New Applied Technology, Efficiency and Lighting Initiative

COOPERATIVE AGREEMENT NO. 114-A-00-05-00106-00

Final Energy audit Report

Final Energy Audit Report

For the common area of the high-rise

Residential Buildings

Addresses: building 17, block 4, Nutsubidze plateau, Tbilisi
9 Petrisi str, Didi digomi
68a, 3 micro district, Gldani
Building 1, block 4, Vazha Pshavela 3 Rcheulishvili str
building 19, block 1, micro district 4, Vazisubani
building 15, block 5, Digomi massive
111a Gorgasali str., building 3 53 Saburtalo str
building 20/1, Kaloubni str, district Varketili
building 24, block 4b, Mukhiani

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0. Executive Summary

The energy audits in selected residential buildings were carried out in the framework of the USAID NATELI Project implemented by Winrock International. The work was conducted under the program component targeting residential energy efficiency in multi – apartment buildings of Tbilisi by a team of auditors put together by foundation “World Experience for Georgia” (WEG).

This project is the first to address the problems of common areas in the buildings. With many poorly lit and unprotected entrances and inefficient old elevator systems in Tbilisi, lessons learned from this project can be extended to thousands of other buildings. The goal of the project is also to support collective efforts of condominium associations created under the Georgian Law on Condominiums (2007) to reduce their energy expenses and improve the living conditions in their common property.

To reduce electricity and natural gas consumption through higher energy efficiency of common areas of multi-apartment buildings energy saving solutions should be identified. The energy audit was conducted in three directions:

1. **Increase thermal insulation of common areas**
2. **Increase the efficiency of elevators**
3. **Install energy efficient lighting systems in entrances and stairwells**

Preliminary and detailed Energy audits and rehabilitation assessments as well as economic analyses were conducted in the common areas of the following buildings.

Table. 0.1 List of audited buildings

Building Address	Floors	Entrances	Number of apartments
building 17, block 4, Nutsubidze plateau, Tbilisi	13, 14, 15	3	162
9 Petrisi str, Didi digomi	16	1	60
68a, 3 micro district, Gldani	9	3	81
Building 1, block 4, Vazha Pshavela	8	3	63
3 Rcheulishvili str	9	1	45
building 19, block 1, micro district 4, Vazisubani	12	1	59
building 15, block 5, Digomi massive	13	2	91
111a Gorgasali str., building 3	8	8	172
53 Saburtalo str	5	5	75
building 20/1, Kaloubni str, district Varketili	16	1	64
building 24, block 4b, Mukhiani	8	3	48
5 Khudadovi str.[1]	16	1	75
Total	298	68	995

[1] Audit of this building was implemented by “Energy Efficiency 21”.

The energy audits were conducted in close cooperation with the chairmen of Condominium Associations of participating buildings. Relevant applicable standards and regulations were used in the process.

Implementation of EE measures will be done in selected buildings subject to further selection and agreement with Tbilisi Corps and Winrock International. Monitoring of the process and results of implementation of EE and rehabilitation works will be conducted by WEG.

Common areas

The technical condition of the residential buildings in Tbilisi is generally poor. In most cases the entrances and stairwells of multi–apartment buildings in Tbilisi are poorly lit, unprotected from weather, and have inefficient elevators. A substantial part of energy waste can be attributed to the problems of common areas of the buildings. The entrances are poorly maintained, need cleaning, painting and in many cases plastering work.

Along with the above problems, there are safety concerns: uneven stairs on the staircases poorly illuminated at night, elevators in questionable technical condition and long passed lifetime, basements with no lighting are a few to mention.

Entrances and Stairwells

Generally entrances and stairwells are poorly maintained. Only a few buildings have steel entrance doors with mechanical codes, many buildings have no entrance doors at all. The walls need plastering and painting and in some cases the internal common space is not completely safe due to uneven stairs or construction material remains from apartment refurbishment. A common practice is “privatizing” part of the common area and transforming them into private areas of the residents. By design or due to broken windows most of the stairwells are not isolated from outside temperatures and air circulation. As a result the internal stairwell walls have practically become external walls for the apartments and cause additional excessive heat losses.

This leads to excessive heat losses in winter and often the temperature in the entrance is the same as the external temperature.

Common lighting

In most buildings audited, entrances and/or stairs are not properly lit either outside or inside. This leads to discomfort for residents and an increased probability of accidents.
In the majority of cases the initial common lighting system is not being used by residents and the lighting wiring and fixtures are damaged and cannibalized by vandals. Light to the common areas is provided separately from each individual entrance. As a result sometimes there is no light on the stairwell while in other situations the simultaneous lighting from different apartments becomes excessive.

Usually there are no lighting circuits for illumination of basements.
Apart from a few exceptions there is no efficient lighting used in entrances and stairwells.

Elevators

Usually, there is one operating elevator per each entrance and, even if under initial design there should be two elevators, there is no single building with both elevators operating. The existing elevators are traction type elevators, with steel ropes.

Most of the elevators are at the end of their useful lifetime or have exceeded the lifetime duration. The mechanical parts are worn out and in many cases need replacement. There was an especially dangerous situation is in 3rd entrance of Vaja Pshavela bdg.1, IV dist. where the elevator is lacking an internal wooden door and therefore constitutes a life hazard.

The money for elevator maintenance and electricity payment is either collected by residents of the relevant building or is collected by electromechanical devices installed in the elevator cabins.

The maintenance is preformed on an ad hoc basis by hired technicians or is taken care of by specialized companies under special agreement. In this latter case the elevator company collects the money for elevator use and pays for elevator electricity consumption as well as maintenance.

Identified Energy Efficiency Measures

Common lighting

Taking into account reasons stated above it was finally recommended to use the efficient compact fluorescent light bulbs as a more common and easier energy efficiency measure related to less upfront cost. This will minimize energy consumption and at the same time provide the adequate level of safety and comfort to the residents. The level of comfort and safety of the common area will increase compared to current conditions and the risk of traumatism due to darkness on the stares will be eliminated. Restoration of the lighting circuits and assuring its safety was considered as a necessary part of energy efficiency measures in both cases. This assumption was used as a basis for economic evaluation in most buildings.

Weatherization

In most of the cases the energy audit identified a high energy saving potential in reducing the heat loss from apartments by closing the stair-wells from external weather and air flow. Restoring of windows can provide adequate insulation and will increase the temperature in the stair-wells by several degrees. It was suggested to close the openings in the entrances and stairwells by installing PVC windows and doors with double glazing since they have a number of advantages over ordinary wooden-framed windows. In the places where the openings are big it was suggested to fill part of the openings by brick or block masonry and to install the PVC windows.

There are a number of buildings with the entrances having decorative perforated walls or openings fitted with a number of decorative pipe-like columns. In this case it was recommended to use Carbolux type plates to close the openings.

Elevators

The modernization of the elevator system by installation of VFD (VVVFD) control devices will provide accurate speed and torque control, smooth starts and stops; and result in minimized energy consumption and wear as well as safe operation and improved passenger comfort.

As principle energy efficiency measure it is recommended to install a new Electrical Control Panel with variable voltage variable frequency drive (VVVFD) system without changing the motor and main mechanical components of the elevator. It is known that Variable frequency drives (VFD) are reliable electronic devices that conduct microprocessor-based controls of the three-phase AC electric motor speed, where the elevators are controlled by software. The AC motor drive controls the speed, torque, direction and resulting capacity of the motor. By reducing the peak startup current and matching the electrical load to the mechanical load, this type of motor drive can save up to 50% of electricity consumption even when the electric motor remains the same. Installation of a Variable Frequency drive can save up to 30% of the electricity, depending on the mode of operation.

The Table 0.2. below summarizes the ranges of energy saving and economic parameters of each considered measures

Table 0.2. Summary of EE measures considered

Type of EE measure	**annual saving**		**Investments**		**Payback**
	KWh	**GEL**	**GEL**	**NPVQ**	**year**
Weatherization (annually per floor)	1876-7850	128-557	75-3268	-0.76-20.28	0.3-25.6
EE Lighting (annually per floor)	85-306	14-49	21-155	0.67-12.2	0.5-1.8
Elevator Upgrade	1109-4557	177-1030	4625-7000	-0.74- -0.39	6.8-26

CO_2 reduction

Each of the considered energy efficiency measures is related to reduction in carbon emissions. The biggest carbon reduction potential is related to weatherization and corresponding reduction of gas consumption for heating. The summary of estimated ranges of CO_2 emissions per entrance of residential buildings audited is given in the Table 0.3 below.

