FINAL ASSESSMENT REPORT FOR TWO RESIEDNETIAL BUILDINGS IN TASHIR

YEREVAN 2022

Disclaimer

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Executive summary

This project is performed under provision of “Technical Assistance to CoM Signatories”, where Technical Support to Tashir has been conducted. The main objective of the assignment is to carry out Energy Assessment of the two multi-apartment buildings in "Dprotsakanneri" district in Tashir municipality

The specific aim of the study is to determine current energy consumption levels and assess and analyze improvement of energy efficiency levels and assess opportunities regarding refurbishment of the building shell components, while also verifying the existing indoor comfort levels. The most appropriate interventions are included in the programme and subsequent steps such as design are planned in an appropriate manner.

The performed services comprised:

- ❖ Preliminary data collection on energy utilisation and costs and building characteristics.
- ❖ Site visit in July and August 2022 for building shell evaluation.
- ❖ Preliminary analysis of findings, initial assessment of thermal refurbishment measures.
- ❖ Analysis of information, technical and financial assessment of potential energy efficiency opportunities, assessment of technicalities for structural reinforcement and retrofits.

Some general findings from the elaboration of site-specific information are:

- ➢ Energy consumption for the baseline year (average for 3 previous years) in Dprotsakanneri No. 13A is about **9,834 kWh** of electricity, and **54,167 kWh** of natural gas, and similarly for in Dprotsakanneri No. 13B is about **9,729 kWh** of electricity, and **94,356 kWh** of natural gas. These figures correspond to average energy consumption figures during years 2019, 2020 and 2021 which was considered as the baseline for calculations of energy savings for electricity and natural gas respectively.
- ➢ Electrical energy is used for lighting, cooking, as well as appliances.
- ➢ The current operational regime reflects under-heating, as a result specific energy consumption is kept at low levels.
- ➢ Specific electricity consumption in Dporotsakanneri No.13A is 7.7 kWh/m^2 and the relevant figure for gas is 84.7 kWh/m^2, and similarly in Dprotsakanneri No.13B is 7.6 kWh/m^2 and the relevant figure for gas is 73.8 kWh/m^2. In absolute terms though and taking into consideration specific ambient conditions and building structure they are lower than the ones that would correspond to acceptable indoor comfort conditions.
- ➢ In fact, from a preliminary theoretical calculation of heating demand of the buildings through the use of a customised tool, it is derived that the actual consumption is at a level of **12%** in Dporotsakanneri No. 13A and **20%** in Dprotsakanneri No. 13B compared with the theoretically calculated (normative value from Energy Passport) and thus the level of comfort is not at the desired levels.
- ➢ Actual Specific Energy Consumption (SEC) of heat energy for heating and ventilation purposes during heating season is 31 kWh/m^2 in Dprotsakanneri No. 13A and 51 kWh/m^2 in Dprotsakanneri No. 13B, Normalised SEC (based on energy passport) is 259 kWh/m^2, which is significantly higher than the international average.
- ➢ Based on AST 362-2013 Energy efficiency class (category) Before Energy retrofit is “E, Very Low”.

Within this analysis, three energy efficiency measures have been elaborated and analysed from a technical and economic point of view.

The formulated package of proposed measures includes all rehabilitation and building shell refurbishment options as well as financially viable EE measure. This package corresponds to:

Improvement interventions

- Energy Efficiency measures, with a budget of **48,878 EUR**, and cost savings of almost **10,456 EUR/year** for each building.

An outline of the technical and financial results from the analysis is shown below.

No	Project	Investment	Annual Energy Savings	Annual Cost Savings	Simple Payback	GHG emissions reduction
		€	kWh/y	€/y	years	(t CO_2/y)
1	Roof Insulation	5,847	17,139	679	8.61	3.51
2	Walls Insulation	40,053	240,679	9,535	4.20	49.27
3	Replacement of old windows and doors	2,978	6,103	242	12.32	1.25
	TOTAL	**48,878**	**263,921**	**10,456**	**4.67**	**54.03**

Introduction and background

Covenant of Mayors for Climate and Energy

The Covenant of Mayors for Climate and Energy is the mainstream European voluntary movement involving local authorities in the development and implementation of sustainable energy and climate policies. Since its launch in 2008, the initiative has progressively grown into a worldwide city movement, extending first to Europe's eastern and then to the southern neighboring and other countries.

Authorities signing up for the Covenant commit to developing and implementing actions at local level to contribute to the climate challenge and the sustainability of their territories. Particularly, signatories in the Eastern Partnership (EaP) region commit to reduce emission of greenhouse gases on its territory by at least 30% by 2030, namely through improved energy efficiency and greater use of renewable energy sources, to increase resilience of communities by adapting to the impacts of climate change and to ensure access of their citizens to secure, sustainable and affordable energy.

These voluntary commitments of the Covenant signatories are translated into specific measures and projects by the development and implementation of the Sustainable Energy and Climate Action Plan (SECAP), which includes the strategies and the main actions that local authorities commit to implement.

Being initially exclusively a European initiative, the Covenant now gathers more than 11,000 local and regional authorities across 55 countries drawing on the strengths of a worldwide multi-stakeholder movement and the technical and methodological support offered by dedicated offices.

EC "Covenant of Mayors East" (CoM East) project

"Covenant of Mayors East" is the EU-funded project aimed at introducing the EU climate and energy initiative to the EaP countries. The project supports local authorities in implementing sustainable energy policies, improving the security of energy supply, and facilities their contribution to climate change mitigation and adaptation.

The overall objective of the project is to enable local authorities in EaP countries to develop and implement sustainable energy and climate actions, therefore significantly contributing to the reduction of greenhouse gas emissions and energy consumption, increasing generation of renewable energy, and adaptation to climate change.

This objective is to be achieved through a number of activities, including capacity building of signatories and stakeholders, provision of tailored support though the technical helpdesk, networking and cooperation with financial institutions and donors, etc.

A strong consortium of 9 partners, led by Energy Cities and powered by Climate Alliance and Kommunalkredit Public Consulting (KPC) as three major European partners, along with six local partners covering all beneficiary countries, are assisting municipalities in taking new, even more ambitious commitments on the horizon 2030.

Technical Assistance to CoM Signatories

While the previous phase of CoM East project focused mostly on facilitating the access of the signatories of the Covenant in EaP region to finance by helping them to develop municipal project proposals and creating synergies with donors' and IFIs' funding programmes, the third phase of the project is aimed to help signatories to secure actual financing by developing and advancing project proposals to the level of solid bankable projects and implement them.

For this purpose, the project is providing robust technical assistance to the eligible signatories with identification of the most promising projects, technical assessment (review) of the proposed projects and development of bankable project proposals to be listed in the CoM East online project pipeline for further advertisement, as well as with liaising with donors. With the limited access of the municipalities to low-interest loan funding, the project will facilitate the access of the signatories to the country-level support mechanisms and advanced climate financing solutions. While selecting target projects the preference will be given to the projects with already secured municipal and national (e.g. through the State Subvention Program) or international co-financing.

Technical Support to Tashir Municipality

Tahsir is one of 27 Covenant signatories in Armenia that joined the Covenant (adhesion took place on 11.11.2016) and one of two advanced signatories with developed SECAP (the action plan was approved by the municipal council on 25.12.2022).

Considering progress of the municipality in developing its SECAP, organization of events within the framework of the EU Sustainable Energy Weeks, participation in the capacity building and awareness raising events organized by CoM East project, etc., Tashir has been selected as the first signatory in Armenia to benefit from the direct and tailored technical assistance of the CoM East project aimed at development and further promotion of bankable project concept for improvement of energy efficiency and use of renewable energy in municipal facilities of the municipality.

Two meetings of the CoM East project team with the local administration of the community were held on 06.06.2020 and 19.17.2020 aimed at presentation of the scope of the technical assistance, identification of municipal facilities to be covered under the assignment, as well as visiting the proposed facilities and collection of baseline information. The introductory visits were followed by a series of visits of the project expert aimed at further collection of technical documents (e.g. detailed designs, blueprints, etc.) and information.

As a result of consultations, the following two municipal objects have been selected: the municipal kindergarten N1 and two multi-apartment buildings in "Dprotsakanneri" district.

The current assessment report is developed by Mr. Andre Ohanian, the project Senior Technical Expert for tailored support to Tashir municipality, for the two typical residential buildings located at No. 13A and No. 13B at Dprotsakanneri Street.

The report covers description of the baseline situation evaluated by the expert through visual inspection of the residential buildings, on-site measurements and analysis of the information collected from the municipality, as well as recommendations on improvement of energy performance of the building to be incorporated into the project proposal.

