zone 2- with the representative city Tbilisi. This zone covers 60.7% of population of Georgia. HDD=2295, CDD=627;
3. Climate zone 3- with the representative small town Tianeti, covers 8.9% of the population of Georgia that lives in the mountainous part of the country. HDD=3560, CDD=170.

6 Building fabric –means all physical elements of a building, excluding technical building systems (e.g. roofs, walls, floors, doors, gates and internal partitions.

Figure 1: Map of Georgia with designated climate zones



Source: NIRAS, ENSI & SDAP Center Consortium

Table 1: Calculation results of three climate zones for Georgia with HDD and CDD[7] benchmarks and population per zone.

Zone	Representative city	Population (building stock) share in the zone	Weighted HDD for the zone	Weighted CDD for the zone
1	Batumi	30,4%	1,697	623
2	Tbilisi	60,7%	2,295	627
3	Tianeti	8,9%	3,560	170

The analysis completed on the identification of climate zones has favored the evaluation on energy performance requirements for the building envelope components.

Table 2: Minimum Energy performance requirements for the exterior building components

Climate zone	Zone 1	Zone 2	Zone 3
Unit	[W/m²K]	[W/m²K]	[W/m²K]
$\bar{U}_{max}$ value for walls	0,5	0,38	0,25
$\bar{U}_{max}$ value for roofs	0,4	0,3	0,2
$\bar{U}_{max}$ value for floors	0,5	0,38	0,25
$\bar{U}_{max}$ value for windows and doors	2,2	1,8	1,8

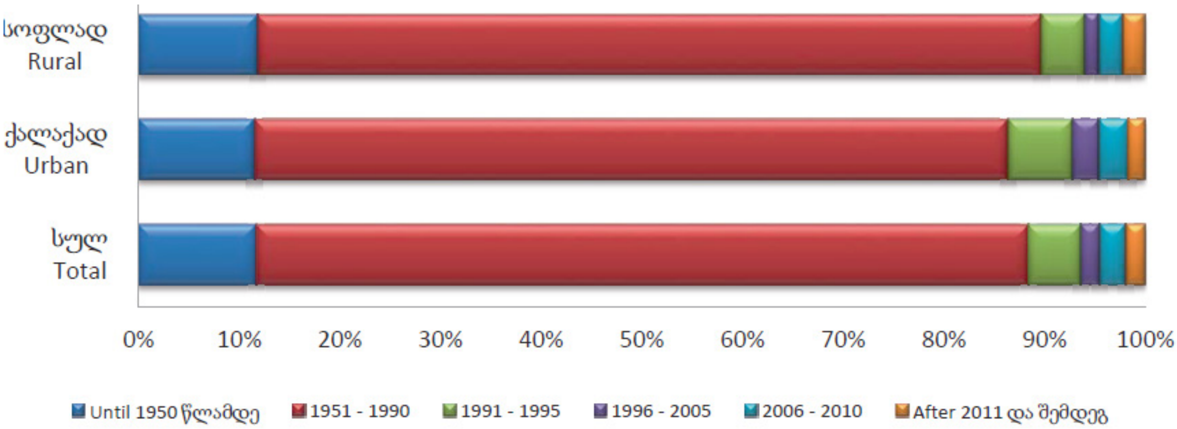
7 Heating degree days (HDD) and Cooling Degree Days (CDD) measure the deviation from a temperature of 65 degrees Fahrenheit over the course of the year. For each day with an average temperature lower than 65 degrees, HDD is the difference between the average temperature and 65 degrees. The annual HDD is the sum of this difference across all days with an average temperature below 65 degrees. CDD is calculated in a similar manner, to measure deviations above 65 degrees. Note that 65oF is equivalent to 18oC.

Residential Building Stock of Tbilisi City - Composition, Structure and Energy Consumption

Overview of the residential building stock in Tbilisi

According to the “Report on Energy Consumption of Households” published by the National Statistics Office of Georgia, majority of dwellings constructed in the urban areas of Georgia were built between 1951-1990, constituting 77.9% of the total dwellings nationwide. Tbilisi also followed this trend.

Figure 2: Dwellings by the year of construction completion



Source: Energy Consumption in Households National Statistics Office of Georgia, 2017

The development of Tbilisi’s residential stock comprises:

1. Pre-1922 residential and historic buildings;
2. Buildings, built from the period of the Great October Revolution in 1917 till mid of 1950s;
3. Buildings, constructed during the mass industrial housing program from the mid-1950s till end of 1960s, under the master plans of the so called “Khrushchev” era;
4. Buildings, built under the master plans of 1969 from 1969 to 1991;
5. Buildings built after the collapse of the Soviet Union since 1991.

The residential building stock inventory, as laid out under EPBD hasn’t been carried out in Georgia yet. However, expert opinion suggests that the total residential building stock area in Tbilisi accounts for over 34,000,000 m². The table below shows the indicative figures of quantity and total area (m²), for each subcategory:

Table 3: Composition of the residential building stock in Tbilisi distributed by subcategories

Composition of the residential building stock by sub categories	Quantity	Total Area, m²
Individual single-family buildings	68,265	6,706,655
2 -story residential buildings	448	371,625
3 – story residential buildings	408	501,619
4 – story residential buildings	629	1,352,789
5-6 – story residential buildings	1,163	3,585,598
7-8 - story residential buildings	1,020	4,379,231
9-10 - story residential buildings	1,562	9,834,019
11-12 - story residential buildings	148	857,005
13-14 - story residential buildings	158	871,368
15-16 - story residential buildings	228	1,453,003
17-18 – story residential buildings	49	376,880
19-20 – story residential buildings	4	36,612

Composition of the residential building stock by sub categories	Quantity	Total Area, m²
Barracks and others	8,599	3,499,038
Total multi-family buildings	**14,416**	**27,118,787**
Total	**82,681**	**33,825,442**

Source: Winrock International, SDAP Center and Remissia, 2011 SEAP of Tbilisi City http://sdap.ge/index.php/charity-store/publications/?lang=en

After the collapse of Soviet Union, the country has not adopted a coordinated approach related to the governmental housing policy. The first reform was initiated in 1991, when the residents were allowed to privatize their apartments. This transformation resulted in the delegation of the ownership and the respective rights to residents of the apartments they lived in.

As of today, the residents typically own their flats and are organized in condominium associations to represent their interests. However, often participation in these associations is low and lack a legal status.

The Tbilisi Municipality assists residents in relation to the maintenance of the common-use areas such as entrances, communal lighting, roofs, elevators etc. Such maintenance is usually completed with the co-financing programs, that can be linked to energy efficiency measures or deep renovation activities.

Residential building stock of Tbilisi built before 1922

Historic part of the City, known as the "Old Tbilisi District" is composed of old residential buildings designed by architects from the 19th century. These buildings usually comprise of 2 or 3 floors, built with wall thickness of δ=0.8-1.0 m. These walls were often additionally insulated with thermal insulation. An expert assessment shows that the U value of such walls are around: U=0,69-0,83 W/m²C.

These buildings have a reduced energy consumption over winter and summer periods, due to the latent heat of building exterior, compared to buildings built during the Soviet era. However, the structural characteristics of this building category, manifest problems associated with cracks and need for reinforcement. This is due to their age, inappropriate maintenance and earthquakes over time.

Rehabilitation of such group of buildings need proper technical/structural evaluation and should be carried out individually, case by case in compliance with the spatial planning priorities and the historic value.

Dwellings constructed between 1922 and mid of 1950s

In early 30s, the monumental buildings with neoclassical and Georgian national elements became notable elements of residential buildings that can be observed on Rustaveli Avenue and the old parts of the city.

During this period the energy prices were artificially lowered, which resulted in the new construction policy approach. This ensued in lowering the U values of the walls. Thus, the walls of these residential buildings were built as a single layer structure, mostly from brick with a thickness of δ=0.4-0.6 m.

In 1940s, the total useful area on average per urban resident constituted about 6.5 square meters. During the war, the housing construction almost stopped until 1945, because the budget for the construction industry were diverted into the manufacturing industry and the armed forces. In the post-war years, houses were mostly built with a small number of floors (2-5) under the type design series No. 228. Other construction series which were used were: № 201-206, 211, 221-227, 241, 242, 261, 262.

Dwellings constructed during the period of the mass industrial housing program from mid 1950s till end of 1960s

The period of mass industrial housing policy dates from 1955 known as "Khrushchev era" housing. The particularity of "Khrushchev" design predominates in the interior planning i.e. specifying individual apartments with the minimum standard of 8 square meters per person. The interior design features were:

- Ceiling height of 2.50 -2.60 m
- Very small hallways and kitchens
- Adjacent rooms in many apartments

- Combined (rarely separate) bathroom/toilet
- Weak sound insulation of internal walls

The period of mass housing construction in Tbilisi started with a 5-story type- design dwellings construction. The most common housing series built in Tbilisi were: 1-319C, 1G-450C, 1-464AC. These different designs were produced with consideration of some variations in layouts of first floors and use of one-layer walls, with medium heat capacity. These dwellings were built with different building materials - the first houses were mostly built of bricks, which were later replaced by large construction blocks and large concrete panels.

The wall thickness of such buildings wasn't specifically defined in accordance with thermal properties of building materials. It was rather based on consideration of technology and structural requirements. Each module housing series was designed with the different construction materials; however, the main requirement was to withstand up to a 7-magnitude earthquake.

The type module dwelling series mostly had a flat roof or had an attic. These roofs composed of concrete reinforced slabs, insulated with mineral wool boards or light building material fillings, such as pumice, with an approximate thickness of 15-20 cm.

Figure 3: A 5-floor apartment building from 1960s, the first wave of the "Khrushchev" housing program

This type of buildings basically do not have any static stability deficiencies. The floor plans showing the total useful area per apartment are a reminder of the unattractive housing policy of that time.

Figure 4: Layout of the typical floor of the "Khrushchev" type design series residential building

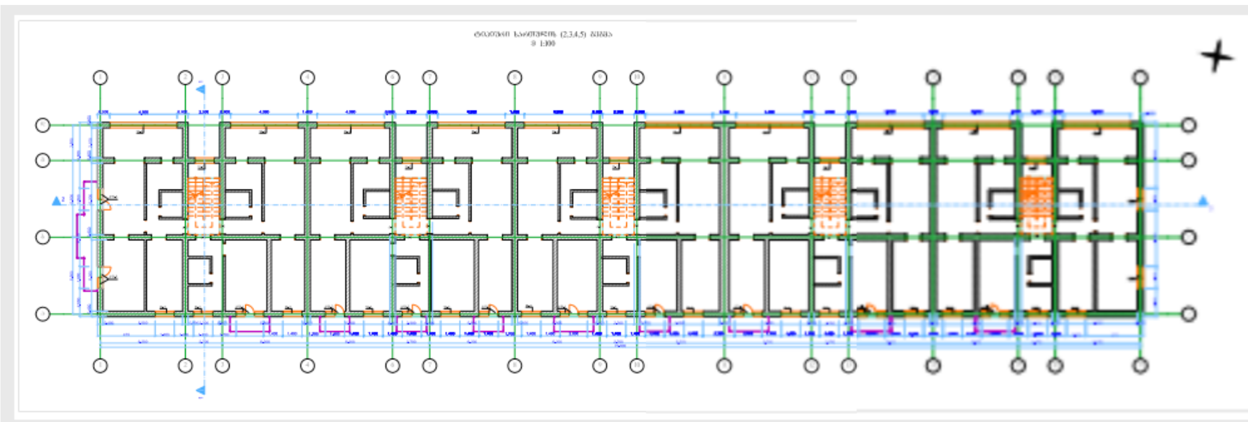
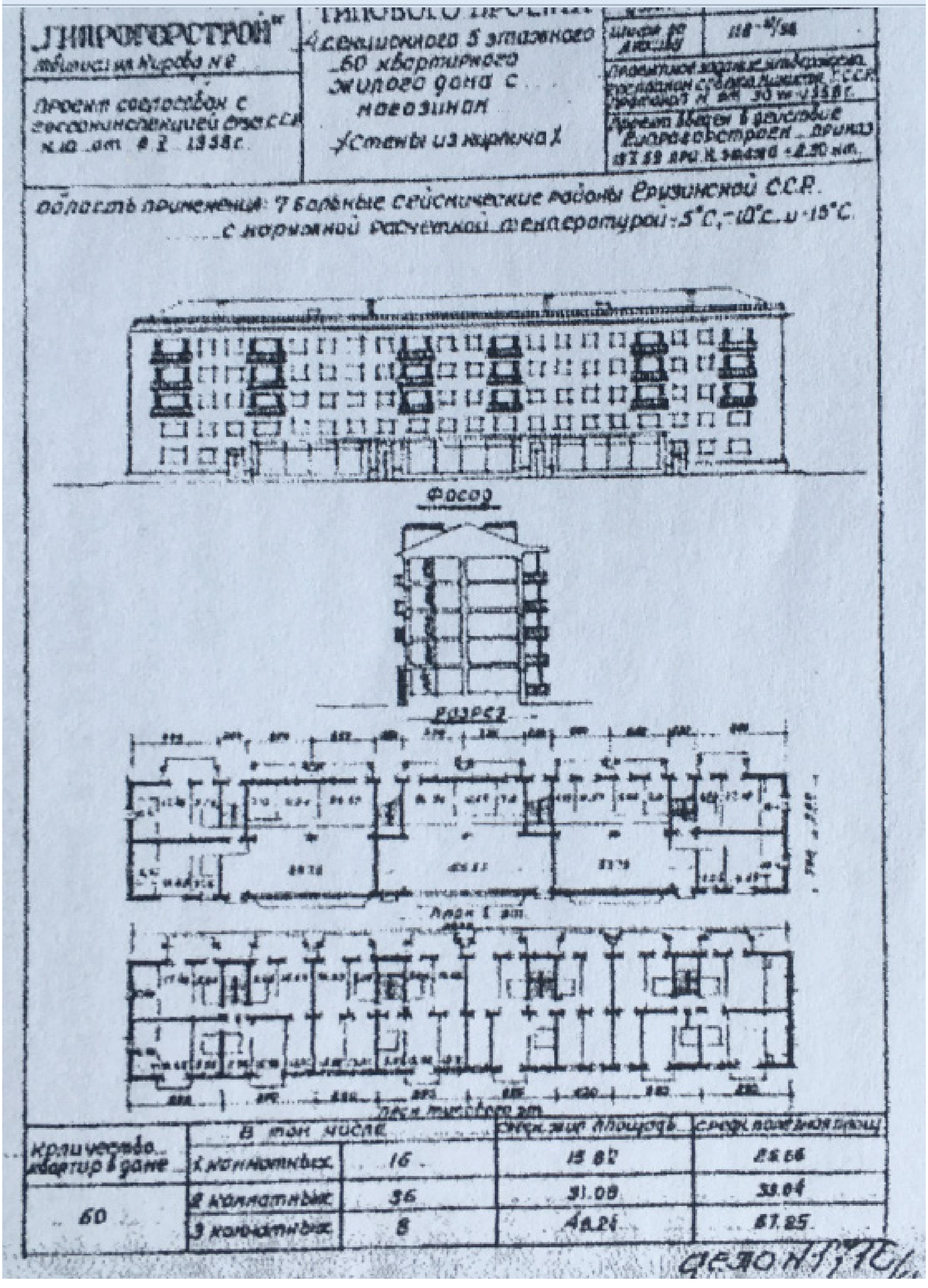


Figure 5: Building passport of the 5-floor residential building



The later series of the mass construction housing in Tbilisi were characterized by a higher number of floors and mostly were built as eight floor buildings. These buildings were known as the "Kalakuri" design and were the upgraded version of the previous type designs series, as the ceiling height was 2.70 m. However, these dwellings almost had the identical living and useful areas as in their predecessors.

Figure 6: An 8-floor apartment building from 1966, the second stage of the "Khrushchev" housing mass construction program.

The 8-floor dwellings were built in Tbilisi according to the type design module series 1G-450 and the building features covered:

- Walls made of large blocks
- Load-bearing bridges made of heavy concrete of grade 200
- Roof slab with reinforced concrete ribbed panels with insulation and 3 waterproofing layers
- Single glazed windows
- Plinth area – monolith, reinforced concrete

Buildings Constructed from 1969 to1991

The housing stock of Tbilisi City continued to grow under the new master plan of 1969. The new type-designs were developed by architects and introduced for construction. Picture along with the building passport of the 14 story (facade of the half section) dwelling, also known as the "Tukhareli design" housing is provided below. Under this type design 1-464AC additional series were developed for 5, 9, and 14 story buildings:

Figure 7: A 14-floor residential building (designed by architect Tukhareli)

Figure 8: Building passport - facade of the type design for the 14-floor building

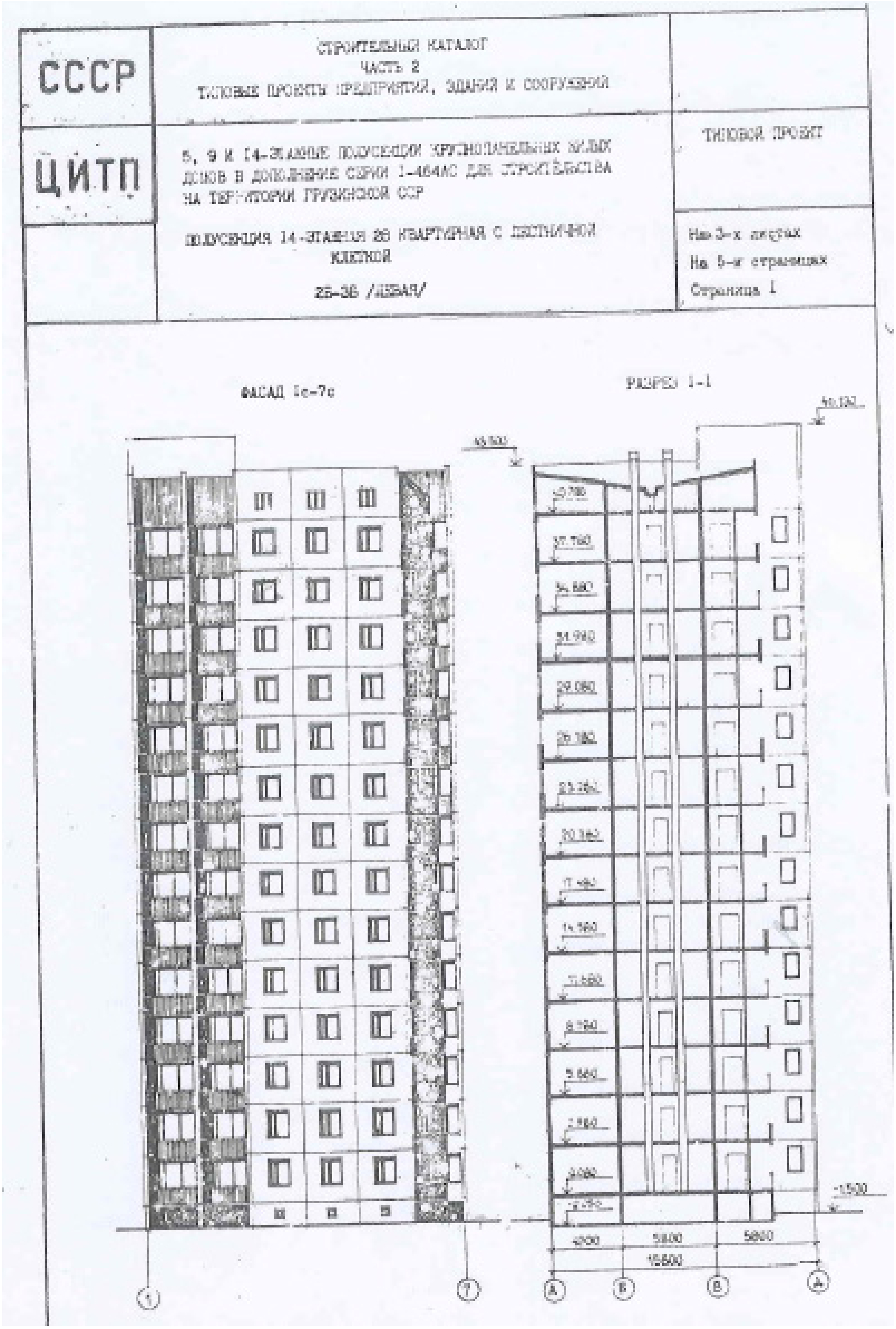


Figure 9: Building passport - floor layout of the 14-floor apartment building

ПОЛУСЕКЦИЯ 14-ЭТАЖНАЯ 28 КВАРТИРНАЯ С ЛЕСТНИЧНОЙ КЛЕТКОЙ 2Б-3Б /ЛЕВАЯ/	ТИПОВОЙ ПРОЕКТ	Лист 1 Страница 2

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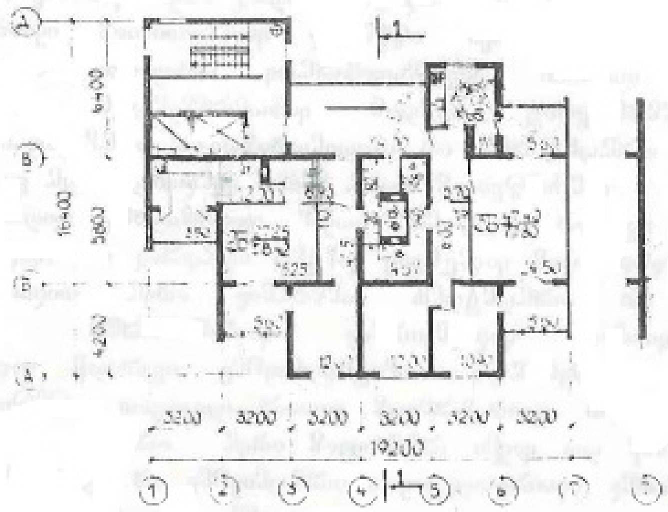

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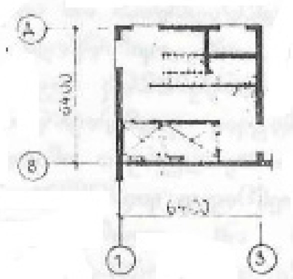

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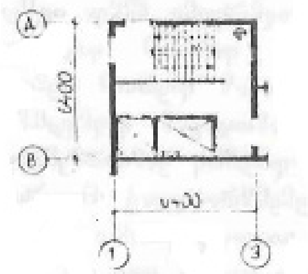


ЭКСПЛИКАЦИЯ КВАРТИР

Квартиры (тип)	Кол	Площадь, м2	
		жилая	общая
Двухкомнатные 2Б	14	27.25	56.42
Трехкомнатные 3Б	14	47.90	77.90

In general, the 1969 master plan considered improvement of housing planning and comfort conditions. Another technical type design of the 9-floor dwellings belonged to a group of architects that was led by Chief Architect of the Tbilisi City, Kavlashvili. This type design series appeared in Tbilisi from mid 1970s and is considered as the best among all the existing type design series because of its interior plans, increased useful area per inhabitant and better quality of construction itself. The total useful area -F by number of rooms in Kavlashvili type design series is shown below:

- One room apartment (with loggia): F useful = 51.2 m^2
- Two room apartments (with loggia): F useful = 69.2 m^2
- Three room apartments (with loggia): F useful = 81.3 m^2
- Four room apartments (with loggia): F useful = 92.2 m^2
- Five room apartments (with loggia): F useful = 110.0 m^2

Buildings Constructed between 1991 and the present day

After 1991, the housing construction almost stopped, due to years of economic hardships. MoESD assisted business sector with the creation of favorable conditions for business application procedures in order to stipulate investments in the construction sector. According to the World Bank report8, Georgia was ranked 8 globally for issuing construction permits.

Despite the absence of Georgia's own national standards, the new attractive dwellings appeared in the different districts of Tbilisi. Builders and developers were competing to offer housing with beautifully designed facades and apartments of different sizes. After the initial period of suspension, the housing construction has boosted and reached its peak in 2007-2008, when almost 2 million m^2 a year was built.

In 2008 after the Russian-Georgian war, construction activities rapidly dropped in Georgia, triggered by uncertainties with the real estate market. However, the Tbilisi City Hall supported boosted confidence by guaranteeing to purchase all finished developments at the cost recovery price.

As of today, the housing sector of Tbilisi is gradually developing, offering innovations to customers. Several advanced companies have started to offer apartments built with enhanced energy performance and energy efficiency of building envelope. Such buildings significantly reduce energy bills in winter, since the energy demand on gas consumption for heating purposes is approximately reduced by 40%. These insulated buildings produce benefits in summer as well, due to reduced need for air conditioning.

Table 4: Completed apartment buildings in Tbilisi in 2014-2018

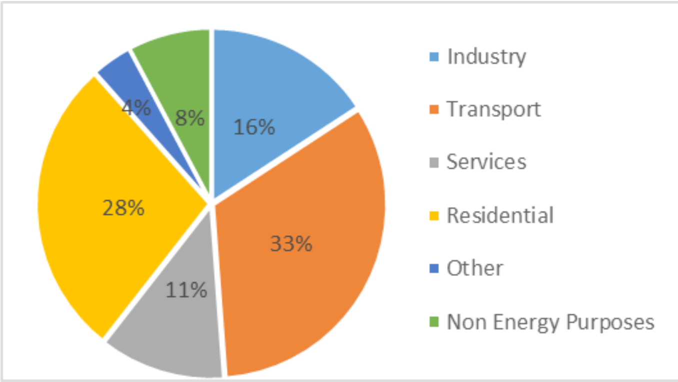
Years	Number	Area (m^2)
2014	937	1,236,585
2015	646	910,568
2016	933	1,551,742
2017	860	1,338,288
2018	744	1,229,317

8 A World Bank Group Flashing Report. Doing Business 2017. Equal Opportunity for All. Economy Profile 2017. Georgia. 14th Edition. © 2017 International Bank for Reconstruction and Development / World Bank.

Energy Consumption of the Residential Building Stock in Georgia

According to the 2019 energy balance report from the National Statistics Office of Georgia, energy consumption of the residential sector constitutes about 28% of the total energy consumption balance of the country, which is the second highest compared to any other sectors nationwide.

Figure 10: Breakdown of the building stock of Georgia by sub-categories



The total area of residential building stock in Georgia is 110.20 million m², of which approximately 31% is in Tbilisi. The energy consumption of residential building stock of Tbilisi amounts to 3.3 million MWh.

Table 5: Energy consumption by the residential stock in Tbilisi

Total area of residential buildings, m²	Quantity	Residential Fuel Consumption, MWh					Total
		Electricity	Natural gas	Liquid gas	Fuel wood	Diesel	
33,825,442	82,681	960,690	2,366,300	0	0	0	3,326,990

Source: NIRAS, ENSI, SDAP and ECN – Program: "Consultancy on Energy Efficiency and Sustainable Energy in Georgia: Report on: Initial data collection and analysis for New National Energy Efficiency Building Code"

The results of the assessment carried out by NIRAS, ENSI, SDAP proved that the mandatory required thermal resistance – Rreq values have decreased significantly during the Soviet period construction, compared to the period of the pre-1922 stock, especially with introduction of the mass construction "Khrushchev era" housing programs.

Figure 11: Changes of thermal transmittance coefficients for exterior walls in Georgia and other countries

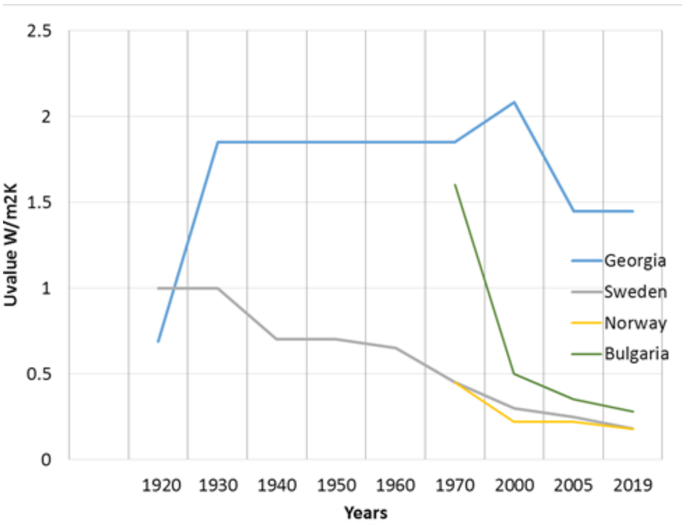


Figure 11 shows the changes of thermal transmittance coefficients (U values) for walls of the housing stock during the one century period in Georgia in comparison with Sweden, Norway and Bulgaria after 1970s. It should be noted that the entire housing stock of Tbilisi built during the Soviet period and after independence, looks identical in relation to heat engineering. Fair to say that the building stock is not efficient and requires high energy consumption to cover its energy demand. Therefore, it can be concluded that housing stock of Tbilisi possesses the great energy saving potential, however appropriate regulation is needed to obtain the positive changes regarding reduction of energy consumption in this sector.