Table 0.3.

Measure per entrance	Energy Saving KW/h	CO_2 Reduction t/a	Approximate value of emissions' reduction GEL
Lighting	700-4000	1-4	18-72
Elevators	1500-4000	1-3	18-54
Weatherization	50 000	35	630

Conclusions and recommendations

The following main conclusions and recommendations have been elaborated based on the work on Energy Audits conducted in the selected multi-apartment residential buildings:

- Energy loss from common areas of residential multi-apartment buildings in Tbilisi is significant and deserves special energy efficiency measures to be conducted.
- Safety and comfort requirements are mostly neglected in common areas of multi-apartment residential buildings—as such, unsafe elevators, a lack of lighting and unorganized space was observed in most buildings audited.
- Information spreading and experience sharing between communities as well as inside the communities is quite slow. There is a need for wider outreach activities to inform and facilitate sharing of positive experience across the communities.
- The ageing stock of elevators in Tbilisi will soon require replacement or major overhauling of these assets in the years to come.

The Energy Audit Team's analysis and assessment of the EA results revealed a great potential for energy savings in common areas of typical multi–apartment residential buildings in Tbilisi. Through the team's detailed energy audit, we were able to optimize energy efficiency interventions and estimate their profitability.

- **Lighting**
  Improvement of lighting systems can bring substantial benefits with minimal investment. It provides the highest return on investment among considered energy efficiency measures and provides a sizeable safety benefit. It is recommended to:
    - Restore common lighting
    - Install fluorescent lighting or motion sensors –cost effective measures
    - Arrange the lighting of basements from entrance circuits
    - Collect the money for lighting together with elevator payments
- **Weatherization**
  The audit revealed that weatherization of entrances, stairwells and common corridors is a highly effective energy efficiency measure. With moderate investment it provides offers a potential for heat loss reduction and thus increased comfort in common area combined with the reduction of heat loss from apartments. This measure provides the greatest saving in energy as well as GHG emissions per entrance.
- **Elevator modernization**
  Many of the elevators are in poor technical and unsafe for operation
    - It is recommended to arrange the inspection of ageing elevator stock in the city with the emphasis on safety and expected growth of technical problems.
    - Elevator upgrade by installation of Variable Frequency Drive (VFD -VVVF) controls systems is the least profitable Energy efficiency measure. It has the longest payback period and can be considered as less attractive option for the time being. However this measure should be considered as a prime option for improving the efficiency and extending lifetime of elevators in case of major overhaul. Economies of scale can be achieved if these measures will be replicated in many buildings.

Implementation of the above measures can serve as an example to many residential buildings of this type all over Tbilisi.

The common areas are not duly taken care of neither from an energy saving nor from comfort and safety point of view. There is definitely a need for better organization and cooperative effort of the residents to improve their living conditions in common areas.

Cooperative effort in communities is a key to success and can enable substantial improvements in living conditions and energy spending. Every building has people who can do some part of the work themselves versus hiring a specialized company that would have to pay taxes and charge profit and overhead costs. The difference in cost to the residents will be at least 25-35% this can be considered an important factor in favour of participation and joint action of community members.

1. Description of NATELI project and energy audits conducted in residential buildings

The New Applied Technology Efficiency and Lighting Initiative (NATELI) is implemented by WInrock International with the support of U.S. Agency for International Development.

This is a two years' activity, which is oriented on:

- Energy efficiency improvements intervention, focusing on hospitals.
- Promotion of residential energy efficiency by working with condominium associations and Tbilisi Municipality and on energy efficiency in higher education with Georgia State Technical University;
- Support in conjunction with BP Georgia for the second year of operations of the USAID/BP Global Development Alliance-funded Energy Bus.

This document was created to further the work of the USAID New Applied Technology Efficiency and Lighting Initiative (NATELI) project. NATELI has three main focal areas, one of which is to improve residential energy efficiency in Georgia.

Energy Audits (EA) have been conducted in 12 residential buildings, and the recommendations of the EA were implemented as pilot projects at selected multi-apartment buildings of Tbilisi, through cooperation with Condominium Associations (CA), Tbilisi Municipality and Energy Service Companies (ESCOs). The buildings were selected in order to represent all major types of multi-apartment block buildings in Tbilisi. Therefore, the results of energy audit and/or pilot projects can be easily replicated in the majority of residential block buildings in Tbilisi.

The Georgian Law on Condominiums (enacted in 2007) created a new type of legal entity for Georgia, a Condominium Association (CA). The CAs is empowered to enter into agreement and allow residents in multi-apartment building to make joint decisions regarding a range of operational and investments issues. The objective of this law is to provide the legal conditions for management, operation and development of the common property (common areas and installations in the building) by the members of Condominium Associations.

Under the Residential Energy Efficiency Component, the NATELI Program focuses on housing improvement projects that will help to maximize energy savings and environmental benefits in selected multi-apartment buildings of Tbilisi (which generally have very low energy efficiency) by means of reducing electricity and natural gas consumption through energy efficiency measures in the common areas of the residential buildings.

To reduce electricity and natural gas consumption through higher energy efficiency of common areas of multi-apartment buildings energy saving solutions should be identified. The energy audit was conducted in three directions:

1. Increase thermal insulation of common areas
2. Increase the efficiency of elevators
3. Install energy efficient lighting systems in entrances and stairwells

To identify energy conservation solutions in the common areas of residential buildings, Energy Audit works were carried out in two stages: a preliminary audit followed by a detailed energy audit. Auditors developed the recommendations for increased energy efficiency in the buildings. The residential buildings in Tbilisi offer significant potential for energy efficiency improvements. Realization of identified energy saving measures will improve the financial well being of consumers and will contribute to environmental protection resulting from reduced greenhouse gas emissions.

The EA of a building is a systematic procedure with the purpose to evaluate the existing energy consumption, to identify saving measures and to report the findings. The EA includes inspection, survey and analysis of energy flows in a building with the objective of understanding the energy dynamics of the system under study.

The term energy audit is commonly used to describe a broad spectrum of energy studies ranging from a quick walk-through of a facility in order to identify major problem areas to a comprehensive analysis of the implications of alternative energy saving measures sufficient to satisfy the financial criteria of potential investors.

The energy audit which was carried out by the Energy Audit Team in the chosen residential buildings includes following steps:

- The Preliminary (Screening) Energy Audit - the simplest and quickest type of audit. It involved minimal interviews with site-operating personnel, a brief review of facility utility bills and other operating data, and a walk-through of the facility to become familiar with the building operation and to identify any glaring areas of energy waste or inefficiency.

- The Detailed Energy Audit expands on the preliminary audit described above by collecting more detailed information about the facility operation and by performing a more detailed evaluation of energy conservation measures, elaboration of recommendations and the associated costs benefits and payback period of the project implementation.

- Assessment of refurbishment rehabilitation needs including common areas of the building, elevators and lighting system.

The task of the preliminary EA for the common area, in the entrance of the residential buildings as to obtain the following main information:

- Baseline of energy consumption by elevator systems
- Preliminary assessment of technical conditions of the elevators
- Baseline of energy consumption of lighting fixtures in the entrances and stairwells

- Preliminary assessment of technical conditions of the lighting systems in entrances and stairwells
- Baseline estimate of heat losses to common areas
- Preliminary assessment of the technical condition of the building and necessary repairs
- Identification of potential Energy Efficiency measures
- Description of systems or equipment audited, their capacities and ratings, design and operating conditions, operation schedules etc, including information such as the type of elevators and lighting circuits etc.

The Preliminary (Screening) Energy Audit involved interviews with building residents, a brief review of electricity bills for the common areas, and a walk-through of the buildings to become familiar with the building arrangement and to identify any glaring areas of energy waste or inefficiency. The heat losses in winter from community areas, electricity consumption for lighting and the operation of elevators were the main focus areas of preliminary Energy Audit.
The following project development process shall be followed to evaluate and implement profitable energy efficiency measures in the common areas of the residential building. The energy saving project development process typically consists of six main activities that will be presented in this audit report; these activities are illustrated in the flow chart below.

