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Overview of Building Stock of Georgia Based on Different Criteria

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Presented report was developed as one of the components of the technical assistance provided by the "Enhancing Capacity for Low Emission Development Strategies (EC-LEDS)/Clean Energy Program" to the Government of Georgia in the process of preparation of the Low Emission Development Strategy. The report reviews an existing building stock of Georgia, analyses the energy consumption and emissions from the building sector and identifies the barriers for implementation of energy efficient and renewable energy measures in Georgia's buildings. The barriers and conclusions identified in the report will be the basis for elaboration of the Low Emissions Development Strategy and measures planned in for this sector.

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1. Introduction

The existing building stock of Georgia is diverse in terms of construction types and functions, and is comprised of the building constructed before, during and after the 20th century soviet era. With 53% of the population living in urban and 47% in rural spaces, there is an especially large diversity in the types of residential buildings. Currently a comprehensive overview of the building stock is not available. However, some information and data collection has been conducted on a city level during the preparation of Sustainable Energy Action Plans (SEAPs).[1] According to this information and other sources, total amount and area of buildings has been estimated during preparing low-emission strategy.

65% of the existing buildings were built between of the 1950s and the 2000s. Most of them are multi-storey building blocks. In the beginning of 1960s so-called “Khrushchovkas” were the most popular type of building. Their engineering and construction criteria reflected the politics of the government of that time that was targeted at satisfying the minimal living conditions. Lifetime of those buildings was 25 years and most of them were built 50 years ago. The most widely-distributed construction project was N 1-319C, N 1-450C, N 1-464AC. Every type within this project was planned with different construction material and durability of earthquakes of magnitude 7. In the beginning, these buildings were built with bricks that was later replaced by big constructing blocks and panels. Construction of the 8-storey buildings under this project began later. Thermal resistance of buildings of that time was low because comfort and sanitary-hygienic criteria were minimal. The thermal resistance coefficient of those buildings satisfied obligatory standards that according to the construction code was not more than $R=0.575\ m^{2}°/W$. It must be said that changes were done to the code regularly but obligatory criteria mentioned above are the highest in engineering practice of the soviet era.

Private houses accommodating one or two families were built during the soviet era too and mostly correspond to the construction practice of that period. Mostly they were built with bricks or cement blocks. Coefficient of thermal resistance of walls was usually on the level of obligatory coefficient ($R=0.575\ m^{2}°/W$) that is an indicator of necessity of supply of superfluous amount of heat to the buildings.

The whole building stock was grouped and estimated by different criteria for implementing energy efficient measures and increasing consumption of renewable energy:

- Property type (7 types)
- Location by climate zone (3 zones)
- Location by technological zone (5 zones)
- Functional purpose of building
- Building types by construction

[1] The information used is based on the survey conducted in 15 municipalities, among them in 6 large self-governing cities (Tbilisi, Kutaisi, Batumi, Rustavi, Poti and Gori) and 5 regional municipalities (Zugdidi, Telavi, Akhaltsikhe, Zestaphoni and Gori). The total number of those interviewed was 2 459 000 which is 55% of the population of Georgia.

- Rate of use and whole consumption of energy by building

2. Building stock by property form

According to statistics and the methodology of GHG inventory, in order to estimate energy consumption and GHG emissions in buildings, the existing building stock was divided into two basic categories: residential and non-residential (commercial buildings). According to this classification, category of state and municipal buildings is considered under commercial buildings but for correct planning of energy efficient measures for buildings, commercial buildings are then divided into commercial and state/municipal buildings.

Residential buildings

Starting with the ownership structure there are four main types of buildings in Georgia. While they are very similar, small but important differences exist, that need to be taken into consideration when attempting the large-scale deployment of energy efficiency and deep renovation within the residential building sector.

Block buildings with common areas. For the maintenance of the common areas (incl. entrances, staircase areas that also need lighting and heating, roofs, elevators etc.), the municipalities usually have co-financing programmes, which are seldom bound to energy efficiency measures or significant renovation activities. The residents within these block buildings typically own their flats and are organised in homeowners associations to represent the interests of the residents. However, often participation in these associations is low and they are currently lacking legal status.

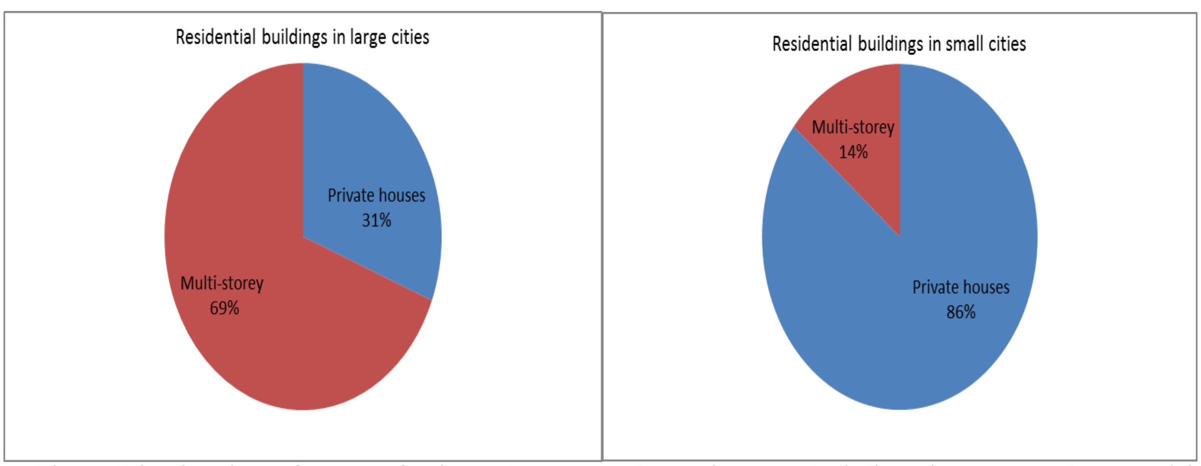

Fig. 1. Distribution of areas of private houses and multi-storey buildings in large and small cities

So-called **social houses** are being built by local-governments for households with a critical amount of low-income, eco-migrants and Internally Displaced People (IDPs). Typically these houses for eco-migrants and IDPs are being constructed through the Municipal Development Fund (MDF) established under the Ministry of Infrastructure and Regional Development (MoRDI). Initially these buildings belong to the municipality or MDF, but after a certain time residents have the opportunity to buy their flat under preferential conditions. In some cases (particularly in case of IDPs) dwellings can also be granted by the government to residents with these particular statuses.

Historical residential buildings can mainly be found in big cities. These 1-3 storey buildings are privately owned, but owners have limited rights to make significant reconstructions, especially in terms of changing the building façade. For such buildings special permission is required from the municipalities to carry out renovation activities or outdoor insulation. Most of these historical buildings have been constructed before the soviet era and while typically the energy efficiency characteristics were high in that era, especially in terms of wall insulation, currently the majority of these buildings are damaged and are not energy efficient mainly due to damaged construction materials.

From the energy audits conducted during the preparation of Sustainable Energy Action Plans (SEAPs) it can be seen that 1-2 storey **private houses** have the highest potential for energy savings if fully heated. This segment of the building stock can mainly be found in rural areas and small cities. **Error! Reference source not found.** shows the distribution of population/families between 1-2 storey private houses and multi-storey buildings in large and small cities. 99% of the population of the rest of the territory lives in 1-2 storey private houses.

Non-residential/commercial buildings

Non-residential/commercial buildings consist of public and commercial buildings where public buildings are property of municipality and central government or autonomous republic.

Public buildings

In the early 1990s with the ending of the post-soviet period the segregation of the state property started in Georgia. This process was based on the law of privatisation of state property issued by the Supreme Council of Georgia, the country's highest legislative body. After a slow start the inventory and privatisation of state property has been on going since 2005. Public buildings still make a significant share of state property, accounting for 40% of total property.

The main holders of the state building stock are the Ministry of Economy and Sustainable Development (MoESD) of Georgia, the Ministries of Finance and Economy of the Autonomous Republic of Adjara as well as other ministries, self-governing cities and municipalities. There are 60 municipalities and 12 self – governing cities in Georgia. All ministries and municipalities have administrative structures, with the relevant administrative buildings having different property status.

Currently, an accurate inventory of all public buildings does not exist in Georgia, however the MoESD of Georgia has been working on this issue. Two types of buildings should be defined when discussing Georgia's public building stock: buildings having an ownership status and registered in the Public Register and buildings not having any ownership status. The registry of buildings, which should be sold by the state, consists of both of these types of buildings.

Public buildings in Georgia can be distributed into three ownership categories:

- Buildings belonging to the **state** and are in possession of the MoESD of Georgia or sectoral Ministries (administrative buildings (ministries, etc.), public schools and universities as well as other scientific-research institutions, buildings in public health system (hospitals, policlinics, etc.), cultural buildings, buildings in penitentiary systems, buildings for military sector, etc.);

- Buildings belonging to the **Autonomous Republic** that are in possession of the Ministry of Economy of Autonomous Republic (e.g. Ajara) or sectoral Ministries (this paragraph includes the same types of buildings that are listed in the previous paragraph. Only they are property of appropriate offices of Autonomous Republic);
- Buildings belonging to the **municipalities** and are in possession of the municipalities or self-governing cities (administrative buildings, kindergartens, cultural buildings, sport buildings, etc.)

Commercial buildings include buildings used in the field of private service (private schools, kindergartens, Universities, buildings in private health system and all other private commercial buildings).

Fig. 2 shows distribution (%) of areas of buildings by ownership.

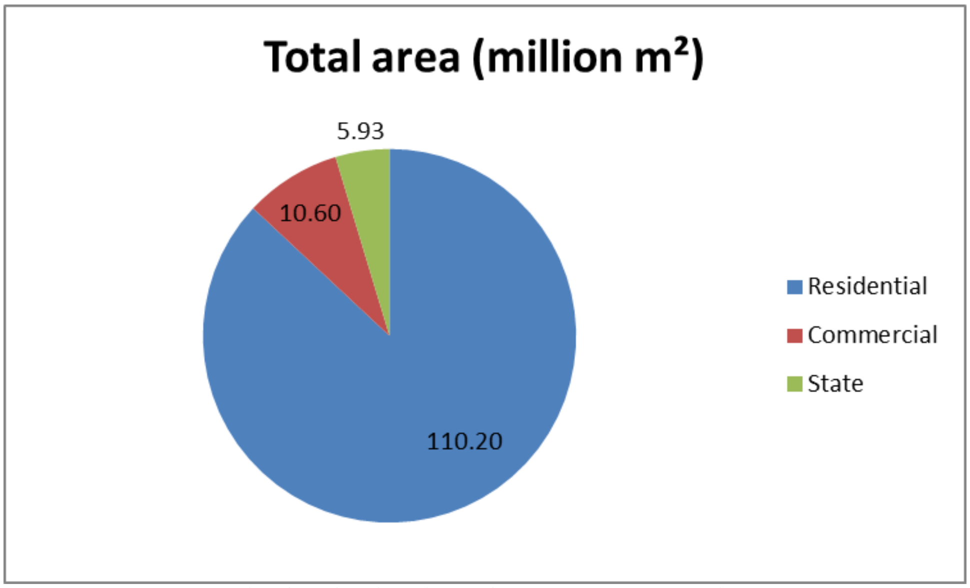

Fig. 2. Distribution of areas by ownership

All municipalities, self-governing cities and ministries have administrative buildings, however only tentative figures on specific buildings are available. **Error! Reference source not found.**represents share of Georgia's public buildings owned by different government entities.

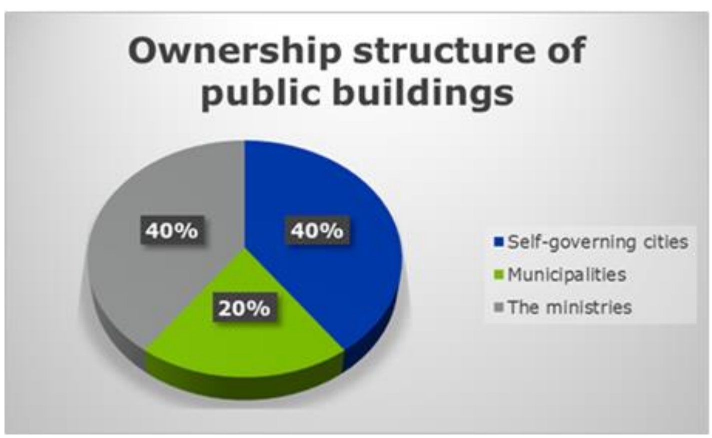

Fig. 3. Share of public buidlings by ownership

Buildings belonging to the state as well as other state property are regulated under the Law on State Property of Georgia[2]. Buildings owned by the municipalities and self-governing cities are regulated by the Local Self-Government Code of Georgia.

The current policy approach of the government aims at maximum privatisation of the state property including public buildings, while keeping the minimum number of buildings needed to perform administration functions and responsibilities as state property.

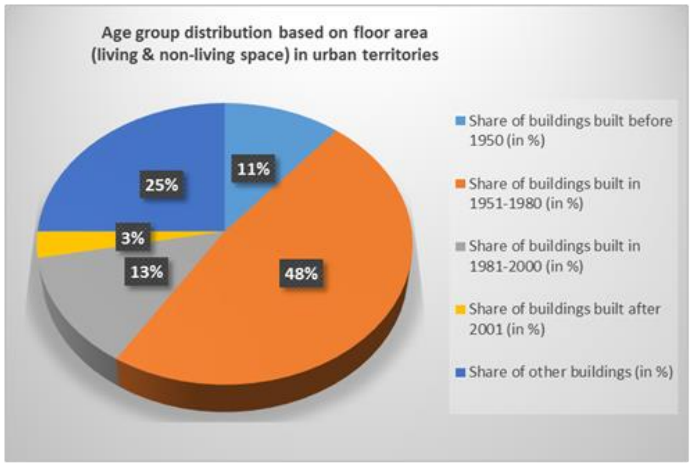

Fig. 4. Distribution of buildings by construction year, based on the survey for EC-LEDS project

Fig. 4 shows distribution of building areas by different years. It should be noted that the share of buildings built after 2001 is quite low (3%) which suggests an error in the data. Further research should be carried out ideally using different methodology.

