



GYUMRI SUSTAINABLE ENERGY AND CLIMATE ACTION PLAN

ENERGY SECURE ARMENIA

March 2024

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ACRONYMS

AMD	Armenian Dram
APP	Autonomous Power Producer
BEI	Baseline Emission Inventory
CAPEX	Capital Expenses
CCSM	Community Climate System Model
CJSC	Closed Joint Stock Company
CNCO	Community Non-Commercial Organization
CNG	Compressed Natural Gas
CO ₂	Carbon Dioxide
ENA	Electric Networks of Armenia CJSC
EPS	Expanded Polystyrene
EU	European Union
GCAP	Green City Action Plan
GOAM	Government of Armenia
GHG	Greenhouse Gas
GHI	Global Horizontal Irradiance
HHP	Hydrometeorological Hazardous Phenomena
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
JRC	Joint Research Center of the European Commission
LED	Light-Emitting Diode
LPG	Liquefied Petroleum Gas
MAB	Multi-Apartment Building

McM(n)	Million Cubic Meters of Natural Gas
NDC	Nationally Determined Contribution
OJSC	Open Joint Stock Company
PV	Photovoltaic
PVC	Polyvinyl Chloride
PVGIS	Photovoltaic Geographical Information System
RA CN	Construction Norms of the Republic of Armenia
SEAP	Sustainable Energy Action Plan
SECAP	Sustainable Energy and Climate Action Plan
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
USD	United States Dollar

UNITS OF MEASURE

kWh	Kilowatt-hour, 1 kWh = 3,600 kJ
MWh	Megawatt-hour, 1 MWh = 1,000 kWh
GWh	Gigawatt-hour, 1 GWh = 1,000 MWh = 1,000,000 kWh
kcal	Kilocalorie, 1 kcal = 1/860 kWh = 4.1868 kJ
kg	Kilogram
ha	Hectare, 1 ha = 10,000 m ² = 100 are
hPa	Hectopascal, 1 hPa = 100 Pa = 9.81 mm H ₂ O = 0.721 mm Hg
l	Liter
m ³	Standard Cubic Meter
McM	Million Cubic Meters
(n)	Normal

t

Ton

W/m*K

Watts per Meter Kelvin

INTRODUCTION

Gyumri's Sustainable Energy and Climate Action Plan (SECAP) was developed by the U.S. Agency for International Development (USAID) Energy Secure Armenia Activity in accordance with the methodology and guidelines of the European Commission's voluntary Covenant of Mayors for Climate and Energy movement¹. The movement involves local authorities as leading actors in the development and implementation of sustainable energy and climate policies, localized via their officially approved SECAPs.

The objective of Energy Secure Armenia is to bolster Armenia's energy security by promoting a shift to renewable energy sources, furthering power market liberalization and trade, and promoting greater energy efficiency. It assists the Government of Armenia (GOAM), the Public Services Regulatory Commission (PSRC), the private sector, and other energy stakeholders to diversify the country's energy supply, reduce dependence on imported gas, and lessen greenhouse gas (GHG) emissions, enabling the Armenian energy sector to serve as a vehicle of long-term economic growth.

Energy Secure Armenia's Activity envisages designing and developing a small-scale integrated pilot project that targets community renewable energy/energy efficiency, including the creation of SECAP.

The community of Gyumri, which was selected as the pilot target site, joined the Covenant of Mayors by the Community Council's Decision No. 71-A of June 6, 2014, committing to the development and implementation of the Sustainable Energy Action Plan (SEAP) aimed at reduction of GHG emission by 20% by 2020. The SEAP was developed in 2017 and accepted by the European Commission Joint Research Center (JRC). On February 2, 2023, Gyumri committed to reach more ambitious mitigation as well as adaptation targets described below by joining the new Covenant of Mayors for Climate and Energy. This SECAP is based on the SEAP as well as on data provided by the municipality, the relevant state authorities, and publicly available sources.

The purpose of this SECAP is to identify measures for climate change mitigation (reducing GHG emissions by at least 35 percent by 2030) and adaptation (increasing the community's resistance to the effects of climate change) as well as the approaches to implement them, deadlines, costs, responsible entities, expected results, and instruments to monitor progress and evaluate achievements.

The team involved in the development of this Plan held a series of consultations and capacity-building events with the partners in Gyumri to lay the groundwork for a smooth implementation process and account for the iterative nature of the data collection and refinement process. During the on-site working meeting held on 13 April 2023 the municipality gave its consent to the development of the baseline emission inventory (BEI) starting 2014 in accordance with the recommendations of the JRC methodology..

The purpose of this document is to outline the progress made thus far and highlight the necessary steps..

¹ Kona A., Bertoldi P., Palermo V., Rivas S., Hernandez Y., Barbosa P., Pasoyan A. *Guidebook-How to develop a Sustainable Energy and Climate Action Plan in the Eastern Partnership Countries*, European Commission, Ispra, 2018, JRC113659

The SECAP reflects Gyumri's current and pending commitments to addressing the mitigation and adaptation challenges of climate change, while transitioning toward sustainable energy solutions, improving the thermal comfort of municipal buildings, and increasing the quality of municipal services. It provides a comprehensive framework for achieving key environmental targets and aligning with national and international climate goals, as well as optimizing municipal budget management.

This SECAP document has been reviewed by the community, and incorporates all available data, stakeholder inputs, and expert analysis.

The SECAP encompasses various components essential for effective climate action planning, including the following:

- A questionnaire was developed and submitted to the municipality so that the departments could properly structure the necessary information, while Energy Secure Armenia maintained continuous communication to support the completeness of the response, including delivering two trainings on SECAP data collection and monitoring for community staff members.
- A preliminary assessment of the municipal energy consumption was conducted, providing a baseline for future measurement and reduction efforts.
- A top-down assessment of GHG emissions based on the above energy consumption data was used to compare the city's carbon footprint with the 2014 baseline.
- An initial analysis of Gyumri's vulnerability to climate change impacts was conducted, identifying key risks and potential adaptation measures.
- Preliminary strategies and measures for reducing GHG emissions and achieving sustainable energy targets were outlined. These strategies will be further refined and expanded based on the city's political will, additional data, and stakeholder engagement.
- An implementation plan was developed, outlining the sequencing, responsibilities, and estimated timelines for the execution of the SECAP measures.

On February 22, 2024 public hearings on the draft SECAP were held in the Gyumri municipality, where all priorities and proposed actions were presented and discussions were organized with the Gyumri community, Council of Elders, non-governmental organizations and citizens, proposals were provided. Suggestions and recommendations received from the stakeholders were taken into consideration and the SECAP was refined before its submission to the Gyumri Council of Elders for final approval..

The SECAP document represents a significant milestone in Gyumri's steps toward sustainable energy and climate resilience, which will serve as a comprehensive roadmap to achieve Gyumri's environmental goals and contribute to a more sustainable future for the community.

1 FOUNDATIONS FOR SECAP ELABORATION

1.1 PURPOSES AND FOCUS SECTORS

The objective of the SECAP is to identify long-term economic, technical, technological, and investment measures to upgrade local energy production in the community, relying on energy performance improvement and the use of renewable resources. These measures are intended to contribute to the wise consumption of energy resources, enhance the community's energy security, reduce GHG emissions, and improve the urban environment. The SECAP aims to strengthen the community's resilience to the effects of climate change through adaptation measures and to help mitigate the energy sector's impacts on global climate change.

In addition to community and state resources, the support of local partners and international organizations is essential, while cooperation with financial institutions is instrumental to implement the proposed measures.

The following sectors are considered as foundational for the purposes of this document: community-owned and public buildings and structures, residential buildings, road transportation, and street lighting.

The following must be addressed:

1. Implementation of energy efficiency and energy saving projects, including by introducing modern energy (green) technologies;
2. Realization of the economically accessible potential of renewable energy sources to expand local energy production;
3. Implementation of measures that will help community institutions reduce energy consumption or use energy more efficiently (including via green procurement practices);
4. Introduction of energy management systems for community structures and implementation of monitoring and control for efficient use of energy sources;
5. Professional assessment of climate risks/hazards and vulnerabilities specific to the community as well as cooperation with scientific entities and experts to revise or update the adaptation measures;
6. Capacity-building on the development of project proposals, fundraising, and project management to help the community implement mitigation and adaptation measures, attract direct investment, and cooperate with relevant stakeholders and beneficiaries; and
7. Awareness raising and information dissemination among the population (especially youth), representatives of community structures, and entrepreneurs on the principles and methods of efficient and economical use of energy resources.

1.2 LEGAL BASES AND METHODOLOGY OF SECAP ELABORATION

The following informational, strategic, and methodological documents served as the bases for the SECAP:

1. JRC, "How to develop a Sustainable Energy and Climate Action Plan (SECAP), Part 1 - The SECAP process, step-by-step towards low carbon and climate resilient cities by 2030, 2018.
2. JRC, "How to develop a Sustainable Energy and Climate Action Plan (SECAP), Part 2 - Baseline Emission Inventory (BEI) and Risk and Vulnerability Assessment (RVA)," 2018.
3. Kona A., Bertoldi P., Palermo V., Rivas S., Hernandez Y., Barbosa P., and Pasoyan A., *How to develop a Sustainable Energy and Climate Action Plan in the Eastern Partnership Countries*, European Commission, Ispra, JRC113659, 2018.
4. Covenant of Mayors and Mayors Adapt Offices, *The Covenant of Mayors for Climate and Energy Reporting Guidelines*, JRC of the European Commission, 2016.
5. Covenant of Mayors—Europe Office, *Reporting Guidance*, 2020.
6. Armenia's Fourth National Communication to the UN Framework Convention on Climate Change (UNFCCC), 2020.
7. *Five-year Development Plan of Gyumri Urban Community of Shirak Marz of the Republic of Armenia, 2022–2026*.
8. *Gyumri's Sustainable Energy Action Plan, 2017*
9. Economic Development and Research Center-United Nations Development Programme - (UNDP), *Residential energy consumption survey: an analytical report*, 2015.
10. Lo Vullo, E.; Muntean, M.; Duerr, M.; Kona, A.; and Bertoldi, P., *National and European Emission Factors for Electricity, 1990–2015 time series in Excel format with country-specific GHG emission factors for electricity consumption*, JRC of the European Commission, 2020.

The SECAP is in line with the key purposes of the following legislative and strategic documents:

1. Law of the Republic of Armenia "On energy," March 7, 2001.
2. Law of the Republic of Armenia "On renewable energy and energy saving," November 9, 2014.
3. Strategic development of the energy sector in the context of Armenia's economic development, June 23, 2005.
4. National Program on Energy Saving and Renewable Energy of the Republic of Armenia, 2007.
5. National Action Plan on Energy Efficiency of the Republic of Armenia, 2010.
6. Action Plan of the GOAM for the Implementation of the National Program on Energy Saving and Renewable Energy of the Republic of Armenia, by GOAM Decision No. 43 of November 4, 2010.

7. Armenia's Energy Security Concept, 2013.
8. Armenia's Intended Nationally Determined Contributions (INDC), 2015.
9. Armenia's Nationally Determined Contributions (NDC), 2021.
10. Comprehensive and Enhanced Partnership Agreement between the European Union and the Republic of Armenia (CEPA), which entered into force in 2021.
11. Strategic Program for the Development of the Energy Sector of the RA (up to 2040), 2021.
12. Armenia's National Communications to the UNFCCC, submitted in 1998, 2010, 2015, and 2020.
13. Armenia's National Adaptation Plan (NAP), 2022.

1.3 FUNDING OPTIONS FOR SECAP IMPLEMENTATION

The implementation of project activities requires significant investments that cannot be funded exclusively from the municipal budget. Therefore, it is necessary to consider all the possibilities to attract both national and international available resources and to apply various funding schemes. An important tool is the funneling of financial flows, both as cost-covering allocations (e.g., subsidies) and as savings-incentive financing (e.g., rewards for reducing the municipal budget's planned expenditure). Another transparent and efficient instrument is to finance energy efficiency and renewable energy projects within the municipality's jurisdiction through a municipal revolving fund. See below for a selection of possible funding options for SECAP activities.

Funding from local sources: In addition to the municipal budget, municipal loans or bonds can be used if secured by state guarantees. Adding these issues to the Five-Year Development Plan of Gyumri Urban Community of Shirak Marz would enable upgrading building energy efficiency, improving the energy performance of urban lighting systems, and financing similar measures by the community. This would enable funding by international financial institutions and donor organizations, which often consider some degree of financial participation as a prerequisite for their own participation (on the principle of co-financing).

Country-level funding sources: National sources include targeted programs and funds, loans, incentives, targeted cash transfers, and others.

State subvention program: The subvention program is implemented by the GOAM for the development of community economic and social infrastructure. Launched in 2018, it is a recent type of community-state horizontal cooperation that offers project co-financing from the state budget if the community submits an infrastructure development project application and receives a positive conclusion from the government (through The Ministry of Territorial Administration and Infrastructure). Depending on the project's sector, distinctive features, geographical location, and impact on the socioeconomic situation in the community, the state budget covers from 30 to 70 percent of the project's total cost. According to the established procedure, subsidy programs can be implemented in 12 sectors, including those directly related to energy saving and renewable energy, namely: construction/repair of street lighting systems, renewable energy (including installation of solar photovoltaic (PV) power plants), construction/reconstruction of kindergartens, reconstruction/construction/repair of public buildings (which are enlisted under community-owned

buildings), and repair and improvement of commonly shared property and premises, including energy saving measures in multi-apartment buildings (MABs).

Financial resources of the population: In the absence of industry, economic enterprises, or other large energy-consuming sectors that are not usual for small and medium-sized communities, or if such sectors are not included in the SECAP, the main energy consumer is usually the residential building sector, which also has the greatest potential to reduce energy consumption and GHG emissions. Without the population's active participation, it is not possible to provide any tangible results in this area under SECAP. Therefore, the municipality should work with the population consistently and encourage their participation in implementing or co-financing activities planned for this sector. If the population shows initiative and engages continuously in the process, the residents would be able to access "soft" and "green" loans, currently operational in several commercial banks. Even partial co-financing by the population, if consistent, would enable and then sustain financial services necessary to strengthen the thermal insulation of their houses and apartments, apply other low-cost measures to reduce the buildings' heat losses, or install energy-efficient heating systems, solar water heaters, or PV systems.

Business as a source of funding: Businesses can promote sustainable energy development technologies such as energy-efficient materials production, entrepreneurship development, etc. They can be involved via advertising, the inclusion of minimum energy requirements in public procurement and planning of orders, co-financing schemes, public-private partnerships, or incentive packages such as international loans and interest compensation or subsidies from the state to ensure soft lending terms.

Financial institutions, funds, and programs: Other key actors are financial organizations, foundations, and programs with grant components whose scopes incorporate climate change mitigation (e.g., energy efficiency and renewable energy) and adaptation. These include the Green for Growth Fund (GGF), Green Climate Fund (GCF), Eastern European Partnership for Energy Efficiency and Environment (E5P), Municipal Project Support Facility, Nordic Environment Finance Corporation (NEFCO), Global Climate Partnership Fund, UNDP Country Office in Armenia (UNDP Armenia), Armenia Renewable Resources and Energy Efficiency Fund (R2E2), Covenant of Mayors – Demonstration Projects (CoM-DeP), and local financing initiatives.

Other sources of funding: These may include international technical assistance funds, local environmental fees of Gyumri, ecological funds, grants, nationwide targeted fundraising, and special financial support funds (subsidies, various types of financial support or compensatory funding).

1.4 MONITORING OF SECAP IMPLEMENTATION

The control, coordination, and monitoring of a community's energy and climate strategy implementation is usually overseen by a department of the local self-governing body formed specifically for this purpose, or by a specialist with the respective qualifications hired specifically for this purpose—the energy manager.

Essentially, having an energy management unit (for example, a department, division, or service) or specialist/responsible (energy manager) as part of the municipality's administrative structure is among the prerequisites for a community to participate in the Covenant of Mayors because it

contributes to the effective implementation of the community's commitments under the Covenant—that is, to the development, implementation, and monitoring of the energy and climate strategy.

Therefore, professionals involved in energy management are among the most important actors under the Covenant, and it is highly desirable that they have education in engineering and energy management, including subjects relevant to adaptation such as environmental studies or nature protection, and communication skills.

In addition, specialists should have access to all information related to the strategy of the respective units and departments of the municipality and to other sectors under the SECAP, such as residential buildings and private houses, private transport, etc.

It is also desirable that the unit or specialist have the skills and authority to cooperate with technical assistance organizations and financial institutions, which can play a significant role in the implementation of the measures identified in the SECAP.

The main functions of the community energy management unit or specialist are:

1. Active participation in strategy development and implementation;
2. Regular collection, recording, and analysis of energy consumption data in the strategy's target sectors;
3. Organization of energy audits, assessments and studies and/or surveys;
4. Implementation of energy management systems in community organizations;
5. Coordination of activities of the municipality's departments and organizations under the SECAP;
6. Cooperation with financial and technical support organizations; and
7. Monitoring of the strategy's implementation and report preparation.

Until the creation of an energy management unit or the involvement of a specialist, the energy management functions under the SECAP will be carried out by the staff secretary of Gyumri municipality, in cooperation with the staff of municipal organizations.

Monitoring of SECAP implementation and submission of reports must be carried out in accordance with the provisions of the Covenant of Mayors through the mycovenant.eumayors.eu platform on the following schedule:

- Simplified monitoring: reports containing only a qualitative description of the measures implemented within the action plans must be submitted once every two years from the moment of the official presentation of the SECAP.
- Full monitoring: a qualitative description of the implemented measures, an assessment of the GHG emissions reduction due to the action plan's implementation, and reports on the upgrade

of the BEI must be submitted once every four years from the moment of SECAP's official submission.

Monitoring project implementation under the community's energy and climate strategy can be more detailed and frequent – for example, once a year (or more frequently) – and broken down into intermediate reporting stages at the local level. This makes it more transparent, quantifiable, and manageable and enables a more objective physical and financial assessment of actual energy consumption as well as the savings and environmental benefits from reducing it.

In addition, a proper monitoring system would allow for a periodic review of the SECAP, taking into account the results of already implemented measures, the expected impact of those not yet implemented, delayed and/or proposed new actions, and changes in the community's priorities. Monitoring would also help the community ensure SECAP alignment with their current strategic issues.

Allocation and management of budget funds to implement the SECAP is carried out per the procedure set forth by the current legislation of Armenia.

2 BRIEF DESCRIPTION OF THE COMMUNITY

2.1 HISTORICAL OVERVIEW

Gyumri, the second city of Armenia, is the center of Shirak Marz and a former industrial center under the Soviet Union. Its area is 4,430 hectares, with a plain relief, covered by 350 meters (m) of lacustrine and volcanic sediment. The territory is furrowed by the gorges of Cherkezi, Jajur, Gyumri, and others. The central part of the city and the Akhuryan Valley, as a natural landscape preservation area, are a part of the Kumayri historical-architectural state reserve-museum. The Mets Kumayri reserve-museum occupies an area of about 1,300 hectares and encompasses 1,170 historical and cultural monuments.

Archaeological monuments from as early as the third millennium BCE have been found in Gyumri. Among the excavated items are bronze objects of the second millennium BCE, iron bracelets and knives from the tenth and ninth centuries BCE, and clay and bronze items from the eleventh to the ninth centuries BCE. In the 1930s, tools and weapons of the Late Bronze and Early Iron Ages were excavated from the ancient settlement: bronze and iron knives, arrows, and spearheads. Some historians associate the ancient name Kumayri with the Cimmerians. Xenophon and historian Ghevond, an Armenian chronicler, also convey information about the settlement of Kumayri.

Before the early 19th century, Kumayri-Gyumri often changed hands between Persia and Turkey, and so it was looted and destroyed many times. The most significant period of the city's development was the 19th century, as it became a part of the Russian Empire along with its surrounding territories in 1804 (earlier than the rest of Eastern Armenia) as a result of the First Russo-Persian war. In 1837, Kumayri was renamed Alexandrapol in honor of the Russian empress. It was officially declared a city in 1840, and it became the center of the newly created Alexandrapol county of Yerevan province in 1849. As a fortress-city on the border, it was an important center of trade and crafts, the largest center of Armenian culture in Transcaucasia. After the Tiflis-Alexandrapol-Yerevan railway line was finished in 1899 and extended to Jugha and Tabriz by 1906, the city became an important railway junction. After Tiflis and Baku, Alexandrapol was considered the third largest trade center in the Caucasus.

A few years after the establishment of Soviet rule in Armenia, in 1924, the city was again renamed Leninakan, this time in honor of Vladimir Lenin. After Armenia became independent in 1991, the city's ancient name of Kumayri was restored for a very short time, and then the name Gyumri was re-established in 1992, a return to the name as it had been known by since the Middle Ages.

On October 22, 1926, an earthquake occurred in Leninakan that impacted the central part of the city. There is no reliable information about the magnitude of the earthquake, but there were almost 300 victims.

On December 7, 1988, a devastating earthquake occurred in the town of Spitak in Lori Marz, also gravely affected Gyumri, with an intensity of 9 points on the MSK-64 scale. Within seconds, many schools, factories, and more than 80 percent of the total residential areas were destroyed. Over 45,000 people, dead or alive, were removed from the rubble by the efforts of the population and

rescuers from all of Armenia; of those, 12,500 people were hospitalized. With the city's industrial basis demolished, more than 40 percent of the industrial enterprises of Armenia closed.

The city has only recently begun to restore its parks and alleys. In Gyumri, streets and urban districts built in the 19th century are still preserved and have been turned into a united open-air Kumayri conservation museum-district. Gyumri was declared the "Cultural Capital of the Commonwealth of Independent States" in 2013 and the "Youth Capital of Armenia" in 2016.

2.2 GEOGRAPHICAL LOCATION OF THE COMMUNITY

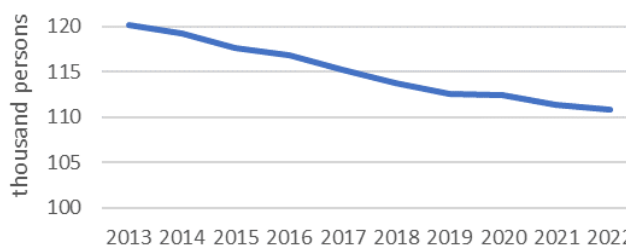
Gyumri's geographical coordinates are N 40°47' and E 43°50'. It is about 120 km from the capital of Yerevan and only 10 km from the Turkish border, in the central part of the Shirak Plain, at an altitude of 1,465 to 1,560 m above sea level, on the left bank of Akhuryan River. The air of Gyumri is invigorating and healthy; the vegetation is steppe; and acacia, maple, ash, and other tree species grow in the river valleys. There are many gushing springs that produce about 1,200 liters of water per second. Akhuryan, one of Armenia's relatively abundant rivers, flows through the territory of the community. In the area surrounding Gyumri, there are deposits rich in building materials: tuff, basalt, diatomite, sand, etc.

The first master plan of the city was drawn up in 1837. In 1925, the chief engineer Alexander Tamanyan developed a new master plan for the city, which was remodeled by architect Davit Chislyan following the earthquake of 1926. Three types of residential two-story houses were proposed to meet the challenge of the local seismic conditions and the social requirements of the time, with a distinct and original structure and appearance: open loggias and staircases, arrow-shaped arches, etc. In the aftermath of the earthquake of 1988, a new master plan was prepared by the Yerevan Project Institute.

2.3 POPULATION

Nearly all of the population in Gyumri are Armenians (94.8 percent), most of whom immigrated from Western Armenia (Erzurum, Kars, Mush). There are also Russians, Ukrainians, Yezidis, Kurds, Greeks, Jews, and Poles, some of whom have organized ethnic unions. Before the devastating earthquake of 1988 and the collapse of the Soviet Union, the population of Leninakan, a developed industrial city, was almost 220,000. Currently, the population is trending downward, as depicted in Figure 1.

FIGURE 1. GYUMRI POPULATION DYNAMICS



Source: Official Population of Armenia, 2013–2022, ArmStat.am

Table 1. DEMOGRAPHIC DATA OF GYUMRI, 2020

REGISTERED POPULATION	GENDER		YEARS OF AGE								
	WOMEN	MEN	UNDER 1 YEAR	1-2	3-5	6-9	10-14	15-17	18-62	63-74	75 AND OLDER
157,454 (110,800*)	83,368	74,086	1,341	2,988	5,253	7,615	9,696	5,268	99,895	18,387	7,011

Source: Database of the Ministry of Territorial Administration and Infrastructure as of 01.01.2020, Five-Year Development Plan 2022–2026

* The National Statistical Service Bulletin for Shirak Marz indicates a substantially smaller population.

2.4 ECONOMY SECTORS

The per capita GDP of Shirak marz is estimated to be about 1.1 million AMD as of 2019². Number of low-income households was about 18 thousand in 2018. According to the Shirak Marz development strategy³, the GDP per capita in Shirak Marz was equivalent to 52% of Armenia’s average GDP per capita in 2017. Over 80% of the approximately 2,150 registered private enterprises are individual entrepreneurs, while less than 1% comprise medium and large sized companies. These are manufacturing enterprises including food, textile, electronics, machinery and metal processing, while most private enterprises are mostly in the retail and service sector. Gyumri acts as the financial services center for the population of the Shirak Marz as branches of 12 banks and six universal credit organizations of Armenia operate in the city. The city initiated, among others, the phasing out of the temporary housing, establishing a Gyumri Technology Centre, and renovation and expansion of the TUMO Centre for Creative Technologies. A key growth sector of the economy in Gyumri is tourism with the growing number of tourists and tourism companies and facilities recently opened supported by an increasing number of flights serving the city. As mentioned above, Gyumri is a major transport hub that is well connected by the interstate highway, the railway station with Yerevan-Tbilisi-Batumi railroad connecting Armenia and Georgia, and Shirak International Airport. Since 2016, with the arrival of low-cost Russian airlines, the airport has dramatically increased its passenger traffic from 12,000 to over 165,000 passengers in 2018. Most of the passengers are seasonal migrant workers commuting between Armenia and Russia. The railway is of critical economic importance as it is used to transport about two-thirds of Armenia’s exports, while the airport is Armenia’s second most internationally significant⁴.

2.5 CLIMATE OF THE CITY

The community is located in a cold climatic zone, where the average temperature in January ranges from –5°C to –12°C and the average monthly temperature in July and August is 19.5°C. Winter is cold and stable, and the snow cover lasts from late November to mid-April. Spring is long and cold. On average, frosts end in mid-May. Summer is short, cool, and wet with changeable weather.

² Marzes of the Republic of Armenia and Yerevan city in figures, 2022, https://www.armstat.am/file/article/marzer_2022_5.pdf

³ <http://shirak.mtad.am/files/docs/37621.pdf>

⁴ Green City Action Plan for Gyumri, 2019, https://ebrdgreencities.com/assets/Uploads/PDF/Gyumri-GCAP_Eng.pdf

Autumn is cold; the first half is dominated by slightly cloudy, warm weather, and in the second half the weather is changeable.

The annual atmospheric precipitation is 498 mm, and maximum daily precipitation is 64 mm. The area is not windy; the average annual wind speed is 1.3 m/s, although it is relatively windy in July at 2.1 m/s. The heating season is 189 days long (with a mean temperature of -2.1°C), and an estimated outdoor air temperature of -25°C (with the coldest five-day period at 98 percent certainty) and the number of heating degree days is 4,177.

The amount of total solar radiation on the horizontal surface is 1,600 kWh/(m²·year), which is about 7 percent below the average in the country. The atmospheric permeability due to cloudiness is 73 percent. The share of direct radiation is 940 kWh/(m²·year), which makes up 58.8 percent of total radiation. The average annual duration of sunshine is 2,500 hours.

