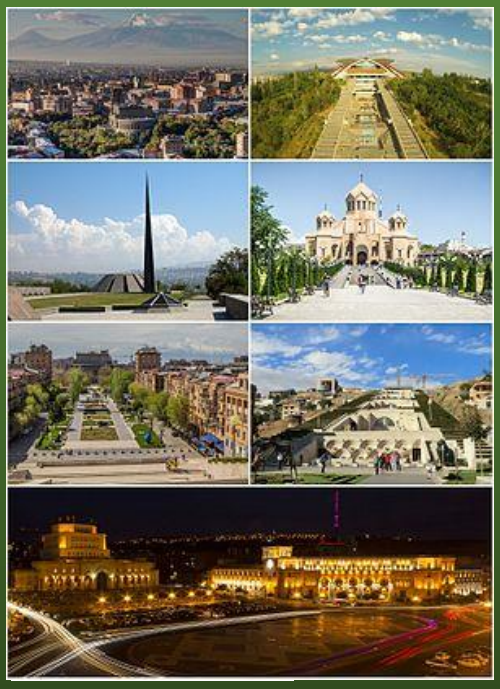
Annex
Yerevan Elders' Council
Decision No 558 N
from 24 June 2016

Covenant of Mayors

# YEREVAN CITY SUSTAINABLE ENERGY ACTION PLAN





*Yerevan Sustainable Energy Action Plan has been developed by the "Foundation to Save Energy" NGO in the framework of "Armenia's First Bieenial Update Report to the UNFCCC" and "Green Urban Lighting" Projects coordinated by the Ministry of Nature Protection of the Republic of Armenia. The Projects are funded by the Global Environment Facility and implemented by the United Nations Development Programme in Armenia.*

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**Abbreviations and Measurement Units Used in the Document**

| | |
|---|---|
| GRS | Gas refuelling stations |
| ADB | Asian Development Bank |
| USAID | United States Agency for International Development |
| NSS | National Statistical Service |
| MAB | Multi-apartment building |
| GEG | Gas engine electric generator |
| GEF | Global Environment Fund (GEF) |
| GWh | Gigawatt hour = 1000 MWh =1000,000 kWh |
| EC | European Commission |
| EU | European Union |
| EIB | European Investment Bank |
| YM | Yerevan Municipality |
| EE | Energy Efficiency |
| NEEAP | National Energy Efficiency Action Plan |
| SEAP | Sustainable Energy Action Plan |
| kcal | kilocalorie |
| MSW | Municipal Solid Waste |
| GCF | Green Climate Fund |
| KW | Kilowatt |
| KWh | Kilowatt hour |
| IPCC | Intergovernmental Panel on Climate Change |
| ha | Hectare = 10,000 m2 |
| HEV | Hybrid electric vehicles |
| NGO | Non-governmental organization |
| RA | Republic of Armenia |
| LPG | Liquefied petroleum gas |
| MNCO | Municipal non-commercial organisation |
| HFHA | Habitat for Humanity Armenia |
| UNDP | United Nations Development Program |
| UN | United Nations Organisation |
| FP | Methane flare plant |
| CDM | Clean Development Mechanism |
| IEA | International Energy Agency |
| MWh | Megawatt hour = 1000 kWh |
| IFI | International financial institutions |
| $nm^3$ | Normal (standard) cubic meters |
| SNCO | State non-commercial organisation |
| GHG | Greenhouse gas |
| GHGE | Greenhouse gas emissions |
| TPP | Thermal power plant |
| CNG | Compressed natural gas |
| EBRD | European Bank for Reconstruction and Development |
| R2E2 | Armenia Renewable Resources and Energy Efficiency Fund |
| AD | Administrative district (of Yerevan municipality) |
| N/A | Not available |
| MTC | Ministry of Transport and Communication of the Republic of Armenia |

| | |
|---|---|
| CJSC | Closed Joint Stock Company |
| CM | Covenant of Mayors |
| SUDIP | Sustainable Urban Development Investment Program |
| MUD | Ministry of Urban Development of the Republic of Armenia |
| E5P | Eastern Europe Energy Efficiency and Environmental Partnership |
| KfW | Development Bank of Germany |

## INTRODUCTION

Yerevan Municipality joined the EU Covenant of Mayors for Climate & Energy initiative on September 9, 2014.[1]

By joining the Covenant of Mayors initiative the City of Yerevan, within the framework of its responsibilities and guided by the principles laid down in the Sustainable Energy Action Plan, committed to achieve by the year 2020 at least 20% reduction of greenhouse gas emissions in the jurisdiction of Yerevan City, compared to the baseline figures.

The Sustainable Energy Action Plan (SEAP) of the City can be characterized as the first step towards implementation of a long-term strategy for environmental protection and improvement of energy efficiency of urban infrastructures in Yerevan.

- Development of the SEAP involved the following steps:

- Identification of energy consumption patterns for the City as a whole and different consumption groups, and preparation of the energy balance;
- Development of the baseline inventory of greenhouse gas emissions (mainly for carbon dioxide);
- Projection of greenhouse gas emission growth trends in relation to baseline levels;
- Outlining general strategies for reduction of energy consumption and greenhouse gas emission (climate mitigation measures); for example: better use of renewable sources, application of energy saving and energy efficiency measures, expansion of green zones, etc.;
- Identification of areas with highest mitigation potential, and definition of benchmarks and targets for implementation of energy saving, energy efficiency and renewable energy production measures aimed at achievement of the 20% greenhouse gas emission reduction goal by the year 2020;
- Public awareness measures.

The present document outlines a set of activities aimed at reduction of energy consumption and greenhouse gas emission in urban infrastructures including municipal transport, street lighting, outdoor lighting at municipal buildings and residential blocks, as well as in solid waste management, provision of public services and other sectors.

[1]Ref. Covenant of Mayors official website:
http://www.covenantofmayors.eu/about/signatories_en.html?city_id=7678

**Executive Summary**

The Sustainable Energy Action Plan of Yerevan City has been developed in the context of Yerevan's membership to the EU Covenant of Mayors initiative. The Plan assesses energy saving opportunities in the identified areas and levels of greenhouse gas emissions from burning of fuel, and recommends measures aimed as achievement of the SEAP target for Yerevan, i.e. 20% reduction of greenhouse gas emissions in the jurisdiction of Yerevan City by the year 2020.

SEAP framework covers the following areas of urban economy:


The SEAP has been developed in accordance with the methodology of the European Commission[2] using the year 2012 as a baseline. Figure 0.1 below shows that the housing sector is responsible for almost half of all emissions and energy consumption; however, in the context of SEAP, the largest share of emissions "belongs" to municipal transport, while the private transport is the leader in energy consumption.

[2] European Commission, Joint Research Center, Institute for Energy and Transport: "How to Develop a Sustainable Energy Action Plan (SEAP) – Guidebook" (Part II gives guidance on how to elaborate the Baseline Emission Inventory), 2010; and "How to develop a Sustainable Energy Action Plan (SEAP) in the Eastern Partnership and Central Asian Cities – Guidebook Part 2", 2014; "How to Become a Successful Member of the Covenant of Mayors, Guidebook for Local Governments", 2013.

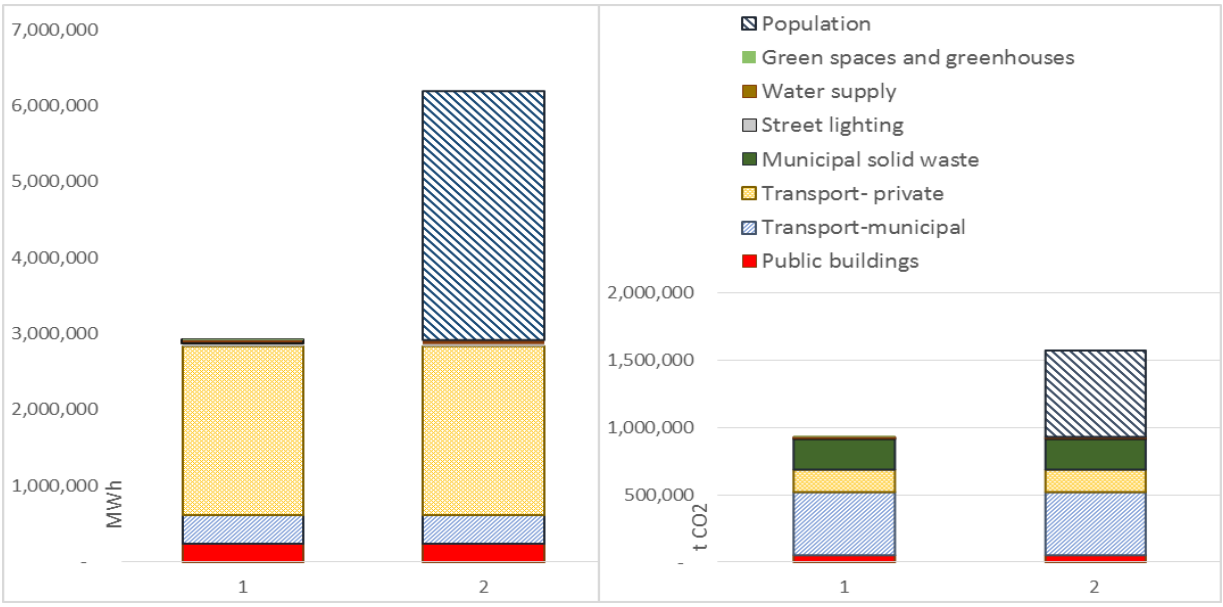



*Figure 0.1. The structure of energy consumption (on the left) and greenhouse gas emission (on the right) in 2012*

Although Yerevan SEAP does not cover the housing sector, the Municipality consistently implements measures for maintenance of the residential blocks of the City and improvement of their energy efficiency. The SEAP incorporates activities, though not included in the Baseline Emissions Inventory nor reflected in the target for reduction of greenhouse gas emissions that refer to reduction of energy consumption and greenhouse gas emission by the residential sector.

*Table 0.1. Greenhouse gas emissions: baseline data, projections and the SEAP target*

| | **In thousand tonnes of $CO_2$** | | | | | |
|---|---|---|---|---|---|---|
| | Baseline data, year 2012 | Projection year 2020* | Estimated target for reduction (20%) | SEAP, expected results | Projected results by the year 2020 from SEAP implementation | Estimated reduction relative to projected 2020 emission level |
| **SEAP framework without housing sector** | 920 | 1,150 | **230** | 237 | 913 | **21%** |
| **SEAP framework including housing sector** | 1,559 | 1,949 | **390** | 250 | 1,699 | **13%** |
| **** - Factor 1.25 applied, as recommended by SEAP Guidebook for Eastern Partnership Countries (Table 8, page 44)*** | | | | | | |

These and other activities planned in the SEAP can lead to at least 21% reduction of the GHG emissions by municipal services and urban transport (both personal and commercial) of Yerevan City by the year 2020 (Table 0.1); at the same time, the energy consumption can be reduced by 16% (Table 0.3). If the residential sector is included in the calculation, the reduction of GHG emissions by the year 2020 will constitute 13% of the total emission.

Achievement of these results will be possible if comprehensive measures (some of which were started already in the base year 2012, while others are in the stage of development and planning) are consistently implemented in all the sectors under direct management or indirect control of the Municipality. Anticipated results of the SEAP are grouped by sectors in Table 0.2 below.

*Table 0.2. Results anticipated from implementation of the SEAP activities*

| **Energy consumption by sectors** | **Energy consumption in MWh/year** | | **GHG emissions in tonnes of $CO_2$/year** | |
|---|---|---|---|---|
| | Base Year 2012 | Reduction by 2020 | Base Year 2012 | Reduction by 2020 |
| **Public buildings** | 247,636 | 61,302 | 51,934 | 12,471 |
| **Transport** | 2,593,884 | 370,806 | 619,530 | 168,999 |
| **Municipal solid waste** | - | 7,000 | 228,270 | 44,644 |
| **Street lighting** | 34,460 | 6,921 | 7,650 | 1,536 |
| **Water supply** | 56,186 | 13,918 | 12,473 | 3,090 |
| **Green spaces and municipal greenhouse** | 763 | 643 | 155 | 1,961 |
| **Horizontal measures:** | - | 18,467 | - | 3,830 |
| ***Total, without residential sector*** | ***2,932,929*** | ***479,057*** | ***920,012*** | ***236,532*** |
| ***Residential Sector*** | 3,255,448 | 67,190 | 639,695 | 13,866 |
| ***Total, including residential*** | ***6,188,377*** | ***546,247*** | ***1,559,707*** | ***250,398*** |

The results of energy saving and emission reduction activities in various sectors relative to 2012 baseline data are presented graphically below in Figure 0.2.