More than 70% of residential buildings built in 1951-2000 are multi-storey block buildings, ranging in size between 5 and 9 stories. These buildings typically have 2-5 entrances 50% of which are open. This characteristic significantly lowers the overall energy efficiency of the whole building. The assessment carried out by several Covenant of Mayor cities show significant potential for savings. Most of these buildings do not meet basic energy performance standards, as they have been constructed in a quick and low-cost manner. Additionally, many of them are not properly taken cares of. Open entrances, thin walls, damaged frame and single glazed wooden windows are only a few characteristics that are in need of improvement.

Compared to the soviet-era block buildings private house with 1-3 stories are in relatively good condition. The majority of these buildings have been built by their owners for their own use and are therefore often of a higher standard, also in terms of energy performance.

In addition to these types, one can also identify "slums" type buildings in the big cities, which are of very low living standard. Since often the municipalities are responsible for constructing these types of social houses, they are an attractive segment for promotion of green buildings and energy efficiency concepts.

Central heating systems in residential sector was demolished after the collapse of the Soviet Union because they had been working as parts of the central hydraulic heating system and after 1991 it became

[2] http://www.economy.ge/uploads/kanonmdebloba/kanoni_qonebis_shesakheb.pdf

impossible to use them to satisfy necessities of private apartments. Reconstruction of these systems is impossible, as their main components do not exist anymore. Nowadays, major part of residential area is heated neither in cities nor in villages.

Share of administrative buildings by area in buildings' sector of Georgia is 1%. Administrative buildings are usually divided into three types:

- Historical buildings that belong to municipalities or to the state but need special permission for rehabilitation;
- Soviet buildings;
- Few modern, mainly glass buildings that were built from 2005 to 2012.

3. Overview of building stock by climate (3) and technological (5) zones

According to different analysis, the building stock of Georgia is 126.7 million m^2 and 59% of it (75.97 million m^2) is being heated. As the accurate data for a residential building stock is not available for the country, the abovementioned figures were derived from different sources (LEDS surveys, SEAP's data) and estimation techniques (Annex I: used sources and methodology of estimation). 110.1 million m^2 from this amount is residential and 57% is being heated. The estimation also shows, that commercial and state-owned building areas are 10.7 million m^2 and 5.9 million m^2 respectively.

44% of buildings and 38% of residential area are concentrated in big cities and 46% of total area is situated in Tbilisi.

To evaluate energy-efficiency and energy consumption of buildings in Georgia, country's territory is divided into three climate zones[3] covering its whole territory. Differentiation into climate zones rests on important parameters: heating and cooling degree-days.

Two additional zones could be identified in each climate zone by population, which strongly determines a type of used technology. These zones are typically referred to as the Fourth Zone and the Fifth Zone. Thus, taking into account the available technology and fuel consumption, five different **technological zones** are considered. Settlements with population of 2 000 or more are in the Fourth Zone, while five biggest cities of the country (Tbilisi, Batumi, Kutaisi, Rustavi and Poti) are in the Fifth Zone. Climate conditions (namely, degree-days), fuel availability, and heating or cooling technologies are parameters that determine the heating or cooling seasons, building types, used technology and general energy-efficiency in each zone. More detailed description of each zone is given below.

For detailed information, see Fig. 5.

[3] Technical Design Regulations - "Building Climatology". http://gov.ge/files/382_40062_363410_71-5.pdf. These regulations are in force according to the Order of the Minister of Economic Development of Georgia №1-1/1743; August 25, 2008 https://www.matsne.gov.ge/ka/document/view/79210

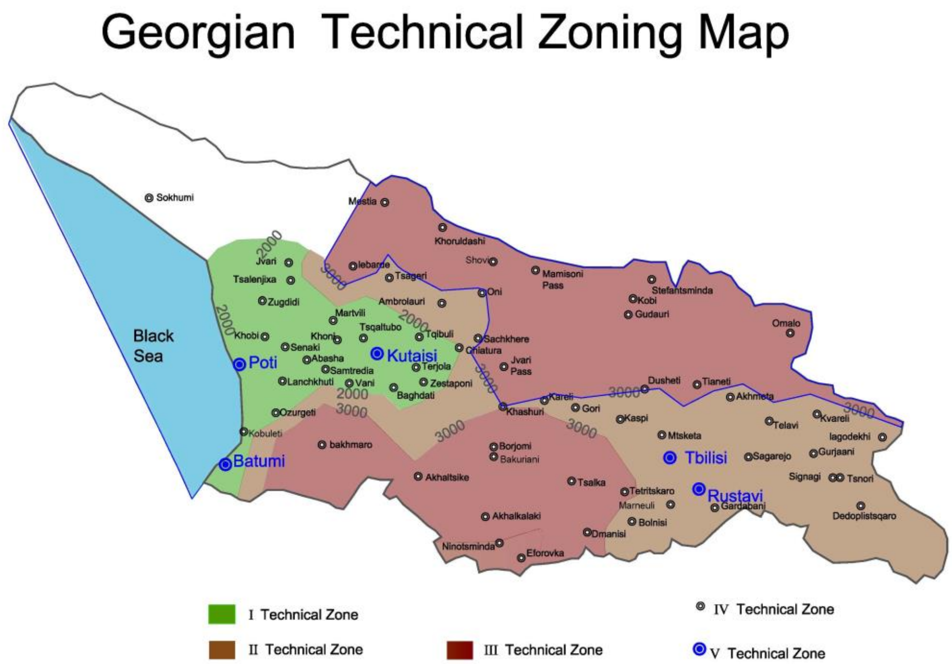

Fig. 5. Climate zone map of Georgia

First Technological Zone

The First Technological Zone is the same as the First Climate Zone, but covers the settlements with less than 2 000 inhabitants. In this zone heating degree-days are less than D =2 000 degrees[4]. Territories of the West Georgia that have altitude of 300 meters or less are calculated in this zone. During the whole year, this climate zone has steadily high temperature, warm and humid sub-tropic climate, hot summer, warm winter, monsoon winds of clear pattern, and a big amount of sunny days. On the map this zone is painted in green. The First Technological Zone has favorable physical-geographical and economic conditions for implementation of alternative-energy (solar, geothermic, biomass, etc.) based technological solutions. In this zone, settlements situated by arterial highways (or close to their crossroads), in recreational zones or on the seacoasts, are abundant with population and buildings. Kutaisi, Zestaponi, Samtredia, Senaki, Batumi, Poti, Zugdidi and Tkibuli have similar qualities[5]. These settlements due to their technological specificities and population densities are not calculated in the Third Zone, and according to their population are counted either in the Fourth Zone or in the Fifth Zone. Total area of this climate zone is 10 000 km^2 (with 10% accuracy), while the population is 640 000 people.

[4] Heating degree-days is an amount of a heat necessary during heating season. Its value differs across climate zones (for more details, see Appendix 1).

[5] http://drm.cenn.org/paper_atlas/RA-part-2.pdf

The majority of the buildings in this technological zone are either single or double-stored, walls are 20-40 cm wide, building material is concrete block or brick, and attics are insulated. In total, there are 135 thousand private residential buildings. Most residents use their residential areas seasonally, or they have separate buildings (50-70 m² area) that are equipped with heating technology. As far as commercial buildings are concerned, their entire area needs heat engineering service.

Detailed information regarding the number, area and heating engeniering characteristics of buildings in this area is given in Annex I: used sources and methodology of estimation

Fuel consumption, available technology and its efficiency for given technological zone are available on the Fig. 6. Recommendations about technologies to be implemented and their efficiency are given in Fig. 7.

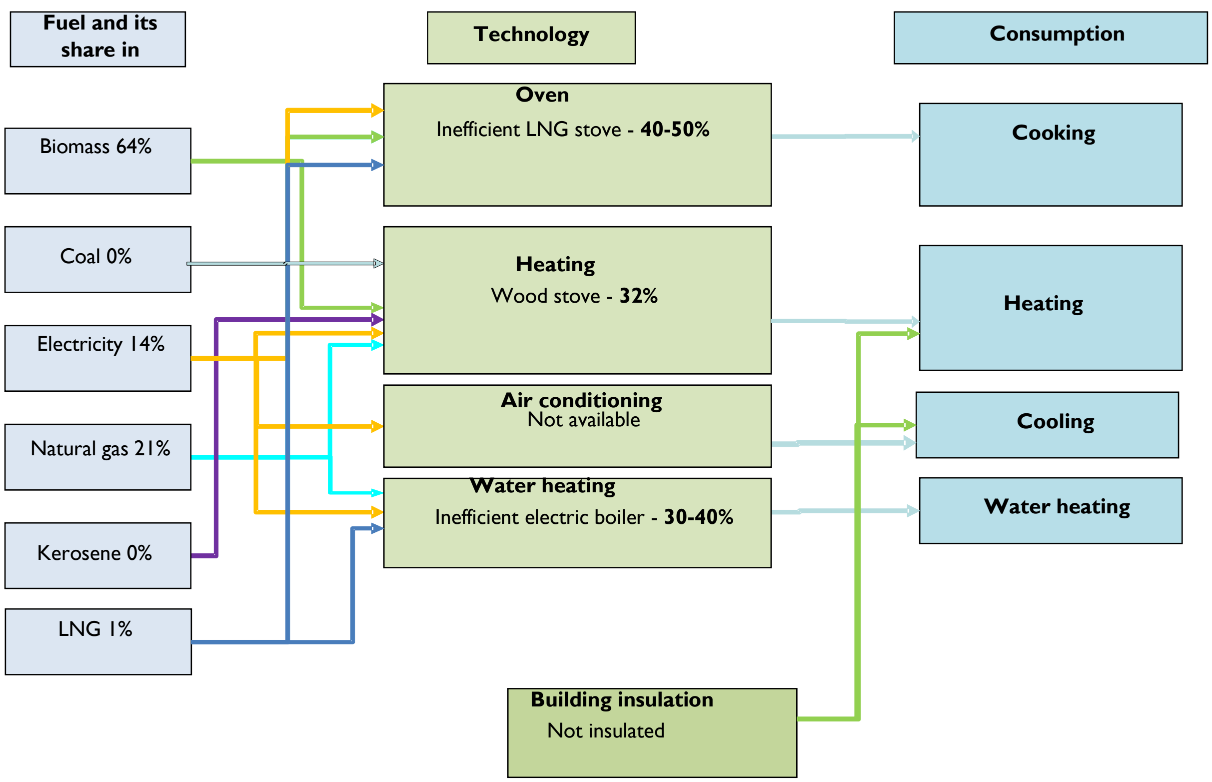

Fig. 6. Available technologies and their efficiency in the First Technological Zone

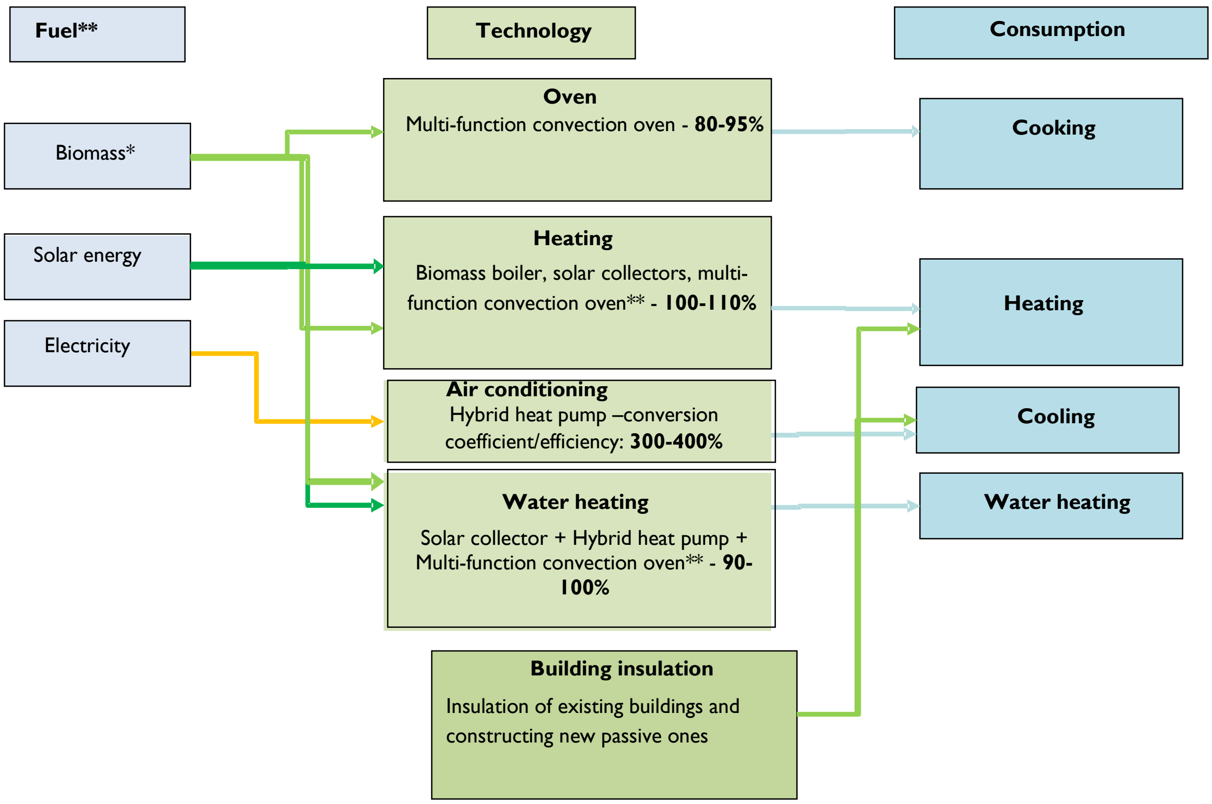

Fig. 7. Technology and corresponding efficiency recommendations for technologies that should be implemented in the First Technological Zone

* Firewood processed according to international standards (Low moisture consistency, increased caloricity), biomass briquettes and pellets

** Multi-function convection oven heats a building and a water, and could be used for cooking

Notice: In special cases (commercial and state-owned buildings), where exploitation area exceeds 500 m^2, individual solutions will be necessary to successfully implement passive low emission ideology. In selected high dense settlements hybrid fuel-run centralized heating system could be organized.