Heating and Domestic Hot Water Supply Systems used by Housing Sector in Tbilisi

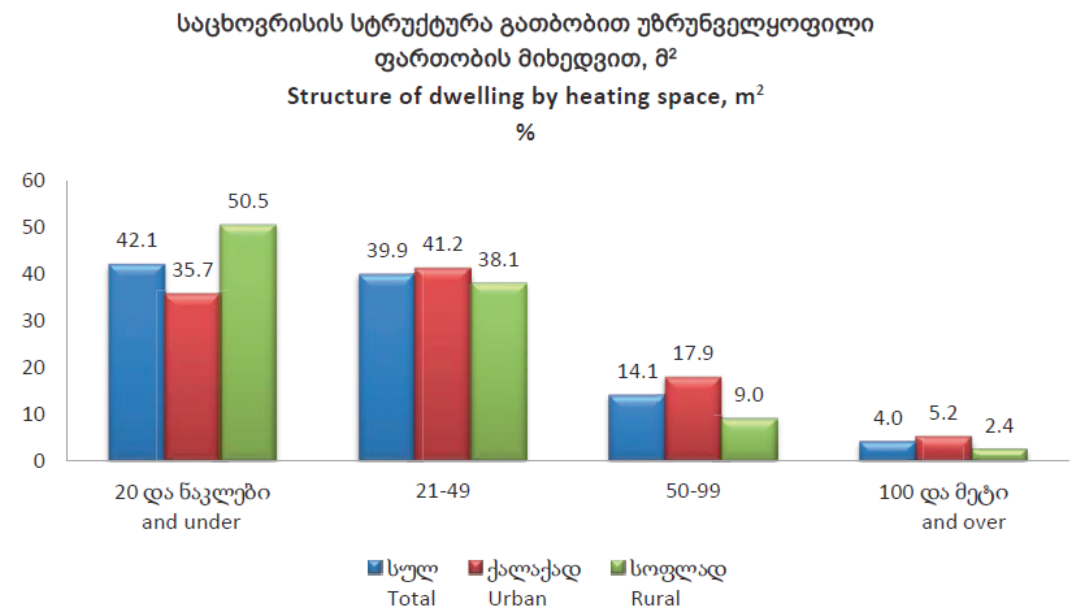
According to the survey carried out by the National Statistics Office of Georgia9 the breakdown of residents by occupied useful area, is as follows:

- 6.2% occupy the useful area under 30m;
- 12.7% occupy range of: 31-50 m of the useful area;
- 42.1% occupy range of: 51-100m of the useful area;
- 39% occupy over 101m of the useful area.

The survey suggests that low income families mostly heat part of their apartments' space. The survey results show that 35% of the population heats one room in the apartment with the area around 20 m², and 41.5 % of the residents' heat the area of 21-49 m². Chart presented below illustrates the percentage of distribution of dwellings by heated space in urban and rural areas of Georgia.

The survey underlines the importance of implementing energy efficiency in buildings that will contribute to reduction in energy consumption for heating and improvement of indoor climate conditions and level of comfort as well. Overview of the heating and hot water supply systems shows preferences to two types of heating and domestic hot water (DHW) systems that are favored by residents, including the multi-apartments dwellings, due to the fact of availability of central gas supply system in the building.

Figure 12: Distribution of dwellings by heated area in urban and rural areas of Georgia



9 Energy Consumption in Households National Statistics Office of Georgia, 2017 https://www.geostat.ge/media/20691/energoresursebi_2017.pdf

Heating systems

Practice of installation of central heating system with single boiler for provision of heating and hot water supply does not exist in Tbilisi. The option of central heating systems is non-existent in newly constructed buildings as well. As of today, the residents of Tbilisi mostly use the following types of heating systems:

- Individual central space heating system for provision of the heating combined with DHW supply;
- Local heater for DHW supply local water heaters running on gas or electricity.

Individual central heating system with the gas boiler consists of main elements such as:

- Combined water-heating gas boiler (hanging models);
- Pipeline system for hot water distribution to radiators and DHW system;
- Water heating radiators with valves.

There are two types of radiators that are used in Georgia - sectional aluminum radiators or panel type steel radiators. Heating radiators are often equipped with the thermostatic valves that allow autonomous temperature control and, consequently provide opportunity to achieve substantial gas savings.

In case of individual central space heating system combined with the DHW supply the gas consumption ranges of 1-1.5 GEL/m² per month10. However, the gas consumption bills differ significantly depending on type of windows features, residents behaviors, boiler efficiency, and the thermal properties of the building envelope.

Domestic Hot water systems

Low-income families are installing local wall mounted gas heaters. These heaters have relatively low cost, and their installation is associated with a very simple and quick performance. These wall mounted units are installed inside, usually under the window.

These heaters have a hermetic combustion chamber in which the combustion process is separated from the indoor environment. Heaters with a closed combustion chamber are equipped with the double chimney system. One chimney is used for the intake of clean air needed for combustion and the second for removal of the combustion products. These heaters tend to have an efficiency of around 75%-80%11 and reach relatively high temperatures during operation, creating a health & safety hazard to the habitants.

The buildings that use the local gas heaters for heating, mostly use the autonomous wall hanging gas or electric water heaters in combination with hot water distribution piping system for hot water supply purposes. These heaters often pose high risks for health and safety.

Outlook of the Energy Saving Potential for the Energy Efficiency Retrofit of the Residential Building Stock in Tbilisi

Rationale for Evaluation of Energy Saving Potential of the Residential 8-Floor Multi Apartment Buildings in Tbilisi

For the purpose of this assignment, a group of the Bank experts in close collaboration with the technical staff from the Mayor's office reviewed a group of multi-apartment buildings from the Soviet period and analyzed them to select a sample building. The selection criteria was the following: (i) three uniform block section units per floor, which is the most common type of construction for the Soviet period, representing the Khrushov Housing Program; (ii) presence of no/minimum interventions or illegal extensions on the building facade (during the post Soviet era, many of the building underwent additional developments by the residents, such as further extending balconies, or building a new section, etc. without proper design and omitting the minimum construction requirements); (iii) willingness of the residents to collaborate during the design development.

10 Winrock International, SDAP Center and Remissia, 2011 SEAP of Tbilisi City

11 Ibid

willingness of the residents for identification of the energy saving potential and the development of the energy efficiency measures.

Evaluation Methodology of Energy Savings Potential and Assessment of the EE Measures

For evaluation of the energy saving potential, a sample "Kalakuri" 8-floor type design residential building was selected. Energy assessment was carried out with the ENSI EAB software program, which is a solution used to calculate the energy performance of buildings in energy audits. The software offers modeling results in a form of energy performance scenarios such as: the "Baseline scenario" and the "EE scenario" and defines energy consumption of building after implementation of EE measures as well. The scope of the energy modeling covered:

- Analysis and establishing of the baseline energy use for the selected building. "Baseline scenario" provides the required energy consumption for the building needed for the provision of comfortable conditions at the present situation. Site visits confirmed that the single glazed windows were partly replaced with double glazed windows in the previous times. Therefore, it was decided to carry out evaluation of the baseline energy consumption scenario under assumption that the 50% of windows area are represented by the single glazed windows with the wooden frames and the remaining part of windows are double glazed with the metal plastic frames.
- Forecast of the future energy use after implementation of energy efficiency improvements;
- Assessment of the calculated energy savings.

In order to provide reliable results of energy modeling, the team made a decision to select the most common type of a 8-floor apartment block with the input data consisting of building geometry and thermal transmittance coefficients: U values of the exterior components that derive from the building and is in use since 1966.

Figure 13: Layout of a typical floor for a typical 8-floor multi-apartment block-section unit

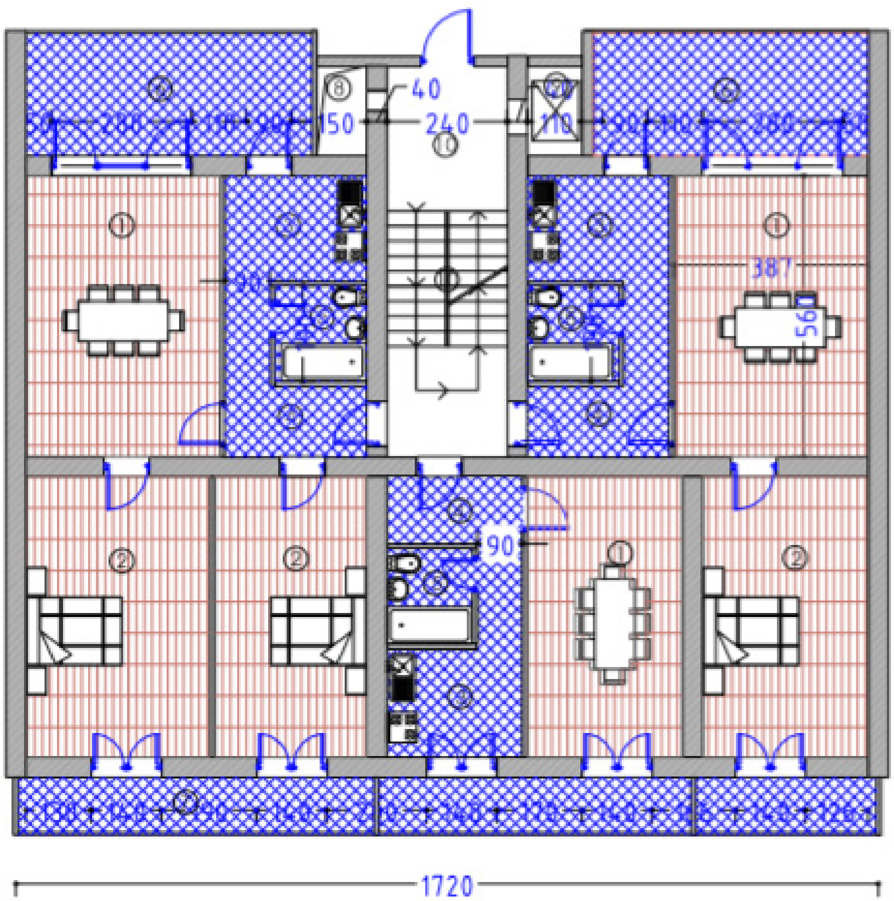
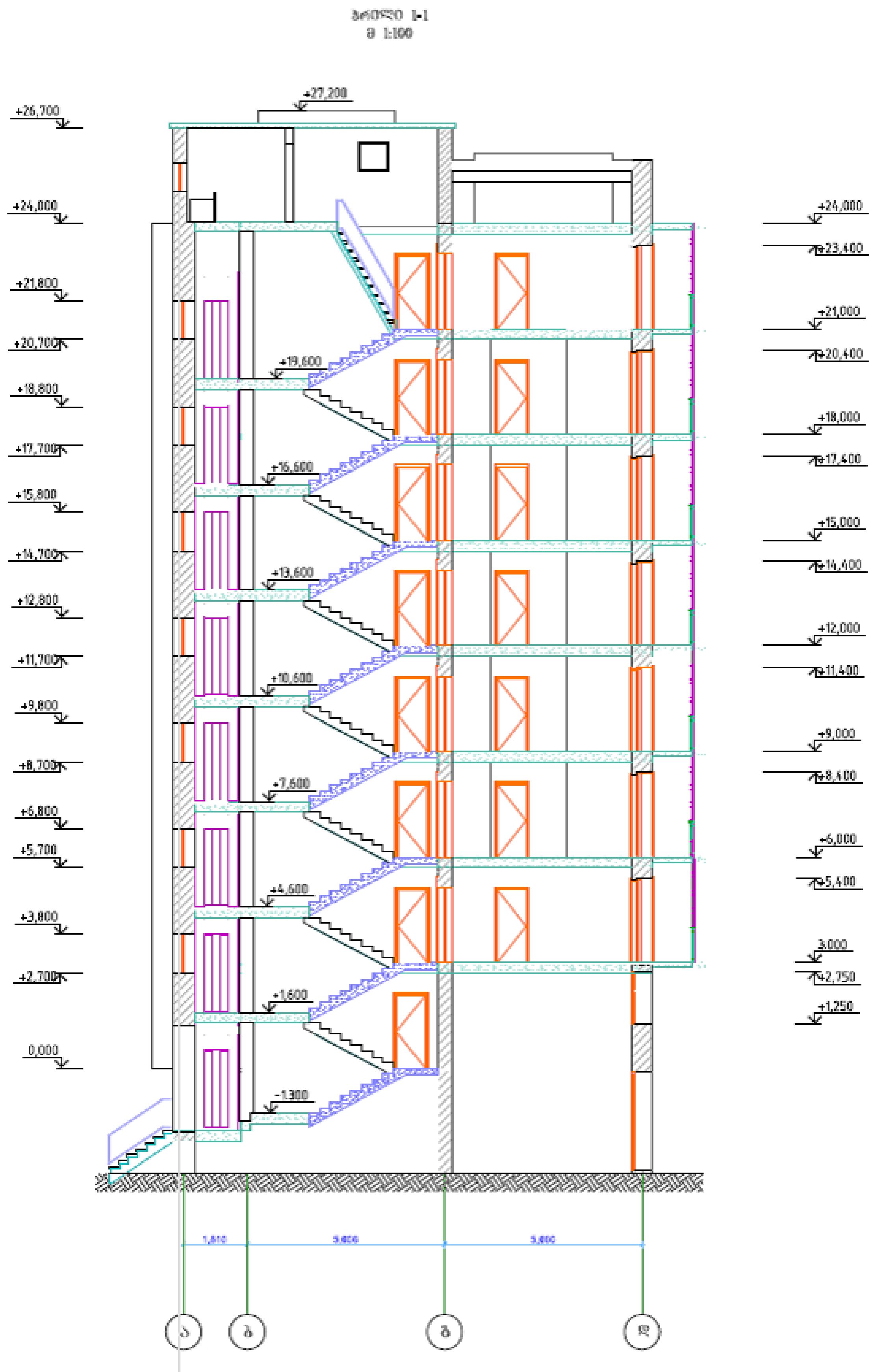


Figure 14: Sections of the selected multi-apartment dwelling with 3 blocks



The selected multi apartment dwelling has 8 floors above ground, unheated basement under the whole building and unheated attic space. The building has the 3 main entrances one per uniform block-section. Building geometry characteristics such as area of the individual building envelope elements together with the energy performance indicators of properties are as follow:

Walls & Area

- Total heated/ inner area of building: F=5,728 m^2
- Footprint area: F=716 m^2
- Total area of the external walls: F=2,500 m^2
- Windows and glazed doors area: F=1,029 m^2
- Roof area: F=716 m^2
- Floor area: F=716 m^2

U values

Walls of dwelling are built from bricks with thickness: δ=0.40m. The overall U-value of the walls is calculated as: U=1,52 W/m^2K including thermal bridges.

Openings are represented by transparent windows and doors and opaque doors as well. Windows and balcony doors are transparent and comprise 50% of single glazed, wooden framed as well as 50% of double glazed and plastic framed windows and doors without the low emissivity glazing.

The solar gain factor is taken as 0.56. Infiltration rate of external air due to aeration and natural ventilation is around 0.5h-1. Heat capacity of the building is 46.0 KWh/m^2K.

Table 6: U values for the "Baseline Scenario"

Climate zone 2	U – wall	U –roof	U –floor	U-window	U –door
	[W/m^2K]				
Tbilisi	1.64	1.2	1.1	4.57	4.57

Heating and DHW

Building is heated partly with apartment space heating systems with boiler installed per flat and partly with the local wall mounted gas heaters or local electric heaters. The DHW supply is run by boilers, operating with the double-circuit in 50% of apartments with the installed space heating systems and the remaining part of apartments have installed local hot water heaters that run on electricity or natural gas.

Lighting

Apartments have enough natural light most of the day. For the remaining time the lighting system is represented by combination of fluorescent (CFL) and incandescent bulbs.

Results of Energy Modeling

In order to satisfy the energy need i.e. the annual energy input for heating, ventilation and domestic hot water systems of the referenced building, ENSI EAB software was used to determine the baseline scenario.

In order to generate energy consumption for the baseline scenario the external areas of building envelope components were used with the associated U values given in the Table 6.

The software generated annual energy budget and provides amount of the saved energy consumption that actually presents difference in energy consumption between the "Baseline Scenario" and "After EE measures and Renovation" scenarios. It also distributed amount of the saved energy per EE measure.

Table 7: Energy balance of the selected building in kWh per year

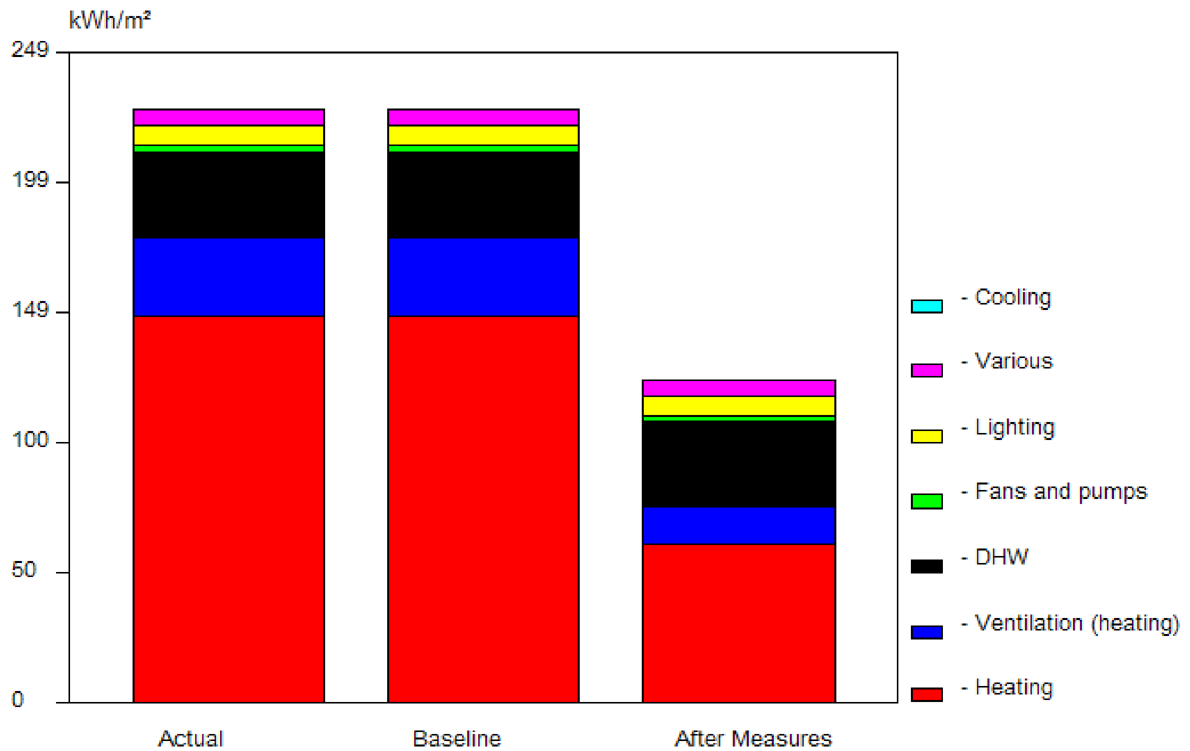
Budget Item	Actual	Baseline / Before EE	After EE Measures
	[kWh/year]		
Heating	846,146	846,146	294,746
Ventilation	202,166	202,165	91,448
DHW	187,946	187,946	187,946
Fans and Pumps	14,071	14,071	14,071
Lighting	41,814	41,814	41,814
Various	35,125	35,125	35,125
Total	**1,327,267**	**1,327,267**	**665,150**

Table 8: Energy balance of the selected building in kWh/m² per year

Budget Item	Actual	Baseline / Before EE	After EE Measures
	[kWh/m²]		
Heating (gas)	147.1	147.1	51.5
Ventilation	35.3	35.3	16.0
DHW	32.8	32.8	32.8
Fans and Pumps	2.5	2.5	2.5
Lighting	7.3	7.3	7.3
Various	6.1	6.1	6.1
Total	**231.7**	**231.7**	**116.1**

Calibration of the software model was done with assumption that the "Actual" and "Baseline" energy consumption scenarios constitute the equal figures. Such assumption is based on understanding that assessment is carried out for the targeted group of the residential buildings and not just for one of them.

Figure 15: Annual energy consumption computed by the ENSI software



Energy Saving Potential and List of EE Measures

The proposed measures were selected for insulation of the building envelope and provision of air circulation and conservation of heat. The energy saving potential constituted 662,117 kWh/year that derived as the difference between the “Baseline” and “After EE Measures” scenarios and accounting for the insulation of roof, exterior walls, installation of the new EE windows and doors, and installation of individual ventilation units with heat recovery.

Table 9: EE potential per measure

Residential multi apartment dwelling heated area:					5,728 m^2
EE measures	**Initial investment [USD/GEL]**	**Net savings [kWh/yr]**	**Net savings [USD/GEL/yr]***	**Payback [year]**	**NPVQ**
Insulation of the roof (attic floor)	21,417.0/60,137	58,190	1,810/5,081	11.8	0.08
Insulation of the walls	127,110/356,912	244,436	10,185/28,600	12.5	0.02
Installation of the new EE windows and doors	116,277/325,495	255,555	10,197/28,631	11,4	0.12
Individual ventilation units with heat recovery	65,520/183,974	103,936	6,848/19,228	9.6	0.25
Total all measures in package	**330,325/927.518**	**662,117**	**29,040/81,540**	**11.4**	**0.05**

** The price of gas is calculated at GEL 0.47 per m^3, and the electricity tariff is calculated at GEL 0.18556 per kWh.*

A brief description for each proposed EE measure, associated costs, savings and the payback period is as follows:

Measure 1: Insulation of walls

- **Description of the existing situation:** Walls of the residential building are constructed from panels with 0.4m thickness. Due to this insufficient thickness and absence of insulation the thermal losses of the building are significantly high.
- **Description of EE measure:** For improvement of thermal properties of walls, it is proposed to insulate walls with the heat insulation, such as rock wool or mineral wool to achieve the suggested by EE standard of new U value = 0.38 W/m²K. The mineral or rock wool insulation is suggested specifically because it is a diffusion open material that will provide a “breathable facade” in combination with the other components of the external thermal insulation composite system/ETICS. This will require application of the 8 cm insulation layer. Insulation is one of the components of a system that includes besides insulation layer also plastic mesh, primer, plastering and paint. The thermal conductivity of insulation layer constitutes: ƛ=0.04W/m²K. It is also foreseen to insulate the plinth area of: F=120 m with the XPS boards approximately 0.8 m below ground level and installation of an additional protective and drainage layer (dimple sheet) for proper insulation of the building. With insulation of walls the amount of saved energy calculated by the software is defined as: 244,436 kWh/y.
- **Investment:** Investment cost per/m² for insulation system covering all other costs related to construction works and transportation constitutes 45 USD per/m², including VAT. For the application of insulation on the northern facade of the building, the installation of a metal frame system is proposed with the subsequent fastening of insulation. This technical solution is predetermined due the thin outer walls (under the windows) of the loggias, built at the time of the commissioning by tenants. With elaboration of above technical solution the thermal insulation will be applied on all facades of the residential building, except the Southern one that will be covered by 60% with insulation. Such decision was made by the WB team, as insulation can’t be applied fully, since part of the residents extended balcony areas to the inner part of apartments by erecting thin walls. Therefore, application of the insulation on these walls isn’t possible from the engineering perspective, since they will not withstand the load of insulation system/ETICS. The total investment for walls will constitute: 110,000 USD (308,869 GEL). Insulation of plinth area, together with excavation works and asphalt covering will be 17,110 USD (48,043 GEL).

- **The total investment for walls and plinth area:** 127,110 USD (356,912 GEL).
- **Net Savings:** 10,185 USD (28,600 GEL) a year.
- **Economic Lifetime:** 30 years.

Measure 2: Insulation of the attic floor

- **Description of the existing situation:** The selected multi apartment building is built with the attic roof, without consideration of energy efficiency.
- **Description of EE measure:** the heat insulation such as the rock wool or mineral wool shall be applied to the attic floor to achieve the proposed by the EE regulation the new U value = 0.30W/m²K. This will require the application of a 10 cm of rock wool or mineral wool with the thermal conductivity ƛ= 0.04 W/m²K over the attic floor.
- **Investment:** Investment cost per/m² for this measure also includes the insulation of attic walls with the height about 1.0m from the attic floor. This is required in order to avoid thermal bridges. It is estimated that for materials and the construction works the investment will be about 25.6 USD/m², including VAT.
- **Total investment cost:** 21,417.0 USD (60,137 GEL)
- **Net Savings:** 1,810 USD (5,081 GEL) a year
- **Economic Lifetime:** 30 years

Measure 3: Replacement of the Windows

- **Description of the existing situation:** The building was commissioned with single glazed windows and doors in wooden frames. Part of the residents replaced old windows with double glazed windows in plastic frames. The above window technology is characterized with higher U value = 3.3 W/m²K, than EE standards suggest to apply.
- **Description of EE measure:** After the renovation works, all existing windows will be replaced by the new double glazed ones with the low emissivity glazing in plastic frames in order to achieve the U value = 1.8 W/m²K.
- **Investment:** Investment cost for installation of new windows and doors with low emissivity glazing, together with the sealing tapes that have to be installed on high quality frames amounts to 113 USD per/m², including VAT.
- **Total Investment:** 116,277 USD (326,495 GEL).
- **Net Savings:** 10,197 USD (28,631 GEL).
- **Economic Lifetime:** 20 years.

Measure 4: Individual ventilation units with heat recovery

- **Description of the existing situation:** As of today, due to the absence of insulation, the infiltration in the building is high. After insulation of the walls and roof infiltration will decrease. Ventilation is key in thermal modernization technical designs. Therefore, it is important to install a ventilation system in the building to ensure provision of comfortable indoor conditions with mechanical intake of a fresh air.
- **Description of EE measure:** To ensure operation of ventilation in the building, it is proposed to install the individual supply/exhaust ventilation wall mounted units with heat recovery/per room. 144 ventilation units with heat recovery such as Micra 60 A3 will be required.
- **Investment:** Installation of the wall mounted ventilation unit with heat recovery costs 455 USD (per unit). The total investment cost with installation for 144 such ventilation units including VAT will be 65,520 USD (183,974 GEL).
- **Total Investment:** 65,520 USD (183,974 GEL)
- **Net Savings:** 6,848 USD (19,228 GEL) a year
- **Economic Lifetime:** 15 years

Roof Insulation

A very important source of heat loss from a house is through roof and attic. Attic insulation is a thermally insulated, protective interior cladding procedure involving the use of glass or rock wool, polyurethane foam or phenolic foam.

The purpose of roof insulation is to reduce the overall heat transfer coefficient by adding materials with low thermal conductivity. Roof and attic insulation in buildings is an important factor to achieving thermal comfort for its occupants. Roof insulation as well as other types of insulation reduce unwanted heat loss and also reduce unwanted heat gain. They can significantly decrease the energy demands of heating and cooling systems. It must be added, there is no material which can completely prevent heat losses, heat losses can be only minimized.

Wall Insulation

An external wall insulation system is a thermally insulated, protective, decorative exterior cladding procedure involving the use of expanded polystyrene, mineral wool, polyurethane foam or phenolic foam, topped off with a reinforced cement based, mineral or synthetic finish and plaster.

The thickness of thermal insulation is dependent on whatever type is required in order to create a partition with a heat transmission factor of U=0.25-0.3 W/m^2K. When calculating the actual insulation requirements, consideration must be given to current Building Regulation standards. Consideration must also be given to exposure and durability, and whether the structure might be subjected to vandalism etc. In many older properties, special attention is required for concrete beams or lintels which act as thermal bridges providing poor insulation.

External wall insulation systems generally comprise firstly an insulation layer (an element which helps to achieve the requisite thermal performance); and secondly, a protected weatherproof finish (usually a render, although brick slips, tiles, and decorative boards can also be used). Insulating render can also be an advantage in certain locations. Choice of types and sizes will depend on the substrate and design exposure requirements.