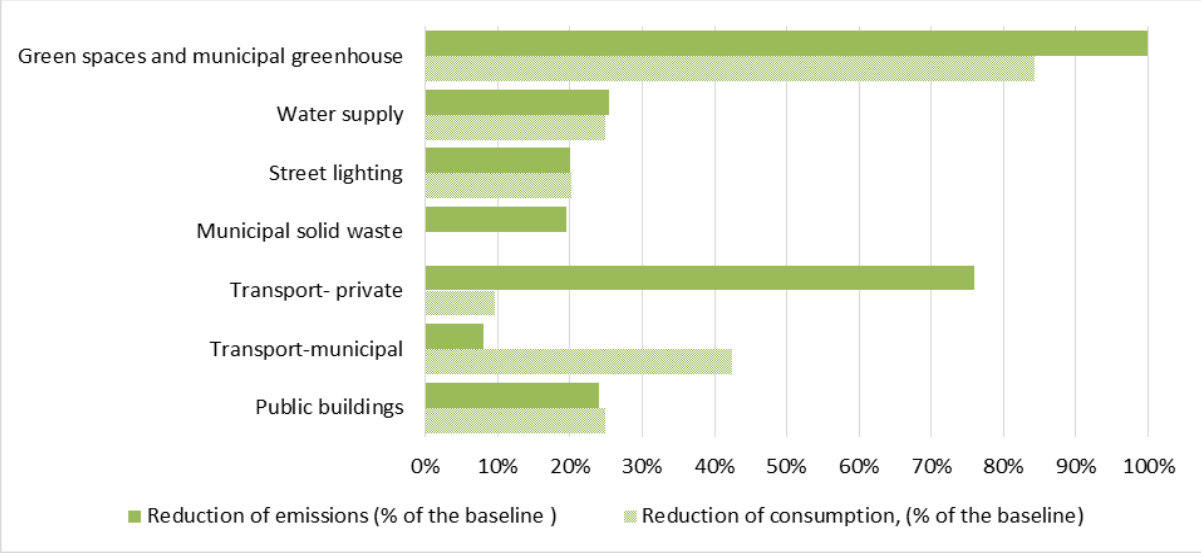



*Figure 0.2. The results of SEAP energy saving and emission reduction activities in various sectors relative to 2012 baseline data (in percentage)*

The energy consumption by the Municipal services and the population of Yerevan can be reduced by 9% by the year 2020, if the housing sector is included in calculations, or by 16%, if the housing sector is not included in the calculations. The estimated impact of the SEAP on energy consumption is presented in Table 0.3 below.

*Table 0.3. Estimated energy saving impact of the SEAP (both with and without housing sector data in the calculations)*

| | Base year (2012) energy consumption (in MWh) | Projected energy saving by the year 2020 (in MWh) | Reduction in energy consumption (%) |
|---|---|---|---|
| **SEAP framework without housing sector** | ***2,932,929*** | 479,057 | 16% |
| **SEAP framework including housing sector** | 6,188,340 | 546,247 | 9% |

It is worth noting that the 25% GHG emission growth projected for the period 2012-2020, in accordance with the SEAP methodology, is substantially higher than the actual (partially already observed) figures for 2012-2015, as well as the estimates based on the national energy demand growth forecast. The official national energy demand growth projection for the period 2012-2020 is only 15%.

The estimated aggregate impact of the SEAP on GHG emission and energy consumption trends is presented below in Figure 0.3 (note, that the emission growth projection is made in accordance with SEAP methodology, while the energy consumption trends are projected by respective national authorities based on MARKAL computer model).

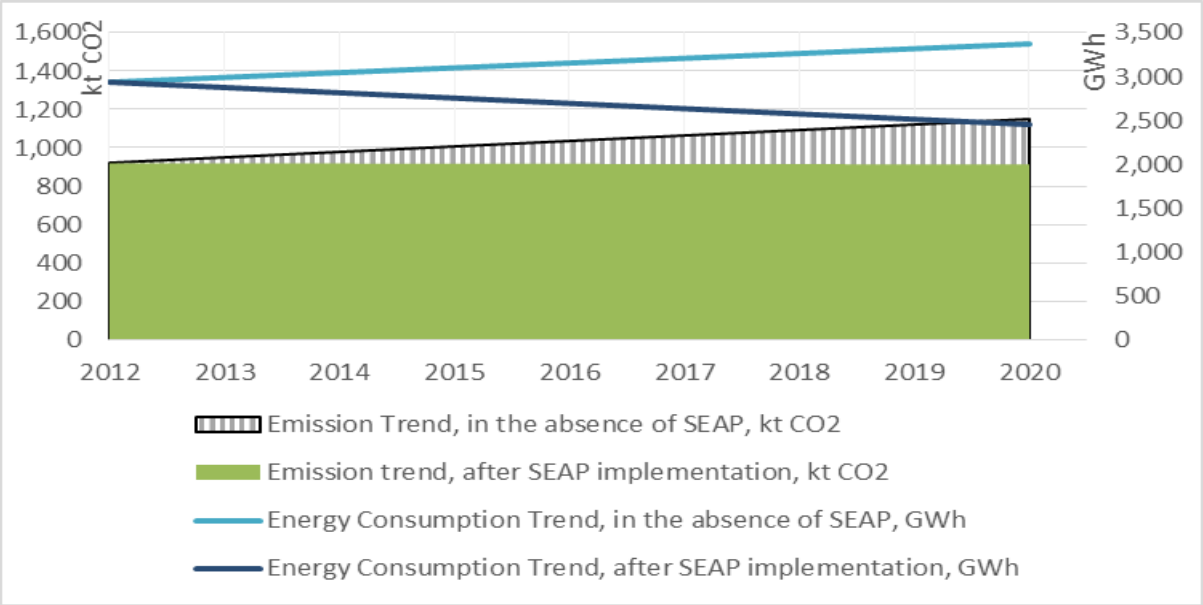



*Figure 0.3. The estimated aggregate impact of the SEAP on GHG emission and energy consumption trends*

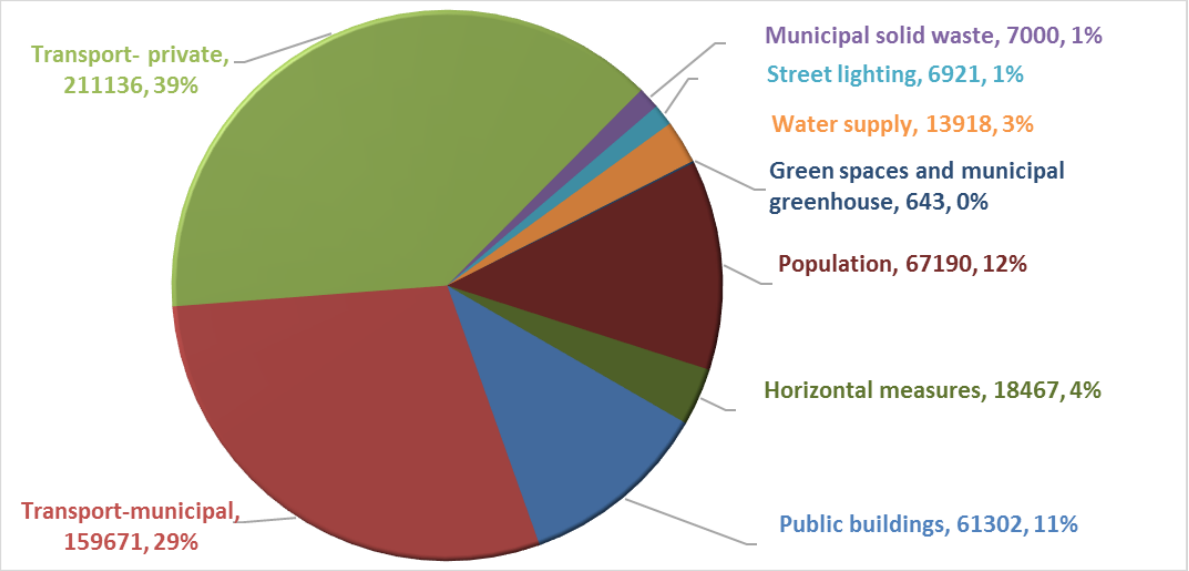



*Figure 0.4. Aggregate impact of the SEAP on reduction of energy consumption by sectors (in MWh and as a percentage of the total reduction)*

As we can see from figure 0.4, the largest potential for reduction of energy consumption by the year 2020 lies in the municipal transport sector due to ongoing and planned programs for modernization and optimization of the sector, including such components as commercialization of services, replacement of conventional fuel, as well as improvement of routs and management efficiency. The next one is the personal and commercial transport sector; the main factors contributing to this are the optimization of municipal road network and the gradual transition of most vehicles to compressed natural gas fuel. Table 0.4 below presents the breakdown of saved energy and fuels by sectors.

*Table 0.4. Reduction of energy and fuel consumption anticipated from SEAP implementation*

| **Sector (code)** | **Anticipated energy saving [MWh/year], by 2020** | | | | | **Anticipated $CO_2$ emission reduction by the year 2020 (in tonnes)** |
|---|---|---|---|---|---|---|
| | Electric energy | Natural gas | Petrol | Diesel | **Total** | |
| **Transport (T)** | 6,218 | 107,665 | 136,560 | 120,364 | 370,806 | 168,999 |
| **Public buildings (P)** | 4,418 | 56,883 | - | - | 61,302 | 12,471 |
| **Municipal solid waste (M)** | 7,000 | - | - | - | 7,000 | 44,644 |
| **Street lighting (L)** | 6,921 | - | - | - | 6,921 | 1,536 |
| **Water supply (W)** | 13,918 | - | - | - | 13,918 | 3,090 |
| **Green spaces and Municipal Greenhouse (G)** | - | 643 | - | - | 643 | 1,961 |
| **Horizontal measures (H)** | 5,005 | 13,462 | - | - | 18,467 | 3,830 |
| **Total without residential sector** | 43,480 | 178,653 | 136,560 | 120,364 | 479,057 | ***236,532*** |
| **Residential sector (R)** | 14,700 | 52,490 | - | - | 67,190 | 13,866 |
| **Total, including residential sector** | 58,180 | 231,143 | 136,560 | 120,364 | 546,247 | 250,398 |

** - This table presents only projections on emission prevention due to reduction of fuel consumption, while the aggregate results from SEAP mitigation measures include also the impact of fuel replacement and development of green zones.*

The largest potential for reduction of greenhouse gas emissions lies in the municipal transport sector; next are the municipal domestic solid waste management and energy efficiency measures in public buildings. The next sector with significant potential is the housing sector; although, the emission reduction in this sector is only 1%, considering the significant size of the sector (in quantitative sense, the GHG emissions from the housing sector exceed the cumulative numbers of all the other SEAP sectors), it constitutes 6% of the total volume of GHG emissions that can be reduced as a result of SEAP implementation (See Figure 0.5 below).

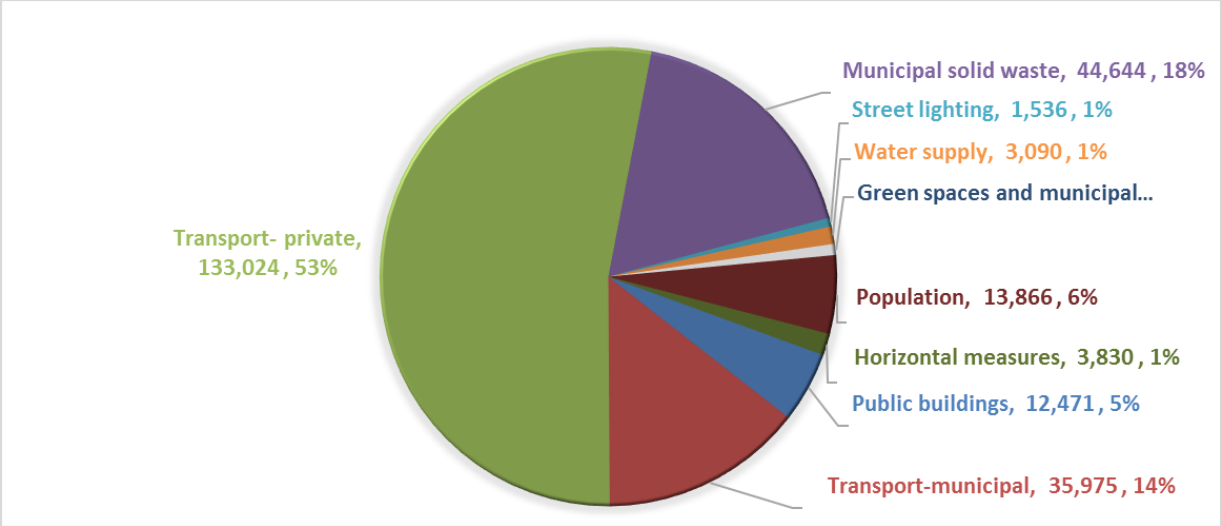



*Figure 0.5. Emission reduction potential by sectors (in tonnes of $CO_2$ and %)*

Costs associated with SEAP activities were estimated based on expenditure reports on similar ongoing or completed projects and activities. Where such reports were not available, cost estimates were prepared based on expert assessment of international experience and SEAP guidelines. The diagram below presents the estimated SEAP activity costs by sectors.[3]

[3]It should be noted that not all the planned costs are for energy reduction and/or prevention of emissions. For example, activities on improvement of water-supply efficiency are primarily aimed at saving of water resources, improvement of the quality and reliability of water-supply services, etc. In this sense, the energy saving impact is of secondary importance, and the amount of investments has only indirect connection with saved energy and reduced emissions. Thus, in those projects where the 'purely' energy saving costs cannot be separated from larger infrastructure improvement investments, the project results, in terms of saved energy, appear to be artificially higher.