General recommendations for the First Zone

Solar energy potential (210-250 days per year) and average annual temperature are high enough in this zone, firewood consumption is the highest and biomass fuel is also available (625 000 GJ per year[6]). Thus, the first recommendation is to utilize heat pump integrated solar systems, and efficient biomass ovens. High-temperature geothermal water resources (water temperature at the surface is 100°C or higher) are also available in this zone, but at present they are used in greenhouses and baths only.

Second Technological Zone

The Second Technological Zone is the same as the Second Climate Zone, but only settlements with more than 2000 people are not counted there. Amount on necessary heating degree-days varies

[6] Waste Biomass Depository, Tbilisi 2013

between D=2000-3000, and the zone covers all Georgian territories with altitude of 300-1000 meters. In this zone the winter is cold and summer is moderately warm. Thus, buildings and constructions are in need of intensive heating in winter times and cooling systems — during summer ones. Climate is close to sub-tropic one, it is steppe-like warm and humid and high intensity of winds are inherent for some regions. On the map this zone is painted in light brown.

Compared to the First Technological Zone, the Second one has less favorable physiographic and economic conditions to develop green and alternate (solar, geothermic, wind, etc.) energy-based technologies. In this zone, settlements situated by highways, on their crossroads, or close to administrative and industrial centers, stand out with building abundance. These settlements — Tbilisi, Rustavi, Marneuli, Khashuri, Gori, etc., — are treated separately in the Fourth and Fifth zones. The total area of this zone is 13 250 km^2 and population is 848 000 people.

In this zone there are 177 000 private residential buildings and most of them have insulated roofs. Buildings built during the end of the 20th century or in the beginning to the 21th, lack wall insulation, while old historic buildings need only windows' and improvement of heating technology characteristic of heat bridges. Most of the populations uses residential area seasonally and heats only part of it (heated area is 60-70 m^2).

Fuel consumption, available technology and its efficiency for given technological zone are available on the Fig. 8. Recommendations about technologies to be implemented and their efficiency are given in Fig. 9.

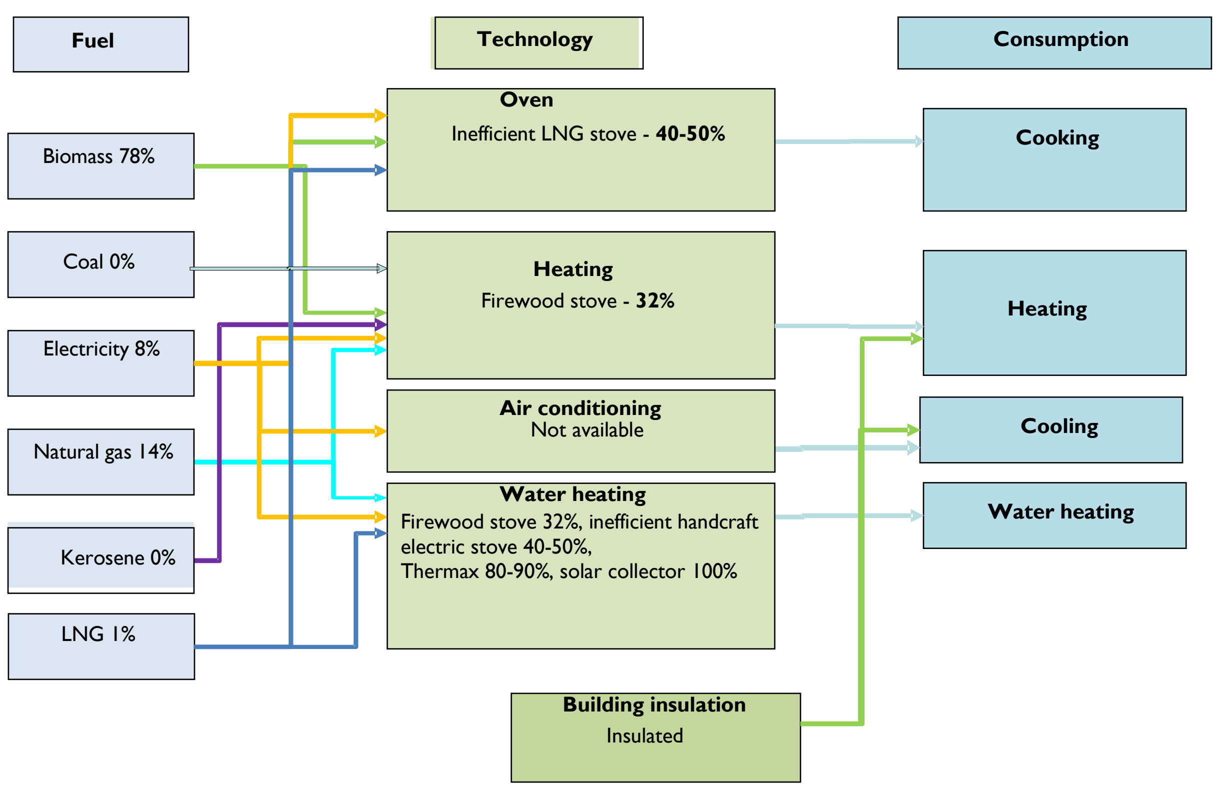

Fig. 8. Available technologies and their efficiency in the Second Technological Zone

Notice: On average, solar energy potential (direct annual amount of radiation on 30 degree slope South oriented surfaces) is 4800 KWh/m^2, and cumulative energetic potential of waste biomass (agriculture, manufacture and wood waste) and wood biomass as high as 1 130 GWh.

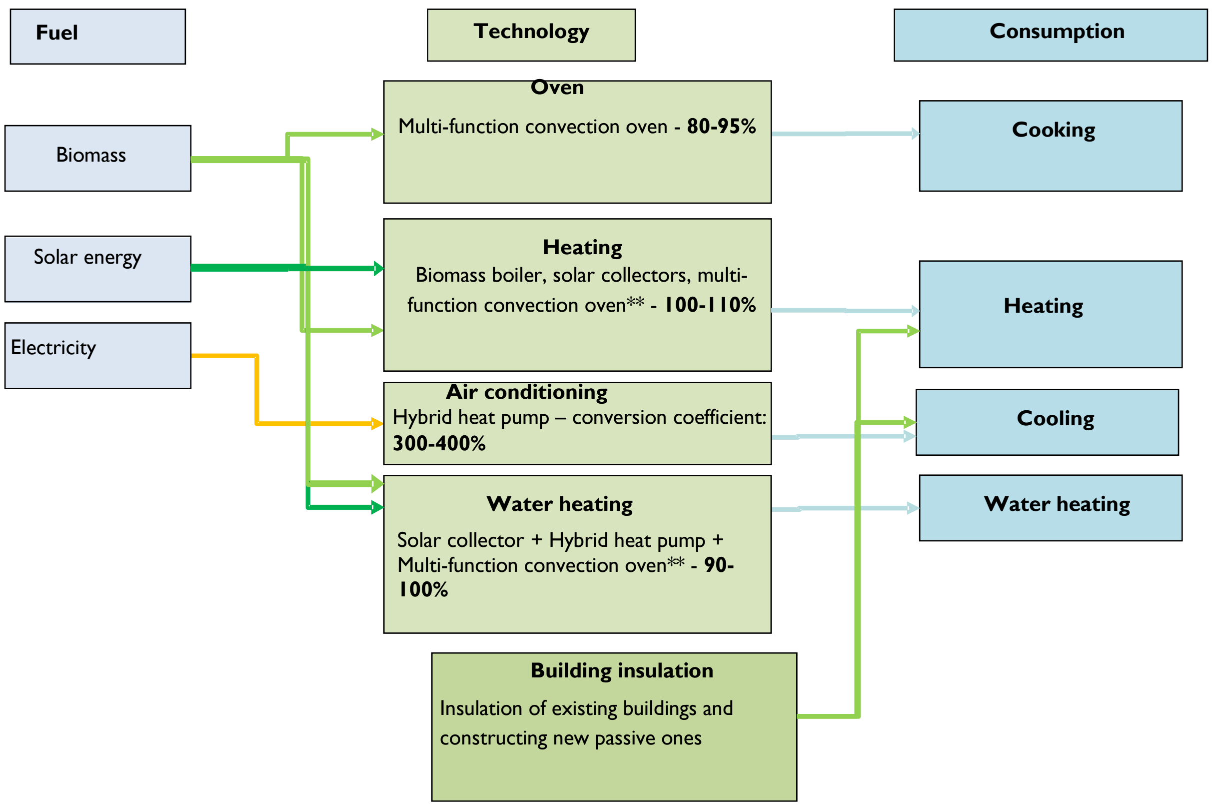

Fig. 9. Technology and corresponding efficiency recommendations for technologies that should be implemented in the Second Technological Zone

General recommendations for the Second Climate Zone

Average indicator of utilization ability of alternate energy sources is characteristic for this zone (solar energy potential is 120-170 days per year, and waste biomass is extremely limited in most of the regions), and due to their insufficiency for heating or cooling purposes, integrating fossil fuel stock-run energy generators is necessary mainly in winter times. Technologies in this zone are relevant: fossil and alternative energy source-run generators.

Third Technological Zone

The Third Technological Zone is the same as the Third Climate Zone, but settlements with 2 000 or less people are counted there. This zone covers (1000 meters or above) geographic regions of Georgia with high hypsometric indicator, including ski resorts, and necessary degree-days are D =3000 or higher there. Cold winter, cool summer and a climate changing from humid maritime to continental are typical for this zone. Total area of this zone equals to 20 000 km^2 with 10% accuracy, and the population on high hypsometric level (1000 meters or above) is 387 000 people.

Building sector overview

This technological zone, unlike previous two, is short of settlements due to harsh climate and weakly developed infrastructure. Historically, buildings are of roofing-type, walls are 60-70 cm wide and window openings are less. Population is aware of importance of insulation, but some of the buildings are still in need of improving heating engineering. Cottage-type wooden houses with high insulation parameters are also met in this zone.

In this zone, there are 114 000 private residential buildings. In most cases, roofs are of roofing-type and insulated. Buildings built during the end of the 20th century or in the beginning to the 21th, need wall insulation, while old historic buildings need only windows' and improvement of heating technology of heating bridges.

Fuel consumption, available technology and its efficiency for given technological zone are available on the Fig. 10. Recommendations about technologies to be implemented and their efficiency are given in Fig. 11.

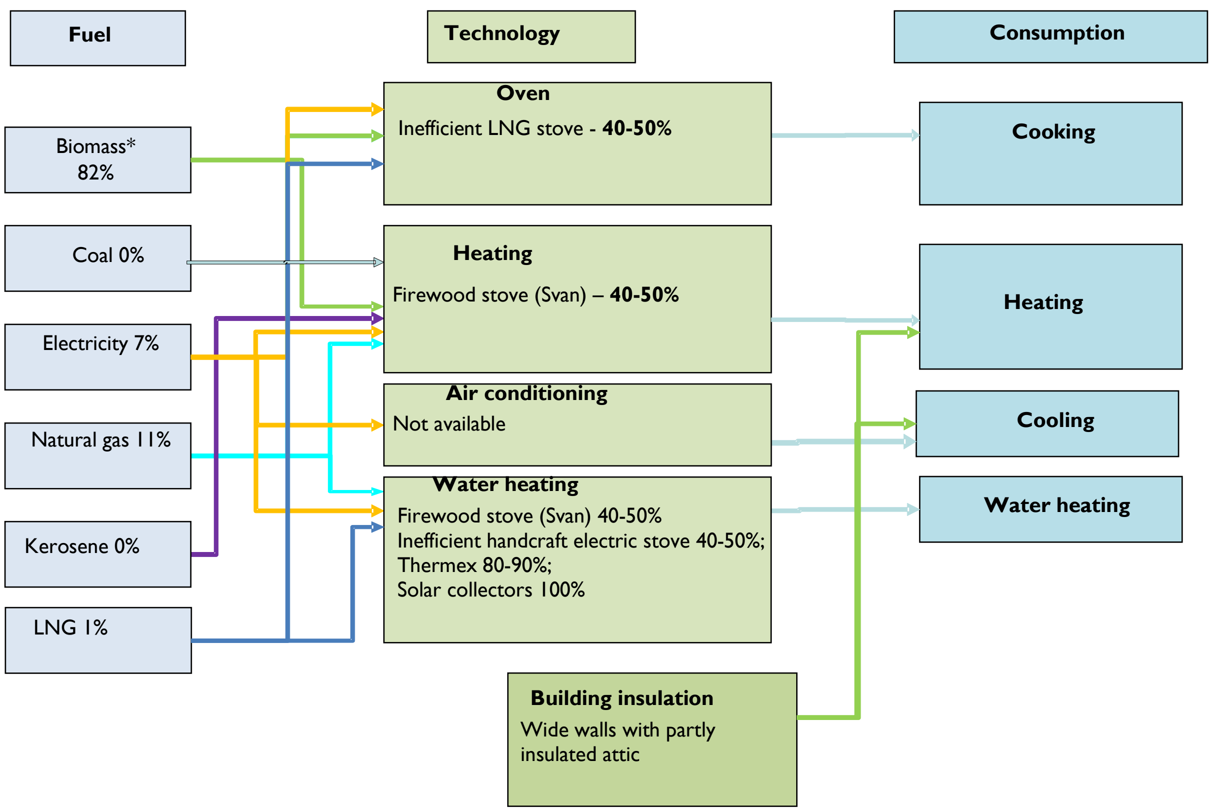

Fig. 10. Available technologies and their efficiency in the Third Technological Zone

__Notice:__ Solar energy potential (direct annual amount of radiation on 30 degree slope South oriented surfaces) is as low as 4800 KWh/m^2, and cumulative energetic potential of waste biomass (agriculture, manufacture and wood waste) and wood biomass as low as 170 GWh.