1. Project Identification

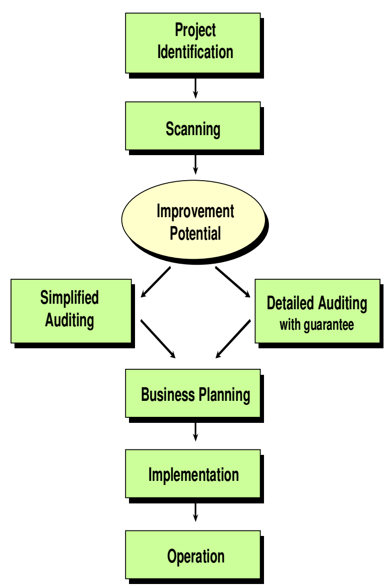
2. Preliminary (Scanning)

3. Energy Audit

4.Business Plan

5. Implementation

6. Operation



The initial project identification was conducted by Winrock International in cooperation with Tbilisi Corps - the municipal service of Tbilisi City Hall, who compiled the list of typical buildings in Tbilisi to be studied. The results of the energy audits and pilot projects in such buildings will be easy to generalize to a great majority of apartment block buildings in Tbilisi.

Table 1.1. List of Audited Buildings

Address of building	Floor	Entrance	Number of apartments
building 17, block 4, Nutsubidze plateau, Tbilisi	13, 14, 15	3	162
9 Petrisi str, Didi digomi	16	1	60
68a, 3 micro district, Gldani	9	3	81
Building 1, block 4, Vazha Pshavela	8	3	63
3 Rcheulishvili str	9	1	45
building 19, block 1, micro district 4, Vazisubani	12	1	59
building 15, block 5, Digomi massive	13	2	91
111a Gorgasali str., building 3	8	8	172
53 Saburtalo str	5	5	75
building 20/1, Kaloubni str, district Varketili	16	1	64
building 24, block 4b, Mukhiani	8	3	48
5 Khudadovi str.[2]	16	1	75
Total	298	68	995

[2] *Audit of residential building 5 Khudadovi str. was implemented by "Energy Efficiency 21".*

Preliminary and detailed Energy audits and rehabilitation assessments as well as economic analyses were conducted by the EA team and then put together by World Experience for Georgia (WEG). Implementation of EE measures will be done in selected buildings subject to further selection and agreement with Winrock International and Tbilisi Corps. Monitoring of the process and results of implementation of EE and rehabilitation works will be conducted by WEG.

Table 1.2 The list of Energy Audit Team members

	Position	Role in the project
Paata Tsintsadze	WEG – Lead Expert	Project Manager Lead Expert –Consultant Weatherization
Murman Margvelashvili	WEG – Director of Energy studies	Project coordinator Lead Expert –Consultant electricity use
Georgi Gogoladze	GBI Ltd. Director	Expert – Consultant Civil engineer
Alexander Tarielashvili	Tbil-Lift Ltd. Senior engineer	Expert –Consultant Elevator
Nodar Kevkhisvili	GTU, Professor	Expert –Consultant weatherization –lighting
Natalia Shatirishvili	WEG, Project Specialist	Analysis and preparation of reports
Givi Adeishvili	ISET Student	Apprentice
Giorgi Mukhigulishvili	ISET Student	Apprentice

Applicable Standards and Regulations

In the process of identifying energy efficiency measures and modernization solutions for common areas of the building, the team used the following Codes, Laws, standards and regulations:

1. The International Energy Conservation Code (2009 Edition);
2. Georgian Law on Condominiums (Edition 2007)
3. Regulations for Elevator Unit Installation and Safe Operations (ПУБЭЛ-ПБ) 10-558-03 (Edition 2003)**;**
4. Regulation, РД-10-104-95 for Upgrade of Elevator Units;
5. Daylight and Artificial Lighting SNIP 23-05-95

2. General overview of common areas in residential buildings.

The technical condition of the residential buildings in Tbilisi is generally poor. In most cases the entrances of multi–apartment buildings in Tbilisi are poorly lit, unprotected from weather, and have inefficient elevators. The entrances are poorly maintained, need cleaning, painting and in many cases plastering work.

A substantial part of energy waste can be attributed to the problems of common areas of the buildings. Along with this, there are safety concerns related to common areas of the buildings: uneven stairs on the staircases poorly illuminated at night, elevators in questionable technical condition and long passed lifetime, basements with no lighting are a few to mention.
There is definitely a need for cooperative effort of the residents to improve their living conditions in common areas.

2.1 Entrances and Stairwells

Generally entrances as well as all common areas of the buildings are poorly maintained. Only few buildings have steel entrance doors with mechanical code. Many of buildings have no entrance doors at all. This leads to excessive heat losses in winter and often temperature in the entrance is the same as external temperature.

Additionally, entrance hoods of some buildings are old and degraded and, therefore, rain water falls directly on the stairs that leads to their damage. The problems of entrances that are listed above can be solved by weatherization and common lighting improvement. Proposed measures are discussed in section 3.1 and 3.2.

By design or due to broken windows most of the stairwells are not isolated from outside temperatures and air circulation. As a result the internal stairwell walls have practically become external walls for the apartments and cause additional excessive heat losses.

Fig. 2.1.1 Stair-well in Mukhiani Vazisubani

Fig.2.1.2 Stair-well in Gorgasali str.

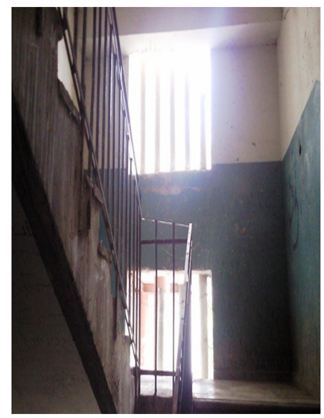


Fig. 2.1.3 Stair-well in

In most cases the doors of apartment access corridors that were I envisaged by initial design are also missing (fig. 2.1.4).

Fig. 2.1.4 stairwell and entrance to corridor in Petrisi str.

The walls need plastering and painting and in some cases the internal common space is not completely safe due to uneven stairs or construction material or remains from apartment refurbishment piled up in the common areas.

A common practice is "privatizing" part of the common area and transforming them into private premises of the residents. In some cases this has helped to reduce the heat losses from common areas but in general it has a significant negative impact on the exterior facade of the building (fig. 2.1.5)

Fig.2.1.5 General view of the building in Vazisubani district

One can conclude that common areas are not duly taken care of neither from energy saving nor from comfort and safety point of view.

2.2 Common lighting

In most buildings audited, entrances and/or stairs are not properly lit either outside or inside. This leads to discomfort for residents and increased probability of accidents.

In all buildings the lighting circuit for common areas was originally arranged by AES Telasi during the meter relocation process. The lines of lighting circuit are running up from separate lighting meters (located in the meter cabinet) in the entrance up to the top floor. In most cases the initial common lighting system is not being used by residents and the lighting wiring and fixtures are damaged and cannibalized by vandals. The light to the common areas is provided separately from each individual entrance. As a result sometimes there is no light on the stairwell while in other situations the simultaneous lighting from different apartments becomes excessive. This is the inefficiency of individual lighting. Table 2.2.1 shows the observed arrangement of lighting in different audited buildings:

Table 2.2.1

Building	Entrances	Floors	Type of lighting individual (I)/ common (KWh/a)	Payment organization		energy efficient lighting
				Separately	with elevator	
building 17, block 4, Nutsubidze plateau	**3**	**39**	**I**			
9 Petrisi str, Didi digomi	**1**	**16**	**I**			
68a, 3 micro district, Gldani	**3**	**27**	**I**			
Building 1, block 4, Vazha Pshavela	**3**	**24**	**665 KWh/a**		**√**	
3 Rcheulishvili str	**1**	**9**	**Upper floors-I Ground floor 294kWh/a**			
building 19, block 1, micro district 4, Vazisubani	**1**	**12**	**I**			
building 15, block 5, Digomi massive	**2**	**26**	**1379 KWh/a**		**√**	**√**
111a Gorgasali str., building 3	**8**	**64**	**I**			
53 Saburtalo str	**5**	**25**	**609 KWh/a**	**√**		**√***
building 20/1, Kaloubni str, district Varketili	**1**	**16**	**I**			
building 24, block 4b, Mukhiani	**3**	**24**	**I**			
5 khudadov str.	1	16				**Partly**

- *Only in one entrance out of five*

One can see that only in three out of twelve building there is an operational common lighting system. Others use individual illumination from apartments. The efficient lighting is used only in some exceptional cases.