2.6 BUILDING STOCK

Gyumri has a large public building stock, of which the majority is under municipal ownership, while schools and universities are under state ownership. As of October 2023, the total surface of the community housing fund is 3.6 million m² with 1,564,285 m² in 1,567 multi-apartment buildings (MABs) - and 2,050,524 m² in 15,036 single-family residential homes (SFH). There are 24,379 apartments in the MABs, with an average of 15.6 apartments per building and an average area of 64 m² per apartment. In 2016, there were 14,350 private homes, including temporary residences, with a total area of 932,750 m² and an average area of 65 m² per private house.

A peculiarity of post-earthquake construction is that it prioritized relatively small residential buildings with pitched roofs. All MABs and private houses are privately owned and 100 percent electrified. Vast majority of Gyumri citizens, about 95%, have access to natural gas⁵. Issues of apartment heat supply are currently being solved at the local level, and no district heating option is available. Due to the sporadic nature of housing construction during the earthquake recovery efforts, the national building norms on energy performance were not always upheld, as the buildings were often designed either according to the donor country's building norms or even with disregard for the building shell's thermal protection. Nevertheless, new districts were formed in the city, with the experience of "building back safer," associated with earthquake relief, taken into account in the design and construction phases. Among them is the residential area Ani, located in the northern part of the city.

2.7 COMMUNITY OWNERSHIP

As Gyumri was selected to be the pilot community, this Project will explore opportunities to help it best utilize the economic, technical, financial, and environmental benefits of sustainable energy investments.

As of 2021, there were 50 organizations with CNCO status, including the municipality building, 21 preschool educational institutions, 12 athletic schools, 5 art schools, 4 music schools, 4 museums and other entities. As of 2016, the total useful area of the reported CNCO buildings was 61,752 m² (per the SEAP 2017). Only 8 of them were constructed after 2000, while 11 were built before World War II. Twenty-five buildings were recently renovated in various ways and to various extents, while

⁵ Ibid, p.27

structural reinforcement is necessary in 19 buildings. All municipal budget institutions meet their energy demand with electricity and natural gas. Other energy carriers (diesel fuel, firewood, etc.) are used episodically to meet the heat demand.

Table 2. OVERVIEW OF THE MUNICIPAL SERVICES OF GYUMRI IN 2018-2019	
Municipal employees (including civil servants)	227
Civil servants	167
CNCO employees	1,510
Women	830
Youth beneficiaries of municipal services (schools, kindergartens, art and athletic schools, etc.)	28,000

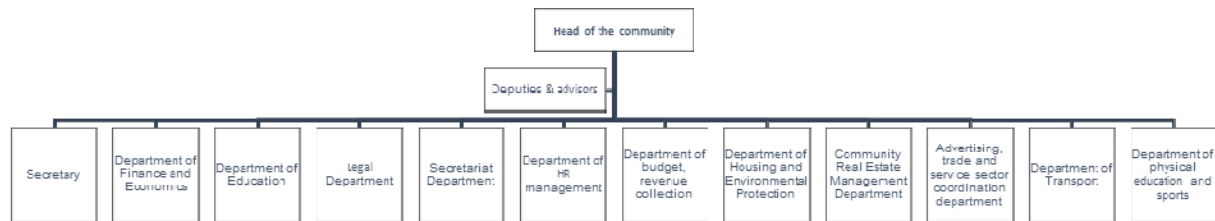
Source: Gyumri Community Passport, 2019

2.8 MANAGERIAL STRUCTURE OF THE COMMUNITY

The Council of Elders of Gyumri city consists of five factions and is the result of local proportional elections held on November 17, 2021.

By the Council’s Decisions No. 202-A of December 10, 2019, and No. 227-A of December 20, 2019, the municipality’s structure incorporates 14 divisions and 3 separate units. There are 227 municipal employees holding political, administrative, discretionary, and community service positions and performing technical maintenance. Details are available on the community’s website.

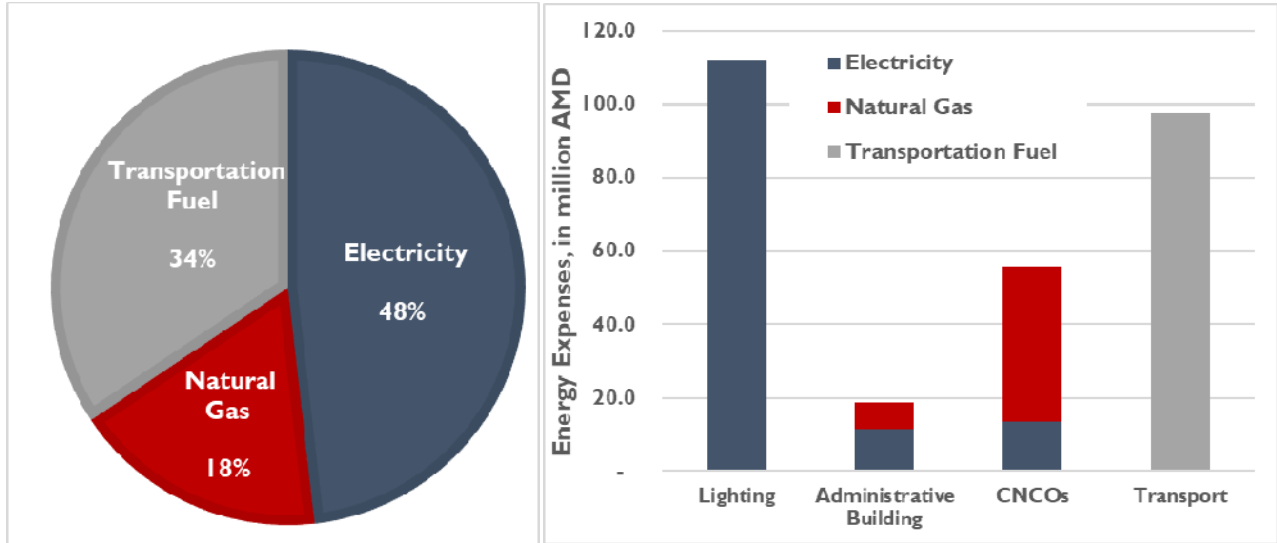
FIGURE 2. STRUCTURE OF GYUMRI MUNICIPAL MANAGEMENT



3 DESCRIPTION OF BASELINE ENERGY CONSUMPTION OF GYUMRI

Gyumri municipality spent nearly AMD 285 million (approximately \$712,500⁶) on energy in 2021, of which nearly half (48 percent) went to electricity (of which 82 percent on external lighting, the rest on office equipment and indoor space lighting), 18 percent to gas-fired space heating, and 34 percent to community-owned public and administrative transport.

FIGURE 3. GYUMRI MUNICIPALITY ENERGY EXPENSES, 2021



Source: Gyumri Municipality, 2023

3.1 INFRASTRUCTURE IN TRANSPORTATION AND ENERGY SECTORS

The public means of transportation are mainly represented by mini-buses (111 in 2022) that burn gasoline, compressed natural gas (CNG) and liquified petroleum gas (LPG), while trucks and road construction vehicles run on diesel fuel. Until 2010, electrified surface transport operated in the city.

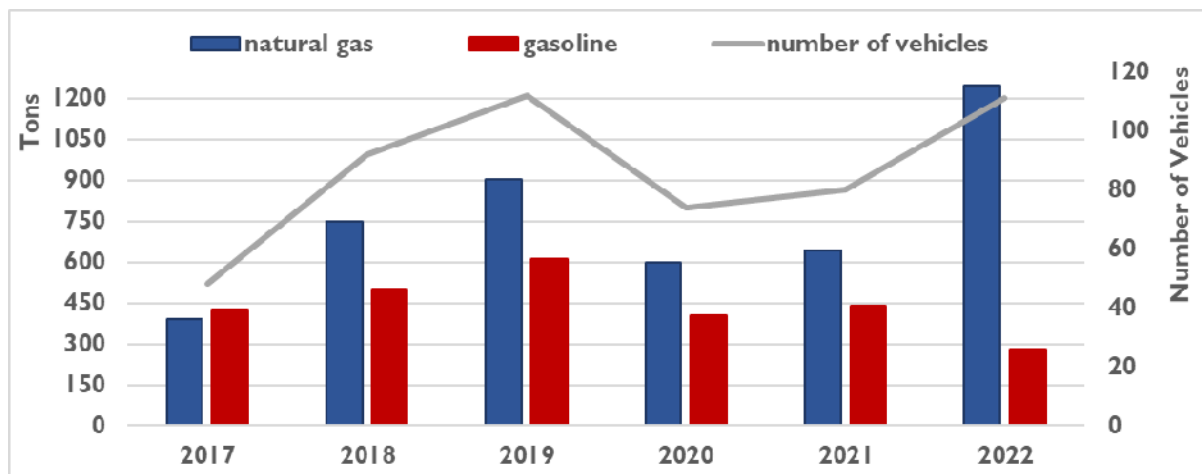
Gyumri is a major railway hub with locomotive and wagon depots and has rail connections with all the neighboring countries, while the city’s modern Shirak International Airport is capable of handling large aircraft.

The city is fully electrified. Gyumri Hydropower Plant was built in 1928 on the Akhuryan River and is still part of the community’s energy system, with installed capacity of 5.3 MW. Before the earthquake of 1988, the city’s heat supply was implemented mainly through centralized systems based on district-scale, grouped boiler houses and boiler houses of industrial enterprises. In general, more than two-thirds of the residential areas were heated from those sources. District heat supply station no. 2 (Mayisyan boiler house) was built about 6 km from the city and commissioned in 1993. It was a Soviet-era project with installed capacity of 314 MW that operated at 15-20 percent load until 2003. It was intended to provide heating supply for apartments in 5,900 MABs in

⁶ Exchange rate: USD 1 = AMD 400.

the newly built Ani, Marmarashen, Mush, and other residential areas as well as steam supply to the industrial district of Hyusisayin.

FIGURE 4. FUEL CONSUMPTION IN PUBLIC TRANSPORTATION



Source: Gyumri municipality, May 2023

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3.2 ENERGY CONSUMPTION IN PUBLIC INSTITUTIONS

The municipal budget of Gyumri finances public institutions and municipal services such as preschools and kindergartens, cultural and athletic institutions, libraries, and museums, as well as the municipality itself. Municipal public lighting (or street lighting), sanitary cleaning of the city, snow collection and removal, and other similar services are also financed by the municipal budget.

A total of 57 public institutions are financed by Gyumri’s municipal budget, of which the largest number are preschools/kindergartens – 23 as of 2014.

Electricity, natural gas, and in some cases diesel fuel and wood are the main energy carriers consumed by public institutions in Gyumri. This excludes motor fuels consumed by road transportation, which is covered separately in upcoming sections.

TYPE OF PUBLIC INSTITUTION	NO. OF INSTITUTIONS	ELECTRICITY, MWH	NATURAL GAS		DIESEL, MWH	WOOD, MWH	TOTAL CONSUMPTION, MWH	TCO2 EMISSION
			McM(n)	MWh				
Municipality	1	249.20	80.60	759.1			1,008.3	212.15
Kindergartens	23	152.07	129.00	1,215.0			1,367.1	281.32
Music schools	6	27.80	19.45	183.2	108.14		319.1	72.44
Sports schools	14	112.46	155.93	1,468.7		68.1	1,649.3	323.22
Museums	4	18.80	3.97	37.4		227	283.2	11.99
Libraries	5	0.99	1.31	12.4			13.4	2.74
Art schools	4	8.25	10.73	101.1			109.4	22.37
Total							4,749.8	926.23

Source: Gyumri SEAP 2017

3.3 LIGHTING SYSTEM IN PUBLIC INSTITUTIONS

In 2014, in all 57 public institutions, including the municipal building, the indoor lighting system comprised 100-watt incandescent lamps. A total of 653 kW of incandescent lamps operates in around 61,752 m² of ventilated (heated, ventilated, or air conditioned) surface area in these buildings. The average specific energy consumption by indoor lighting systems is around 10.58 watts per square meter, which exceeds the standards; specific energy consumption at the Gyumri municipal building is 21.6 watts per square meter, compared to 9.2 watts per square meter at other institutions.

3.4 ENERGY CONSUMPTION BY RESIDENTIAL BUILDINGS

There are 830 MABs occupied by 20,452 people, compared to 14,350 private houses in Gyumri (the total number of households is 34,800). Electricity, natural gas, and wood are the main energy carriers consumed by the residential sector, with natural gas having the largest share (63 percent)

Table 4. ENERGY CONSUMPTION AND CO2 EMISSIONS BY Residential Buildings, 2014

TYPE OF RESIDENTIAL INSTITUTION	ELECTRICITY, MWH	NATURAL GAS		WOOD		TOTAL CONSUMPTION, MWH	TCO ₂ EMISSION
		McM(n)	MWh	McM	MWh		
MABs	34,120	14,146	133,238	16.67	37,850	205,208	34,966
Private houses	29,630	16,668	156,990	30.97	70,293	256,913	38,705
Total	63,750	30,814	290,228	47.64	108,143	462,121	73,671

Source: Gyumri SEAP 2017

3.5 ENERGY CONSUMPTION BY ROAD TRANSPORTATION

Transportation includes the community-owned fleet as well as public and private means of transportation. Gasoline, diesel, LPG and CNG are the main fuel types consumed for road transportation. Electric buses, the subway, trams, and electric vehicles are not used in Gyumri (as of 2014).

In order to convert the physical units of consumed energy carriers into energy units (MWh), the following conversion factors are used, in accordance with the JRC's guidebook, "How to develop a Sustainable Energy and Climate Action Plan (SECAP):"

- Gasoline: 9.2 kWh/liter or 12.3 kWh/kg, density: 0.75 kg/liter
- Diesel fuel: 10 kWh/liter or 11.9 kWh/kg, density: 0.84 kg/liter
- Natural gas: 8,100 kcal/m³(n) or 9.419 kWh/ m³(n) (approximate annual average)

Only data on consumption of CNG were obtained from an official source, Gazprom Armenia CJSC, whereas the data on consumption of other energy carriers are based on expert evaluation. The following tables indicate the number of vehicles per type (passenger car, truck, etc.), purpose of use (private, public, community-owned), and type of fuel consumed, along with the amount of fuel consumed in 2014.

Table 5. TYPE, PURPOSE, AND ENERGY CONSUMED BY DIFFERENT MEANS OF TRANSPORTATION, 2014

VEHICLE TYPE	PURPOSE	CNG	GASOLINE	DIESEL	TOTAL	CNG, McM(N)	DIESEL, THOUSAND LITERS
Minibus	Public	85	0	0	85	2,295	
Bus	Public	11	0	0	11	400.95	
Passenger car	Community	13	0	0	13	29.25	
Truck	Community	4	0	3	7	17.28	12.6
Waste collection vehicle	Community	3	0	8	11	43.2	32.4
Water tanker	Community	4	0	0	4	15.36	
Road construction vehicle	Community	0	0	4	4		25
Crane	Community	1	0	0	1	2.8	
Other	Community	0	0	10	10	0	12
Passenger car	Private	12,679	3,169	171	16,019	15,327	574.6
Truck	Private	1,386	0	808	2,194	3,686.07	9,308.2
Bus	Private	475	0	96	571	1,320.68	1,575.9
Minibus	Private	221	0	36	257	454.17	383.6
Special vehicle	Private	0	96	0	96		
Total transport		14,882	3,265	1,136	19,283	23,591.76	11,924.3

Source: Gyumri SEAP 2017

Table 6. ENERGY CONSUMED PER PURPOSE OF USE AND FUEL TYPE (MWH/YR), 2014

PURPOSE OF USE	CNG	GASOLINE	DIESEL
Public	25,521.20		
Community-owned	1,021.30		822.30
Private sector	195,803.30	73,470.10	118,422.70
Total transport	222,345.80	73,470.10	119,245.00

Source: Gyumri SEAP 2017

CNG is the most widely consumed fuel in the Gyumri transportation sector. Trends indicate that gasoline will be substituted with CNG, considering the economic aspects for end users, this which will also have a positive impact in terms of reducing CO₂ emissions by the transportation sector.

3.6 URBAN LIGHTING SYSTEM

Urban lighting is another major power consumer in the municipal economy. In 2014, Gyumri had about 110 km of lit road, with approximately 4,392 luminaires with installed capacity of 1.2 MW. They 2,088 MWh/year they provide does not meet the full electricity demand due to incomplete lighting, the delayed replacement of broken bulbs, and the failure to deliver the quality of lighting required by standards. If the lighting on all streets is brought to the required level, electricity consumption will increase further.

Table 7. TECHNICAL SPECIFICATIONS OF THE URBAN LIGHTING SYSTEM, 2014

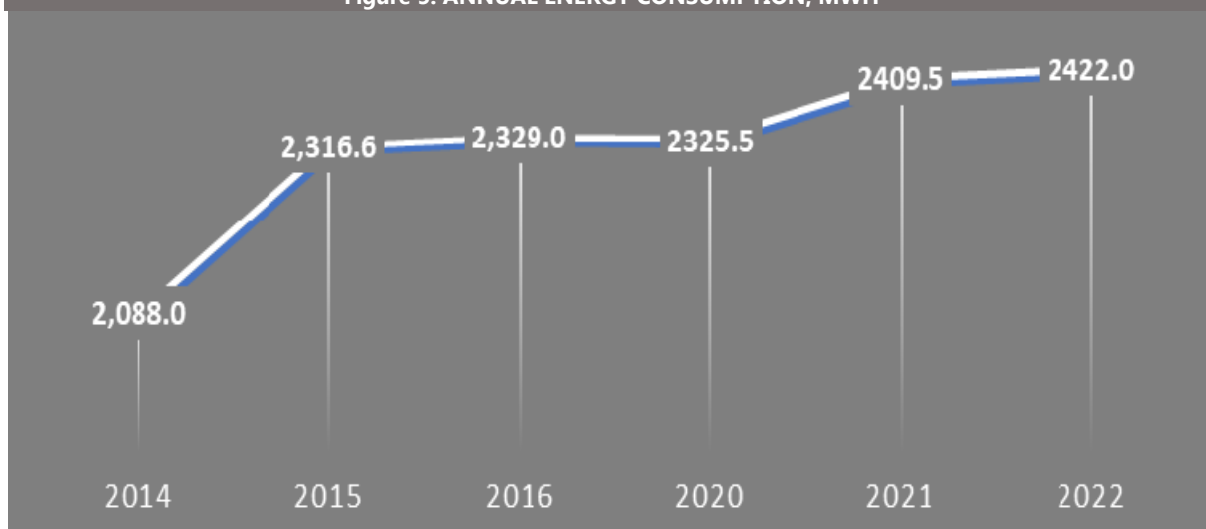
CHARACTERISTICS	UNIT	VALUE
Total number of lighting poles	piece	4,392
Total number of lamps	piece	4,392
Sodium-vapor lamp	piece	2,251

Table 7. TECHNICAL SPECIFICATIONS OF THE URBAN LIGHTING SYSTEM, 2014

CHARACTERISTICS	UNIT	VALUE
	watt	250
Mercury lamps	piece	1,500
	watt	400
Neon lamps	piece	240
	watt	25
LED lamps	piece	401
	watt	48
Total power of lamps	kW	1,188
Annual energy consumption	MWh	2,088
Daily operating hours in cold season	hours per day	6
Daily operating hours in hot season	hours per day	4
Overall distance of lit roads	km	110

Source: Gyumri SEAP 2017

Since then, the distance of illuminated roads has grown from 110 km to 200 km. This increase in lit road distance aligns with the rising trend in the annual energy consumption of street lighting, as depicted in the figure below.

Figure 5. ANNUAL ENERGY CONSUMPTION, MWH

Source: Gyumri SEAP 2017; Gyumri Municipality, 2023

Gyumri uses light-emitting diode (LED) lightbulbs for over 80 percent of its illuminated streets, which promotes energy efficiency and introduces the public to the use of energy-saving technologies in their everyday lives. In the meantime, lighting for 40 percent of community roads has yet to be raised to modern standards.

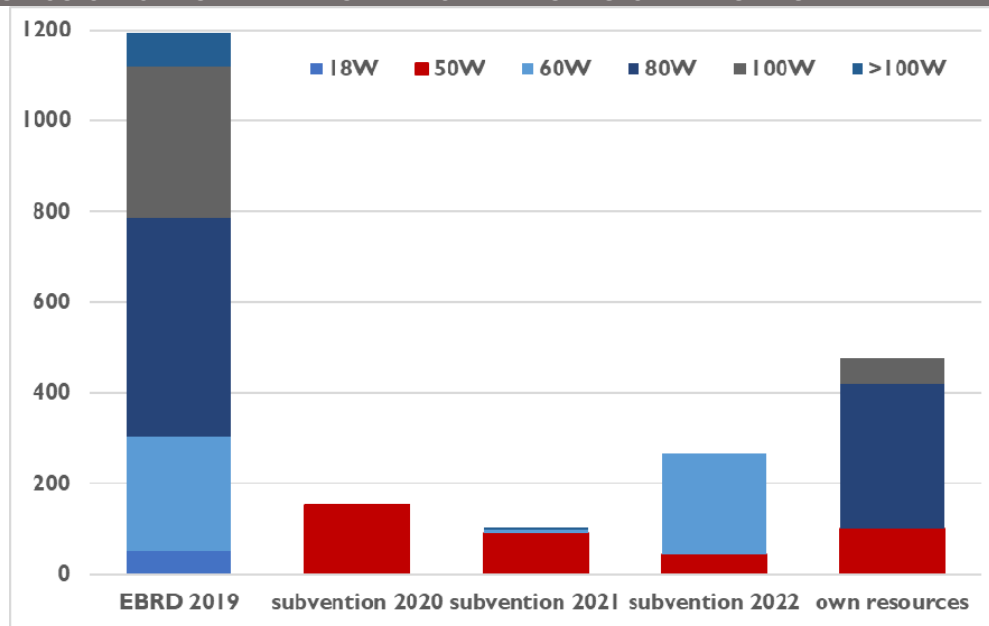
Table 8. KEY TECHNICAL PARAMETERS OF GYUMRI STREET-LIGHTING INFRASTRUCTURE IN 2021

INDICATOR	UNIT OF MEASURE	MAGNITUDE
Network length	km	400
Luminaire quantity including LEDs	piece	6,100
		5,000
Share of community roads lit	%	60
Energy consumption in 2021	AMD million	112.11

Source: Gyumri Municipality, March 2023

The below graph presents the cumulative number of new LEDs installed over the past few years, grouped by the year and financing source.

Figure 6. STRUCTURE OF INSTALLED LED STREET LUMINAIRES IN GYUMRI BY CAPACITY



Source: Gyumri Municipality, May 2023

3.7 MUNICIPAL WASTE MANAGEMENT

According to summary information from the Environmental and Mining Inspectorate Body and those municipalities that implement organized waste collection, 88,736,000 tons of waste were generated in Armenia in 2021, with 55.4 percent transported to landfills. That year, 487,400 tons of solid household waste were transported to landfills, including 461,200 tons delivered to urban landfills –164.5 kg per capita and 243.7 kg per urban resident. The share transported solid waste of Shirak Marz was 19,600 tons, or about 4 percent of the country’s total. Industrial waste in Armenia made up the other 88,248,600 tons (29.8 tons per capita); Shirak Marz’s share in this type of waste was miniscule, below one fifth of 1 percent of the total, 6.6 kg per capita.

4 OVERALL CONSUMPTION OF ENERGY CARRIERS AND BASELINE EMISSION INVENTORY (BEI)

Gyumri’s BEI is set at the 2014 level, in agreement with the municipality and in accordance with the JRC’s guidebook, “How to develop a Sustainable Energy and Climate Action Plan (SECAP): Part 2 – Baseline Emission Inventory (BEI) and Risk and Vulnerability Assessment (RVA)”, point 2.5.3: “The signatories who already have a commitment for 2020 targets shall continue to monitor and report on the progress to 2020 while starting reporting on 2030 targets. They shall use the same baseline year for the 2030 target in order to ensure that their 2030 commitment is a continuation of the ongoing efforts. Changing the baseline year can be made only in exceptional circumstances, in which, using the original baseline year, it is not possible to compile a consistent time-series from BEI to 2030”. This decision also relied on the availability of accurate historical data on consumption of energy carriers by BEI sector, which is why progress in reducing GHG emissions by 2030 will be compared to the levels of the baseline year 2014.

4.1 TOTAL ENERGY CONSUMPTION BY GYUMRI

Energy carriers consumed by the BEI sectors are electricity, natural gas, CNG, gasoline, diesel fuel, and wood. The sole transmitter and distributors of electricity and natural gas are, respectively, Electric Networks of Armenia (ENA) CJSC and Gazprom Armenia CJSC. Services provided by these companies and retail tariffs are governed by the Public Services Regulatory Commission.

The BEI was established based on the dataset provided by utility service providers and the respective departments of Gyumri municipality.

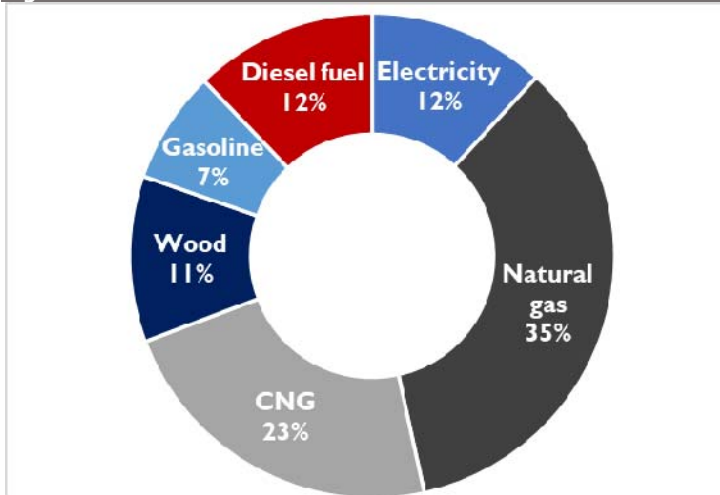
Table 9. TOTAL CONSUMPTION OF ENERGY CARRIERS, CO₂ EMISSIONS BY GYUMRI, 2014

ENERGY CARRIER	TOTAL CONSUMPTION		CONSUMPTION, MWH	TCO2 EMISSION
Electricity	GWh	115.94	115,940.00	27,361.84
Natural gas	McM(n)	36,100.10	340,027.09	68,685.47
CNG	McM(n)	23,606.1	222,345.87	44,913.87
Wood	McM(n)	47.77	108,437.90	-
Liquid motor fuels	Thousands of liters	19,910.4	192,715.08	50,132.47
<i>Gasoline</i>	Thousands of liters	7,985.9	73,470.10	18,294.05
<i>Diesel fuel</i>	Thousands of liters	11,924.5	119,244.99	31,838.41
		Total	979,465.94	191,093.65

Source: Gyumri SEAP 2017

According to the table above, 57.4 percent of consumption is of natural gas (including CNG), where CNG is the most common energy carrier used for transportation. Meanwhile, electricity, wood, and diesel fuel are consumed almost equally in Gyumri as of the baseline year.

Figure 7. Structure of TOTAL CONSUMPTION OF ENERGY CARRIERS IN GYUMRI, 2014



Source: Gyumri SEAP 2017

As of 2014, annual energy consumption per capita in Gyumri was 8.18 MWh.

4.2 KEY SOURCES OF GHG EMISSIONS

The BEI only covers carbon dioxide (CO₂) as the key GHG emission. Emissions of methane (CH₄), nitrogen dioxide (NO₂), fluorocarbons, and other derivatives as well as fugitive emissions are not considered in the BEI.

The following sources of CO₂ emissions are considered in the scope of Gyumri's SECAP:

- CNCOs, including the municipality, where the consumption of electricity, natural gas, and wood are the main sources of GHG emissions;
- The residential sector, where the consumption of electricity, natural gas, and wood are the main sources of GHG emissions;
- The urban external lighting network, which only consumes electricity; and
- Transportation, where consumption of gasoline, diesel fuel, and CNG are the main sources of GHG emissions.