1. Description of the building

Two typical multi-story residential buildings in Tashir community, located at No. 13A and No. 13B at Dprotsakanneri Street (41°06'44.2"N 44°17'03.3"E) were built in early 1990's. Each residential building is comprised of two detached premises, consisted of 4 aboveground floors and a basement. The number of apartments in each premise is 8 units, 16 apartments in each building. Only 50% of the apartments are occupied all year round and are heated. The total number of inhabitants is 23 (12 in the building N13A and 9 in the building N13B).

The buildings are typical with identical structural solutions with other buildings built in the area, which was due to rehabilitation and part of disaster relief operations after devastating earthquake in Spitak in 1988. The external walls are built with 300 mm thick reinforced concrete, and the covers are comprised of 220 mm hollow core reinforced concrete slab. The roofs are open gable, covered with asbestos slates with a supporting timber frame underneath.

Figure 1: Aerial image of the two residential buildings in Tashir

Figure 2: Facial sides of the buildings

The building is placed on a flattened area. Building dimensions are about 12.4 x 16.5 m. The total height of the building is 13.6 m, and the floor to ceiling height is 3.0 m.

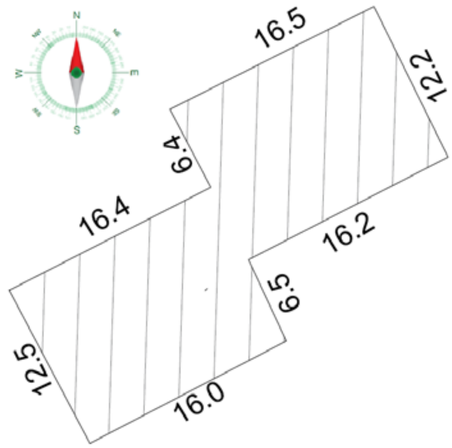


Figure 3: Top view and orientation of the building

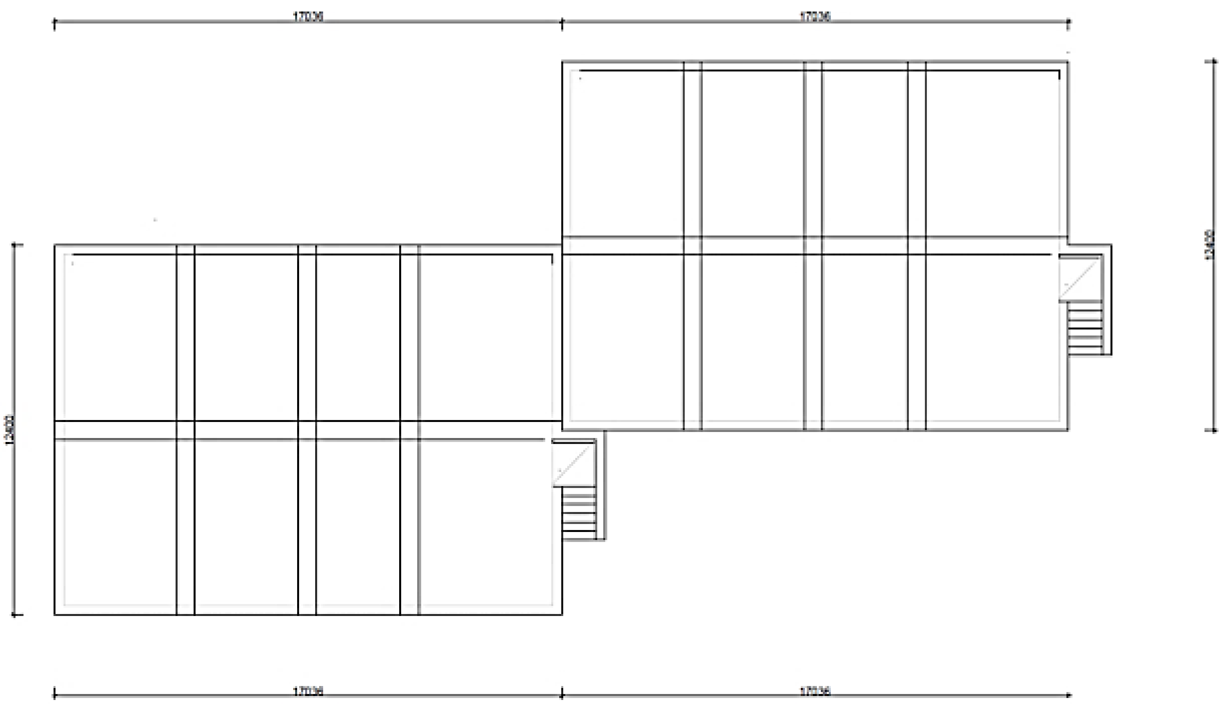
Each premise of the buildings has a **total area of 897.6 m^2**.

There are 8 apartment units in each premise, hence each building encapsulates 16 apartments, where only 50% of the apartments are occupied all year round and are heated. The **total living surface area (heated area) of each premise of the building is 816 m^2**.

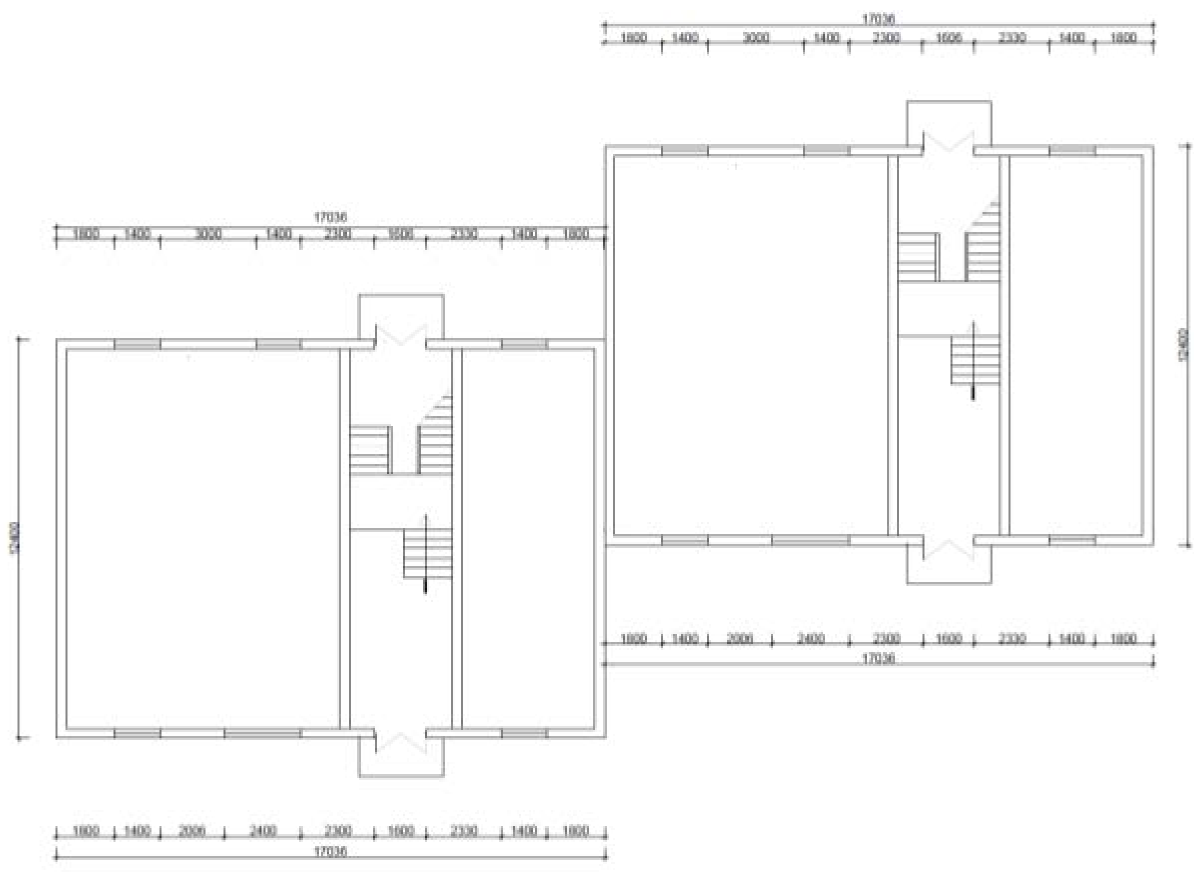
No major cracks or structural defects, or traces of settlements have been recorded in the buildings, as these have been built after the 1988 Spitak earthquake, and are considered fresh structures, and are in sound condition. No defects with roof cladding and rainwater management system (gutters and downpipes) were observed. Commonly owned windows and doors in staircases and entrances are in poor condition (and missing in some sections) and are subject to replacement.