One can conclude that common lighting is not practical in high rise 10-15 storied buildings due to organizational difficulties in money collection and payment. On the opposite in the buildings where the money for common lighting is collected together with payment for elevator electricity consumption and maintenance costs, this resolves the problem and provides the viable option for having common lighting in the common areas.

In some cases the main supply lines are in place and can be used for lighting of the floors, while bulb sockets and switches need restoration. The existing lighting system is not safe and it does not provide adequate illumination of the common areas. Incandescent bulbs are wasting electricity and residents do not demonstrate awareness with comparatively inexpensive energy-efficient lighting.

In some cases electricity was cut due to unpaid bills and residents arranged individual lighting. Being probably the only reasonable decision in this situation this measure, however, is very energy inefficient. As a result entrances are unlit in most cases, the stair-wells are either unlit or lit from several apartments simultaneously. This is neither efficient nor safe.

Fig. 2.2.1 Motion sensors in Digomi massive **Fig. 2.2.2** Individual lighting in Didi Digomi

Fig. 2.2.3 Energy efficient lighting in Digomi massive **Fig. 2.2.4** Daylight access in Nutsubidze

The need for lighting depends on daylight access as well as on the geometry of common areas. Daylight access defines the needed duration of artificial lighting while the total area and the geometry of separated spaces defines the number of lighting sources and strength of light needed.

The daylight access to common areas varies significantly between different types of buildings. In some cases (Rcheulishvili, Gorgasali, Mukhiani) the stairwells are completely open while in others (Varketili, Nutsubidze) almost completely closed. There are also mixed cases with partly open and partly closed areas (Petritsi).

There is no lighting provided to the basements and only a few residents have arranged wiring from their apartments to their individual cellars however cellar access corridors are still dark.

In general the lighting in common areas is not properly arranged and requires both technical and organizational solutions.

2.3 Elevators

In the inspected buildings there is one operational elevator per each entrance, even where under initial design there are two elevators installed. The existing elevators are traction type elevators, with steel ropes. The elevators have machine rooms above the elevator shaft, to house elevator equipment, including the drive and elevator electrical control systems. In the machine room a control system operates a motor that turns a sheave. Cables roll over this deeply grooved pulley to pull a car up or lower it down. The cables are also attached to a counterweight that weighs about as much as the car on the other side of the sheave. In the machine room the winches with AC motors and the gear box are installed. The motor turns a gear train that rotates the sheave. The motor requires a gearbox to reduce the motor speed and produce the required torque to start the elevator car to move. The elevator motor drive adjusts motor torque output to achieve desired acceleration, deceleration, and travel speed independent of car loading. The elevators are equipped with inefficient electro-mechanical control systems with electromechanical relays—a fairly outdated design.

Most of the elevators are at the end of their useful lifetime or have exceeded the lifetime duration. The mechanical parts are worn out and in many cases need replacement. The specialists of the audit team concluded that in several cases elevators are unsafe and need to be stopped and in other cases the elevators are beyond repair and should be replaced. The audit team discovered an especially dangerous situation is in the 3rd entrance of Vaja Pshavela bdg.1, IV dist. where the elevator is lacking internal wooden door and therefore constitutes a life hazard.

There are different options of organizing the maintenance and payment for electricity consumption by elevators as well as money collection for these needs.

The money for elevator maintenance and electricity payment is either collected by residents of relevant building or is collected by electromechanical devices installed in the elevator cabins. In this latter case each trip costs 5-10 tetri to elevator passengers.

In some cases (e.g Nutsubidze) maintenance is performed on an ad hoc basis by technicians hired for this purpose by condominium members. Other buildings have entered into service agreements with elevator maintenance company who performs regular maintenance and also pays for electricity consumption from the money collected by electromechanical boxes.

Regular maintenance is preferred as a more safe practice.

Another positive experience is when the money collected for elevator use is jointly used by condominium members also for other expenses; e.g. covering electricity cost for common lighting and other maintenance and repair works needed for in the building.

2.4 Lofts and basements

Though lofts and basements are the part of common areas of the buildings, the heat losses from these areas are affecting only the residents of the top and bottom floors. There is a limited possibility of joint actions for reduction of these losses by condominium's joint action.

In most of the cases the loft is a free area of 1.2m height on the top floor of the entrance. It is a part of communal property however is not easily accessible and hardly can be used for any purposes. The loft has a flat roof covered with slag and hydro-insulation. The bottom is a made of reinforced concrete slabs covered by a layer of slag for thermal insulation and for dew absorption.

The basements are in poor technical condition. There is no electricity supplied to the basement, thus the residents have difficulty in utilizing the basement space. In each block the basement has small ventilation windows along the perimeter of the building. These openings provide some daylight into the basement. The heat loss from the basements affects only heating of the first floor inhabitants. The share in the total heat losses of the building is insignificant.

Although basement entrances are common property, usually there is no lighting circuit installed for illumination of these entrances. Arranging the lighting of basements connected to common lighting system is recommended as a measure for improving safety and comfort of residents.

3. Energy Efficiency Measures

3.1 lighting

3.1.1 Technical description[2]

Most common lighting devices used throughout the housing sector are ordinary incandescent bulbs. The electric energy in such bulbs heats the Tungsten spiral and causes it to radiate light. Approximately 90% of the power consumed by an incandescent light bulb is emitted as heat, rather than as visible light. Therefore the efficiency of incandescent lighting is low and needs improvement.

A fluorescent lamp is a gas-discharge lamp that uses electricity to excite mercury vapor. The excited mercury atoms produce short-wave ultraviolet light that then causes a phosphor to fluoresce, producing visible light. A fluorescent lamp converts electrical power into useful power more efficiently than an incandescent lamp. The lamp is more costly because it requires a ballast to regulate the current through the lamp. However, lower energy cost typically offsets the higher initial cost of the lamp. Here we consider compact fluorescent (CF) bulbs that can use the same sockets as ordinary incandescent light bulbs.

Another measure for reducing the energy consumption for lighting is the use of switches activated by motion sensors. Energy saving and safety improvement potential for the lighting system can be realized through installation of switches with motion sensors. The lights would be out most of the time and would be lit only once needed when somebody would get into the corridor and stairwell.

Motion sensors are often used in indoor spaces to control electric lighting. If no motion is detected, it is assumed that the space is empty, and thus does not need to be lit. Turning off the lights in such circumstances can save substantial amounts of energy. Occupancy sensors for lighting control use infrared (IR) or acoustic technology, or a combination of the two. The field of view of the sensor must be carefully selected/adjusted so that it responds only to motion in the space served by the controlled lighting. Sensors and their placement are never perfect, therefore most systems incorporate a delay time before switching. This delay time is often user-selectable, but a typical default value is 15 minutes. This means that the sensor must detect no motion for the entire delay time before the lights are

[2] Source- www.wikipedia.com

switched off. If lights are off and an occupant re-enters a space, most current systems switch lights back on when motion is detected. However, systems designed to switch lights off automatically with no occupancy, and that require the occupant to switch lights on when they re-enter are gaining popularity due to their potential for increased energy savings. These savings accrue because in spaces with access to daylight the occupants may decide on their return that they no longer require supplemental electric light.

One can expect that the most energy efficient option would be installation of motion sensors together with fluorescent bulb, however, this measure is related to higher cost and brings little additional benefit. Use of efficient light bulbs in combination with motion sensors was not finally recommended because of three following reasons:

1. Frequent switching reduces the life time of fluorescent bulbs and will result in higher costs for their replacement. In extreme cases its lifetime may even become less than that of ordinary incandescent bulb.
2. In the short time when residents are in the zone of lighting the fluorescent bulbs will not achieve their efficient operation regime and thus will have only little saving.
3. Economic analysis shows that even without consideration of the above factors CF bulbs and motion sensors provide little incremental economic benefit if used one on top of other. I.e. if there is a motion sensor or efficient bulb installed, adding another component is not economical.