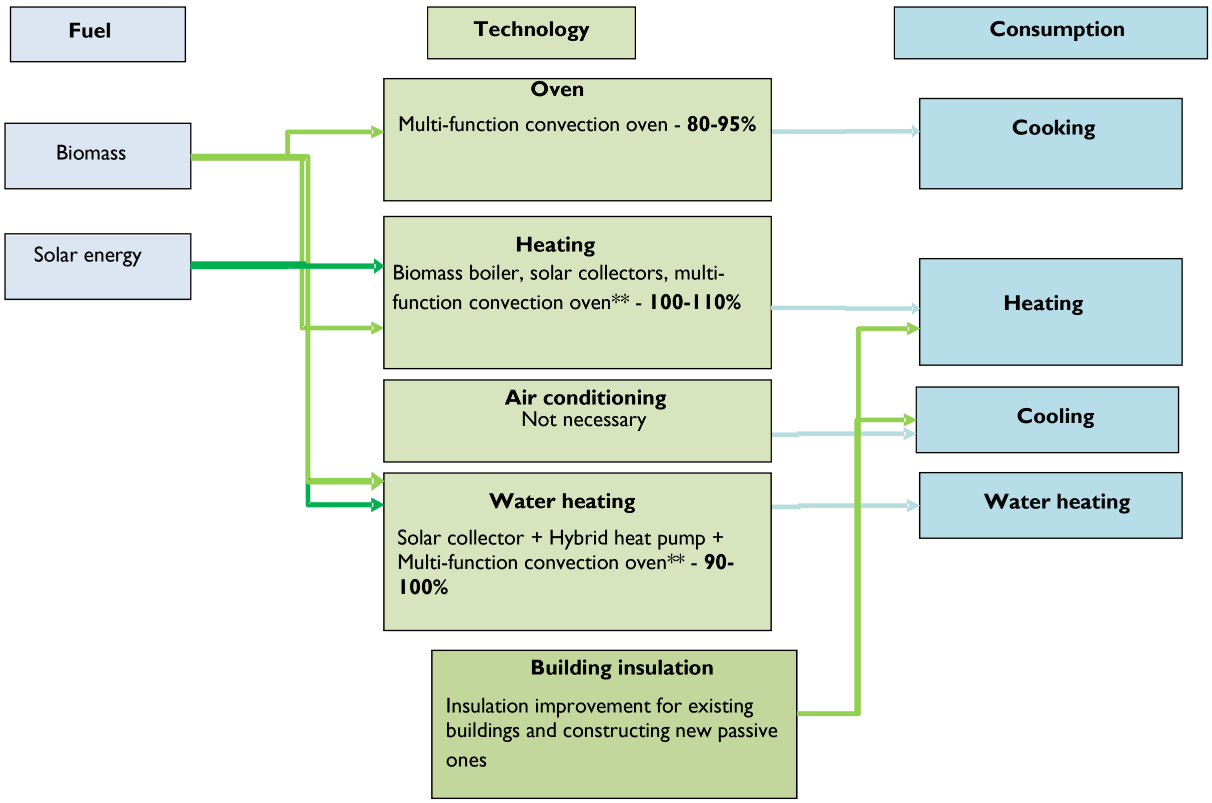

Fig. 11. Technology and corresponding efficiency recommendations for technologies that should be implemented in the Third Technological Zone

General recommendations

In this zone, due to low alternative energy resources potential (solar -150 days per year, solid waste biomass is below the average), main emphasis should be on reduction of energy-losses from surfaces of building envelope and retaining high level of density. Any type of high energy-efficiency solid biomass could serve as an efficient fuel for these regions. Utilization of briquettes and pellets in pyrolysis combustion chambers, or connecting gas condensate water heating systems to the net (except territories without gas supply), is vital there. Requirements for the secondary use of the heat and, consequentially, for interior's climate systems are strict for efficient organization of micro energy-management systems.

In each of these three climate zones several subzones could be identified, where buildings consume energy while applying the technologies different from the rest of the same zone. They are referred as the Forth and the Fifth zones and are mainly defined according to the population. Climatic indicators of the Fourth and the Fifth zone coincide with the figures of those zones inside which they are situated. Nevertheless, urban effects might cause the deviation of heating or cooling parameters from zone's average figures. As usual, it is reasonable, to calculate degree-days for similar settlements separately, especially for these settlements. This is also important as in the Forth and in the Fifth zones the prevalent technologies, corresponding efficiency figures and consumed energy resources differ from the similar figures of the rest parts of the zones.

Fourth Technological Zone

The Fourth Technological Zone ties medium and small administrative unis and small towns with energy-consumers of mixed type and with population more than 2000. Territories in this zone might fall in all three previously described climate zones. List of towns in the Fourth Technological Zone is given in Appendix 2.

Building overview

For these towns a family of three members is typical and residential area per family is 130 m^2 (three or four bedrooms, one reception-room, one kitchen, one bathroom, and one toilet). Heating area reaches 80 m^2.

Fuel consumption, available technology and its efficiency for given technological zone are available on the Fig. 12. Recommendations about technologies to be implemented and their efficiency are given in Fig. 13.

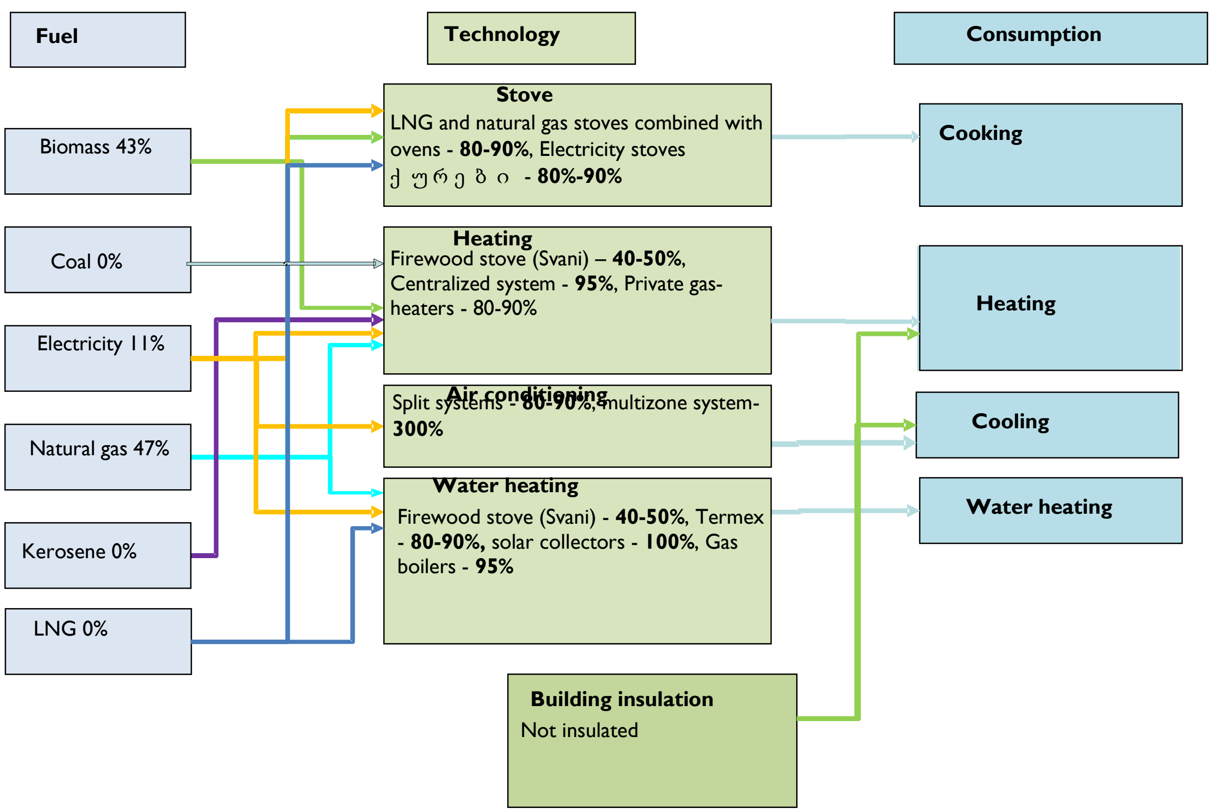

Fig. 12. Available technologies and their efficiency in the Fourth Technological Zone

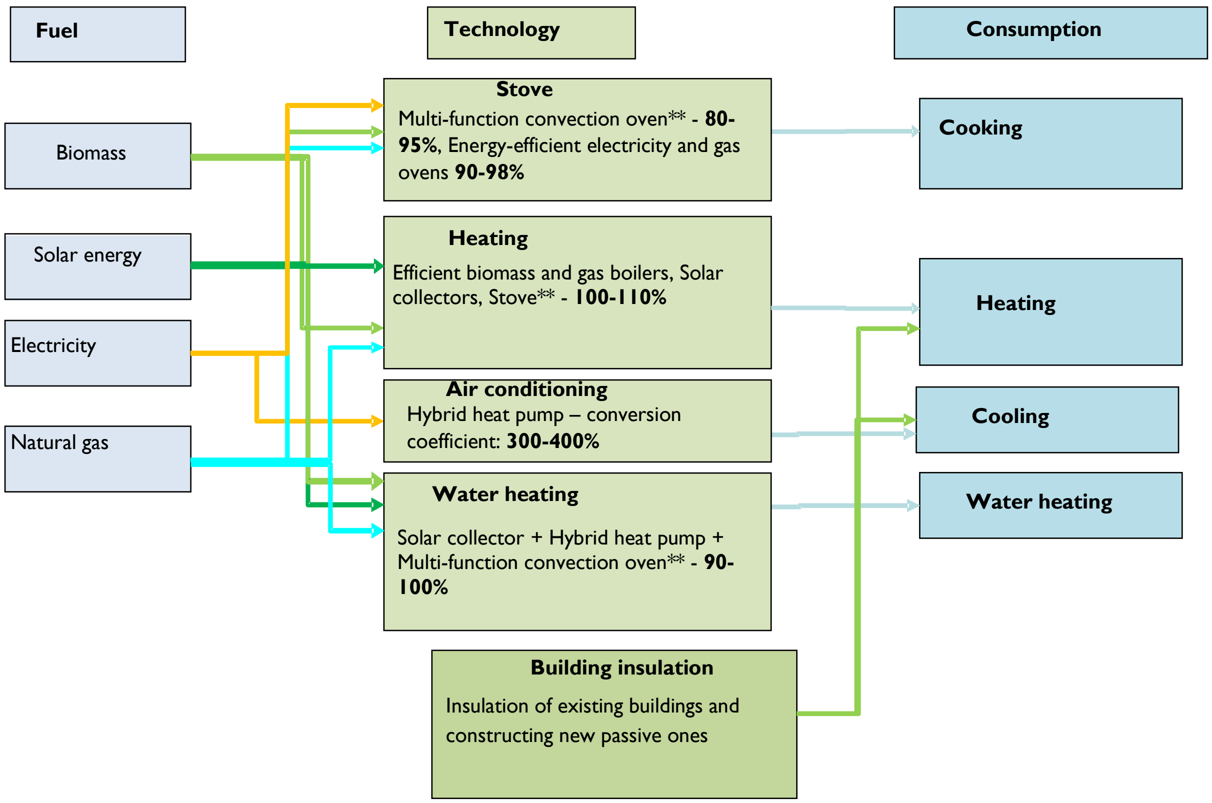

Fig. 13. Technology and corresponding efficiency recommendations for technologies that should be implemented in the Fourth Technological Zone

General recommendations

For the fourth zone, fossil fuel- or biomass-run co and tri energy-generation stations are reasonable. Utilization of renewable energy where it is available (for example, in the third zone) is also recommended.

<u>Fifth Technological Zone</u>

The Fifth Technological Zone includes gasified cities with population of 100 000 or more. Territories (in most cases, big cities) in this zone might be in all abovementioned climate zones. Cities in this technological zone are Batumi, Kutaisi, Tbilisi and Rustavi. Despite the fact that self-governing city of Poti is the seventh city by population in the country, it might be included in the Fifth Technological Zone thanks to its highly developed marine and sea port infrastructure.

So, in case of Georgia, territories of the Fifth Technological Zone are in the First, as well as in the Second Climate Zone. For this technological zone, intense use of gas fuel is typical.

Building sector overview

In addition to residential, commercial and state-owned buildings, zones could be characterized according to specific energy-consumers buildings and constructions. For example: seaports, airports, big trading centers, metro, major railway stations, specialized military fortifications, bridges, tunnels, etc.

For these cities a family of three members is typical and living area per family is 78 m^2 (two bedrooms, one shared lounge, one kitchen, one bathroom, and one toilet).

Fuel consumption, available technology and its efficiency for given technological zone are available on the Fig. 14. Recommendations about technologies to be implemented and their efficiency are given in Fig. 15.

This zone is the most advanced technological zone and significant number of Georgian-based innovative companies is concentrated there. Well-developed commercial sector supports market's quick adaptation to modern technologies.