Floor plans of the building and side views are presented below.

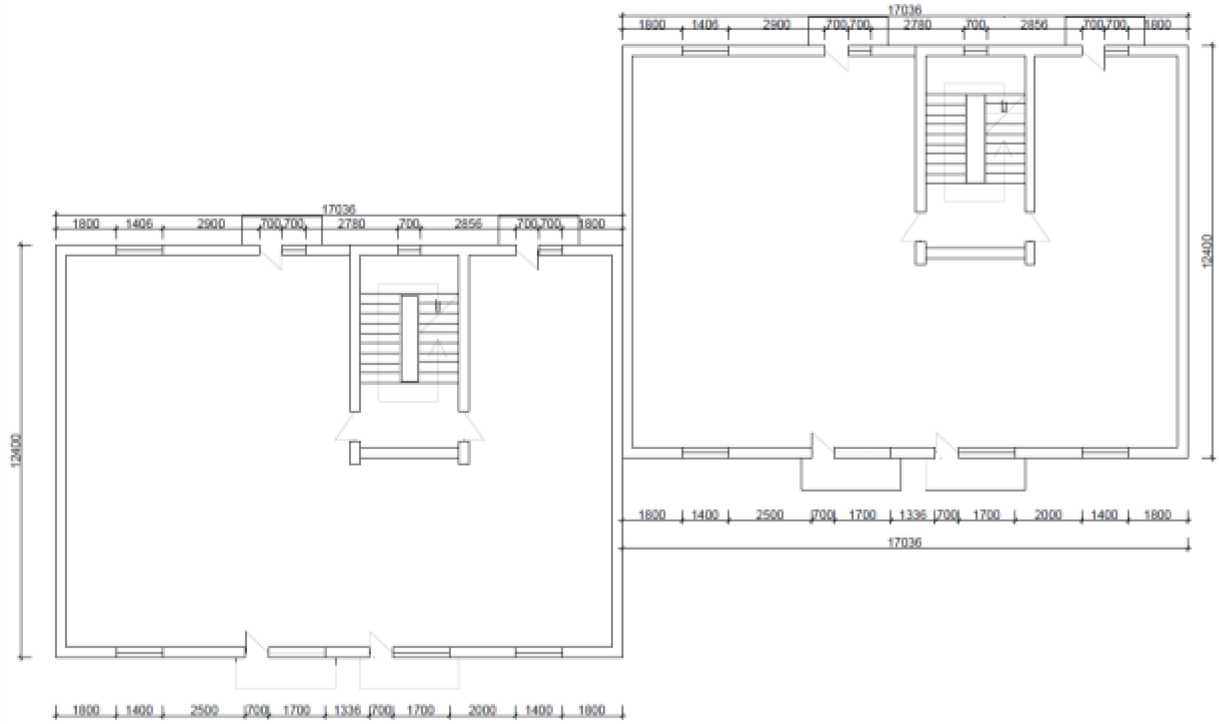
Figure 4: Floor plans of the building



Basement floor plan



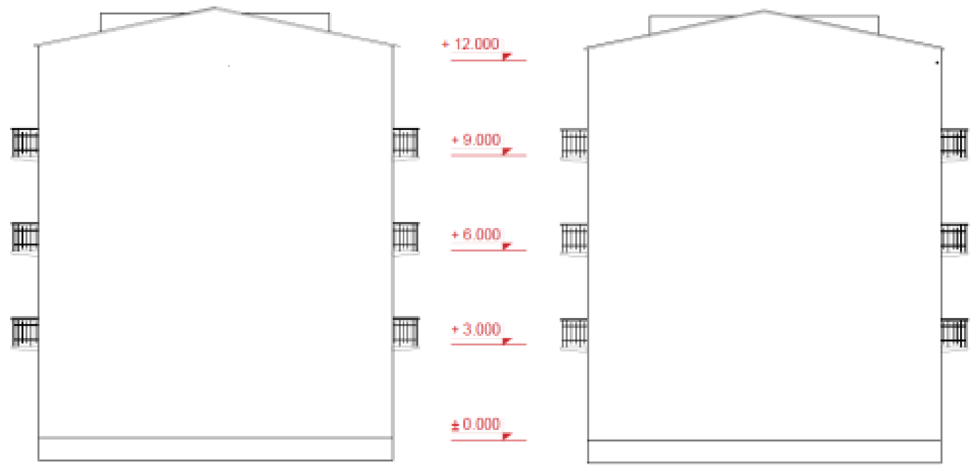
First floor layout



Second, third and fourth floor layout (typical)

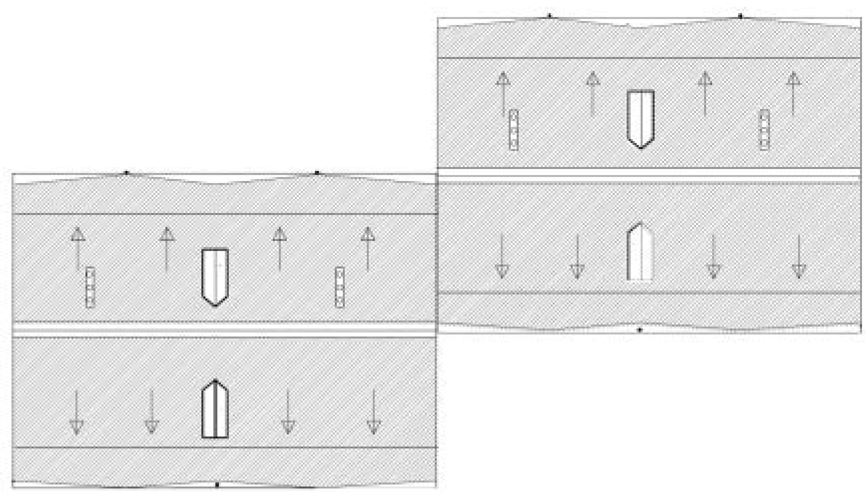
Figure 5: Side Views

South-East side



South-West/North-East side

North-West side



Top view (roof layout)

For each premise:

Total wall area = 542.6 m^2

Total windows, doors and glazed area = 137 m^2

Roof flat area (attic floor) = 204 m^2

For Each building, comprised of two premises:

Total building area = 1,795.2 m^2

Building heated area = 1,632 m^2

Building heated volume = 5,385.6 m^3

1.1 Occupancy patterns and thermal comfort

The rate of area occupancy in the building is currently 50% (half of living area being occupied). For energy saving related investments and savings, the occupancy has been assumed as 100%. The normalized thermal comfort level, in order to assess the building's energy consumption volume, is set at 20°C, as the minimum requirement set per local construction norm (RACN 24-01-2016, Thermal Protection of Buildings).

1.2 Climatic conditions and code requirements

Tashir has an average height of 1505 m (above sea level). In Tashir, the summers are comfortable, dry, and mostly clear and the winters are freezing, snowy, and partly cloudy.

The number of degree-days during the heating period is used to select normative indices and make calculations (the indicator deduced from initial conditions of microclimate maintenance), which is calculated with the help of following formula:

$$HDD = (t_i - t_{a.t}) \cdot n$$

Where

n – The duration of the heating period, days

t_i – the inside temperature of the building, ˚C

$t_{a.t}$ – the outside average temperature during the heating period, ˚C

Average ambient temperature for heating season is -0.1°C and the duration of heating season in Tashir is 197 days.

According to RACN II-7.02-95 "Building thermal physics of building envelopes: design standards", RACN 24-01-2016 "Thermal Protection of Buildings" and RACN II-7.01-2011 "Building climatology", Heating Degree Days (HDD) for Tashir, for residential buildings, is:

HDD = (t_j – $t_{a.t}$) × n = (20 – (-0.1)) x 197 = 3,959.7 ˚C·day

1.3 Building codes and Building Energy Performance (BEP) indicators

The following building codes approved by Urban Development Committee are currently into force and are subject to compliance:

a) RACN II-7.02-95 "Construction thermophysics of building envelope; construction norms"

The norm is clarified in CNM II-7.102-98 "Manual on RACN II-70.2-95 Construction thermophysics of building envelope" and regulates the energy efficiency related parameters (minimum code requirements) to be addressed during building design and construction stages.

b) RACN 24-01-2016 "Thermal Protection of Buildings"

The norm (based on advanced development of CIS interstate building codes) regulates the minimum energy efficiency requirements in terms of useful heat energy demand for heating and ventilation in $W/(m^3.^oC)$ for different types of buildings.

c) RACN II-7.01-2011 "Construction Climatology"

The norm specifies climatic conditions in various towns in Armenia, including data about temperature, relative humidity, precipitation, wind, solar irradiation, duration of heating season, climatic zones, etc.