Double Glazed Windows

An insulated glass unit (IGU) combines multiple glass panes into a single window system. Most IGUs are double glazed (two panes of glass) with three panes (triple glazing) or more becoming more common due to higher energy costs. The panes of glass in IGUs are separated by a spacer and a still layer of air or gas. The glass is then fitted into window frames, which is made wider to accommodate the two panes, thus becoming double glazed. Double glazed windows are an ideal energy efficient choice with the added benefit of minimizing noise. The sealed air gap between the two panes acts as an added layer of insulation. This added thermal resistance reduces the amount of heat escaping in winter and keeps the space at a more comfortable temperature. Double glazing has the reverse effect in summer, preventing unwanted heat from coming into the home. This extra insulation lessens the reliance on artificial heaters and air conditioners and can ultimately reduce your energy costs.

Ventilation and Heat Recovery

The system of mechanical ventilation with heat recovery not only ventilates premises, but also provides a sufficient amount of preheated outdoor air, which is saturated with oxygen and natural ions. Air flows pass through a copper heat exchanger located inside the working module, where they are separated from each other both inside the working module and at the “input-output”. The two air flows do not mix at any point.

In the ventilation system warm exhaust air, which is removed from premises, heats up the fresh cold air that enters from the outside. In summer, on the contrary, it cools the air down.

The system uses sensors to monitor, correct and control the airflow in any indoor environment. The sensors are capable of detecting changes to atmospheric pressure, temperatures, air quality, CO_2 build up and humidity. This allows Prana to be far more effective than any other competing device on the market.

Guidelines: Technical Solutions & Recommendations for the Energy Efficiency Retrofitting Designs

Overview

The guidelines presented below follow the regulation requirements on maximum allowed thermal transmittance $\bar{U}_{max}$ of aggregated elements of thermal building envelope, as defined in Table 2 of this report.

Insulation of walls

Wall insulation will help reduce energy costs. All exterior walls shall be insulated to effectively reduce the flow of heat in and out of the building indoor space. Insulating exterior walls should always be a priority over insulating the interior of the home. The thermal transmittance value $\bar{U}_{max}$ for walls, according to the guidelines, is proposed as U value of 0.38 W/m² K. The existing U value of the walls for the selected building is 1.64 W/m²K. Therefore, to meet the requirement stated in the regulation, it will require the application of 8 cm insulation layer to the walls.

Insulation of the attic floor

To reduce the energy losses, the insulation shall be applied to the attic roof as well. The thermal transmittance value $\bar{U}_{max}$ of the attic floor shall be 0.3 W/m²K. The existing thermal transmittance U value of the attic for the selected building is 1.2 W/m²K. To meet the requirement, application of a 10-cm rock wool or mineral wool with the thermal conductivity of λ= 0.04 W/m²K over the attic floor will be required.

Installation of windows

The new double glazed windows with the low emissivity glazing in plastic frames with the U value = 1.8 W/m²K are proposed in the guidelines. This is fully aligned with the regulation requirements for transparent elements/windows and doors, as guided by Table 2.

Individual ventilation units with heat recovery

Ventilation systems provide controlled ventilation of the building space while minimizing energy losses. They reduce the costs of heating ventilated air in the winter by transferring heat from the warm inside air being exhausted to the fresh supply air. When conducting energy retrofitting of a building, individual ventilation units with heat recovery can serve as a best solution. This measure comprises with the regulation requirement – the obligatory installation of the heat recovery as the required element of a new ventilation system. SNIP 2.08.01-89* defines the required standards of air exchange for multiple types of living and support spaces. For easy reference, it can be summarized as the following: the total living space to be ventilated must be multiplied by 3 (other factors, such as natural ventilation, shall be also considered) to meet the required air exchange. For instance, if the space to be ventilated is 20 m², 60 m³ of air exchange is required per hour.

Technical Solutions for the Insulation of Building Envelope Components

The exterior components of the building shape its envelope that presents barrier and divides the inside and outside environment. In return the thermal performance of the building envelope stipulates demand on energy consumption for provision of comfortable indoor conditions.

Insulation of Walls

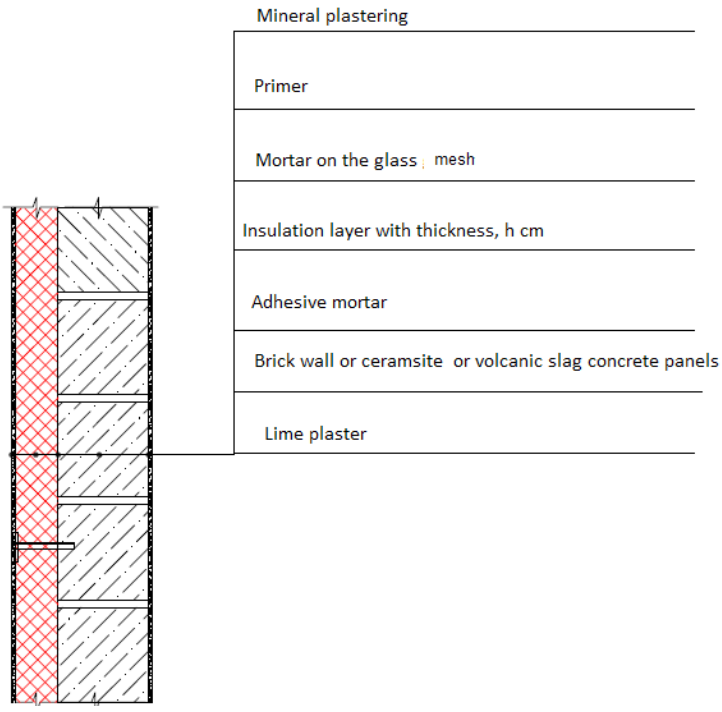
External walls are the most important structural element of the building. They support ceilings and the roof and protect the interior of the building against external factors. At a time of rising energy prices, walls should, above all, protect a house from the escape of heat. Appropriate thermal insulation can prevent heat from escaping.

As part of the current regulations, exterior wall must be a part of an approved and certified system. The insulation material has to comply with the following standards:

- Mineral wool (MW): EN 13162
- Extruded Polystyrene (XPS) for areas that are exposed to splash water: EN 1316

For insulation of walls the insulation layer has to be fixed on the wall, together with other elements of the composite system such as: glass fibre mesh, mortar, primer and mineral plastering as well. Scheme for fixation of insulation (depending on the density of insulation material itself as well as other particularities) is provided usually by manufacturer, meaning that instructions have to be followed properly at the installation phase.

Figure 16: Application of insulation on the exterior walls



Technological steps for application of the composite insulation system onto the walls above the ground level are shall be the following:

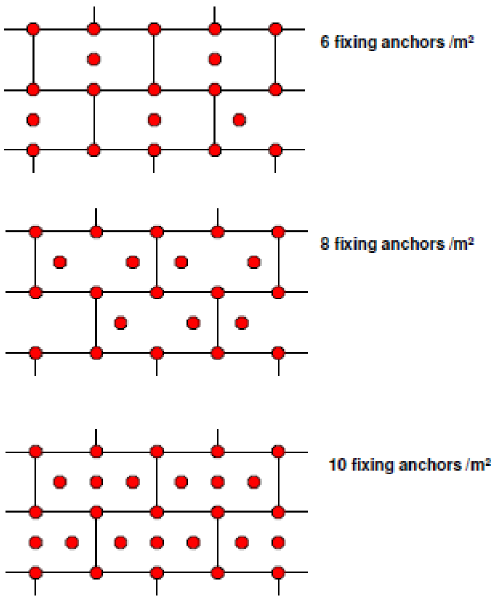
- Preparation of surfaces of external building envelope for works on insulation;
- Fixing of perforated plinth profiles to the bottom of the building along its perimeter;
- Applying a primer on the surface of the outer walls;
- Preparation of adhesive mortar solution made of dry mixture and water;
- Applying adhesive mortar solution on the surface of insulation plates and gluing them to the surface of the building envelope;
- Sealing of the places of junction of insulation plates to window and door frames with, as well as junction points of insulation plates with a cornice plate;

- Arrangement of expansion joints in the insulating coating;
- Fixing insulation plates on the building envelope structures with the help of connecting elements (anchors);
- Preparation of adhesive mortar solution of dry mixture and water and applying it to the surface of the insulation;
- Fixing the perforated profiles on the edges of the first floor, as well as on the perimeter of the window openings of the building and gluing the strengthening fiberglass mesh over the entire facade of the building;
- Applying a primer on the surface of a hydro protective layer;
- Preparation of decorative plaster solutions from dry mix and water;
- Plastering the surface of the facade;
- Painting the facade of the building;
- Ensuring the protection of the ends and abutments of the thermal insulation structures from precipitation.

According to the technological steps described above the typical refurbishment works for insulation of the exterior walls must start with preparation of walls for application of the insulation system. Description of the preparatory works are listed as follows and are subject to variation according to the actual needs of the individual project. Generally, it must start with:

- Temporary removal of all kind of equipment that is mounted onto external walls such as metal service staircase and ladders, air conditioning units, pipes, electric equipment, etc.;
- Demolition of all building elements, which are not of any structural importance. The evenness of the facade allows a simpler installation. Ornaments can be replicated with special heat-insulation profiles;
- Removal of the old plaster from the exterior walls.

Figure 17: Distribution scheme for fixation of anchors



Manufacturers' instructions on arrangement of fixation of the insulation with the anchors must be executed. The distribution scheme for fixation of anchors depends on density of insulation material and can differ as shown on the Figure above.

Afterwards the base coat has to be prepared and applied according to the instructions of the system supplier. The glass fiber mesh has to be embedded in the freshly applied base coat with an overlap of at least 10 cm. The glass fiber mesh must be covered with at least 1 mm of base coat mortar.

On corners of window and door apertures, diagonal reinforcements are necessary and should be embedded in the base coat before applying the surface reinforcement and have to be fixed so that the edge of the strip is applied directly to the corner at an angle of approximately 45 degrees. The dimensions of the reinforcement strips are approximately 20x40 cm.

Profiles with laminated glass fiber mesh and fabric corner strips are used for corners and edges. The connection with the surface reinforcement is to be executed with an overlap of at least 10 cm. Plastic profile with laminated glass fiber mash are used for the connection to windows/doors.

After allowing the base coat sufficient time to harden and following application of the system primer (follow manufacturer's instructions) and given suitable weather conditions, the final coating can be applied. A minimum layer thickness of ≥ 1.5 mm for a primarily structure is required.

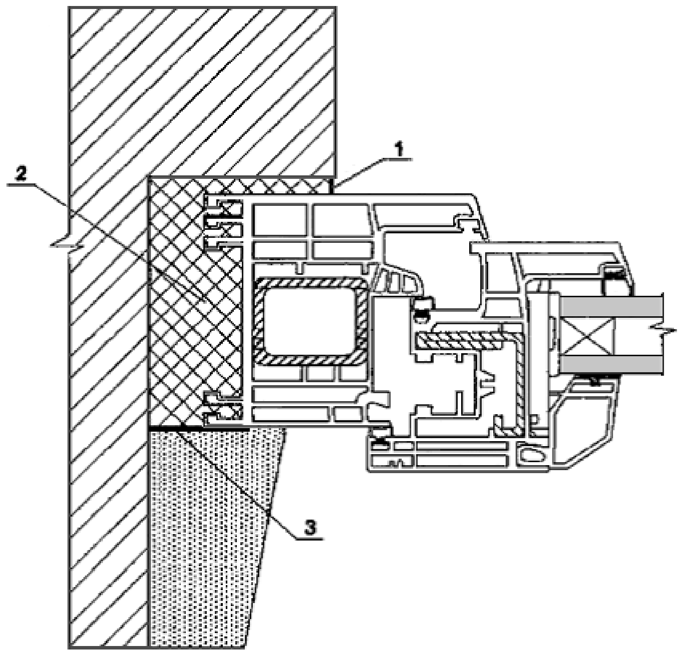
In the perimeter area, the finishing coat should be protected against the penetration of moisture through appropriate sealing. After determining the exterior level, all system components in the area coming into contact with the earth are given a waterproof coating, i.e. sealing compound or bitumen coating, and protected by a textured waterproof membrane

Diffusion tight XPS boards covered with the protective membrane will be used, for the insulation of building and protection of foundation from water penetration. Excavation of soil approx. 1m below ground level around the building for this purpose, in order to install a hydrophobic insulation with additional protective and drainage layer.

Installation of Windows

For enabling energy efficiency, the junctions of windows and doors to the walls will be sealed in such a way that air tightness of the junctions is maintained throughout the operation period of windows. The principal scheme should be the following:

Figure 18: Junction principal scheme



1- External waterproof vapor permeable layer (pre-compressed sealing tape or diffusion open sealing tape type SOUDAL or similar);
2- Intermediate thermal insulation layer;
3-Internal vapour-proof layer (diffusion tight sealing tape type SOUDAL or similar).

The connection joint of the window/door and the building shell must meet the requirements of stability, thermal protection, moisture proofing and sound insulation.

Requirements for windows installation encompass the following steps:

- Removing of all loosen parts of the wall;
- Application of a trowel-finished layer (smooth finish) to the existing reveal of walls;
- The surface of the wall opening must be smoothed (as accurately as possible) and fair faced in order to allow a proper sealing;

- The fixing of the window must take into account the transmitted loads, the strength of the surrounding structural elements and the movements in the connection joint;
- The minimum distance between the window/door case and the wall opening must be at least 10 mm, the max distance shall not more than 20 mm.

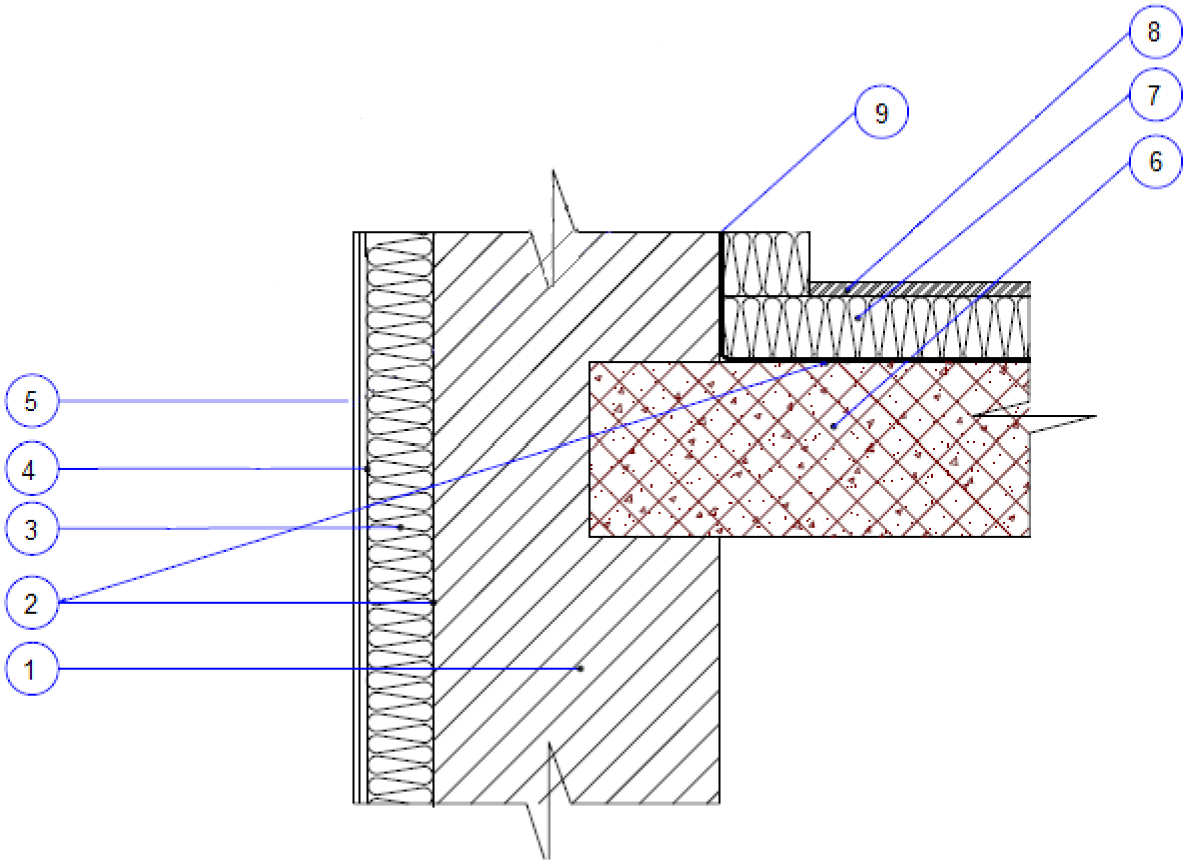
For installation of the external window sills it is suggested to consider the following recommendations such as:

- The material of the window sill should be aluminum;
- The joint of the window sill with contiguous building elements (window frame, reveal, guide rails for solar shading, etc.);
- The slope of the window sill will not be less than 5 degrees;
- A wedge-shaped insulation block shall be installed underneath the window sill;
- The overhang of the window sill shall be min. 40 mm (to the finished surface of the facade).

Insulation of the Attic Floor

Insulation of floor of the attic is one of the common measures of the high energy performance buildings.

Figure 19: Insulation of the attic floor



1- Wall structure
2-Adhesive mortar layer
3- Facade insulation (the rock wool or mineral wool) layer
4-Mortar layer applied onto fiber glass mesh
5- Primer and Plastering
6- Reinforced concrete slab
7- Insulation layer of attic
8-Cement sand screed over the mineral wool
9- Vapor barrier

As shown in the figure, the insulation layer shall be applied on the walls inside of attic with consideration of 1.0 m height from the level of the attic floor. This is in accordance with the application of external thermal composite insulation systems (ETICS) to avoid thermal bridging.

Installation of the vapor barrier on top of the reinforced concrete slab of the attic floor and the walls inside the attic will prevent moisture penetration inside of the building. It is recommended to apply the roofing material like Ruberoid over the cement screed.

Thermal Insulation of the Flat Roof

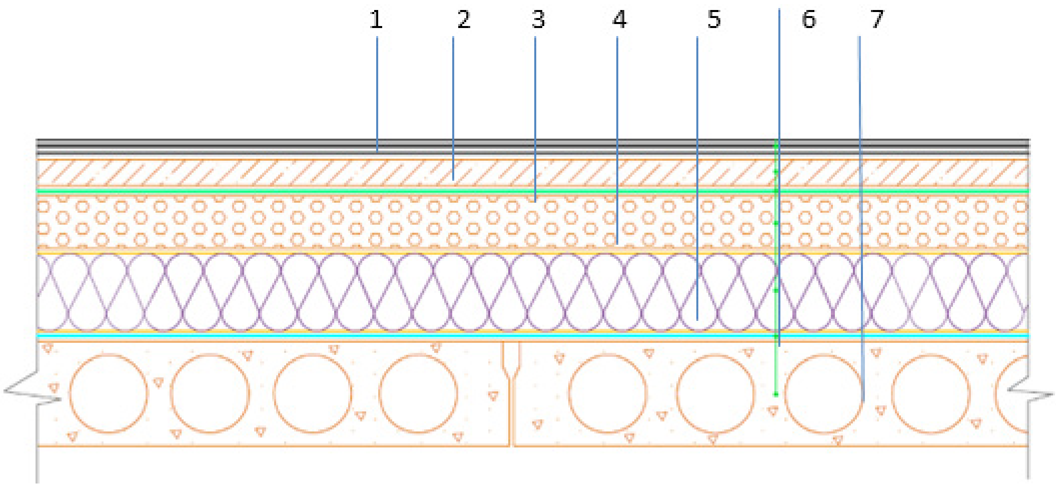
Thermal insulation of a flat roof will be carried out based on particularities of the building envelope. A thermal roof insulation may consist of the below mentioned layers:

- Reinforced concrete slab
- Vapour seal
- Mineral wool insulation layer
- Water proofing layer
- Cement bed

Three layers of external water proofing cover of “Uniflex” or “Linocrone” type or similar material with bituminous adhesive elements and special additives are recommended. For the lower layer, the weight of the waterproofing material per 1 m² is min 3.8 kg, the thickness is min 2.8 mm. The waterproofing material with a polymer film on the both sides of the layer shall be used. For the top layer, the weight of the waterproofing material per 1 m² is min 4.9 kg, the thickness is min 3.8 mm. Heat resistance for 2 hours shall be min 95 degrees Celsius. Waterproofing material with a coarse-grained cover on the front side and a polymer film on the weld side of the layer shall be used.

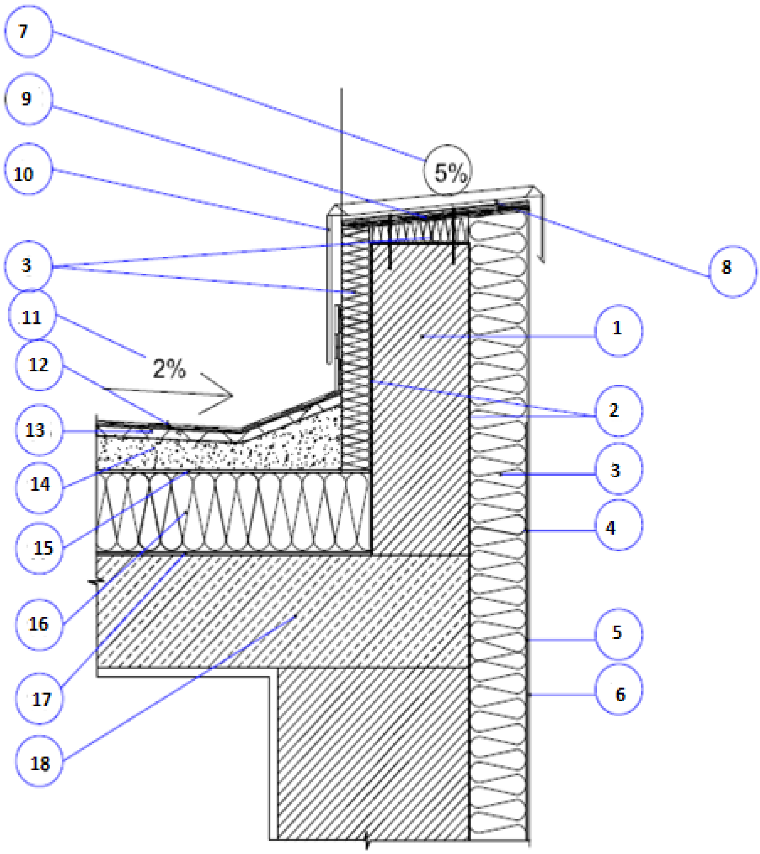
The required thickness of the heat insulating layer shall be taken in accordance with the thermal calculation with the achievement of the heat transfer coefficient max U=0.30W/m²K. and must be at least 100 mm. The minimum density of the mineral wool plate should be at least 180 kg/m³. Technical solution for insulation of a flat roof is described in the below figure.

Figure 20: Insulation of the flat roof



1-Multilayer roof cover
2-Reinforced cement-sand bed
3-Waterproofing layer
4-Expanded clay filling
5-Mineral wool thermal insulation plates
6-Vapour barrier
7-Reinforced concrete slab

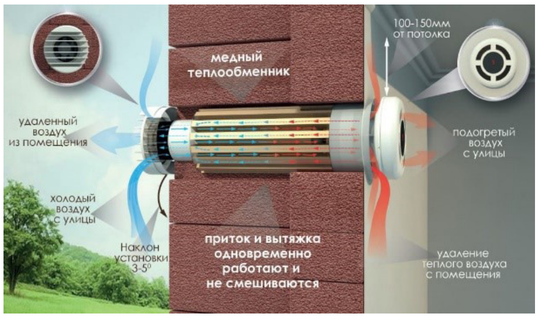
Figure 21: Schematic drawing of connection of the roof with parapet (with a metal sheet cover)



1 - Parapet
2 - Adhesive layer
3 - Facade insulation boards
4 - Coating
5 - Finishing layer
6 - Boundary profile
7 - Parapet sloping by 5 %
8 - Profile
9 - Wooden beam
10 - Galvanized tank sheet
11 - Roof sloping by 2%
12 - Waterproofing layer
13 - Cement covering with thickness: 5 cm
14 - Pumice filling for the provision of 2% sloping
15 - Waterproofing layer
16 - Thermal Insulation layer
17 - Vapour barrier
18 - Roof slab/substrate

Individual Ventilation Units with Heat Recovery

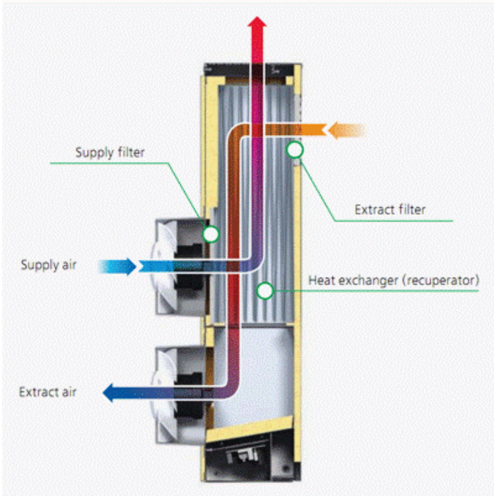
Figure 22: Individual ventilation wall mounted unit with heat recovery (sample 1)



Energy efficiency and significant air exchange capabilities make it possible to apply the inflow-exhaust individual ventilation. The individual wall mounted ventilation units with heat recovery *such as Prana -150* are recommended for apartments and have to be installed in the upper part of the outer wall. This unit will be installed in the mounting hole on the mounting foam or other sealant. Thus, the entire working module is in the body of the wall, and only the ventilation grilles will be visible. The total length of unit is 475 mm. To ensure the normal operation of the ventilation system, it is necessary that the air intake pipe (from outside) protrudes outside the wall min by 5 mm. The ventilation module installed inside of the wall is shown in the Figure above.

The basis of the technical solution for energy efficiency is a heat recovery, which makes possible to form two different-directed airflows in the volume of one cylinder. The warm exhaust air that is removed from the room, is passing through a copper heat exchanger and transmits its heat to the counter stream of fresh air from the outside.

Figure 23: Individual ventilation wall mounted unit with heat recovery (sample 2)



Another device, which can be for energy retrofitting is MICRA 60 with heat recovery. It has to be installed on the front wall from inside of apartment. The unit is equipped with a plastic heat exchanger with efficiency of 78%. Operational logic of the ventilation unit with heat recovery is described as follows:

- Fresh intake air from outside moves through the filter and heat regenerator and is supplied to the premise with a supply exhaust fan.
- Warm air from the room moves through the filter and heat regenerator and then is exhausted outside with an exhaust axial fan.
- Heat energy of warm exhaust extracted air is transferred to cold intake air flow from outside in the heat exchanger.
- Heat energy utilization results in reducing heat energy losses and operating costs for heating in cold season.
- The intake and extract air flows are fully separated.

Case Studies and Lessons Learned from Other Countries

Retrofitting of existing residential buildings for energy efficiency is considered as the most effective measure to lower the overall energy consumption, as well as for reducing the carbon footprint and GHG emissions. Governments and relevant organizations around the world have put much emphasis on the development of standard energy-efficient retrofitting standards for existing buildings.

Retrofitting an existing building is one of the solutions to reduce the dependency on constructing new buildings. There are huge numbers of existing building stocks that suitable to be retrofitted such as historical buildings, offices, residential, warehouse, factories, vacant buildings, etc.

Therefore, the aim of this chapter is to provide information on the application, benefits and challenges of retrofitting an existing building. The application of retrofit should be promoted across the construction and conservation industries since it has significant tangible and intangible benefits. It is one of the most environmentally friendly and efficient solutions to optimize the energy performance and could also help to extend the life of the existing building or historical buildings while ensuring optimum thermal comfort for the occupants which leads to higher productivity. Here we have looked at some studies which have been carried out around the world that depict the benefits of the retrofits to increase the EE of the existing building stock

Zhenjun Ma et al12 gives a systematic approach to identify and select the best suited retrofitting options of existing dwellings. The research presents the generic barriers to retrofit, while also identifying the issues related to the investment decisions for existing building retrofitting programs. The study also discussed different retrofit activities including economic analysis, energy auditing, risk assessment, quantification of energy benefits and other activities that are essential for the success of a retrofitting project. The overall aim of the study was to bring a better understanding of the retrofitting activities and encourage energy conversation.