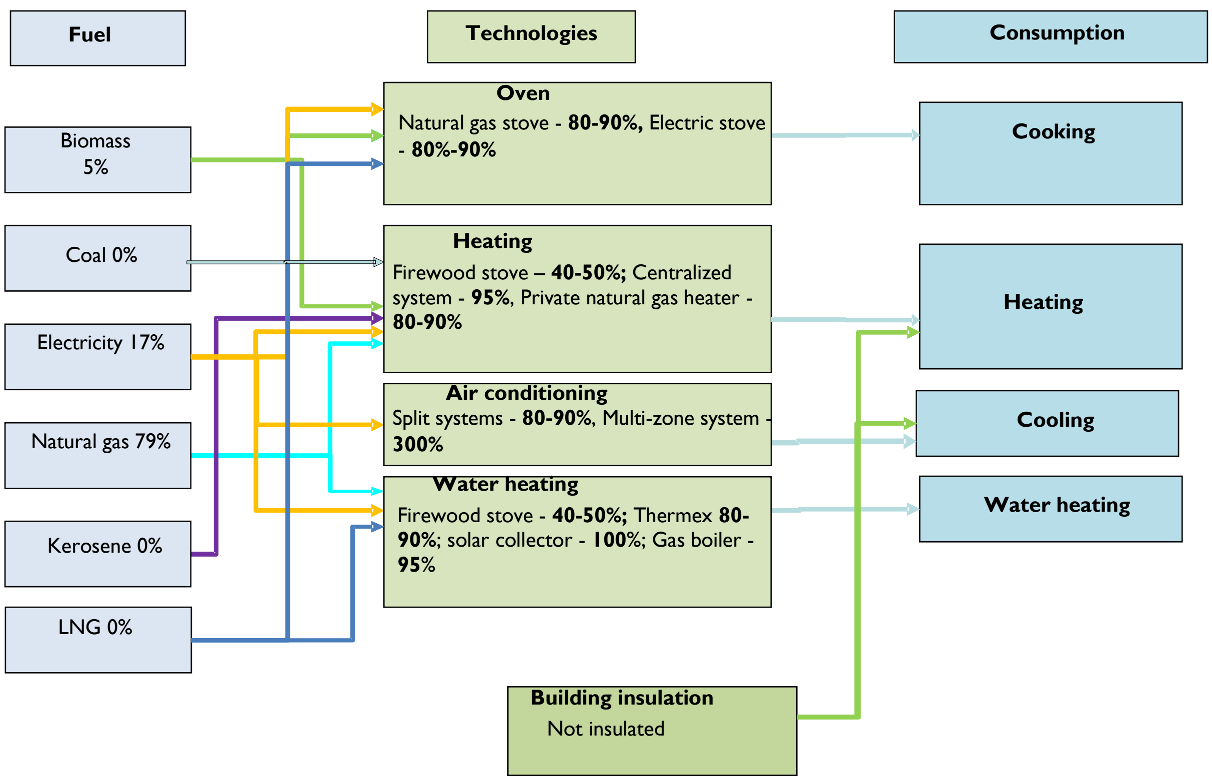

Fig. 14. Available technologies and their efficiency in the Fifth Technological Zone

Notice: In this zone there are specialized constructions like airports, seaports, metro, military objects, etc. Their energy consumption is specific and, thus, a subject to a separate analysis.

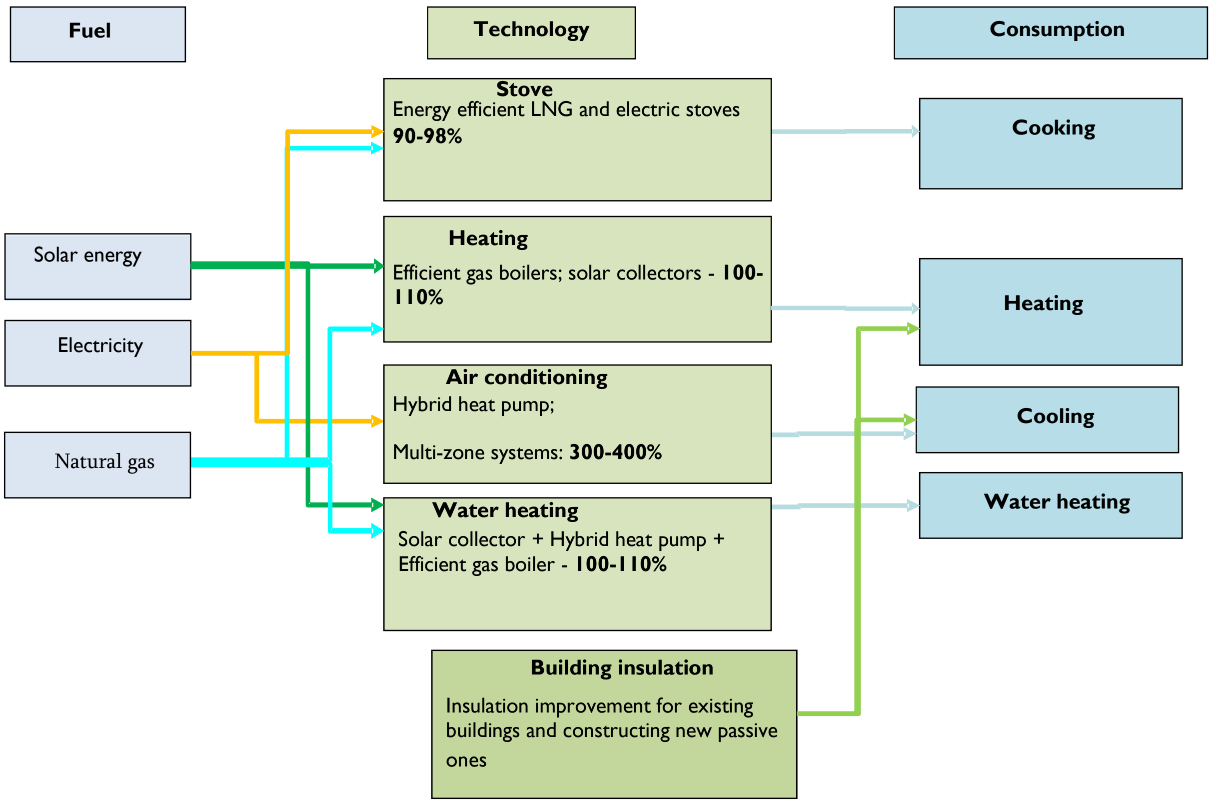

Fig. 15. Technology and corresponding efficiency recommendations for technologies that should be implemented in the Fifth Technological Zone

General recommendations

Among these cities, some subzones similar to the Fourth Zone could be identified. This fact makes reasonable to organize centralized co- and tri-energy generation stations that will run on fossil fuels or on biomass. For example, for the cities (Batumi, Poti) in the First Climate Zone, heat pumps integrated to solar systems, or solid biomass utilization efficient means, or utilization of secondly recuperated heat and cold, or using thermal insulation buffer technologies are recommended. In terms of equipment of buildings and constructions technologically in this technological zone, the priority should be given to energy efficient appliances. Therefore, using alternative energy source-run generators and their buffer storage hybrid schemes is an optimal option. In this case, electric network should be organized according to dual principles[7].

[7] Free access to electricity grid with dual principle means an ability to directly exchange, or to sell produced energy surplus to the distributor or to neighboring territories and buy it back during pick hours.

4. Indicators of consumed energy and emission by buildings sector

Trends of energy consumption in building sector of Georgia statistically do not look reliable. Most importantly, the data of 2012 does not fit the general picture of the situation. As we know, since the 1990's official energy balances of Georgia had been done sporadically and after the energy balance for 2000 the first official energy balance was prepared for 2013. 2013 and 2014 energy balances of Georgia are now available. According to the National Office of Statistics of Georgia, the country will have annual energy balances in the future.

From 2001 to 2012 International Energy Association (IEA) that was provided with data from Georgia had prepared energy balances of Georgia but the Office of Statistics was not involved in this process. As energy effectiveness of buildings is one of the main priorities for European Union and the Association Agreement requires fulfillment of defined directives, we should compare the situation in buildings sector of Georgia with EU countries in terms of energy consumption.

Fig. 16 and Fig. 17 describe energy consumption per capita in residential buildings and energy consumption per 1 USD in non-residential buildings of Georgia and EU countries.

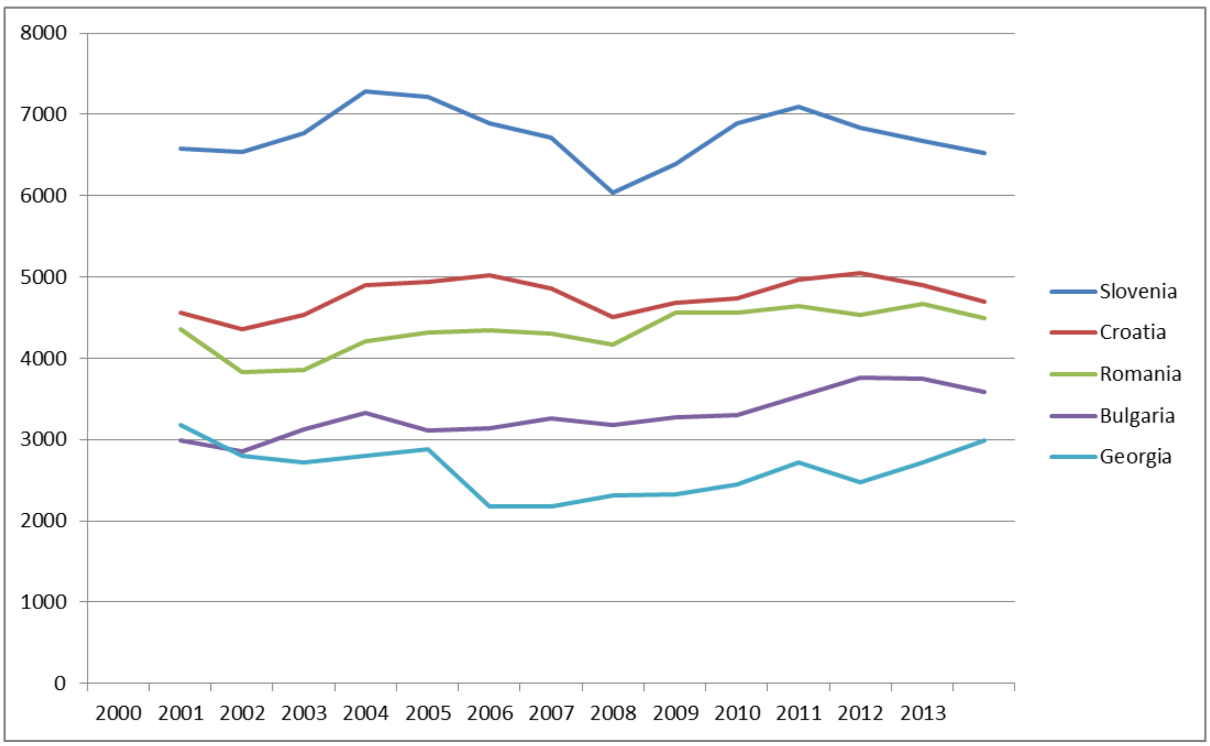

Fig. 16. Energy consumption per capita in residential buildings of Georgia and EU countries

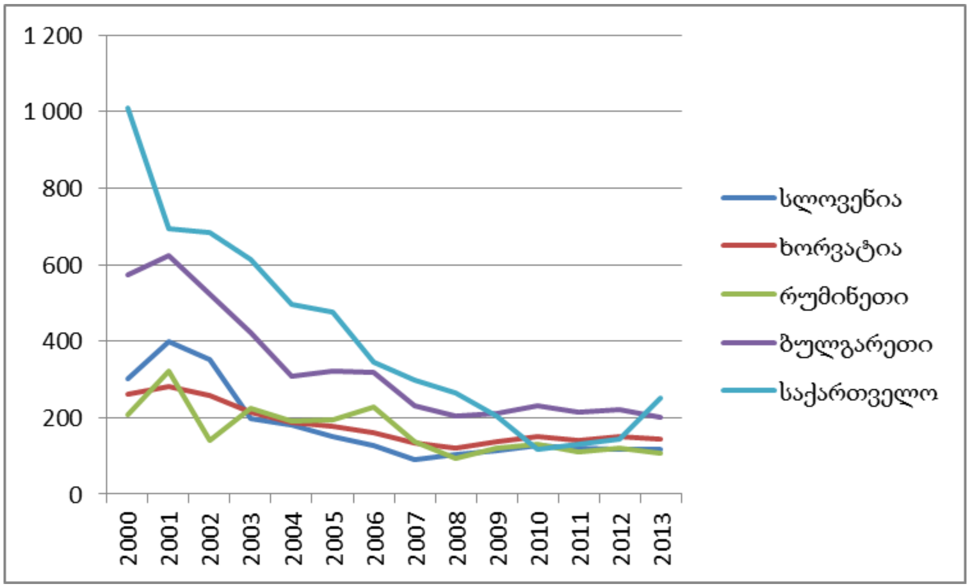

Fig. 17. Energy consumption per 1 USD in non-residential buildings of Georgia and EU countries

Fig. 16 shows that energy consumption in residential buildings of Georgia is much less than in other countries but has increasing trend at the end. Fig. 17 shows that trend of energy consumption per 1 USD of GDP in non-residential buildings is decreasing in all countries but it must be foreseen that this trend is changeable for Georgia in the last years.

Estimations have shown that there was no correlation between energy consumption and GDP in 2000-2014. Correlation coefficient between the income of family and energy consumption in residential buildings is about 0.4 and this value is not important.

In order to see clearly the trends of fuel consumption by types we divided the total consumption trend for 2000-2014 according to fuel types used. The results for both, residential and commercial buildings are shown below (Fig. 18 and Fig. 19)

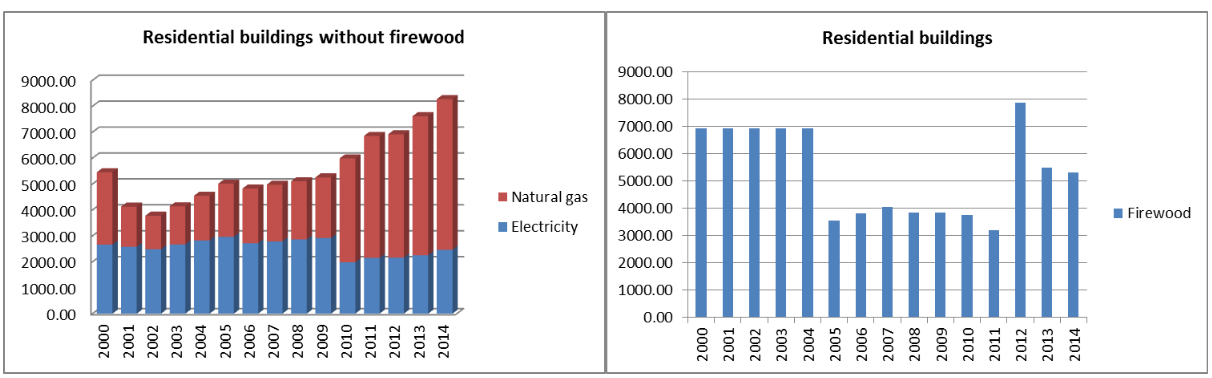

Fig. 18. Fuel consumption trend in residential buildings

From Fig. 18 it is easily noticeable that in the context of a general growth of consumption, the firewood consumption trend is quite different. Gathered information within the SEAPs showed that firewood consumption was reduced in big cities but did not reduce at all in the regions. Therefore, the reduction in 2005-2011 is probably the result of faulty statistics. The municipalities confirm the same information that during the recent years, in the context of improved statistics, firewood consumption has raised.