In Armenia, the energy performance requirements in building norms **are only based on thermal resistance of the elements of the building envelope and the heating degree-days for the building, taking into account heat gains, infiltration and factors related to heating self-regulation. Currently the efficiency of the building systems, type of energy (energy carriers) used, the energy for cooling, domestic hot water (DHW), lighting and the generated emissions are not part of the energy performance requirements**.

The Building Energy Performance (BEP) assessment in Armenia is based on the AST 362-2013 "Energy conservation. Building energy passport. Basic rules. Standard form" local standard.

The standard regulates the basic principles of energy passports of buildings, defines the form of energy passports for residential and public buildings, and proposes a unified legal solution to the structure of the energy passports. The defined energy performance indicator is the specific useful energy for heating and ventilation.

The BEP assessment is based on the specific thermal load for heating and ventilation in $W/m^3/^oC$ (without taking into consideration the energy for cooling, DHW, lighting and other technical building systems).

The minimum R-values for different building shell components for different building typologies, as required by RACN 24-01-2016 "Thermal Protection of Buildings" code is regulated by the number of annual heating degree days (HDD).

Based on RA norms of II-7.02-95 and RA CN 24-01-2016, the thermal resistance values (R-values) for building envelope in Tashir for residential buildings are presented in the table below:

Table 1: Thermal resistance values (R-values) for building envelope in Tashir

Building Element	**R_0 ($m^2.^\circ C/W$)**
Attic floor	**3.88**
Exterior walls	**2.98**
Windows, balcony doors, fenestration	**0.45**

2. Assessment of building shell components and their thermal characteristics

2.1 Basement

The basement ceiling is built with precast hollow core reinforced concrete slabs, with a thickness of 220 mm. The basement does not have any openings. Total surface of the basement ceiling is **182.4** m^2.

The basement ceiling elements, thicknesses and thermal conductivities of materials are specified below:

Material	RC hollow core slab	Cement-sand screed and mortar	Parquet
d - thickness (m)	0.22	0.08	0.015
λ – thermal conductivity (W/m˚C)	0.85	0.76	0.19
R – thermal resistance (m^2.˚C/W)	0.259	0.105	0.079
U – thermal transmittance (W/m^2.˚C)	3.863	9.50	12.67

Internal surface heat emission coefficient: α_{in} = 8.7 (W/m^2.˚C)
External surface heat emission coefficient: α_{out} = 6 (W/m^2.˚C)

The heat transfer resistance (R $_{Basement}$) of the basement ceiling (m^{2o}C/W) would be 1.096. However, due to factoring in the positive temperature in the basement area during the heating season (set as 12 ^{o}C), the heat transfer resistance of this element for the HDD defined will be: **R $_{Basement}$ = 1.658 m^2.˚C/W**

The existing R-value of the external walls does not comply with the requirements of RA CN II-7.02-95 and RA CN 24-01-2016 norms, however, due to not proper access to basement in these buildings, thermal insulation of this element is not practical, nor feasible.

2.2 Exterior walls

External walls of both residential buildings (all four premises) are 300 mm thick reinforced concrete cast. Total surface of the external walls is **558.2** m^2 for each premise.

The external walls elements, thicknesses and thermal conductivities of materials are specified below:

Material	Gypsum	Hollow-core slab	Decorative render
d - thickness (m)	0.02	0.30	0.01
λ – thermal conductivity (W/m˚C)	0.41	1.46	0.76
R – thermal resistance (m^2.˚C/W)	0.049	0.205	0.013
U – thermal transmittance (W/m^2.˚C)	20.5	4.87	76.0

Internal surface heat emission coefficient: α_{in} = 8.7 (W/m^2.˚C)
External surface heat emission coefficient: α_{out} = 23 (W/m^2.˚C)

The heat transfer resistance (R $_{Walls}$) of the walls (m^{2o}C/W) would be: **R $_{Wall}$ = 0.426 m^2.˚C/W**

The existing R-value of the external walls does not comply with the requirements of RA CN II-7.02-95 and RA CN 24-01-2016 norms, therefore thermal resistance of this element should be improved.

Figure 6: External walls of the residential buildings made with reinforced concrete

2.3 Roof

The roof of the building is pitched (open gable shaped), supported by wooden timber-frame, covered with asbestos and/or metal sheeting. The roof cover is in a demerited condition and requires major replacement with new galvanized sheeting. The total area of the flat roof (attic floor) is **174.6** m^2. In average, around 150 mm thick slag layer has been applied in the attic floor level. The cover slab is constructed by hollow-core slabs, covered by a thin screed layer.

Figure 7: Wooden timber-frame of the roof and asbestos and/or metal sheeting

The specific building elements and their properties of the roof are shown below:

Material	Gypsum	Hollow-core slab	Screed	Slag
d - thickness (m)	0.02	0.22	0.03	0.15
λ – thermal conductivity (W/m˚C)	0.41	0.85	0.76	0.19
R – thermal resistance (m^2.˚C/W)	0.049	0.259	0.039	0.789
U – thermal transmittance (W/m^2.˚C)	20.50	3.86	25.33	1.27

Internal surface heat emission coefficient: α_{in} = 8.7 ($W/m^2.^\circ C$)
External surface heat emission coefficient: α_{out} = 12 ($W/m^2.^\circ C$)

The heat transfer resistance ($R_{Attic\ floor}$) of the roof ($m^{2o}C/W$) would be: **$R_{Attic\ floor}$ = 1.335 $m^2.^\circ C/W$**

The existing R-value of the attic floor does not comply with the requirements of RA CN II-7.02-95 and RA CN 24-01-2016 norms, therefore thermal resistance of this element should be improved.

2.4 Windows and doors, fenestration

Around half of the apartment windows and balcony doors are PVC framed double glazed windows, and the rest are old wooden framed double glazed/framed units, which are in a degraded shape and condition. The total area of the apartment windows and balcony doors is **70.44** m^2. Windows in staircases and stairways (commonly owned) are also wooden, with a single pane of glazing (even in some cases without any glazing) and in a deteriorated and very poor condition, which are to be changed accordingly. The area of these windows is **5.25** m^2 and these units cannot be considered as thermal shields due to their thermal characteristics and degradation level.

Entrance doors of the buildings, with an area of **6.72** m^2 are old wooden doors and are subject to change due to their degradation level and non-compliance with RA CN norms.

Figure 8: The entrance doors and windows of the buildings

R-value for the staircase windows and entrance doors is assumed to be 0.39 $m^2.^{\circ}C/W$, and for the apartment windows and doors a weighted average of 0.42 $m^2.^{\circ}C/W$ (0.44 $m^2.^{\circ}C/W$ assumed for PVC double glazed and 0.39 $m^2.^{\circ}C/W$ assumed for wooden windows) is considered.

3. Heating and hot water supply, ventilation and air conditioning

There is no district or centralized heating system in the buildings, and heat and hot water supply is through individual heating electrical (convectors, resistant and instant heaters) and/or natural gas (wall hung combi boilers) devices.

The options for heating level regulation and control are the manual thermostat (quality regulation) incorporated in the boiler and regulation manual valves on each radiator (quantitative regulation).

It was reported that due to lack of thermal insulation, the temperatures in apartments vary from 17-18 ºC, depending on the season and the winter intensity.

There are no mechanical/forced ventilation systems available in the buildings and only natural ventilation shafts exist in the building.

4. Consumption of energy and other utilities

4.1 Electrical energy

Monthly electricity consumption and costs have been presented from the records obtained from the municipality/homeowners' association and the Electric Networks of Armenia (ENA). The table below summarizes monthly figures for two residential buildings during the last 3 years.