Taking into account reasons stated above it was finally recommended to use the efficient compact fluorescent light bulbs as a more common and easier energy efficiency measure related to less upfront cost. This will minimize energy consumption and at the same time provide the adequate level of safety and comfort to the residents. The level of comfort and safety of the common area will increase compared to current conditions and the risk of traumatism due to darkness on the stares will be eliminated. Restoration of the lighting circuits and assuring its safety was considered as a necessary part of energy efficiency measures in both cases. This assumption was used as a basis for economic evaluation in most buildings.

The LED lighting was considered as impractical for the use in common areas due to its higher cost, need for special fixtures, directed lighting and higher vulnerability to theft.

3.1.2 Economic evaluation

As mentioned above there is no common lighting in most of the audited buildings. Therefore there is no data on baseline electricity consumption for common lighting that would be useful for assessment of energy efficiency measure. As a result the audit team used the estimated consumption corresponding to comfort and safety conditions in the common areas.

Initially lighting system improvement measures included renovation of the existing system. However, the cost of renovation sufficiently increases the cost of the lighting system improvements measure itself. Terefore, it was decided to calculate two types of investments: pure energy efficiency measures (arrangement fluorescent bulbs and minimum network repairs) and energy efficiency measures plus renovation. The table 3.1.1 shows the efficiency of investments in minimum EE measures.

Table 3.1.1a. Economic evaluation of minimum EE measures for common lighting

			annual saving		Investments	Payback
Building	**Floor**	**Entrance**	**KWh**	**GEL**	**GEL**	**year**
building 17, block 4, Nutsubidze plateau	**39**	**3**	3971	635	290	0.5
9 Petrisi str, Didi digomi	**16**	**1**	Corridors: 16553; stair-well: 4380	Corridors: 2648; stair-well: 701	Corridors: 4636; stair-well: 4306	1.8
68a, 3 micro district, Gldani	**27**	**3**	1301	208	210	1
Building 1, block 4, Vazha Pshavela	**24**	**3**	679	109	191	1.8
3 Rcheulishvili str	**9**	**1**	1575	252	210	0.8
building 19, block 1, micro district 4, Vazisubani	**12**	**1**	3002	480	405	0.8
building 15, block 5, Digomi massive	**26**	**2**	N/A	N/A	N/A	N/A
111a Gorgasali str., building 3	**64**	**8**	1278	205	183	0.9
53 Saburtalo str	**25**	**5**	520	83	104	1.2
building 20/1, Kaloubni str, district Varketili	**16**	**1**	4888	782	408	0.5
building 24, block 4b, Mukhiani	**24**	**3**	1244	199	217	1.1
5 khudadov str	16	1	2805	448.8	2480	0.6

Table 3.1.1 b. Data includes EE plus renovation costs

			annual saving					
Building	**Floor**	**Entrance**	**KWh**	**GEL**	**Investments (GEL)**	**NPVQ**	**cost of saving**	**Payback**
building 17, block 4, Nutsubidze plateau	**39**	**3**	11912	1906	2680	3.28	0.22	1.4
68a, 3 micro district, Gldani	**27**	**3**	3902	624	2538	0.74	0.65	4.2
Building 1, block 4, Vazha Pshavela	**24**	**3**	2037	326	2503	-0.22	1.23	7.7
3 Rcheulishvili str	**9**	**1**	1575	252	1211	0.26	0.77	4.8

building 19, block 1, micro district 4, Vazisubani	**12**	**1**	3002	480	1275	1.27	0.42	2.7
building 15, block 5, Digomi massive	**26**	**2**						
111a Gorgasali str., building 3	**64**	**8**	10226	1636	3659	1.69	0.36	2.2
53 Saburtalo str	**25**	**5**	2602	416	1874	0.34	0.72	4.5
building 20/1, Kaloubni str, district Varketili	**16**	**1**	4888	782	1202	2.92	0.25	1.5
building 24, block 4b, Mukhiani	**24**	**3**	3731	597	2557	0.41	0.69	4.3

The following assumptions were used when considering energy efficiency measures for common lighting: In common areas with daylight access lights are on during 8 hours per day, minimum 3.5w incandescent lighting is needed per square meter. The capacity that is needed to light common area was calculated simply by multiplying area (m^2) of corridors and stair-well by 3.5w. Another assumption is that CF bulbs are 4 times more economical than the incandescent lights. In fact the rated efficiency of high quality CF bulbs is higher, however our assumption seems to be more adequate to lower cost and quality bulbs dominating the Georgian market.

Once capacity is known and taking into account the fact that fluorescent light bulb consumes one-fourth of energy consumed by incandescent bulb, one can calculate how much energy will be saved by exploitation of fluorescent bulb. The formula looks as follows:

Annual Saving = Common area ((corridors + stairwells)*3.5W*(1 - 1/4) *8 h*365

Obtained numbers ranged from 32.3 to 348 KWh of saved energy per apartment. The obtained number is then multiplied by average tariff on electricity, which is equal 0.16 GEL, in order to obtain monetary equivalent of saved energy. Numbers ranged from 5 to 55.8 GEL per apartment.

3.1.3 Practical recommendations

When using the fluorescent bulbs their following features should be taken into account:

a. Fluorescent lamp will age rapidly where it is frequently switched on and off.
b. If a fluorescent lamp is broken, a very small amount of mercury can contaminate the surrounding environment. About 99% of the mercury is typically contained in the phosphor, especially on lamps that are near their end of life. The broken glass is usually considered a greater hazard than the small amount of spilled mercury.
c. Fluorescent lamps operate best around room temperature. At much lower or higher temperatures, efficiency decreases. At below-freezing temperatures standard lamps may not start. Special lamps may be needed for reliable service outdoors in cold weather.

The practice of multistoried buildings has shown that money collection for common lighting among a big number of residents is related to serious organizational difficulty and forces the residents to switch to individual lighting of common areas. Therefore it is recommended to combine the lighting bill with electricity bill for elevators and collect the payments together. E.g. pay common electricity bills from money collected by mechanical device installed in elevator. Such system successfully works in some of the studied buildings and could serve a good example. This may be the most reasonable solution of the problem of common electricity bills.

3.2. Weatherization

3.2.1 Technical description

For consideration of the energy efficiency measures, the common area of residential buildings can be subdivided into:

a. Ground floor entrance
b. stairwell

By design or due to broken windows most of the stairwells are not isolated from outside temperatures and air circulation. As a result the internal stairwell walls have practically become external walls for the apartments and cause additional excessive heat losses.

The winter temperatures in the stairwell are little above the ambient temperature but much lower than the temperatures of apartments. The first floor entrance is colder due to better access of ambient air.

Analysis of gas consumption information for audited buildings shows thatthe , residents of these buildings annually spend on heating 151 GEL on average. An Interesting fact is that residents of building in Nutsubidze district spend the highest amount on heating (185 GEL) while residents of building in Gorgasali st. spend half the amount (95GEL). One possible explanation of such difference could be the fact that Nutsubidze district is located on a hill and, as a rule, the temperature there is several degrees lower than in central districts of Tbilisi. Moreover, buildings there are often exposed to strong winds that lead to increased heat losses from buildings. One needs to keep in mind that this is only a part of energy consumption for heating, since about 20-30% of residents use electricity as a means for heating their apartments.

The heat loss from the common areas is equal to the heat loss from apartments into these common areas. Due to the timing of the energy audit, there was no possibility to make the measurements of heat losses in winter conditions. The parameters of wall thickness and material were used to estimate the baseline of annual heat loss from apartments into the stair-wells and further into the outside air with the use of ENSI program. The heat losses from the apartments were estimated with the help of this program by assuming the balance of heat while keeping 19 degrees centigrade inside the apartments and estimating the heat loss into the stair-wells having constant average monthly temperatures 1-3^{0}C above ambient temperature. In most of the cases the energy audit identified a high energy saving potential in reducing the heat loss from apartments by closing the stair-wells from external weather and air flow. Restoring of windows can provide adequate insulation and will increase the temperature in the stair-wells by several degrees. It was suggested to install PVC windows and doors with double glazing since they have a number of advantages over ordinary wooden-framed windows. Because of its very nature, PVC provides a high level of resistance to corrosion, rot, fading, discoloration. The addition of Aluminum increases the rigidity and strength of the products, which further increases the defense of the building.

Fig. 3.1. Gldani. Carbolux windows are arranged in decorative stair.