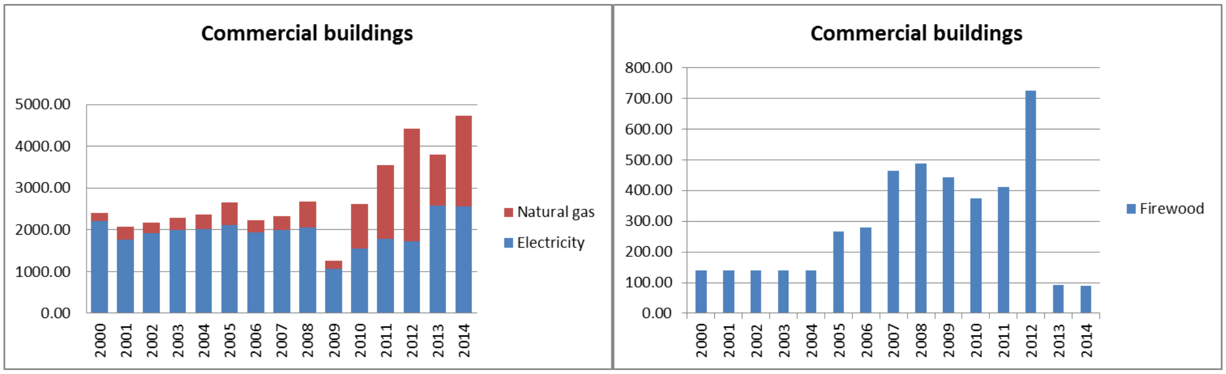

Fig. 19. Fuel consumption trend in commercial buildings

Fig. 19 shows energy consumption in commercial buildings (including state buildings). Decreasing of electricity and natural gas consumption in 2009 can be explained with the post-war period in 2008.

Firewood consumption, as well as other fuel consumption was significantly increased in 2012. Heating season of 2012 has been checked with National Agency of Environment and the fact has been enacted that the heating season of that year was one of the coldest in 2000-2015(Fig. 8). Firewood consumption in 2012 coincides with the amount of demand on firewood officially stated by a Minister of Environment and Natural Resources Protection of Georgia (3.7 million m³ per year)

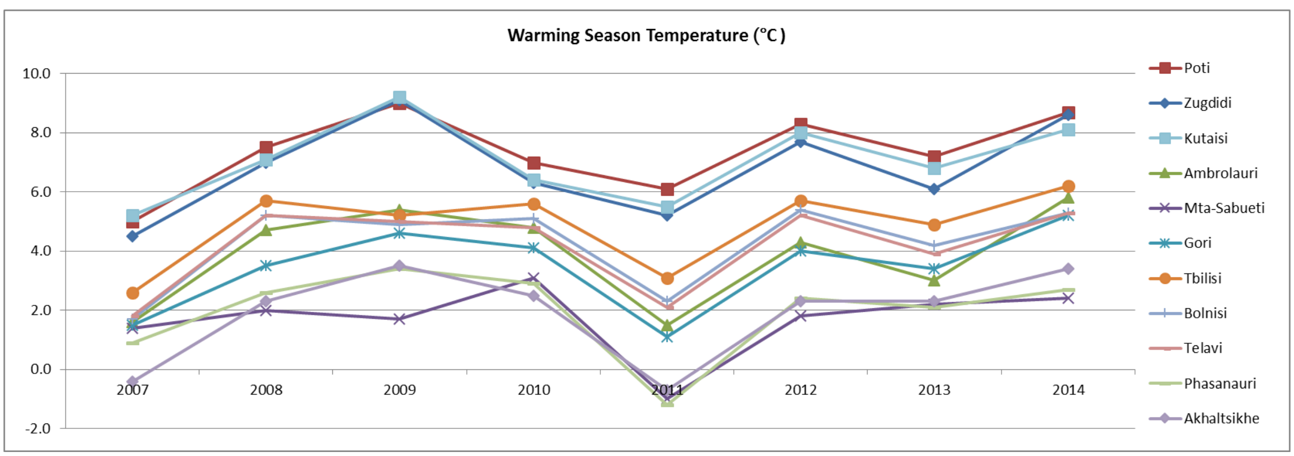

Fig. 20. Warming season temperature in Georgia in 2000-2015

Correlation between energy consumption of buildings and warming temperature has also been verified. Results are shown on Fig. 21.

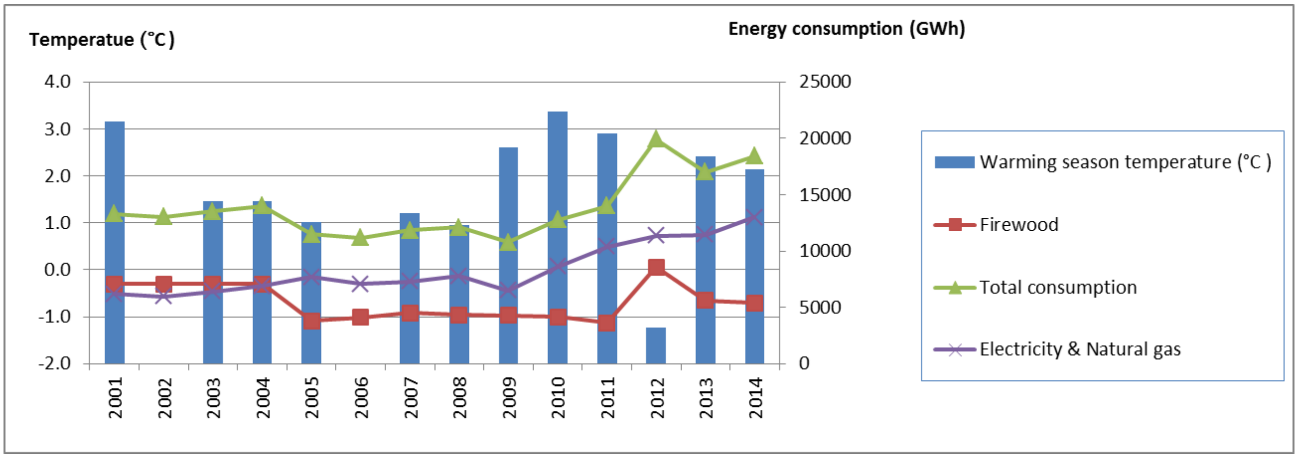

Fig. 21. Correlation between energy consumption and warming temperature

Analysis has shown that there is no correlation between warming season temperature and production of natural gas and electricity without foreseeing firewood. But the reason of this can be unreliable statistics, short period or using more energy effective technologies in case of natural gas and electricity. On this stage it is hard to make any exact conclusions until there are no reliable statistics in this sector. It is visible from Fig. 21 that correlation between firewood consumption and warming season temperature is quite high (0.6-0.8 in different small cities). Data for Fig. 21 is received from Pasanauri meteorological station (blue columns) where correlation was the highest.

According to more reliable statistics of years 2013-2014, energy consumption in 2014 was more by 8% than in 2013 and change in distribution of energy consumption by residential and commercial buildings is described inFig. 22. Energy consumption by residential and commerical buildings in 2013-2014.

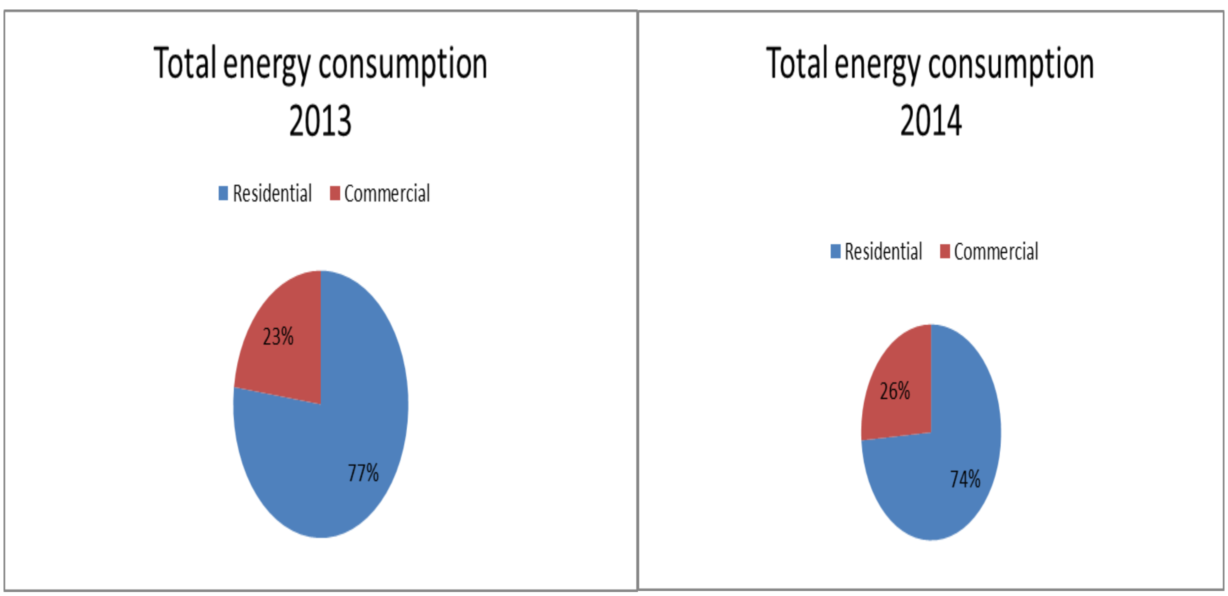

Fig. 22. Energy consumption by residential and commerical buildings in 2013-2014

Fig. 23 describes appropriate CO_2 emissions by fuel types.

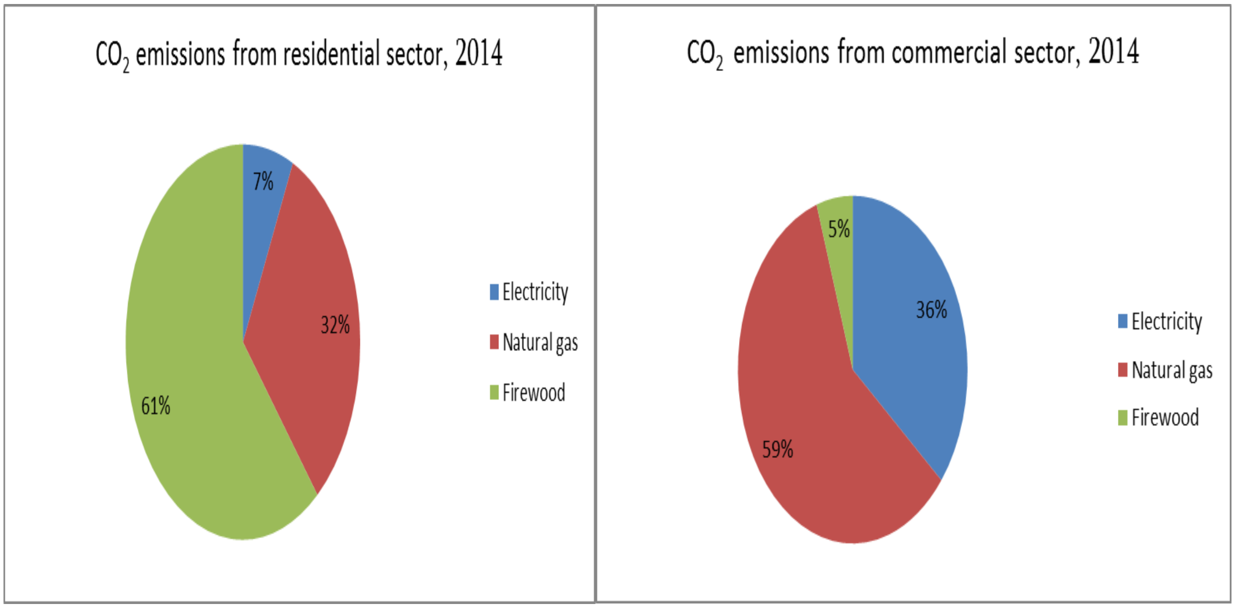

Fig. 23. Distribution of CO2 emissions in percentages by fuel and building types

It is noticeable from the figure that share of emission from firewood consumption is the highest in total consumption as well as in consumption by residential buildings. This is foreseen during planning emission reduction measures.