Table 2: Monthly electricity consumption and costs for No. 13A Dprotsakanneri Building (2019-2021)

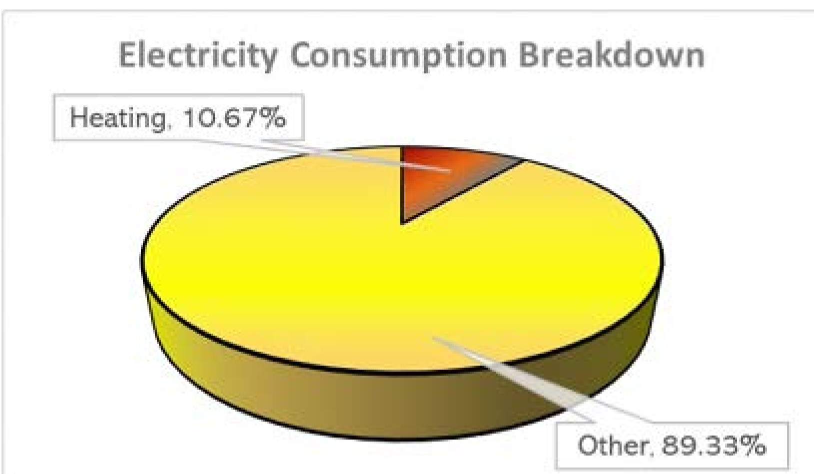
Year	2019		2020		2021	
	Usage (kWh/month)	Cost (AMD/month)	Usage (kWh/month)	Cost (AMD/month)	Usage (kWh/month)	Cost (AMD/month)
Jan	1,087	48,893	942	42,371	847	39,707
Feb	1,012	45,520	1038	46,689	812	38,067
Mar	1,244	55,955	761	34,230	760	35,629
Apr	1,136	51,097	920	41,382	724	33,941
May	1,020	45,880	696	31,306	683	32,019
Jun	853	38,368	703	31,621	661	30,988
Jul	755	33,960	594	26,718	671	31,456
Aug	819	36,839	695	31,261	730	34,222
Sep	790	35,534	705	31,711	654	30,660
Oct	737	33,150	652	29,327	700	32,816
Nov	860	38,683	862	38,773	812	38,067
Dec	838	37,693	879	39,537	850	39,848
Total	**11,151**	**501,572**	**9,447**	**424,926**	**8,904**	**417,420**

Table 3: Monthly electricity consumption and costs for No. 13B Dprotsakanneri Building (2019-2021)

Year	2019		2020		2021	
	Usage (kWh/month)	Cost (AMD/month)	Usage (kWh/month)	Cost (AMD/month)	Usage (kWh/month)	Cost (AMD/month)
Jan	1,472	66,211	944	42,461	975	45,708
Feb	793	35,669	842	37,873	927	43,458
Mar	711	31,981	778	34,994	903	42,333
Apr	771	34,680	959	43,136	796	37,316
May	583	26,223	627	28,202	629	29,488
Jun	631	28,382	631	28,382	658	30,847
Jul	635	28,562	874	39,313	612	28,691
Aug	739	33,240	657	29,552	657	30,800
Sep	576	25,908	669	30,092	712	33,379
Oct	654	29,417	734	33,015	934	43,786
Nov	729	32,790	893	40,167	1,611	75,524
Dec	870	39,133	928	41,741	1,073	50,302
Total	**9,164**	**412,196**	**9,536**	**428,928**	**10,487**	**491,632**

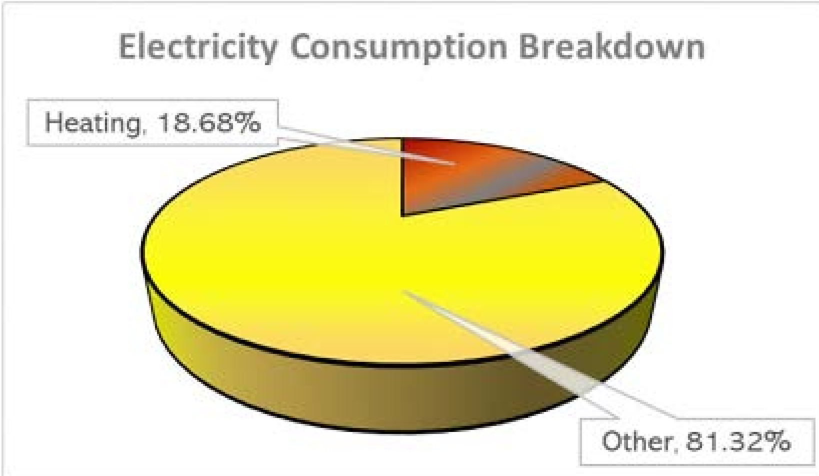
The daytime tariff (AMD/kWh) for electricity, as set by the Public Service Regulatory Commission (PSRC) for years 2019 and 2020 has been 44.98 AMD/kWh, and for the year 2021 is set as 46.88 AMD/kWh.

The average energy consumption figures during years 2019, 2020 and 2021 have been considered as baseline data for further benchmarking, and the broken-down shares for heating versus non-heating share is illustrated below:



Usage	kWh/year
Heating	1,050
Lighting & Appliances, Other	8,784
Total	**9,834**

Figure 9: Electricity consumption breakdown for No. 13A Dprotsakanneri Building



Usage	kWh/year
Heating	1,817
Lighting & Appliances, Other	7,912
Total	**9,729**

Figure 10: Electricity consumption breakdown for No. 13B Dprotsakanneri Building

4.2 Natural gas

Both buildings utilize natural gas for heating, hot water supply and cooking purposes. Monthly gas consumption and costs have been presented from the records obtained from the municipality. The table below summarizes monthly figures for the last 3.5 years.

Table 4: Monthly consumption of natural gas and related costs for No. 13A Dprotsakanneri Building (2019-2021)

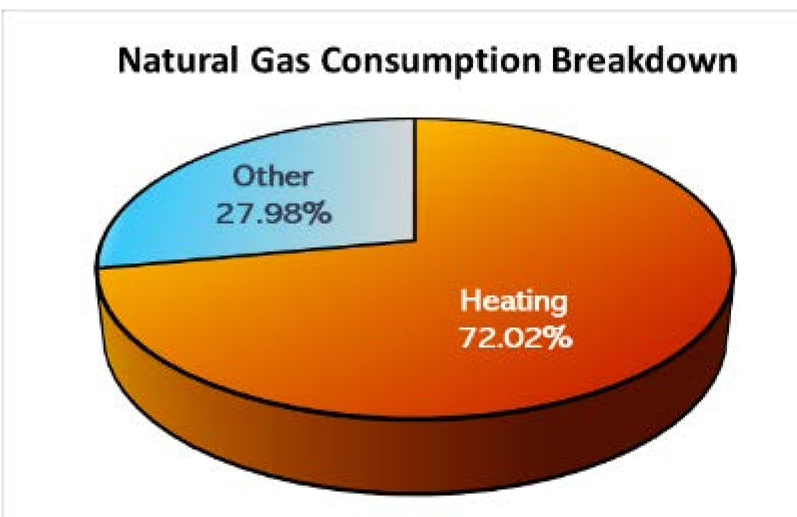
Year	2019		2020		2021	
	Usage (Nm^3/month)	Cost (AMD/month)	Usage (Nm^3/month)	Cost (AMD/month)	Usage (Nm^3/month)	Cost (AMD/month)
January	948	131,772	1046	145,394	1001	139,139
February	734	102,026	871	121,069	825	114,675
March	984	136,776	604	83,956	734	102,026
April	320	44,480	570	79,230	465	64,635
May	131	18,209	244	33,916	221	30,719
June	86	11,954	110	15,290	104	14,456
July	104	14,456	124	17,236	113	15,707
August	128	17,792	122	16,958	120	16,680
September	101	14,039	134	18,626	123	17,097
October	403	56,017	224	31,136	301	41,839
November	694	96,466	531	73,809	604	83,956
December	872	121,208	1229	170,831	931	129,409
Total	**5,505**	**765,195**	**5,809**	**807,451**	**5,542**	**770,338**

Table 5: Monthly consumption of natural gas and related costs for No. 13B Dprotsakanneri Building (2019-2021)

Year	2019		2020		2021	
	Usage (Nm^3/month)	Cost (AMD/month)	Usage (Nm^3/month)	Cost (AMD/month)	Usage (Nm^3/month)	Cost (AMD/month)
January	1,725	239,775	1,801	250,339	1,734	241,026
February	1,335	185,565	1,681	233,659	1,572	218,508
March	1,632	226,848	1,198	166,522	1,220	169,580
April	694	96,466	982	136,498	810	112,590
May	392	54,488	461	64,079	420	58,380
June	262	36,418	268	37,252	233	32,387
July	155	21,545	238	33,082	224	31,136
August	158	21,962	241	33,499	201	27,939
September	263	36,557	280	38,920	263	36,557
October	767	106,613	449	62,411	424	58,936
November	894	124,266	886	123,154	853	118,567
December	1,329	184,731	1,698	236,022	1,620	225,180
Total	**9,606**	**1,335,234**	**10,183**	**1,415,437**	**9,574**	**1,330,786**

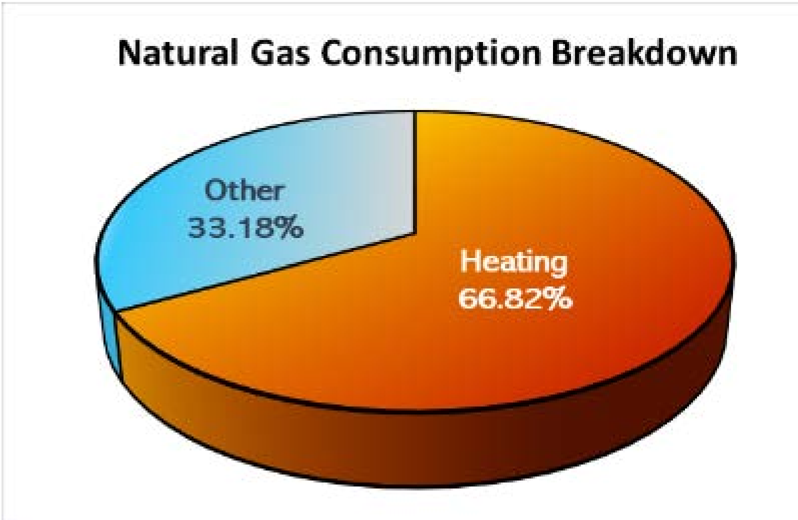
The natural gas tariff (AMD/Nm^3), as set by the Public Service Regulatory Commission (PSRC) for the period March 2019 – March 2022 has been 139 AMD/Nm^3.