Claire Far and Harry Far13 simulate the annual energy consumption for heating and cooling of nine benchmark buildings using FirstRate514 thermal comfort modeling software. The study recommended the most effective and financially viable retrofitting measures based on quantitative energy modeling. The study offers two retrofitting cases; ceiling insulation and ceiling plus external wall insulation for existing residential dwelling, which proved to be efficient in significantly lowering the energy consumed for heating and cooling systems of existing buildings. The payback period for the retrofitting investment was estimated to be less than 3 years for the study.

Morshed Alam et. al15 gives a detailed review of the retrofitting guidelines implemented in different parts of the world, barriers to retrofitting and research progress for EE retrofitting of existing buildings that have been carried out. The fundamental barriers to the EE retrofitting include the regulatory, economic, knowledge and social barriers. The study also identified the lack of "risk assessment and management" steps in existing EE retrofitting guidelines implemented in different parts of the world. According to the study, the retrofitting guidelines of the USA was found to be better and most comprehensive, as compared to the guidelines implemented in other parts of the world. The study also proposed new guidelines, aimed to overcome the existing barriers, especially in terms of integrating risk assessment as a necessary step of retrofitting guidelines.

Lessons Learned from Other Countries

To increase the adoption of energy-efficient investments and behaviors in buildings, public policies are necessary to eliminate barriers that discourage stakeholders from pursuing energy efficiency. Beyond removal of barriers, proactive instruments are imperative to give consumers positive reasons to adopt efficient practices.

In this area, a variety of public policies and measures have been implemented, often successfully, in different countries. Although there are few rigorous, quantified evaluations of these policies and their results, there is nevertheless much practical experience that can be analyzed for insights into what works and what does not.

This chapter presents and discusses international experience with policies and measures to promote energy efficiency in buildings. It also offers some guidelines for future initiatives on prioritizing targets, choosing types of policies, and designing mechanisms.

Energy Efficiency: Lessons Learned from Success Stories16

A study conducted by the World Bank for nine countries namely Belarus, Ireland, Lithuania, Romania, Sweden, Germany, Ukraine, Denmark, and Poland analyze the success stories for the EE policies implemented in the sample countries. The study also evaluates in detail the change in energy consumption in these countries for the period 1990 to 2007.

12 Ma, Zhenjun, Cooper, Paul, Daly, Daniel & Ledo, Laia. (2012). Existing Building Retrofits: Methodology and State-of-the-art, University of Wollongong: Energy and Buildings, Volume 55, December 2012, Pages 889-902

13 Far, Claire & Far, Harry. (2019). Improving energy efficiency of existing residential buildings using effective thermal retrofit of building envelope. Indoor and Built Environment. 28. 744-760. 10.1177/1420326x18794010.

14 FirstRate5® is an easy-to-use interactive tool with a graphic user interface that enables designers and thermal performance assessors to generate energy ratings

15 Alam, Morshed & Zou, Patrick & Sanjayan, Jay & Stewart, Rodney & Sahin, Oz & Bertone, Edoardo & Wilson, John. (2016). Guidelines for Building Energy Efficiency Retrofitting

16 http://documents.worldbank.org/curated/en/966991468030250095/pdf/Energy-efficiency-lessons-learned-from-success-stories.pdf

According to the study, the total energy consumption for Europe and Central Asia (ECA) and EU-15 countries decreased overall by 32% for the time. The decrease in energy consumption remains 25% for EU-15 countries (mainly because these countries were already more energy efficient in 1990), whereas, for ECA countries the overall decrease in energy consumption was recorded at 40%, which is a remarkable feat.

The study revolves around answering the following five questions:

- How can market penetration be accelerated?
- What measures can be taken to foster acceleration in energy intensity improvements to enable others to approach EU standards?
- Can the least successful countries benefit from the lessons learned in successful countries?
- How did successful countries undertake their transition?
- Can good energy efficiency policies help promote economic growth?

The overall lessons learned from the study can be characterized into 5 broad categories:

1. Get the Pricing Right: As expected, the pricing comes as the top factor to encourage energy efficient policies in the countries. The key lessons learned in this point are countries that were successful in promoting energy efficiency among the populace increase the energy prices rapidly at politically convenient times; which subsequently sent shockwaves and encourage people to adopt energy-efficient measures (this was the case that was experienced in Poland and Lithuania). Other countries like Denmark, Germany, and Sweden also increased the energy pricing, however, this was done with a comprehensive outreach program and by engaging the civil society in the decision-making process. These higher-income countries also implemented environmental taxed to raise awareness regarding the environmental impact of energy consumption and promote energy conversation practices.

2. Good Governance: Best practices in governance identified in the study can be subdivided into 4 categories including:

    a. Enabling the right framework: Countries that have been successful in promoting energy efficient measures start-off with a comprehensive energy efficient policy, which is backed up with a robust action plan for the implementation of the policy. Also, setting tangible short and medium-term targets, making relevant legislation and offering incentives helps in the implementation of the action plan.

    b. Making institutional arrangements: The study also identifies the efficiency of establishing a concerned Agency (larger / developed countries) or Ministry (typically in smaller / developing countries) for the implementation of EE programs. Also, successful countries tend to set aside a significant budget for the agency to attract top professionals, responsible for creating, advising, monitoring and evaluating the action plan, setting the targets and reporting on the program progress.

    c. Develop coordination mechanisms: Another important finding of the study is the close inter-ministerial / inter-governmental cooperation for the successful implementation of EE programs. Subnational entities like mayor's office, relevant ministries (energy, housing/ construction, infrastructure, environment, finance, economics, education, health, and others) need to collaborate to meet the desired level of energy efficiency gains. The study finds the vertical coordination among the federal, country and municipal levels of Government implemented in Sweden as an effective governance measure to maximize EE gains.

    d. Arranging low-cost financing to support investments: The study identifies the importance of arranging low-cost financing funds to supplement commercial funds as a governance measure to address environmental externalities and market rigidities.

    e. Consistent evaluation: Most successful countries that are succeeding in significantly lowering the overall energy consumption were identified as ones, which invest heavily in continuous reviewing and upgrading the EE programs, learning from others and adjusting to changing circumstances.

    f. Different pace of implementation for industrial and residential sector

i. For the industrial sector: It was found in the study that the industrial sector tends to implement EE programs faster as compared to the residential sector. While the role of government in the implementation of EE policies for the industrial sector is limited, it nonetheless is important. Here, the most important step for the government is to provide the right environment to industries (setting the right pricing for energy) to promote EE practices.

ii. For households and commercial buildings: In this sector, successful countries have taken three-pronged approach:

- Setting building standards as a short-term measure for new and relatively new buildings;
- Running Building Certifications Programs with energy consumption as a prerequisite for sale or rental of properties as a medium-term measure;
- As a long-term measure, countries have successfully engaged housing/construction sector for "near-zero energy" designs and offer grants as part of the energy-efficient investments, as well as, offer low-cost energy audits.

g. Market Forces alone can't ensure energy-efficient practices: An important finding of the study was that successful countries don't just rely on market principles to promote EE programs. That's because while the incremental cost of adding energy-efficient design in new buildings is just 5 percent of the building cost, the cost of retrofitting an existing building is much higher and difficult to justify. Thereby, the government needs to play an important role to regulate building construction, implement appliance standards and run knowledge sharing programs to maximize the adoption of EE programs.

Promoting Energy Efficiency in Buildings: Lessons Learned from International Experience17

This study was conducted by United Nations Development Program (UNDP), that aims to offer governments and policymakers the most efficient policies for energy efficiency initiatives. The study focuses on building design, its envelope, ventilation, and heating & cooling systems to estimate the energy consumptions in buildings. The report identifies the implementation of mandatory Energy Building Codes as one of the most widely used and effective policies to encourage EE measures in the country. The study has identified that the best results for EE programs are achieved when governance and policy measures are supplemented by informational awareness programs and financial incentives.

Key Findings of the Report from the Lessons Learned through Success Stories

1. Regulatory measures, where can be enforced securely are the most cost-effective measures to improve the EE of buildings on a long-term basis.
   - For new buildings, the regulatory measures can be the Energy building Codes, which can greatly help in the integration of energy efficiency measures;
   - At places where Energy Building Codes can't be implemented completely, establishing minimum energy efficiency mandatory requirements can be used as the first step towards energy transformation;
   - Voluntary performance standards (for entire buildings or for individual components) is identified as yet another helpful alternate to Energy Building Codes to promote the implementation of EE measures in buildings,
2. On the secondary level, promotion of energy efficiency measures directly at the consumer level is identified as an effective policy to promote energy conservation from the consumer side
   - Demand-side management (DSM) programs run by electricity and gas utilities for recommending clients efficient energy consumption is identified as a useful measure to raise awareness and promote energy conservation. Offering certain financial incentives for utilities against effective

17 https://www.thegef.org/sites/default/files/publications/EEBuilding_WEB_2.pdf

energy consumption is also a highly encouraging measure to promote energy conservation at consumers' level;
- The study identifies the significant success of energy efficiency programs undertaken in the USA and Western Europe that tackles promote activities on heating and insulation. One reason for the high success rate of such a program is because it offers consumers a turn-key solution;
- Energy service companies (ESCOs) have proved to be highly successful in the USA and Western European markets as advocates of energy efficiency. However, this hasn't been the success model for all countries, as the success of the ESCO model requires meeting certain conditions including favorable legal and contractual framework and adequate financing. Provided the favorable environment is offered to ESCOs, these can prove detrimental in promoting energy-efficient measures at the consumer level.

3. Many countries have targeted municipalities and public buildings for EE programs at national and local levels:
    - Often municipalities lack the technical knowledge required to undertake EE programs by themselves. Thereby, it is important to hire and train the municipal staff with the technical knowledge and expertise for the successful implementation of the program.
4. Awareness programs are identified as an important step to achieve high uptake of EE measures at consumer levels:
    - One of the most common reasons identified in the study for the slow spread of energy efficiency, even when it offers significant cost benefits is the lack of consumer awareness. Thereby, running comprehensive awareness campaigns is necessary to engage consumers towards energy efficiency measures;
    - The study also identifies that once a certain level of awareness is reached, the government then needs to offer technical assistance to consumers to transform the positive intentions of consumers into real investments.
5. Lastly, financial incentives are identified as essential measures from the government side to complement EE policies:
    - Increasing energy pricing, imposing environmental tax and offering certain incentives for low energy consumptions are some of the proven measures that overall encourage energy conservation activities at consumers' level.

Review of Successful Global National Programs for Energy Efficiency

There are a large variety of energy efficiency policy measures that exist. Some are mandatory, some are informative, and some use financial incentives to promote diffusion of efficient equipment. From country to country, financial incentives vary considerably in scope and form, the type of framework used to implement them, and the actors that administer them.

They range from National KredEx Loan Program in Estonia to National Operational Program for Infrastructure and Services in Latvia to a more complex Kozloduy International Decommissioning Support Fund towards the Rehabilitation of the district heating network in Bulgaria. All have the primary objective of transforming the building stock to accelerate the dispersal of efficient technologies by addressing up-front cost barriers faced by consumers.

Tackling the residential sector has been a challenge across Eastern Europe due to the underdeveloped markets, aging building stock and lack of functioning HOAs. As a result, investment subsidies have been made available for housing renovation and energy efficiency programs in most Eastern European countries.

In this chapter, we review the different market transformation measures involving the use of financial incentives in the countries that have similarities to Georgia. We characterize the main types of measures, discuss their mechanisms, and provide information on program impacts to the extent that ex-ante or ex-post evaluations have been conducted. As a result, we have used a World Bank18 study to disseminate results in Poland, Romania & Lithuania.

18 http://documents.worldbank.org/curated/en/966991468030250095/pdf/Energy-efficiency-lessons-learned-from-success-stories.pdf

POLAND was able to cut in half its energy intensity from 1990 to 2009. The significant success to drive down the energy intensity required in the country is primarily due to the gains made from energy efficiency (EE) and not much has been achieved in terms of structural changes. Some of the core elements that derived success in Poland's energy efficiency reforms include:

1. The Big Bang Electricity Tariffs

With the fall of communism in the country in the late 1980s, the country began its effort towards economic reforms, which included the significant correction in heat and electricity tariffs. The energy prices saw a six and thirteen-fold increment in the country for the years 1990 to 1995. While the tangible impacts of the energy price inflation can't be estimated, it nonetheless provided a much-needed environment for investments in EE measures.

2. Unbundling the Energy Sector

Opening up the energy sector for energy completion to determine the prices for electricity for consumers. The creation of regulatory authority19 for the energy sector helped sustain the energy price reforms.

3. Introduction of Thermo-Modernization and Renovation Fund (TMRF)

TMRF was created in 1998 as a financial measure to support the investment needs of existing buildings for energy efficiency retrofits. The project offered eligible EE housing project with subsidy (Thermo-modernization bonus) on commercial terms, through selected commercial banks. The first phase of the project didn't prove to be quite successful with a few projects being initiated in the first five years. Subsequently, by streamlining the application process and arranging the financial resources promptly by the government, the program saw rapid success. Under the program between 1998 and 2009 approximately 16,700 applications were granted financial incentives with a total value of EUR 1.3 billion. The retrofitting of the household under the TMRF program is estimated to save as much as 40% of the heating costs in an average household.

4. Construction Regulations

Construction regulations have also proven an important legislative step in Poland for energy efficiency transformation in the residential sector. The country increasingly tightened the regulations for EE housing during the early 1990s, which saw a significant decrease in energy consumption by the residential sector. On average, there was a 25% decrease in energy consumption per square meter between 1990 and 2002.

ROMANIA was able to successfully drop down its energy consumption by more than half between 1992 and 2008. Energy efficiency has been the leading factor contributing to the decrease in energy intensity in the country since 1994. Some of the core elements that derived success in Romania's energy efficiency reforms include:

1. Integration of EU directives into the legal framework

Since the 1990s, Romania transposed the majority of the EU directives on energy efficiency performance of buildings and household appliances into its legal framework. This combined with strong domestic legislation, provided the ideal framework towards energy efficiency in the country.

2. Energy Conservation Agency

The Agency for Energy Conservation was established in the country in the 1990s, which prodigiously contributed to the efficient institutional arrangements required for EE transformation.

3. Tackling and Evaluation of energy efficiency programs

Stringent and consistent tracking and evaluation of energy efficiency programs remains a core strategy that has significantly contributed to the successful implementation of energy efficiency programs in Romania. Over the years, the country has successfully created and maintained a large statistical database for energy efficiency, which helps close monitoring and success evaluation of EE programs undertaken by the government.

19 In Poland, the administrative authorities that are responsible for determining the regulatory policy are the Minister of Energy and the President of the Energy Regulatory Authority (ERA)

4. Financial Grants

Financial grants have also proven significant in reducing energy consumption in Romania. Most of the financial grants offered by the country are towards feasibility studies of EE projects, energy audits, as well as, partial grants towards finance works. The major contributor towards EE funding in Romania have been international organizations including World Bank, UNDP, EU and others.

5. Romanian Energy Efficiency Fund (FREE)20

FREE is a great example of how strong and well-monitored domestic financial mechanisms can help countries in achieving energy efficiency goals. The revolving trust fund encourages the industrial sector and other energy consumers in the country to adopt energy-efficient technologies by offering them financial grants. The project proved to be an international benchmark with seed financing constituting about 0.08 US¢/kWh.

LITHUANIA is yet another success story for its energy efficiency programs. The country was able to reduce its energy consumption in half between 1994 and 2007, driving it to the top ranks among the EU 12 countries. Some of the core components that helped Lithuania achieve energy efficiency goals include:

1. Energy Price Adjustment

Soon after the collapse of communism, Lithuania introduced a "big bang" adjustment to its energy prices. Since the country is largely dependent on oil and gas imports from Russia to meets its energy needs, as well as, with a limited financial cushion, the country passed on the full cost of energy production to customers, which quickly rationalized the consumption to address the affordability issues.

2. Establishment of Energy Agency

Lithuania was quick to establish its Energy Agency21 in 1993, right after its independence. The agency has proved to be fundamental in the implementation of various government's driven energy efficiency programs in the country. Integration of EU directives into the legal framework

Lithuania quickly transposed the majority of the EU directives on energy efficiency performance of buildings and household appliances into its legal framework. Quick actions on the directives coupled with prior completion of analytical work by the EU helped in the early realization of the benefits of the efforts.

3. Comprehensiveness of program

One of the prime success reasons for Lithuania's efforts towards energy efficiency targets in comparison to other countries is the comprehensive approach adopted by the country. Lithuania undertakes an intensive and all-inclusive EE approach including legislating the building regulations, implementing pilot projects for energy efficiency, introducing energy audits, promoting disseminating campaigns, and close evaluation and monitoring of each program. This led to a comprehensive approach that decreased energy consumption for domestic buildings from 200 kWh/m² to 140kWh/m² between 1995 and 2007.

4. Financial Grants

As with other successful countries, financial grants proved an effective approach to encourage consumers for energy efficiency practices. Lithuania in collaborating with the EU offered 30% financial grants that covered up to 30% of the energy efficiency investments for households, which significantly encourages consumers up taking the EE initiative.

Conclusion

Energy consumption is often among the largest overall costs of a building over its useful life and there are substantial technical-economic potentials to minimize this through good design, construction, operation and retrofitting (where appropriate). The current study was focused to improve the understanding,

20 The Romanian Energy Efficiency Fund's main activity is financing investment projects aimed at increasing the efficient use of energy in the country, as well as managing the Global Environment Fund granted to Romania through the International Bank for Reconstruction and Development. This is in line with the national energy efficiency priorities and policy

21 National Commission for Energy Control and Prices (NCC) is an independent national regulatory authority regulating activities of entities in the field of energy and carrying out the supervision of state energy sector in Lithuania

knowledge, as well as, the technical capacity of the municipal bodies under the Tbilisi City Hall, for the retrofitting requirements of the residential buildings.

ENSI/EAB was used to generate models in a form of energy performance scenarios including; the baseline scenario and the EE scenario. In order to provide reliable results of energy modeling, the decision was made to select the most common eight story building in Tbilisi city.

Energy performance calculations of this building were carried out with the input data consisting of building geometry and U values of the exterior components that were derived from the real residential eight story buildings, that are in existence since 1966. The energy balance values for Heating, Ventilation, DHW, Fans and Pumps, Lighting and other components were also estimated using ENSI/EAB software tool.

In order to ensure better understanding and the transfer of knowledge to the local municipality on implementation of the EE in residential buildings, the current guidelines, are structured in a logical way that encircles the legislative framework of the construction sector in Georgia. The guidelines also detail the results of the survey on the total number of the residential stock of the Tbilisi with the breakdown by the subgroups of buildings.

Based on the results of the study, the energy-saving potential constitutes to 652,057 kWh/year for the retrofit building, which the difference of the computed results of energy consumption evaluated separately for baseline and after EE measures scenarios.

The proposed EE measures include insulation of roofs, insulation of walls, replacement of windows and external doors, and installation of the wall-mounted ventilation units with heat recovery. The investment cost assessed for the proposed EE measures is estimated at USD 330,325 (927.518 GEL). The investment cost for implementation of the EE measures per m² constitutes USD $57.7 (161.9 GEL)

The findings of the reports are believed to assist the City government to increase the knowledge of its technical staff concerning the appropriate EE standards, taking into account the cost considerations and benefits they can bring for decreased energy consumption and GHG emissions, developing terms of reference for building retrofitting designs and incorporating EE requirements, and carrying out monitoring activities for EE during the construction phase.

The study also aims to support the Tbilisi's Infrastructure Department with the development of comprehensive EE standards based on modeling estimates on international standards. This in turn will help the administration to incorporate the EE standards into the rehabilitation and reconstruction engineering designs of the deteriorated housing stock, which constitutes the major portion of the housing stock in the city. The proposed measures in the report are detailed with a logical approach which also supplement the capacity building workshop that will be offered as part of the study to the City Infrastructure department and district level staff. The study will further enhance skill set for City government to undertake recommended EE standards to initiate the Khrushovka retrofitting program, while significantly reducing the energy consumption on part of the residents of the rehabilitated apartments. This will result in lower electricity bills of the low-income communities.

The findings of the publications will further assist Tbilisi city government to understand and implement appropriate EE standards, taking into account the cost considerations. The study will further benefit the municipality in the following aspects:

1. Help realize the benefits they can bring for decreased energy consumption and GHG emissions
2. Develop terms of reference for building retrofitting designs and incorporating EE requirements
3. Reviewing and inspecting submitted engineering designs for EE and carrying out monitoring activities for EE during the construction phase.

Furthermore, the commercial benefits of the EE measures recommended in the study will help make industries more competitive, increasing their market share and creating more job opportunities for the community benefit.

The report ultimately has used lessons learned to help identify and define a set of best practices—design elements and techniques that should be avoided in domestic buildings, as well as elements that should be carried forward to the other retrofit programs in Georgia. Best practices are proven, real-world technologies and processes that can lead to high-performance commercial buildings.

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Annex 1: Energy Assessment Report of the Selected Residential Multi-Apartment Building

Summary

Energy audit was carried out with the ENSI EAB GE 8.1 software to assess energy consumption of the selected residential building, located at Vazha Pshavela Avenue, Block 4, Building 24, Tbilisi. The software was calibrated for the evaluation of the baseline level, elaboration of the energy efficiency potential and development of the energy efficiency consumption profile. ENSI profitability software was used to determine economic viability of the EE measures. As a result, the overall expected energy and monetary savings after the thermal modernization of the building are the following:

- Savings in delivered energy: 662,117 kWh/Year
- Net savings: 29,040 USD (81,540 GEL) annually
- Investments: 330,325 USD (927.518 GEL)
- Payback: 11.4 years

Introduction

Background

The energy audit of the selected building was carried out within the scope of the World Bank Project for “Tbilisi Urban Regeneration and Energy Efficiency - phase 2“, aiming at improving Tbilisi Mayor’s Office knowledge about the EE measures. The goal of this report is to show the benefits of reduced energy consumption and related energy costs, improvement of the indoor climate conditions, and reduction of the associated greenhouse emissions.

The multi-apartment residential building, comprising 8 floors with 3 unit-sections, was selected in close coordination with the representatives of the Infrastructure Department of the Mayor’s Office.

The EE technical design was shared with the residents and owners of the building in a meeting on January 30, 2020. Their feedback on the suggested EE improvements was incorporated into the final package.

The selected residential building was built in the mid of 1960s under “Khrushchev” construction era with poor construction standards. It was built under the type design series that commonly foresaw installation of high energy consuming technical buildings systems running on the natural gas such as: heating & domestic DHW that were operated by district heat supply network system with the district boilers.

After the collapse of the Soviet Union, the district heat supply systems were dismantled as the post-Soviet government failed to sustain the service. In response, some residents installed central heating systems with distribution pipes, radiators/emitters, and boiler in each apartment, while the others continue using wall mounted ”Karma” type local gas heaters and DHW is supplied through a local natural gas or electrical hot water heater.

Energy Audit Development Process

The project development covers evaluation and implementation of profitable EE measures in the buildings. Every building is unique in its design and technical characteristics. Therefore, every case must be evaluated individually to best identify energy savings opportunities. To achieve this goal, project development process is comprises six main activities, as shown below.

Figure 24: Project Development Process

Project Organization

- Name of the selected building: Multi Apartment Residential Building
- Address: Vazha Pshavela Avenue, Block 4, Building 24
- Building owner: HOA
- Contact persons and Telephone numbers from the Mayor's Office:
  - Davit Doghonadze: +995 599 033 761
  - Irakli Darakhvelidze: +995 591 910 430
- Beneficiary: Tbilisi Mayor's Office

Table 10: Energy Assessment Team Composition

Name	Phone	Function
Dr. Karina Melikidze	+99532 299 08 02 (office)	Energy assessment and development of the EA report
Dr. Valerian Melikidze	+995 599 90 65 71 (cell)	Preparation of the energy assessment and quality assurance
Giga Lekveishvili	+995 598 50 16 79 (cell)	Economic calculations
Zurab Tsikhiseli	+995 599 98 23 33 (cell)	Architectural design, inspection and design of EE measures of the building envelope

Standards and Regulation

Technical regulations and construction standards are still being developed in Georgia. Therefore, the Soviet Technical Regulations - SNIPs - with the relevant subsequent modifications are still active in accordance with the Government's Decree No. 52, issued on January 14, 2014. For energy assessment and retrofiring measures the following standards, regulations and requirements are considered relevant:

- Heating, Ventilation, and Conditioning (SNIP 2.04.05-86);
- Sanitary Regulations;
- Construction Thermal Engineering (SNIP II-3-79, updated).

Building Description

General Conditions

During the preparation of the assessment, the audit team visited the building to inspect conditions and carry out measurements for the development of the architectural design.

Table 11: General Information about the Building

Type of Building	Multi-apartment residential building		
Year of Construction	1960s		
Residents	220		
Average Indoor Temperature:	19°C		
	In regular operation (hours a day)		
	Working days	Saturday	Sunday
Maintenance	24	24	24
Heating Schedule	24	24	24

Building Data

Information obtained during the site inspection was analyzed by the project team. The building geometry data was obtained from the architectural part of the technical design and processed as an input for the software model. The ENSI EAB software requires the following input building data:

- The total area and total volume of the building;
- The total area of the external walls, windows and doors exposed over cardinal points;
- The roof and floor area.

The building plans were developed by the architect and together with the layouts of facades, formulates the architectural part of "as built" technical design. The technical information obtained from the architectural design is as follows:

Table 12: Total Building Data

Total Area	5,728 m^2
Total Volume	16,325 m^3
Floor Area (footprint)	716 m^2

Heated Area	5,728 m^2
Heated Volume	16,325 m^2
Number of Floors	8

Table 13: External Wall Data

General evaluation of the condition of the walls: medium thermal capacity				
Total area of external walls	2,500 m^2		U value (average)	1.64 W/m^2K
Orientation	N	E	S	W
Total	975	338	844	337
Material Type (m1)	The walls are constructed from large panel concrete blocks. The overall wall thickness constitutes: δ=0.4 m. The thermal resistance value: R value of existing walls was assessed by the energy audit team as $R_{present}$ = 0.61m^2.* K/W. Thermal transmittance U value: U=1/0.61=1.64 W/m^2K			

Table 14: Windows and Doors Data

Total Area of Windows & Doors: 1,029 m^2					
General evaluation of condition of windows: partly old single glazed wooden framed windows and partly double-glazed metal plastic framed windows.					
Orientation	**Material**	**Type**	**Area**	**U value (existing)**	**U value (average)**
			m^2	**W/m^2K**	**W/m^2K**
N	W,P	S,D	403	5.8 3.3	4.57
E	W,P	S,D	32	5.8 3.3	4.57

S	W,P	S,D	844	5.8 3.3	4.57
W	W,P	S,D	25	5.8 3.3	4.57
Total on all cardinal points: 1,029 m^2					
Material[1]	Wood (W), Aluminum (Al), Plastic (P), Metal (M)				
Type[2]	Single-frame (S), Double-frame (D), Bonded-frame (B), Single-glazed (1G), Double-glazed (2G), Triple-glazed (3G)				

Table 15: Roof Data

General evaluation of condition of the roof: acceptable							
Total roof area		716 m^2		U value (average)		1.20 W/m²K	
Roof type	Material type	Insulation type	Insulation thickness (m)	Slab thickness (m)	Avg. temp. (°C)	Area (m^2)	U value
Roof with the attic	m1	n/a	n/a	0.22	-	-	
Total	R value for the roof has been calculated as R required value for Tbilisi climatic conditions, based on the methodology highlighted in the old Soviet Thermal Engineering codes that has been in force when the building was constructed. According to SNIP II-3-79* the R value for roof slab should not be lower than: $R_{required}$ = 20-(-9)/4*8.7=0.83m² K/W Approximate thermal transmittance U value of the existing roof constitutes: U=1/$R_{required}$=1/0.83=1.20 W/m²K						
Existing Insulation type	n/a						

Table 16: Floor Data

Floor (with heat losses through the ground or unheated cold, basement)

General evaluation of the condition of the floor: acceptable			
Total Floor Area	716 m^2	U value (average)	1.1 W/m²K
Type of Floor	Floor is suspended with the unheated basement located under the floor		

Heating System

The heating system is arranged individually by residents that runs with a boiler, distribution pipes and radiators/emitters. However, certain apartments continue heating with the wall mounted "Karma" type local gas units.