4.3 BASELINE EMISSION INVENTORY

A BEI is established based on the amount of energy consumed from certain energy carriers by BEI sectors during the baseline year, in this case 2014. Road transport covers both public and community, as well as private and commercial transport that use gasoline as energy carrier. Switching from gasoline to CNG does not result in considerable energy savings; however, the environmental impact can be reduced by 19 percent, as the emission factor of gasoline is 0.249 tCO₂/MWh and that of CNG is 0.202 tCO₂/MWh.

BEI quantifies the amount of CO₂, or CO₂-equivalent emissions produced mainly due to energy consumption in the territory of the local authority during the selected baseline year, which is 2014 in the case of Gyumri. The BEI identifies the principal anthropogenic sources of CO₂ emissions and allows prioritizing the mitigation measures accordingly. Two sets of coefficients were used to convert the energy factors and to estimate GHG emissions.

Table 10. ENERGY CONVERSION FACTORS AND INDICES USED IN CALCULATIONS

Natural gas	9.41 kWh/m ³	Corresponds to the lower heat of combustion of gas, 8,100 kcal/m ³
Gasoline	9.2 kWh/l	or 12.3 kWh/kg
Diesel fuel	10 kWh/l	or 11.9 kWh/kg
Firewood	2.49 MWh/m ³	Corresponds to the lower heat of combustion of firewood, 3,000 kcal/m ³ . Volumetric mass of firewood is taken as 710 kg/m ³ .
Livestock biomass	4.19 kWh/kg	or 3,600 kcal/kg dry weight

Source: JRC of the European Commission

Table 11. COEFFICIENTS USED TO ESTIMATE GHG EMISSIONS

Electrical energy	0.236 tons CO ₂ /MWh
Natural gas	0.202 tons CO ₂ /MWh
Automotive gasoline	0.249 tons CO ₂ /MWh

Table 11. COEFFICIENTS USED TO ESTIMATE GHG EMISSIONS

Diesel fuel	0.267 tons CO ₂ /MWh
Firewood (non-sustainable)	0.403 tons CO ₂ /MWh
Firewood (sustainable)	0 tons CO ₂ /MWh - According to the Covenant of Mayors' methodology, in sustainable forest management or wood growing, emissions from fuelwood burning are considered to be zero. Sustainable forest management means that forest growth equals or exceeds the volume of deforestation, on average.
Firewood (actual)	0.121 tons CO ₂ /MWh The emission factor of firewood is assumed to be 0.121 tons CO ₂ /MWh for the purposes of this SECAP.
Livestock biomass	0 tons CO ₂ /MWh

Source: JRC of the European Commission

Table 12 indicates consumption of energy carriers and respective CO₂ emissions by BEI sectors.

Table 12. TOTAL CONSUMPTION OF ENERGY CARRIERS AND RESPECTIVE CO₂ EMISSIONS BY GYUMRI, 2014

ENERGY CARRIER	BEI SECTORS				TOTAL CONSUMPTION, MWH	TCO ₂ EMISSION
	CNCOS AND MUNICIPALITY	RESIDENTIAL SECTOR	ROAD TRANSPORT	PUBLIC STREET LIGHTING		
Electricity	569.58	63,750.0		2,088.0	66,407.6	14,742.5
Natural Gas	3,776.94	290,227.7			294,004.6	59,388.9
Wood	295.10	108,143.0			108,438.1	0.0
CNG			26,542.5		26,542.5	5,361.6
Gasoline*			73,470.1		73,470.1	18,294.1
Diesel fuel	108.14		822.3		930.4	248.4
Total	4,749.76	462,120.7	100,834.9	2,088.0	569,793.4	98,035.5

* Only private and commercial means of transportation.

Source: Gyumri SEAP 2017

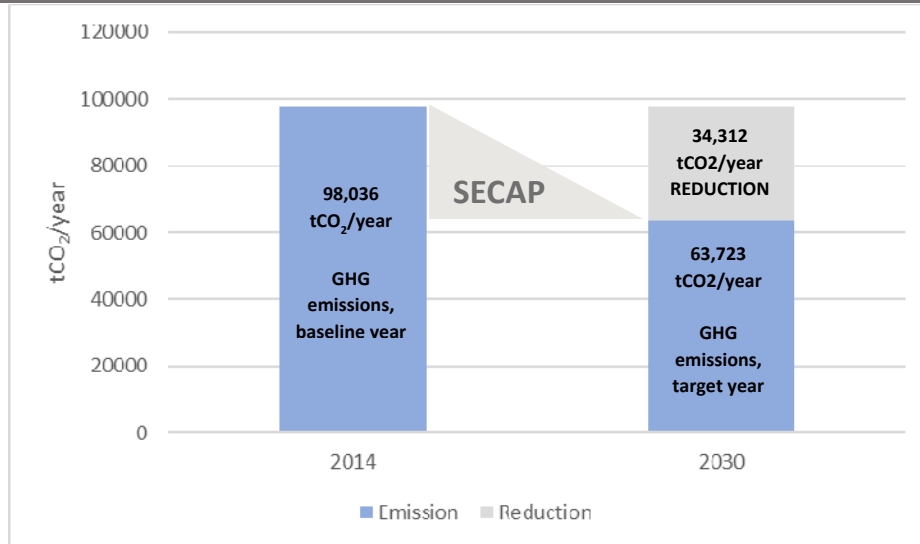
The total CO₂ emissions from the four BEI sectors is 98,035.5 tons, which is around 51.3 percent of the total CO₂ emissions due to consumption of energy carriers by Gyumri in 2014.

4.4 CO₂ EMISSIONS REDUCTION TARGET COMMITMENTS

The CO₂ emissions reduction target is set as an absolute reduction, compared to the overall emissions accounted for in the BEI (referring to tons of CO₂-eq). Therefore, Gyumri commits itself to cut emissions by 35 percent of its baseline emissions by 2030, which is equal to:

$$98035.5 \times 0.35 = 34,312.43 \text{ tCO}_2$$

Figure 8. GRAPHICAL ILLUSTRATION OF THE GHG EMISSION REDUCTION TARGET



Source: Expert estimations based on the JRC methodology, 2023

Gyumri will reduce 34,312 tons of CO₂ per year, of which 90 percent will be achieved by the implementation of hard measures described in Section 5, while the other 10 percent will be achieved by implementing the soft measures defined in Section 7.

Hard measures, will require \$64.2 million in investment and will reduce emissions by 30,851 tCO₂ per year. The hard measures include EE retrofits and the integration of RES, mainly through installing solar PV systems at CNCOs and other municipal services, such as but not limited to urban lighting and public transport.

By implementing soft and hard measures, Gyumri will reduce consumption of energy carriers by around 154,213 MWh and CO₂ emissions by 34,312 tons per year. Implementing both types of measures will require over \$64.6 million in investment by 2030 (see more in Table 47).

Continuous and consistent implementation of the proposed measures largely depends on the city's commitment to promote the climate action agenda and on its persistence in the efforts to involve the residents and businesses in activities. Furthermore, hard measures are technical and investment-intensive in nature, so there are enough tools to precisely assess their effectiveness, while evaluating soft measures' impact relies primarily on expert judgement.

Note: The targets are subject to verification and ambition for soft and hard measures will need to be discussed and potentially revised with the local Gyumri administration.

5 HARD MEASURES

According to GOAM Decree 1504-N dated December 25, 2014, “On the application of measures aimed at improving energy efficiency and energy saving in facilities being built (reconstructed, repaired) at the expense of state funds,” the following energy saving and EE measures should be applied in order to reduce the amount of thermal and electric energy consumption of buildings/facilities, reduce their operating costs, and ensure the required comfort level:

1. Thermal insulation of the building envelope elements
2. Application of technical solutions that will reduce the total surface area of the building envelope
3. Application of coating, plaster, and water-resistant and heat-resistant paints on external surfaces of walls
4. Application of energy-efficient windows and doors
5. Sealing of all joints of openings, external walls, and roof elements
6. Application of certified insulating materials
7. Application of energy-efficient heating, ventilation, air conditioning, hot water supply, and lighting systems and equipment
8. Application of renewable sources of energy, e.g., solar water heating and PV systems

Measures proposed in this chapter are in line with the abovementioned requirements.

5.1 ENERGY-EFFICIENT MODERNIZATION OF PUBLIC BUILDINGS

The efficiency of energy use in Gyumri’s municipal economy is quite low, which is largely due to persistent budget limitations, lack of awareness and institutional capacities, and the failure of the policy framework, which does not have adequately enforceable provisions to incentivize or mandate EE in buildings. The typical interventions mainly focus on internal periodic repairs, which have minimal or no energy saving potential. Armenia’s regulatory framework still has significant gaps in compliance for energy efficiency in buildings⁷. Moreover, there is a notable lack of experience and capacity to transition to state-of-the-art EE and performance-based regulations.

The energy losses identified in ten analyzed public buildings (kindergartens, as well as art and athletic facilities) stem from high thermal losses from the building envelopes (walls, windows, doors, and roofs) as well as the low efficiency of heating and lighting devices. Given the high number of heating degree days in Gyumri, insulation (10 cm expanded polystyrene [EPS]) and the replacement of old wooden windows with polyvinyl chloride (PVC), vacuum-sealed windows with higher thermal resistance properties are expected to reduce the specific energy consumption in

⁷ EU4Energy, “Armenian Building Energy Efficiency Regulatory Review, Comparison with EU Best Practices and Recommendations for Enhanced Enforcement of Minimum Energy Performance Requirements in Buildings,” 2018.

those buildings by nearly half, helping buildings achieve the desired thermal comfort levels while saving on energy bills.

The state of disrepair of the internal walls, ceilings, and leaking roofs indicates that isolated energy efficiency and renewable energy measures cannot be sustainable solutions, because the buildings require indoor remodeling/renovation; capital replacement of asbestos roofs; installation of new, metal-based roof covers; insulation (20 cm expanded perlite sacks or 100 mm polyurethane spray foam application) with proper structures; and augmented canopies for the expansion of rooftop PV. To ensure proper indoor air quality, the team recommends installing forced ventilation with heat recovery units at the kindergartens and athletic facilities.

The most underheated spaces—the performance and athletic halls—require the installation of additional heating capacities. Given these buildings’ interrupted use schedule (two to three hours per day for competitions or performances), they would strongly benefit from the installation of high-efficiency electric heating systems (infrared heaters or heat pumps), which could benefit from the green energy supply while providing adequate thermal comfort.

The lighting systems are inefficient and, while replacing CFL or fluorescent tube lights seems like an evident choice, the use of artificial lighting is quite limited in the kindergartens, whereas the athletic facilities lack adequate lighting capacity to produce enough light for precision, color rendering, and efficiency at the same time.

5.1.1 MITIGATION MEASURES IN PUBLIC BUILDINGS

The community has selected and listed seven public buildings operating as athletic facilities in 2023–2024 state subvention program applications. The energy-saving potential in these facilities is estimated to be up to 50 percent due to high infiltration losses and lack of insulation in the building shell elements as well as the outdated and inefficient heating, ventilation, and lighting technologies in use.

Based on walk-through energy audits and analysis of energy bills, these buildings have the potential to save up to 180 MWh/year on thermal and electrical energy, which can be achieved by insulating different building shell components and replacing fenestration, installing LED lighting and heat recovery units, and renewing/modernizing heating systems and thermal networks. Due to degraded internal finishes, it will be necessary to include internal renovation measures to improve the inside conditions of these facilities.

5.1.1.1 MITIGATION MEASURE: CARRY OUT ENERGY-EFFICIENCY RETROFITS OF PUBLIC BUILDINGS

Proposed actions: The following energy-efficiency works are proposed for public buildings:

1. Insulation of attic floor with expanded perlite sacks (200 mm thick) with underlying vapor barrier
2. Insulation of external walls with EPS foam boards (100 mm thick, with thermal conductivity of $\leq 0.042 \text{ W}/(\text{m} \times \text{K})$)
3. Insulation of basement ceiling with EPS foam boards (80 mm thick)
4. Installation of windows and doors in commonly owned premises (entrances and stairways) with aluminum- and PVC-framed, double-glazed units

5. Installation of forced ventilation and heat recuperation system
6. Replacement of current heating system with condensation boilers for training spaces and infrared heaters or heat pumps for large halls (with high ceilings and designated for large audiences)

Table 13. EXPECTED RESULTS FROM EE MEASURES IN ALL 50 PUBLIC BUILDINGS

IMPLEMENTING BODY	INVESTMENT COST (THOUSAND USD)	TOTAL ENERGY SAVING (MWH/YEAR)		CO ₂ EMISSIONS REDUCTION (TCO ₂ /YEAR)
		Electricity	Natural Gas	
Gyumri Municipality	14,600*	313.6	1254	327

* The estimate is intended for the full capital renovation of the buildings, of which only \$4.5 million is intended for energy efficiency measures.

The majority of the remaining public buildings operated by local CNCOs are in dire need of similar interventions, but at this stage, only the above seven athletic facilities have been politically approved for capital investments. The Energy Secure Armenia team will work with Gyumri to include additional measures for other public buildings, including kindergartens and cultural facilities.

5.2 ENERGY-SAVING MEASURES IN RESIDENTIAL BUILDINGS

Due to high energy bills, households only heat selected parts of the house, underheat those spaces, and partially limit occupancy of owned space in the winter. While electricity use is lower because there is less use of lighting and limited appliance ownership (26.57 kWh/m² in residential buildings), due to fierce winters, households cannot further reduce the use of electricity. Although heat is not very affordable, heating energy consumption has been continuously growing and is objectively rated as “red” (374.97 kWh/m² in residential buildings). In the household/residential sector, natural gas consumption is offset by significant use of firewood, which was quantified in Gyumri SEAP. While this is a trend throughout Armenia, in Gyumri and Shirak Marz in general, the indicators are higher due to the significantly colder climate and longer heating season. The use of firewood is a desperate measure to deal with growing utility bills, so this indicator should be considered a priority. The only way to reduce firewood consumption is to raise the efficiency of energy use by promoting energy-efficient stoves/boilers, insulating building envelopes, raising awareness, and conducting outreach.

The dynamics of energy consumption in Gyumri is presented in the diagrams below. In 2022 compared to 2014, the electric power consumption changed by a negligible amount for MABs and decreased by about 20 percent for private houses, while natural gas consumption increased by more than 30 percent for both GHGs and private houses. Natural gas is consumed mostly by private houses, which may be due to the prevalence of individual boilers.

Figure 9. ELECTRIC POWER CONSUMPTION IN RESIDENTIAL SECTOR, MLN KWh

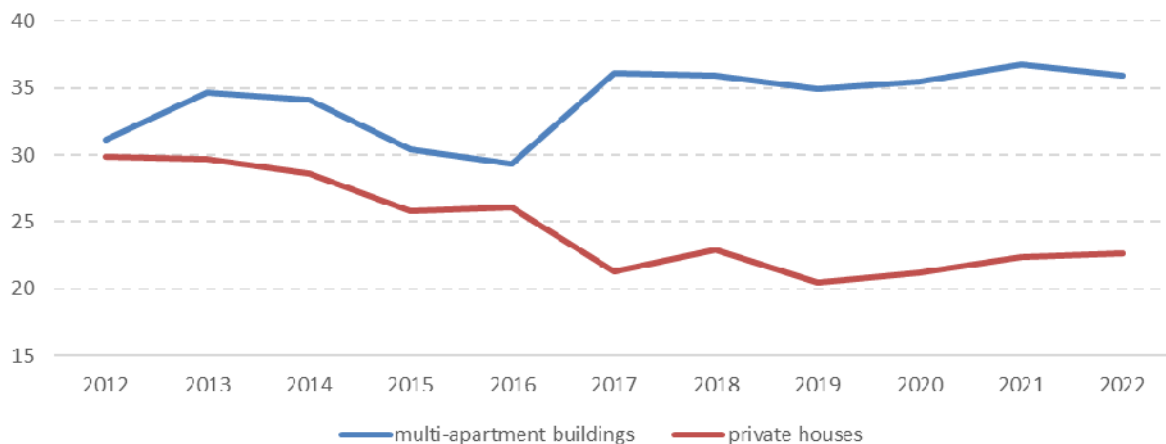
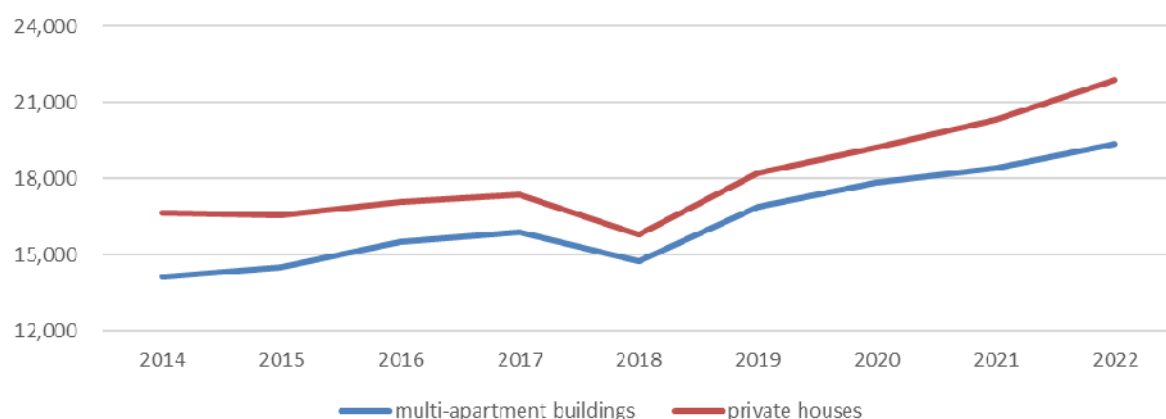


Figure 10. NATURAL GAS CONSUMPTION IN RESIDENTIAL SECTOR, THOUSAND M³



As Shirak Marz is in Armenia’s coldest climate zone, and heating poses a major affordability issue for the population, Energy Secure Armenia advises the municipality to continue its efforts to insulate MAB facades, like the three buildings that were committed to co-financing with the UNDP/Green Climate Fund Project on De-risking and Scaling-up Investments in Energy Efficiency in Building Retrofits.

5.2.1 MITIGATION MEASURES IN RESIDENTIAL BUILDINGS

Based on the findings of energy audits and energy-efficiency retrofits conducted by implementing partners, the building shell components’ thermal characteristics do not comply with the construction codes in force on thermal protection of buildings and provide insufficient indoor thermal comfort due to the intentional underheating of apartments. Households deliberately choose to underheat their homes so they can afford their monthly energy bill.

Consequently, insulating building envelopes will not only save energy and reduce utility bills, but also improve indoor thermal comfort (retrofit designed to achieve 100 percent thermal comfort), leading to reduced cold-related illnesses.

5.2.1.1 MITIGATION MEASURE: CARRY OUT ENERGY-EFFICIENCY RETROFITS OF MABS

Proposed action: apply energy-efficiency measures in 100 typical MABs, either separately per measure or per building or concurrently as a large-scale investment project.

1. Insulate attic floors, with an area of around 2,100 m², with expanded perlite sacks (200 mm thick) with underlaying vapor barrier.
2. Insulate external walls, with an area of around 4,700 m², with EPS foam boards (100 mm thick, with thermal conductivity of ≤ 0.042 W/(m x K)).
3. Insulate basement ceilings, with an area of around 2,500 m², with EPS foam boards (80 mm thick).
4. Install windows and doors in commonly owned premises (entrances and stairways) with aluminum- and PVC-framed, double-glazed units.
5. Install new LED lighting systems in commonly owned premises (entrances and staircases), embedded with motion and light sensors. This can be coupled with small rooftop solar systems, which can supply the total amount of energy associated with lighting consumption.

Proposed action: Perform non-energy efficiency works.

1. Replace roof cladding with galvanized sheeting, including rainwater management system components.
2. Install basalt plinth, accessibility ramps, and sidewalk around the building.

Considering the benefits listed above, the project recommends that Gyumri dedicate attention and funding to energy-efficiency retrofits of MABs. The municipality has applied for a state subvention to partially retrofit 100 MABs, but all its investment ideas are primarily roof repairs, partial insulation of rooftops, and replacement of doors and windows in stairways, while a more extensive and comprehensive focus on energy efficiency should be considered due to the high number of heating degree days in Gyumri and the associated potential thermal energy-saving gains. Through the application of full-fledged (building envelope insulation) interventions, there is potential to reduce up to 150 kWh/m²/year in targeted residential buildings in Gyumri.

Table 14. EXPECTED RESULTS FROM EE MEASURES IN 100 RESIDENTIAL BUILDINGS

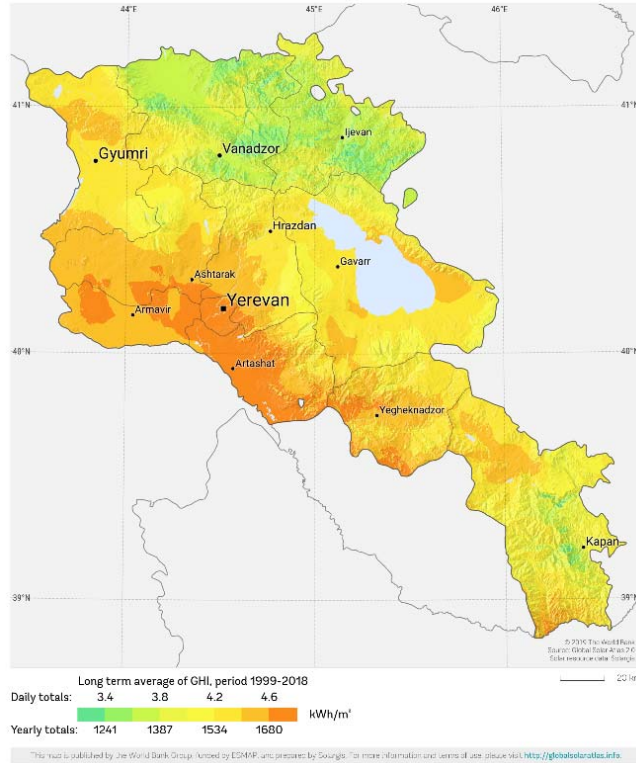
IMPLEMENTING BODY	INVESTMENT COST (THOUSAND USD)	TOTAL ENERGY SAVING (MWH/YEAR)		CO ₂ EMISSIONS REDUCTION (TCO ₂ /YEAR)*
		Electricity	Natural Gas*	
Gyumri Municipality	25,000	29,121	95,985	26,262

* Average over seven years, from 2024 to 2030

5.3 APPLICATION OF RENEWABLE SOURCES OF ENERGY

According to the Solar Map of Armenia generated by SOLARGIS, Gyumri is located in a territory with relatively high solar resource. The annual global horizontal irradiance (GHI) of the territory varies between 1,534 and 1,610 kWh/m² which exceeds that of most European Union countries.

FIGURE 11. SOLAR IRRADIATION AND PV POWER POTENTIAL MAP OF ARMENIA



Source: <http://globalsolaratlas.info>

A solar resource assessment provides the means to accurately determine the availability of solar radiation resources for developing, deploying, and operating cost-effective solar energy technologies. Since 2016, a solar spectral network has been deployed in Armenia to improve knowledge about national solar resources. This network is composed of four stations located in Hrazdan, Masrik, Yerevan, and Talin, with the intention of expanding it in the future. According to numbers generated by the network within one to two years after its deployment, available solar resources in Gyumri are as follows:

- Global horizontal irradiance = 1,794 kWh/m²
- Direct horizontal irradiance = 590.5 kWh/m²

However, due to ongoing changes in weather patterns due to climate change, the solar resource is changing over time. As data collected by the solar spectral network has not been analyzed and published since its first version, in order to produce more precise and reliable figures, the team analyzed satellite data collected in the Photovoltaic Geographical Information System (PVGIS) meteorological data set under the SARA 2.0 series between 2005 and 2020. The table below presents the outcomes with 50 percent and 90 percent precision.

Table 15. P(50) AND P(90) VALUES OF THE SOLAR RESOURCE AVAILABLE IN GYUMRI (PVGIS SARA 2.0 SERIES)

SOLAR IRRADIANCE	LONG-TERM AVERAGE P(50), KWH/M2	ANY SINGLE YEAR		AVERAGE OVER 16 YEARS	
		UNCERTAINTY AT P(90), %	MAX. EXPECTED AT P(90), KWH/M ²	UNCERTAINTY AT P(90), %	MIN. EXPECTED AT P(90), KWH/M ²

Table 15. P(50) AND P(90) VALUES OF THE SOLAR RESOURCE AVAILABLE IN GYUMRI (PVGIS SARAH 2.0 SERIES)

SOLAR IRRADIANCE	LONG-TERM AVERAGE P(50), KWH/M2	ANY SINGLE YEAR		AVERAGE OVER 16 YEARS	
		UNCERTAINTY AT P(90), %	MAX. EXPECTED AT P(90), KWH/M ²	UNCERTAINTY AT P(90), %	MIN. EXPECTED AT P(90), KWH/M ²
Global Horizontal Irradiance	1,529.57	0.75	1,518.11	3.84	1,470.80
Diffuse Horizontal Irradiance	620.59	0.48	617.60	2.47	605.28

Source: JRC. Default Solar Radiation Databases in PVGIS 5.2. European Union, 2022

In addition to the P(50) and P(90) values presented above, the annual energy yield of a solar PV system can be estimated using the typical meteorological year, which is generated based on long-term meteorological data following the ISO 15927-4 procedure. Uncertainties regarding the solar resource and the system can be balanced by introducing additional losses in the energy yield assessment process.

In the climatic conditions of Gyumri, solar water heaters can produce up to 50–60 liters per square meter of collector area per day in the summer (hot water temperature up to 55°C). During the heating period, their productivity decreases by several times due to the reduced solar radiation. A hybrid system consisting of flat or evacuated tube solar water heaters and an auxiliary electric or gas heater can produce up to 900–1,000 kWh/m² of useful heat per year.

5.3.1 MITIGATION MEASURES IN RENEWABLE ENERGY SYSTEMS AT PUBLIC BUILDINGS AND MUNICIPAL PUBLIC SERVICES

5.3.1.1 MITIGATION MEASURE: EQUIP COMMUNITY-OWNED PUBLIC BUILDINGS WITH SOLAR PV SYSTEMS

Proposed actions: Equipping the community-owned public buildings and municipal public services with solar PV systems will not only reduce the environmental impact of supplying those facilities and services with electrical power, but it will also play an inevitable role in raising public awareness about the application of renewable sources of energy.

Around 50 community-owned buildings, including kindergartens, sports schools and facilities, art and music schools, art and cultural centers, theaters, museums, and the administrative building of the municipality will be equipped with around 2.58 MW solar PV systems, which will operate as autonomous power producers (APPs).

Since the Energy Law of Armenia (AL-261-N) was amended in 2022 to introduce the concept of APP groups, the individual surplus of an APP can be used by other members of an APP group. In this case, instead of injecting the surplus into the grid and receiving 3.9 U.S. cents per kWh, the surplus will balance the daytime and nighttime consumption of other APP group members at 8 and 6 U.S. cents per kWh respectively (a transmission fee of 5 U.S. cents is applied by ENA per kWh transported through the electric networks⁸).

⁸ Daytime tariff = 14 U.S. cents; nighttime tariff = 11 U.S. cents; transmission fee = 5 U.S. cents. Values of 8 and 6 U.S. cents are calculated considering the 5-cent transmission fee paid to ENA CJSC.

In order to ensure the financial performance - meaning proper revenue generation, hence, adequate payback period - it is required to consume the produced electricity internally by the CNCO itself and reduce the amount of electricity injected to the grid and/or virtually metered with other APP Group members. This is achievable through combining this measure with application of new and efficient electrical heating capacities at under-heated spaces of CNCOs (see Section 5.1).