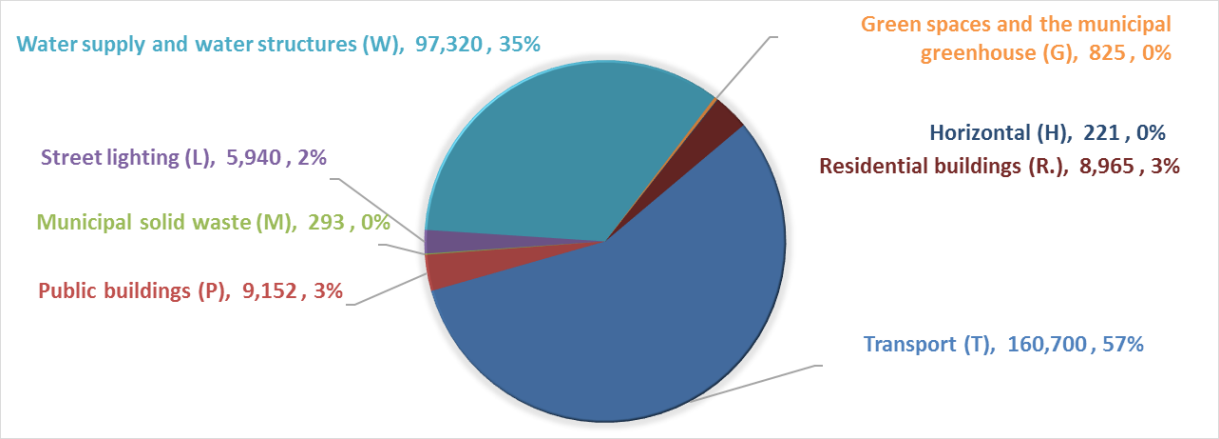



*Figure 0.6. The estimated costs of mitigation measures by sectors (in thousand Euros and %)*

The diagram below presents the return on share of investments targeted at energy efficiency compared based on the energy production cost. As we can see from the Figure 0.7, the energy saving costs across the sectors vary significantly. For the public and residential buildings, municipal solid waste, and horizontal measures, the cost of 1MWh energy saving is less than the long-term weighted average cost of energy production within the Armenian power system. As for the housing sector, the primary objective of the Municipality's Investment Program here is the maintenance and repair of the housing stock, while energy saving is viewed only as an indirect impact. Note, the return on targeted energy efficiency investments in the housing sector is comparable with that of the public buildings.

It should be also noted that, although the main purpose of the SEAP is the annual reduction of emissions by the year 2020, the cumulative payback from energy saving measures during the next 15 years and onward will yield significant economic benefits. (See Figure 0.7)

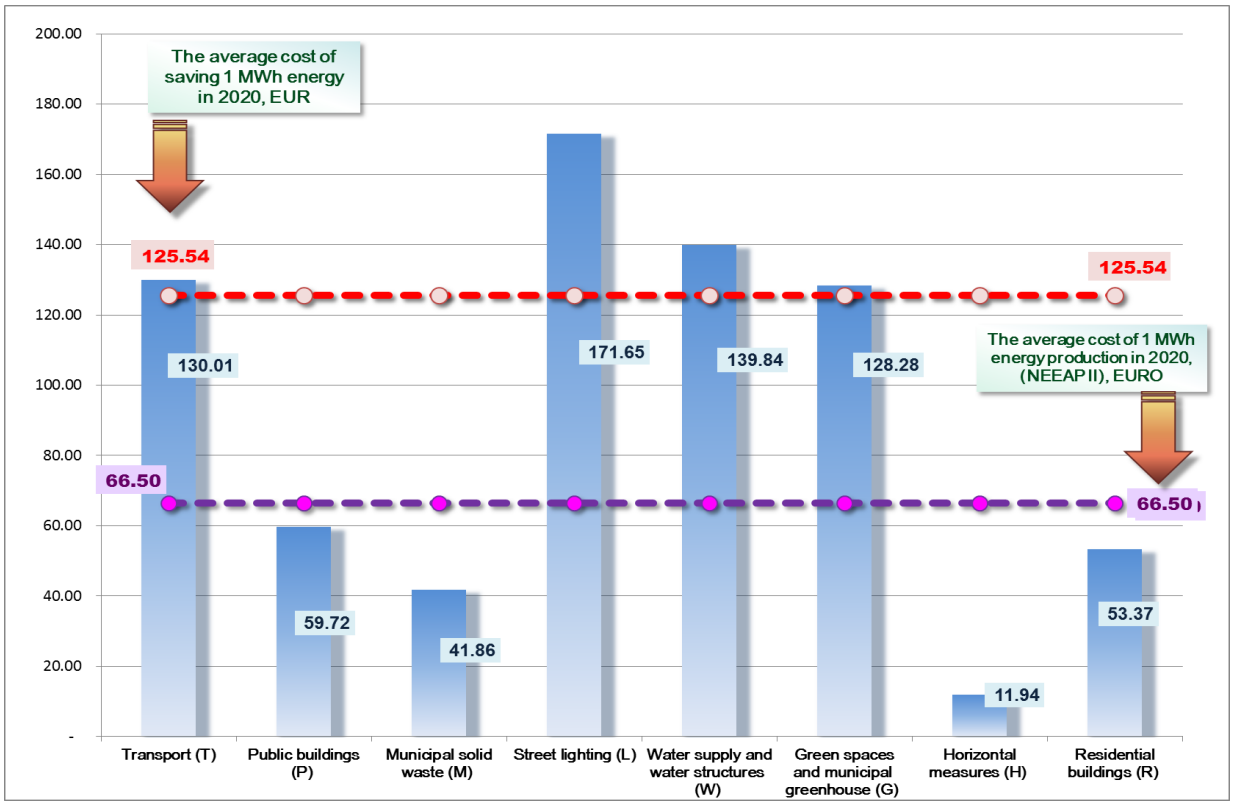



*Figure 0.7. Investment rationale in view of the weighted average cost (in EUR) of energy production in the energy system of the Republic of Armenia*

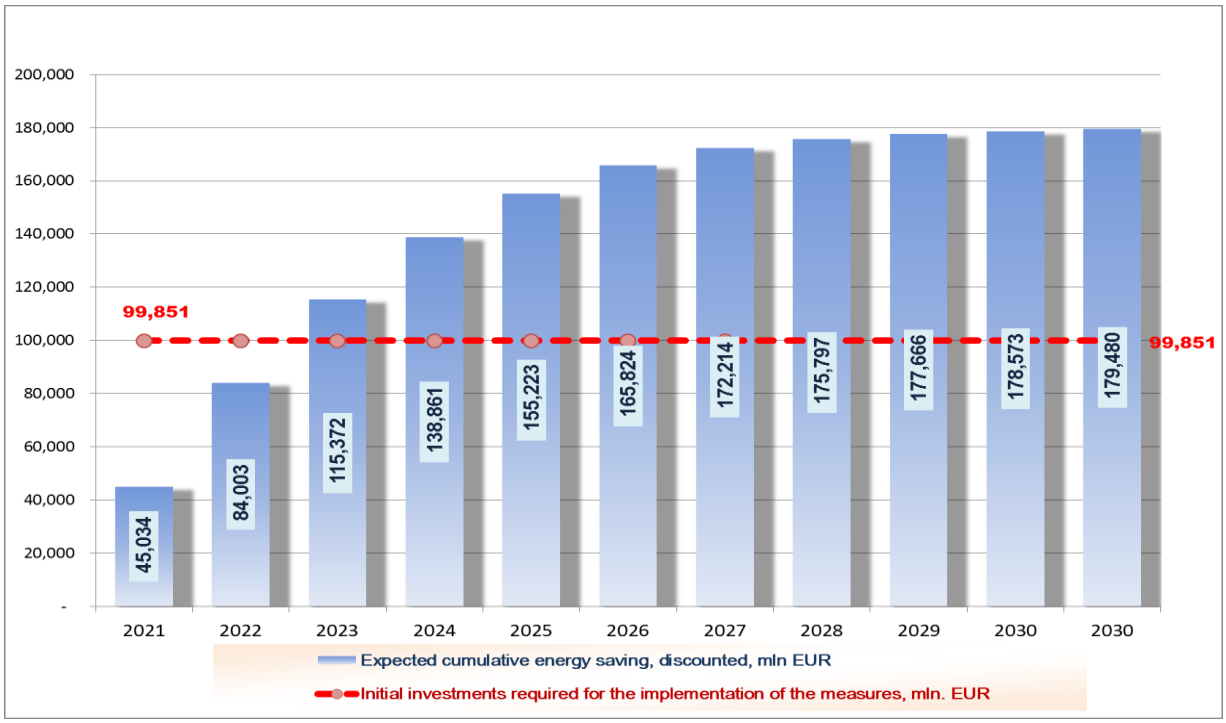



*Figure 0.8. Long-term cumulative payback on energy efficiency measures (in thousand EUR)*

The simple payback on investments is four years, except for investments in improvement of water-supply systems and landscaping, since the energy saving and climate change mitigation impact here is indirect; therefore a longer payback period for these investments is quite acceptable. (See figure 0.9)

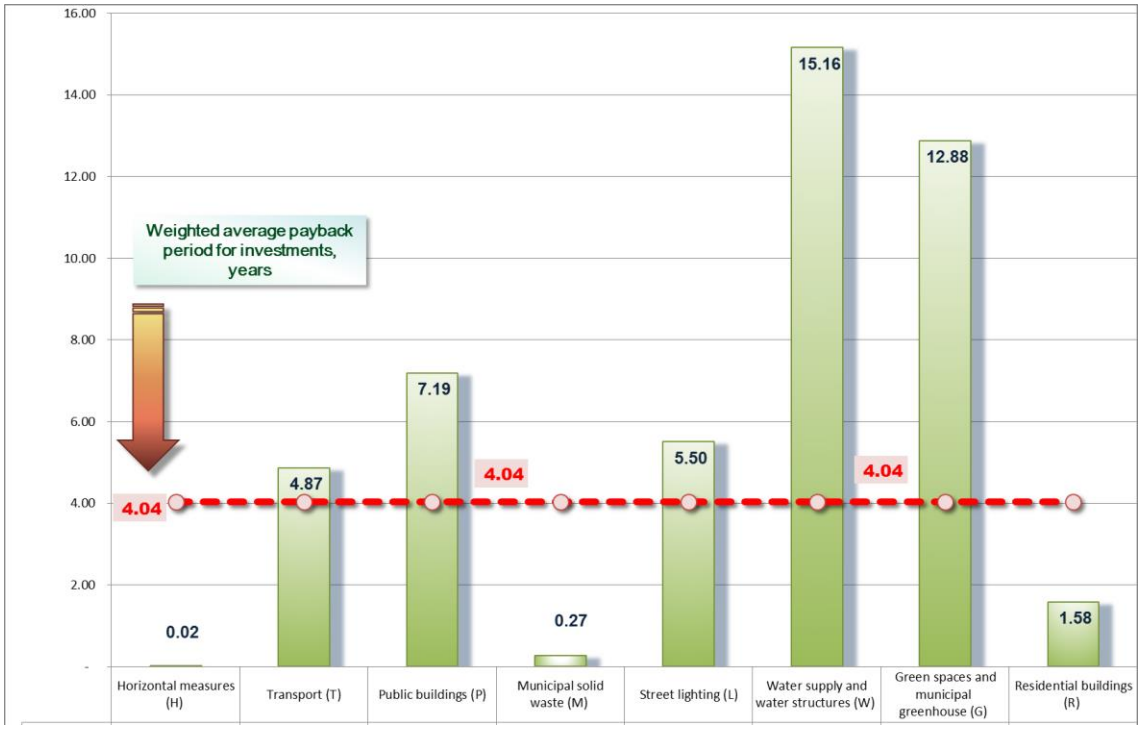



**Figure 0.9. Simple payback on investment in energy efficiency measures (by sectors)**

The table below presents consolidated data on activities planned under the SEAP, followed by analysis of the energy consumption structure, energy balance, quantitative assessment of emissions, and summary baseline assessment for each sector. In addition to these, for each sector included in the Plan, a description of energy efficiency and energy saving measures, as well as measures for promotion of the use of renewable energy sources is presented. All these measures together aim at reduction of greenhouse gas emissions, ultimately contributing to mitigation of global climate change.