Hot Water Supply System

The hot water supply in the building is arranged individually by the residents.

Ventilation System

There is no mechanical ventilation systems installed in the building. The building only has natural ventilation channels in the kitchens and toilets.

Lighting System

The lighting data can depend on type of the building, lamp type, and its average operational period. The data which was entered in the energy modeling for lighting is given below:

Table 17: Lighting Data

Average Power Demand	3.5 W/m²
Operation Period	52 weeks/year
Max. Simultaneous Power	5.0 W/m²

Various

Various exploitable equipment data is dependent on the building type, capacity characteristics of the equipment and its operational period. The data which was entered in the energy modeling tool is as follows:

Table 18: Exploitable Equipment Data

Average Power Demand	1.5 W/m²
Operation Period	52 weeks/year
Max. Simultaneous Power	4.0 W/m²

Energy Consumption

Calibration of the ENSI EAB model was carried out to identify the "baseline" and "after EE renovation measures" scenarios. The energy consumption baseline for the suggested building was determined approximately as: 1,327,267 kWh/year.

Energy Budget

Calibration of the software model was conducted with the assumption that the "actual calculated" and "baseline" energy consumption scenarios constitute the equal figures.

Table 19: Energy Budget per m²

Budget Item	Actual Calculated	Before EE, baseline*	After EE measures**
	[kWh/m²year]		
Heating	147.1	147.1	51.5
Ventilation	35.3	35.3	16.0
DHW	32.8	32.8	32.8
Fans/ Pumps	2.5	2.5	2.5
Lighting	7.3	7.3	7.3
Various	6.1	6.1	6.1
Total	231.7	231.7	116.1

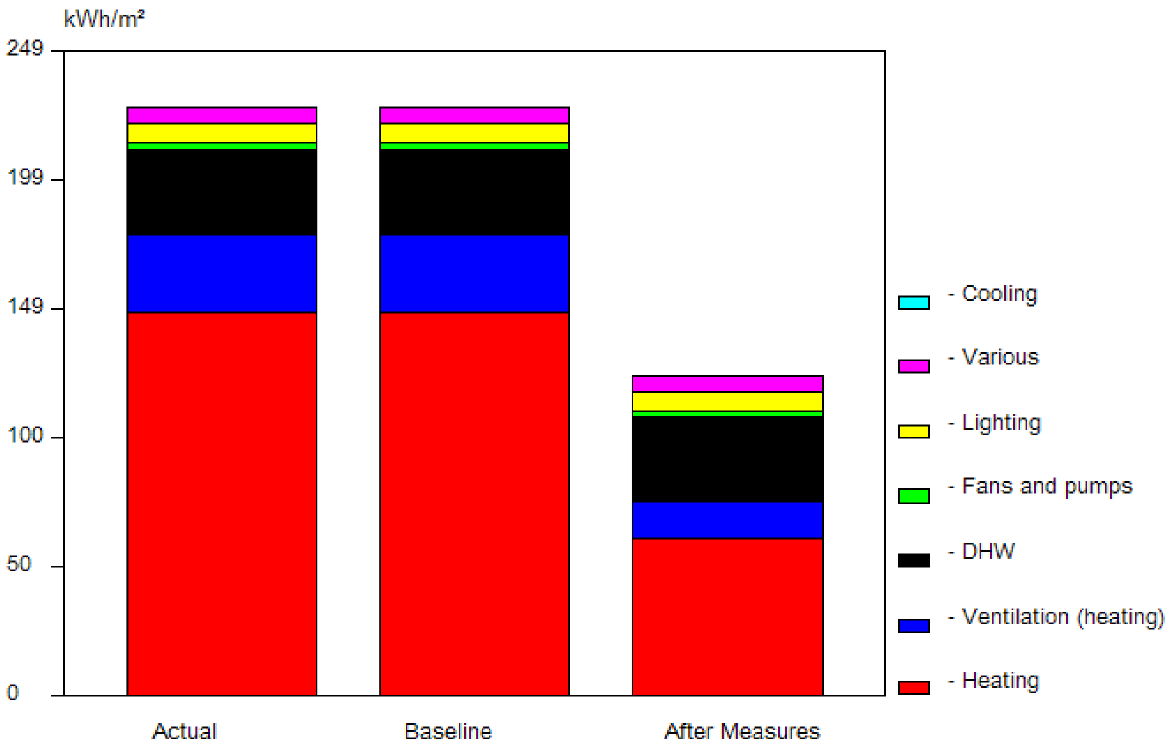
* *Baseline represents the amount of energy consumed to heat the whole building.*

** *After EE renovation measures represents the energy consumption envisioned after the implementation of the EE measures.*

Table 20: Energy Budget Per Year

Budget Item	Actual Calculated	Before EE, baseline	After EE measures
	[kWh/year]		
Heating	846,146	846,146	294,746
Ventilation	202,166	202,165	91,448
DHW	187,946	187,946	187,946
Fans/ Pumps	14,071	14,071	14,071
Lighting	41,814	41,814	41,814
Various	35,125	35,125	35,125
Total	1,327,267	1,327,267	665,150

Figure 25: Annual energy consumption



Energy Efficiency Potential

The overall expected energy and monetary savings after the thermal retrofitting of the building are the following:

Table 21: EEM's Value and Payback

Savings in delivered energy	662,117 kWh a year
Net savings	29,040 USD (81,540 GEL) a year
Investments	330,325 USD (927.518 GEL) a year
Payback	11.4 years

The energy savings potential and renovation measures ranked by their profitability - Net Present Value Quotient (NPVQ) - are summarized in the following table.

Table 22: Energy Savings via NPVQ

EE Measure	Initial investment [USD/GEL]	Net savings		Payback	NPVQ
		[kWh/yr]	[USD/GEL/yr]	[year]	
Installation of a wall mounted individual ventilation units	65,520/183,974	103,936	6,848/19,228	9.6	0.25
Replacement of the windows	116,277/325,495	255,555	10,197/28,631	11,4	0.12
Insulation of the attic floor	21,417.0/60,137	58,190	1,810/5,081	11.8	0.08
Insulation of walls	127,110/356,912	244,436	10,185/28,600	12.5	0.02
Total	**330,325/927.518**	**662,117**	**29,040/81,540**	**11.4**	**0.05**

It is important to note that there are some measures that may be comparatively expensive but are still worthwhile in relation to the reduction of energy consumption and greenhouse emissions. Thus, addressing issues of sustainability, safety and other social improvements at the same time.

Energy Efficiency Measures

Description of all measures that have been evaluated is as follows:

Measure 1: Insulation of walls

- **Description of the existing situation:** Walls of the residential building are constructed from panels with 0.4m thickness. Due to this insufficient thickness and absence of insulation the thermal losses of the building are significantly high;
- **Description of EE measure:** For improvement of thermal properties of walls, it is proposed to insulate walls with the heat insulation, such as rock wool or mineral wool to achieve the suggested by EE standard of new U value=0.38 W/m²K. The mineral or rock wool insulation is suggested specifically because it is a diffusion open material that will provide a "breathable facade" in combination with the other components of the external thermal insulation composite system/ETICS. This will require application of the 8 cm insulation layer. Insulation is one of the components of a system that includes besides insulation layer also plastic mesh, primer, plastering and paint. The thermal conductivity of insulation layer constitutes: ƛ=0.04W/m²K. It is also foreseen to insulate the plinth area of: F=120 m with the XPS boards approximately 0.8 m below ground level and installation of an additional protective and drainage layer (dimple sheet) for proper insulation of the building. With insulation of walls the amount of saved energy calculated by the software is defined as: 244,436 kWh/y;
- **Investment:** Investment cost per/m² for insulation system covering all other costs related to construction works and transportation constitutes 45 USD per/m², including VAT. For the application of insulation on the northern facade of the building, the installation of a metal frame system is proposed with the subsequent fastening of insulation. This technical solution is predetermined due the thin outer walls (under the windows) of the loggias, built at the time of the commissioning by tenants. With elaboration of above technical solution the thermal insulation will be applied on all facades of the residential building, except the Southern one that will be covered by 60% with insulation. Such decision was made by the WB team, as insulation can't be applied fully, since part of the residents extended balcony areas to the inner part of apartments by erecting thin walls. Therefore, application of the insulation on these walls isn't possible from the engineering perspective, since they will not withstand the load of insulation system/ETICS. The total investment for walls will constitute: 110,000 USD (308,869 GEL). Insulation of plinth area, together with excavation works and asphalt covering will be 17,110 USD (48,043 GEL);
- **The total investment for walls and plinth area:** 127,110 USD (356,912 GEL);
- **Net Savings:** 10,185 USD (28,600 GEL) a year;
- **Economic Lifetime:** 30 years.

Measure 2: Insulation of the attic floor

- **Description of the existing situation:** The selected multi apartment building is built with the attic roof, without consideration of energy efficiency;
- **Description of EE measure:** the heat insulation such as the rock wool or mineral wool shall be applied to the attic floor to achieve the proposed by the EE regulation the new U value = 0.30W/m^2K. This will require the application of a 10 cm of rock wool or mineral wool with the thermal conductivity λ= 0.04 W/m^2K over the attic floor;
- **Investment:** Investment cost per/m^2 for this measure also includes the insulation of attic walls with the height about 1.0m from the attic floor. This is required in order to avoid thermal bridges. It is estimated that for materials and the construction works the investment will be about 25.6 USD/m^2, including VAT;
- **Total investment cost:** 21,417.0 USD (60,137 GEL);
- **Net Savings:** 1,810 USD (5,081 GEL) a year;
- **Economic Lifetime:** 30 years.

Measure 3: Replacement of the Windows

- **Description of the existing situation:** The building was commissioned with single glazed windows and doors in wooden frames. Part of the residents replaced old windows with double glazed windows in plastic frames. The above window technology is characterized with higher U value = 3.3 W/m^2K, than EE standards suggest to apply;
- **Description of EE measure:** After the renovation works, all existing windows will be replaced by the new double glazed ones with the low emissivity glazing in plastic frames in order to achieve the U value = 1.8 W/m^2 K;
- **Investment:** Investment cost for installation of new windows and doors with low emissivity glazing, together with the sealing tapes that have to be installed on high quality frames amounts to 113 USD per/m^2, including VAT;
- **Total Investment:** 116,277 USD (326,495 GEL);
- **Net Savings:** 10,197 USD (28,631 GEL) a year;
- **Economic Lifetime:** 20 years.

Measure 4: Individual ventilation units with heat recovery

- **Description of the existing situation:** As of today, due to the absence of insulation, the infiltration in the building is high. After insulation of the walls and roof infiltration will decrease. Ventilation is key in thermal modernization technical designs. Therefore, it is important to install a ventilation system in the building to ensure provision of comfortable indoor conditions with mechanical intake of a fresh air;
- **Description of EE measure:** To ensure operation of ventilation in the building, it is proposed to install the individual supply/exhaust ventilation wall mounted units with heat recovery/per room. 144 ventilation units with heat recovery such as Micra 60 A3 will be required;
- **Investment:** Installation of the wall mounted ventilation unit with heat recovery costs 455 USD (per unit). The total investment cost with installation for 144 such ventilation units including VAT will be 65,520 USD (183,974 GEL);
- **Total Investment:** 65,520 USD (183,974 GEL);
- **Net Savings:** 6,848 USD (19,228 GEL) a year
- **Economic Lifetime:** 15 years.

Environmental Benefits

The calculated savings in the delivered energy and related reductions in CO2 emissions for the residential building with total area of F=5,728 m^2 are summarized as follows:

Table 23: CO2 reductions

Parameter	Units	Existing situation (baseline)	After implementation	Net reduction
Gas in Nm^3	Nm^3/year	86,342	30,076	56,266
Gas as heat	kWh/year	846,146	294,746	551,400
Electricity	kWh/year	202,165	91,448	110,717
CO2 gas	tons/year	170.922	59.539	111.383
CO2 el	tons/year	24.260	10.974	13.286
CO2 total	tons/year	195.182	70.513	124.669

- 56,100 kg CO2/TJ (or 0.202 kg/kWh)
- The emission factor for electricity: 0.120 kg/kWh (120g/kWh)

Net calorific value for gas is taken as:

Energy carrier	Net caloric value	Comments
Gas	9.8 KWh/Nm^3	or 35.28 MJ/Nm^3 NCV

Conclusion

Based on the results of the study, the energy-saving potential for the selected multi-apartment residential building constitutes 652,057 kWh/year, which is the difference of the computed results of energy consumption evaluated separately for baseline and after EE measures scenarios.

The proposed EE measures include insulation of roofs, insulation of walls, replacement of windows and external doors, and installation of the wall-mounted ventilation units with heat recovery. The investment cost assessed for the proposed EE measures is estimated at USD 330,325 (927,518 GEL). The investment cost for implementation of the EE measures per m² constitutes USD $57.7 (161.9 GEL)

The findings of the reports are believed to assist the City government to increase the knowledge of its technical staff concerning the appropriate EE standards, taking into account the cost considerations and benefits they can bring for decreased energy consumption and GHG emissions, developing terms of reference for building retrofitting designs and incorporating EE requirements, and carrying out monitoring activities for EE during the construction phase.

In summary, with the aid of this energy efficient rehabilitation program, the internal climate conditions of residents will be improved, by ensuring normal thermal comfort with adequate fresh air. It is also anticipated that the overall process will help raise public awareness towards energy efficiency among tenants and general public.

Annex 2: Detailed Design for the Energy Efficiency Rehabilitation of the Selected Residential Building

Explanatory Note

Architectural part

The building in the Saburtalo district (address: Vazha-Pshavela Avenue, Block 4, Building 24) has been selected for the energy efficiency rehabilitation project. The building is located on a relatively flat terrain with an area of 2,286 m². In geometric form, the building is parallelepiped-shaped with a flat roof and attic. Unlike the most of the buildings built in 1970s, the selected building does not have construction annexes (extensions) and the attic area is not privatized.

The building is constructed with blocks. Cracks and deformities have not been identified during the visual inspection. The norms of insulation and natural lighting are also not violated. Eastern and Western facades are fully in accordance with the design project and are intact. On the North facade, loggia openings that were originally designed are filled with walls as constructed by the residents. On the South facade part of balcony areas of one-room apartments are added to kitchens and the remaining parts are added to the living rooms. The wall constructions added by the residents on the South and on the North facades are completely different from each other by size, construction material and color. In general the walls are constructed by 7-20 cm bricks, blocks, or plasterboards and openings are filled in by plastic, wooden or aluminum frame windows.

In order to increase the energy efficiency of the building, it is suggested to arrange additional structures on the northern facade that will allow to attach the proper wall insulation. Since it is impossible to insulate various individually-built walls, only part of the South facade (506 m²) will be insulated. The remaining 338 m² area of the South facade will be processed only visually. Insulation of the eastern, northern and western facades and their structural consolidation into the integral system is foreseen by the project design.

In addition to the energy efficiency, the unified facade system will be provided for the entire building. The facade walls painted into two colors (gray and white) in addition to dark brown window and door frame openings with their vertical and horizontal lines, will make the building visually appealing.

Facade structure:

- Facade - 3,529 m²
- Walls - 2 500 m²
- Openings - 1,029 m²

North facade

- Total area - 1,378 m²
- Total wall area - 975 m²
- Total opening area - 403 m²

South Facade

- Total area - 1,412 m²
- Total wall area - 844 m²
- Total opening area - 568 m²

East facade

- Total area - 370 m²
- Total wall area 338 m²
- Total opening area 32 m²

West facade

- Total area - 368 m²
- Total wall - area 343 m²
- Total opening area - 25 m²

Architect Z. Tsikhiseli

საქართველოს იუსტიციის სამინისტრო

საჯარო რეესტრის ეროვნული სააგენტო

საკადასტრო გეგმა

მიწის ნაკვეთის საკადასტრო კოდი: *01.14.04.003.003*
განცხადების რეგისტრაციის ნომერი882012046999
მიწის ნაკვეთის ფართობი: *2286* კვ.მ.
დანიშნულება: *არასასოფლო-სამეურნეო*
მომზადების თარიღი 08.02.12

შენობა-ნაგებობა, პირობითი ნომერი/სართულიანობა — ვალდებულება — ხაზობრივი ნაგებობა

მიწის ნაკვეთის საკადასტრო საზღვარი — მშენებარე ნაგებობა — მიწისქვეშა ნაგებობა — UTM (საერთაშორისო) სისტემის კოორდ.

ENERGY EFFICIENCY REHABILITATION DESIGN OF THE TYPICAL 8-STOREY RESIDENTIAL BUILDING WITH 3 BLOCK-SECTIONS		
Architectural Part		Address
Architect	Z. Tsikhiseli	Vaja-Pshavela avenue, IV district, block # 24
Structural Engineer	B. Dgebuadze	

ENERGY EFFICIENCY REHABILITATION DESIGN OF THE TYPICAL 8-STOREY RESIDENTIAL BUILDING WITH 3 BLOCK-SECTIONS		
Architectural Part		Address
Architect	Z. Tsikhiseli	Vaja-Pshavela avenue, IV district, block # 24
Structural Engineer	B. Dgebuadze	

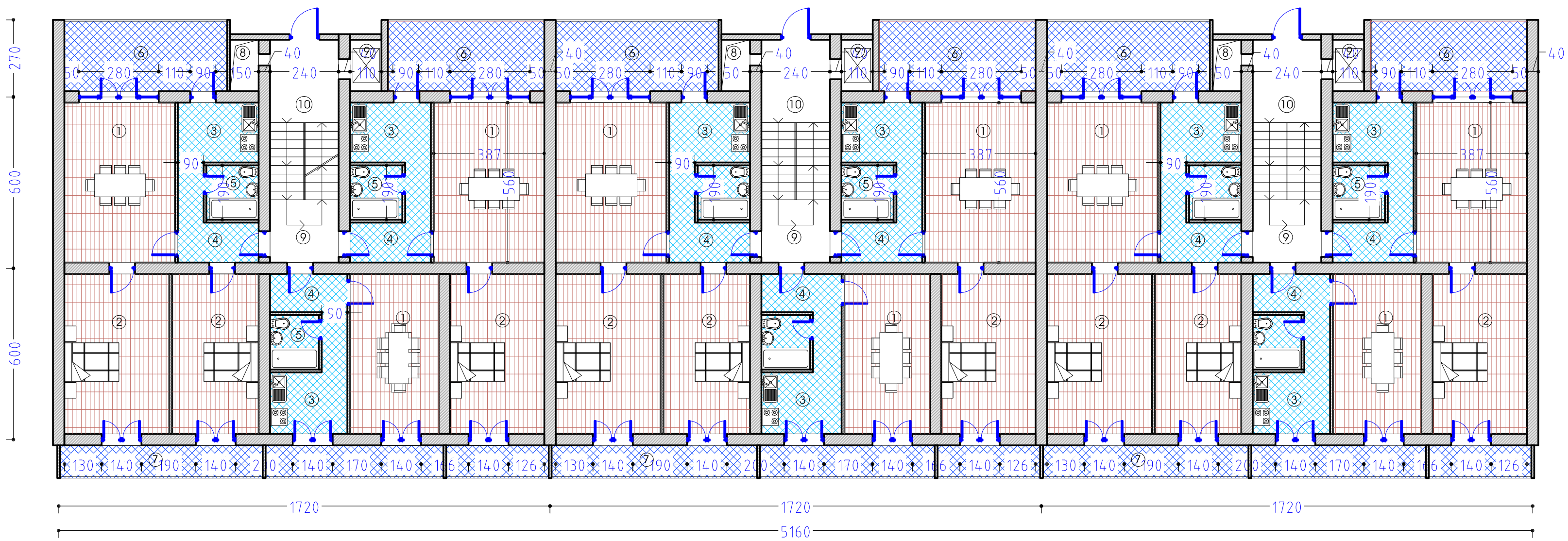
1

2

3

4

TYPICAL 8-STOREY RESIDENTIAL BUILDING WITH 3 BLOCK-SECTIONS



Explication of Typical 3-Apartment Section

1 Common Room
2 Bedroom
3 Kitchen
4 Hall
5 Bathroom & Toilet
6 Lodge
7 Balcony
8 Garbage Shaft
9 Elevator Shaft
10 Staircase

ENERGY EFFICIENCY REHABILITATION DESIGN OF THE TYPICAL 8-STOREY RESIDENTIAL BUILDING WITH 3 BLOCK-SECTIONS		
Architectural Part		Address
Architect	Z. Tsikhiseli	Vaja-Pshavela avenue, IV district, block # 24
Structural Engineer	B. Dgebuadze	

Explication of Typical 3-Apartment Section

1 Common Room
2 Bedroom
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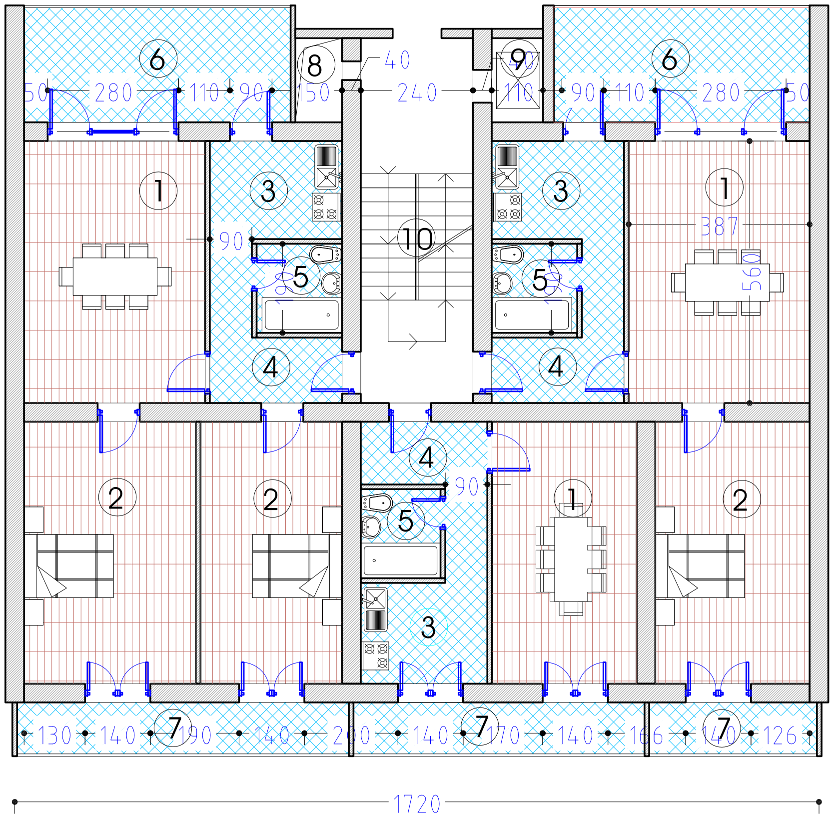
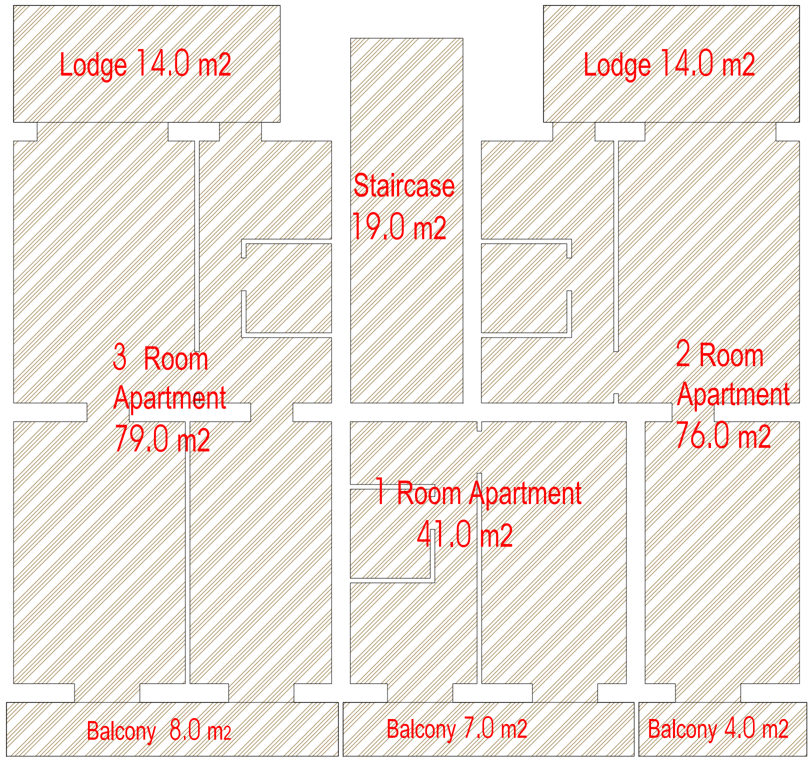


Total Floor Area of 3-Apartment Section 218 m2

3-Room Apartment 101 m2	1-Room Apartment 41 m2	2-Room Apartment 76 m2
Apartment 79 m2	Apartment 34 m2	Apartment 58 m2
Lodge 14 m2	Balcony 7 m2	Lodge 14 m2
Balcony 8 m2		Balcony 4 m2



ENERGY EFFICIENCY REHABILITATION DESIGN OF THE TYPICAL 8-STOREY RESIDENTIAL BUILDING WITH 3 BLOCK-SECTIONS		
Architectural Part		Address
Architect	Z. Tsikhiseli	Vaja-Pshavela avenue, IV district, block # 24
Structural Engineer	B. Dgebuadze	

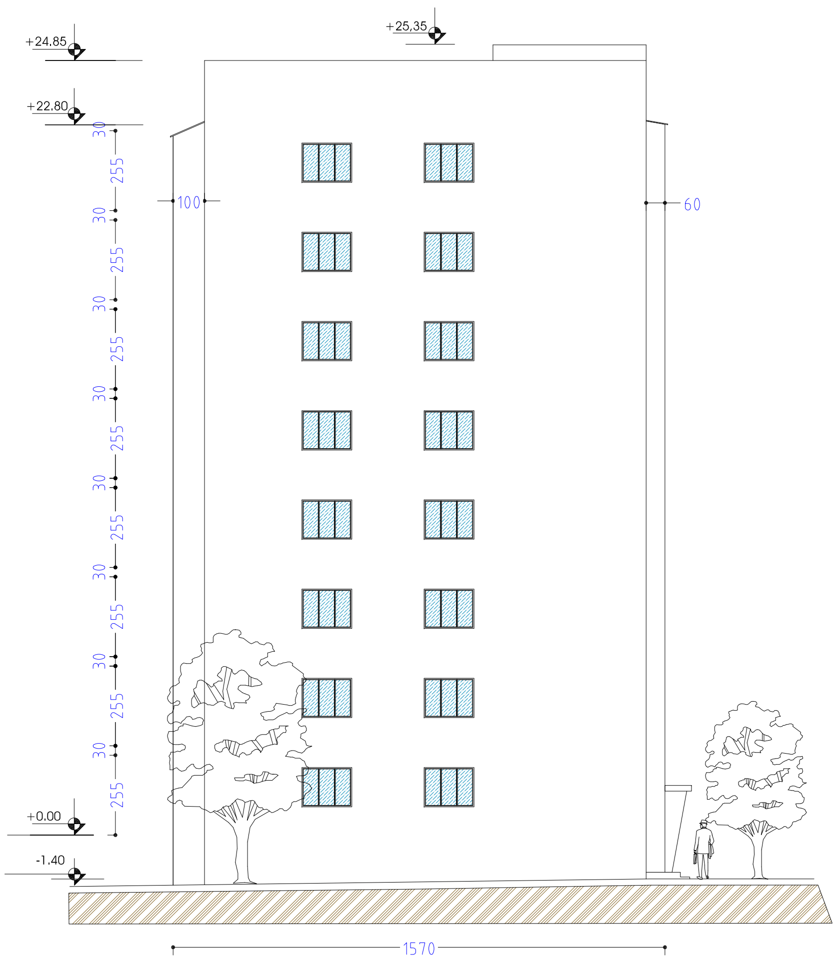
South Facade

ENERGY EFFICIENCY REHABILITATION DESIGN OF THE TYPICAL 8-STOREY RESIDENTIAL BUILDING WITH 3 BLOCK-SECTIONS		
Architectural Part		Address
Architect	Z. Tsikhiseli	Vaja-Pshavela avenue, IV district, block # 24
Structural Engineer	B. Dgebuadze	