The gradual transition to electric heating is justified by the pending gas price increases, which will otherwise create heating bill burdens. Combination of solar PV systems with electric heating would protect the municipal services from heat affordability risks in the medium-term, while the increasing electricity tariff will improve the economic viability of the solar system installations.

Table 16. P(50) AND P(90) VALUES OF THE SOLAR RESOURCE AVAILABLE IN GYUMRI (PVGIS SARAH 2.0 SERIES)

COMMUNITY-OWNED ORGANIZATION	PLANNED PV CAPACITY, KW	CAPEX, USD	ANNUAL ENERGY YIELD, MWH	tCO ₂ AVOIDED
Municipality of Gyumri	150	180,613.75	223.88	52.83
Daycares and kindergartens				
Tsiatsan Kindergarten CNCO	50	42,329.43	61.94	14.62
Lusastghik Kindergarten CNCO	50	42,329.43	61.94	14.62
Jpit Daycare-Kindergarten» CNCO	50	42,329.43	61.94	14.62
Lianna Daycare-Kindergarten CNCO	30	26,581.57	37.30	8.80
Nanulik Kindergarten CNCO	25	23,013.98	30.97	7.31
Hansel & Gretel SNCO	50	42,329.43	61.94	14.62
Ani Daycare CNCO	70	59,261.20	86.71	20.46
Huso Aragast CNCO	50	42,329.43	61.94	14.62
Eylita Daycare-Kindergarten CNCO	40	33,863.54	49.73	11.74
Lapterik Kindergarten CNCO	50	42,329.43	61.94	14.62
Lilit Kindergarten CNCO	25	23,013.98	30.97	7.31
Karmir Glkhark SNCO	35	31,011.84	43.52	10.27
Dzyunik Daycare-Kindergarten CNCO	50	42,329.43	61.94	14.62
Arevik CNCO	35	31,011.84	43.52	10.27
Tornik Manushak Kindergarten CNCO	50	42,329.43	61.94	14.62
Anulik Kindergarten CNCO	40	33,863.54	49.73	11.74
Paros Kindergarten CNCO	70	59,261.20	86.71	20.46
Yerazank Kindergarten CNCO	50	42,329.43	61.94	14.62
Gohar CNCO	50	42,329.43	61.94	14.62
Ararat Educational Center CNCO	80	67,727.08	99.10	23.39
Ardzagank Primary School	55	46,562.37	68.13	16.08
Sports schools and facilities				
Hamalir Youth Sports School CNCO	50	42,329.43	61.94	14.62
Water Sports School CNCO	150	180,613.75	223.88	52.83
Aram Sargsyan's Sports School CNCO	50	42,329.43	61.94	14.62
Arthur Alexanyan Greco-Roman Wrestling Sports School CNCO	30	26,581.57	37.30	8.80
A. Hakobyan Tennis & Table tennis Sports School CNCO	25	23,013.98	30.97	7.31
Y. Vardanyan Weightlifting School CNCO	20	18,411.18	24.87	5.87
Boxing Sports School CNCO (1)	80	67,727.08	99.10	23.39
Sambo-Judo Sports School CNCO	150	180,613.75	223.88	52.83
Chess Sports School CNCO	15	13,808.39	18.58	4.39
Boxing Sports School CNCO (2)	25	23,013.98	30.97	7.31
Freestyle Wrestling Sports School CNCO	25	23,013.98	30.97	7.31

COMMUNITY-OWNED ORGANIZATION	PLANNED PV CAPACITY, KW	CAPEX, USD	ANNUAL ENERGY YIELD, MWH	tCO ₂ AVOIDED
Youth Sports School CNCO	150	180,613.75	223.88	52.83
Museums				
Mher Mkrtchyan's Museum CNCO	5	4,602.80	6.19	1.46
Avetik Isahakyan's Museum CNCO	20	18,411.18	24.87	5.87
Hovhannes Shiraz Memorial Museum CNCO	40	33,863.54	49.73	11.74
Aslamazyan Sisters' Gallery CNCO	30	26,581.57	37.30	8.80
Art and music schools				
A. Tigranyan Nb.3 Music School CNCO	50	42,329.43	61.94	14.62
Brutyanyan Nb.4 Music School CNCO	30	26,581.57	37.30	8.80
N. Tigranyan Nb.1 Art School CNCO	30	26,581.57	37.30	8.80
Nb.5 Music School CNCO	30	26,581.57	37.30	8.80
Dance School CNCO	30	26,581.57	37.30	8.80
Merkurov's Art School CNCO	15	13,808.39	18.58	4.39
Ani Brass Band	15	13,808.39	18.58	4.39
Nb.7 Music School CNCO	25	23,013.98	30.97	7.31
Art and cultural centers				
Puppet Theater CNCO	150	180,613.75	223.88	52.83
Youth Art Palace CNCO	40	33,863.54	49.73	11.74
Youth Palace CNCO	150	180,613.75	223.88	52.83
Total	2585	2,538,987.06	3,432.76	810.13

Source: JRC. Default Solar Radiation Databases in PVGIS 5.2. European Union, 2022

The expected results from equipping public buildings with solar PV systems are as follows:

Table 17. EXPECTED RESULTS FROM EQUIPPING PUBLIC BUILDINGS WITH SOLAR PV SYSTEMS

IMPLEMENTING BODY	CAPEX, THOUSANDS OF USD	SAVED ENERGY, MWH/YR		AVOIDED CO ₂ EMISSIONS, TON/YR *	IMPLEMENTATION PERIOD
		Electricity*	Natural Gas		
Gyumri Municipality	2,539	3,335	-	787	2024–2030

* Average over seven years, from 2024 to 2030

5.3.1.2 MITIGATION MEASURE: EQUIP MUNICIPAL PUBLIC SERVICES WITH SOLAR PV SYSTEMS

Proposed actions: Equip Gyumri Bus Company CJSC, Gyumri Gardens CNCO, and the urban lighting network, which is operated by Elevator Industry of Gyumri OJSC, with solar PV systems/plants. Gyumri Gardens CNCO operates several pumps to irrigate public gardens all around Gyumri. The proposed solar PV systems will cover the annual electricity consumed by the CNCO.

The proposed solar PV system for Gyumri Bus Company will not only cover the electricity consumed at the administrative building of the company, but can also power electrical charging stations for the community-owned fleet.

In the meantime, the community has approximately 400 km of internal roads, of which only 60 percent are lit. Of the total 6,100 light sources, 5,000 are already equipped with LEDs. The urban lighting system consumes around 2,422 MWh of electricity annually, which is subject to change due to the expansion of the network to cover the remaining 40 percent of internal roads (which will

increase the demand) and the replacement of the remaining 1,100 light sources with LED lamps (which will reduce the demand to some extent). It is proposed to construct 7 ground-mounted solar PV plants, each of 150 kW capacity.

Table 18. LIST OF MUNICIPAL PUBLIC SERVICES TO BE EQUIPPED WITH SOLAR PV SYSTEMS

COMMUNITY-OWNED ORGANIZATION	PLANNED PV CAPACITY, KW	CAPEX, USD	ANNUAL ENERGY YIELD, MWH	TCO ₂ AVOIDED
Gyumri Gardens CNCO	5	4,603	6	1.5
Gyumri Bus CJSC	150	180,614	186	44
Urban lighting	1,050	1,264,296	1,630	385
Total	1,205	1,449,512	1,823	430

The expected results from equipping municipal services with solar PV systems are as follows:

Table 19. EXPECTED RESULTS FROM EQUIPPING MUNICIPAL PUBLIC SERVICES WITH SOLAR PV SYSTEMS

IMPLEMENTING BODY	CAPEX, THOUSANDS OF USD	SAVED ENERGY, MWH/YR		AVOIDED CO ₂ EMISSIONS, TON/YR *	IMPLEMENTATION PERIOD
		ELECTRICITY*	NATURAL GAS		
Gyumri Municipality	1,450	1,771	-	418	2024–2030

* Average over seven years (2024–2030)

In case of expanding the street lighting network to cover all internal roads and in the meantime replacing the existing 1,100 non-LED lighting sources with LED ones, it is estimated that the annual electrical energy consumption will be around 2600 MWh. In order to meet the extended energy needs it is recommended to introduce additional 750 kW (five ground-mounted PV systems each 150kW). The expected results from introducing additional 750kW solar PV capacity are as follows:

TABLE 20. EXPECTED RESULTS FROM INTRODUCING ADDITIONAL 750KW SPV FOR EXTENDED STREET LIGHTING NETWORK

IMPLEMENTING BODY	CAPEX, THOUSANDS OF USD	SAVED ENERGY, MWH/YR		AVOIDED CO ₂ EMISSIONS, TON/YR *	IMPLEMENTATION PERIOD
		ELECTRICITY*	NATURAL GAS		
Gyumri Municipality	930	1,094	-	258	2026–2030

* Average over five years (2026–2030)

5.3.2 MITIGATION MEASURES IN RENEWABLE ENERGY SYSTEMS AT RESIDENTIAL BUILDINGS

Equipping a multi apartment building (MAB) with renewable energy systems (mainly solar PV and solar water heaters) mainly depends on the stability of the building, the load-bearing capacity of the roof, and the space available to install and to safely and efficiently operate those systems.

5.3.2.1 MITIGATION MEASURE: EQUIP RESIDENTIAL BUILDINGS WITH SOLAR PV SYSTEMS

Proposed action: Install solar PV systems with aggregated capacity of 800 kW on the rooftops of 30 MABs (20-, 30-, or 40-kW PV systems). Twenty-six of these buildings have four or five stories and were constructed or reconstructed after the earthquake with reinforced concrete structures, whereas the other four are nine-story buildings with concrete-panel elements, constructed in 1984–1985. There are 954 apartments in these 30 buildings, occupied by 3,697 residents.

TABLE 21. EXPECTED RESULTS FROM EQUIPPING RESIDENTIAL BUILDINGS WITH SOLAR PV SYSTEMS

IMPLEMENTING BODY	CAPEX, THOUSANDS OF USD	SAVED ENERGY, MWH/YR		AVOIDED CO ₂ EMISSIONS, TON/YR *	IMPLEMENTATION PERIOD
		Electricity*	Natural Gas		
Gyumri Municipality	710.41	109.03	-	25.73	2025–2030

* With consideration of productivity decline over seven years (2024–2030)

5.3.2.2 MITIGATION MEASURE: INSTALL SOLAR WATER HEATERS AT RESIDENTIAL BUILDINGS

Proposed action: As a result of extensive awareness campaigns organized by Gyumri municipality, it is expected that at least 2 percent of households in the 830 MABs will be interested in installing solar water heaters (410 of the total 20,452 households living in the MABs). It is assumed that those households will procure thermosiphon passive solar water heaters, each with a 2.088 square meter aperture area of 20 evacuated tubes, 200-liter water tank (Zero-loss collector efficiency: 0.75, $a_1=3$ W/m²K), at \$1,300 per unit. Considering the 1650 kWh annual solar irradiation per square meter each unit will produce 918 kWh worth of hot water per year. As it is not financially viable to tie solar water heaters to gas-fired water boilers, saved energy and avoided CO₂ emissions are compared those from electrical water heaters.

Table 22. EXPECTED RESULTS FROM INSTALLING SOLAR WATER HEATERS in MABs

IMPLEMENTING BODY	CAPEX, THOUSANDS OF USD	SAVED ENERGY, MWH/YR		AVOIDED CO ₂ EMISSIONS, TON/YR	IMPLEMENTATION PERIOD
		Electricity	Natural Gas		
Homeowners	518.4	376.38	-	89	2025–2030

5.3.2.3 MITIGATION MEASURE: INSTALL SOLAR WATER HEATERS AT PRIVATE HOUSES

Proposed action: As a result of extensive awareness campaigns organized by Gyumri municipality and current co-financing mechanisms in the market, it is expected that at least 5 percent of the 14,350 private houses will be interested in installing solar water heaters (717 solar water heaters). The sizing of the solar water heaters and savings are calculated the same way as under mitigation measure 5.3.2.2.

Table 23. EXPECTED RESULTS FROM INSTALLING SOLAR WATER HEATERS IN PRIVATE HOUSES

IMPLEMENTING BODY	CAPEX, THOUSANDS OF USD	SAVED ENERGY, MWH/YR		AVOIDED CO ₂ EMISSIONS, TON/YR	IMPLEMENTATION PERIOD
		Electricity	Natural Gas		
Homeowners	909.3	658	-	155	2025–2030

5.3.2.4 MITIGATION MEASURE: INSTALL SOLAR PV SYSTEMS AT PRIVATE HOUSES

Proposed action: As a result of extensive awareness campaigns organized by Gyumri municipality and current co-financing mechanisms in the market, it is expected that at least 5 percent of the

14,350 private houses will be interested in installing 2–5 kW solar PV systems. Approximately 2.5 MW solar PV systems will be installed at 717 private houses.

Table 24. EXPECTED RESULTS FROM INSTALLING SOLAR PV SYSTEMS AT PRIVATE HOMES

IMPLEMENTING BODY	CAPEX, THOUSANDS OF USD	SAVED ENERGY, MWH/YR		AVOIDED CO ₂ EMISSIONS, TON/YR *	IMPLEMENTATION PERIOD
		Electricity *	Natural Gas		
Homeowners	2,311.75	3,154	-	744.4	2025–2030

* Average over six years (2025–2030)

5.3.2.5 MITIGATION MEASURE: Establish Two groups of APP solar PV producers each 1050kW for EV charging stations

Proposed action: According to measures for energy saving in urban public transport, it is proposed to replace 10-percent of the existing community-owned public buses and passenger cars with electrical buses and vehicles. The target can gradually increase and even reach up to 15-20 percent by 2030.

In order to reduce the strain on electrical networks and to completely offset the footprint of those vehicles (3,300 MWh/a), it is proposed to establish 2 groups of autonomous solar PV plants each with 1,050 kW aggregate capacity. In case of gradual increase in the number of community-owned electrical vehicles, another 1,050 kW APP group can be established till 2030.

Table 25. EXPECTED RESULTS FROM ESTABLISHING 2 SOLAR PV APP GROUPS EACH 1050 kW FOR EV CHARGING STATIONS

IMPLEMENTING BODY	CAPEX, THOUSANDS OF USD	SAVED ENERGY, MWH/YR		AVOIDED CO ₂ EMISSIONS, TON/YR *	IMPLEMENTATION PERIOD
		Electricity *	Natural Gas		
Gyumri Municipality	2,529	3,064	-	723	2025–2030

* Average over five years (2025–2030)

The following table provides a brief list of the proposed mitigation measures for renewable energy systems integration in this section, along with their expected outcomes.

Table 26. PROPOSED MEASURES FOR RES INTEGRATION

MITIGATION MEASURE	CAPEX, THOUSANDS OF USD	SAVED ENERGY, MWH/YR			AVOIDED CO ₂ EMISSIONS, TON/YR *
		ELECTRICITY*	NATURAL GAS	TOTAL	
5.3.1.1. Equip community-owned public buildings with solar PV systems	2,539	3,335	-	3,335	787
5.3.1.2. Equip municipal public services with solar PV systems	1,450	1,771	-	1,771	418
5.3.1.2.1. Additional 750kW solar PV for extended street lighting network	930	1,094	-	1,094	258
5.3.2.1. Equip residential buildings with solar PV systems	710.41	109	-	109	26
5.3.2.2. Install solar water heaters at residential buildings	518.4	376	-	376	89
5.3.2.3. Install solar water heaters	909.3	658	-	658	156

MITIGATION MEASURE	CAPEX,	SAVED ENERGY, MWH/YR			AVOIDED CO ₂
at private houses					
5.3.2.4. Install solar PV systems at private houses	2,311.75	3,154	-	3,154	744
5.3.2.5 Two groups of APP solar PV producers each 1050kW for EV charging stations	2,529	3,064	-	3,064	723
5.3.2.5.1. Additional 1050kW APP group for gradual increase in community-owned solar PV	1,264	1,532	-	1,532	362
Total	13,136	15,094	-	15,094	3,562

5.3.3 ENERGY-SAVING MEASURES IN THE URBAN LIGHTING SYSTEM

Urban lighting is another major power consumer in the municipal economy. As of 2014, of the 4,392 total luminaries operating in the urban lighting system, only 401 were LEDs, and the remaining 3,991 were composed of high-pressure sodium mercury and neon lamps with 250, 400, and 25-watt power. The total length of the urban lighting system used to be 200 km, while 20 km of the internal roads were not illuminated at that time. It is proposed to replace all Natrium, Mercury and Neon lamps with LED lamps (i.e., 48-watt) until 2030. In case of extending the urban lighting network so that it will cover all internal roads in Gyumri, it is estimated that there will be around 300-kilowatt of high-efficiency light bulbs installed in the urban lighting system. The total annual electrical energy consumption is estimated around 540 MWh, which is only 25-percent of the baseline energy consumption (1633 MWh per year consumption reduction which will enable Gyumri to avoid 362 tCO₂ emissions per year).

Table 27. ENERGY SAVING MEASURES AND RESULTS IN URBAN LIGHTING

IMPLEMENTING BODY	CAPEX, THOUSANDS OF USD	SAVED ENERGY, MWH/YR		AVOIDED CO ₂ EMISSIONS, TON/YR *	IMPLEMENTATION PERIOD
		Electricity *	Natural Gas		
Gyumri Municipality	1,500	1633	-	385	2020–2030

(While Gyumri has come a long way from its 2014 baseline, and information on the more recent energy performance of the lighting infrastructure is presented (see Table 8), to maintain the original baseline of Gyumri’s first SEAP, 2014 consumption is critical for reporting the dynamics and reflecting on the united trajectory of the Covenant since the first planning cycle.)

5.3.4 ENERGY-SAVING MEASURES IN THE URBAN PUBLIC TRANSPORT

While a detailed feasibility study will be necessary, the preliminary proposal is to introduce fast charging Battery Electric Buses (BEBs), which are considered technically and financially the best option for electrifying bus services in small to medium municipalities. They can be operated on any route, can be re-charged within 15-30 minutes, are not reliant on overhead catenaries and can also operate without problems during the harsh winter days common to Gyumri’s climate. BEBs only

consume electricity during off-peak hours. Consequently, they do not use electric generation capacity and transmission networks at times (winter) when are scarce. Operation of BEBs will increase electricity demand, however, this will be offset by Gyumri’s growing solar electricity generation capacity, reducing transportation operation cost.

Similarly, because most of Gyumri’s municipal administrative and service fleet operates on CNG, it can benefit from transitioning to electric vehicles. A sample comparison of a typical passenger vehicle/sedan illustrates the significant environmental benefit from switching to electricity-powered mobility.

If Gyumri succeeds in expanding its solar PV capacity, the indicated carbon footprint of this sector will be completely offset. Furthermore, another important difference is that an electric vehicle has one moving part, the motor, whereas natural gas- and gasoline-powered vehicles have hundreds of moving parts. Fewer moving parts means electric vehicles requires less periodic maintenance and are more reliable.

Both BEBs and electric cars will require investments in charging infrastructure. The charging technology and infrastructure scale will require thorough feasibility analysis and cost-benefit assessments as well as integration with the solar energy generation.

As electric vehicles’ carbon footprint is less than 50 percent of that of gas-powered vehicles, and as Gyumri only intends to replace a fraction (approximately 10 percent) of its public buses and municipal passenger car fleet, the preliminary estimates of the mitigation impact are as follows.

Table 28. EXPECTED RESULTS FROM INTEGRATING E-MOBILITY IN MUNICIPAL FLEET

IMPLEMENTING BODY	CAPEX, THOUSANDS OF USD	SAVED ENERGY, MWH/YR		AVOIDED CO ₂ EMISSIONS, TON/YR *	IMPLEMENTATION PERIOD
		Electricity*	Natural Gas		
Gyumri Municipality, residents, donors/ international financial institutions	10,000		1,555	314	2026–2030

The proposed integration of e-mobility is expected to save nearly 1,571 MWh of engine fuel, by replacing the energy source with locally generated surplus solar electricity, which will reduce CO2 emissions by 2,355 tons during 2026-2030.

6 ASSESMENT OF COMMUNITY VULNERABILITY TO CLIMATE CHANGE AND ADAPTATION MEASURES

6.1 CLIMATE CHANGE AND THE COVENANT OF MAYORS

The warming of the climate is unequivocal.⁹ Over the last century, the Earth’s surface temperature has increased, with noticeable effects on physical and biological systems. Due to the continuous

⁹ Sixth Assessment Report on Climate Change. 2022. Intergovernmental Panel on Climate Change, available for download at <https://www.ipcc.ch/report/ar6/wg1/#SPM>

increase in the frequency of extreme climate events and the severity of their consequences, it is all the more critical to meaningfully assess and effectively manage climate risks and to study options to mitigate and adapt to them. This will affect future generations because of increased social, economic, physical, and other vulnerabilities as well as hazards in various sectors and for diverse population groups.

As studies project an increase in the scale of extreme climate events in the 21st century, policymakers are focusing their efforts on mitigation and adaptation to climate risks that arise from hazardous hydrometeorological phenomena. This means enhancing countries' and their communities' capacity to withstand these challenges, dubbed "climate resilience," which supports economic growth and widens the prospects for development and prosperity. Therefore, climate and disaster risk reduction are consistently at the forefront of national, regional, and community development strategies.

The Covenant of Mayors has focused on mitigation since 2008, while adaptation was first presented as one of the cornerstones of sustainable community development strategies in 2014 under the Mayors Adapt initiative launched by the European Commission, which operated in parallel with the Pledge of Mayors initiative. The Mayors Adapt initiative was designed to support communities with commitments for climate change adaptation. In 2015, the European Commission merged these two initiatives, resulting in the Covenant of Mayors for Climate and Energy.

Under the new Covenant, communities extend the scope of climate action to include adaptation measures in addition to mitigation. Therefore, their SECAPs are to incorporate actions in the sectors most vulnerable to the consequences and risks of climate change. Vulnerable sectors can vary significantly from community to community and include buildings, transportation, energy, waste management, land use planning, and more. For this reason, local governments' in-depth understanding of climate hazards and vulnerabilities is of paramount importance in developing a relevant adaptation strategy.

6.2 CLIMATE CHANGE POLICY OF ARMENIA

In order to meet the challenge of climate change, the Paris Agreement was adopted in December 2015 and entered into force in November 2016. Armenia ratified this agreement in 2017 and, along with all signatory countries, has been implementing measures to reduce GHG emissions.

Within this process, Armenia developed and adopted its Intended Nationally Determined Contributions (INDC) document to develop a realistic implementation strategy to reduce GHG emissions and tackle the risks to the country's sustainable development, as well as to set priorities for adaptation measures. The document has the necessary legal status and officially represents the obligations and position of Armenia on climate change mitigation and adaptation.

As stipulated by the process, Armenia continues enhancing its mitigation efforts toward economywide absolute emission reduction or limitation targets under changing national circumstances. Therefore, INDC 2015 was updated and officially submitted as the country's Nationally Determined Contributions (NDC) 2021, with a ten-year implementation period. The updated document is based on the principle of a green economy and is compatible with the Sustainable Development Goals reflected in Armenia's social and economic development targets.

The localization findings of regional scenarios of climate change and the vulnerability of various economic sectors and natural ecosystems under these scenarios have been evaluated and incorporated into each of the four National Communications of Armenia under the UN Framework Convention on Climate Change (UNFCCC), published in 1998, 2000, 2015, and 2020. The National Communications feature a comprehensive study that includes national GHG inventory by major sources and projections of future emissions, country policies and measures to reduce GHG emissions, expected climate change impacts under different scenarios, and vulnerability assessment and adaptation measures at the national level.

Of note is that the fourth National Communication of Armenia focuses on generating a favorable investment environment for renewable resources and energy efficiency, as one of the country's recorded achievements in mitigation of climate change impacts and adaptation efforts among the involved sectors. In order to solve climate change adaptation problems, the UNDP/Green Climate Fund National Adaptation Program in Armenia was implemented, the most important component of which was the planning and implementation of measures to increase the climate resilience of regions and communities. In this context, it is of extreme importance for Armenia that communities identify climate change risks and develop their strategies and adaptation measures to minimize negative impacts on the population's livelihood and economy.

6.3 CLIMATE CHANGE IN ARMENIA

6.3.1 OBSERVED CHANGES IN THE CLIMATE

6.3.1.1 Trends in Air Temperature Changes

Armenia's first, second, and third National Communications featured estimates of changes in annual air temperature and precipitation. They showed that during the last decades, there has been a significant increase in ambient air temperature in the country.

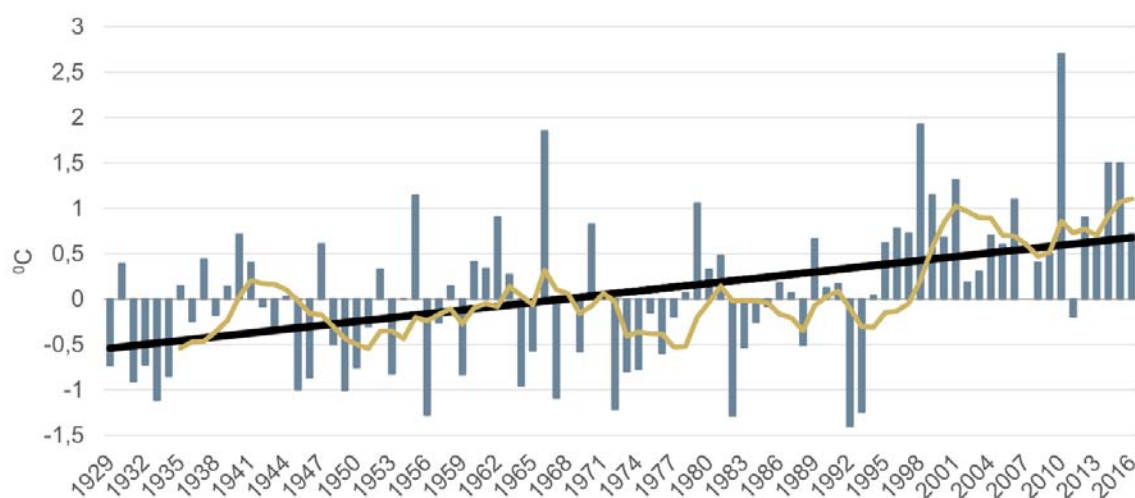
Table 29. CHANGES IN AVERAGE ANNUAL AIR TEMPERATURE OF 1929–2016 FROM THE BASELINE AVERAGE OF 1961–1990

PERIOD	AIR TEMPERATURE, °C
1929–1996	+0.4
1929–2007	+0.85
1929–2012	+1.03
1929–2016	+1.23

Source: Fourth National Communication to the UNFCCC, 2020

Between 1994 and 2016, annual average temperature deviations from the average values for the baseline period of 1961–1990 (5.5°C) have been mainly positive (except for 2011). The year 2010 was the warmest in Armenia, and 1998 and 1966 were the next warmest years throughout the entire observation period. In those three years, deviations from the norm were 2.7°C, 2.0°C and 1.9°C, respectively, and 2014 and 2015 recorded deviations of 1.5°C. On July 31, 2011, a temperature of 43.7°C was recorded in Meghri, which is the absolute maximum temperature in Armenia for the entire monitoring period; it exceeded the previously observed maximum by 0.7°C.

Figure 12. DEVIATION OF THE AVERAGE ANNUAL TEMPERATURE IN ARMENIA FROM THE BASELINE AVERAGE FOR 1961–1990



Source: Fourth National Communication to the UNFCCC, 2020

Changes in air temperature at different seasons have different trends. During 1966–2016, the average summer temperature rose by about 1.3°C, with extremely hot summers observed during the last 20 years (2000, 2010, 2015).

Changes in winter temperature demonstrate a completely different trend, with a very slight upward movement of 0.4°C. Extreme warm winters were observed in 1966 and in 2010, and an extreme cold winter in 1972.