Fig.3.2. Mukhiani. Masonry and new arranged windows

3.2.2 Economic evaluation

Since entrances, corridors and stair-wells are badly maintained initially the assessment of weatherization works included refurbishment works as well. However, refurbishment works considerably increase cost of the measure and, therefore, it was decided to calculate two types of investment for this measure: pure energy efficiency measures and energy efficiency measures plus refurbishment works.

The amount of saved energy was calculated with the help of ENSI program. This program is designed to estimate heat loss from the buildings. Due to the specific configuration of our problem (only three of out of four walls are related to heat loss from the apartments) there was a need to adapt the input to ENSI to reflect the heat loss from the common areas of the building. The output of the program was heat loss expressed in KWh used for heating annually before and after implementation of energy efficiency measures. Subtracting heat loss after implementation of measures from number representing heat loss before implementation one can obtain amount of saved energy expressed in KWh. However, KWh spent on heating is nothing but burned gas and, therefore, te obtained number should be converted to m^3.

Using the standard conversion unit of 9.36kwh/m^3 and efficiency of 80% for home heating appliances, conversion to saved gas volume happens as follows:
Saved gas= (annual amount of saved energy in KWh)/(9.36kwh/m^3)/ 0.8
Obtained numbers ranged from 50.08 to 279.5 m^3 per apartment.

In order to get the monetary equivalent of saved energy, the amount in m^3 was multiplied by the tariff on gas which equals to 0.51GEL per m^3. Numbers ranged from 25.5 to 148.6 GEL per apartment annually.

Table 3.1.2a

	annual saving		Investments	Cost of saving	Payback
Building	KWh	GEL	GEL	GEL/KWh	year
building 17, block 4, Nutsubidze plateau*	160407	10926	4242	0.003	0.4
9 Petrisi str, Didi digomi	125584	8916	18364	0.015	2.1
68a, 3 micro district, Gldani*	151767	10335	29390	0.019	2.7
Building 1, block 4, Vazha Pshavela*	79170	5225	10672	0.013	2.04
3 Rcheulishvili str*	16884	1150	29408	0.174	25.6
building 19, block 1, micro district 4, Vazisubani*	69024	4701	21071	0.031	4.5
building 15, block 5, Digomi massive					
111a Gorgasali str., building 3	210163	14314	29416	0.014	2.1
53 Saburtalo str*	65400	4454	13374	0.020	7.5
building 20/1, Kaloubni str, district Varketili	62448	4253	1204	0.002	0.3
building 24, block 4b, Mukhiani *	62273	4241	19325	0.031	4.6

- **data for these buildings includes EE measures only.**

Table 3.1.2b Data includes EE plus renovation costs

			annual saving		Investments		Cost of saving	Payback
Building	Floor	Entrance	KWh	GEL	GEL	NPVQ	GEL/KWh	Year
building 17, block 4, Nutsubidze plateau	39	3	162747	11085	8214	7.13	0.005	0.7
building 15, block 5, Digomi massive	26	2						
53 Saburtalo str	25	5	69300	4720	17878	-0.36	0.020	9.5
building 24, block 4b, Mukhiani	24	3	65232	4443	22822	0.17	0.031	5.1

3.2.3 Practical recommendations

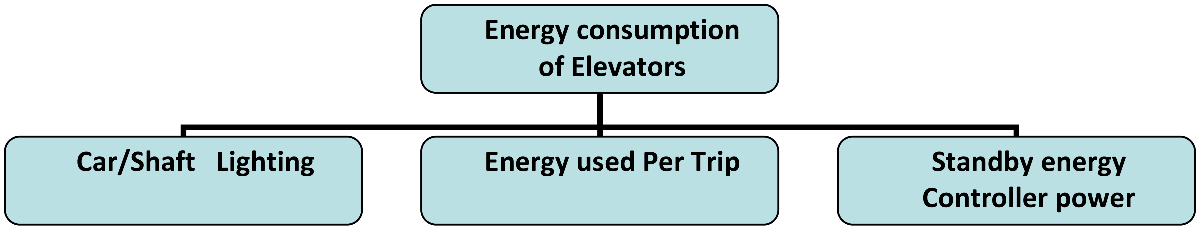
This section describes key features of PVC windows and doors as well as practical recommendations for their exploitation. There are numerous advantages to using PVC windows over timber and metal frames.

1. Low Maintenance - The pristine appearance of plastics windows is maintained by an occasional cleaning with mild detergent such as soapy water. Some items of window hardware (e.g. hinges and handles) may need occasional lubrication in accordance with the manufacturer's recommendations.
2. No Painting - Unlike timber frames, finished plastics frames never need repainting or re-staining.
3. Color Fast - Plastics frame materials are subjected to rigorous tests to ensure that the appearance of the frames will not deteriorate with time.
4. No Rotting, Rusting or Corroding - Timber and metal frames are normally subject to rotting, rusting and corroding. This cannot happen to plastics frames.
5. Resists Combustion - Plastics frames will only burn when subjected to an intense fire source. The material is classified as self-extinguishing.
6. Insulation - Plastics frames have inherently high thermal and acoustic performance. This can be further enhanced by the use of gas filled Double Glazed Units and/or different types of glass.
7. Cost Competitive - Plastics windows are long lasting and virtually maintenance free and therefore are the most cost-effective option.
8. The Environment - The plastics frame materials are recyclable into alternative applications and are also energy efficient in production. And unlike timber, there is no adverse effect on the world's rain forests.

3.3 Elevator improvements

3.3.1 Technical description

Energy consumption of elevators depends on the type of a drive, number of floors served, capacity of the elevator, weight of the elevator, building traffic pattern (density) and hours of use. The picture below presents various types of electricity consumption by elevator:



According to the information obtained from the elevator service company Tbillift LTD the efficiency of main drive system of the elevators is low. They need frequent repairing but the operational characteristics of the gear box and mechanical equipment is satisfactory. The pushbutton lights are not working on each floor and the elevators requires refurbishment in order to increase its safety and comfort.

The Energy Audit identified the measures to reduce peak electricity demand (kW) and electricity consumption (kWh). It was determined that refurbishment and modernization of elevators is the most cost effective method of reducing energy use and increasing the comfort of residents.

As a principle energy efficiency measure, it is recommended to install a new Electrical Control Panel with variable voltage variable frequency drive (VVVFD) system without changing the motor and main mechanical components of the elevator. It is known that Variable frequency drives (VFD) are reliable electronic devices that conduct microprocessor-based controls of the three-phase AC electric motor speed, where the elevators are controlled by software. The AC motor drive controls the speed, torque, direction and resulting capacity of the motor. By reducing the peak startup current and matching the electrical load to the mechanical load, this type of motor drive can save up to 50% of electricity consumption even when the electric motor remains the same. Installation of a Variable Frequency drive can save up to 30% of the electricity, depending on the mode of operation.

Modern AC Elevator drives are often the most electrically efficient part of the elevator control apparatus, often exceeding 94%, including the necessary EMC filters. AC motors themselves are typically between 90-96% efficient when running at rated load, although with conventional 2-speed or AC-VV types drive systems, the user is penalized during light-load stages of the Lift cycle, i.e. full-car-down & empty-car-up where motor loadings are light and resultant power-factor is poor.

One of the main benefits of fitting a variable speed drive is that for all conditions of running load, the drive system efficiency will be typically 96-97% and the power factor will be approaching unity, resulting in electricity savings by a reduction in kWh consumption.

The modernization of the elevator system by installation of VFD (VVVFD) control devices will provide accurate speed and torque control, smooth starts and stops; and result in minimized energy consumption and wear as well as safe operation and improved passenger comfort.

After the modernization works are completed the following improvements will be made:

- the existing Elevator Control System with electromechanical relays will be replaced by a new Control Station (Panel) with VVVFD and microprocessor-based elevator controls;
- new Regulator (Stop) Box for the speed;
- Cabin interior will be renovated including a new push-button system;
- The mechanical systems will be maintained and renovated;
- new push -buttons will be provided for each floor;

Installation of proposed type of elevator system will bring the following benefits to the residents:

1	Consumption of electricity	Reduced	up to 40%
2	Lifetime of elevator system	increased	up to 15 years
3	Reliability and safe	increased	modern standards
4	Deterioration of power equipment	Reduced	up to 50%
5	Noise	Reduced	up to 30%
6	Level of comfort	increased	modern standards

3.3.2. Economic evaluation

The cost of elevator upgrade and refurbishment is usually very high while its lifetime is more than 10 years. The high cost is mostly due to the fact that almost all elevators are old and need renovation. Therefore, two types of investments were calculated: pure energy efficiency measures and energy efficiency measures plus renovation. However, NPVQ of both types is negative. That implies that upgrades and refurbishment measures are not profitable in any case.