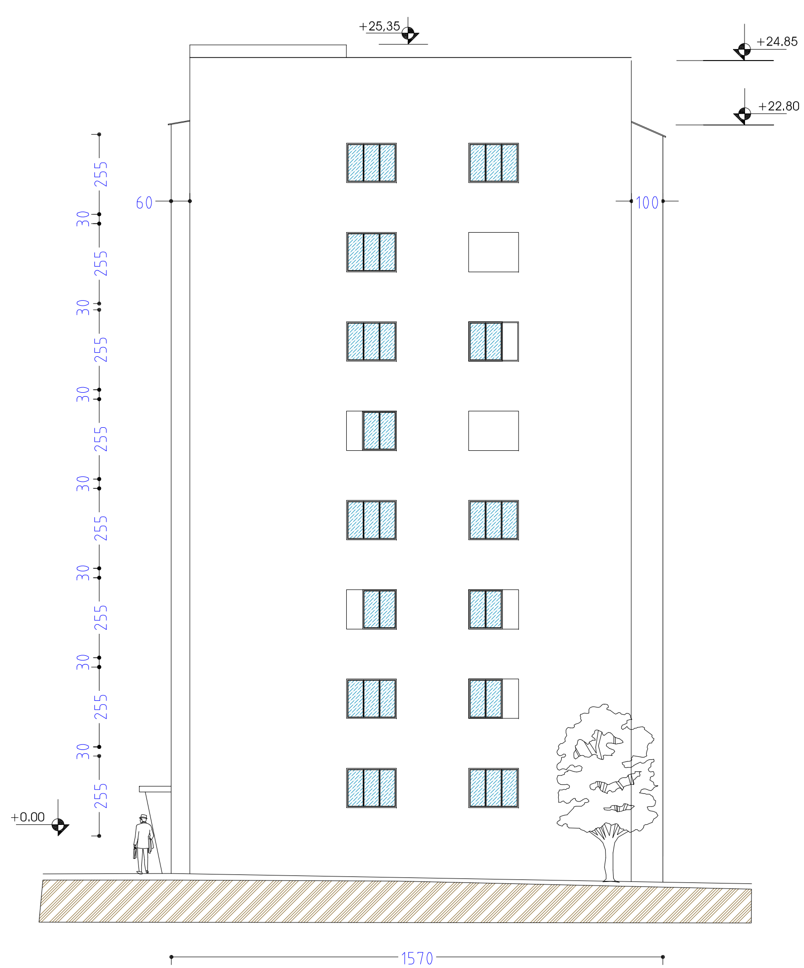
North Facade

ENERGY EFFICIENCY REHABILITATION DESIGN OF THE TYPICAL 8-STOREY RESIDENTIAL BUILDING WITH 3 BLOCK-SECTIONS		
Architectural Part		Address
Architect	Z. Tsikhiseli	Vaja-Pshavela avenue, IV district, block # 24
Structural Engineer	B. Dgebuadze	

East Facade

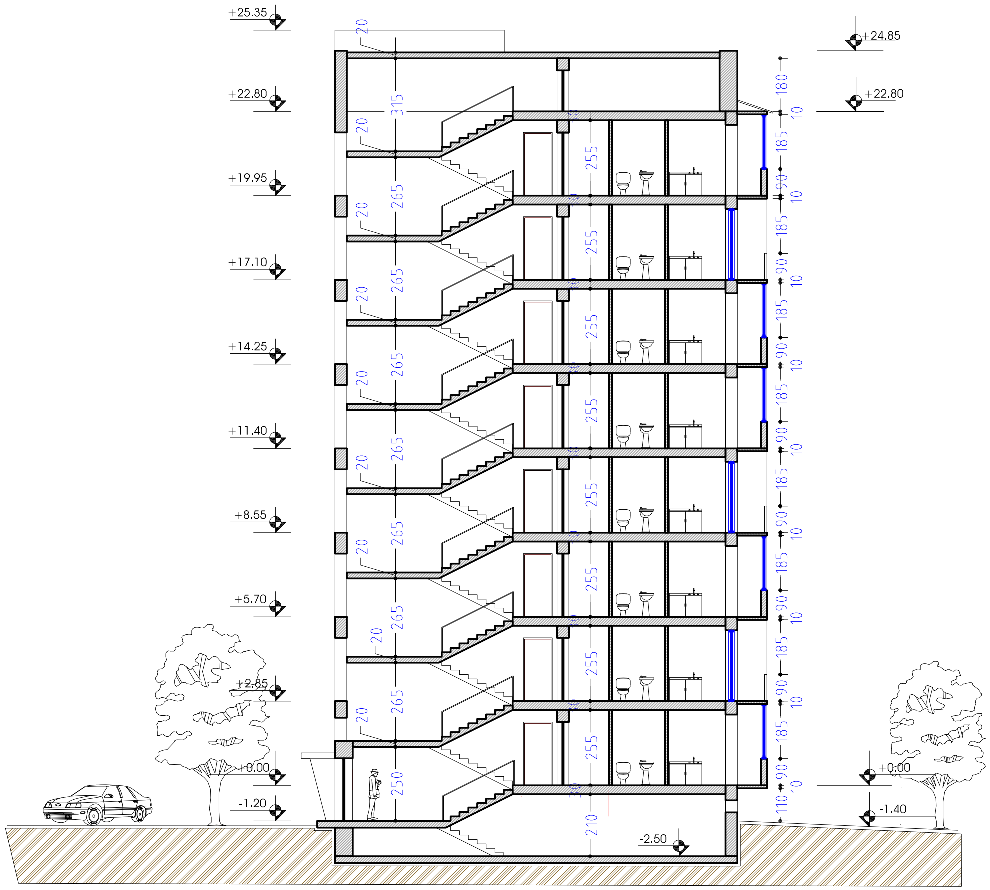


West Facade



ENERGY EFFICIENCY REHABILITATION DESIGN OF THE TYPICAL 8-STOREY RESIDENTIAL BUILDING WITH 3 BLOCK-SECTIONS		
Architectural Part		Address
Architect	Z. Tsikhiseli	Vaja-Pshavela avenue, IV district, block # 24
Structural Engineer	B. Dgebuadze	

Cutavay 1-1 a.1;200



ENERGY EFFICIENCY REHABILITATION DESIGN OF THE TYPICAL 8-STOREY RESIDENTIAL BUILDING WITH 3 BLOCK-SECTIONS		
Architectural Part		Address
Architect	Z. Tsikhiseli	Vaja-Pshavela avenue, IV district, block # 24
Structural Engineer	B. Dgebuadze	

ENERGY EFFICIENCY REHABILITATION DESIGN OF THE TYPICAL 8-STOREY RESIDENTIAL BUILDING WITH 3 BLOCK-SECTIONS		
Architectural Part		Address
Architect	Z. Tsikhiseli	Vaja-Pshavela avenue, IV district, block # 24
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ENERGY EFFICIENCY REHABILITATION DESIGN OF THE TYPICAL 8-STOREY RESIDENTIAL BUILDING WITH 3 BLOCK-SECTIONS

Architectural Part		Address
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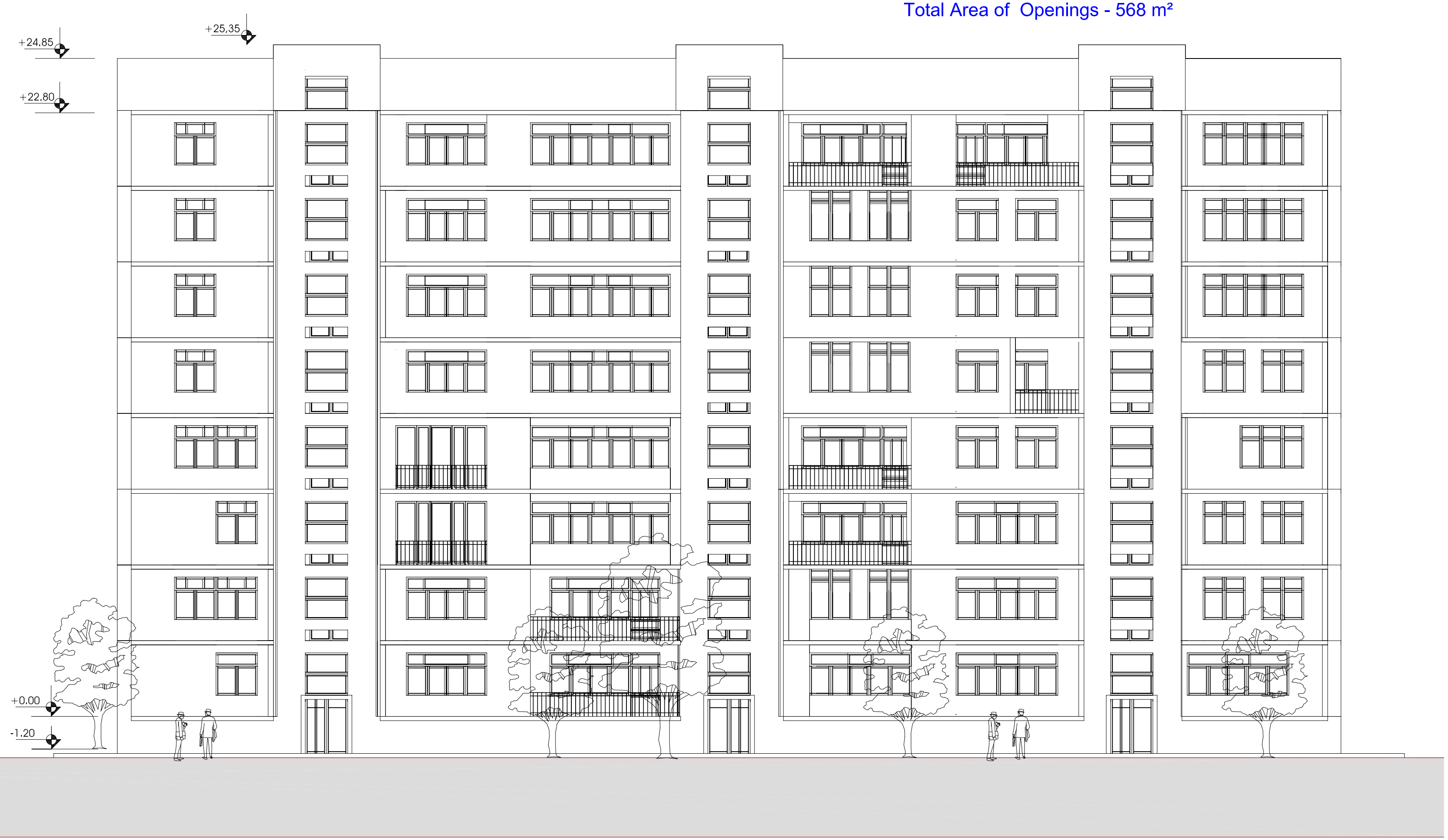
ENERGY EFFICIENCY REHABILITATION DESIGN OF THE TYPICAL 8-STOREY RESIDENTIAL BUILDING WITH 3 BLOCK-SECTIONS		
Architectural Part		Address
Architect	Z. Tsikhiseli	Vaja-Pshavela avenue, IV district, block # 24
Structural Engineer	B. Dgebuadze	

North Facade

North Facade Area - 1378 m²
Total Area of Wall - 975 m²
Total Area of Openings - 568 m²



ENERGY EFFICIENCY REHABILITATION DESIGN OF THE TYPICAL 8-STOREY RESIDENTIAL BUILDING WITH 3 BLOCK-SECTIONS		
Architectural Part		Address
Architect	Z. Tsikhiseli	Vaja-Pshavela avenue, IV district, block # 24
Structural Engineer	B. Dgebuadze	

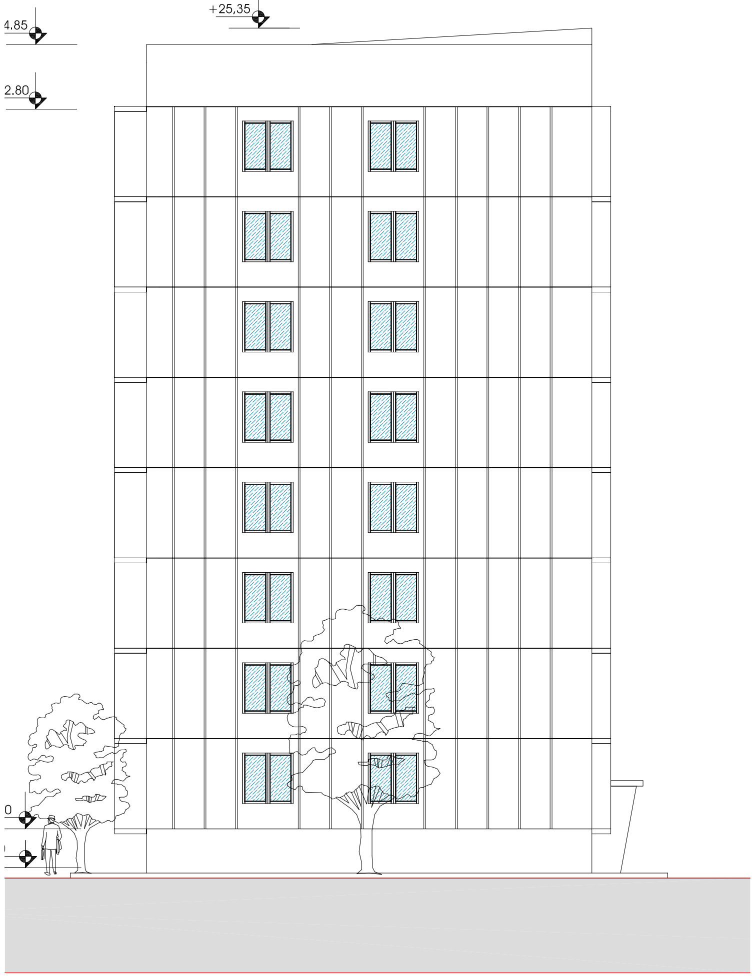
South Facade

South Facade Area - 1412 m²
Total Area of Wall - 844 m²
Total Area of Openings - 568 m²

ENERGY EFFICIENCY REHABILITATION DESIGN OF THE TYPICAL 8-STOREY RESIDENTIAL BUILDING WITH 3 BLOCK-SECTIONS		
Architectural Part		Address
Architect	Z. Tsikhiseli	Vaja-Pshavela avenue, IV district, block # 24
Structural Engineer	B. Dgebuadze	

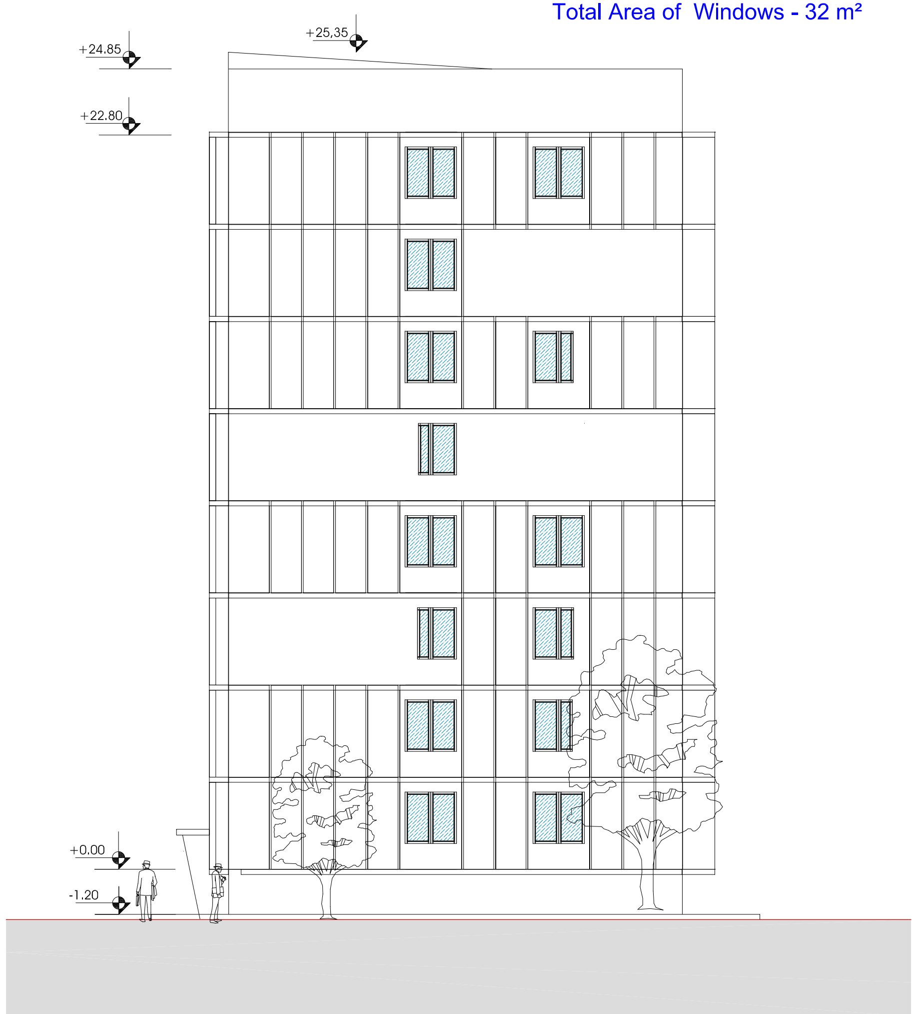
East Facade

East Facade Area - 368 m²
Total Wall Area - 343 m²
Total Area of Windows - 25 m²



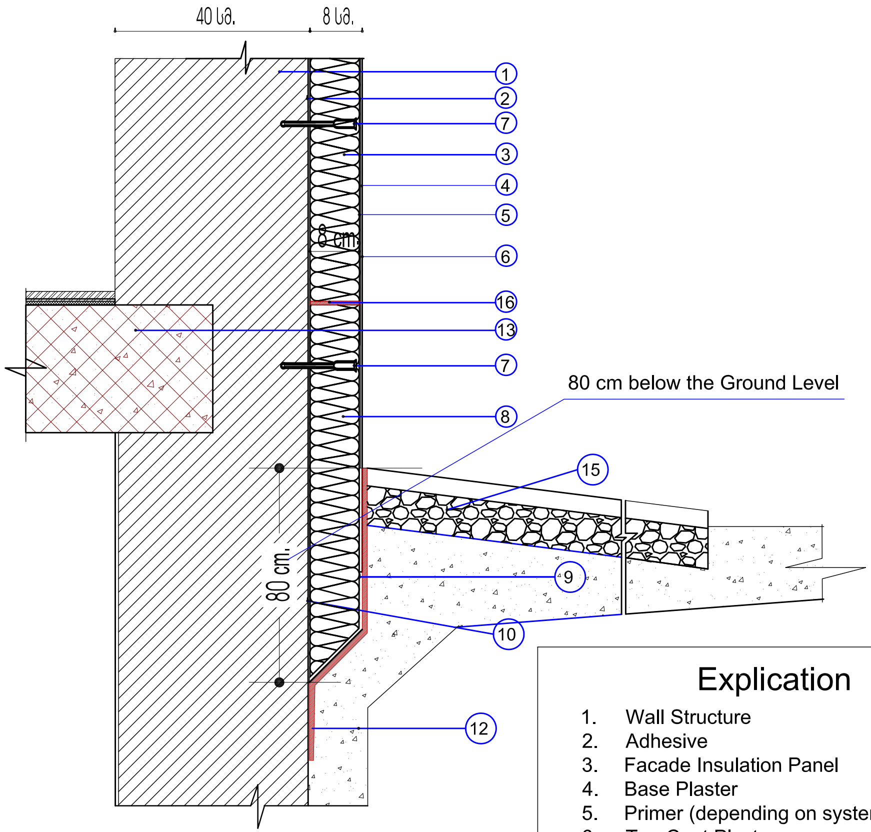
West Facade

West Facade Area - 370 m²
Total Wall Area - 338 m²
Total Area of Windows - 32 m²

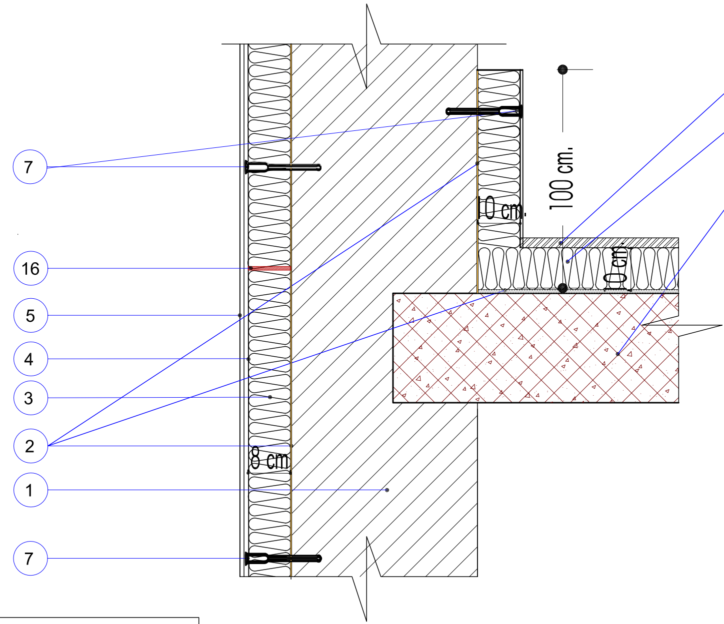


ENERGY EFFICIENCY REHABILITATION DESIGN OF THE TYPICAL 8-STOREY RESIDENTIAL BUILDING WITH 3 BLOCK-SECTIONS		
Architectural Part		Address
Architect	Z. Tsikhiseli	Vaja-Pshavela avenue, IV district, block # 24
Structural Engineer	B. Dgebuadze	

Insulation of a Plinth Area and Foundation of Building
Detail 1



Insulation of Attic of Building
Detail 2



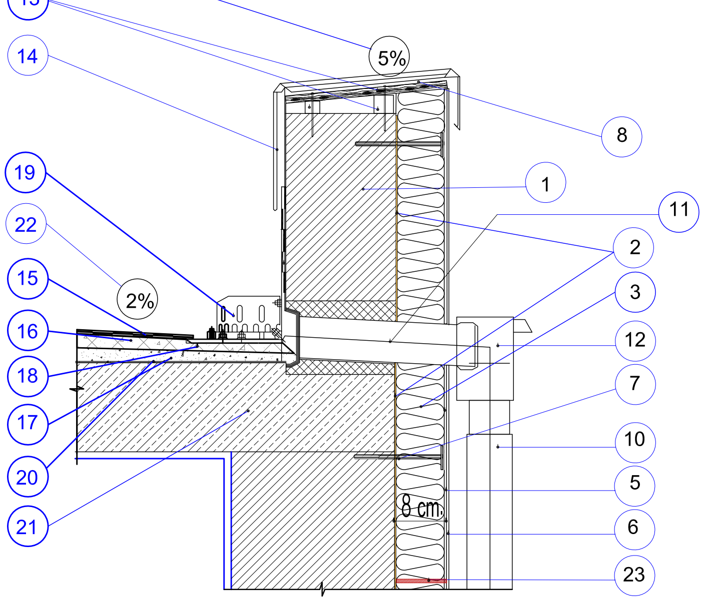
Explication

1. Wall Structure
2. Adhesive
3. Facade Insulation Panel
4. Base Plaster
5. Primer (depending on system)
6. Top Coat Plaster
7. System Anchor (with plug/flush)
8. Plinth Area Insulation Panel)
9. Sealing Compound (depending on system)
10. Existing Sealing of Building Structure
11. -
12. Delta Membrane
13. Rood Slab
15. Blind Area
16. Vertical Seams
17. Cement Send Screed over the Mineral wool

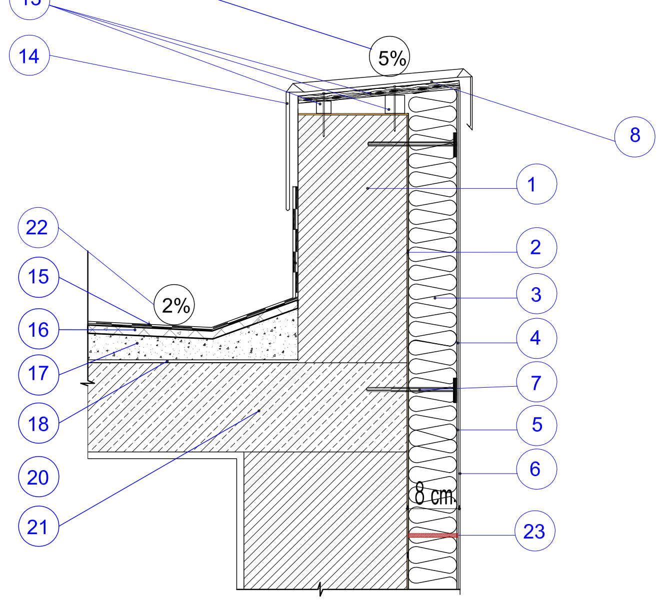
Notice
The Height of the Insulation Layer on Walls of the Roof from Ground on 1 m Height

ENERGY EFFICIENCY REHABILITATION DESIGN OF THE TYPICAL 8-STOREY RESIDENTIAL BUILDING WITH 3 BLOCK-SECTIONS		
Architectural Part		Address
Architect	Z. Tsikhiseli	Vaja-Pshavela avenue, IV district, block # 24
Structural Engineer	B. Dgebuadze	

Parapet Detail 3



Parapet Detail 4

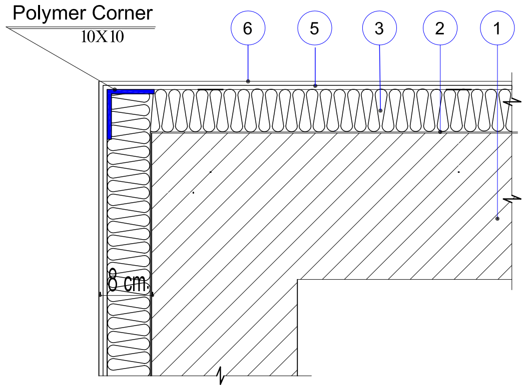


Explication

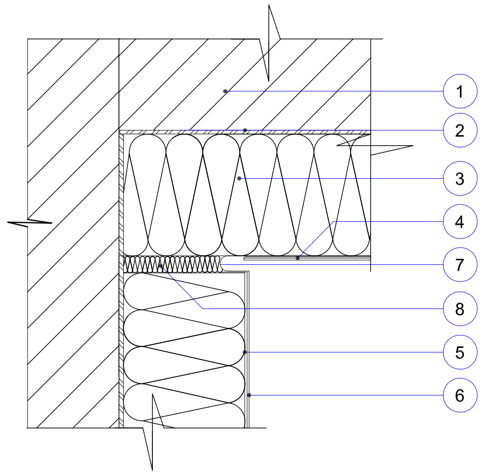
1. Building Parapet
2. Adhesive
3. Facade Insulation Plate
4. Base Plaster
5. Surface (depending on system)
6. Top Layer
7. System Anchor (with plug/flush)
8. Border Profile
9. Parapet Sloping 5%
10. Rain Gutter
11. Water Carrier 10 cm
12. Water Collector
13. Wooden Beam
14. Tin Sheet
15. 2 Layers of Ruberoid
16. Cement Covering with Thickness 3 cm
17. Vapor Barrier
18. Insulation Layer
19. Water Collector Detail
20. Waterproofing Layer
21. Roof Slab
22. Roof Sloping 2%
23. Vertical Seams

ENERGY EFFICIENCY REHABILITATION DESIGN OF THE TYPICAL 8-STOREY RESIDENTIAL BUILDING WITH 3 BLOCK-SECTIONS		
Architectural Part		Address
Architect	Z. Tsikhiseli	Vaja-Pshavela avenue, IV district, block # 24
Structural Engineer	B. Dgebuadze	

Detail 5
Insulation of External Corner (External Walls)



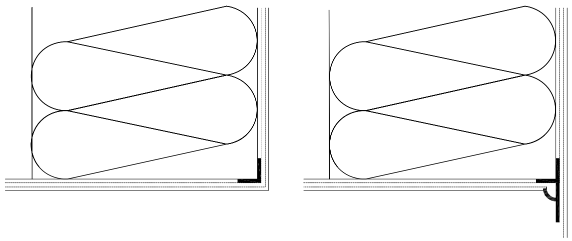
Detail 6
Insulation of Internal Corner (External Walls)