6.3.1.2 TRENDS IN PRECIPITATION CHANGES

Starting in 1935, a comparison of estimated changes in the amount of precipitation over different periods shows a decreasing trend in precipitation. Over 1935–1996, average annual precipitation decreased by 6 percent, and during 1935–2016, by about 9 percent.

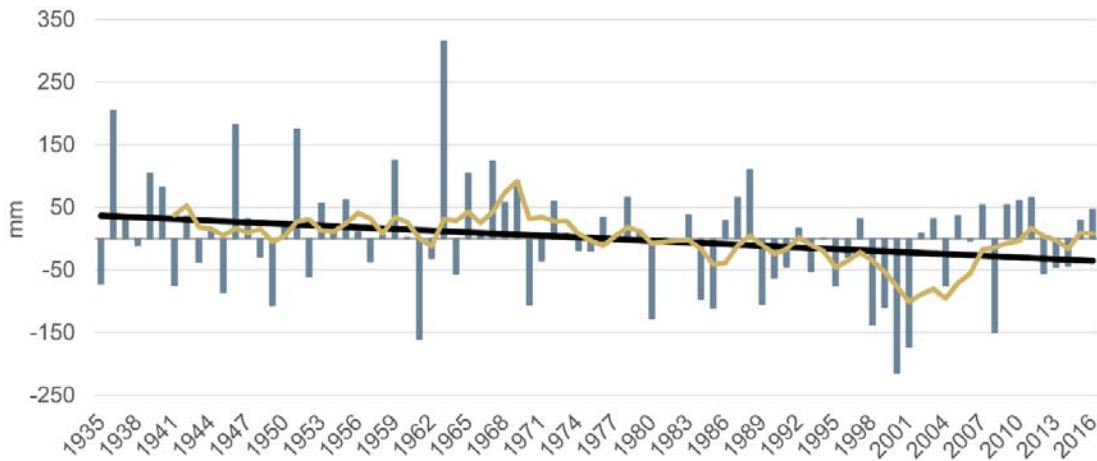
The spatial distribution of precipitation is quite irregular. During 1935–2016, the climate in the northern (Vanadzor, Stepanavan), southern (Meghri), and central (Ararat valley) regions became more arid. Precipitation increased in the Shirak plain, in the Lake Sevan basin, and in Aparan-Hrazdan geographical region.

Table 30. CHANGES IN AVERAGE ANNUAL PRECIPITATION IN 1935–2016 FROM THE BASELINE AVERAGE OF 1961–1990

PERIOD	PRECIPITATION, MM (% CHANGE)
1935–1996	-35 (-6)
1935–2007	-41 (-7)
1935–2012	-59 (-10)
1935–2016	-50 (-9)

Source: Fourth National Communication to the UNFCCC, 2020

FIGURE 13. DEVIATION OF AVERAGE ANNUAL PRECIPITATION IN ARMENIA FROM THE BASELINE AVERAGE FOR 1961–1990



Source: Fourth National Communication to the UNFCCC, 2020

6.3.1.3 HAZARDOUS HYDROMETEOROLOGICAL PHENOMENA

The frequency and intensity of natural disasters has increased dramatically due to climate change over the last decades, both around the world and in Armenia; the threshold values adopted to characterize those phenomena have altered as well.

Hazardous hydrometeorological phenomena (hailstorm, frost, strong wind, heavy rainfall, flood, drought, heat wave) can contribute to the occurrence (or intensification) of natural disasters, such as landslides, avalanches, mudslides, forest fires, the spread of infectious diseases, and others.

Table 31. NUMBER OF HAZARDOUS HYDROMETEOROLOGICAL PHENOMENA OBSERVED IN ARMENIA, 1975–2016

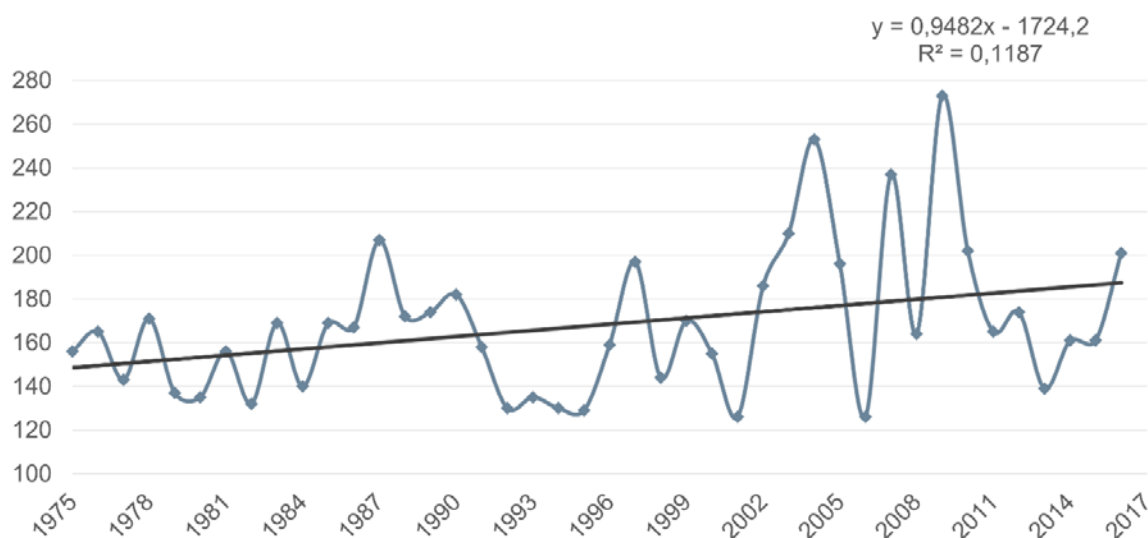
	FROST	HAILSTORM	STRONG WIND	HEAVY RAINFALL	TOTAL
Maximum	139	71	59	73	273
Minimum	32	20	6	22	126
Average	61	40	26	41	168
Change	2.5	-10.1	17.9	6.6	39.8
Change in %	4.1	-25.5	68.8	16.1	23.7

Source: Fourth National Communication to the UNFCCC, 2020

The number of cumulative cases of hazardous hydrometeorological phenomena observed in Armenia during 1975–2016 increased by about 40 from the baseline average (168 cases) for 1961–1990, constituting 23.5 percent of the multi-annual average value (Figure 9). Hailstorm cases were mostly observed in the Shirak plain, heavy rainfall cases in the Tashir and Ijevan regions, and frost in the Ararat valley and foothill regions.

According to the available studies, droughts are observed in the lower regions of Armenia almost every year, and in the foothill regions recurrence of droughts is about 50 percent. Drought indices show that the number of strong and very strong droughts during 2000–2017 increased by 33 days relative to the baseline average (87) for 1961–1990.

FIGURE 14. CUMULATIVE NUMBER OF CASES OF HAZARDOUS HYDROMETEOROLOGICAL PHENOMENA OBSERVED IN ARMENIA, 1975–2016



Source: Fourth National Communication to the UNFCCC, 2020

Based on the data from meteorological stations positioned by zone, drought assessment results show that in recent years, the upper boundary of the drought zone has expanded to include mountainous areas, and the droughts start earlier.

It is clear that Armenia is at risk of climate change impacts, already seeing **a significant increase in average annual temperature, a reduction in precipitation, and a significant increase in the frequency and intensity of natural disasters**. Consequently, the country is severely affected by climate hazards and natural disasters such as drought, mudslides, floods, frost, hail, forest fires, soil erosion, and landslides.

6.3.2 CLIMATE CHANGE SCENARIOS FOR ARMENIA

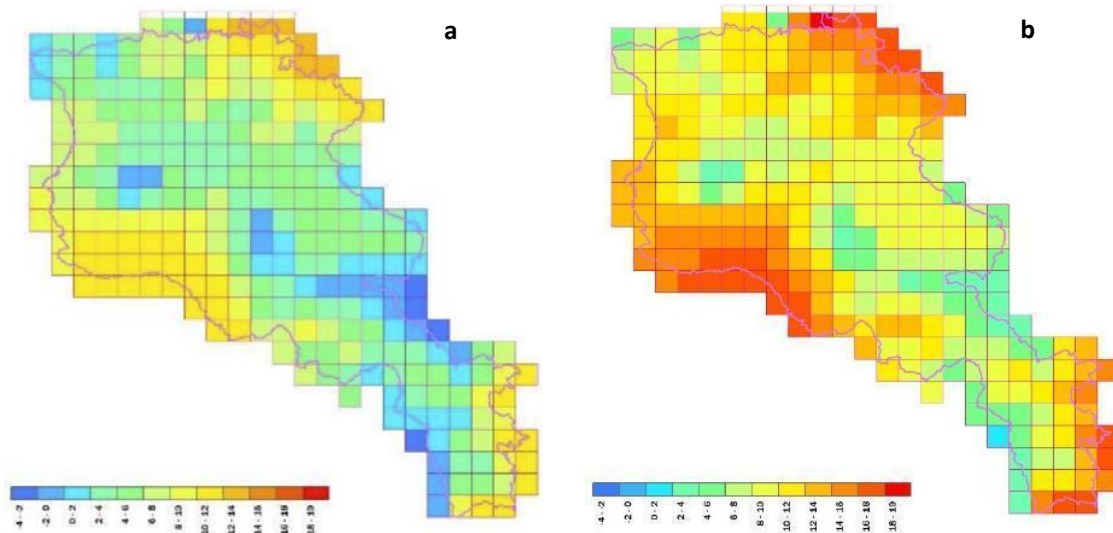
The average annual temperature across Armenia is projected to increase by up to 1.6°C by 2040, by 3.3°C by 2070, and by 4.7°C by 2100 relative to the baseline annual average (5.5°C) for 1961–1990. The projections rely on the output of the CCSM4 Global Climate Model, on the high-resolution METRAS (12x12 km) regional climate model, and on the revisions of Intergovernmental Panel on Climate Change scenarios in light of new data on air temperature and atmospheric precipitation¹⁰.

As shown in the temperature distribution maps, the color shades corresponding to high temperatures are expected to expand and intensify by the end of the 21st century, and cold zones characterized by low temperatures are shrinking. While in 1961-1990 the average annual

¹⁰ GHG emissions and their accumulation in the atmosphere comprise one of the four scenarios proposed by the Intergovernmental Panel on Climate Change, which assumes that by 2100, GHG concentration in the atmosphere will reach 936 parts per million (ppm). Essentially, it is the worst-case scenario, also called the “business-as-usual scenario,” as it refers to global economic development tied to fossil fuel use without climate policy action. In this case, the average global temperature of the Earth will reach 16.8°C; that is, 2.4°C of global warming will be recorded within 2010–2100. The remaining three scenarios assume “softer” GHG concentration effects: 421 ppm under the RCP2.6 scenario, 538 ppm under the RCP4.5 scenario, and 670 ppm under the RCP6.0 scenario.

temperature in the Ararat valley and in the Tavush and Syunik valleys was 10-14°C, during 2071–2100 it is projected to reach 16-18°C.

FIGURE 15. DISTRIBUTION OF AVERAGE ANNUAL TEMPERATURES (°C) IN ARMENIA FOR THE PERIODS (A) 1961–1990 AND (B) 2071–2100 BASED ON THE METRAS MODEL AND RCP8.5 SCENARIO



Source: Fourth National Communication to the UNFCCC, 2020

These regions, which are highly vulnerable to climate change, represent the main agricultural zones of Armenia. The anticipated increase in temperature in these areas will further exacerbate various issues related to arid conditions and water scarcity, which will have an adverse impact on agriculture.

Atmospheric precipitation is projected to decline by up to 2.7 percent by 2040, 5.4 percent by 2070, and 8.3 percent by 2100 relative to the baseline annual average (592 mm) for 1961-1990. In summer, the average air temperature in altitudes comparable to Gyumri (1,509m above sea level) can reach up to 19.5°C,¹¹ and precipitation is expected to decrease by approximately 13 percent.

6.3.2.1 WATER RESOURCES

The vulnerability of the river flow to climate change varies across different river basins due to the differences in the natural and climatic conditions of the basins and the various factors that impact the flow formation. The vulnerability of the annual river flow was assessed with an array of climate models and scenarios for 2040, 2070, and 2100. The results projected a minimum river flow reduction of 8.27 percent until 2100 (under the RCP6.0 scenario and CCSM4 model) and a maximum reduction of 39.0 percent (under the RCP8.5 scenario and METRAS model). Along with the decrease in the natural flow, the hydrochemical composition and content of the rivers is also expected to change.

¹¹ Seasonal projections of annual average air temperature and precipitation for Armenia, Fourth National Communication on Climate Change of the Republic of Armenia under UNFCCC. Table 5-3. 2020. Available for download at https://unfccc.int/sites/default/files/resource/NC4_Armenia_.pdf

The analysis of climate change scenarios shows a negative impact on Lake Sevan's habitat, and the pessimistic scenario projects a decrease in the total river inflow into Lake Sevan by about 34 percent (265 million m³) by 2100. In addition to the anthropogenic impact, the quality of the lake water will be significantly affected by climate change. Along with the increase in air and water temperatures, the biomass of phytoplankton in the lake is increasing, which will lead to an abrupt deterioration of the lake's water quality and the acceleration of eutrophication processes.

6.3.2.2 AGRICULTURE

Agriculture is one of the key sectors of the Armenian economy and has strategic importance for gross the country's domestic product (GDP), macroeconomic stability, improvement of the foreign trade balance, food security, income generation, and consistency in the development of farming enterprises and rural settlements. The predominant part of the income of the rural population (about 32 percent of the country's population) comes from agricultural production and wage labor in that sector. Therefore, the level of poverty in rural areas is largely determined by the state of agricultural development.

Agriculture as a sector of the economy is the most dependent on weather conditions; therefore, its vulnerability to natural risks is quite high. Furthermore, vulnerability varies across soil zones and individual crops. It is most manifested in the low- and medium-altitude zones of the country.

Hydrometeorological hazards (hail, early frosts, spring floods, mudslides, landslides, drought) have a negative impact on agriculture every year, and their higher frequency and increased duration not only limits production and bankrupts the economy, but also leads villagers to abandon agricultural livelihoods and emigrate from rural to urban areas—and in some cases, to emigrate from Armenia.

Climate risks caused by drought, hail, floods, spring frosts, heat waves, and mudslides have a particularly significant impact on the loss of agricultural crops, especially evident in recent years, with most of the damage coming from hail. According to climate change scenarios, the frequency of changeable weather accompanied by thunderstorms and hail is likely to increase in spring and summer.

About 80 percent of the territory of Armenia is exposed to various degrees of desertification, which is not only the consequence of anthropogenic activity but also affected by natural factors, such as water and wind erosion of soils, hot dry spells, drought, lack of humidity, landslides, natural salinization, alkalization, etc. Climate change, along with various anthropogenic phenomena, contributes to the vulnerability of organic carbon reserves in soils.

According to climate change forecasts for Armenia over the next 100 years, the following changes are expected in agriculture:

- Decrease in the level of soil moisture by 10–30 percent; decrease in soil moisture provision for various agricultural crops by 7–13 percent
- Shortage of water for irrigation; increase in soil water deficit by 25–30 percent
- Reduction in productivity of irrigated land by about 24 percent

- Degradation of lands and natural pastures; decrease in overall pasture area and productivity by 4–10 percent by 2030; decrease in pasture yield by 7–10 percent; decrease in fodder production volumes
- Crop yield decline by 8–14 percent by 2030

The negative impact of climate change on the yield of agricultural crops is mainly a consequence of changes in temperature and precipitation, increased demand for irrigation water and reduced irrigation water reserves because of reduced precipitation and high evaporation, and the increase in the frequency, intensity, and duration of climate risks and the expansion of their spatial distribution. The effects are most pronounced during the summer growing season.

In the livestock breeding sector, it has been estimated that if the current growth rate of large and small livestock headcount is maintained and modern scientific standards for pasture utilization are followed, the availability of fodder stock will not cause any concerns until 2030. However, failure to comply with grazing norms and standards or to implement appropriate remediation measures will accelerate the pastures' deterioration.

Climate change can also affect the composition and distribution of natural focal and communicable infections among agricultural animals. Due to climate change and rising temperatures, some areas previously considered non-vulnerable have now become vulnerable to bloodborne parasitic disease, blackleg, and a number of other diseases.

6.3.2.3 NATURAL ECOSYSTEMS

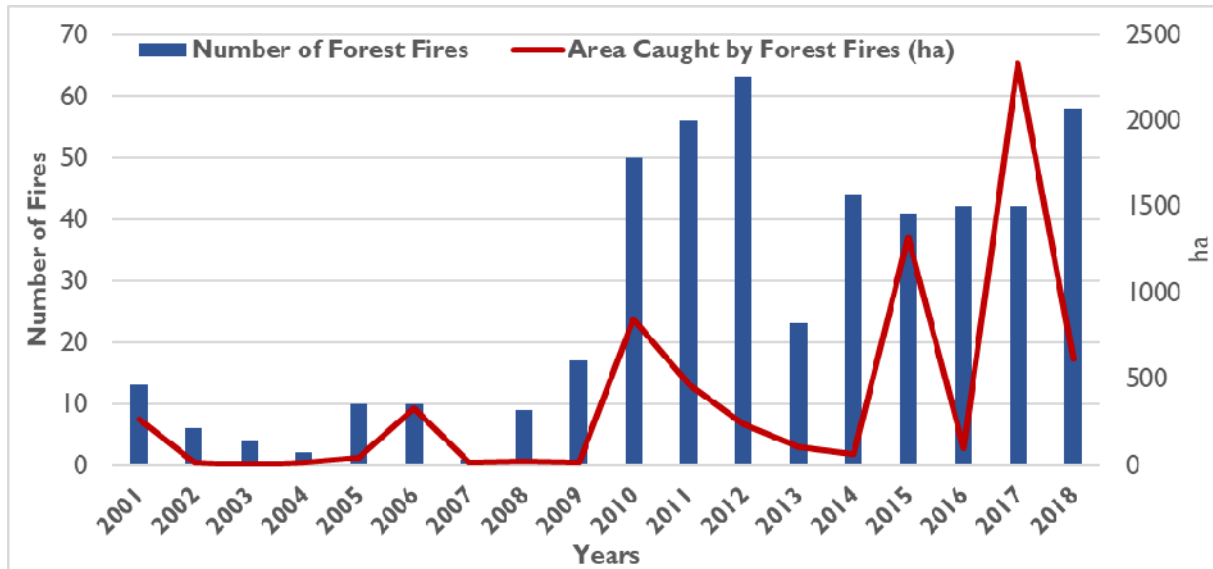
Climate change affects natural ecosystems' composition, structure, and productivity as well as relationships among species and with the environment. It also causes the territorial redistribution of natural ecosystems by changing the natural habitats of certain species of plants and animals and contributes to the spread of invasive species.

Annual soil erosion in arable lands in the mountainous steppe zone of the country is 1.5–24.0 tons per ha. The loss of this amount of eroded soil means a loss of 60–960 kg/ha of humus (4 percent humus content).

The main impacts of climate change on forest ecosystems include the upward movement of vertical zones due to the development and spread of other ecosystems, forest fires, and outbreaks of pests and diseases.

According to official sources, there has been an increase in the number of fires in forest-covered areas and fields due to both human and climate change factors (increase in temperature and in the number of dry days, decrease in precipitation). The last decade saw an increase in the number of forest fires and an expansion of burned areas compared to the first decade of the current century. Forest fire incidents are most evident in years with extremely hot summers.

FIGURE 16. NUMBER OF FOREST FIRES AND AREAS CAUGHT BY FOREST FIRE, 2001–2018



Source: Fourth National Communication to the UNFCCC, 2020

6.3.2.4 SETTLEMENTS AND INFRASTRUCTURE

Armenia experiences a number of climate-induced natural hazards, including floods, river inundations, mudflows, landslides, rockfalls, and avalanches, which can result in considerable destruction and damage to settlements, roads, nearby facilities and infrastructure in a particular territory, as well as human casualties.

Heavy precipitation, snowmelt, river inundations, and damage to hydrotechnical installations are the main reasons for floods in Armenia. The year 2007 was notable in terms of excessive floods, while a considerable decrease was observed in 2012–2018. The highest numbers of floods were registered in Vayots Dzor and Gegharkunik Marzes.

The majority of mudflow-related phenomena are caused by the mountainous terrain, by heavy rainfalls, and rarely by snowmelt. Most mudflows (around 80 percent) are registered in May and June. As in the case of floods, 2007 was also notable in terms of excessive mudflows, while 2012–2018 showed a decreasing trend. The highest number of mudflows were observed in Lori, Aragatsotn, and Vayots Dzor Marzes.

According to the results of a comprehensive study aimed at landslide disaster management in 2005, over 2,500 landslide-prone sites were identified in Armenia, with their total area comprising around 4.1 percent of the country’s territory.

Landslide-prone sites are located mainly in mountainous areas and at the foot of the mountains, where rock sliding occurs due to the force of gravity on the slopes. They are often triggered by heavy atmospheric precipitation, intense water saturation, and over-humidity of slopes. The majority of landslides are located within the administrative borders of Dilijan, Ijevan, Kapan, Vanadzor, and other communities as well as in the basins of the Debed, Aghstev, Vedi, Getik, and Vorotan Rivers.

The number of cases of rockfalls recorded in 2012–2018 increased in comparison with figures registered during previous years. The highest number of rockfall cases, 61, was registered in 2016. In that period, rockfalls were recorded predominantly in Lori and Syunik Marzes and in Yerevan.

Avalanches, to a certain extent, endanger all mountainous regions and are especially hazardous in mountains during the winter season. While they are not very frequent in Armenia, their consequences can be major and irreversible, such as the destruction of settlements and communication channels and the loss of life. They pose a major threat in the Zangezur, Bazum, and Aragats highland zones.

6.3.2.5 HUMAN HEALTH

Temperature increases, changes in precipitation, and increased incidence of hazardous hydrometeorological phenomena can have serious adverse impacts on the health of the population. The adverse impacts of climate change coupled with high atmospheric pollution contributes to an increase in incidence of cardiovascular and respiratory diseases.

In Armenia, there is a risk that a number of infectious diseases will spread due to climate change. The structure of infectious diseases will change and water borne diseases will increase, especially in areas where water quality, sanitation, and personal hygiene levels are not sufficient. There are still diseases in the country that have a tendency to spread or are already widespread due to climate change. The prevention of and fight against such diseases stands high on the agenda: the list of such diseases includes, among others, leishmaniasis, brucellosis, and intestinal and airborne infections.

Outdoor workers are considered vulnerable to the impact of extreme weather conditions. The urban population is particularly vulnerable to cardiovascular and respiratory diseases due to atmospheric pollution associated with climate change. Inhabitants of rural settlements and population groups that are in direct contact with natural landscapes or natural products are included in the groups susceptible to risks related to natural focal infections, including especially hazardous ones. For gastrointestinal infections, the vulnerable population groups include those who live in conditions with low levels of water quality, sanitary facilities, and personal hygiene (residents of rural settlements not included in the networks of specialized water supply organizations and others).

Thus, climate change is expected to have negative consequences on the country's water resources, energy, agriculture, ecosystems, settlements and infrastructure, human health, and a number of other climate-dependent sectors, including tourism.

6.4 CLIMATE OF GYUMRI

Gyumri is located on the left bank of the Akhuryan River within the Shirak lowlands. The Gyumri plain, which is situated about 1,580 m above sea level, is surrounded by the Jajur and Kamkhut Mountains and is bordered by the slopes of the Mount Aragats in the southeast, the Shirak Mountain chain in the north, Ararat Valley in the south, and Pambak Ridge in the east. It is lined by the Cherkes, Jajur, Gyumri, and other canyons. While Gyumri is on the same latitude as Napoli and Thessaloniki, it has a continental climate.

A key geographical point is Gyumri's vulnerability to natural **FIGURE 17. URBAN DEVELOPMENT MAP**

disasters. Armenia is listed in the top 60 countries exposed to multiple hazards, with earthquakes, floods, droughts, hail, and landslides all major risks to Gyumri as well as the rest of the country. Armenia is more vulnerable to natural hazards than any other European or Central Asian country, with 80 percent of the population at risk of exposure to catastrophic events. All of Armenia is prone to earthquakes, 91 percent is exposed to the risk of drought, and 31 percent is vulnerable to floods. Landslide sites cover approximately 122,000 ha in Armenia, which is over 4 percent of the country’s territory, and Gyumri is among the 35 percent of settlements in Armenia that are located in landslide-prone areas.

Seismic risk is the greatest natural disaster threat for Gyumri, with several active faults within 150 km of the city. Gyumri has been hit by multiple earthquakes with a magnitude of more than 8.0 on the Richter scale, with the most devastating ones occurring in 1846, 1926, and most recently in 1988. The 1988 earthquake had severe impacts on Armenia’s economy and population, with more than 25,000 people killed, 19,000 injured, and 517,000 homes damaged. It resulted in an estimated economic loss of \$20 billion. Armenia is currently working with several international organizations to assess its natural disaster risk in more depth and to develop risk mitigation and emergency preparedness plans.

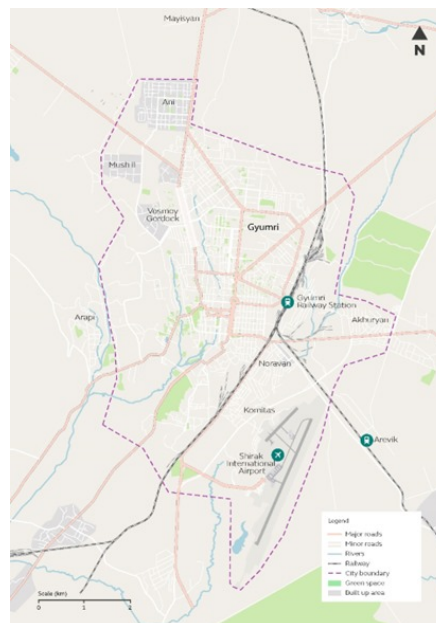
According to Construction Norm of the Republic of Armenia (RA CN) II-7.01-2011, the territory of Gyumri is located in the “cold-C” construction climate zone, with cool summers, cold winters, an average annual air humidity level of 72 percent, a favorable wind regime (average annual speed of 1.3 m/s, average monthly speeds of 0.6–2.1 m/s). Winter is long, with constant snow cover. On average, it begins in early November and ends in mid-April. The average temperature in January is –9.0°C, and the absolute minimum reaches –36°C. The weather is stable in winter. The average temperature in July and August is 19.5°C, and the absolute maximum is 38°C. In the driest months for the country—July and August—atmospheric precipitation reaches 40–47 mm, and the relative humidity is 60–62 percent. Autumn is cool, with changeable weather. Early autumn frosts begin in late September or early October. The average annual amount of precipitation is 498 mm. Thus, the main climatic indicators show mostly favorable conditions for residence, recreation, and agriculture.

The tables below provide the values of parameters characterizing the climate of Gyumri.