Same as electricity, for natural gas the average energy consumption figures during years 2019, 2020 and 2021 have been considered as baseline data for further benchmarking, and the broken-down shares for heating versus non-heating share is illustrated below:



Usage	Nm^3/year
Heating	4,047
Hot water and Cooking	1,572
Total	5,619

Figure 11: Natural gas consumption breakdown for No. 13A Dprotsakanneri Building



Usage	Nm^3/year
Heating	6,540
Hot water and Cooking	3,247
Total	9,788

Figure 12: Natural gas consumption breakdown for No. 13B Dprotsakanneri Building

4.3 Breakdown-baseline energy consumption

According to "National Greenhouse Gas Inventory Report of Armenia 1990-2017"[1], weighted average Net Calorific Value of the natural gas (standard conditions t=20°C, P=101.325 kPa) for the years 2011-2017 is 8,290 kcal/m^3 or **9.64 kWh/m^3**.

Breakdown of energy, in kWh, for all the end-users is presented below.

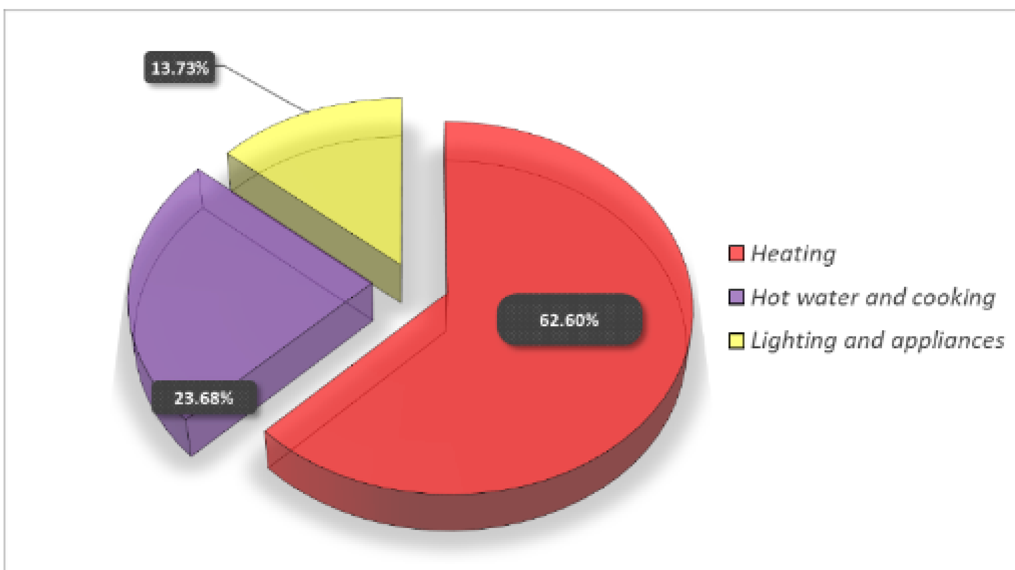


Figure 13: Breakdown of end-use energy consumption for No. 13A Dprotsakanneri Building

End-user (kWh/year) in No. 13A Dprotsakanneri Street	Heating	Hot water and cooking	Lighting and appliances	Total
	40,060	15,154	8,784	**63,998**

[1] National Greenhouse Gas Inventory Report of Armenia 1990-2017
https://drive.google.com/file/d/1q6Jz3YT9vLKFEq1A7yTbGN2FccFNsqw1/view?usp=sharing

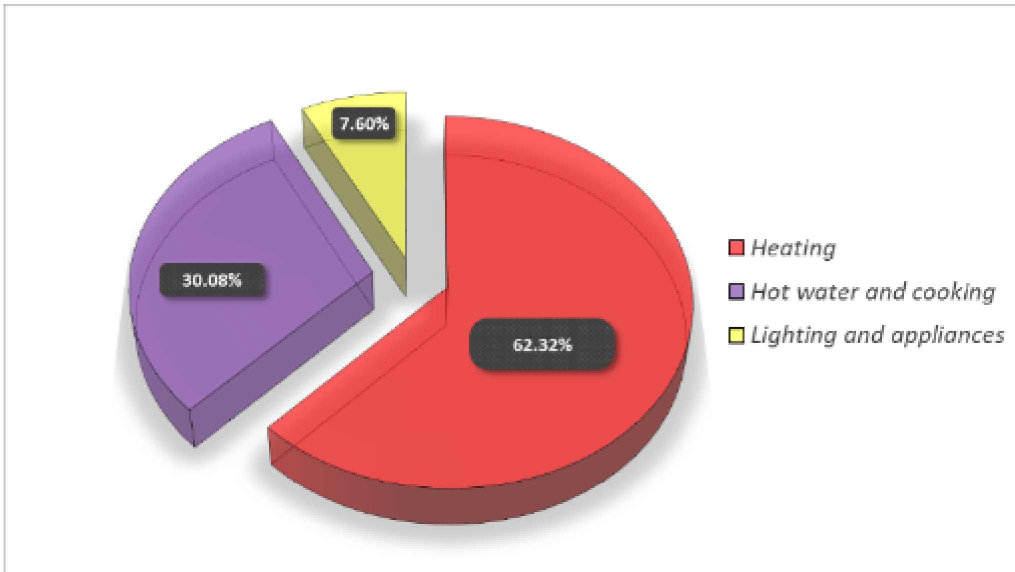


Figure 14: Breakdown of end-use energy consumption for No. 13B Dprotsakanneri Building

End-user (kWh/year) in No. 13B Dprotsakanneri Street	Heating	Hot water and cooking	Lighting and appliances	Total
	64,867	31,303	7,912	**104,082**

4.4 Assessment of comfort conditions

The comfort conditions in both buildings are considered to be well below the international standards. This is due to lack of insulation in building shell components and poor condition of the building envelope. An attempt to calculate theoretical heat consumption based on structural and ambient conditions has been made through the use of a customized model.

Results and detailed calculations (based on RACN 24-01-2016 and AST 362-2013) are shown in the energy passports of the building (before and after cases). Apparently the **theoretical (recalculated to normative conditions) heat consumption is in the range of 259 kWh/m^2/y.** This means that both buildings are underheated and internal comfort conditions are suboptimal. It should be noted that out of 16 apartments in each building, only 8 units are currently being occupied.

Considering the current occupancy patterns and energy consumption rates[2], the level of thermal comfort is around 12.1% for No. 13A Dprotsakanneri Building and 19.6% for No. 13B Dprotsakanneri Building *and therefore current level of comfort conditions appear to be significantly low. The difference from the theoretical/normative value is attributed partly to under heating and partly to poor conditions of the building envelope and lack of proper insulation, as well as unoccupied and non-heated apartment units.*

[2] Normative useful energy consumption figure of each building, as presented in section 7 of this report, is **331.65 MWh/year**.

5. Energy Efficiency Measures

5.1 Roof insulation

Taking into consideration the thermal resistance of the attic floor ($R_{Attic\ floor}$) does not meet the requirements of RA construction norms, it is strongly recommended to insulate the roof of the both buildings.

Figure 15: Expanded perlite sacks

Recommended insulation material would be the swelled expanded perlite sand blanket/sacks [GOST 10832-96], with thermal conductivity of 0.065-0.072 W/m°K, and a thickness of 200 mm.

The insulation of the pitched roofs includes the following works:

- Removal of construction waste and existing slag layer, cleaning attic floor slab (special treatment for asbestos removal should be considered);
- Repair of the slab at these points using screed or elastomeric cement (polymer concrete injection in the joints between hollow core slabs);
- Installation of vapor barrier on the concrete slab (PE foil, Ruberoid, etc.);
- Covering the attic floor with swelled perlite sacks.