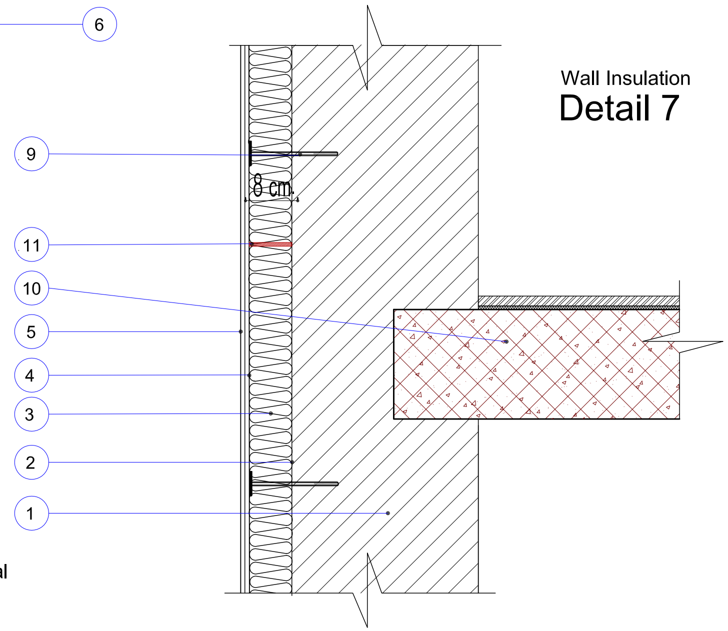
Explication

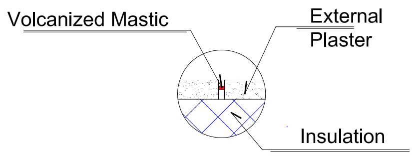
1. Wall Structure
2. Adhesive
3. Facade Insulation Layer
4. Base Plaster
5. Primer
6. Top Coat Plaster
7. Extension of the Connection
8. Sealing Layer
9. System Anchor (with plug/flush)
10. Floor Slab
11. Vertical Seams

Structure of Window Corners



Wall Insulation
Detail 7



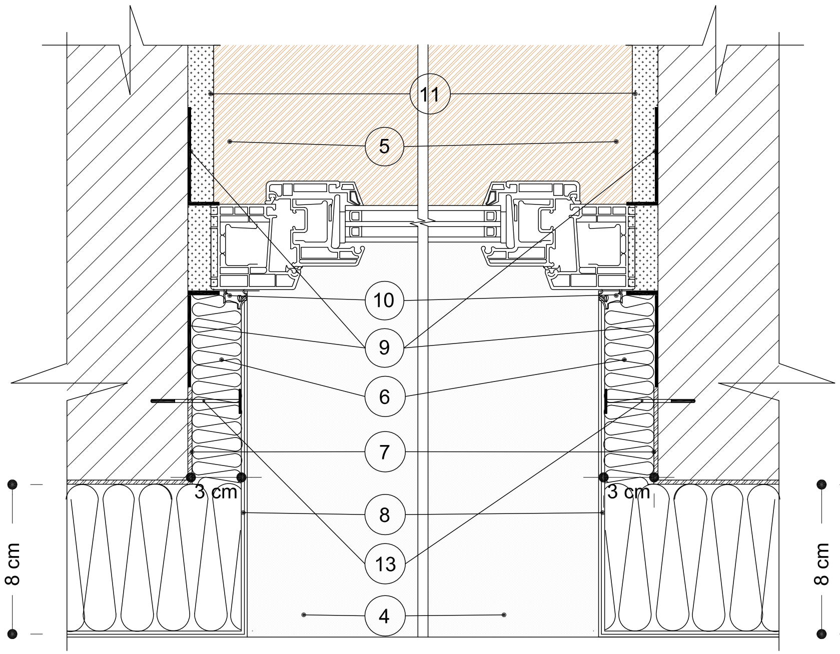


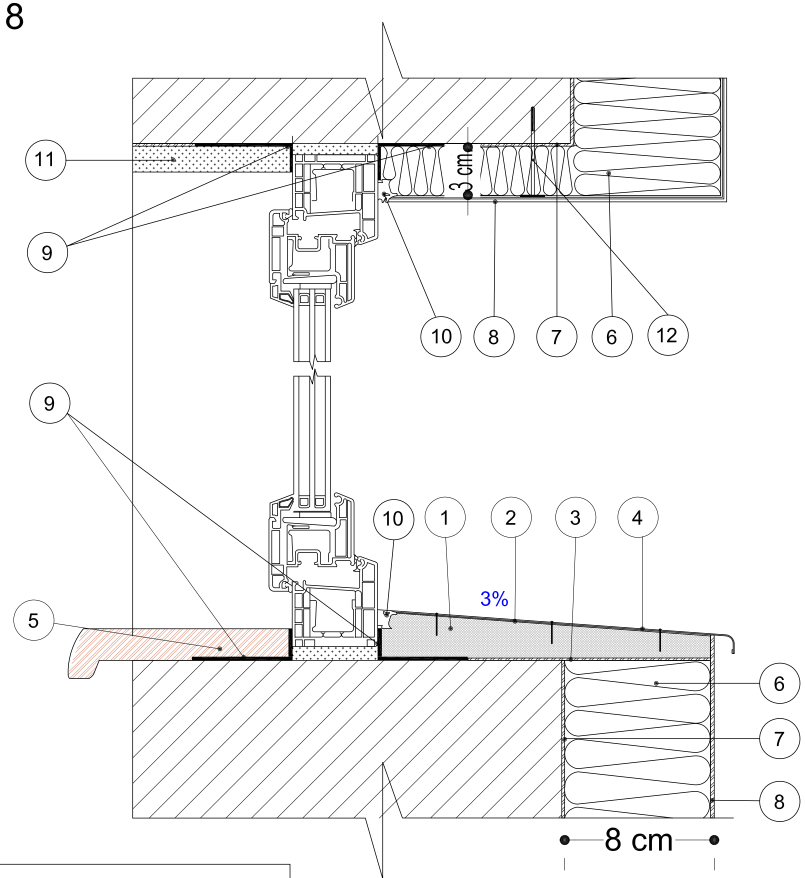
Vertical Seam should be cut with
Thickness of 6 mm in every 8 m

ENERGY EFFICIENCY REHABILITATION DESIGN OF THE TYPICAL 8-STOREY RESIDENTIAL BUILDING WITH 3 BLOCK-SECTIONS		
Architectural Part		Address
Architect	Z. Tsikhiseli	Vaja-Pshavela avenue, IV district, block # 24
Structural Engineer	B. Dgebuadze	

Window Insulation

Detail 8





Explikation

1. External window seals should be installed after proper insulartion with the slope no less then 3 degrees
2. Insulation of spaces with strog insulation material (ex. Hard phenolic foam)
3. Armor belt and mineral coation as the base of the window seal
4. Tin sheet
5. Internal window seal
6. Insulation plate
7. Adhesive
8. External protection layer
9. Insulation layer of the window fram
10. Conetion profile + hermetic insulation
11. Internal plaster
12. Sistem anchor (with plug/flush)

ENERGY EFFICIENCY REHABILITATION DESIGN OF THE TYPICAL 8-STOREY RESIDENTIAL BUILDING WITH 3 BLOCK-SECTIONS		
Architectural Part		Address
Architect	Z. Tsikhiseli	Vaja-Pshavela avenue, IV district, block # 24
Structural Engineer	B. Dgebuadze	

STRUCTURAL PART

The following design envisages the energy efficient retrofitting measures for a typical 8-storey residential building located at Vazha-Pshavela Avenue, Block 4, Building 24 (cadaster code 01.14.003.003), in order to achieve maximum savings in energy consumption and related energy expenditures. The building was selected as a typical structure by the Tbilisi Municipality, which represents the majority of the city housing stock.

The building has load bearing walls, eight floors, three entrances and a basement. The building walls are constructed by large wall blocks, fixed on the top of the floors by modular girdle reinforced concrete blocks, the foundation is a band type, basement walls are of modular concrete blocks, floor and roof slabs are of modular hollow reinforced concrete panels.

The proposed design for the selected building will cover the following:

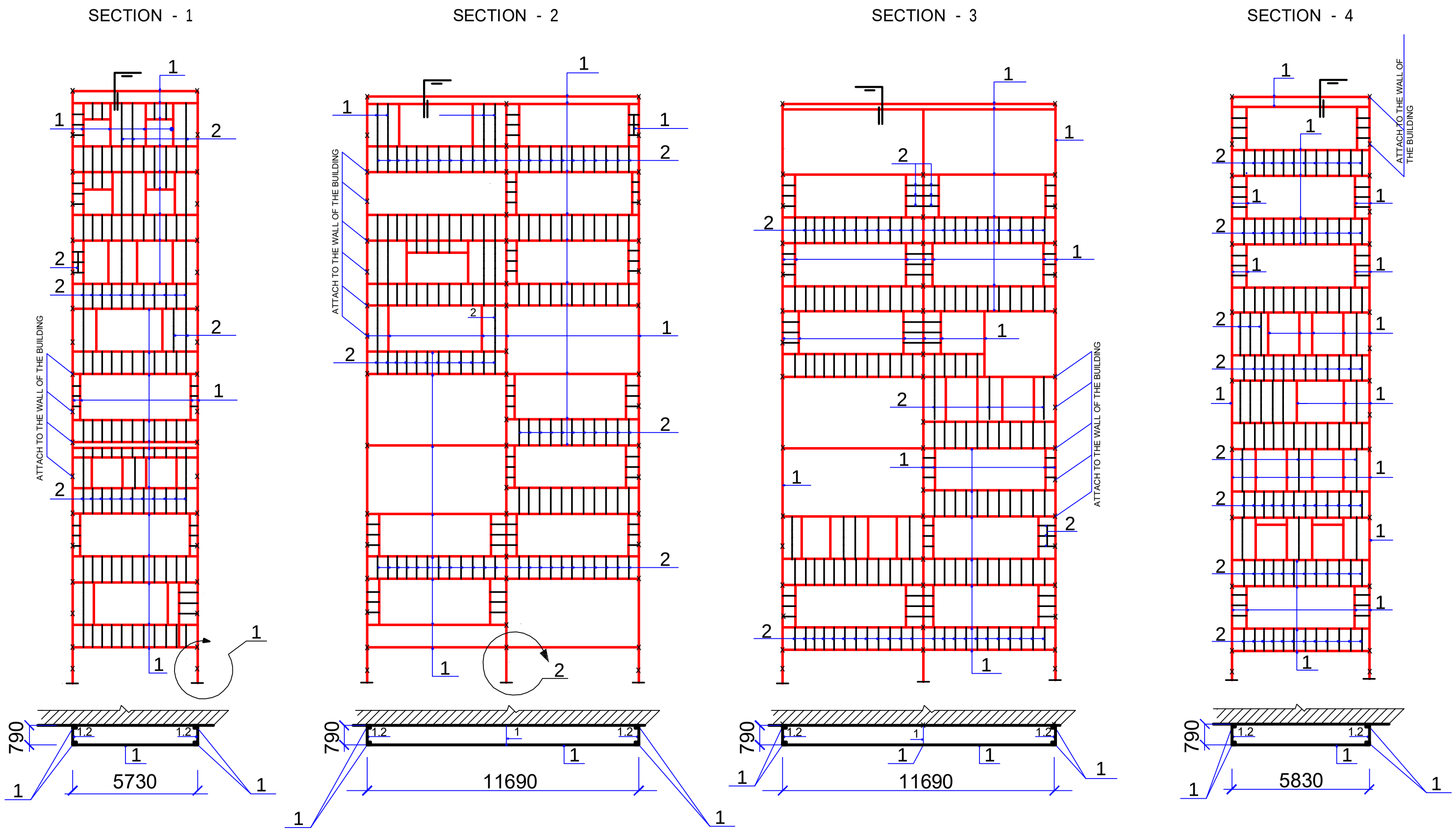
- Insulation of the external load barring walls (with 80 mm rockwool);
- Replacing windows with efficient ones;
- Insulation of the individually constructed lodgias on the North facade of the building;
- Glazing the entrance openings and insulation of the walls;
- Insulation of the lodgia roofing (on the 8th floor) with rockwool and new corrugated tin on the roof;
- Insulation of the attic floor with rockwool;
- Creation of the individual ventilation unit network with heat recovery, in order to achieve efficient air exchange in the apartments.

North facade loggias brick walls (thickness 70-120 mm) were arbitrarily erected by the residents without permission from the Tbilisi Municipality and the appropriate design plan. Therefore, the rehabilitation foresees sectional metal construction to attach insulation boards to the brick walls.

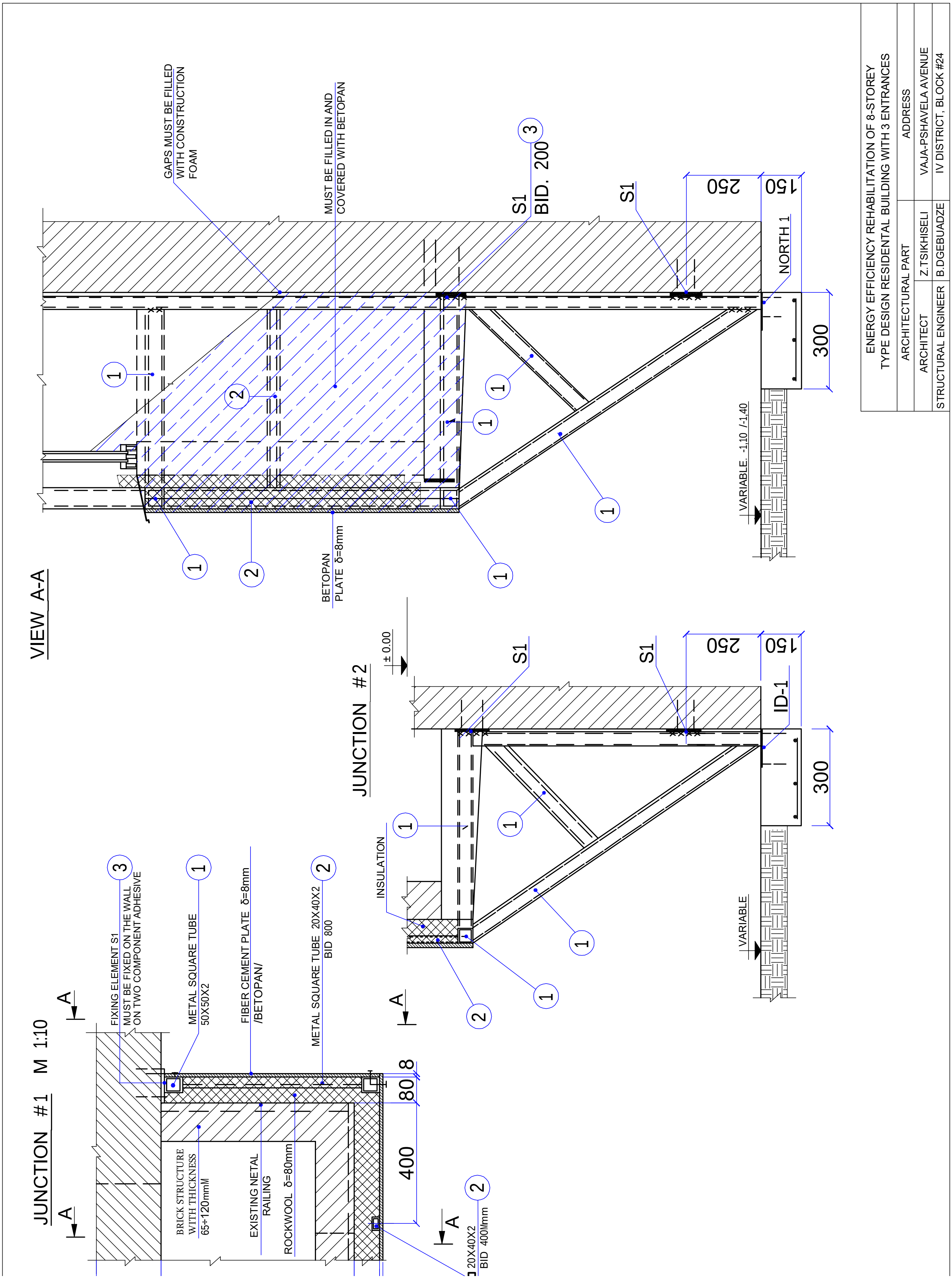
Metal constructions are designed in accordance with the "SNIP II - 2381 Steel Constructions. Design Norms" and "SNIP 2.01.07-85 Loads and Interaction". All metal constructions are designed by rolled and welded sections. Welding of metal construction must be done with 42 (235, 245 metal types) electrodes (GOST 9467-75). Construction installation must be done in accordance with "SNIP 3.03.01-87 Rules of Carrying Out and Acceptance of works" and "SNIP 111-1-80 Safety Norms of Construction". All metal constructions need to be covered with paint in accordance with "SNIP 2.03.11-85 Protection of Constructions", thickness of the covering is unlimited.

SECTIONAL METAL CONSTRUCTION FOR INSULATION APPLICATION ON THE NORTH FACADE OF THE BUULDING

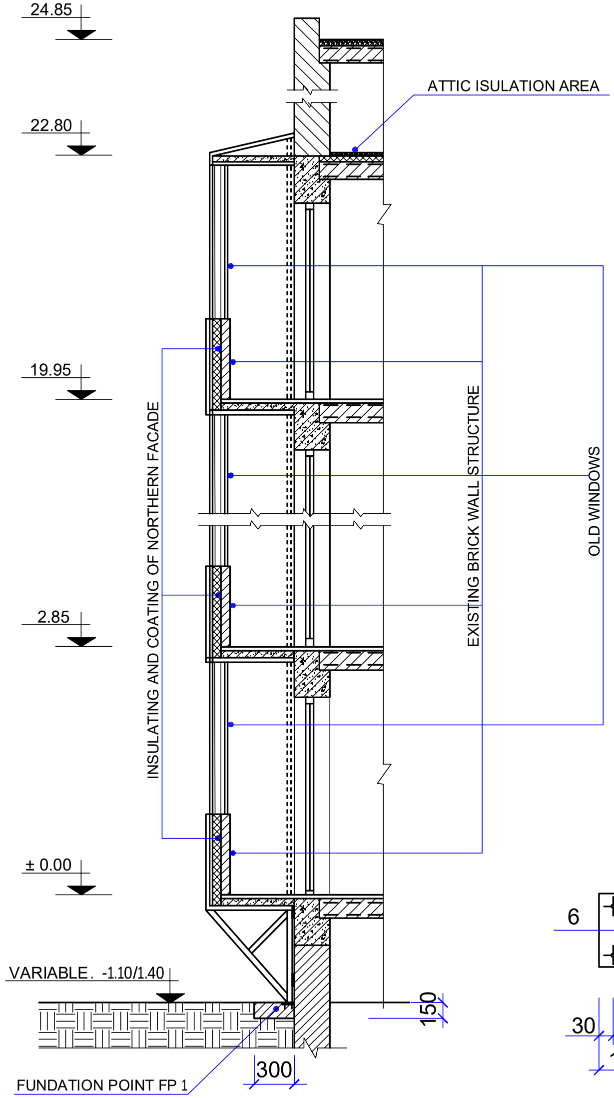
ENERGY EFFICIENCY REHABILITATION OF 8-STOREY TYPE DESIGN RESIDENTAL BUILDING WITH 3 ENTRANCES		
ARCHITECTURAL PART		ADDRESS
ARCHITECT	Z.TSIKHISELI	VAJA-PSHAVELA AVENUE
STRUCTURAL ENGINEER	B.DGEBUADZE	IV DISTRICT, BLOCK #24



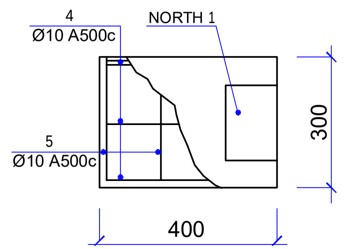
ENERGY EFFICIENCY REHABILITATION OF 8-STOREY TYPE DESIGN RESIDENTAL BUILDING WITH 3 ENTRANCES		
ARCHITECTURAL PART		ADDRESS
ARCHITECT	Z.TSIKHISELI	VAJA-PSHAVELA AVENUE
STRUCTURAL ENGINEER	B.DGEBUADZE	IV DISTRICT, BLOCK #24


VIEW A-A
GAPS MUST BE FILLED WITH CONSTRUCTION FOAM
MUST BE FILLED IN AND COVERED WITH BETOPAN
S1
BID. 200
3
S1
250
150
NORTH 1
300
VARIABLE. -1.10 /-1.40
BETOPAN PLATE δ=8mm
1
2
JUNCTION #2
± 0.00
S1
S1
250
150
ID-1
300
INSULATION
VARIABLE
JUNCTION #1 M 1:10
A
FIXING ELEMENT S1 MUST BE FIXED ON THE WALL ON TWO COMPONENT ADHESIVE
METAL SQUARE TUBE 50X50X2
FIBER CEMENT PLATE δ=8mm /BETOPAN/
METAL SQUARE TUBE 20X40X2 BID 800
BRICK STRUCTURE WITH THICKNESS 65÷120mmM
EXISTING NETAL RAILING
ROCKWOOL δ=80mm
80
8
400
20X40X2 BID 400Mmm
ENERGY EFFICIENCY REHABILITATION OF 8-STOREY TYPE DESIGN RESIDENTAL BUILDING WITH 3 ENTRANCES
ARCHITECTURAL PART
ADDRESS
ARCHITECT
Z.TSIKHISELI
STRUCTURAL ENGINEER
B.DGEBUADZE
VAJA-PSHAVELA AVENUE
IV DISTRICT, BLOCK #24

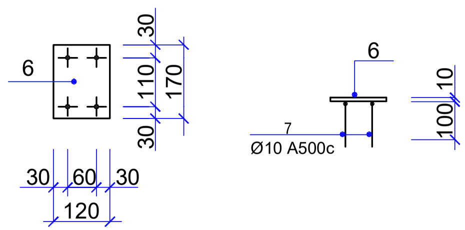
CUTAWAY 1-1   M 1:50



FUNDATION POINT FP1 /10 PIECES/



INSERT DETAL ID-1

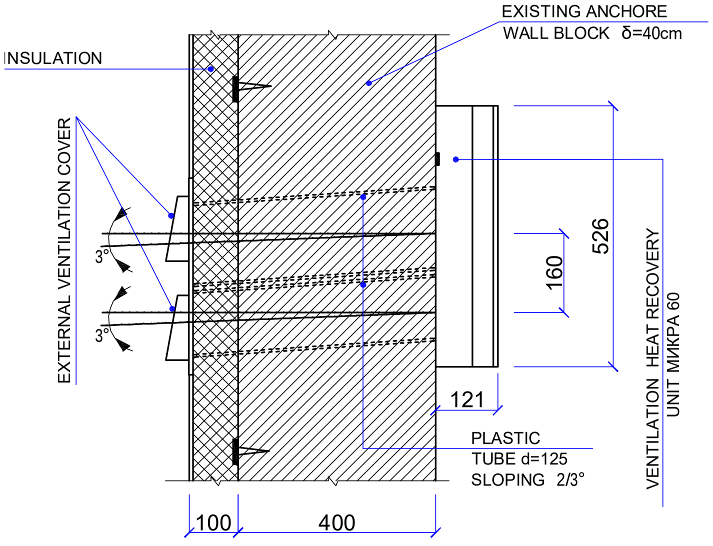


MATERIAL SPECIFICATION

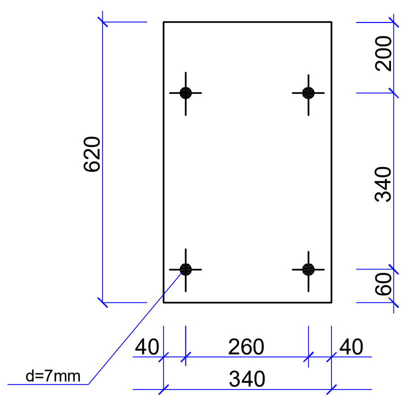
POST #	MARKING	NAME	QUANTITY	NOTE	
		NORTH FACADE SECTIONS #1 AND 4			
		DETALS			
1	MUST BE CUT ON SITE	□50X50X2 L=500,0 m		1570,0 kg	
2	——//——	□20X40X2 L=322.0 m		605,4 kg	
3	FIXING ELEMENT FE1	-10X100X240	116	1,89 kg	219,24
		MATERIALS			
	COATING OF INSULATED WALL	FIBER CEMENT PLATE δ=8mm	—	216,2 m²	
	LODGE ROOF	CORUGGATED TIN δ=0.55	—	9,0 m²	
	GUTTER	TIN SHEET δ=0.55	—	15,4 m²	
		ROCKWOOL δ=80mm	—	225,2 m²	
		ANCHORS Ø12,L=100/120	—	464 PIECES	
		NORTH FACADE SECTIONS #2 AND 3			
		DETALS			
1	MUST BE CUT ON SITE	□50X50X2 L=676.0m	—	2122,7 kg	
2	——//——	□20X40X2 L=380.2m	—	714,8 kg	
3	FIXING ELEMENT FE 1	-10X100X240	146	1,89 kg	276,9
		MATERIALS			
	COATING OF INSULATED WALL	FIBER CEMENT PLATE δ=8mm	—	216,0 m²	
	LODGE ROOF	CORUGGATED TIN δ=0.55	—	27,9 m²	
		TIN SHEET δ=0.55	—	14,7 m²	
		ROCKWOOL δ=80mm	—	244 m²	
		ANCHORS Ø12,L=100/120	—	584 PIECES	
		SECTION 1 - 4 FUNDATION POINT /10 PIECES/			
		DETALS			
4		Ø10 A500c L=380	40	0,24 kg	7,2
5		Ø10 A500c L=280	40	0,18 kg	7,2
6	NORTH 1 /10 PIECES/	-10X120X170	10	1,60 kg	16,0
7		Ø10 A500c L=100	40	0,07 kg	2,8
		MATERIALS			
		B25 CONCRETE	—	0,18 m3	

ENERGY EFFICIENCY REHABILITATION OF 8-STOREY TYPE DESIGN RESIDENTAL BUILDING WITH 3 ENTRANCES			
ARCHITECTURAL PART		ADDRESS	
ARCHITECT	Z.TSIKHISELI	VAJA-PSHAVELA AVENUE	
STRUCTURAL ENGINEER	B.DGEBUADZE	IV DISTRICT, BLOCK #24	

JUNCTION OF THE VENTILATION UNIT WITH HEAT RECOVERY IN 40cm. WALL



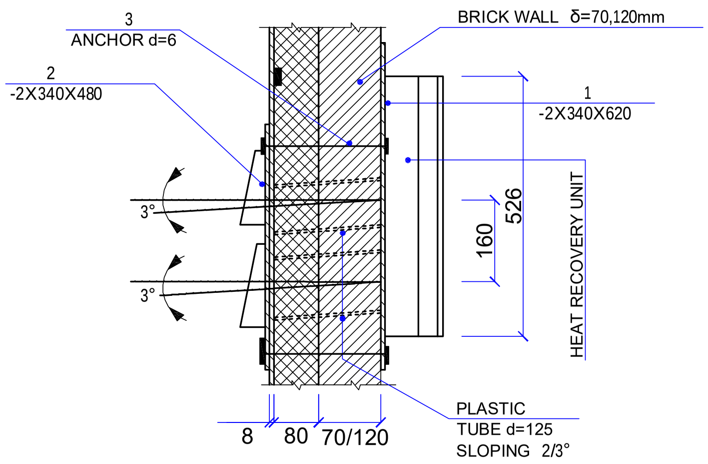
POS.1 δ=2mm



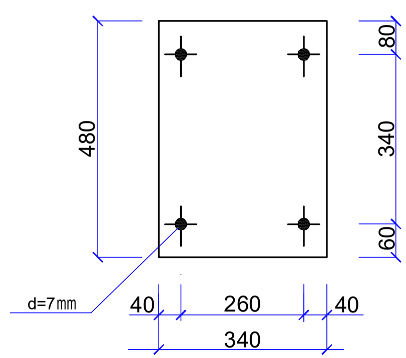
MATERIAL SPECIFICATION

POS #	MARKING	NAME	QUAN TITY	NOTE	
	VENTILATION UNIT ELEMENTS ON NORTHERN FACADE DETALS				
		DETALS			
1	SHEET	-2X340X620	48	3,3 kg	158,
2	SHEET	-2X340X480	48	2,56 kg	122,
3	ANCHOR	d=6mm L240	192	0,06 kg	11,5
		METERIALS			
		PLASTIC TUBE Ø125 L=500	192		
		———//——— d=125, L 210	96		

JUNCTION OF THE VENTILATION UNIT WITH HEAT RECOVERY ON THE NORTHERN FACADE



POS.2 δ=2mm



ENERGY EFFICIENCY REHABILITATION OF 8-STOREY TYPE DESIGN RESIDENTAL BUILDING WITH 3 ENTRANCES		
ARCHITECTURAL PART		ADDRESS
ARCHITECT	Z.TSIKHISELI	VAJA-PSHAVELA AVENUE
STRUCTURAL ENGINEER	B.DGEBUADZE	IV DISTRICT, BLOCK #24

Structural Conclusion

The building was built in 1960s. The building has load bearing walls, eight floors, three entrances and a basement. The building walls are constructed with large wall blocks, fixed on the top of the floors by modular girdle reinforced concrete blocks, the foundation is a band type, basement walls are of modular concrete blocks, floor and roof slabs are of modular hollow reinforces concrete panels. Visual inspection of building facades, entrances and interior spaces identified the following:

- The overall building structure is in a satisfactory condition
- No contraction or fractures were visible.