Parallel to the above quantitative measures the SEAP offers a number of soft, cross-cutting (horizontal) measures aimed at building of institutional capacities, introduction of energy management system, improvement of resource use efficiency, increasing stakeholder awareness and other similar measures. In addition to these, the SEAP includes a number of far-reaching proposals aimed at introduction of best international practices for development of “smart” and “green” cities, and lays the grounds for transition to a new level of sustainable energy development after the 2020 benchmark.

*Table 0.5. All the SEAP activities by sector and by impact (for the activities highlighted in green no funding is available yet)*

| Index | Sector/measure | Possible funding sources, cooperating partners | Implementation period (start - end) | Estimated cost (thous. EUR) | Expected energy savings [MWh / year], 2020. Total | Reduction of GHG emissions in 2020 (tonnes of CO2) |
|---|---|---|---|---|---|---|
| **Transport (T)** | | | | | | |
| Measure T.1 | Public Transport (PT) Optimization Program. PT park upgrades, staff optimization, route optimization, unified ticketing system | Yerevan Municipality, other state institutions, ADB/SUDIP | 2013-2020 | 17200.00 | 145340.00 | 33139.47 |
| Measure T.2 | Public electric transport (trolley) park and infrastructure upgrade | Yerevan Municipality, other state institutions, EBRD | 2018-2019 | 28000.00 | 2558.49 | 566.65 |
| Measure T.3 | Public electric transport (Yerevan metro) refurbishment | EIB, "Yerevan Metropoliten" LLC, EBRD, Yerevan Municipality, | 2017-2018 | 21000.00 | 3726.00 | 827.17 |
| Measure T.4 | Supporting the public and private transport's switching to CNG through allocation of places for CNG stations in city districts and formulation of safety requirements | Yerevan Municipality, other state institutions, Private businesses, green loans | 2013-2020 | 0.00 | 0.00 | 79690.00 |
| Measure T.5 | Development of road infrastructure (new, including bypass roads and road junctions) | Yerevan Municipality, ADB, SUDIP | 2015-2020 | 82800.00 | 211135.57 | 53333.94 |
| Measure T.6 | City transport optimization; management efficiency improvement (including waste disposal, sanitation and other machinery) | Yerevan Municipality | 2014-2020 | 10000.00 | 7875.00 | 1362.59 |
| Measure T.7 | Modernization of the city transport fleet: Yerevan Municipality's strategic plan of dissemination of electric vehicles | Yerevan Municipality, other state institutions, donors | 2017-2020 pilot phase | 1700.00 | 171.10 | 79.20 |
| ***Total transport*** | | | | ***160700.00*** | ***370806.16*** | ***168999.03*** |

| Index | Sector/measure | Possible funding sources, cooperating partners | Implementation period (start - end) | Estimated cost (thous. EUR) | Expected energy savings [MWh / year], 2020. Total | Reduction of GHG emissions in 2020 (tonnes of CO2) |
|---|---|---|---|---|---|---|
| **Public buildings (P)** | | | | | | |
| Measure P.1 | Introducing energy managers in municipal institutions. | Yerevan Municipality | 2017-2018 | 34.00 | 4685.00 | 978.07 |
| Measure P.2 | Implementation of heat preservation measures in municipal buildings | Yerevan Municipality | 2017-2018 | 12.00 | 3488.00 | 728.34 |
| Measure P.3 | Use of energy efficient luminaires for internal lighting systems in the administrative buildings | Yerevan Municipality | 2017-2020 | 69.00 | 385.40 | 85.56 |
| Measure P.4 | Targeted investments of energy savings in public buildings within the jurisdiction of Yerevan Municipality | Yerevan Municipality | 2013-2020 | 289.05 | 2533.70 | 511.81 |
| Measure P.5 | Use of renewable energy in municipal buildings | Yerevan Municipality, other state institutions | 2018-2020 | 1227.00 | 3408.85 | 689.91 |
| Measure P.6 | Investments in construction renovations of municipal buildings through energy efficiency measures | Yerevan Municipality | 2013-2020 | 5396.00 | 9788.03 | 1977.18 |
| Measure P.7 | De-Risking and Scaling-up Investment in Energy Efficient Building Retrofits Project – Public Buildings | Yerevan Municipality, GCF, UNDP, EIB | 2016-2020 | 1723.90 | 35818.79 | 7235.40 |
| Measure P.8 | Modernization of energy-consuming appliances in kindergartens. | Yerevan Municipality | 2013-2020 | 400.76 | 1193.80 | 265.02 |
| ***Total public buildings*** | | | | ***9151.71*** | ***61301.57*** | ***12471.29*** |

| Index | Sector/measure | Possible funding sources, cooperating partners | Implementation period (start - end) | Estimated cost (thous. EUR) | Expected energy savings [MWh / year], 2020. Total | Reduction of GHG emissions in 2020 (tonnes of CO2) |
|---|---|---|---|---|---|---|
| **Municipal solid waste (M)** | | | | | | |
| Measure M.1 | Methane capture and electric power generation from the Nubarashen urban MSW landfill | Yerevan Municipality, EIB, E5P | 2018-2020 | 293.00 | 7000.00 | 44644.00 |
| ***Total municipal solid waste*** | | | | ***293.00*** | ***7000.00*** | ***44644.00*** |
| **Street lighting (L)** | | | | | | |
| Measure L.1 | Improving the energy efficiency in urban lighting systems | Yerevan Municipality, UNDP/GUL | 2013-2017 | 490.00 | 2183.00 | 484.63 |
| Measure L.2 | Improving the efficiency and reliability of Yerevan street-lighting | Yerevan Municipality, EBRD, E5P | 2016-2017 | 5450.00 | 2554.00 | 566.99 |
| Measure L.3 | Installation of photovoltaic luminaries in the lighting systems of yard areas and entrances of multi-apartment buildings | Yerevan Municipality, Yerevan Municipal Lighting Co., donor organizations | 2018-2020 | 4650.00 | 2184.00 | 484.85 |
| ***Total street lighting (L)*** | | | | ***10590.00*** | ***6921.00*** | ***1536.46*** |
| **Green spaces and the municipal greenhouse (G)** | | | | | | |
| Measure G.1 | Restoration and expansion of landscaped and forested areas. | Yerevan Municipality | 2013-2020 | 370.37 | 0.00 | 1831.00 |
| Measure G.2 | Application of modern EE technologies in municipal greenhouses. | Yerevan Municipality | 2019-2020 | 454.55 | 643.08 | 129.90 |
| ***Total green spaces and greenhouses*** | | | | ***824.92*** | ***643.08*** | ***1960.90*** |
| **Water supply and water facilities (W)** | | | | | | |
| Measure W.1 | Refurbishment and renovation projects for drinking water supply systems in Yerevan | IFIs, EBRD, EIB, EU, Yerevan Municipality, YerevanJur | 2013-2020 | 44000.00 | 13510.38 | 2999.30 |
| Measure W.2 | Water supply: measures of fountain lightings and EE of engines. | Yerevan Municipality, Water Institutions LLC, IFIs | 2013-2020 | 53320.00 | 408.00 | 90.58 |
| ***Total water supply and water structures*** | | | | ***97320.00*** | ***13918.38*** | ***3089.88*** |

| | | | |
|---|---|---|---|

| Index | Sector/measure | Possible funding sources, partners | Implementation period (start - end) | Estimated cost (thous. EUR) | Expected energy savings [MWh / year], 2020. | Reduction of GHG emissions in 2020 (tonnes of CO2) |
|---|---|---|---|---|---|---|
| | | | | | Total | |
| **Horizontal (H)** | | | | | | |
| Measure H.1 | Urban energy planning and management | Yerevan Municipality | 2017-2020 | 100.00 | 0.00 | 0.00 |
| Measure H.2 | Establishment of plans and rules for "Green Procurements", engagement of energy audit in the process of procurement planning. | Yerevan Municipality | 2017-2020 | 25.00 | 0.00 | 0.00 |
| Measure H.3 | Elaboration of energy certificates for buildings. | Yerevan Municipality | 2018-2020 | 34.00 | 1044.89 | 213.49 |
| Measure H.4 | Participation in "Earth Hour" global event | Yerevan Municipality | 2013-2020 | 6.00 | 32.90 | 7.30 |
| Measure H.5 | Participation in "Sustainable Energy Days" pan-European event. | Yerevan Municipality | 2017 - 2020 | 15.00 | 6276.50 | 1303.79 |
| Measure H.6 | Engagement of schools in the urban energy development process. | Yerevan Municipality, schools, universities, NGOs | 2018-2020 | 33.50 | 8112.74 | 1683.85 |
| Measure H.7 | Holding workshops and training courses for specialists of institutions. | Yerevan Municipality | 2018 - 2020 | 7.00 | 3000.00 | 622.00 |
| ***Total, horizontal measures*** | | | | ***220.50*** | ***18467.03*** | ***3830.43*** |
| ***Total, excluding population*** | | | | ***279100.13*** | ***479057.21*** | ***236531.99*** |

| Index | Sector/measure | Possible funding sources, partners | Implementation period (start - end) | Estimated cost (thous. EUR) | Expected energy savings [MWh / year], 2020. Total | Reduction of GHG emissions in 2020 (tons of CO2) |
|---|---|---|---|---|---|---|
| **Residential buildings (R.)** | | | | | | |
| Measure R.1 | Improvement of energy saving in buildings, elaboration of secondary legislative acts for energy conservation of buildings; financing of the inaugural pilot project of thermal modernization of a multi-apartment residential building in Avan district. | Yerevan Municipality, UNDP/GEF | 2013-2017 | 645.00 | 406.00 | 82.01 |
| Measure R.2 | Financing of energy efficiency. Commercial bank loans for the energy efficiency of residential buildings. | Yerevan Municipality, HFHA, USAID | 2013-2018 | 1100.00 | 5067.00 | 1023.53 |
| Measure R.3 | De-Risking and Scaling-up Investment in Energy Efficient Building Retrofits Project – Residential Buildings | Yerevan Municipality, UNDP, GCF, E5P, EIB, other state institutions | 2016-2020 | 700.00 | 6930.70 | 1400.00 |
| Measure R.4 | Installation of solar water heaters in private residential zones. | Households, green loans | 2017-2020 | 5700.00 | 15245.00 | 3079.49 |
| Measure R.5 | LED lamps for socially vulnerable households. | Yerevan Municipality, donor organizations | 2018-2020 | 645.00 | 14700.00 | 3263.40 |
| Measure R.6 | Replacement of entrance doors and windows in MABs by the Municipality. | Yerevan Municipality | 2013-2020 | 175.00 | 24841.00 | 5017.88 |
| ***Total population*** | | | | ***8965.00*** | ***67189.70*** | ***13866.32*** |
| **Total, including population** | | | | **288065.13** | **546246.91** | **250398.30** |

# 1 Development of Yerevan SEAP: Background

## 1.1 Objectives and Sectors Covered

The main purpose of the SEAP is to define integrated organizational, economic, technical and technological measures along with related funding mechanisms, aimed at achievement of long-term and far-reaching goals for sustaining higher level of energy efficiency, reducing the consumption of energy resources, cutting greenhouse gas emissions, and ultimately improving the urban environment.

SEAP covers those sectors, where the implementation of proposed activities can be supported by local partners and international organizations, and where opportunities exist for cooperation with financial organizations. SEAP includes also public outreach activities with targeted groups and individual citizens for awareness raising and public involvement.

The following tasks need to be accomplished for achieving the objectives of the Yerevan SEAP:

1. Introduction of modern energy use technologies;
2. Implementation of energy efficiency and energy saving projects, as well as renewable energy projects;
3. Implementation of projects for both reduction of energy consumption and improvement of the level of comfort in municipal institutions;
4. Introduction of energy management practices in the public sector, involving monitoring and supervision for ensuring the efficient use of energy resources;
5. Leveraging funds for energy efficiency, energy saving and renewable energy projects;
6. Propagation of the principles of energy efficiency and energy saving.

Primary focus of the Municipal Energy Saving Program should be on urban infrastructures, including: municipal transport, street lighting, solid waste management, public buildings, and municipal organizations.

## 1.2 Legal/regulatory Framework and Methodology for SEAP Development

Key provisions from the following documents were used for development of the SEAP:

1. European Commission, Joint Research Centre, Institute for Energy and Transport: “How to develop a Sustainable Energy Action Plan (SEAP) in the Eastern Partnership and Central Asian Cities – Guidebook Part 1”, 2013;
2. European Commission, Joint Research Centre, Institute for Energy and Transport: “How to develop a Sustainable Energy Action Plan (SEAP) in the Eastern Partnership and Central Asian Cities – Guidebook Part 2, Baseline Emission Inventory”, 2014;
3. Association “Energy Efficient Cities of Ukraine” (EECU): “How to Become a Successful Member of the Covenant of Mayors, Guidebook for Local Governments”, 2013.