Investment costs and estimation of energy/cost savings for each building

The total area of the attic floors in each building is around 349.2 m^2 and therefore the cost of this investment assuming a unit price of 35,000 AMD/m^3 for all the related works is around **2,450,000 AMD.**

The energy savings derived from insulating roof have been calculated with the utilization of building heat losses calculations methodology, in accordance with AST 362-2013 “Energy conservation. Building energy passport. Basic rules. Standard form”.

The calculated energy savings from the measure have been derived to be **17,139 kWh/year**, amounting to **6.5%** of total energy consumption for heating, where due to significant underheating, instead of baseline year energy consumption figures, normative figures with 100% comfort level and full occupancy pattern is considered for cost-benefit analysis.

Table 6: Annual energy and costs savings resulting from roof (attic floor) insulation for each building

Annual savings in natural gas* (kWh/year)	**17,139**
Annual savings in natural gas (Nm^3/year)	**1,976**
Annual costs benefit (AMD/year)**	**283,876**
Simple payback (year)	**8.61**

*Due to small share of electrical energy in heating (around 3%) in the baseline year breakdowns, savings are considered and monetarized by natural gas only.
** Natural Gas tariff = 143.7 AMD/Nm^3

5.2 Wall insulation

The walls of the buildings are made of 300 mm thick reinforced concrete, covered by a cementitious decorative rendering.

The present R value of uninsulated walls is less than minimum requirements set forth in the norms. It is proposed to install 100mm of Extruded Polystyrene (XPS) insulation (λ≤0.040 W/m˚K) externally to improve the R-Value.

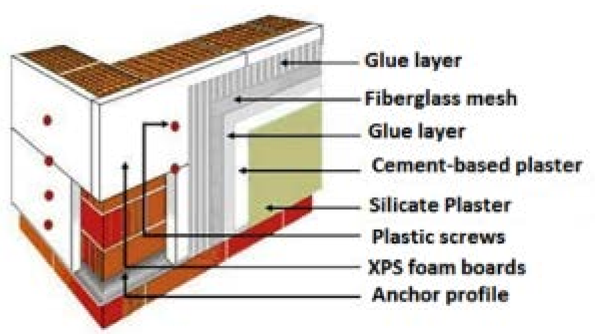


Figure 16: Cross section of an insulated wall (exterior thermal insulation composite system)

The specific works to be foreseen in this project are shown below:

- Deposition of plaster loose parts
- Covering of exposed steel reinforcing bars with epoxy or cementitious corrosion inhibitor
- Repair of the plaster in these points with cementitious render
- Coating of the insulation board with a cementitious adhesive using a notched trowel. Any excess adhesive from the edges of the boards must be scraped off on order to avoid the creation of thermal bridges.
- Placing of the XPS[3] foamboards on the walls. Voids or spaces larger than 1.6 mm between the boards should be filled with an insulating material. The boards should be fastened to the walls with appropriate plastic screw or hammer fixing. Considering the flammability of XPS, the areas around the windows/doors and fenestration should be insulated with a non-flammable material (e.g. mineral wool slabs, with a minimum width of 300 mm), in order to minimize the risks associated with fire.

[3] Material to be selected based on fire safety and indoor air quality requirements, with internal insulation material to have no lower than class B fire safety and no toxic additives which may pose an evaporation and indoor air quality contamination hazard.

- Applying on the XPS boards a cement-free reinforcing coat that encapsulates a reinforcing fibreglass mesh.
- Coating of the surface with a decorative render finish.

Investment costs and estimation of energy/cost savings for each building

The total walls area is around 1,116 m^2 and therefore the cost of this investment assuming a unit price of 12,000 AMD/m^2 for all the related works is around **16,745,000 AMD.**

The energy savings derived from insulating of the external walls have been calculated with the utilization of building heat losses calculations methodology, in accordance with AST 362-2013 “Energy conservation. Building energy passport. Basic rules. Standard form”.

The calculated energy savings from the measure have been derived to be **240,679 kWh/year**, amounting to **91.2%** of total energy consumption for heating, where due to significant underheating, instead of baseline year energy consumption figures, normative figures with 100% comfort level and full occupancy pattern is considered for cost-benefit analysis.

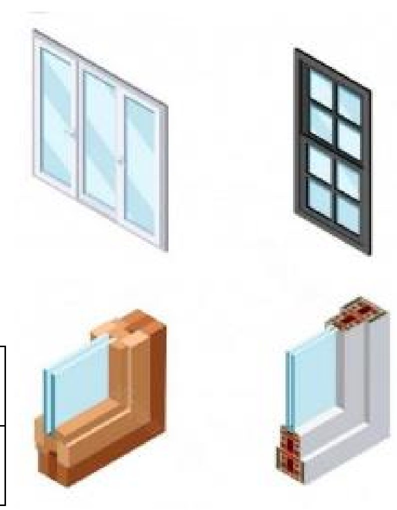
Table 7: Annual energy and costs savings resulting from wall insulation for each building

Annual savings in natural gas (kWh/year)	240,679
Annual savings in natural gas (Nm^3/year)	27,741
Annual costs benefit (AMD/year)	3,986,354
Simple payback (year)	4.20

5.3 Replacement of old windows and doors in the staircases and entrances in each building

All wooden framed windows in staircases, as well as entrance doors which are wooden (R = 0.39 $m^2 \cdot °C/W$) should be replaced. The condition of these windows and doors is very poor and all the mentioned windows and doors are subject to change with new PVC framed 4 chamber double glazed units ($U_{window} \leq 1.9\ W/m^2 \cdot °C$, $U_{door} \leq 2.1\ W/m^2 \cdot °C$).

Unit cost for this measure will be around 52,000 AMD per m^2; therefore the total investment cost would be **1,245,000 AMD**.



Area of staircase windows and entry doors to be replaced (m^2)	**23.94**
Total cost associated with replacement of Staircase windows and entry doors (AMD)	**1,245,000**

The energy savings derived from replacement of doors and windows walls have been calculated with the utilization of building heat losses calculations methodology, in accordance with AST 362-2013 “Energy conservation. Building energy passport. Basic rules. Standard form”. The calculated energy savings from the measure have been derived to be **6,103 kWh/year**, amounting to **2.3%** of total energy consumption for heating, where due to significant underheating, instead of baseline year energy consumption figures, normative figures with 100% comfort level and full occupancy pattern is considered for cost-benefit analysis.

Table 8: Annual energy and costs savings resulting from door and window replacement

Annual savings in natural gas (kWh/year)	**6,103**
Annual savings in natural gas (Nm^3/year)	**703**
Annual costs benefit (AMD/year)	**101,084**
Simple payback (year)	**12.32**

5.4 Summary of the introduced Energy Efficiency Measures

The following table summarizes key results regarding the financial viability of the introduced energy efficiency measures in each building.

Table 9: Financial viability of the proposed energy efficiency measures for each building

No.	Project	Investment		Annual Savings			Simple Payback
		AMD	€*	kWh/year	AMD/year	€/year	year
1	Roof Insulation	2,444,400	5,847	17,139	283,876	679	8.61
2	Walls Insulation	16,745,700	40,053	240,679	3,986,354	9,535	4.20
3	Replacement of old windows and doors	1,244,880	2,978	6,103	101,084	242	12.32
	TOTAL	**20,434,980**	**48,878**	**263,921**	**4,371,314**	**10,456**	**4.67**

*AMD/EUR = 418.09 (https://www.cba.am/am/SitePages/ExchangeArchive.aspx?FilterDate=2022-09-19)

Hence, the total investment cost for No.13A and No.13B Dprotsakanneri Street buildings will be AMD 40.867 mln (EUR 97,750).

6. Greenhouse Gas (GHG) emissions reduction

According to "National Greenhouse Gas Inventory Report of Armenia 1990-2017[4],", country-specific CO_2 emission factors are calculated based on the imported natural gas characteristics. The average CO_2 emission factor for the years 2011-2017 is 56,863.3 kg/TJ, or 0.2047 kg/kWh.

Grid emission factor for the electricity system of the Republic of Armenia, according to the standardized baseline[5], sets the emission factor value as 0.39 kg/kWh.

The following table presents an estimation of GHG emissions reduction as a result of the implementation of all the proposed measures.