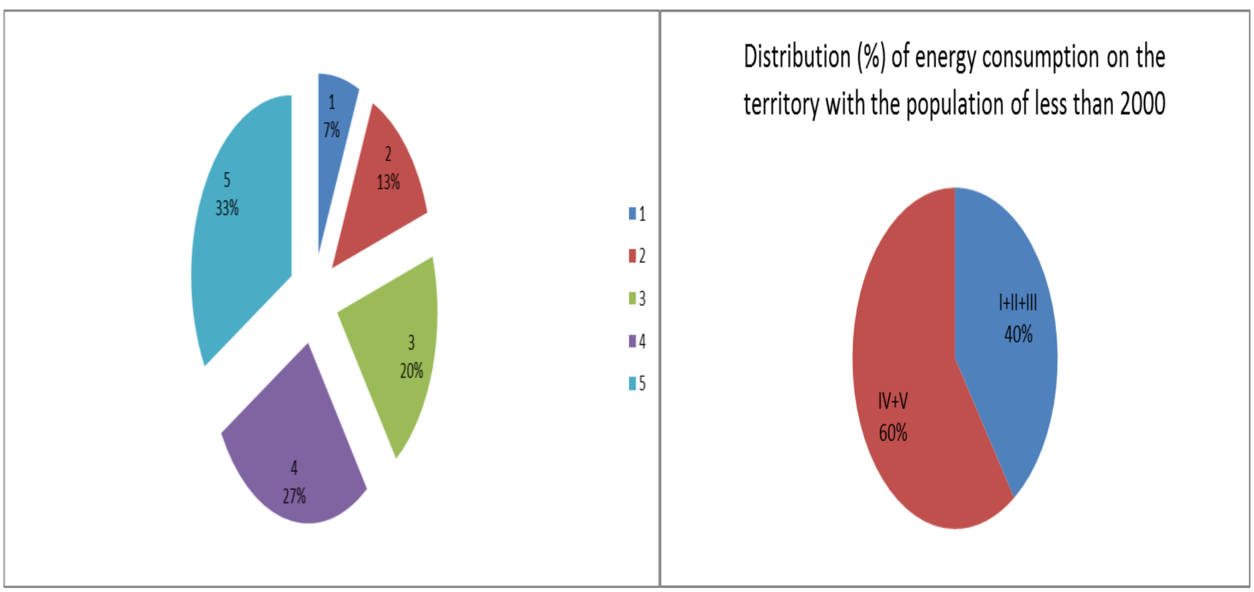

Fig. 24. Total energy consumption by zones (%)

Energy consumption in climate-technological zones (described above) has been estimated for more effective planning of emission reduction measures. Fig. 24 describes energy consumption distribution (%) in buildings sector by zones. Fig. 25 shows emissions respectively.

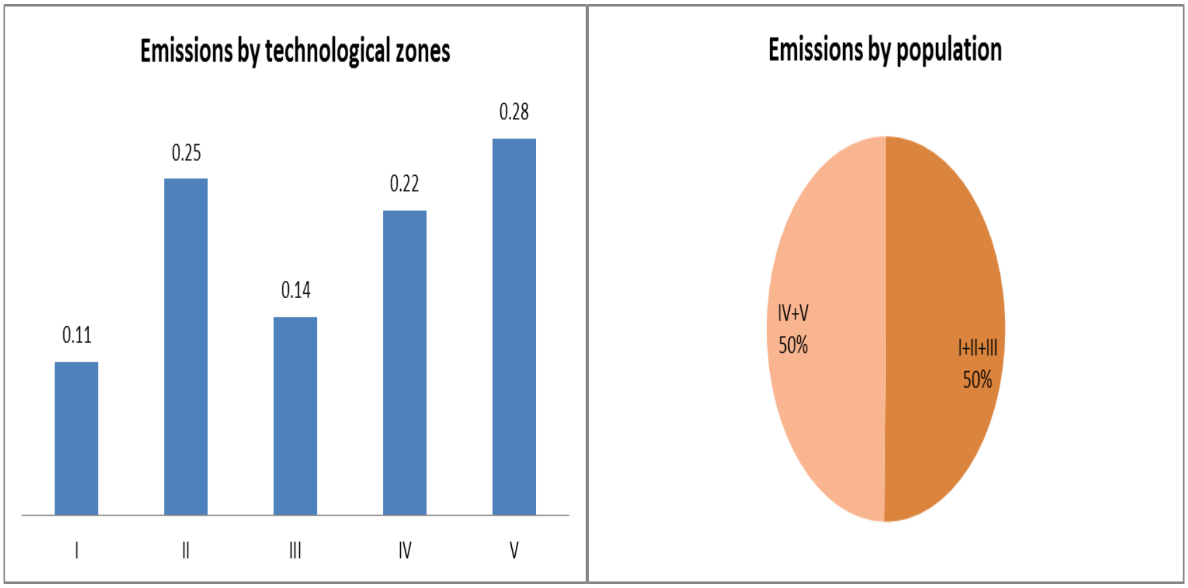

Fig. 25. Distribution of CO2 emissions by zones (%)

From Fig. 24 and Fig. 25 it is noticeable that CO_2 emissions from I, II and III zones, where firewood consumption is high, are the same as in IV and V zones together, despite the fact that energy consumption in the last one is higher by 20%. **As a conclusion, it can be said that in the strategy for emission reducing from buildings sector the first priority of Georgia should be the reduction of firewood fuel in the first three zones.**

Fig. 26 provides the summary of parameters for the zones and shows that emission in the II zone is less by 0.03% than in the V zone where the population is the biggest and, respectively, energy consumption is the highest, too. In this case, reasons for this are high consumption of firewood in combination with longer and colder heating periods that are typical for this zone.

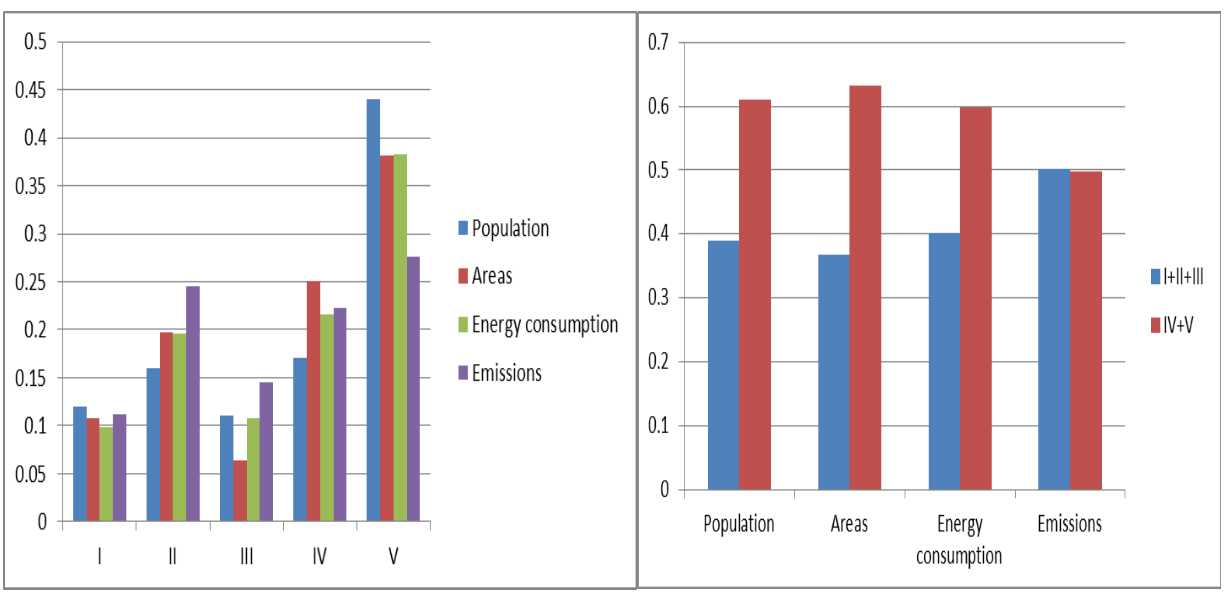

Fig. 26. Distribution of CO_2 emissions by zones (%)

For even more effective planning of emission reduction measures the distribution of consumed energy according to consumption purpose was also estimated. This is described on Fig. 27

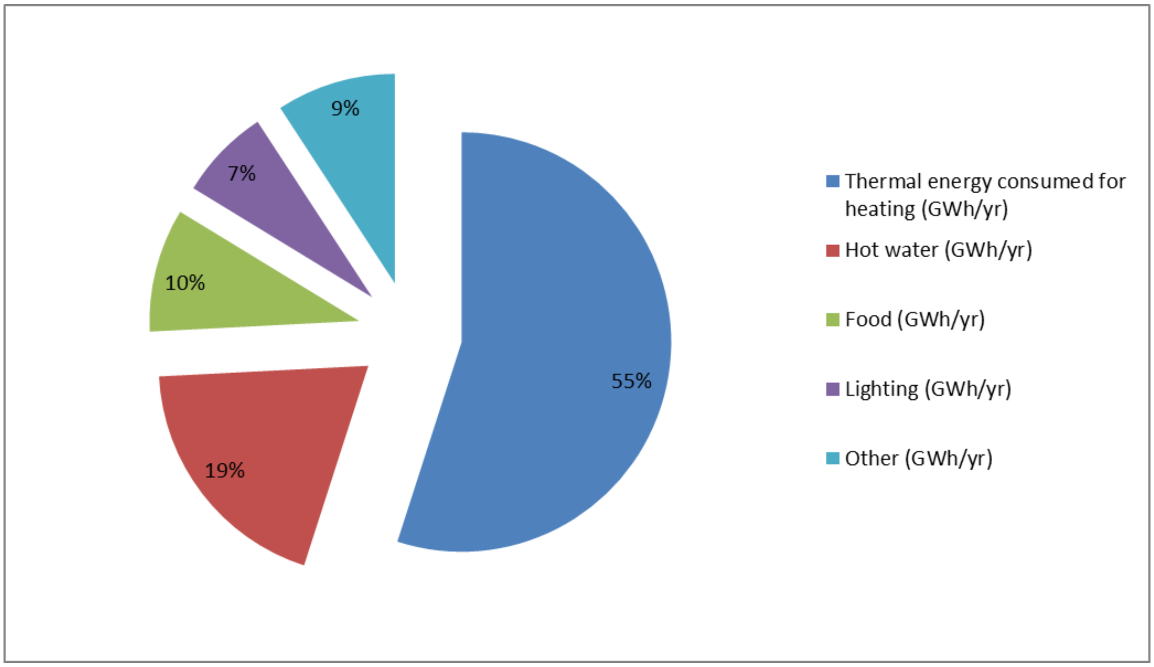

Fig. 27. Distribution of energy consumption by purposes (%)

It is visible from Fig. 27 that the main measures for reduction of energy consumption should be focused on the heating sector that implies high effective measures, as well as reduction of demand on heat by buildings. The second priority must be energy consumption for water heating. In this case, an emphasis should be made on IV and V zones where the population is 61% of the whole population and consumption of hot water is high.

5. Major obstacles faced by energy-efficiency improving activities

Analysis of building sector's energy consumption, surveys conducted under SEAPs' and building NAMAs' preparation processes, as well as results of pilot projects for improving buildings' energy efficiencies showed the main barriers faced by energy-efficiency improving activities. Overcoming these barriers is the main goal of activities carried out for low-emission strategic development plan:

- In the country **there is no responsible body** that will formalize and carry out policy regarding **existing buildings** (rehabilitation, increasing energy efficiency, etc.);
- Unified **construction standards** and monitoring system during the construction process do not exist. Probably, standards are different across different climate zones;
- There is no clear policy regarding multi-storey buildings' maintenance and rehabilitation, and **the role of a community** in this process is not distinct. Legal base concerning communities is oriented only on community's rights, and responsibilities are not defined;
- Situation on construction market is chaotic. In buildings' rehabilitation process **quality is not guaranteed**, which is vital in energy efficiency improving efforts to obtained desired results;
- Specific **fund**, to financially support energy efficiency supporting activities, does not exist;
- **There are no ESCO-type** (full package of energy-service) companies, which would indeed save the energy in buildings where comfort is guarnteed;
- Approximately 30% (schools, kindergartens, residential houses) of buildings' total area has **unsatisfactory level of comfort** and this hinders energy-saving process, because increasing the comfort is a priority;
- **60% of existing building stock** was built during 60s-80s of 20th century and is already **outdated**. Carrying out energy-efficiency supporting activities for these buildings have no effect and is often unprofitable;
- In the country big-scale international funds (GCF, GEF, etc.) **accredited national authority**, which would attract big investments, low-interest rate loans or grants for improving energy-efficiency, developing renewable energy industry and financing energy-efficiency fund, do not exist;
- **Certification of** electric appliances is **not mandatory**;
- **Certification** of buildings according to their **energy consumption levels** is not required;
- Domestic **building materials are not certified**;
- **Construction companies** are **not certified**;

To overcome all aforementioned barriers, implementation of constructions' and buildings' energy consumption standards is necessary:

- Technology market and population/comsumer survey revieled that non of them have perfect information regarding technologies. Namely:

a) 28 retailers of cooling-ventilation systems across Georgia were surveyed. Majority (64%) of them operates in the Fifth Technological Zone, and 22% of them in Tbilisi. According to results, the most widespread (28%) heating-cooling system in this zone is of split-type. The second place is tied between Chiller-Fan Coil and Channel-type air conditioning systems, while the highest portion (29%) of respondents could not answer the question;

b) Surveys showed that only a quarter (25%) of population is aware of energy-efficient technologies. For 27% of the population energy-saving activities are limited to using energy-efficient light bulbs;

c) Significant share of heating-cooling systems' providers and consumers do not know the energy-efficiency class of corresponding energy-system and prefer cheap alternatives;

d) Only 33% of companies selling energy-efficient and renewable energy-run products believe that these type of products are demanded on the market, while 25% believes that the main potential for their utilization is in Georgia's regions (the First, the Second and the Third Technological Zones), 17% believe that country's geography does not affect demand, and 25% could not answer the question.