The savings are not covering costs within the reasonable period of time and this measure is not profitable from an energy-efficicncy economic point of view (NPVQ analysis, section 3.4.3). While investment may be profitable from an energy efficiency perspective, this measure still provides some energy saving benefits to residents as well as environmental benefits through improved comfort and reduced CO_2 emissions.

Energy saving provided by this measure was calculated in the following way:
Knowing monthly electricity consumption of existing elevators and taking into account the fact that AC motor with VVVFD drive system consumes 50% less energy than conventional two-speed system, saving in energy calculated as follows: (KWh consumed annually by existing elevators) – 0.5*(KWh consumed annually by existing elevators)
The obtained numbers ranged from 28.2 to 75.95 KWh per apartment.
The monetary equivalent of saved energy is calculated as follows:
saved amount=saved electricity * 0.16 GEL
Numbers ranged from 4.5 to 17 GEL per apartment per year.

Table 3.3.2

	Annual saving		Investment		Cost of saving	payback		
Building	KWh	GEL	GEL	NPVQ	GEL/KWh	year	Annual electricity consumption (KWh)	Annual electricity consumption (GEL)
Gldani	3328	532	ee + renovation: 22425 ee only: 13875	-0.73	ee +renovation: 0.67 ee only: 0.42	26	6657	1065
Average[3]				-0.59		14.7	7789	1247

Since data presented in the table above is similar for all buildings it was decided to represent only one typical building. As noted above, the NPVQ for elevator upgrades in Gldani as well as for other buildings is negative which basically means that this measure is not profitable. Additionally, payback is the highest in comparison with other proposed measures which also indicates that investment is less profitable.

3.3.3 Practical recommendations

In order for elevators system to be reliable and safe the following installation and equipment considerations should be taken into account.

a. Safety considerations require that the metal chassis and cabinet components of all exposed electrical apparatus be connected to earth ground for Personnel protection
b. The AC drive unit is to be mounted on a non-painted back plate, within a steel electrical enclosure.
c. The elevator motor is to be located nearby and on a suitable steel bedplate.
d. The velocity encoder is to be directly coupled to the motor shaft.
e. The elevator car controller may or may not be in a separate electrical enclosure.
f. The encoder housing and shaft should be electrically insulated from the motor frame and shaft. It is essential to always use shielded cable for encoder wiring, ensuring the shield of this cable only terminates at the receiver (drive) end.

Two factors, whilst often overlooked, will ensure longevity of operation. These are:

a. Providing sufficient drive ventilation & cooling as per the drive manufacturer's recommendations.
b. Ensuring solid earthling integrity for each and every drive installation.

It is recommended to conduct installation of VVVFD systems together with elevators overhauls to minimize the additional costs related to mobilization and refurbishment works.

3.4. Summary of Main Assumptions and Methods

3.4.1 Main Assumptions Used

When evaluating potential of increased energy efficiency of common lighting the following advantages of fluorescent bulbs were taken into account:

a. it lasts up to 10 times longer than incandescent one
b. it uses about one-fourth the energy
c. The cost of CF bulb was taken to be 7 GEL versus 0.5 GEL for incandescent bulb

[3] The average represents average for all examined buildings.

When evaluating potential of increased energy efficiency of elevators and reduction in energy consumption caused by elevator upgrades the following features of AC motor drive were taken into account:

a. Efficiency of AC motor drive is between 90-96% when running at rated road.
b. kWh consumption for AC-VVVF drives is typically half that of 2-speed systems.

The positive effects of weatherization measures were estimated using ENSI program which is initially designed for estimation of heat losses in apartments. Therefore, in order to exploit the program for estimation of heat losses in common areas of the building it was necessary to make certain assumptions:

a. It was assumed that residents keep 19 degrees centigrade inside the apartments
b. The average temperature in the common areas (corridors and stair-well) was taken to be 1-3^{o}C above ambient temperature in the heating season.

3.4.2 Environmental benefits and CO_2 emissions reduction

Implementation of energy efficiency and rehabilitation measures will improve the environmental situation for the residents of the building. Some of the benefits are:

- Reduced noise and vibration of elevators
- More comfortable temperature at apartment entrances
- Elimination of safety hazards due to darkness in public areas of the building

At the same time, a decrease in energy consumption will result in a decrease of CO_2 emissions to atmosphere and will give global environmental benefits.

Weatherization of the common area will result in heating reduction and save a certain amount of m^3 of burned natural gas annually. Assuming specific CO_2 emission coefficient 1.89 kg CO_2/m^3 for burned natural gas (provided by CDM Designated National Authority of Georgia), and knowing the amount of saved gas due to reduction in heat loss we can calculate annual CO_2 emissions reduction by the following formula:

CO_2 emission reduction= amount of saved gas (m^3)* specific CO2 emission coefficient

Assuming Georgia specific CO2 emission coefficient 0.4 kgCO2/KWh and knowing amount of reduced electricity consumption we can calculate CO_2 emission reduction we can estimate reduction in CO_2 emissions due to lighting system improvements and elevator upgrades.

CO_2 emission reduction= amount of saved electricity (m^3)* Georgia specific CO2 emission coefficient

Estimated reduction of CO_2 emissions after all measures are implemented ranged from 17.54 to 47.82 ton per building annually.

Table 3.4.1. summarizes the ranges of resulting emissions from each EE measure considered, together with potential based on $10/per ton of CO_2 emission avoided.

Table 3.4.1. Summary of emissions reduction by EE measure considered

Per entrance	Saved energy KWh	CO2 reduction t/a	Approximate cost of emissions reduction GEL
Lighting	700-4000	1-4	18-72
Elevators	1500-4000	1-3	18-54
Weatherization	70000-160400	16-40	288-720

3.4.3 Economic calculations

Payback simply shows in what period of time (years) an investor will return his invested money. It was calculated as follows:
Payback (years)= Investment/annual saving

All other things equal, the better investment is the one with shorter payback period. However, there are two main problems with the payback period method:

a. It ignores any benefits that occur after the payback period and, therefore, does not measure profitability.
b. It ignores the time value of money (depreciation/appreciation)

Because of these reasons, other methods of capital budgeting like net present value and net present value quotient are generally preferred.

NPV is a difference between the present value of discounted cash inflows and present value of discounted cash outflows. It is used to analyze the profitability of an investment. NPV compares the value of money today to the value of the same money in future, taking inflation and returns into account (interest rate). If the NPV of a prospective project is positive, it should be accepted. However, if NPV is negative, the project should probably be rejected as cash flows will be also negative.

Net present value quotient (NPVQ) is a more natural parameter to show the profitability of investment. It is a ratio of NPV to amount of investments and was calculated for evaluation of profitability of energy efficient measures and shows the amount of net profit (loss) per unit of money spent. If NPVQ is <0 this means that project is not profitable and if NPVQ is >0 the project is supposed to be profitable. The higher is NPVQ the more profitable the project is.

NPVQ is presented for an effective real discount rate of 10.47%: 10.47% real interest rate was arrived at by taking the nominal interest rate of 14% provided by Georgian banks (e.g. by Tao Private Bank) on deposits, and corrected by the 3.2% annual inflation rate.
NPVQ was calculated by the following formula:
NPVQ =NPV/Investment
Both NPV and NPVQ were calculated by ENSI program.

3.5 Financing and Implementation of Energy efficiency Measures

Residents have two basic options: either hire a company which will conduct all necessary measures or directly hire workers without intermediaries. Obviously, the latter option is a cheaper one. Taking into account taxes and overhead costs it has been estimated that on average implementation of energy efficiency measures by the residents (wherever possible to normal technical and safety standards) can be 25-35% cheaper than hiring construction/installation companies. This factor is one more incentive in favor of cooperation between community members and their joint action.