Table 10: Estimation of GHG emissions reduction through the proposed measures for each building

No.	Project	GHG emissions reduction (t CO2/y)
1	Roof Insulation	3.51
2	Walls Insulation	49.27
3	Replacement of old windows and doors	1.25
	TOTAL	**54.03**

[4] National Greenhouse Gas Inventory Report of Armenia 1990-2017

[5] https://cdm.unfccc.int/sunsetcms/storage/contents/stored-file-20210303100626127/ASB0038-2021.pdf

7. Energy passport of a typical detached premise of each building

According to Armenian Standard AST 362-2013 “Energy conservation Building energy passport, Basic rules. Standard form” and Construction Norms RACN 24-01-2016, “Thermal Protection of Buildings”

1. General information	
Passport elaboration date	18.10.2022
Address	No. 13A Dprotsakanneri district/No. 13B Dprotsakanneri district (one of the two typical premises), Tashir, Armenia
Building type	Residential/multi apartment
Number of floors	4 aboveground
Estimated number of occupants	16

2. Design conditions				
N	**Index name**	**Index**	**Unit of measure**	**Design value**
1	Design outdoor temperature	t_{out}	°C	**-21.0**
2	Average outdoor temperature during the heating season	$T_{average}$	°C	**-0.1**
3	Duration of the heating season	z_{dd}	day/year	**197**
4	Degree days of heating season	D_d	°C ·day/year	**3,959.7**
5	Design indoor temperature	T_{ins}	°C	**20.0**
6	Design temperature of attic	T_{attic}	°C	**-**
7	Design temperature of cellar	T_{cellar}	°C	**-**

3. Geometric indexes						
N	**Index name**	**Index**	**Unit of measure**	**Required values**	**Actual values**	**Improved values**
8	Total area of floors	A_{total}	m^2	**1,025.60**	**1,025.60**	**1,025.60**
9	Inhabited area	A_{heat}	m^2	**639.60**	**639.60**	**639.60**
10	Calculated area (for public buildings only)	A_{calc}	m^2	-	-	-
11	Heated volume	V_{heat}	m^3	**1,918.80**	**1,918.80**	**1,918.80**
12	Glazing ratio	**f**		**12.9%**	**12.9%**	**12.9%**
13	Index of the compactness	K_{comp}	m^{-1}	**52.0%**	**52.0%**	**52.0%**
14	Total area of building envelope	$A_{envelope}$	m^2	**997.60**	**997.60**	**997.60**
	Including:					
	– Facade	A_{facade}	m^2	**640.60**	**640.60**	**640.60**
	– External walls (reinforced concrete)	A_{wall}	m^2	**558.19**	**558.19**	**558.19**
	– Apartment windows & balcony doors	$A_{apt.window}$	m^2	**70.44**	**70.44**	**70.44**
	– Staircase windows & entry doors	$A_{staircase\ window}$	m^2	**11.97**	**11.97**	**11.97**
	– Basement ceiling	$A_{basemnet}$	m^2	**182.40**	**182.40**	**182.40**
	– Roof (attic floor)	A_{roof}	m^2	**174.60**	**174.60**	**174.60**

4. Thermal technical indexes						
N	**Index name**	**Index**	**Unit of measure**	**Required values**	**Actual values**	**Improved values**
15	Weighted thermal resistance of building envelope, including:	$R^{weight.}_{env.}$	m^2·°C /W			
	– External walls (reinforced concrete)	$R^{weight.}_{wall}$	m^2·°C /W	**2.984**	**0.426**	**2.935**
	– Apartment windows & balcony doors	$R^{weight.}_{apt.windows}$	m^2·°C /W	**0.448**	**0.420**	**0.420**
	– Staircase windows & entry doors	$R^{weight.}_{staircase\ window}$	m^2·°C /W	**0.448**	**0.390**	**0.480**
	– Basement ceiling	$R^{weight.}_{roof}$	m^2·°C /W	**3.880**	**1.658**	**1.658**
	– Roof (attic floor)	$R^{weight.}_{floor-1}$	m^2·°C /W	**3.880**	**1.335**	**3.424**

5. Auxiliary indexes						
N	**Index name**	**Index**	**Unit of measure**	**Required values**	**Actual values**	**Improved values**
16	Reduced heat transmission coefficient	$K_{gen.}$	W/(m^2·°C)	**0.464**	**1.754**	**0.545**
17	Rate of air circulation over heating season for specific norm of ventilation	N_{air}	hour^{-1}	**0.199**	**0.238**	**0.199**
18	Specific household heat release factor	q_{house}	W/m^2	**11.407**	**11.407**	**11.407**
19	Tariff of thermal energy for designed building	C_{price}	AMD/kWh	-		-
20	Unit price heating appliance and connection to the heating network in the area of construction	C_{heat}	AMD/ (kWh/year)	-		-
21	Specific return from unit energy saving	$W_{ret.}$	AMD/ (kWh/year)	-		-

6. Specific Indexes						
N	**Index name**	**Index**	**Unit of measure**	**Required values**	**Actual values**	**Improved values**
22	Specific performance factor of heat-shielding	$k_{heat\text{-}shielding}$	W/(m^3·°C)	**0.2412**	**0.9120**	**0.2834**
23	Specific performance factor of ventilation	k_{vnt}	W/(m^3·°C)	**0.0613**	**0.0731**	**0.0613**
24	Specific performance factor of household heat release	$k_{household}$	W/(m^3·°C)	**0.189**	**0.189**	**0.189**
25	Specific performance factor of solar radiation heat inputs	$k_{radiation}$	W/(m^3·°C)	**0.0460**	**0.0460**	**0.0460**

7. Coefficients			
N	**Index name**	**Index**	**Required values**
26	Efficiency factor of heating self-regulation	ζ	**0.50**
27	The factor considering decrease in heat consumption of residential buildings in the presence of the every apartment accounting of thermal energy on heating	ξ	**0.10**
28	Efficiency factor of recuperation (heat recovery)	$k_{recovery}$	**0%**
29	Coefficient accounting for decrease in use of heat inputs during their exceeding the heat losses	ν	**0.77399**
30	Coefficient accounting for additional heat losses from heating system	β_h	**1.13**

8. Complex Energy Efficiency Indexes						
N	**Index name**	**Index**	**Unit of measure**	**Required values**	**Actual values**	**Improved values**
31	Estimated specific performance factor for heating and ventilation in heating season	$q^{estimated}_{heat}$	W/(m³·°C)	**0.215**	**0.909**	**0.258**
32	Standardized specific performance factor for heating and ventilation in heating season)	$q^{standard.}_{heat}$	W/(m³·°C)	**0.359**	**0.359**	**0.359**
33	Energy efficiency class (category)			**A**	**E**	**B**
34	The compliance of the building's design with the requirements of the existing norms on thermal protection			**YES**	**NO**	**YES**

9. The energy load of the building						
N	**Index name**	**Index**	**Unit of measure**	**Required values**	**Actual values**	**Improved values**
35	Specific consumption of heat energy for heating and ventilation purposes during heating season	**q**	kWh/m³·year	**20.45**	**86.42**	**24.53**
			kWh/m²·year	**61.34**	**259.26**	**73.58**
36	Consumption of heat energy for heating and ventilation purposes during heating season	$Q^{annual}_{heating}$	kWh/year	**39,231**	**165,824**	**47,059**
37	Total heat loss during heating season	Q^{annual}_{total}	kWh/year	**55,170**	**179,646**	**62,867**

For each premise of the two typical buildings, the Specific consumption of heat energy for heating and ventilation purposes during heating season (q) in improved case is derived to be **73.58 kWh/m² per year**, which is **71.6%** reduction compared to the normative consumption in non-improved (baseline) version.

Considering the efficiency of the heating system as 90%, the final Consumption of heat energy for heating and ventilation purposes during heating season for each premise of the typical buildings will be **131,961 kWh per year**.

Similarly, for each of the buildings (No.13A and No.13B, Dprotsakannersi Street), the total final Consumption of heat energy for heating and ventilation purposes during heating season will be **263,921 kWh per year.**

8. References

1. Armenian Standard AST 362-2013 “Energy conservation Building energy passport, Basic rules. Standard form”.
2. Armenian Standard AST 371-2016 “Methodology for performing energy audit in residential and public buildings”.
3. Construction Norms RACN 24-01-2016, “Thermal Protection of Buildings”.
4. Construction Norms RACN II-7.01-2011, “Building climatology”.
5. Construction Norms RACN II-7.02-95, “Building thermal physics of building envelopes: design standards”.
6. Construction Norms RACN IV-12.02.01-04, “Heating, air conditioning and air improvement”.
7. Construction Norms RACN II-8.04.01-97, “Fire safety of buildings and infrastructure”.
8. Construction Norms RACN 22-03-2017 “Artificial and Natural Lighting”.
9. Construction Norms RACN 31-03-2018 “Public Buildings and Structures”.
10. Construction Norms RACN 40-01.01- 2014 “Indoor water supply and drainage of buildings”.