Besides, the SEAP is consistent with the goals and objectives of the following National and International documents:

1. The United Nations Framework Convention on Climate Change (UNFCCC) (09.05.1992);
2. RA Law on Energy (07.03.2001);
3. RA Law on Energy Saving and Renewable Energy (09.11.2004);
4. Energy Sector Development Strategies in the Context of Economic Development in Armenia (23.06.2005);

5. RA National Program on Energy Saving and Renewable Energy (2007);
6. The First National Energy Efficiency Action Plan (NEEAP I) of the Republic of Armenia (2010),
7. Action Plan of the Government of the Republic of Armenia for Implementation of the National Program on Energy Saving and Renewable Energy (RA Government Decision № 43, 04.11.2010);
8. The Energy Security Concept of the Republic of Armenia (2013);
9. One-Year Development Program of Yerevan City (years 2013, 2014, 2015, and 2016) and Four-Year Development Program of Yerevan City (periods 2010–2013, and 2014–2017);
10. Implementation Report on Year-2015 Development Program of Yerevan City;
11. Reports on Yerevan 2025 International Conference.

## 1.3 SEAP Financing Opportunities

To ensure reliable financing for SEAP activities it is planned to involve multiple sources of funding. Important tools to consider here are: 1) the reallocation of financial flows from funding of expenditures (subsidies) to funding of savings (rewarding reduction of utility-related expenditures); 2) establishment of municipal revolving funds for energy efficiency projects in the jurisdiction of the Municipality.

***Local Sources of Funding***

At local level, the Municipal Budget may be the main source of funding of the SEAP activities. Funds can be generated also by issuing municipal bonds under sovereign warranties. Yerevan City already allocates significant resources from the municipal budget for funding of projects on thermal insulation of buildings, efficient urban lighting, modernization of municipal transport, and other similar projects. This initiative allows leveraging funds from international financial institutions and donor organizations, for which the active participation of the beneficiary community is often considered as a precondition for financing a project.

***National Sources of Funding***

National sources of funding may include targeted state programs and funds, bonds, subsidies, etc.

***Financial Resources of the Population***

Should there be initiatives, the population can undertake to implement activities included in the SEAP, they can access several soft “green” loans operating within the commercial banks, often provided along with a grant component, that can be used to finance the costs related to thermal insulation and efficient heating of apartments, and installation of solar water-heating systems.

***Businesses as a Source of Funding***

Promotion of sustainable energy technologies can be done also through private businesses (facilitating the production of materials, development of entrepreneurship, etc.). This can be done through assistance in advertising respective products and services; through introduction of minimum energy efficiency requirements in public procurement procedures and respective contracts; as well as through introduction of mechanisms of co-financing, public-private partnership and incentives (including international loans, reimbursement of interest payments by the State or provision of subsidies for softening the loans).

***Other Sources of Funding***

Other sources of funding may include proceeds from international technical assistance, environmental charges paid by polluting industries in the jurisdiction of Yerevan City,

environmental donations and grants, National fund-raising initiatives, international grants and credits, special financial assistance (subsidies, direct financial assistance or reimbursement tools).

SEAP activities may also be funded by enterprises, ministries, extra-budget energy saving funds of local governments, investment foundations, local government funds for assistance to small businesses, credit organizations and other sources not prohibited by law.

Below is the list of donor organizations and financial institutions that cooperate with the Municipality on energy efficiency, energy saving and renewable energy projects already now:

- European Bank for Reconstruction and Development (EBRD)
- European Investment Bank (EIB)
- Global Environment Fund (GEF)
- United Nations Development Program (UNDP)
- Global Climate Partnership Fund (GCPF)
- Green Climate Fund (GCF)
- Armenia Renewable Resources and Energy Efficiency Fund (R2E2)
- World Bank (WB)
- Asian Development Bank (ADB)
- Development Bank of Germany (KfW)
- Eastern Europe Energy Efficiency and Environmental Partnership (E5P)
- Habitat for Humanity Armenia (HFHA), etc.

### 1.4 Result Monitoring as a Tool for Controlling Energy Efficiency and Ensuring Sustainable Development

Yerevan Municipality is responsible for coordination and supervision of the SEAP implementation process. The supervision of specific projects and activities will be done by respective specialized departments and units of the Municipality through Energy Managers appointed and authorized specifically for this purpose. Introduction of the energy planning and management system is a mandatory component of the Sustainable Energy Development Initiative for Yerevan. The steps required for introduction of the system are presented in the Section on Mitigation Measures.

The monitoring of SEAP activities will be carried out in accordance with the procedure defined in the respective provisions of the Covenant of Mayors. However, the level of detail of the monitoring process can be further increased and at local level intermediate accounting requirements can be introduced. The use of transparent procedures, measurable performance criteria and practical control tools will allow creating a comprehensive system of monitoring, accounting and supervision for all the municipal energy intensive sectors. Such a system is important for identifying energy consumption patterns, defining priorities for energy efficiency measures, and ultimately evaluating savings and direct financial benefits from reduction of energy consumption.

Public control over the process of SEAP implementation will be done by those NGOs that are involved in environmental protection, energy saving and energy efficiency sectors. Supervision over the use of budget resources allocated for funding of SEAP activities will be done in accordance with the procedure defined by the applicable Legislation of the Republic of Armenia.

## 2 Brief Overview of Yerevan City

### 2.1 Yerevan as the Capital of Armenia

Yerevan is the Capital City of the Republic of Armenia. The predecessor of Yerevan, Erebuni Fortress was founded by King Argishti I in the year 782 BC.

At present, Yerevan is the largest economic, scientific and cultural centre of Armenia, and an important juncture of regional transport and communication corridors. In total, 42.1% of all the industry, 53.9% of construction activity, 82.6% of retail trade, 85.5% of services, 77.6% of residential housing construction, and 33.2% of hotel business is concentrated in Yerevan.


**Figure 2.1.** *Administrative building of Yerevan Municipality*

The offices of all the three branches of the Government: Legislative, Executive and Judiciary are located in Yerevan. For effective local government and regional administration Yerevan City is divided into 12 administrative districts: Ajapnyak, Avan, Arabkir, Davitashen, Erebuni, Kentron, Malatia-Sebastia, Nor-Nork, Nork Marash, Nubarashen, Shengavit, and Kanaker-Zeytun.

The following map shows the division of Yerevan City into administrative districts; the interactive version of the map is presented on the official website of Yerevan City.[4]

[4] See at: https://www.yerevan.am/am/administrative-districts/


**Figure 2.2. Administrative districts of Yerevan City**

**Figure 2.3**. *Views of Yerevan City*

## 2.2 Geographical Position

Yerevan ($40^0$ N, $44^0$ E) is located in the north-eastern part of Ararat Valley, on both banks of Hrazdan River, at an altitude ranging between 850m-1300m above sea level. Geological formation is that of young volcanic rocks and sedimentary basements, with seismicity ranging between M7 to

M8. The overall surface of the City is 223 km$^2$, stretching 19.7 km from north to south and 19.1 km from east to west. Yerevan, as the rest of the country, is located in GMT+4 time zone.[5]

The city has the form of a circus with the centre in the lower part of it and the residential districts in the upper parts. The lowest points of the city are in the south, in Shengavit and Malatia-Sebastia districts. The highest locations are in Avan and Nor Nork districts. The Republic Square in the centre of the city is 1000 m high above sea level.

## 2.3 Climate Conditions

Yerevan is located in temperate continental climate zone due to which all four seasons of the year are clearly distinguished. Winters in Yerevan tend to be cold and often accompanied with heavy snowfalls. Summers are usually hot and dry. Rainfalls occur mainly in spring and autumn. The relatively dry weather is the reason for bright and sunny sky in most time of the year. Misty and cloudy days are rare, especially for the period from May to September.

For calculation of the parameters of heating systems the outside air temperature is considered -19$^0$C;[6] the duration of the heating season amounts to 140 days, the average air temperature during the heating season is 1$^0$C. The average air temperature in January reaches -3.6$^0$C, and +26.3$^0$C in July. The average speed of prevailing northeast winds makes 2.7 - 2.8 m/s in January: The average annual air humidity is 62%, annual fluctuations range between 30 to 67 %:

The total annual solar radiation on horizontal surface measures about 1690 kWh/m$^2$, which almost equals to the average indicator of the republic. The average share of direct radiation is 62 %, in January it makes 37 %, and 69 % in July. The yearly average of sunshine duration is estimated at 2578 hours, the number of sunny days is estimated at 324 day/year.

The total annual amount of atmospheric precipitations in Yerevan, equalling to 286 mm, is significantly lower than the average level of precipitations in the republic that equals to 620 mm. The maximum amount of precipitations around 45 mm falls in May.[7]

## 2.4 Urban population

As of 1 January 2016 the urban population amounted to 1073.7 thousand comprising 35.8% of the total number of population of the Republic of Armenia. As of 1 January 2015 the highest density of population was in Kanaker-Zeytun administrative district with where population density equalled to 96 people/ha, then Kentron administrative district with the indicator of 94 and Nor Nork administrative district with the indicator of 92 people/ha. Nubarashen is the low-density populated administrative district with the population density reaching only 6 people/ha. As of 2015 the average indicator of Yerevan amounted to 48 people/ha.[8]

[5] From purely geographical viewpoint Armenia is in the third time zone (GMT+3) , however, for certain reasons it is included in the 4$^{th}$ time zone.
[6] This methodology is observed in 98% of cases. Source: RACN II-7.01-2011, “Construction Climatology”.
[7] See: *RACN II-7.01-2011, “Construction Climatology”, Yerevan, 2011*
[8] Year 2015 statistical data; source: http://armstat.am/am/?module=publications&mid=6&id=1712

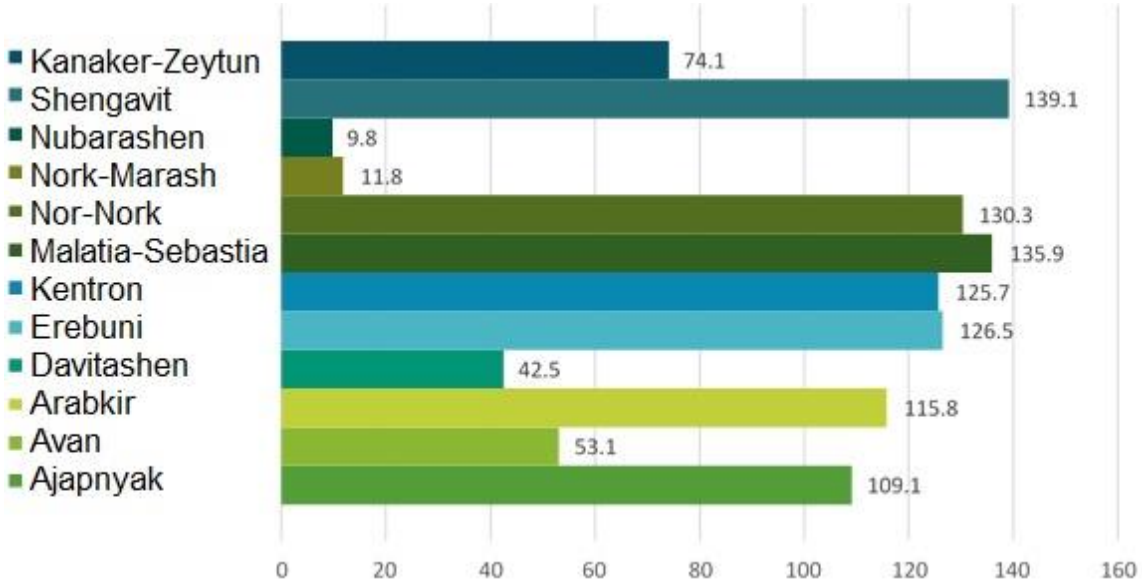



*Figure 2.4. Permanent population of the urban community of the city of Yerevan (thousand people) as per administrative districts, as of 1 January 2016 (Source: NSS)*

*Figure 2.5. National Gallery of Armenia, on the left; Sasuntsi David square and train station, on the right*

## 2.5 Community governance structure

The city of Yerevan experienced unprecedented development especially in recent years by transforming into a more clean, beautiful, comfortable, welcoming and citizen-oriented city. Legislative amendments played a significant role in this process according to which in 2009 the status of the city changed from marz to municipality.

In the city of Yerevan the system of local self-governance is established by the Law of the Republic of Armenia “On Local Self-Governance in the City of Yerevan”.

Hence, priority was provided for local self-governance in the process of addressing issues of local significance in Yerevan; within the limits of the municipality local self-government bodies exercise their powers by way of autonomous management of the municipal property, generation, approval and execution of the local budget, introduction and collection of local taxes and implementation of other measures. Empowerment of local self-government bodies is one of the crucial approaches of legally regulating public relations arising in the course of activities of these bodies.