The proposed design covers the following interventions:

- Insulation of the external load bearing walls (with 80 mm rock wool);
- Replacing windows with the more efficient ones;
- Insulation of the individually built-up loggias on the North facade of the building by rock wool;
- Glazing of entrance openings and insulation of the walls;
- Insulation of attic overhead cover (on the 8th floor) with rock wool;
- Installation of individual ventilation units in the external walls.

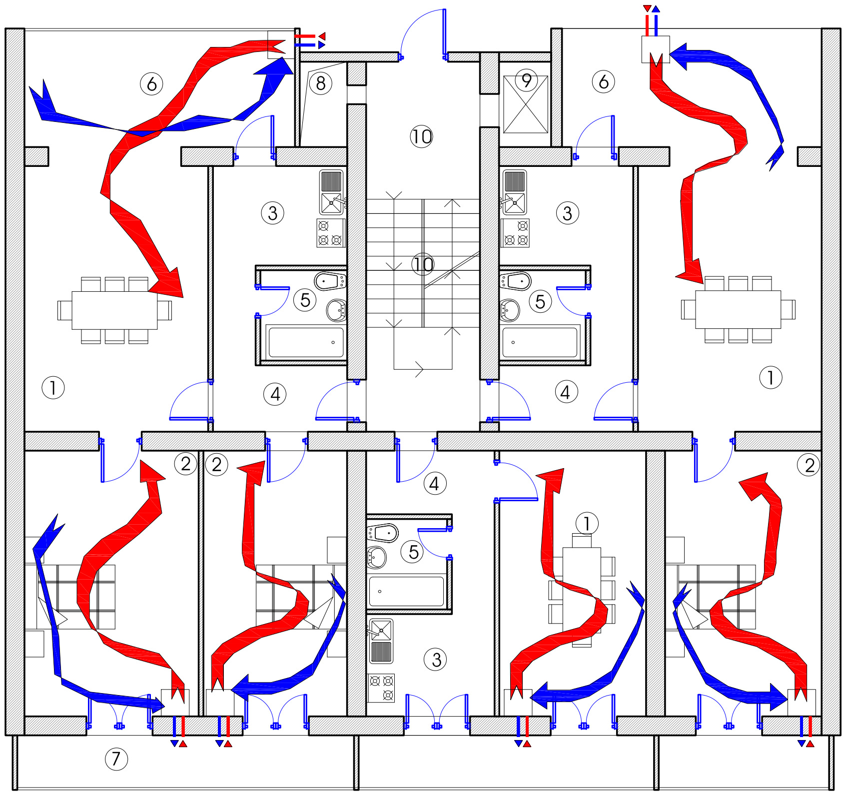
Taking into account the proposed measures, it can be concluded that if the construction works of the facade insulation foreseen under the design will be held in accordance with the existing construction and safety norms, they will have no negative effect on the building condition and it will not cause any damage of the building.

Structural Engineer B. Dgebuadze

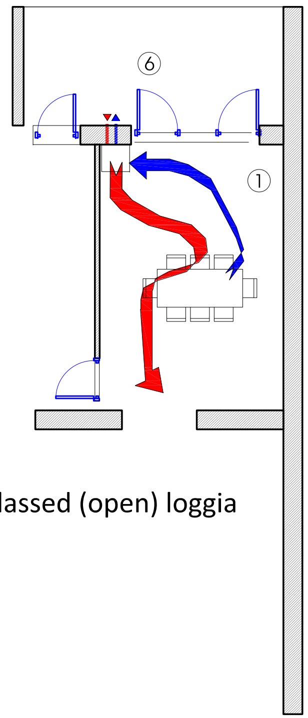
Ventilation

The proposed design includes the energy efficient ventilation for the interior spaces. The proposed ventilation is designed for the typical residential apartments. Heat recovery ventilation devices are suggested. Their location on the layout is conditional and must be individually matched during the installation to achieve maximum efficient airflow in the apartments. The installation should ensure that air flows should not cause discomfort to the residents. Air flows must not be directed towards places where residents are most frequently located. Besides, air flow speed should be minimal and must not be higher than 0.3 m/second. For the heat recovery units to function properly it is assumed that the building is properly insulated, rooms have at least minimal heating during winter, and during summer, direct solar impact is reduced at maximum. Ventilation nominal capacity is selected according to construction norms and rules: SNIP 2.08.01-89, MGSN 3.01-01, ASHRAE 62-1999. The average area of a living room in this typical building is about 20 m^2, where the average celling height is 2.55-2.75 m. Selected apartments are outfitted with standard toilets-bath rooms and kitchens. Therefore, it is acceptable to have 50-60 m^3/h airflow for the standard average size room. The noise level should not be higher than 35 dB(A). Mikra 60 by VENTS company is fully compliant for the noted parameters. Total number of units required for the proposed building is 144 (18 ventilation recovery units for each floor).

typical section for 3 apartments

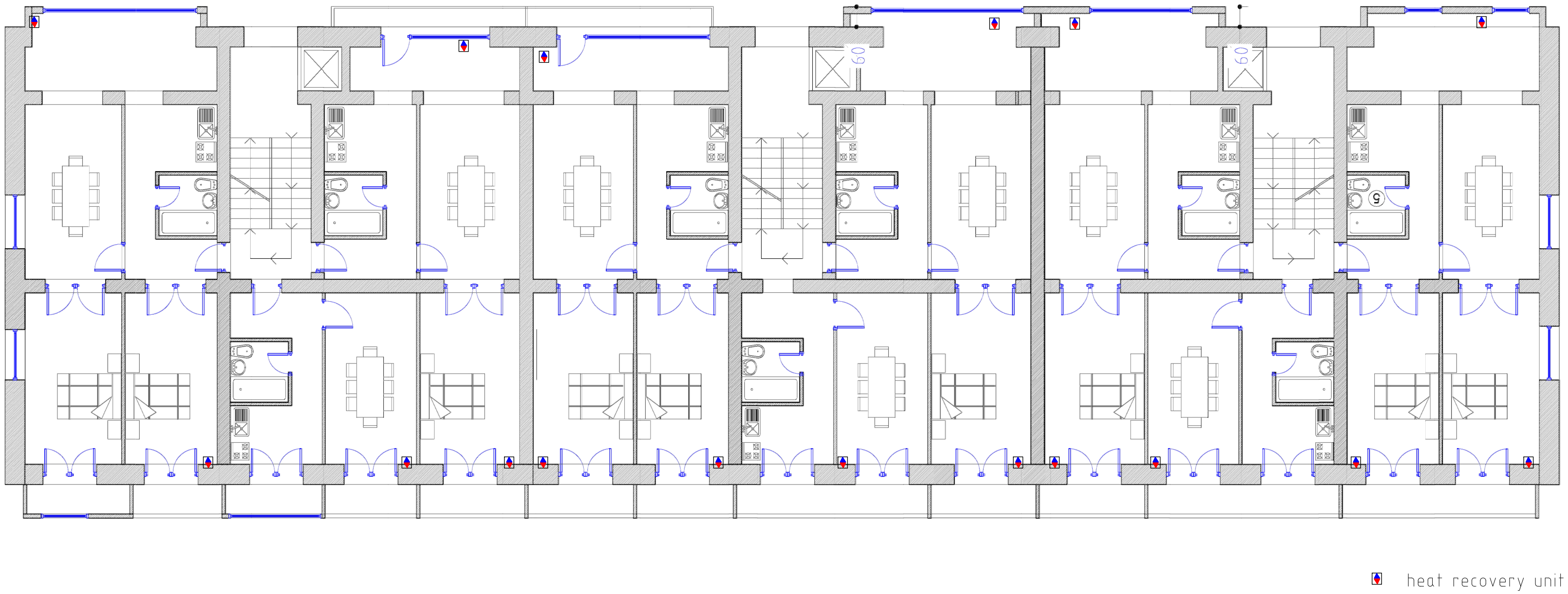


1	Common room
2	Bedroom
3	Kitchen
4	Hallway
5	W C
6	Loggia
7	Balcony
8	Garbage mine
9	Elevator shaft
10	Staircase
	Ventilation unit



For not glassed (open) loggia

Designed by G. Shengelia



Mikra 60 by VENTS Technical data:

Speed 1, 2, 3

Supply Voltage, 50-60 Hz [V] 1 ~ 100-240

Power [W] 4.2, 9.6, 15.4

Total unit current [A] 0.02, 0.04, 0.07

Air capacity [m3 /h] (CFM) 30 (17.7), 45 (26.5), 60 (35.3)

RPM [min-1] 1165, 1720, 2685

Noise level dB(A) 22 (0.38), 25 (0.42), 29 (1.0)

Max. transported air temperature [°C] (°F) from -20 (-4) up to +50 (+122)

Heat recovery efficiency 79 %, 74 %, 70 %

Heat exchanger type Counterflow

Bill of Quantities

Compiled in current prices, March 2020

#	Name of works and costs	Cost Estimation (USD)
1-1	Insulation of walls	127,110.00
1-2	Insulation of attic floor	21,418.00
1-3	Replacement of windows	116,277.00
1-4	Installation of individual ventilation units with heat recovery	65,520.00
Total		**330,325.00**

Local Cost Estimation 1-1: Insulation of Walls

Compiled in current prices, March 2020	Total Cost: USD 127,110.00

#	Line item	Unit	Qnty	Material Rate	Material Total	Salary Rate	Salary Total	Transportation Rate	Transportation Total	Total
CONSTRUCTION PART										
1	Digging pits for bearing posts	pc	10			1.95	19.50			19.50
2	Pouring mass concrete bearing posts	m^3	1.80			27.35	49.23			49.23
	Reinforcing bar A-500c Ø10 k=1.04	t	0.017	508.50	8.88					8.88
	Concrete B25	m^3	1.84	36.25	66.56					66.56
	Wood material	m^3	0.13	172.20	21.70					21.70
	Nails	kg	0.72	0.80	0.58					0.58
	Fastening wire	kg	1.35	0.74	1.00					1.00
3	Embedding parts of concrete bearing posts with weight up to 3 kg	pc	10	2.38	23.80	1.95	19.50			43.30
NORTHERN FACADE SECTIONS 1 AND 4 *Rockwool insulation is included into facade insulation volumes*										
1	Drilling wall for fasteners Ø14mm	pc	464	0.02	9.28	0.12	55.68			64.96
2	Attaching fasteners s-1 with anchors on the walls and filling in the holes with double component adhesive	pc	116			3.13	363.08			363.08
	Fastener - 10x100x240 mm k=1.05	kg	230.20	0.88	202.58					202.58
	Anchors Ø12 L=100/120 mm	pc	464.00	0.27	125.28					125.28
	Double component adhesive	kg	11.60	14.75	171.10					171.10
3	Metal frame with square tubes	t	2.175			195.31	424.88			424.88
	Truck Crane 10t	truck/h	13.052					16.55	216.02	216.02
	Device for welding and cutting	device/h	2.175					0.88	1.91	1.91
	Welding machine	device/h	59.388					3.72	220.92	220.92
	Metal square tube 50X50X2 mm	t	1.680	593.75	997.44					997.44
	Metal square tube 20X40X2 mm	t	0.648	593.75	384.62					384.62
	Industrial oxygen	m^3	5.656	2.65	14.99					14.99
	Propane-butane mixture	kg	1.088	1.19	1.29					1.29
	Electrode	kg	46.771	1.19	55.66					55.66

Line item			Qnty	Material		Salary		Transportation		Total
				Rate	Total	Rate	Total	Rate	Total	
4	Covering metal constructions with rust-preventive coating	m^2	138.64			0.78	108.14			108.14
	Substance for corrosion removal	kg	13.864	2.65	36.74					36.74
5	Primer for metal constructions	m^2	138.64			0.78	108.14			108.14
	Primer enamel	kg	22.182	1.69	37.49					37.49
	Solvent	kg	9.705	1.31	12.71					12.71
6	Double-painting metal constructions with rust-preventive	m^2	138.64							
	Salary	m^2	138.64			1.17	162.21			162.21
	Rust-preventive paint	kg	37.433	1.59	59.52					59.52
	Varnish	kg	4.159	1.41	5.86					5.86
7	Coating insulated walls with fiber cement boards with thickness 8 mm	m^2	216.2			2.35	508.07			508.07
	Fiber cement boards, thickness 8mm	m^2	227.01	4.40	998.84					998.84
	Screws	pc	1297.20	0.02	25.94					25.94
8	Arrangement of loggia roof with corrugated tin δ=0,55	m^2	9.0			2.35	21.15			21.15
	Corrugated tin δ=0,55	m^2	10.35	3.75	38.81					38.81
	Srews with rubber layer	pc	54.00	0.05	2.70					2.70
9	Manufacturing and installing colored tin cill with thickness 0,55 mm	m	52.00			1.95	101.40			101.40
	Colored tin tickness 0,55mm	m^2	18.20	3.90	70.98					70.98
	Silicone	pc	5.00	1.90	9.51					9.51
	Anchors	pc	104.00	0.05	5.20					5.20
Northern facade sections 2 and 3 *Rockwool insulation is included into facade insulation volumes*										
1	Drilling wall for fasteners Ø14mm	pc	584	0.02	11.68	0.12	70.08			81.76
2	Attaching fasteners s-1 with anchors on the walls and filling in the holes with double component adhesive	pc	146			3.13	456.98			456.98
	Fastener 10X100X240 mm k=1,05	kg	289.74	0.88	254.97					254.97
	Anchors Ø12 L=100/120 mm	pc	584.00	0.27	157.68					157.68
	Double component adhesive	kg	14.60	14.75	215.35					215.35
3	Metal Frame with square tubes	t	2.838			195.31	554.19			554.19
	Truck Crane 10tn	truck/h	17.025					16.55	281.76	281.76
	Device for welding and cutting	device/h	2.838					0.88	2.50	2.50
	Welding machine	device/h	77.464					3.72	288.17	288.17
	Metal square tube 50X50X2 mm	t	2.271	593.75	1348.58					1348.58
	Metal square tube 20X40X2 mm	t	0.765	593.75	454.12					454.12
	Industrial oxygen	m^3	7.378	2.65	19.55					19.55
	Propane-butane mixture	kg	1.419	1.19	1.69					1.69
	Electrode	kg	61.006	1.19	72.60					72.60
4	Covering metal constructions with rust-preventive coating	m^2	180.83			0.78	141.05			141.05
	Substance for corrosion removal	kg	18.083	2.65	47.92					47.92

Line item			Qnty	Material		Salary		Transportation		Total
				Rate	Total	Rate	Total	Rate	Total	
5	Primer for metal constructions	m^2	180.83			0.78	141.05			141.05
	Primer enamel	kg	28.933	1.69	48.90					48.90
	Solvent	kg	12.658	1.31	16.58					16.58
6	Double-painting metal constructions with rust preventive	m^2	180.83							
	Salary	m^2	180.83			1.17	211.57			211.57
	Rust preventive paint	kg	48.824	1.59	77.63					77.63
	Varnish	kg	5.425	1.41	7.65					7.65
7	Coating of the insulated walls with fiber cement boards with thickness 8 mm	m^2	216.0			2.35	507.60			507.60
	Fiber cement boards, thickness 8mm	m^2	226.80	4.40	997.92					997.92
	Screws	pc	1296.00	0.02	25.92					25.92
8	Arrangement of loggia roof with corrugated tin δ=0,55	m^2	27.9			2.35	65.57			65.57
	Corrugated tin δ=0,55	m^2	32.09	3.75	120.32					120.32
	Srews with rubber layer	pc	167.40	0.05	8.37					8.37
9	Manufacturing and installing colored tin cill with thickness 0,55 mm	m	49.00			1.95	95.55			95.55
	Colored tin tickness 0,55mm	m^2	17.15	3.90	66.89					66.89
	Silicone	pc	5.00	1.90	9.51					9.51
	Anchors	pc	98.00	0.05	4.90					4.90
FACADE										
1	Arrangement of outrigger scuffolding with height up to 30 m	m^2	3218.0			1.68	5394.66			5394.66
	Metal elements for scuffolding	t	1.4	500	707.96					707.96
	Wood elements for scuffolding	m^3	0.3	172.2	49.87					49.87
	Platform	m^2	61.1	5.32	325.28					325.28
2	Application of rockwool boards with thicknes of 80 mm to facade and fixing with plastic anchors	m^2	2500.00			7.81	19525.00			19525.00
	Adhesive AD for board application	kg	12500.00	0.22	2750.00					2750.00
	Rockwool boards with thickness 8 cm	m^2	2625.00	5.28	13860.00					13860.00
	Polypropylene mesh	m^2	2750.00	1.11	3052.50					3052.50
	Anchors	pc	12500.00	0.17	2125.00					2125.00
	Filler LF	kg	12500.00	0.22	2750.00					2750.00
	Mineral decorative facade filler, second layer	kg	8250.00	0.27	2227.50					2227.50
3	Application of 30 mm rockwool boards on window and door openings with plastic anchors	m^2	242.50			7.81	1893.93			1893.93
	Adhesive AD for board application	kg	1212.50	0.22	266.75					266.75
	Rockwool boards with thickness 3 cm	m^2	247.35	2.25	556.54					556.54
	Polypropylene mesh	m^2	249.78	1.11	277.25					277.25
	Anchors	pc	1940.00	0.17	329.80					329.80
	Filler LF	kg	1212.50	0.22	266.75					266.75

Line item			Qnty	Material		Salary		Transportation		Total
				Rate	Total	Rate	Total	Rate	Total	
	Mineral decorative facade filler, second layer	kg	800.25	0.27	216.07					216.07
4	Painting facades and openings with water based paint	m^2	2742.50			3.13	8570.31			8570.31
	Facade water based paint	l	877.60	2.12	1860.51					1860.51
	Primer	l	411.38	1.41	580.04					580.04
	Facade filling	kg	2742.50	0.34	932.45					932.45
	Emery cloth roll width 25 cm	m	109.70	2.00	219.40					219.40
	Pigment	pc	35.00	3.18	111.30					111.30
PLINTH AREA										
1	Removing 5 cm asphalt concrete covering from blind area	m^2	125.00			1.57	196.25			196.25
2	Removing packed stone and soil by hand	m^3	100.00			6.25	625.00			625.00
3	Application of 8 mm XPS boards on plinth area and fixing them with plastic anchors	m^2	99.20			5.86	581.31			581.31
	Adhesive AD for board application	kg	496.00	0.22	109.12					109.12
	XPS boards with thickness 8 cm	m^2	104.16	5.28	549.96					549.96
	Polypropylene mesh	m^2	109.12	1.11	121.12					121.12
	Anchors	pc	496.00	0.17	84.32					84.32
	Frost-resistant cementitious adhesive	kg	496.00	0.35	173.60					173.60
4	Application of Linecrom single layer waterproof insulation on the wall primer	m^2	350.00			1.57	549.50			549.50
	Mastic primer	kg	105.00	0.94	98.70					98.70
	Linecrom insulation	m^2	420.00	2.25	945.00					945.00
	Gas	kg	70.00	1.19	83.30					83.30
5	Filling in and compressing small grained gravel in the blind area	m^3	100.00			4.69	469.00			469.00
	Small grained gravel	m^3	125.00	7.02	877.50					877.50
6	Application of concrete covering around the building B20 thickness 10 cm	m^3	12.500			15.63	195.38			195.38
	Concrete B20 thickness 10 cm	m^3	13.125	35.63	467.64					467.64
7	Loading the excess soil on the truck	m^3	127.50					1.57	200.18	200.18
8	Taking out excess soil from the construction site for up to 20 km	m^3	127.50					2.38	303.30	303.30
Total					**44,333.01**		**42,184.94**		**1,514.75**	**88,032.71**
Overheads 10%										8,803.27
Total										96,835.98
Planned accumulation 8%										7,746.88
Total										104,582.85
Unexpected works 3%										3,137.49
Total										107,720.34
VAT 18%										19,389.66
Total										127,110.00

Local Cost Estimation 1-2: Insulation of the Attic Floor

Compiled in current prices, March 2020	Total Cost: USD 21,418.00

Line item			Qnty	Material		Salary		Transportation		Total
				Rate	Total	Rate	Total	Rate	Total	
DEMOLITION WORKS										
1	Removing attic pumice insulation layer and other construction litter and taking out to the yard	m^3	80.00			19.54	1563.20			1563.20
2	Loading the construction litter on the truck	m^3	80.00					1.57	125.60	125.60
3	Removal of the construction litter from the construction site for up to 20 km	m^3	80.00		s			2.38	190.12	190.12
ATTIC										
1	Application of 10 cm rockwool boards on the attic floor	m^2	694.70			0.78	541.87			541.87
	Adhesive AD for board application	kg	3473.50	0.22	764.17					764.17
	Rockwool boards with thickness 10 cm	m^2	729.44	6.46	4712.15					4712.15
2	Sand-Cement mortar layer with thickness 30 mm	m^2	694.70			3.13	2174.41			2174.41
	Sand-cement mortar m-100	m^3	21.26							0.00
	Sand	m^3	25.72	13.60	349.82					349.82
	Cement M400	t	7.44	61.70	459.06					459.06
3	Application of rockwool boards with thicknes of 100 mm on attic walls and fixing with plastic anchors	m^2	122.00			5.86	714.92			714.92
	Adhesive AD for board application	kg	610.00	0.22	134.20					134.20
	Rockwool boards with thickness 10 cm	m^2	128.10	6.46	827.53					827.53
	Polypropylene mesh	m^2	134.20	1.11	148.96					148.96
	Anchors	pc	610.00	0.17	103.70					103.70
PARAPET AND ROOF										
1	Arrangement of drain bowls	pc	5.00	9.38	46.90	3.91	19.55			66.45
2	Arrangement of colored tin rain gutter	m	125.00			1.57	196.25			196.25
	Rain gutter	m	75.00	4.75	356.25					356.25
	Anchor	pc	250.00	0.03	7.50					7.50
	Cracing	pc	125.00	0.94	117.50					117.50
3	Arrangement of colored tin elbows of the rain gutter	pc	10.00	3.12	31.20	0.78	7.80			39.00
4	Covering the parapet with colored tin sheet on the wood roof boarding	m	123.80			2.74	339.21			339.21
	Wood roof boards 40X50mm	m	264.93	0.71	187.01			0.05	13.25	200.25
	Expanding anchor d=8mm, l=120mm	pc	742.80	0.30	222.84					222.84
	Galvanized colored tin sheet δ=0.50mm	m^2	99.04	3.90	386.26			0.30	29.71	415.97
	Tapping screw	pieces	742.80	0.02	14.86					14.86
	Silicone	pieces	15.00	3.18	47.70					47.70
Total					**8,917.60**		**5,557.21**		**358.68**	**14,833.48**

Line item			Qnty	Material		Salary		Transportation		Total
				Rate	Total	Rate	Total	Rate	Total	
Overheads 10%										1,483.35
Total										16,316.83
Planned accumulation 8%										1,305.35
Total										17,622.18
Unexpected works 3%										528.67
Total										18,150.84
VAT 18%										3,267.15
Total										21,418.00

Local Cost Estimation 1-3: Replacing Windows

Compiled in current prices, March 2020	Total Cost: USD 116,277.00

Line item			Qnty	Material		Salary		Transportation		Total
				Rate	Total	Rate	Total	Rate	Total	
DEMOLITION WORKS										
1	Removing windows from East and West facades	m^2	57.00			1.95	111			111
2	Removing windows and doors from North and South facades	m^2	971.00			1.6	1554			1554
3	Taking removed windows to the yard, loading on the truck, and taking out of the construction site	m^2	1028.00			0.3	308			308
WINDOWS AND DOORS										
1	Installation of the double glazed plastic windows and doors with low emission glass package	m^2	1028.00	64.50	66306.00	3.90	4009.20			70315.20
2	Installation of the internal plastic window sills with width 20 cm	m	475.00	5.32	2527.00	1.56	741.00			3268.00
3	Arrangement of the sand-cement layer for external window seals with width 27 cm and thickness 5 cm	m	475.00			2.70	1282.50			1282.50
	Sand-cement m-100	m^3	6.54							0.00
	Sand	m^3	7.91	13.60	107.63					107.63
	Cement M400	t	2.22	61.70	137.21					137.21
4	Manufacturing and installation of external colored tin window seals with thickness 0,5 mm	m	475.00			1.95	926.25			926.25
	Colored tin sheet 0,5mm	m^2	190.00	3.90	741.00					741.00
	Silicone	pc	25.00	1.90	47.55					47.55
	Anchor	pc	950.00	0.05	47.50					47.50
5	High quality plastering of inside openings with thickness 3 cm	m	1215.00			1.18	1433.70			1433.70
	Plastering material	t	9.72	25.76	250.39					250.39
Total					**70,164.28**		**10,365.80**		**0.00**	**80,530.08**
Overheads 10%										8,053.01
Total										88,583.09
Planned accumulation 8%										7,086.65
Total										95,669.74
Unexpected works 3%										2,870.09

Line item			Qnty	Material		Salary		Transportation		Total
				Rate	Total	Rate	Total	Rate	Total	
Total										98,539.83
VAT 18%										17,737.17
Total										116,277.00

Local Cost Estimation 1-4: Individual Ventilation Units with Heat Recovery

Compiled in current prices, March 2020	Total Cost: USD 65,520.00

Line item			Qnty	Material		Salary		Transportation		Total
				Rate	Total	Rate	Total	Rate	Total	
1	Bore Ø140 mm diameter hole in 40 cm thickness wall and inserting plastic tube	pc	192	0.10	19.20	5.00	960.00			979.20
	Plastic tube Ø125, L=500 mm 192 pieces	m	96.00	5.00	480.00					480.00
2	Bore Ø140 mm diameter hole in 12 cm thickness wall and inserting plastic tube	pc	96	0.10	9.60	3.00	288.00			297.60
	Plastic tube Ø125, L=210 mm 96 pieces	m	20.16	5.00	100.80					100.80
3	Fill in the drillings with frost-resistant cementitious adhesive	pc	288	0.20	57.60	1.00	288.00			345.60
4	Bore Ø8 mm diameterhole in 12 cm thickness wall	pc	384			0.35	134.40			134.40
5	Attach metal sheets on the walls with fastener anchor	pc	96			7.00	672.00			672.00
	Metal Sheet -2X340X620 with weight 3,3kg	pc	48	4.00	192.00					192.00
	Metal Sheet -2X340X480 with weight 2,56kg	pc	48	3.58	171.66					171.66
	Fastener d=6mm, L=240mm	pc	384	1.00	384.00					384.00
6	Copper cable with double insulation and with fireproof layer, diameter 3X2.5 m^2	m	720	1.00	720.00	0.50	360.00			1080.00
7	Purchase and installation of ventilation unit VENTS MICRA 60	pc	144	285.00	41040.00	15.00	2160.00			43200.00
8	Transportation costs of ventilation units and other materials (including loading, unloading and on site delivery)		3.00					100.00	300.00	300.00
Total					**43,174.86**		**4,862.40**		**300.00**	**48,337.26**
Overheads 10%										4,617.73
Device installation overhead costs 68%										1,468.80
Total										52,954.98
Planned accumulation 8% (excluding goods)										953.20
Total										53,908.18
Unexpected works 3%										1,617.25
Total										55,525.43
VAT 18%										9,994.58
Total										65,520.00