It is also up to residents to decide whether to conduct only pure energy efficiency measures or both energy efficiency measures and renovation. Investment costs for both types of measures were calculated separately. Note that energy saving provided by both types of measures is equal. The cost-benefit analysis has been conducted with the help of ENSI profitability software. The calculations were done with the discount rate of 14%. This analysis assumes that the cost of money for the consumer having his or her own cash is defined by the interest on deposits that he may obtain from a bank in Georgia. Thus the profitability of investment in energy efficiency measures is compared the profitability depositing the same money in a bank and obtaining 14% annual interest (in this case from Tao Private Bank). The calculations are made in GEL assuming 3.2 % GEL annual inflation to arrive at real interest rates of 10.47%.

The calculations show that weatherization and lighting of stair-well are both profitable energy efficiency measures. Elevator upgrade is negative in NPV both because of the high interest rate and inclusion of rehabilitation measures that have no direct relation to energy savings but are rather related to safety and refurbishment.

3.5.1 Energy Credit

There are several ways how proposed measures can be financed. One of these ways is to take a loan from Energy Credit an EE and RE financing facility created by EBRD and implemented by a number of local banks in Georgia. BP has committed to subsidize the loans taken through Energy Credit mechanism by 15% of the total loan amount. Below we provide the conditions for Energy Credit loan combined with BP subsidy.

In order to take credit the following conditions should be satisfied:

1. Age of borrower at least 20 years
2. Income at least 350 GEL
3. Salary certification

Key features of credit:

1. Loan should be repaid monthly.
2. In case of salary, monthly repayment up to 600 GEL do not exceeds 25%, up to 1000 GEL do not exceeds 30%, 1500GEL—35%, more than 1500 GEL – 40%.
3. Interest rate is 20%, in mortgage case 19 %.
4. BP subsidy is 15% and is donated in 3 years after product is acquired and installed.
5. Fee for payment in advance is 2%
6. Energy credits are available in Kutaisi, Poti and Tbilisi.

There are 3 banks that provide energy credits, namely, TBC, Bank Republic and Cartu. However, the consumer's loans are provided only by TBC. Cartu and Bank Republic work only with corporate clients and they do not classify CA as eligible legal persons. Moreover, the BP subsidy is not provided for the loans issues by these banks. Therefore below we discuss only Energy Credit conditions for the loans provided by TBC banks to physical persons.

Energy credit is provided by TBC bank (www.tbc.ge) with 20% interest rate in domestic currency and maximal duration of 5 years. After the credit is taken out and product is acquired and installed, by submission of corresponding document to TBC bank BP will return 15% of taken loan back to the borrower's account. Taking into consideration both Bank's interest rate and BP subsidy, the effective increase rate of loan amount is 9-10% annually.

For more detailed calculations a special calculator was developed for facilitating decision on borrowing from Energy Credit. It will be posted on WEG website www.weg.ge

While deciding on taking the loan versus own financing of considered energy efficiency measures, the condominium members will be able to estimate the effective interest rate provided by Energy Credit in combination with BP loan and to compare it to their perceived or real cost, expected benefit and availability of money. The final decision can be taken with due consideration of this factors.

The calculator allows to calculate NPV, monthly cash flow, annual repayment, etc of different financing options: own financing, energy credit or combination of both. As a result, residents can evaluate on their own which financing option is better by simply looking at NPV which is the main indicator of profitability of an option. The higher the positive NPV, the more beneficial the choice is.

The calculator was created based on an Excel spreadsheet in a way to be comprehensible to a wide audience that may not have an economic background. Part of the cells are kept open for the user to enter his own estimates and project parameters. Changeable variables are:

a. Capital expense. Amount needed for financing of implementation of energy efficiency measures.
b. Annual saving. Monetary amount of saved energy as a result of increased energy efficiency (numbers are presented in report for each particular building)
c. Equity participation. Amount of own financing (cash collected by residents)
d. Loan period (years). Number of years in which the loan is supposed to be repaid.

By altering these variables one can decide for himself which financing option to choose. For instance, by changing the loan period one can clearly see that the highest benefits are achieved when the loan is repaid in shorter period of time.

3.6 Conclusions & recommendations

The following main conclusions and recommendations have been elaborated based on the work on Energy Audits conducted in the selected multi-apartment residential buildings:

- Energy loss from common areas of residential multi-apartment buildings in Tbilisi is significant and deserves special energy efficiency measures to be conducted.
- Safety and comfort requirements are mostly neglected in common areas of multi-apartment residential buildings unsafe elevators, lack of lighting and unorganized space
- Information spreading and experience sharing between communities as well as inside the communities is not at an appropriate level. There is a need for wider outreach activities to inform and facilitate sharing of positive experience across the communities.
- The ageing stock of elevators in Tbilisi will soon require replacement or major overhauling and at that time

The Energy Audit Team's analysis and assessment of the EA results revealed a great potential for energy savings in common areas of typical multi–apartment residential buildings in Tbilisi. Through the team's detailed energy audit, we were able to optimize energy efficiency interventions and estimate their profitability.

- **Lighting**
  Improvement of lighting systems can bring substantial benefits with minimal investment it provides the highest return on investment among considered energy efficiency measures and provides sizeable safety benefit. It is recommended to:
    - Restore common lighting
    - Install fluorescent lighting or motion sensors –cost effective measures
    - Arrange the lighting of basements from entrance circuits
    - Collect the money for lighting together with elevator payments
- **Weatherization**
  The audit revealed that weatherization of entrances, stairwells and common corridors is a highly effective energy efficiency measure. With moderate investment it offers the potential for heat loss reduction and thus increased comfort in common area combined with the reduction of heat loss from apartments. This measure provides the greatest saving in energy as well as GHG emissions per entrance.
- **Elevator modernization**
  Many of the elevators are in poor technical and unsafe for operation
    - It is recommended to arrange the inspection of ageing elevator stock in the city with the emphasis on safety and expected growth of technical problems.
    - Elevator upgrade by installation of Variable Frequency Drive (VFD -VVVF) controls systems is the least profitable Energy efficiency measure. It has the longest payback period and can be considered as a less attractive option for the time being. However this measure should be considered as a prime option for improving the efficiency and extending lifetime of elevators in case of a major overhaul. Economies of scale can be achieved if these measures will be replicated in many buildings.

Implementation of the above measures can serve as an example to many residential buildings of this type all over Tbilisi.

A cooperative effort in communities is a key to success and can enable substantial improvements in living conditions and energy spending. Differences in costs between a community's own implementation and hiring a specialized company is around 25-35% and can be considered an important factor in favor of cooperation and joint action of community members.

3.6.2 Suggestions for pilot projects

The considered energy efficiency measures offer substantial benefits in terms of improving the living conditions and reducing energy consumption in the multi apartment residential buildings.

The summary of proposed measures for examined buildings is presented in table 3.6.1. It also illustrates the extent of profitability of each particular measure for each building with simple ranking from "very profitable" to "non-profitable".

Table 3.6.1 Proposed measures in examined buildings.

	Building	Weatherization	Lighting	Elevator
1	building 17, block 4, Nutsubidze plateau	+++	+++	-
2	9 Petrisi str, Didi digomi	++	+[4]	-

[4] recommended for corridors only

3	68a, 3 micro district, Gldani	++	++	-
4	Building 1, block 4, Vazha Pshavela	++	+	no suggestions
5	3 Rcheulishvili str	-	++	-
6	building 19, block 1, micro district 4, Vazisubani	+	++	-
7	building 15, block 5, Digomi massive	no suggestions	no suggestions	-
8	111a Gorgasali str., building 3	++	+	no suggestions
9	53 Saburtalo str	-	+	no suggestions
10	building 20/1, Kaloubani str, district Varketili	+++	+++	-
11	building 24, block 4b, Mukhiani	+	++	-
12	5 khudadov str	no suggestions	++	-

+++ very profitable
++ profitable
+ brings little benefit
- non-profitable

It is recommended to implement a pilot project in one or two of the studied buildings in order to practically achieve and demonstrate the potential benefits of energy efficiency measures. Along with profitability of EE measures, pilot site selection criteria shall include the level of community organization, the spread of particular building type in the city and other factors. A live example of energy efficiency measures that will be properly implemented, metered and publicized can serve as a serious incentive for partial or full replication in many residential buildings of Tbilisi.