Table 32. AIR TEMPERATURE (CONSTRUCTION CLIMATOLOGY, RA CN II-7.01-2011)

SETTLEMENT	MONTHLY AVERAGE, PER MONTH											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Gyumri	-9.0	-7.2	-1.2	6.7	11.7	15.5	19.5	19.5	15.2	8.5	1.7	-5.1
Average annual, °C			Absolute minimum, °C					Absolute maximum, °C				
6.3			-36					38				

OF GYUMRI



Source: Green city action plan for Gyumri, 2019

Table 33. RELATIVE AIR HUMIDITY (CONSTRUCTION CLIMATOLOGY, RA CN II-7.01-2011)

SETTLEMENT	RELATIVE AIR HUMIDITY BY MONTH, %											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Gyumri	83	82	76	68	69	66	62	60	63	70	75	84
Average annual, °C	Monthly average at 3:00 p.m.											
	Coldest month, %						Warmest month, %					
	72						39					

Table 34. ATMOSPHERIC PRECIPITATION AND SNOW COVER (CONSTRUCTION CLIMATOLOGY, RA CN II-7.01-2011)

SETTLEMENT	AMOUNT OF PRECIPITATION, monthly average/daily maximum, MM											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Gyumri	23/17	25/26	30/24	55/30	90/53	71/55	46/40	36/47	31/64	39/39	28/25	24/32
Annual	Maximum height, ten-day period, cm	Snow cover										
		Number of snow cover days in a year					Maximum content of water in snow, mm					
	498/64	61	94					129				

Table 35. WIND (CONSTRUCTION CLIMATOLOGY, RA CN II-7.01-2011)

MONTH OF YEAR	RECURRENCE OF WIND DIRECTION, % / AVERAGE WIND SPEED, M/S											
	BY DIRECTION											
	N	NE	E	SE	S	SW	W	NW				
JAN	15/0.7	18/0.6	8/0.5	3/0.6	13/0.8	19/0.5	10/0.5	14/0.5				
APR	14/1.8	17/1.4	11/1.9	4/1.6	12/1.7	19/1.7	12/1.5	11/1.5				
JUL	19/1.9	39/1.9	24/2.2	2/1.6	2/1.4	4/1.4	5/1.2	5/1.6				
OCT	18/0.8	20/0.7	9/0.7	2/0.6	12/0.8	17/0.6	13/0.6	9/0.7				
	Repeatability of windless events, %	Average monthly speed, m/s	Average annual speed, m/s	No. of days with strong winds (>15 m/s)	Calculated wind speed (m/s) that is possible once every "n" years							
					20	50	100					
					1.3	30	24	27	29			
										JAN	85	0.6
										APR	61	1.7
JUL	56	2.1										
OCT	79	0.8										
Average annual atmospheric pressure, hPa											846.9	

Table 36. SOLAR RADIATION (CONSTRUCTION CLIMATOLOGY, RA CN II-7.01-2011)

SETTLEMENT	TOTAL (DIRECT AND DIFFUSED) RADIATION ON A HORIZONTAL SURFACE UNDER CLOUDLESS SKY, MJ/M ² (BY MONTH)											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Gyumri	334	414	655	774	976	954	1,008	889	673	551	352	304
Annual total											7,884	

Table 37. DURATION OF SUNSHINE (CONSTRUCTION CLIMATOLOGY, RA CN II-7.01-2011)

SETTLEMENT	DURATION BY MONTH, HOURS											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Gyumri	89	108	158	185	244	306	346	337	275	221	136	94
Annual total											2,499	

Table 38. DAYS WITHOUT SUNSHINE (CONSTRUCTION CLIMATOLOGY, RA CN II-7.01-2011)

SETTLEMENT	NUMBER OF DAYS, BY MONTH											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Gyumri	9	6	4	2	1.6	0,1	0	0.02	0.3	1	4	8
Annual total											35	

Table 39. CLIMATE PARAMETERS OF THE COLD SEASON OF THE YEAR (CONSTRUCTION CLIMATOLOGY, RA CN II-7.01-2011)

SETTLEMENT OR METEOROLOGICAL STATION	AIR TEMPERATURE, °C									
	Coldest day, confidence, %		Coldest five-day period, confidence, %		Average, coldest period	Absolute minimum	Average daily variation, coldest month	Duration, days		
	0.98	0.92	0.98	0.92				≤0°C	≤8°C	≤10°C
Gyumri	-29	-26	-25	-22	-9.0	-36	11.1	118	189	208
								-5.7	-2.1	-1.0
Relative air humidity of the coldest month, %		Atmospheric precipitation and depth of ground freezing				Wind				
Monthly average	Monthly average at 3:00 p.m.		Amount of precipitation in November–March, mm		Maximum depth of ground freezing, cm		Prevalent direction in December–February		Maximum average speeds by direction in January, m/s	
83	71		130		142		North		0.6	

Table 40. CLIMATE PARAMETERS OF THE WARM SEASON OF THE YEAR (CONSTRUCTION CLIMATOLOGY, RA CN II-7.01-2011)

SETTLEMENT OR METEOROLOGICAL STATION	AIR TEMPERATURE, °C					
	Confidence, %		Absolute maximum	Average maximum, warmest month	Average daily variation, warmest month	
	0.95	0.99				
Gyumri	28	29	38	26.7	14.1	
Relative air humidity of the warmest month, %		Atmospheric precipitation and depth of ground freezing			Wind	
Monthly average	Monthly average at 3:00 p.m.		Amount of precipitation in April–October, mm	Maximum depth of ground freezing, cm	Prevalent direction in June–August	Maximum average speeds by direction in January, m/s
60	39		368	64	Northeast	1.9

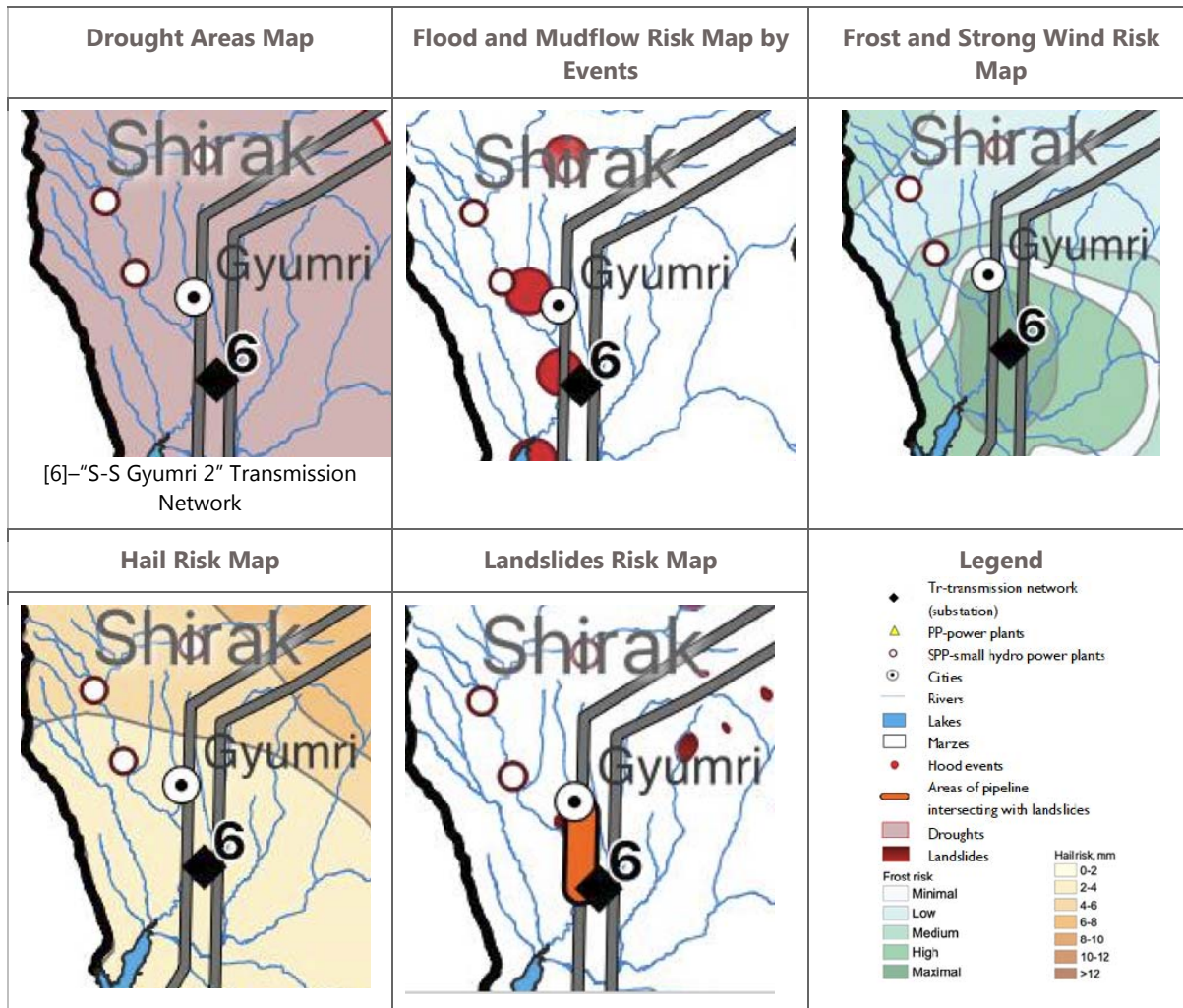
6.5 GYUMRI CLIMATE RISKS AND VULNERABILITIES

As the above section indicates, the primary climate vulnerabilities for Gyumri, based on the expected impacts of climate change in Shirak Marz, are as follows:

- Increased temperatures
- Increased frequency and intensity of precipitation, predominantly hail
- Degradation of soil
- Reduced productivity of plant cultivation and cattle-breeding
- Increased frequency and intensity of extreme weather events (drought, floods, frost, frost and strong wind, hail, and landslides).
- Reduced overall volume of precipitation and drop in surface runoff and river flow

These are expected to have a significant impact on incomes, leading to economic stress, particularly for the most socially vulnerable, risking their livelihoods and accelerating the already high migration of youth.

FIGURE 18. CLIMATE CHANGE IMPACTS PROJECTIONS IN GYUMRI, SHIRAK MARZ (2070-2100)



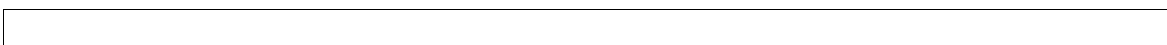
Source: UNDP Armenia Climate Change Program (adapted by authors)

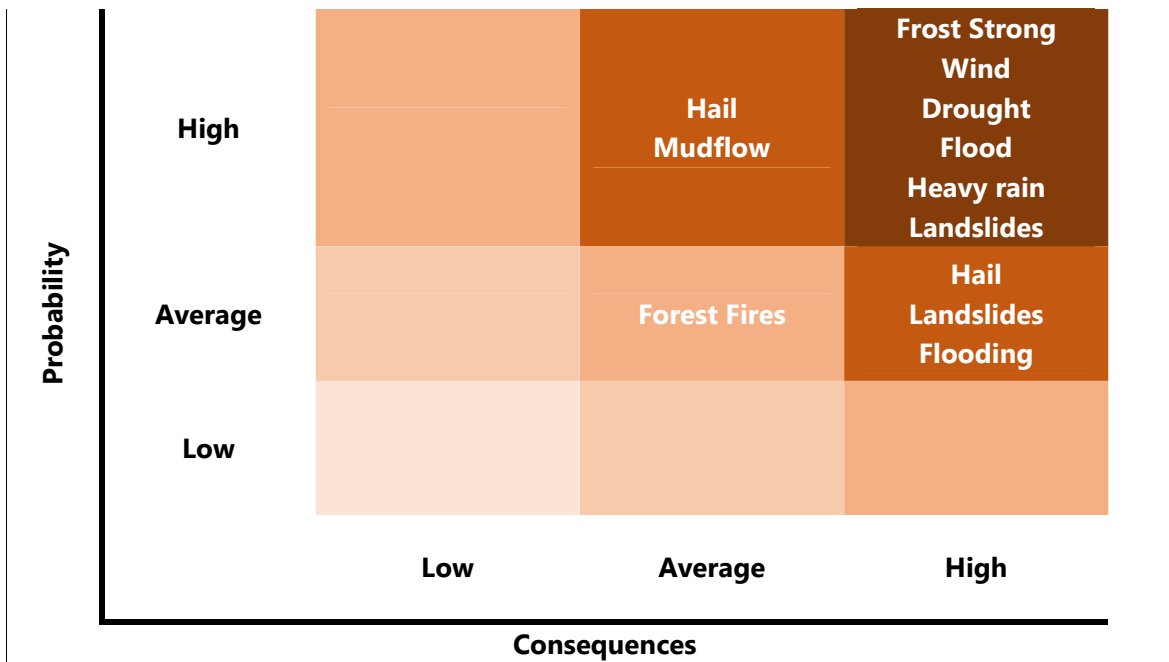
Based on these vulnerabilities, a climate risk heat map was developed that indicates the highest risks to infrastructure from droughts, floods, frost, and landslide; moderate risks from hail; and low risks from mudflows.

While hail risks are high for Shirak Marz in general, Gyumri is currently rated as lower risk. As for mudflows and forest fires, the maps did not indicate moderate or high risks for the Gyumri area.

Based on the likelihood and consequences of the dangerous phenomena presented above, the risk matrix below has been developed, with the highest level of risk to the city of Armenia, Strong winds, droughts, and heavy rains. They are followed by hail, forest fires, heavy rain and floods, mudflows, strong winds and landslides, as well as extreme cold and frost.

FIGURE 19. CLIMATE RISK HEAT MATRIX FOR GYUMRI





Source: Developed by authors

The impact of the above respective weather extremes or weather-related phenomena on ecosystems and green spaces, infrastructure, energy and transport assets are summarized below.

6.6 VULNERABILITY OF BUILDING STOCK OF GYUMRI

A significant part of Gyumri's building stock, including 95% of frame-panel buildings and 100% of buildings constructed by the method of raising roofs (which were mostly multi-apartment residential buildings), was damaged in 1988 as a result of the earthquake. What relates to the residential areas, the two-storey houses in the Textile district (located near the old textile factory) and Gorky historical district (located near the Gorky Park) are still relatively well preserved. Mainly the taller buildings (5, 9, 14, and 24-storey) were destroyed, most of which were located in more modern residential areas (mid/late 20th century) and were not suitable for Gyumri clay soils. In 1988 after the earthquake several new districts, such as Ani, Mush, Austrian and Sheram were built simultaneously in the areas beyond the destroyed districts. These districts were not properly adapted to the city layout, due to which the residents still feel isolated from city life. In other parts of the city (e.g. Savoyan Street) the presence of temporary accommodations has led to the formation of shanty settlements ("domics") which have not yet received government support due to a number of difficult claims for recognition of ownership rights and unresolved disputes over the amounts of compensation or replacement of damaged residencies expected from the government. In 2018-2019, Gyumri Municipality reevaluated the shanties in order to prepare an inventory of needs of the housing fund, and the RoA government, in response to this initiative provided 3 billion AMD in 2019 to solve the housing issue of these families. 30 years after the 1988 earthquake there are still 2,300 families living in temporary shelters in Gyumri, and 10% of the city's residential buildings are still at risk of collapse due to damage caused by the earthquake in 1988 and require urgent reconstruction, repair or dismantling.

The 1988 earthquake showed the vulnerability of the country and the Gyumri community in seismic situations, the lack of preparedness for emergency situations, as well as the need for the development of urban projects and infrastructures that will be sensitive to environmental issues

and resistant to earthquakes. The World Bank and the Japan International Cooperation Agency (JICA) have conducted a vulnerability assessment of residential buildings and schools in Armenia, as a result of which it was revealed that 90% of schools built during the Soviet era need to improve the level of seismic safety. However, the local design and construction industry has no sufficient capacity and experience to implement efficient improvement.

Plans have been developed for creation of a housing stock in a phased and continuous manner to gradually remove the temporary shelters left after the 1988 earthquake.

However, the population living in these slums is particularly vulnerable to the dangers associated with climate change and natural disasters.

Residents of temporary slums actually live on the most vulnerable areas and districts of the city that are considered undesirable by others and therefore are affordable. Thus, the density of the most socially vulnerable citizens of the Gyumri population is higher in slums than elsewhere. Their dwellings have the lowest structure resistance, as they were not originally intended for permanent residence. Therefore, the residents of these areas are more frequently exposed and vulnerable to landslides, mudslides, high winds and other hazards. The risk exposure is increased by overcrowded living conditions, lack of adequate infrastructure and services, unsafe housing, malnutrition and poor health. These conditions can turn a natural hazard or climate change into a disaster and lead to the loss of essential services, damage or destruction of shelters, loss of livelihoods, malnutrition, disease, disability and loss of life. The actual residents of slums are exposed to all the major traditional challenges faced by the poorest urban population, taking into consideration the risks associated with climate change and disasters.

As the frequency and severity of natural disasters increase, so do the risks of the slums destruction, and from the point of view of management, one inadequately constructed house can cause the collapse of several houses. Accumulation of garbage in such areas can block access to aid. For example, a building collapse after an earthquake can cause a large fire, which in turn can damage other structures that were not initially affected, collapses can block access to transportation networks, prevent effective recovery operations, and make recovery more difficult.

Table 41. THE IMPACT OF EXTREME WEATHER EVENTS AND SLOW ON-SET CLIMATE PHENOMENON BY SECTOR

Climate Hazard	Probability	Description of Potential Threats and Their Impact Magnitude by Sectors			
	Low, average, High	Impacts: small, medium, large			
		Ecosystems and Green Space	Infrastructure	Energy	Transport
Drought	Low	<ul style="list-style-type: none"> Increased demand for irrigation water and water structures Use of potable water for irrigation purposes, filling swimming pools Fire conditions Young, especially drying newly planted plants Activating biological processes attributed to high water temperatures in outdoor pools that can be harmful to health <p>Impact: Medium</p>	<ul style="list-style-type: none"> The foundations deteriorate and descend unevenly, from a lack of moisture in the soil layers and disruption of the connection between them Construction elements produce cracks, horizontal elements (floor, ceiling) acquire curves, openings (doors) <p>Impact: Small</p>	<ul style="list-style-type: none"> overload energy transmission and distribution infrastructure due to additional demand for irrigation water Fire risk conditions <p>Impact: Medium</p>	<ul style="list-style-type: none"> The foundations deteriorate and descend unevenly, from a lack of moisture in the soil layers and disruption of the connection between them Bridges and other construction elements produce cracks and curves) <p>Impact: Small</p>
Frost	Average	<ul style="list-style-type: none"> Young, especially newly planted, and non-frost-resistant plant damage <p>Impact: Medium</p>	<ul style="list-style-type: none"> In some of the materials used in the structure, permanent cooling-melting cycles contribute to their degradation Freezing in the roofs, where melting water refreezes in the aqueducts, gets retained and penetrates the roof cover Water supply/removal pipes can explode, contributing to damage to constructions <p>Impact: Medium</p>	<ul style="list-style-type: none"> overloaded energy transmission and distribution infrastructure due to additional energy requirements for heating <p>Impact: Medium</p>	<ul style="list-style-type: none"> Ice and/or naked layer of roads and other linear infrastructure <p>Impact: Medium</p>
Heavy rain	High	<ul style="list-style-type: none"> Activation of landslides and erosion processes 	<ul style="list-style-type: none"> Exterior covering elements have accumulated damage, especially 	<ul style="list-style-type: none"> Disruption of stations and 	<ul style="list-style-type: none"> Collapse of roads and other linear infrastructure

Climate Hazard	Probability	Description of Potential Threats and Their Impact Magnitude by Sectors			
	Low, average, High	Ecosystems and Green Space	Infrastructure	Energy	Transport
		<ul style="list-style-type: none"> Young, especially newly planted, and damage to small plants Impact: Medium	<ul style="list-style-type: none"> smooth roofs and balconies, nodes of exterior constructions, curved roofs, and elements adjacent to the soil Water penetration and the presence of long-term unpredictable humidity contribute to their degradation and recurrence Physical and visual damage whose removal imposes significant financial costs Impact: Small	<ul style="list-style-type: none"> underground networks Impact: Medium	<ul style="list-style-type: none"> Movement Difficulty and Slowdown Impact: Medium
Mudflow	Average	<ul style="list-style-type: none"> Young, especially newly planted, one-year-old and small plants Impact: Small	<ul style="list-style-type: none"> Especially significant damage to all kinds of roofing materials Aqueducts on the roofs are damaged (the lightest expression of which is the deterioration of their appearance) and occurs in a congestion Damage to window glass elements and other glass structures Impact: Small	<ul style="list-style-type: none"> Disruption of external wires and other linear infrastructure Impact: Small	<ul style="list-style-type: none"> Collapse of roads and other linear infrastructure Movement Difficulty and Slowdown Impact: Small
Strong Wind	High	<ul style="list-style-type: none"> Damaging or collapsing plants, especially trees Impact: Small	<ul style="list-style-type: none"> The force of absorption has a detrimental effect on specific vertical elements (days: walls), and horizontal and curved elements (day: roofs) Partial or Complete Roofing Damage caused by collision with small elements swept away Impact: Medium	<ul style="list-style-type: none"> Disruption of external wires and other linear infrastructure Impact: Small	<ul style="list-style-type: none"> Dust cloud formation and visibility reduction Movement Difficulty and Slowdown Impact: Small

Climate Hazard	Probability	Description of Potential Threats and Their Impact Magnitude by Sectors			
	Low, average, High	Ecosystems and Green Space	Infrastructure	Energy	Transport
Landslides	Average	<ul style="list-style-type: none"> Local nature impacts and can cause segmental damage, particularly water supply and sewage systems Impact: Small	<ul style="list-style-type: none"> Damage from debris strikes to external structures Water penetration with lower and underground floors damages weapons as well as specific and non-structural elements and property Impact: Medium	<ul style="list-style-type: none"> Disruption of external wires and other linear infrastructure Impact: Small	<ul style="list-style-type: none"> Wiring infrastructure damage Impact: Small
	Average	<ul style="list-style-type: none"> High risk in terms of water quality management can lead to changes in the quality of sources Impact: Large	<ul style="list-style-type: none"> Cracks of different sizes in wearable and covering structures Separation of exterior walls and adjacent structures (days: staircases) from the main building Only the collapse of a roof or whole building Impact: Medium	<ul style="list-style-type: none"> Disruption of external wires and other linear infrastructure Impact: Small	<ul style="list-style-type: none"> Collapse of roads and other linear infrastructure Movement Difficulty and Slowdown Impact: Medium
Rockfall	Average	<ul style="list-style-type: none"> Local landscape change can cause segmental damage, particularly water supply and sewage systems Impact: Small	<ul style="list-style-type: none"> Side and bottom pressure from water accumulation damage external structural elements; the higher the level of external flow of water, the greater the pressure Long-term contact with water, construction materials begin to lose their calculated bearing strength Damage to foundations and bearing structures due to a change in grunt Water penetration causes damage to reinforcements and internal structural and non-structural elements Impact: Small		<ul style="list-style-type: none"> Collapse of roads and other linear infrastructure The Impossibility of Movement Impact: Small

Climate Hazard	Probability	Description of Potential Threats and Their Impact Magnitude by Sectors			
	Low, average, High	Ecosystems and Green Space	Infrastructure	Energy	Transport
Forest fire	Low		<ul style="list-style-type: none"> Thermal aging process accelerates asset depreciation, especially when accompanied by high humidity <p>Impact: Small</p>	<ul style="list-style-type: none"> Accidents in wiring infrastructure in rapid spread of fires <p>Impact: Small</p>	
Average annual temperature increase	Average	<ul style="list-style-type: none"> Distribution of invasive species from the lower part of the city of Armenia to the upper part Disease and Pest Control and Intensification Limitation or impossibility of further use of certain traditional vegetation in greenery Accelerating the Evaporation Process Total demand for irrigation water Expansion of the irrigation season Severe work restrictions or impossibilities in outdoor conditions during the day <p>Impact: Small</p>	<ul style="list-style-type: none"> Lack of moisture in the soil causes a change in the foundations, which degrade the foundations of buildings and descend unevenly Buildings/Buildings Sit Constructive elements produce cracks, horizontal elements (floor, ceiling) acquire curves, openings (doors) <p>Impact: Small</p>	<ul style="list-style-type: none"> overload of electric transmission lines. and distribution infrastructure, driven by additional energy requirements for cooling Reduced efficiency of power generation Acceleration of equipment ratings and decay rates <p>Impact: Medium</p>	<ul style="list-style-type: none"> Overload of public transportation and other means Increased fire danger <p>Impact: Small</p>
Reduction in Precipitations	Low	<ul style="list-style-type: none"> Limitation or impossibility of further use of certain traditional vegetation in greenery Total demand for irrigation water 		<ul style="list-style-type: none"> Decline in efficiency of hydroelectric power plants Reducing access to water used to produce 	

Climate Hazard	Probability	Description of Potential Threats and Their Impact Magnitude by Sectors			
	Low, average, High	Ecosystems and Green Space	Infrastructure	Energy	Transport
		<ul style="list-style-type: none"> Expansion of the irrigation season Impact: Small		<ul style="list-style-type: none"> manufacturing power overload of energy efficiency, transmitter, and distribution infrastructure due to additional demand for irrigation water Fire conditions Impact: Large	

Taking into account Gyumri's main vulnerabilities to climate hazards, specialists from the municipality and Energy Secure Armenia experts developed this plan to mitigate the impact of hazards and risks by 2030. Implementing the proposed measures should help improve the community's climate resilience and sustainable development. In that context, it is necessary to mention the main characteristics of a city resilient to climate hazards or disasters.

According to the "Making Cities Resilient" Campaign, a city can be categorized as resilient if it meets the following criteria:

- Disasters are minimized because the population lives in homes and communities with organized services and infrastructure that adhere to sensible building codes, without informal settlements built on flood plains or steep slopes because no other land is available.
- An inclusive, competent, and accountable local government is concerned about sustainable urbanization and commits the necessary resources to develop capacities to manage and organize itself before, during, and after a natural hazard event.
- The local authorities and the population understand their risks and develop a shared, local information base on disaster losses, hazards, and risks, including who is exposed and who is vulnerable.
- People are empowered to participate, decide, and plan their city together with local authorities and value local and Indigenous knowledge, capacities, and resources.
- Steps are taken to anticipate and mitigate the impact of disasters, incorporating monitoring and early warning technologies to protect infrastructure, community assets, and individuals, including their homes and possessions, cultural heritage, and environmental and economic capital, and is able to minimize physical and social losses arising from extreme weather events, earthquakes, or other natural or human-induced hazards.
- There is an ability to respond, implement immediate recovery strategies, and quickly restore basic services to resume social, institutional, and economic activity after such an event.
- An understanding exists that most of the above are also central to building resilience to adverse environmental changes, including climate change, in addition to reducing GHG emissions.

Adaptation measures intended to cope with climate change impacts are meant for weather's extreme impacts, while hard and soft measures, along with their mitigation effects, will help cope with the growing energy demands.

Natural disaster risks are directly linked to several pressure indicators of the Gyumri Green City Action Plan (GCAP).¹² However, some of them are not populated due to the lack of data. In particular, pressure indicators on resilience in the transport sector ("Interruption of public transport systems in case of disaster" and "Efficiency of transport emergency systems in case of disaster") and the resilience of the electricity network ("Average share of population with prolonged power outage in climate extremes over the last five years") are not populated, and it is difficult to assess

¹² Atkins, LDK, and ESF, *Gyumri Green City Action Plan*, European Bank for Reconstruction and Development, 2019. https://ebrdgreencities.com/assets/Uploads/PDF/Gyumri-GCAP_Eng.pdf

the pressure on these sectors to adapt to climate change in Gyumri. None of the industrial waste or wastewater generated in Gyumri is treated in line with national standards. Untreated water contributes to increased sediment in riverbeds. Additional impact arises from municipal solid waste being disposed of in open dumps or bodies of water, on which there is also a lack of data. This indicates that to respond to the challenges of the accelerating climate crisis, Gyumri needs to start by collecting data and monitoring resilience indicators for the critical municipal assets and infrastructure, which will serve as a basis for developing adaptation measures.

Gyumri's GCAP climate adaptation indicator is the percentage of households at natural disaster risk, which was last calculated for 2013, the year before the 2014 and 2018 floods. It shows that 0.29 percent of households are at risk, setting the benchmark value as "green." While floods are registered and reported as part of Gyumri's disaster risk reduction activities, the economic impact is not routinely assessed or reported. For example, the 2018 flood report only mentions that "several families were evacuated as a result of river flooding," without further reporting the cost of physical loss or suffering, post-disaster damage mitigation costs, etc.

Apart from the loss of human lives and injuries, damage to buildings would have the biggest economic impact on the city. The economy remains highly vulnerable to a natural disaster with a 20 percent chance of a major disaster resulting in losses of 12.7 percent of GDP in any given year. Deforestation that occurred in the period of economic crisis and blockade (1990–2005) led to the loss of close to 20 percent of Armenia's forest cover (around 63,000 ha), which has greatly increased the likelihood of mudflows and landslides.