6. Annex I: used sources and methodology of estimation

Table 1. Characteristics of technologocal zones

Technological zone #	1	2	3	4	5	Total
Population (thousand persons)	460	602	387	631	1 650	**3 730**
Technological zone #	1	2	3	4	5	
Degree day	<2000	2000-3000	>3000	-	-	
Average warming season duration (day)	101	151	185	128. 02	128. 12	
Daily cycle of heating systems (hour)	8	8	12	8	8	
Average residential area (m^2)	100	150	70	130	78	
Share of heated area in residential buildings (%)	45	45	40	62	57	
Average commercial area (m^2)	100	100	85	100	200	
Share of heated area in commercial buildings (%)	80	80	80	85	90	
Average state area (m^2)	200	200	200	200	200	
Share of heated area in state buildings (%)	60	60	60	70	80	
Reported consumed energy for heating 1 m^2 building (KW/m^2)	0.082	0.120	0.203	0.135	0.107	
Heated with natural gas (%)	5.0%	6.0%	5.0%	40.8%	79.0%	
Heated with electricity (%)	22.0%	8.6%	6.4%	7.1%	14.0%	

Heated with firewood (%)	73.0%	85.4%	88.6%	52.1%	7.1%
Water heating with natural gas (%)	23.0%	23.0%	23.0%	60.9%	70.9%
Water heating with electricity (%)	12.0%	12.0%	12.0%	27.7%	28.3%
Water heating with firewood (%)	65.0%	65.0%	65.0%	11.4%	0.8%
Cooking with natural gas (%)	57.0%	57.0%	57.0%	61.4%	93.1%
Cooking with electricity (%)	0.0%	0.0%	0.0%	5.6%	3.6%
Cooking with firewood (%)	43.0%	43.0%	43.0%	33.0%	3.3%
Emission factor (Kg/KWh)	0.340	0.380	0.389	0.309	0.204

Table 2. Summary tables of Technological Zones

Technological zone #	1	2	3	4	5	Total
Population (thousand persons)	460	602	387	631	1 650	3 730
Overall area of residential buildings (mln. m^2)	13.5	26.6	8.0	24.1	38.0	110.1
Overall area of commercial buildings (mln. m^2)	1.3	1.7	1.1	1.8	4.7	10.7
Overall area of state and municipal buildings (mln. m^2)	0.8	1.0	0.7	1.6	1.8	5.9
Overall area of buildings (mln. m^2)	15.6	29.3	9.7	27.6	44.5	126.7
Overall area of heated buildings (mln. m^2)	7.7	14	4.5	17.8	27.2	71.2

Used sources:

- Year of used sources – 2014;
- Population of Georgia (except occupied territories): 3 730 million;
- Number of persons living in one apartment – 3.4
- Average residential area per family for different zones is based on surveys being held under the project EC-LEDS and information in SEAPs that has been corrected on the basis of the information from surveys of municipalities. Only zone #5 is estimated by the population number;
- Share of heated area (%) is estimated based on surveys (Annex 2: Winrock Outputs municipality version 01) conducted under the project EC-LEDS and information in SEAPs;
- Armed forces of Georgia – 37 000 persons (source: Ministry of Defence of Georgia);
- Persons in penitentiary system – 11 000 persons (source: Ministry of Corrections of Georgia);
- Amount of foreign visitors per year – 5 493 492 (source: Geostat);
- Average amount of nights of foreign visitors spent in Georgia – 2.16 (source: Geostat);

- Distribution of average monthly amount of visitors by living place for zone 1 is 40% (source: Department of Statistics). The same data for other zones was calculated in proportion to population, foreseeing touristic zones;
- Average area of restaurants, bars and other food places in Tbilisi is 170 m^2 (source: Tbilisi | Real Estate Market Report 2014, Colliers International);
- Number of restaurants, bars and other food places in Tbilisi, Batumi and Kutaisi is 1168 (source: Georgia | Entertainment Industry Report 2014, Colliers International), calculated in proportion to population for other cities of the fifth zone, as well as for other zones;
- Area of commercial buildings in Tbilisi – 3.21 million m^2 (source: Tbilisi | Real Estate Market Report 2014, Colliers International), is used for calculating commercial area in other cities and zones (pro rata);
- Share of heated area in whole area of commercial buildings in percentage is calculated by selective survey and expert judgement;
- Area of state buildings by zones was estimated in the following way: from SEAPs of cities of the zone V, for the other zones based on SEAPs of cities of zone IV, in the way of pro rata distribution of population;
- Average area of state buildings is 200 m^2 (according to selective survey, it is not the whole area of state building but it is a sum of the areas occupied by different subjects (departments, offices, legal entities, etc.) located in building. This data is used for calculating consumed energy for hot water and cooking);
- Share of heated area in whole area of state buildings in percentage is calculated by selective survey and expert judgement;
- Consumed energy (KW/m^2) for heating of 1 m^2 for different zones was calculated according to audits of buildings for SEAPs cities in appropriate zones;
- Share of fuel consumptions by types and zones is based on EC-LEDS surveys (Annex 2: Winrock Outputs municipality version 01.);
- Average energy consumption for lighting by 1 m^2 – 10.37 KWh/yr (source: energy audits of buildings held for SEAPs);
- Average energy consumption for different purposes by 1 m^2 (except heating, hot water, cooking and lighting) is 14 KWh/yr for residential sector and 10 KWh/yr for commercial and state sector. (Source: energy audits of buildings held for SEAPs);
- Average residential area per capita in Tbilisi – 23 m^2 (source: Tbilisi | Real Estate Market Report 2014, Colliers International) is used for calculating residential area of zone V. Calculation of residential area in other zones is described in the Paragraph 4.
- Emission factors on 1 KWh by fuel types: natural gas – 0.202 kg, electricity – 0.104 kg, firewood – 0.202 kg.

Methodology of estimating other data:

1. Number of residential buildings by zones is calculated by dividing population of a zone by average number of persons living in one apartment;
2. Number of commercial buildings in each zone is calculated by dividing total commercial area in a zone by average area of commercial buildings in that zone;
3. Number of state buildings in the cities of zone V is based on corresponding SEAPs;
4. Number of state buildings for those cities of zone IV that have SEAPs is based on SEAPs. For those cities without SEAPs the same parameter is calculated pro rata of population of those cities of zone IV that have SEAPs;
5. For the I, II and III zones it was calculated in the same way as for those cities of zone IV that have SEAPs, pro rata of population.

7. Annex II

Table 3. Cities in technological zone IV

#	City	Population	Warming season (day)
1	Zugdidi	69 600	101
2	Gori	54 700	148
3	Samtredia	29 761	92
4	Khashuri	28 560	160
5	Senaki	28 082	85
6	Zestafoni	24 158	109
7	Telavi	21 801	141
8	Ozurgeti	20 636	106
9	Marneuli	20 065	139
10	Chiatura	19 587	124
11	Kaspi	19 901	143
12	Akhaltsikhe	18 452	165
13	Kobuleti	18 302	109
14	Tskaltubo	16 841	90
15	Borjomi	14 445	179
16	Tkibuli	13 801	130
17	Sagarejo	12 566	151
18	Gardabani	11 858	133
19	Khoni	11 315	94
20	Gurjaani	10 029	133
21	Bolnisi	9 944	140

22	Akhalkalaki	9 802	207
23	Kvareli	9 045	134
24	Tsalenjikha	8 956	108
25	Akhmeta	8 571	139
26	Lanchkhuti	8 000	101
27	Dedoplistskaro	7 724	161
28	Mtskheta	7 718	139
29	Dusheti	7 315	162
30	Kareli	7 185	154
31	Sachkhere	7 000	140
32	Lagodexi	6 875	135
33	Abasha	6 430	102
34	Ninotsminda	6 287	238
35	Tsnori	6 066	132
36	Martvili	5 609	97
37	Khobi	5 604	71
38	Terjola	5 489	109
39	Jvari	4 794	97
40	Baghdati	4 724	109
41	Vani	4 641	102
42	Tetritskaro	4 041	176
43	Dmanisi	3 427	182
44	Oni	3 342	157
45	Ambrolauri	2 541	145
46	Sighnaghi	2 146	155
47	Tsageri	1 961	142
48	Tsalka	1 741	201
	Total:	631 438	

8. Annex III. Example of calculating heat-engineering parameters (1st technological zone)

1.0 Heating

- Average duration of heating: 101 days;
- Daily working duration: 8 hours per day;
- Thermal costs for heating 1 m^2 area: 0.135 KWh/m^2;
- Heating area: 18 000 000 m^2

$Q = 18\ 000\ 000\text{x}\ 101\text{daysx}8\text{hours/dayx}0.135\text{KW/m}^2 = 1963.44$ GWh

2.0 Hot water supply

- Hot water supply grid: non-isolated stands with towel dryer;
- Heater: individual bowl;
- Hot water supply, g = 105 l/day;
- Period of hot water supply termination, m = 21 days;
- Warming season for this technological zone lasts for 101 days;
- Operational temperature- requested temperature of warm water is 40°C

Methodology

1. Average daily amount of hot water consumed in residential area during warming season V_{hw} is calculated with the following formula:

$$V_{hw} = gm_ч \cdot 10^{-3}, \quad (1)$$

Where g is the amount of consumed warm water per capita during warming season and equals to 105 liter in the next calculations (see СНиП 2.04.01–85* «Внутренний водопровод и канализация зданий»); $m_ч$ is a number of consumers, $V_{hw} = 105 \cdot 3 \cdot 10^{-3} = 0.315$ m³/day.

2. Average hourly thermal energy is calculated with (2) formula (see СНиП 2.04.01–85*).

$$Q_{hw} = \frac{V_{hw}(55 - t_{wc})(1 + k_{hl})\rho_w c_w}{3,6 \cdot 24}, \quad (2)$$

V_{hw} is parameter calculated by formula (1), t_{wc} – temperature (°C) of cold water in the system, t_{wc} = 15°C; k_{hl} – thermal loses of the grid (see table (1)), ρ_w – density of water kg/l, ρ_w = 1 kg/l; c_w is specific heat J/(Kg• °C); c_w = 4,2 J/ (Kg• °C). After the calculation Q_{hw} = 0.735 KW.

Table 4. Values of k_{hl} coeficient foreseeing thermal loses of tubes

Type of hot water supply	k_{hl} coefficient	
	In case of existence of hot water supply grid	In case of non-existence of hot water supply grid
Isolated stands without towel dryer	0,15	0,1
Isolated stands with towel dryer	0,25	0,2
Non-isolated stands without towel dryer	0,35	0,3

3. Consumed energy annually on hot water supply Q^{y}_{hw} is calculated with formula:

$$Q^{y}_{hw} = \frac{24Q_{hw}}{1+k_{hl}} =$$
$$= \left((365-m)k_{hl} + z_{ht} + \alpha(365-m-z_{ht}) \frac{55-t_{wcs}}{55-t_{wc}} \right), (3)$$

Q_{hw} is calculated with (2) formula ;k_{hl}, t_{wc} – the same as formula (2); m – days of water supply termination, m = 21 days;z_{ht} – number of days with temperature less than 8°C (according to СНиП 23-01–99*) 101 days, for the territory of Georgia t_{ext} = –8 °C and less, average temperature of exterior 15°C, α – correcting coefficient of summer water supply: α = 0.8 for residential buildings, 1 – for all other. t_{wcs} – cold water temperature in summer - 15 °C, t_{wc} –requested temperature of warm water - 40°C. Finally, Q^{y}_{hw} = 688 KW/yr.

For 135 000 residential buildings (families with 3.4 persons) will be 135 000*3.4*((365-21)*0.2+101+0.8*(365-21-101)*(55-15) / (55-40)) =317 GWh per year.

Annual energy consumption for water supply in commercial building is calculated with formula below:

(G+I+k/3.4)*((365-21)*0.2+101+1*(365-21-101)*(55-15) / (55-40)).

Where:

G is the number of commercial buildings (1 bathroom on every 100 m^2) that is used for calculating interior consumption of commercial buildings;

I represents the area of feeding objects (restaurants, bars, etc.) that is used for calculating consumption of visitors and clients;

K is the amount of tourists that is used for calculating hot water consumed in hotels.

Annual energy consumption for water supply in state building is calculated with formula below:

(H+I+k/3.4)*((365-21)*0.2+101+1*(365-21-101)*(55-15) / (55-40)),

Where:

H represents the number of state buildings (1 bathroom on every 200 m^2) that is used for calculating interior consumption of state buildings;

I represents the area of state buildings with the level of hot water consumption (kindergarten, clinic, school, etc.);

K is the number of people under penitentiary system.

3.0 Energy consumption on cooking is calculated according to the results of survey. It was determined that a family with 3 (3.4) persons needs 117 m^3 natural gas annually in village conditions. Ejected energy after burning this amount of natural gas is 117*9.4 KW/m^3=1 099.8 KW annually.

For 135 000 families it will be 1 100*135 000=148 500 000 Kw=148.5 MW annually.

Energy consumption on cooking in commercial sector is calculated with formula below:

(I+K)*L,

Where

I is the number of visitors of feeding objects (restaurants, bars, etc.);

K is the number of visitors of hotels;

L is the amount of energy consumed by feeding objects for cooking for 1 person annually that is 483.8 KWh.

Energy consumption on cooking in state sector is calculated with formula below:

(I+K)*L,

Where

I is the number of persons eating in state buildings with feeding objects (kindergarten, clinic, etc.);

K is the number of people under penitentiary system

L is the amount of energy consumed by feeding objects for cooking for 1 person annually that is 483.8 KWh.

9. Annex IV. Heating degree days

HDDheat, user-defined heating degree days: annual sum of T_b – TM where T_b is a user-defined location-specific base temperature.

Let TM*ij* be the daily mean temperature on day *i* in period *j* and let T_b be a user-defined location-specific base temperature (e.g. needed to heat a building). Then,

DDheat= $\sum_j T_b - TM_{ij}$ where $TM_{ij} < T_b$

CDDcold, user-defined cooling degree-days: annual sum of TM – T_b where T_b is a user-defined location-specific base temperature.

Let TM*ij* be the daily mean temperature on day *i* in period *j* and let T_b be a user-defined location-specific base temperature (e.g. needed to cool a building). Then,

CDDcold = $\sum_j TM_{ij} - T_b$ where $TM_{ij} > T_b$

ID	Indicator name	Definitions	UNITS	ETCCDI index	Sector
HDDheat	Heating degree Days	Annual sum of T_b- TM (where T_b is a user-defined location-specific base temperature and TM < T_b)	°C	N	H
CDDcold	Cooling degree Days	Annual sum of TM - T_b (where T_b is a user-defined location-specific base temperature and TM > T_b)	°C	N	H