In the city of Yerevan local self-government bodies are the following: head of municipality (mayor) and municipal Elders’ Council. Elections of Yerevan Elders’ Council are held under the

proportional electoral system.[9] Elections of the mayor are held by the newly elected Elders' Council.[10]

Local self-governance in Yerevan is implemented on the basis of principles established by the Law of the Republic of Armenia "On Local Self-Governance". The municipal local self-government body operates at its place of location at the following address: 1 Argishti Street.

The Elders' Council is the highest body of local self-government of Yerevan which exercises oversight over the activities of the Mayor. When exercising its powers under the Constitution and law of the Republic of Armenia the Elders' Council is free and acts solely to the benefit and on behalf of Yerevan.

The Mayor of Yerevan organizes its activities through Deputy Mayors, heads of administrative districts, advisors, assistants, press secretary of the Mayor, and Staff of Yerevan Municipality. The Mayor of Yerevan has vital and significant role in the development of the capital; and the development tendencies of the Capital have an important meaning and impact in terms of development of other municipalities of the Republic of Armenia. The Mayor of Yerevan submits plans for development of the city to the Yerevan Elders' Council and implements these plans contributing to the social and economic development of the city and improving the urban environment in the fields of urban development, utilities, ensuring public order, transport and road construction, agriculture, land use, trade and services, education, culture and youth issues, healthcare, physical culture and sports, social protection, nature protection and other fields. The Mayor always promotes dialogue with the public with the view of effective management of urban economy.

**Elders' CouncilCouncil of Elders**

According to the Law of the Republic of Armenia "On Local Self-Government in the City of Yerevan" the Elders' Council of Elders is elected under the procedure defined by the Electoral Code of the Republic of Armenia and consists of 65 members. The Elders' Council is elected for a term of four years. The term of powers of the newly elected Elders' Council commences from the moment when the first sitting is convened. The term of powers of the previous Elders' Council terminates from that moment. The sitting of the Elders' Council is convened and held by the Mayor and in case of absence thereof — by the First Deputy Mayor. The sitting of the Elders' Council is considered quorate if attended by a sufficient number of member of the Elders' Council necessary for adopting a decision. The sitting of the Elders' Council is public. In cases defined by the Rules of Procedure of the Elders' Council, closed-door discussions may be held upon the decision adopted by at least half of the total number of members present at the sitting of the Elders' Council.

[9] For details see Electoral Code of the Republic of Armenia at http://www.parliament.am/legislation.php?sel=show&ID=4216#2.7

[10] See Law of the Republic of Armenia "On Local Self-Governance in the City of Yerevan" at http://www.parliament.am/legislation.php?sel=show&ID=3484

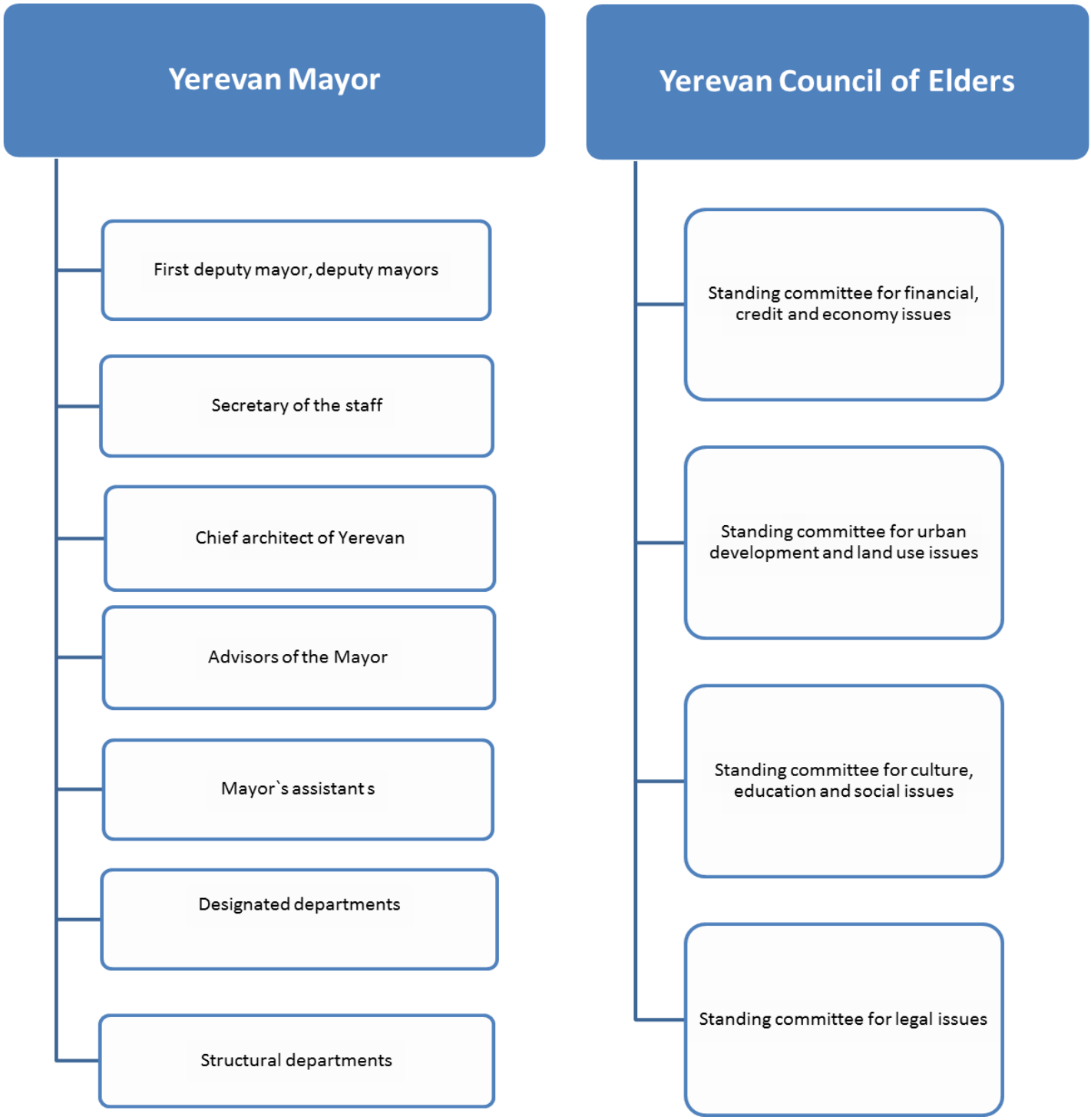



***Figure 2.6. Structure of Yerevan governance system***

Initiation of relevant investment programs, allocation of funds, procedure for adoption of policy decisions regarding implementation, as well as control over the implementation are of key importance from the perspective of implementation of the SEAP. This process is schematically shown in the diagram below.

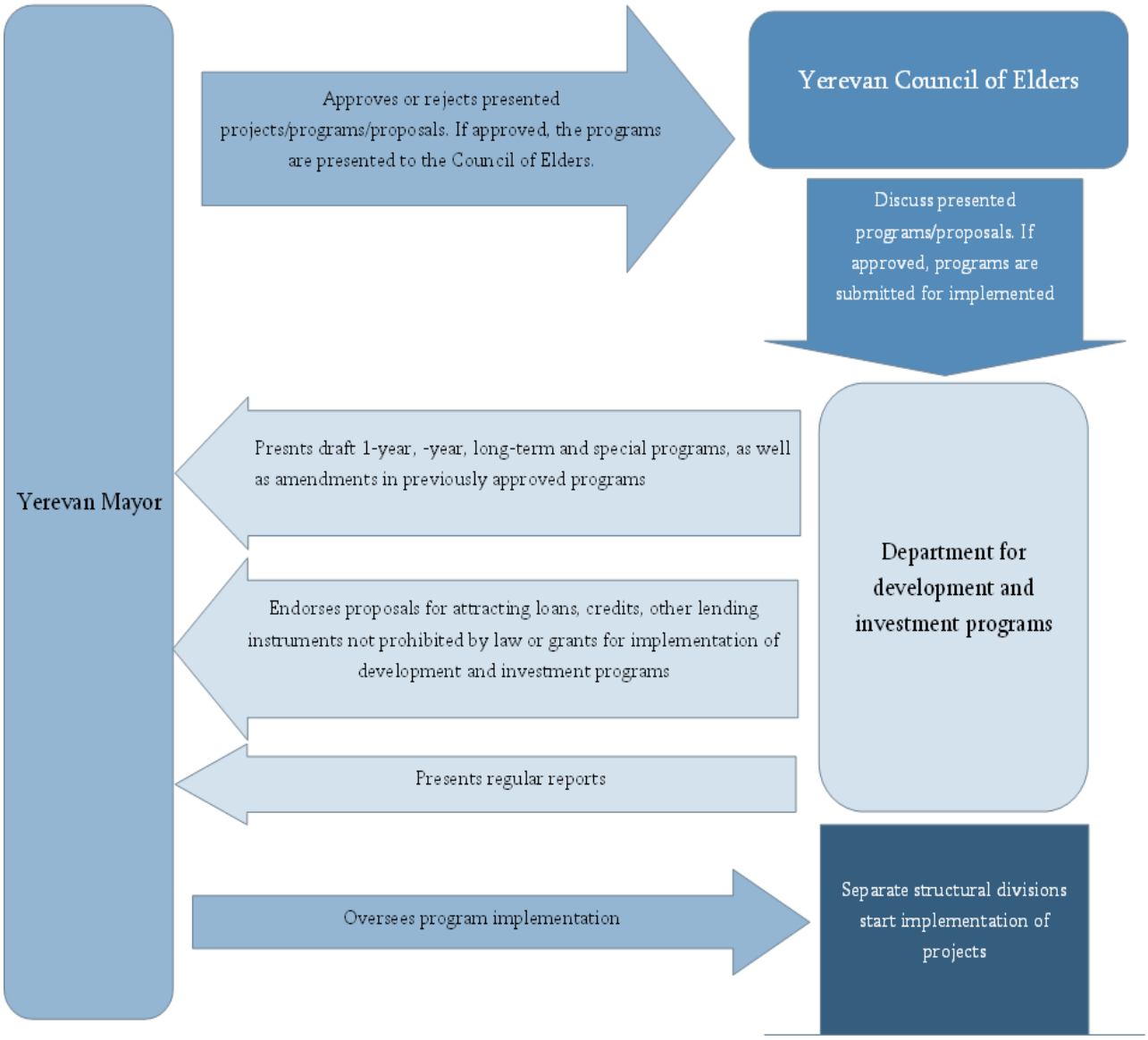



*Figure 2.7. Management process of development and investment programs*

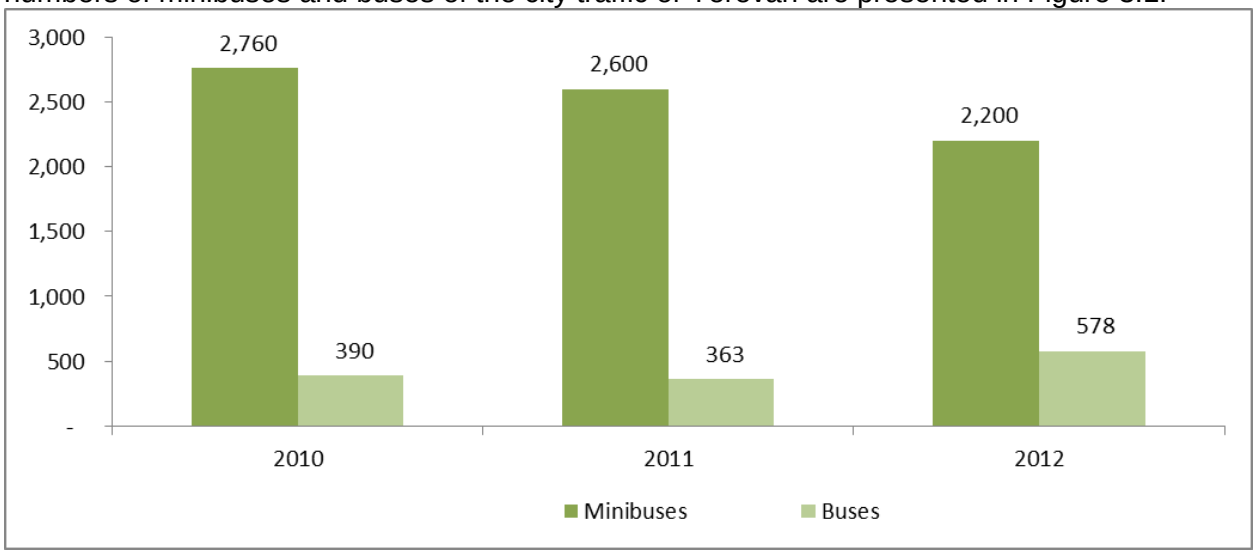
# 3 Transport

Primary streets and roads, that constitute the base of the road and street network of Yerevan, provide the major traffic flow. The main transport communications are provided through primary streets that interconnect the adjacent suburban residential areas and through radial primary roads that start from the central part of the city.[11] Due to the unequal distribution of traffic for public and private transport the main traffic load falls on the central part of the city. Three key directions are highlighted in terms of improvement of the road and street network of Yerevan: (a) unloading the city centre; (b) improvement of the road and street network of the city centre; (c) arrangement of primary roads bypassing the City of Yerevan.