Cumulatively, while there is no quantitative estimate of the share of Gyumri public infrastructure at risk, any plan must consider the above countrywide risks and the fact that, at least for seismic risks, new construction in Gyumri is dedicated to structural resilience.

Extreme climate events and natural disasters are putting pressure on the resilience of the transport sector (e.g., interruption of public transport systems and efficiency of transport emergency systems in case of disaster) and the resilience of the electricity network (average share of the population with prolonged power outage in climate extremes over the last five years).

6.7 GYUMRI CLIMATE RISK MITIGATION AND ADAPTATION ACTIONS

Recommendations aimed at adapting to climate change imply a change in the logic of public administration in three main directions:

- Building data-driven decision-making frameworks, including data on current and projected climate change
- Consideration of urban planning as the main tool of urban governance, taking into account climate risks
- Formation of a new culture of community-private (public-private) cooperation, taking into account the existing and expected problems related to climate change

6.7.1 BUILDING DATA-DRIVEN DECISION-MAKING FRAMEWORKS, INCLUDING DATA ON CURRENT AND PROJECTED CLIMATE CHANGE

The data-driven decision-making process involves the collection, classification, analysis and storage of data by various departments or bodies responsible for different sectors. It can both serve as a

decision-making tool, and can also contribute to internal and external (public) monitoring and accountability, as well as organization and control of coordinated work. Taking into consideration the nature of the management of the urban economy and other areas, the need to combine data and decisions related to different spheres, data-driven management processes can contribute to integrated and smart community management. The creation of a city-wide smart management center through a centralized platform for data collection, classification, analysis and storage is the most recommended option for decision-making.

In terms of data security and access, certain steps need to be taken, particularly through the development of legal and operational frameworks to ensure interoperability with other agencies (such as and, if necessary, with the private sector).

The creation of data-driven decision-making frameworks will allow to more effectively incorporate considerations related to climate change risks and vulnerabilities into the planning processes of the city of Gyumri. In this way, it will also be possible to contribute to the promotion of adaptation priorities in decision-making processes.

6.7.2 CONSIDERATION OF URBAN PLANNING AS THE MAIN TOOL OF URBAN GOVERNANCE, TAKING INTO ACCOUNT THE CLIMATE RISKS,

As a result of climate change, the proposed solutions in the scope of identifying and assessing various risks mainly have long-term technical solutions based on the collection of spatial data. The only solution for their integration or complementation can be by reflecting them in various spatial planning documents developed at the city level. For example, in the framework of the management of expected mudslides or landslides, the proposal of basic technical and construction regulation solutions, regardless of the entities responsible for their implementation (state, community, private), should be reflected in urban planning documents and addressed in a phased manner. In this context, the solution of problems associated with the slum dwellings is especially important in the concept of urban planning, taking into account the risks of climate change. Municipal governments shall be the driving force to overcome these risks. Local authorities shall play an essential role in providing basic services that are critical to increase the resilience of vulnerable slum residents. Climate change adaptation and disaster risk reduction can be best addressed and the results be maintained over time by being integrated into existing urban planning and management practices. Substantial financial support is also needed to address the shortfalls in securing permanent housing, provision of basic services and adaptation of basic infrastructure.

6.7.3 FORMATION OF A NEW CULTURE OF COMMUNITY-PRIVATE (PUBLIC-PRIVATE) COOPERATION, TAKING INTO ACCOUNT THE EXISTING AND EXPECTED PROBLEMS RELATED TO CLIMATE CHANGE

Cooperation with the private sector, in different formats, is important in the process of the development of various sectorial policies and strategies. This can be implemented through incentive tools, applicable in cases of implementation of certain non-mandatory steps aimed at climate change adaptation, such as within the framework of granting permits for various types of activities (construction permit, installation permit, etc.). For example, provision of water-permeable surfaces, tree/garden planting areas, or provision of certain additional opportunities in the case of energy-saving solutions, or submission of stricter requirements than the ones at the national level. Those can be part of the city planning documents in force in the community or have legal regulations approve by the decision of the Council of the Elders.

Table 42. 2024-2030 CLIMATE CHANGE ADAPTATION ACTIONS

No.	Actions and Steps (<i>dangerous phenomena</i>)	Expected Result	Time (month)
1	Establishing a comprehensive early warning system for climate hazards		
1.1	Identification of the most vulnerable groups (depending on the type of the risk, the most vulnerable groups may be different, for example, in the case of heat waves, those suffering from cardiovascular diseases, the elderly, in the case of deteriorating air quality, those suffering from respiratory diseases, etc.), and the development of a <u>comprehensive</u> mechanism to inform them about climate hazards (the given mechanisms should include various communication channels, including text messages, phone applications, TV and radio announcements)	- Establishing sustainable communication with vulnerable groups	12
1.2	Development of a protocol plan for dealing with a possible climate hazard/risk, including different actions and actors for different groups/structures (medical institutions, social workers, some strategically important public places, shanty towns etc.)	- Mitigation of consequences of climate hazards	48
1.3	Implementation of projects in schools and community institutions, aimed at increasing public awareness on appropriate behavior in case of climate hazards and decision-making within the functions of local government.	- Awareness raising - Increasing population resilience	ongoing
2	Improving the skills of the primary health care and emergency system, with particular emphasis on the most likely risks of climate change adaptation: heat waves and frost damage		
2.1	Development of guidelines, algorithms, normative documents for rapid response actions, strengthening of systems	- Methodically developed system	36
2.2	Strengthening the rapid response system of primary health care medical workers and emergency medical workers (emergency doctors, primary health care workers, family doctors and nurses) through periodic courses, trainings, as well as provision of appropriate equipment.	- A system appropriately built and strengthened for rapid response	12
2.3	Raising awareness on climate change-related health risks and mitigation options and possibilities	- An awareness program developed and delivered	ongoing
2.4	Development of educational events for the staff of departments in charge of addressing primary needs of citizens, particularly for public health professionals, as well as planning a separate block of educational/training events for the vulnerable groups and population at large.	- Improving knowledge on and capacity to address climate change - Community meetings to raise awareness on resilient behaviors	24

No.	Actions and Steps (dangerous phenomena)	Expected Result	Time (month)
2.5	Raising awareness about health effects of heatwaves, vulnerable groups, diseases, prevention, early response, and other related issues.	<ul style="list-style-type: none"> - Conducting a public awareness raising campaigns - Production of a video clip and other awareness raising materials 	
3	Creation of a smart management center in Gyumri, which will contribute to the transition to a qualitatively different level of planning and implementation of actions related to climate change adaptation, disaster risk management, as well as management of climate change mitigation efforts (energy efficiency and renewable energy projects in buildings, transport, and lighting)		
3.1	Developing a methodology for collecting data, including data on climate risks, specifying the scope of the data in advance	<ul style="list-style-type: none"> - Data collection and storage system - Exchange of interoperable data 	18
3.2	Analysis and clarification of the relevant legal framework	<ul style="list-style-type: none"> - Facilitation/simplification of data collection - Protected data system 	24
3.3	Creation of a smart management center in Gyumri	<ul style="list-style-type: none"> - Creation of a necessary center for smart management 	24
	Training of the relevant staff of the Gyumri Smart Management Center and the Municipality to improve data-based decision-making skills	<ul style="list-style-type: none"> - Staff with capacity for data collection and storage - Ability to make data-based decisions - Smart management capacity 	24
4	Review of urban (spatial) planning documents and construction regulation procedures, taking into account the risks of climate change		
4.1	Defining the requirements for urban planning documents and creating the necessary legislative basis, taking into account the predicted changes in the climate in Gyumri city and the risks associated with climate change.	<ul style="list-style-type: none"> - Necessary prerequisites for the development of effective urban planning documents 	18
4.2	Revision of the requirements for construction density, sun exposure, cross-ventilation, mitigation of winds, increase of permeable surfaces (for example, provision of sand or other permeable surfaces), and other regulations aimed at mitigating risks caused by climate change and reflecting these regulations in relevant legal documents.	<ul style="list-style-type: none"> - Saving electricity for cooling and lighting purposes - Reduction of greenhouse gases 	24
4.3	Development of a system of pedestrian and other active movement paths, providing standard solutions for different types of movement and road junction types, for the purpose of their organization and furnishing	<ul style="list-style-type: none"> - Facilitation of pedestrian and other active movements - Reduction of greenhouse gases 	24

No.	Actions and Steps (<i>dangerous phenomena</i>)	Expected Result	Time (month)
4.4	Establishing a legislative framework to promote private sector participation in public-private partnerships in climate change adaptation actions in the urban economy through tax and duty incentives and low interest or interest subsidies on loans, including for the purpose of resettlement of slum dwellers through social housing construction (community support for the profit-seeking construction of housing stock by private developers in exchange of allotment of housing to families without permanent housing).	<ul style="list-style-type: none"> - Expanding the range of adaptation-oriented actors - Saving public funds - Construction of social housing stock, increasing the resilience of the slum dwellers. 	24
4.5	Implementation of restrictions and other regulations related to the use of private swimming pools	- Reducing water use	24
5	Promoting the use of nature-based solutions		
5.1	Development and implementation of a plan to increase permeable surfaces to mitigate hazards associated with heavy rainfall/snowfall	<ul style="list-style-type: none"> - Reducing the risk of damage to public and private property - Expanding green areas 	48
5.2	Development and implementation of a project to strengthen the banks of water units/reservoirs and other sloping surfaces by planting appropriate plants in order to reduce risks during flood-prone periods.	<ul style="list-style-type: none"> - Cost-Effective Management of Erosion and Landslide Hazards - Expansion of green areas - Improvement of quantitative and qualitative indicators of water: lowering of temperature, natural filtering of inflowing waters 	36
5.3	Development and implementation of mitigation plans for the identified risks for Gyumri caused by climate change, especially water flows, winds, landslides, fires (in vegetated areas and buildings) and rockfalls	- Long-term adaptation solutions in various sectors	24
6	Comprehensive review and development of the urban tree/garden planting system, taking into account the risks caused by climate change		
6.1	Detailed mapping and assessment of existing and potential urban green areas according to climatic conditions (including heat islands/spots), air pollution mitigation potential, existing plant species, age and condition of plants, for the purpose of assessing the potential for expansion of green (tree-lined) area surfaces (e.g., using the Miyawaki method).	- Availability of a more detailed database for implementation of landscaping/tree planting works	18
6.2	Development of a tree/garden planting methodology based on climate change adaptation priorities and creation of appropriate legal framework, including mandatory water saving norms	<ul style="list-style-type: none"> - Specification of urban tree/garden planning procedures - Availability of effective tree/garden planting 	24

No.	Actions and Steps (dangerous phenomena)	Expected Result	Time (month)
		system procedures - Wider use of local and imported water-saving non-invasive plant species, and gradual elimination of plant species with opposite properties	
6.3	Inventory of undeveloped and/or communal and state-owned areas for the purpose of expansion of green areas and tree/garden planting, preserving the historically formed bioscape (landscape), reservoirs and irrigation systems	- Broadening green spaces - Preservation and integration of man-made bioscape (landscape) into the system of public green spaces	36
6.4	Reflection of urban tree/garden planting system in spatial planning documents	- Providing long-term and multifaceted innovative spatial solutions for the creation and further development of a unified tree/garden planting system at the city level	36
6.5	Development of local tree/garden planting improvement projects for each medium and large green area, taking into account the local characteristics of climate change	- Detailed design of green spaces that are part of the system and its implementation	18
6.6	Negotiations with the authorized body in order to adjust the irrigation water supply dates based on the current and expected climatic conditions (based on weather conditions without clearly defined dates)	- Availability of irrigation water throughout the plant growing season	48
6.7	Assessment of professional capacity needs for the maintenance and development of the urban landscaping system and development of relevant capacities of the community landscaping management body	- Highest level of professionalism of the landscaping system	12
6.8	Setting/updating professional qualification standards for community landscaping management authority employees to reflect climate change risk management issues in these standards (development of job descriptions)	- Proper management of human resources - Appropriately qualified and experienced staff	18
6.9	Development and implementation of regular training programs for relevant personnel	- Staff with appropriate capacities and skills	Ongoing
6.10	Creation of legal regulations aimed at ensuring private participation, promoting the creation of green spaces in the areas of limited use as well as in public areas.	- Given the availability of a system and methodology, ensuring private participation in urban tree planting works, thus reducing public costs	Ongoing

No.	Actions and Steps (dangerous phenomena)	Expected Result	Time (month)
6.11	Establishing a monitoring system (including through a public monitoring toolkit), particularly to avoid wind-related risks through early identification and cutting of dry trees or branches	<ul style="list-style-type: none"> - Availability of a continuous and controllable monitoring system aimed at improving the quality of landscaping and the development of methodology - Reduction of damage to urban infrastructure, vehicles and other property during strong winds 	24
7	Introduction of passive cooling and ventilation systems, as well as energy-saving solutions in new constructions and public transport stops, in order to limit the volume of electricity consumption and limit additional pressures on the power supply system.		
7.1	Development of standardized solutions for passive cooling and ventilation systems and creation of a legal basis for their application, as a result of evaluating the possibilities of localization of international experience in cities in similar climate zones (for example, natural ventilation, energy-saving cladding, etc.)	<ul style="list-style-type: none"> - Ability to develop solutions based on best practices - Application of reusable and standard solutions that will lead to time and cost reduction 	24
7.2	Consideration of opportunities to involve the private sector to implement passive cooling and ventilation systems, as well as energy-saving solutions at public transport stops (for example, granting the right to use advertising surfaces for the purpose of furnishing stops)	<ul style="list-style-type: none"> - Increasing the quality of public services while saving public funds 	24
7.3	Raising awareness on energy saving opportunities in schools and community facilities (e.g. encouraging the use of natural ventilation solutions)		36
8	Adapting the existing public transport infrastructure to the challenges of climate change		
8.1	Installation of drinking water fountains or other drinking devices at selected public transport stops or adjacent areas	<ul style="list-style-type: none"> - Network of drinking fountains based on standard solutions 	36
8.2	Painting the roofs of public vehicles (buses, trolleybuses, taxis, etc.) with high-albedo materials, also providing for the reflection of identification data (vehicle serial number and/or license plate) for security and emergency management	<ul style="list-style-type: none"> - A public transport system requiring less cooling resources 	36
8.3	Allowable tinting of windows of public transport vehicles as a means of their passive cooling	<ul style="list-style-type: none"> - More comfortable conditions in public transport in hot weather conditions 	48
8.4	Design of a phased implementation plan for the developed solutions	<ul style="list-style-type: none"> - Good quality public transport system 	48
9	Application of heat-reflective, low heat absorption solutions for the roofs of communal buildings and structures		

No.	Actions and Steps (<i>dangerous phenomena</i>)	Expected Result	Time (month)
9.1	In case of flat roofs, promoting and supporting the creation of green roofs with water-saving or no-irrigation plants, considering wind-related risk management.	- High albedo roofs that also provide some green space	24
9.2	Increasing the albedo index of materials used on roofs by using light colors	<ul style="list-style-type: none"> - Mitigating the Urban Heat Island Phenomenon - Extending the service life of roofs and reducing maintenance costs through landscaping (tree planting) - Increasing heat reflection and reducing absorbed heat, using light-colored materials on roofs, - Creating thermal comfort in buildings and reducing energy demand for cooling through reducing roof overheating. 	30
9.3	Development of public-private partnerships to rebuild roofs, that will also aim at mitigating hazards associated with strong winds.	- Spread of green roofs	48
10	Development of pedestrian and other active movement paths (for pedestrians, bicycles, scooters and other similar devices), taking into consideration their landscaping, installation of sun protection measures and application of water-permeable covering		
10.1	Development of the concept of active urban movement management (for pedestrians, bicycles, scooters and other similar devices)	- Development of a common vision, system and iterative solutions for existing movement organization in an overall urban environment	18
10.2	Creation of rules and other legal regulations for traffic by means of active transportation/movement	- Safe active transportation system	24
10.3	Reflecting the concept of active movement and traffic rules in spatial planning documents	- A system of active transportation that gives systemic and long-term results	24
10.4	Development and implementation of standard solutions for the implementation of movement paths for pedestrians, bicycles, scooters and other wheeled devices, thus contributing to the reduction of design and implementation dates and costs	- Versatile and standard solutions for facilitating the movement of pedestrians, bicycles, scooters and other similar devices, as well as the application of crossings, which will lead to reductions in time and costs for planning, decision making and implementation.	36
10.5	Gradual introduction of movement paths for pedestrians, bicycles, scooters and other wheeled	- Reduction of pavement maintenance costs	48

No.	Actions and Steps (dangerous phenomena)	Expected Result	Time (month)
	devices	- Mitigation of the possible negative effects of the sun on pedestrians through the creation of opportunities for faster movement.	
11	Removal/relocation of dangerous surface infrastructures to mitigate risks associated with strong winds (SW)		
11.1	Refinement of wind maps and mapping of risk areas in cooperation with specialized organizations	- Completing a comprehensive picture of the current situation based on spatial data	24
11.2	Revision of installation and placing conditions of roofs, overground infrastructures, billboards vulnerable to strong winds (for example, relocating and changing wiring, shifting to underground wiring)	- Infrastructural facilities, particularly power supply and communication systems, protected against accidents during strong winds	54
12	Application of windbreak forest layers and nets in areas most susceptible to the influence of strong winds, considering the possibility of mitigating other negative impacts, such as, for example, unpleasant smells coming from landfills/garbage dumps (SW)		
12.1	Reflection of wind protection measures in spatial planning documents	- Prerequisites for creating a multi-beneficial and long-term system	18
12.2	Gradual implementation of wind protection measures within the competence of community authorities and in community-owned areas	- Reducing the impact of winds - Expanding the scope of the multi-stakeholder system	36
13	Reorganization of water-carrying and drainage systems in flood-prone urban areas (F)		
13.1	Mapping of flood-prone areas	- Identification and risk assessment of flood risk areas	18
13.2	Assessment of the technical condition of flood water pipes and other drainage structures	- Flood Resilience Capacity Assessment	30
13.3	Development and implementation of landscaping plan for flood-prone areas, definition of the norm for the exclusion of construction	- Reducing flood risk areas	30
13.4	Modeling of a system overload caused by flooding in developed areas and implementation of measures for alternative flows	- Flood risk management	30
13.5	Reflection of necessary measures in spatial planning documents for flood hazard areas	- Prerequisites for creating a multi-beneficial and	30

No.	Actions and Steps <i>(dangerous phenomena)</i>	Expected Result	Time (month)
		long-term system	
13.6	Development and implementation of a program for monitoring and periodic cleaning of flood water-pipes and other drainage structures	- Constant readiness	ongoing
14	Tightening of mandatory requirements for the use of energy-saving solutions and increased control in new constructions to manage additional pressures on energy infrastructure		
14.1	Increasing the control over the requirements in the projects submitted for approval, for maintaining the thermal indicators defined by the construction standards	<ul style="list-style-type: none"> - Reduction of energy demand for cooling and heating in buildings - In the long term, ensuring the transition process to stability 	38

7 CLIMATE CHANGE MITIGATION WITH SOFT MEASURES

This section of the SECAP focuses on so-called “soft” or mild measures, the key objective of which is the creation of favorable conditions for projects promoting energy saving and improving energy efficiency. The measures are provided below, together with their energy, financial, and environmental values.

7.1 MITIGATION MEASURE: MUNICIPAL ENERGY PLANNING AND MANAGEMENT

The Covenant of Mayors calls for an energy manager to be appointed by the municipality and, within the scope of their powers, to be responsible for implementing the municipality’s energy policy. Their functions are as follows:

1. Create an energy information system and ensure its regular updating, analysis, and monitoring.
2. Monitor the state of municipal electricity consumers and the amount of fuel and energy they consume.
3. Submit periodic analytical reports and recommendations on energy consumption tendencies.
4. Initiate and develop projects related to the efficient use of energy and cooperate with potential financial institutions in order to attract financing for these projects.
5. Involve energy managers of public buildings and services in the process of monitoring buildings’ energy consumption.
6. Cooperate with mass media, private companies, and the population on all aspects of energy efficiency to ensure the SECAP’s visibility and popular participation; promote initiatives such as Municipal Energy Days, Earth Hour, Car-Free Days/No CO₂ Emissions Days, etc.
7. Involve, if necessary, external consulting services in municipal SECAP implementation, improvement, monitoring, and other activities requiring professional qualifications.
8. Negotiate on behalf of the municipality and consolidate, organize, and coordinate daily SECAP activities by foreign labor and project implementation units.

A permanent SECAP task force will be formed from the relevant departments of the municipality that will provide a two-way flow of information about energy consumption with the sectoral structures, including information on energy statistics, energy efficiency needs, efficiency of activities, and other related issues. The activities of the task force will be coordinated by the energy manager.

The energy manager and the energy management task force will also carry out SECAP monitoring and provide two-year reporting.

Table 43. EVALUATION OF EXPECTED RESULTS FROM IMPLEMENTING MUNICIPAL ENERGY PLANNING AND MANAGEMENT

POSSIBLE SOURCE OF FINANCING, COOPERATING PARTNERS	VALUE, THOUSAND USD	ENERGY CARRIERS SAVING, MW/YEAR	CO2 EMISSIONS REDUCTION, TONS	INVESTMENT YEARS
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POSSIBLE SOURCE OF FINANCING, COOPERATING PARTNERS	VALUE, THOUSAND USD	ENERGY CARRIERS SAVING, MW/YEAR	CO2 EMISSIONS REDUCTION, TONS	INVESTMENT YEARS
Gyumri Municipality	100.0	N/A	N/A	2024–2030

7.2 MITIGATION MEASURE: GREEN PROCUREMENT RULES AND ENERGY AUDIT

In order to avoid further problems associated with high rates of energy consumption, the municipal procurement system provides for relevant technical requirements when implementing procurements financed by the municipal budget. These technical requirements must specify energy-efficiency criteria for the products or services procured apart from the principle of low price; for example, when procuring lamps, it is necessary to specify the lamp power (wattage), the amount of light falling on an illuminated surface (lux or lumens/m²), and the term of service (thousand hours). Alternatively, the municipality can be guided by the approach of acquiring at least “Class A” devices when procuring appropriate equipment, etc. Such limitations may contribute to ruling out the procurement of energy-intensive equipment at the expense of municipal funds.

Likewise, prior to design and cost estimation for construction and repair operations, energy audits will be carried out for facilities to be renovated. The audit opinion will be the underlying rationale for formulating technical criteria that will serve as clear and verifiable guidelines on using energy-efficient technologies for contractors carrying out design, construction, and technical monitoring. A considerable part of these norms is already defined in the current legislation (such as the Law “On energy efficiency and renewable energy,” norms and conditions on construction thermophysics, the GOAM Decision on approving the procedure for energy expert examination, and Armenia’s Standard on energy performance assessment of buildings, certification, and labeling).

The following steps are necessary for procurement planning:

1. Conduct mandatory energy audits for reconstruction, capital repair, and construction of buildings.
2. Specify and follow minimum energy consumption norms and standards by using minimum quality and comfort criteria for every public building or service, such as the W/m² norm for lighting, kW/m²/year norm for thermal energy demand, W/lux/m² norm for street lighting, etc.
3. Involve professional services in the initial stage of organizing competitive bidding procedures to develop technical specifications, terms of reference, and/or project orders with verifiable and measurable energy-efficiency criteria, such as the term of service of lamps, quality of the light emitted, color, temperature, boiler efficiency, heat transfer coefficient of the wall constructed, and so on.

Testing and monitoring of luminaires in terms of their quality and effectiveness will be carried out by certified testing laboratories for lighting equipment at the National Polytechnic University of Armenia or the Renewable Resources and Energy Efficiency Fund.

Table 44. EVALUATION OF EXPECTED RESULTS FROM INTRODUCING GREEN PROCUREMENT RULES AND PROCEDURES, INCLUSION OF ENERGY AUDIT IN PROCUREMENT PLANNING

POSSIBLE SOURCE OF FINANCING, COOPERATING PARTNERS	VALUE, THOUSAND USD	ENERGY CARRIERS SAVING, MWH/YEAR	CO2 EMISSIONS REDUCTION, TONS	INVESTMENT YEARS
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POSSIBLE SOURCE OF FINANCING, COOPERATING PARTNERS	VALUE, THOUSAND USD	ENERGY CARRIERS SAVING, MWH/YEAR	CO2 EMISSIONS REDUCTION, TONS	INVESTMENT YEARS
Gyumri Municipality	25.0	N/A	N/A	2017–2020

7.3 MITIGATION MEASURE: ENERGY PERFORMANCE CERTIFICATION OF BUILDINGS

The objective of introducing energy certification of buildings is to determine the actual energy intensity of buildings and identify their potential to achieve energy savings. This requires monitoring and inspecting buildings, using standardized methods to assess external technical conditions or other contemporary devices recording that record the intensity of infrared radiation (thermal imaging or infrared cameras) and identifying the thermal protection value of building envelopes.

Energy performance certificates enable a city to assess baseline conditions in terms of thermal protection qualities and the internal lighting system before and after implementing energy-saving measures. For the purposes of certification, administrative districts will be required to recruit qualified specialists and use appropriate measuring devices. One of Gyumri’s advantages is the fact that, given the urban development and construction conditions, the majority of buildings are typical, and a single method of inspection may be developed for each type of building. When developing certificates, the National Standard “Energy efficiency. Building energy passport. Main provisions. Typical forms” (AST 362–2013) will be taken into consideration.

In addition to verifying energy efficiency, an energy performance certificate is also an effective tool to build public awareness of the value of construction in the real estate market. Building energy certificates help people make informed decisions about where to live or work and influence their real estate purchasing or rental decisions. Building certification also creates a financial incentive for people to improve the energy efficiency of their buildings and raises awareness of the importance of energy efficiency, triggering behavior changes and informed decisions. Once a significant number of buildings in Gyumri are certified, the value of a building certificate will become public information, improving citizens’ understanding of building energy performance and what affects it, especially in retrofitted buildings.

Hence, it will be possible to discuss ordering the certification of residential MABs and public CNCO buildings after the energy-efficiency retrofits of these buildings are completed.

Table 45. EVALUATION OF EXPECTED RESULTS OF ENERGY PERFORMANCE CERTIFICATION OF BUILDINGS, 2020

POSSIBLE SOURCE OF FINANCING, COOPERATING PARTNERS	VALUE, THOUSAND USD	ENERGY CARRIERS SAVING, MWH/YEAR		CO2 EMISSIONS REDUCTION, TONS	INVESTMENT YEARS
		ELECTRICAL ENERGY	NATURAL GAS		
Gyumri Municipality, other partners	34.0	121.0	923.9	213.5	2024–2030

7.4 MITIGATION MEASURE: PARTICIPATION IN GLOBAL EARTH HOUR CAMPAIGN

Many countries organize this event in early March each year to raise public awareness of the importance of energy saving. Since joining this initiative in 2010, Yerevan has turned off the city's street lighting for one hour on that day, saving 17.1 MWh of energy and preventing 3.8 tons of CO₂ emissions. One of the other objectives of this event is to demonstrate to the population how much energy can be saved through collective action in just one hour of a single day. Moreover, besides street lighting, budget-funded institutions will also join this initiative by turning off their power supply for one hour, subject to strict compliance with safety rules. Effectively organized awareness measures will encourage the population and the private sector to join this initiative. These include printed and online sources on EE and RES advantages and integration approaches into the existing energy system.

To assess the hourly consumption rates of consumer groups, the following have been taken as a basis:

1. Seventy percent of daily average electricity consumption by the population occurs within ten hours.
2. Ninety-five percent of daily electricity consumption by budget-funded institutions occurs within eight hours.
3. One hundred percent of street lighting occurs within five hours.

Table 46. EVALUATION OF EXPECTED RESULTS OF PARTICIPATION IN EARTH HOUR, 2020

POSSIBLE SOURCE OF FINANCING, COOPERATING PARTNERS	VALUE, THOUSAND USD	ENERGY CARRIERS SAVING, MWH/YEAR		REDUCTION OF EMISSIONS, TONS OF CO ₂	INVESTMENT YEARS
		ELECTRICAL ENERGY	NATURAL GAS		
Gyumri Municipality	6.0	32.9	-	7.3	2024–2030

7.5 MITIGATION MEASURE: PARTICIPATION IN EUROPEAN SUSTAINABLE ENERGY DAYS EVENT

Participants in this event include the population and budget-funded institutions, which mostly use electrical energy and natural gas. People can save energy by taking a more thoughtful attitude toward energy, especially when using it for food preparation, household electrical appliances, and internal lighting systems. Such days are held within the framework of European cooperation and under the Covenant of Mayors initiative.

The Sustainable Energy Days event includes numerous mechanisms that may take any creative and innovative format, such as outdoor sustainable energy expos in Gyumri on non-working days in the main pedestrian areas. Expo stands may be equipped by manufacturers and importers operating in Armenia that are engaged in energy-efficient construction, alternative energy, landscaping, and other thematic technology activities. The theme may be changed in line with the priorities of the given year (for example, efficient thermal insulation, lighting, heating, or use of renewable energy).

As an example of expected results calculation for a soft measure, it is assumed that 80 percent of Gyumri residents are informed about and apply energy-saving measures, which are implemented only on weekdays and include saving up to five minutes' worth of electricity and natural gas. In this

case, held on an annual basis, the event will last 0.903 of full day¹³. Using Gyumri’s baseline residential energy consumption from 2014, the annual energy use can be averaged to hourly or daily energy consumption by city residents, to further calculate how much energy can be saved if residents adopt regular energy saving practices for minutes, which add up to hours and days over the year.

Table 47. EVALUATION OF EXPECTED RESULTS OF PARTICIPATION IN EUROPEAN SUSTAINABLE ENERGY DAYS

Possible source of financing, cooperating partners	Value, thousand USD	Energy carriers saving, MWh/year		Reduction of emissions, TONS of CO ₂	Investment years
		ELECTRICAL ENERGY	NATURAL GAS		
Gyumri Municipality	15.0	796.8	1,479.7	502.9	2024–2030

7.6 MITIGATION MEASURE: INVOLVEMENT OF SCHOOLS IN SUSTAINABLE URBAN ENERGY DEVELOPMENT PROCESSES

The purpose of a sustainable energy–related event is to build responsible and careful attitudes in schoolchildren toward energy and nature in general. Accordingly, such events pursue more future-oriented targets. This activity will create monitoring groups in schools that participate in developing, organizing, and implementing activities as part of the soft measures. Various participation formats have been widely used in such programs, such as “school energy auditor squads,” “energy police,” “sustainable energy theater,” “green schools,” “energy-efficient school competitions,” “energy-efficiency patrols,” and other creative formats, and the schoolchildren themselves will actively be involved in choosing one of them. Such events may be carried out among students in a technologically advanced format. The generated experience can then be used to localize relevant online courses and implemented for a wider audience.

This measure will aim to build a thoughtful attitude among students toward natural resources, which will contribute to the effective implementation of the abovementioned measures. It will probably be about 50 percent as effective as the European Sustainable Energy Days event while requiring less investment.

Table 48. EVALUATION OF EXPECTED RESULTS OF SCHOOL INVOLVEMENT IN SUSTAINABLE URBAN ENERGY DEVELOPMENT PROGRAMS

POSSIBLE SOURCE OF FINANCING, COOPERATING PARTNERS	VALUE, THOUSAND USD	ENERGY CARRIERS SAVING, MWH/YEAR		REDUCTION OF EMISSIONS, TONS OF CO ₂	INVESTMENT YEARS
		ELECTRICAL ENERGY	NATURAL GAS		
Gyumri Municipality, schools, universities	33.5	253.9	858.9	1,683.9	2024–2030

7.7 ORGANIZING SEMINARS AND TRAINING COURSES FOR SPECIALISTS OF CNCOS

¹³ Calculated as $5 \cdot 2606024 = 0.903$

This activity focuses on relatively new and inexperienced employees as well as energy managers of public/municipal institutions to raise awareness, develop professional skills, and exchange experience.

The training will emphasize the opportunities for and necessity of saving energy and will enable specialists to develop more substantiated and feasible proposals for energy efficiency improvement and renewable energy.

While it will be impossible to directly and immediately assess the energy and environmental outcomes of the measure, it will presumably have the same quantitative results as the previous measure, specifically by triggering short intervals of energy-saving behavior over time.

Table 49. EVALUATION OF EXPECTED RESULTS THE RESULTS OF SEMINARS AND TRAINING COURSES FOR CNCO SPECIALISTS

IMPLEMENTING ENTITY	ENERGY CARRIERS SAVING, MWH/YEAR		REDUCTION OF EMISSIONS, TONS OF CO ₂	INVESTMENT YEARS
	ELECTRICAL ENERGY	NATURAL GAS		
Gyumri Municipality	800.0	2,200.0	622.0	2024–2030

7.8 MULTI-VENDOR CENTRALIZED SOLAR SYSTEM MONITORING AND MANAGEMENT PLATFORM

The Energy Secure Armenia project recommends assessing the feasibility of and exploring technical options for establishing a platform that allows solar system owners, operators, and maintenance teams to efficiently monitor, manage, and optimize their solar installations from different vendors in a single centralized location. The system must include the following:

- Compatibility with and capability to integrate and support various solar system vendors and solar inverters, meters, sensors, and other monitoring devices commonly used in the industry seamlessly and securely.
- Capability to collect and aggregate energy generation, system performance, weather, and other data from multiple solar installations of various origins and manufacturers in real time.
- User-friendly and accessible centralized interface for monitoring, troubleshooting, visualization, and analytics on all connected solar installations.
- Robust alert system that can notify users about any deviations or malfunctions in the solar systems via real-time notifications, enabling immediate reaction and system maintenance.
- Comprehensive performance analysis tools to evaluate the efficiency and productivity of each solar installation based on historical data analysis, trend identification, benchmarking, and performance comparisons between different systems.
- Advanced fault and malfunction detection algorithms for analyzing the collected data, identifying anomalies, and providing diagnostic insights to troubleshoot and resolve issues efficiently, minimize downtime, and improve system reliability.
- Capability to generate customized reports and export data for further analysis, perform in-depth analysis using external tools, or integrate the data with other management systems, potentially

related to municipal services' energy consumption and expansion of electric consumption centers, including e-mobility.

- Capability to integrate and expand to include new capacities as they appear, while also being interoperable with other energy management systems, asset management platforms, or third-party applications, can be beneficial.

The absence of an efficient monitoring system results in responsive maintenance rather than preventive maintenance, which affects the performance of solar PV systems in two major ways. First, it increases the annual degradation of the performance of the system by 0.2 percent. Second, it means systems may be unavailable for reasons that are not visible without an effective monitoring system; it is possible that solar PV systems will be unavailable for two days per month (aggregate of short-term unavailability from several locations).

In this case, the additional 0.2 percent annual degradation and overall unavailability of two days per month will result in underperformance (loss of opportunity) of 1,670 MWh per year, which is equal to 395 tons of CO₂, averaged over seven years.

Table 50. MULTI-VENDOR CENTRALIZED SOLAR SYSTEM MONITORING AND MANAGEMENT PLATFORM

IMPLEMENTING ENTITY	VALUE, THOUSAND USD	ENERGY CARRIERS SAVING, MWH/YEAR		REDUCTION OF EMISSIONS, TONS OF CO ₂	INVESTMENT YEARS
		ELECTRICAL ENERGY	NATURAL GAS		
Gyumri Municipality	150	1,670	-	395	2024–2030

The simple payback period of this investment is around two years.

7.9 IMPLMENETATION OF GCAP SOFT MEASURES IN TRANSPORT SECTOR

The Gyumri Green City Action Plan, in addition to those measures listed above, includes a set of soft measures for transport sector optimization, reduction of its carbon footprint for climate change mitigation and adaptation purposes. These are largely focusing on raising public awareness on sustainable transportation, promoting alternative, unmotorized, low-carbon transportation alternatives, as well as providing innovative solutions for optimizing the transportation services through digitalization, better modeling, planning and management, as presented in the table below.

Table 51. GCAP SOFT MEASURES IN TRANSPORT SECTOR

Action reference	Action title	Alignment with mid-term targets for 2025
A_TR_01	New public transport network operator model and integrated	Reduction of annual CO ₂ emissions per unit of GDP by 20% on the 2014 level Reduction of annual CO ₂ equivalent emissions per capita to 3.0 t/yr/capita Increase in the hare of public transport fleet run by electric, hybrid fuel cell, Liquefied Petroleum Gas (LPG) and Compressed Natural Gas (CNG) energy to 60% Reduction of private vehicle modal share in commenting to 80%

Action reference	Action title	Alignment with mid-term targets for 2025
	tariffs and ticketing	
A_TR_02	Upgrading bus stop infrastructure including with Real Time Passenger Information (RTPI)	Reduction of annual CO ₂ emissions per unit of GDP by 20% on the 2014 level Reduction of annual CO ₂ equivalent emissions per capita to 3.0 t/yr/capita Increase in the share of public transport fleet run by electric, hybrid fuel cell, Liquefied Petroleum Gas (LPG) and Compressed Natural Gas (CNG) energy to 60% Reduction of private vehicle modal share in commenting to 80% Reduction of public infrastructure at risk to 12% Reduction in the estimated economic damage from natural disasters floods droughts earthquakes as a share of GDP to 1%
A_TR_04	New cycle lanes and cycle parking infrastructure	Reduction of annual CO ₂ emissions per unit of GDP by 20% on the 2014 level Reduction of annual CO ₂ equivalent emissions per capita to 3.0 t/yr/capita Increase non-motorized transport modal share in total trips 2% Reduction of public infrastructure at risk to 12% Reduction in the estimated economic damage from natural disasters floods droughts earthquakes as a share of GDP to 1%
A_TR_05	City-wide pedestrian wayfinding signage network	Reduction of annual CO ₂ emissions per unit of GDP by 20% on the 2014 level Reduction of annual CO ₂ equivalent emissions per capita to 3.0 t/yr/capita Increase non-motorized transport modal share in total trips 2% Reduction of public infrastructure at risk to 12% Reduction in the estimated economic damage from natural disasters floods droughts earthquakes as a share of GDP to 1%
A_TR_06	Promotional campaigns for walking and cycling	Reduction of average annual concentration of dust to 0.15 µg/m ³ Reduction of annual CO ₂ emissions per unit of GDP by 20% on the 2014 level Reduction of annual CO ₂ equivalent emissions per capita to 3.0 t/yr/capita Increase non-motorized transport modal share in total trips 2%
A_TR_09	Sustainable Urban Mobility Plan (SUMP) for Gyumri	Reduction of annual CO ₂ emissions per unit of GDP by 20% on the 2014 level Reduction of annual CO ₂ equivalent emissions per capita to 3.0 t/yr/capita Reduction of private vehicle modal share in commenting to 80% Increase in the share of public transport fleet run by electric, hybrid fuel cell, Liquefied Petroleum Gas (LPG) and Compressed Natural Gas (CNG) energy to 60% Increase of non-motorized transport modal share in total trips to 2% Increase of share of municipal vehicles operating on electricity to 20% Increase modes of transport subject to annual data collection to 100% Reduction of public infrastructure at risk to 12% Reduction in the estimated economic damage from natural disasters floods droughts earthquakes as a share of GDP to 1% Increase funding provided for DRR and resilience enhancement in GCAP lifetime to a sufficient level for the implementation of local DRR plans
A_TR_12	City-wide data collection program and transport model	Reduce annual CO ₂ emissions per unit of GDP by 20% on the 2014 level Reduction of annual CO ₂ equivalent emissions per capita to 3.0 t/yr/capita Increase modes of transport subject to annual data collection to 100%

Source: Gyumri GCAP, 2019

Similarly, the Gyumri GCAP had approved a number of soft, organizational, management, planning and optimization measures, which can contribute the climate change mitigation and adaptation tasks of the SECAP as well. See below.

7.10 IMPLEMENTATION OF GCAP SOFT MEASURES IN BUILDINGS, ENERGY AND LIGHTING

The Gyumri GCAP also included a number of measures related to climate change mitigation and adaptation in the buildings, energy and lighting system, most of which were closely synchronized with the original Sustainable Energy Action Plan, but others, as presented below, were new.

These include a crowd-funded low-income LED-lamp campaign, energy performance contracting, and promotion of green buildings, as presented in the table below.

Table 52. BUILDING, ENERGY AND LIGHTING ACTIONS

Action reference	Action title	Alignment with mid-term targets for 2025
A_BEL_02	Low-income LED transformational programme and campaign	Reduction of annual CO ₂ emissions per unit of GDP by 20% on the 2014 level Reduction of annual CO ₂ equivalent emissions per capita to 3.0 t/yr/capita Reduction of electricity consumption in residential buildings to 23 kWh
A_BEL_05	Energy Performance Contracting (EPC) and Energy Service Company (ESCO) contracts	Reduction of annual CO ₂ emissions per unit of GDP by 20% on the 2014 level Reduction of annual CO ₂ equivalent emissions per capita to 3.0 t/yr/capita Reduction of Heating energy consumption in public buildings to 96kWh/m ² Reduction of energy consumption from street lighting to 25,000 kWh/km
A_BEL_08	Promoting green building	Reduction of annual CO ₂ emissions per unit of GDP by 20% on the 2014 level Reduction of annual CO ₂ equivalent emissions per capita to 3.0 t/yr/capita Reduction of Heating energy consumption in residential buildings to 104 Wh/m ² Reduction in the estimated economic damage from natural disasters floods droughts earthquakes as a share of GDP to 1%

Source: Gyumri GCAP, 2019

7.11 IMPLEMENTATION OF GCAP SOFT MEASURES IN LAND USE AND GREEN SPACE DEVELOPMENT

While the SECAP does not include land use and green space development as its key sector, the Gyumri GCAP included a significant number of actions, which were vetted by the local civil society and the Elders Council, and have significant potential for climate change mitigation and adaptation.

Table 53. LAND USE AND GREEN SAPCE DEVELOPMENT ACTIONS

Action reference	Action title	Alignment with mid-term targets for 2025
A_LU_01	Develop a Sustainable Urban Planning Framework for the city of Gyumri and develop an updated master plan and zoning regulations	<p>Reduction of average annual concentration of dust to 0.15 µg/ m3</p> <p>Reduction of annual CO₂ emissions per unit of GDP by 20% on the 2014 level</p> <p>Reduction of annual CO₂ equivalent emissions per capita to 3.0 t/yr/capita</p> <p>Reduction of ammonium (NH₄) concentration in rivers and lakes to 0.4-1.2 mg/l</p> <p>Increase of ratio of open green area per inhabitant to 6 m2/inhabitant</p> <p>Reduction of number of polluted and potentially polluted areas by 40% on 2017 levels</p> <p>Reduction of public infrastructure at risk to 12%</p> <p>Reduction of households at risk to 12%</p> <p>Reduction in the estimated economic damage from natural disasters floods droughts earthquakes as a share of GDP to 1%</p> <p>Increase funding provided for DRR and resilience enhancement in GCAP lifetime to a sufficient level for the implementation of local DRR plans</p>
A_LU_02	Develop a GIS based land use database and City Information Model (CIM) for Gyumri	<p>Reduction of average annual concentration of dust to 0.15 µg/ m3</p> <p>Reduction of annual CO₂ emissions per unit of GDP by 20% on the 2014 level</p> <p>Reduction of annual CO₂ equivalent emissions per capita to 3.0 t/yr/capita</p> <p>Reduction of ammonium (NH₄) concentration in rivers and lakes to 0.4-1.2 mg/l</p> <p>Increase of ratio of open green area per inhabitant to 6 m2/inhabitant</p> <p>Reduction of number of polluted and potentially polluted areas by 40% on 2017 levels</p> <p>Increase of the share of land use and environment data collected and made accessible on a GIS platform</p> <p>Reduction of public infrastructure at risk to 12%</p> <p>Reduction of households at risk to 12%</p> <p>Reduction in the estimated economic damage from natural disasters floods droughts earthquakes as a share of GDP to 1%</p> <p>Increase funding provided for DRR and resilience enhancement in GCAP lifetime to a sufficient level for the implementation of local DRR plans</p>
A_LU_03	Create targeted urban planning guidance and tools	<p>Reduction of average annual concentration of dust to 0.15 µg/ m3</p> <p>Reduction of annual CO₂ emissions per unit of GDP by 20% on the 2014 level</p> <p>Reduction of annual CO₂ equivalent emissions per capita to 3.0 t/yr/capita</p> <p>Reduction of ammonium (NH₄) concentration in rivers and lakes to 0.4-1.2 mg/l</p> <p>Increase of ratio of open green area per inhabitant to 6 m2/inhabitant</p> <p>Reduction of number of polluted and potentially polluted areas by 40% on 2017 levels</p> <p>Reduction of public infrastructure at risk to 12%</p> <p>Reduction of households at risk to 12%</p> <p>Reduction in the estimated economic damage from natural disasters floods droughts earthquakes as a share of GDP to 1%</p>
A_LU_04	Enforce planning policy and building regulations	<p>Reduction of average annual concentration of dust to 0.15 µg/ m3</p> <p>Reduction of annual CO₂ emissions per unit of GDP by 20% on the 2014 level</p> <p>Reduction of annual CO₂ equivalent emissions per capita to 3.0 t/yr/capita</p> <p>Reduction of ammonium (NH₄) concentration in rivers and lakes to 0.4-1.2 mg/l</p> <p>Increase of ratio of open green area per inhabitant to 6 m2/inhabitant</p> <p>Reduction of number of polluted and potentially polluted areas by 40% on 2017 levels</p> <p>Reduction of public infrastructure at risk to 12%</p> <p>Reduction of households at risk to 12%</p> <p>Reduction in the estimated economic damage from natural disasters floods droughts earthquakes as a share of GDP to 1%</p>
A_LU_05	Urban planning and	<p>Reduction of average annual concentration of dust to 0.15 µg/ m3</p> <p>Reduction of annual CO₂ emissions per unit of GDP by 20% on the 2014 level</p> <p>Reduction of annual CO₂ equivalent emissions per capita to 3.0 t/yr/capita</p>

	sustainable development public-sector capacity building	<p>Reduction of ammonium (NH₄) concentration in rivers and lakes to 0.4-1.2 mg/l</p> <p>Increase of ratio of open green area per inhabitant to 6 m²/inhabitant</p> <p>Reduction of number of polluted and potentially polluted areas by 40%</p> <p>Reduction of public infrastructure at risk to 12%</p> <p>Reduction of households at risk to 12%</p> <p>Reduction in the estimated economic damage from natural disasters floods droughts earthquakes as a share of GDP to 1%</p> <p>Increase funding provided for DRR and resilience enhancement in GCAP lifetime to a sufficient level for the implementation of local DRR plans]</p> <p>Increase in municipal staff in the planning department with up-to-date training in related policy and planning to 100%</p>
A_LU_06	Management strategy for public parks and green spaces	<p>Reduction of average annual concentration of dust to 0.15 µg/ m³</p> <p>Reduction of annual CO₂ emissions per unit of GDP by 20% on the 2014 level</p> <p>Reduction of annual CO₂ equivalent emissions per capita to 3.0 t/yr/capita</p> <p>Reduction of ammonium (NH₄) concentration in rivers and lakes to 0.4-1.2 mg/l</p> <p>Increase of ratio of open green area per inhabitant to 6 m²/inhabitant</p> <p>Reduction of number of polluted and potentially polluted areas by 40% on 2017 levels</p> <p>Increase in the diversity of bird's population</p> <p>Increase of the share of land use and environment data collected and made accessible on a GIS platform</p> <p>Reduction of public infrastructure at risk to 12%</p> <p>Reduction of households at risk to 12%</p> <p>Reduction in the estimated economic damage from natural disasters floods droughts earthquakes as a share of GDP to 1%</p> <p>Increase funding provided for DRR and resilience enhancement in GCAP lifetime to a sufficient level for the implementation of local DRR plans</p>
A_LU_07	Provision of green infrastructure, parks and open space	<p>Increase of ratio of open green area per inhabitant to 6 m²/inhabitant</p> <p>Increase in the diversity of bird's population</p>

Source: Gyumri GCAP, 2019

8 SUMMARY OF SUSTAINABLE ENERGY AND CLIMATE INTERVENTIONS

In its 2021 NDC update, Armenia adopted the ambitious new mitigation target of reducing GHG emissions by 40 percent from 1990 levels by 2030. In the framework of the Covenant of Mayors, however, the goals are linked to local country and city contexts and are more cautious. While for the countries of the European Union, the GHG emission reduction commitment is 40 percent, for the Eastern Partnership region, after extensive discussions with the mayors and the European Commission, the target was set at 35 percent as a more realistic achievement by 2030. Nevertheless, each city makes its own statement in this regard when it signs the Adhesion Form when joining the Covenant. For Gyumri, this target is set at 35 percent.

The summary below reflects both soft and hard measures proposed to the city for effective GHG emission reduction. Soft measures are not associated with significant financial costs; rather, they are organizational in nature and mainly aim to increase awareness and strengthen the capacities of the target groups of society, such as youth, relevant specialists working for community structures, beneficiaries of climate action, and local governance bodies. Hard measures aim for energy and thermal retrofits of buildings and structures, the use of energy-saving technologies in lighting systems, the transition to environmentally cleaner fuels in transport or the development of electric vehicle infrastructure, energy generation from local sources of renewable energy, and other such activities. Implementing these requires certain investments, although they will contribute the bulk of progress toward achieving the GHG emission reduction targets. The costs can be covered via co-financing from the municipal budget funds and from other sources discussed in section 1. Because of the residential sector's high emission reduction potential, the municipality should make an exhaustive effort to ensure the active involvement of residents, both in the organization of works and direct/financial participation, in SECAP implementation for the community's sustainable development.

It is critical that neither soft nor hard measures be implemented once as an exceptional activity, but that they be incorporated into the community's administrative and communications routine. Establishing and operationalizing a municipal energy planning and management system is the most prominent effort in that regard, with a long-term effect. For one, establishing a viable and reliable statistical reference system with regular data updates make the municipality more efficient in evaluating and improving energy performance and proposing measures for the use of renewable energy sources. Another important action is sharing information with owners of condominiums and private houses, both directly and via local media, and supporting energy-efficient actions by local companies: this educates consumers and services providers and directs their attention to solutions to the energy issues.

A measure with similar long-term effect is the involvement of schools in developing sustainable urban energy programs that target students and teachers alike and bring coherent, user-friendly information on energy efficiency and energy-saving daily routines to families from yet another source. A similar impact is expected from introducing a centralized platform for solar systems,

which would make companies' efforts to monitor and manage systems more focused and better informed.

As the vast majority of the hard measures are technical in nature, soft measures would implement yet another function: raising awareness among involved parties, especially residents of MABs and private homes, of the benefits of solar PV systems and solar water heaters, the meaning and intended results of energy-efficient retrofits in residential buildings, and the higher energy performance of the improved lighting systems. The core impact would come from the introduction of green procurement rules and procedures and the inclusion of energy audits in the procurement planning process.

Table 54. SUMMARY OF HARD AND SOFT MEASURES FOR CLIMATE CHANGE IMPACT MITIGATION

	Mitigation Measure / Activity Content	Possible source of financing, cooperating partners	CapEx / Value, thousand USD	Energy carriers saving, MWh/year			Reduced / Avoided CO ₂ emissions, ton/year	Investment years
				electrical energy	natural gas	total		
	"Hard" measures							
5.1.1.1.	EE-Retrofits in all 50 Public Buildings	Gyumri Municipality	14,600	313.6	1,254	1,568	327	2024-2030
5.2.1.1.	EE-Retrofits of 100 Multi-Apartment Residential Buildings *	Gyumri Municipality	25,000	29,121	95,985	125,106	26,262	2024-2030
5.3.1.1.	Equip community-owned public buildings with solar photovoltaic systems	Gyumri Municipality, building responsible, contractor company	2,539	3,335	-	3,335	787	2024-2030
5.3.1.2.	Equip municipal public services with solar photovoltaic systems	Gyumri Municipality, service responsible, contractor company	1,450	1,771	-	1,771	418	2024-2030
5.3.1.2.1	Additional 750kW SPV for extended street lighting system	Gyumri Municipality, service responsible, contractor company	903	1,094	-	1,094	258	2026-2030
5.3.2.1.	Equip residential buildings with solar photovoltaic systems	Gyumri Municipality, residents, contractor company	710.4	109.0	-	109.0	25.7	2024-2030
5.3.2.2.	Installation of solar water heaters at residential buildings	Gyumri Municipality, residents, contractor company	518.4	-	376.4	376.4	89.0	2024-2030
5.3.2.3.	Installation of solar water heaters at private houses	Gyumri Municipality, residents, contractor company	909.3	658.0	-	658.0	155.0	2024-2030
5.3.2.4.	Installation of solar PV systems at private houses	Gyumri Municipality, residents, contractor company	2,311.8	3,154.0	-	3,154.0	744.4	2024-2030
5.3.2.5.	Two groups of APP solar PV producers each 1050kW for EV charging stations	Gyumri Municipality	2,529	3,064	-	3,064	723	2026-2030
5.3.2.5.1.	Additional 1050kW APP group for gradual increase in community-owned solar PV	Gyumri Municipality	1,264	1,532	-	1,532	362	2028-2030
5.3.	LEDification of the urban lighting system	Gyumri Municipality	1,500	1633	-	1633	385	2020-2030

	Mitigation Measure / Activity Content	Possible source of financing, cooperating partners	CapEx / Value, thousand USD	Energy carriers saving, MWh/year			Reduced / Avoided CO ₂ emissions, ton/year	Investment years
				electrical energy	natural gas	total		
5.4.	Integration of e-mobility in municipal fleet	Gyumri Municipality, residents, donors / IFIs	10,000.0	1,555.4	-	1,555.4	314.2	2026-2030
	"Hard" Sub-Total		64,236	47,717	97,239	144,956	30,851	
	"Soft" measures							
7.1	Municipal Energy Planning and Management	Gyumri Municipality	100.0	30.0	30.0	60.0	18.7	2024-2030
7.2	"Green Procurements" Rules and Procedures, Inclusion of Energy Audit in the Process of Procurement Planning	Gyumri Municipality	25.0	30.0	30.0	60.0	18.7	2024-2031
7.3	Energy Performance Certification of Buildings	Gyumri Municipality, other partners	34.0	121.0	923.9	1,044.9	213.5	2024-2030
7.4	Participation in "Earth Hour" Global Campaign	Gyumri Municipality	6.0	32.9	-	32.9	7.3	2024-2030
7.5	Participation in European Sustainable Energy Days Event	Gyumri Municipality	15.0	796.8	1,479.7	2,276.5	502.9	2024-2030
7.6	Involvement of Schools in Sustainable Urban Energy Development Programs	Gyumri Municipality, schools, Universities NGOs	33.5	253.9	858.9	1,112.8	1,683.9	2024-2030
7.7	Organizing Seminars and Training Courses for CNCO Specialists	Gyumri Municipality	50.0	800.0	2,200.0	3,000.0	622.0	2024-2030
7.8	Introducing a Multi-Vendor Centralized Solar System Monitoring and Management Platform	Gyumri Municipality	150.0	1,670.0	-	1,670.0	395.0	2024-2030
	"Soft" Sub-Total		413.5	3,734.6	5,522.5	9,257.1	3,462.0	-
	Grand Total		64,650	51,451	102,762	154,213	34,313	

* Natural gas and electrical energy savings estimates are an average over five to seven years.