Transport services to residents of the capital are provided by buses, trolleybuses, minibuses and the underground. "Yerevan electric transport" CJSC has 79 trolleybuses (1 for technical aid) on its balance, including 9 Renault, 34 Skoda and 36 LiAZ models. The company operates 5 trolleybus routes; and, on average, 46-48 units of vehicles are used daily for operating the route.[12] The Yerevan underground has 10 stations; the length of the railway measures 12.1 km; 45 wagons are put in operation. ON working days 26 wagons (13 rolling-stocks) are operated, while in weekends 24 wagons (12 rolling-stocks) are operated.

Other public land transportation includes buses and minibuses that bear the major load of transport services provided to citizens. These transportation means use diesel fuel and CNG as motor fuel.

Taking into consideration the tendency of growth in the quantity of vehicles the city authorities adopted a policy of increasing the relative share of busses and in parallel decreasing the number of minibuses in the route network of the city.[13] During this period optimization of the route network became necessary. Already in 2012 the number of minibuses operated only by private operators was deduced to 2200 (88% passenger transportation), while the number of buses operated by municipal organizations reached 578. The indicators reflecting the changes in the numbers of minibuses and buses of the city traffic of Yerevan are presented in Figure 3.1.




[11] See "Yerevan 2025" international conference materials at: https://www.yerevan.am/uploads/media/default/0001/27/bd04d039fca646748435c40cabb174b8563c1de5.pdf

[12] See official website of Yerevan Municipality, https://www.yerevan.am/am/transport-department/

[13] See "Yerevan 2025" international conference materials at: https://www.yerevan.am/uploads/media/default/0001/27/1d835edc5df46836d0aad08c7258f771ba7485c2.pdf

**Figure 3.1. Quantity indicators of minibuses and buses of the city traffic of Yerevan, 2010-2012**

For SEAP analysis purposes the road vehicles of the capital city have been conventionally classified under the following three groups:

1. Public transport: the underground, electrified land transport (trolleybuses), buses and minibuses. Private taxi-cabs, which are part of public transport as well, are not included in this group since they are private vehicles operating, either in grouping or not, under the control of small or medium companies, and therefore have been include in the "Private and commercial" section;
2. Municipal transport: all passenger motor vehicles providing services to all the administrative districts and the city municipality, motor vehicles of all budget-funded institutions subordinate to the city municipality, passenger and load-carrying vehicles, minibuses, vehicles and machinery of all organizations subordinate to the city municipality;
3. Private and commercial transport: this is a conventional category since these vehicles were calculated based on whatever is left, *i.e.*, having all the vehicles as per fuel and leaving out the previous two categories. Thus, this category conventionally includes also all other transportation means. *i.e.*, passenger and non-passenger vehicles servicing public institutions, taxi-cabs, private load-carrying trucks, etc.

For the purposes of analysing the total fuel consumption rate the mileage of different types of vehicles was analysed for the city of Yerevan. According to Figure 3.2[14], the mileage of passenger buses and minibuses reduced during the years 2010-2012 which resulted from replacement of some part of minibuses with buses of middle carrying capacity.

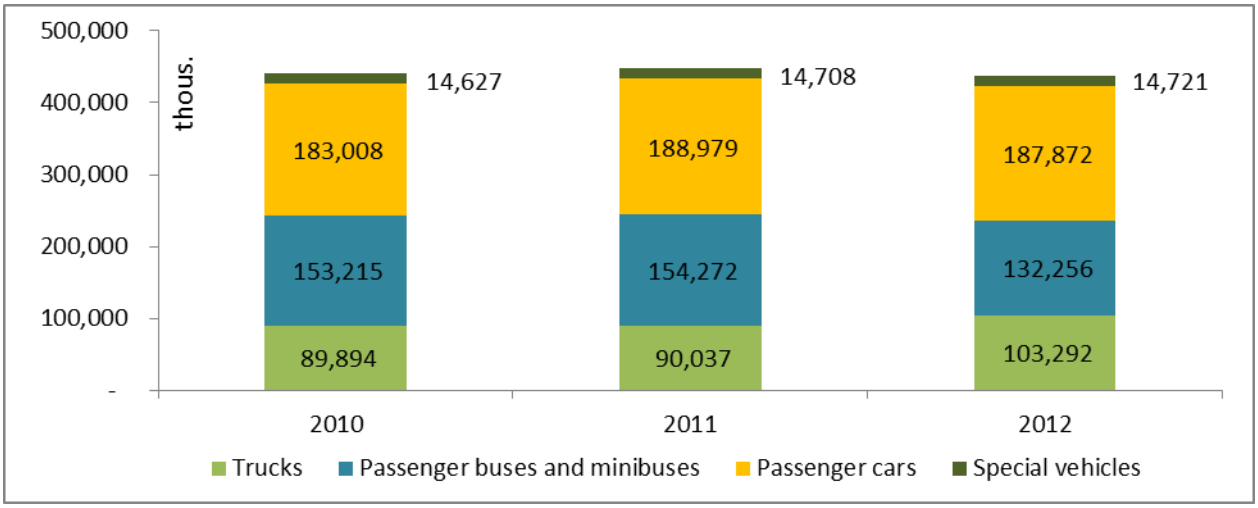



**Figure 3.2. Mileage of different types of vehicles in Yerevan, 2010-2012 (thousand km)**

## 3.1 Energy Consumption in the Transport Sector

The transport sector includes public, municipal and private vehicles which run on electricity (Yerevan Metro, trolleybuses) or which use petroleum, diesel fuel, compressed natural gas (CNG) as motor fuel. Up to the year of 2013 the level of liquefied petroleum gas consumption was insignificant and then equalled to zero. For the conversion of physical units to energy units in terms of consumption of motor liquid fuel the following factors are used provided under European Commission Research Centre guidelines:

For petroleum — 9.2 kWh/l or 12.3 kWh/kg,
For diesel fuel — 10 kWh/l or 11.9 kWh/kg.

[14] Source: National Statistical Service

The adequacy factor established in the Republic of Armenia for standard natural gas, 9.186 kWh/kg, applies to compressed natural gas.[15]

The city may well be a record-breaker in terms of the number of petrol filling and gas refuelling stations (GRS). According to the data of the three main organisations having networks of petrol filling stations, 74 petrol filling stations are functioning in the City of Yerevan. According to the information provided by Gazprom Armenia CJSC, in 2012 172 GRSs were operational in the Republic of Armenia that had a sales rate of 1 million $m^3$ and more (hereinafter referred to as "large GRS") the amount of gas supplied to them equalled to 320,6 million $m^3$. The quantity of gas supplied to GRSs with sales rates lower than 1 million $m^3$ (hereinafter referred to as "small GRS") amounted to 97,9 million $m^3$. According to the «Worldwide NGV statistics» data[16] there are 345 GRSs in Armenia. Accordingly, the number of small GRSs is 173 (345-172).

According to the information provided by the Ministry of Energy and Natural Resources of the Republic of Armenia, in 2012 Yerevan GRSs received 88,3 million $m^3$ gas supply. If we assume that the proportion of large and small GRSs and their average annual sales rates are the same in Yerevan and in the country, it appears that 73 GRSs were operating in 2012 in Yerevan from which 36 were large and 37 were small. If we assume that only large GRSs operate in Yerevan, which is more likely, then their number will be equal to 47.

The Table 3.1 below compares the statistics and the data determined through expert estimations.

*Table 3.1. Sales rates of natural gas in Yerevan and the number of suppliers, 2012*

| Name | GRS, quantity in units | Quantity of supplied gas, million $m^3$ | Average sales rate for 1 GRS |
|---|---|---|---|
| | | | |
| **GRSs with sales rates equal to 1 million $m^3$ and more** | 172 | 320.6 | 1.864 |
| **GRSs with sales rates less than 1 million $m^3$** | 173 | 97.9 | 0.566 |
| **Total** | 345 | 418.5 | |
| **Including Yerevan** | 73/47 | 88.3 | |
| **GRSs with sales rates equal to 1 million $m^3$ and more** | 36 | 67.6 | |
| **GRSs with sales rates less than 1 million $m^3$** | 37 | 20.7 | |

### 3.1.1 Energy consumption of public transport

In the city of Yerevan public transport includes Karen Demirchyan Yerevan Metro, electrified land transport (trolleybuses), city buses and minibuses and taxi-cabs. Taxi-cabs are fully private and are operated by private companies or natural persons. Within the meaning of consumption of energy carries they are classified under the private vehicles group (see 3.1.3). The absolute and relative electrical energy consumption indicators (per one passenger) of electrically propelled vehicles for 2010-2012 are presented below.

*Table 3.2. Electrical energy consumption in the electrified transport sector*

| Name | Measurement unit | Electrical energy | | |
|---|---|---|---|---|
| | | 2010 | 2011 | 2012 |

[15] Consumption of natural gas is expressed in MWh by using 9.186 MWh/thousand $m^3$ factor (taking as a basis standard calorific value of 7900 kcal/$m^3$).

[16] S Ł ´ u http://www.ngvjournal.com/worldwide-ngv-statistics

| | | | | |
|---|---|---|---|---|
| Yerevan Metro | MWh/year | 18,131 | 18,411 | 17,712 |
| | kWh/ passenger | 0.9 | 1.1 | 1.2 |
| Land electric transport | MWh/year | 6,075 | 6,552 | 6,042 |
| | kWh/ passenger | 1.5 | 1.5 | 1.4 |
| **Total** | **MWh/year** | **24,206** | **24,963** | **23,753** |

*Source: Statement of information presented by the Yerevan Municipality based on the letter by Karen Demirchyan Yerevan Metro CJSC of the RA No 39/02-09-67 dated 03.02.2015*

Energy consumption of Yerevan Metro has a stable character ranging between 7.6 and 18.4 GWh/year. Though the energy consumption rates of land electric transport per one passenger have reduced from 1.5 to 1.3 kWh/passenger for the period of 2010-2012; however they are still higher than the consumption rate indicator of the underground. Taking into consideration the current amount of passenger fare for trolleybuses (AMD 50 which is two times cheaper than the fares for other types of public transport) it becomes obvious that this type of transport, in addition to its ecological significance, also has an important social implication.

In Armenia the volume of consumption of CNG as motor fuel reached 480 million $m^3$ in 2015. Armenia is an absolute leader in the world with its share in using CNG in the transport sector. The quantities of land public transport vehicles, annual volumes of consumption of diesel fuel and CNG, and overall energy intensity indicators are presented in Table 3.3.

*Table 3.3. Motor fuel indicators of land transport*

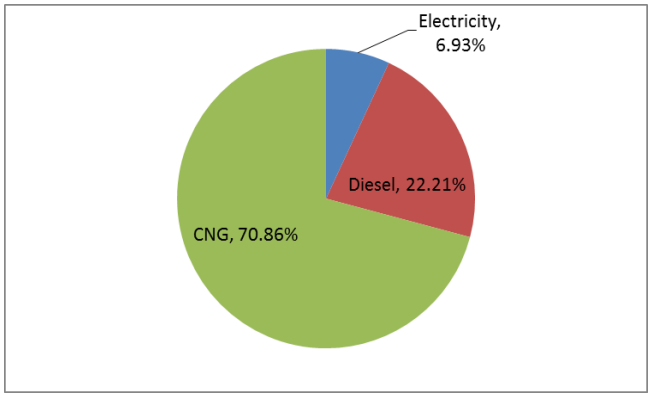
| Name, measurement unit | Diesel fuel | | | CNG | | |
|---|---|---|---|---|---|---|
| | 2010 | 2011 | 2012 | 2010 | 2011 | 2012 |
| **City minibuses** | | | | | | |
| 1. Quantity, *unit* | 215 | 180 | 100 | 2,455 | 2,420 | 2,100 |
| 2. Quantity of operated vehicles, *unit* | 160 | 140 | 85 | 1,940 | 1,860 | 1,815 |
| 3. Monthly fuel consumption rate, *litre (petroleum, diesel) or $m^3$ (CNG)* | 1,112 | 1,112 | 1,112 | 1,179 | 1,179 | 1,179 |
| 4. Total yearly fuel consumption rate, *thousand litres* | 2,135 | 1,868 | 1,134 | | | |
| 5. Total yearly fuel consumption rate, *thousand $m^3$* | | | | 27,441 | 26,309 | 25,673 |
| 6. Total yearly energy consumption rate, *MWh* | 21,350 | 18,680 | 11,340 | 252,069 | 241,675 | 235,828 |
| **City buses** | | | | | | |
| 1. Quantity, *unit* | 290 | 290 | 508 | 100 | 73 | 70 |
| 2. Quantity of operated vehicles, *unit* | 178 | 196 | 315 | 62 | 49 | 35 |
| 3. Monthly fuel consumption rate for 25 days, *l or $m^3$* | 1,714 | 1,714 | 1,714 | 1,816 | 1,816 | 1,816 |
| 4. Total yearly fuel consumption rate, *thousand litres* | 3,660 | 4,030 | 6,477 | | | |
| 5. Total yearly fuel consumption rate, *thousand $m^3$* | | | | 1,351 | 1,068 | 763 |
| 6. Total yearly energy consumption rate, *MWh* | 36,600 | 40,300 | 64,770 | 12,410 | 9,811 | 7,009 |
| **Total, *MWh*** | **57,951** | **58,983** | **76,113** | **264,483** | **251,485** | **242,835** |

*Source: Statement of information of the Municipality on the quantities of vehicles and the relevant report*[17]

Total aggregate indicators of electrical energy and motor fuel consumed in 2010-2012 by vehicles operated by public transport service companies are presented in Table 3.4.

*Table 3.4. Energy consumption of public transport vehicles*

| Name of the energy carrier (fuel) | Measurement unit | Value 2010 | 2011 | 2012 |
|---|---|---|---|---|
| **1. Electrical energy** | MWh | 24,206 | 24,963 | 23,753 |
| **2. Diesel fuel** | thousand litres | 5,795 | 5,898 | 7,611 |
| | MWh | 57,951 | 58,983 | 76,113 |
| **3. CNG** | thousand $m^3$ | 28,792 | 27,377 | 26,435 |
| | MWh | 264,483 | 251,485 | 242,835 |
| **Total, only motor fuel** | MWh | 346,640 | 335,431 | 343,701 |
| **Total** | **MWh** | **347354** | **336,630** | **343,881** |




Among the three types of motor fuels CNG has a prevailing role the share of which reduced nevertheless, from 76.3% up to 70.8% for the period of 2010-2012. During the same period of time the share of diesel fuel increased from 16.7 to 22.2%. The share of energy consumption by the underground and land transport, that are the main consumers of electrical energy, remained almost unchanged in the overall balance.

*Figure 3.3. Structure of energy consumption in public transport, 2012(%)*

The structure of energy carriers used in public transport for 2012 is presented in Figure 3.3.

### 3.1.2 Energy consumption of municipal transport

Municipal transportation means include passenger motor vehicles on the balance of the municipality and administrative districts, passenger and load-carrying vehicles of commercial organizations (CJSCs) of the administrative districts, special purpose vehicles and machinery (ambulances, municipal service vehicles, etc.), passenger and load-carrying vehicles of healthcare institutions. The number of passenger vehicles operated under the control of administrative districts during the years of 2010-2012 ranged between 51 and 54. All the vehicles were using solely petroleum. The basic data on the average annual mileage of vehicles and the quantity of fuel consumed are summarized in Table 3.5 according to the information received from the municipality and administrative districts.

*Table 3.5. Petroleum consumption of vehicles of Yerevan Municipality (YM) and administrative districts (AD)*

| Administrative district | 2010 | 2011 | 2012 |
|---|---|---|---|

[17] See: httTs://www.yerevan.am/uTloads/media/default/0001/08/6ba6d56e8f3236e2daed739916e101a7aa7d42ff.Tdf :

| | thousand litres | MWh | thousand litres | MWh | thousand litres | MWh |
|---|---|---|---|---|---|---|
| 1.Municipality | 327 | 3,047 | 347 | 3,194 | 560 | 5,150 |
| 2.Ajapnyak | 22 | 205 | 32 | 294 | 31 | 288 |
| 3.Avan | N/A | N/A | 27 | 248 | 24 | 216 |
| 4.Arabkir | 16 | 149 | 15 | 140 | 16 | 149 |
| 5.Davitashen | 13 | 121 | 17 | 155 | 16 | 143 |
| 6.Erebuni | 27 | 252 | 27 | 252 | 27 | 248 |
| 7.Kentron | 116 | 1,068 | 106 | 974 | 65 | 597 |
| 8.Malatia-Sebastia | 13 | 121 | 13 | 122 | 11 | 103 |
| 9.Nor Nork | 16 | 143 | 12 | 112 | 14 | 124 |
| 10.Nork Marash | 11 | 103 | 11 | 103 | 13 | 115 |
| 11.Nubarashen | 5 | 46 | 1 | 12 | 7 | 64 |
| 12.Shengavit | 50 | 461 | 47 | 435 | 45 | 418 |
| 13.Kanaker-Zeytun | 14 | 127 | 14 | 127 | 14 | 127 |
| **Total ADs** | 304 | 2,797 | 323 | 2,974 | 282 | 2,593 |
| **Total (YM and ADs)** | 631 | 5,844 | 670 | 6,169 | 842 | 7,743 |

Passenger motor vehicles of municipal closed joint stock companies also use petroleum with insignificant exceptions. Table 3.6 shows the basic fuel and energy indicators for 2010-2012 for the operation of the pool of approximately 60 passenger vehicles and about 35 load-carrying trucks that have mainly gasoline engines.

*Table 3.6. Fuel consumption rates of motor vehicles belonging to commercial closed stock companies*

| Type of fuel | Type of vehicle | 2010 | | 2011 | | 2012 | |
|---|---|---|---|---|---|---|---|
| | | thousand litres ($m^3$) | MWh | thousand litres ($m^3$) | MWh | thousand litres ($m^3$) | MWh |
| Petroleum | Passenger | 343.5 | 3,198.8 | 13.5 | 124.2 | 251.7 | 2,316.0 |
| | Load-carrying | - | - | - | - | 57.1 | 525.5 |
| CNG | Passenger | 27.9 | 256.5 | 28.5 | 261.8 | 17.5 | |
| | Load-carrying | 7.5 | 68.9 | 9.0 | 83.0 | 65.5 | |
| Diesel fuel | Passenger | | | | | 0.3 | |
| | Load-carrying | 24.6 | 226.3 | 12.0 | 110.4 | 21.2 | |

Garbage collection and sanitary cleaning services in the capital are provided by “Sanitek” company, the contract winner, which yearly collects in average 290-295 thousand tonnes of domestic garbage and removes in garbage-removal trucks from the territory of the capital to Nubarashen garbage dump.[18]

*Table 3.7. Fuel consumed by garbage collection companies*

| 2012 | Petroleum, thousand litres | Diesel, thousand litres | CNG $nm^3$ | Mileage, thousand km |
|---|---|---|---|---|
| | | | | |
| **Load-carrying trucks** | 418.2 | 503.5 | 1,258,136.0 | 4,841.7 |
| **Special** | 206.2 | 209.5 | 538,877.0 | 1,872.8 |

[18] S ł ´ u
https://www.yerevan.am/uploads/media/default/0001/41/fbc4fccc71d0e09a9b1d24155d0d84c1606be725.pdf

| | | | | |
|---|---|---|---|---|
| **Passenger carrying** | 61.0 | | | 408.8 |
| **Total** | **685.4** | **713.1** | **1,797,013.0** | **7,123.3** |

Public transport includes also various vehicles of a number of healthcare institutions having the status of municipal non-commercial organizations (MNCO); practically 70% of share in fuel and energy consumption belongs only to Ambulance Service Company. Moreover, the pool of vehicles includes solely petroleum-powered vehicles. The total number of vehicles using diesel fuel and CNG in these institutions is two. Fuel consumption rates for 2010-2012 of vehicles of healthcare MNCOs are presented in Table 3.8.

*Table 3.8. Fuel consumption rates of vehicles of healthcare institutions*

| **Type of fuel** | **2010** | | **2011** | | **2012** | |
|---|---|---|---|---|---|---|
| | **thousand litres** | **MWh** | **thousand litres** | **MWh** | **thousand litres** | **MWh** |
| **Petroleum** | 397.412 | 3,656.19 | 393.385 | 3,619.14 | 417.015 | 3,836.54 |
| **Diesel fuel** | 2.2 | 22 | 0.9 | 9 | 0.04 | 0.4 |
| **CNG** | 1.565 | 15.43 | N/A | 0 | N/A | 0 |

The prevailing share of petroleum used by healthcare institutions' vehicles as motor fuel is obvious as regards the whole period concerned. Most probably, the insignificant share of CNG is explained by the fact that vehicles used in this sector need to be reliable and operational to the maximum extent irrespective of weather or other conditions. Indisputably, from this perspective petroleum-propelled engines are beyond competition.

Summarized data on fuel and energy indicators of municipal vehicles for the period of 2010-2012 are presented in Table 3.9.

*Table 3.9. Energy consumption of municipal vehicles*

| **Name of energy carrier (fuel)** | **Measurement unit** | **Value** | | |
|---|---|---|---|---|
| | | **2010** | **2011** | **2012** |
| Petroleum | thousand litres | 1,869 | 1,893 | 2,062 |
| | MWh | 17,199 | 17,416 | 18,969 |
| Diesel fuel | thousand litres | 792 | 851 | 845 |
| | MWh | 7,922 | 8,512 | 8,446 |
| CNG | thousand $m^3$ | 1,915 | 1,962 | 2,012 |
| | MWh | 17,592 | 18,019 | 18,479 |
| Liquefied petroleum gas (LPG) | thousand litres | 4 | 4 | 4 |
| | MWh | 31 | 31 | 31 |
| **TOTAL** | **MWh** | 42,744 | 43,977 | 45,925 |

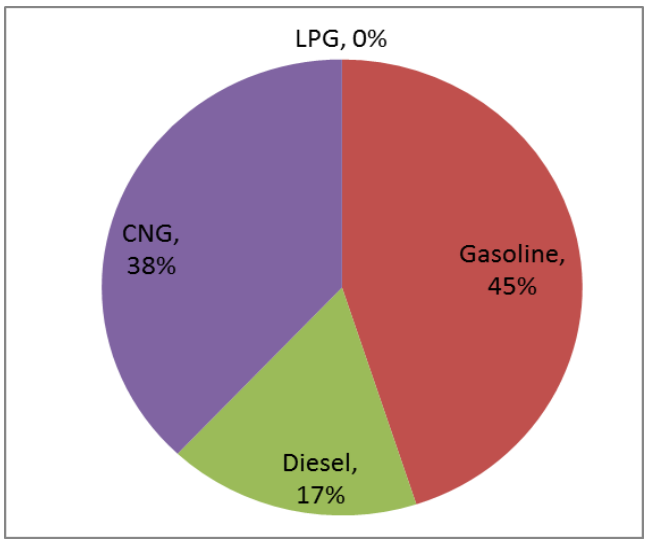



*Figure 3.4.Structure of energy consumption in the municipal transport, 2012 (%)*

Figure 3.4 shows the balance (in shares) of motor fuels used in municipal transport for the year of 2012.

The share of liquefied petroleum gas (LPG) as motor fuel was equal to 0.06 % in 2012. It fell out of use since 2013.

### 3.1.3 Energy consumption of private and commercial vehicles

This subsection includes all the vehicles registered in Yerevan except for the public and municipal transport mentioned above. This subsection includes also the pool of vehicles of taxi services operating in the capital city. The vehicles included in this subsection mainly use petroleum, diesel fuel and compressed natural gas as motor fuel. Since no mileage or fuel consumption accounting is carried out for private vehicles, the so called “mass balance approach” was used for determining the amount of energy consumption of vehicles include in this group. Calculation was made to determine the total energy consumption of all the vehicles registered in Yerevan less the energy consumption rates of vehicles of public and municipal transport.

It should be noted that there is no information on the quantities of petroleum and diesel fuel consumed in Yerevan. There is only the official data provided by Gazprom Armenia CJSC on the quantities of CNG sold in gas refuelling stations in Yerevan. There is also official data on the vehicles registered in Yerevan, vehicles registered in the territory of the Republic of Armenia, on quantities of petroleum and diesel fuel imported into Armenia, and CNG sold in gas refuelling stations of the Republic of Armenia. One of the main complications in this case is the fact that there is no data on the quantity of vehicles converted to run on CNG. Actually, all the vehicles that are converted to run on CNG are registered in the RA Police as petroleum vehicles.

A special methodology was elaborated for determining the consumption rates of petroleum and diesel fuel in Yerevan based on the above mentioned data which works as follows:

*Determining petroleum consumption rates*

- Calculate the number of vehicles converted to run on CNG based on CNG consumption data and average consumption rate of one vehicle using CNG;
- For determining the real number of petroleum vehicles, the number of vehicles converted to run on CNG was deducted from the number of registered petroleum vehicles;
- The yearly average petroleum consumption rate was determined for one vehicle based on the quantity of petroleum imported into the Republic;
  The petroleum consumption rate in Yerevan was determined based on the number of vehicles not converted to run on CNG and the yearly average petroleum consumption rate of one vehicle.

*Determining diesel fuel consumption rates*

- 
- Calculation was made to determine the yearly average diesel fuel consumption rate for one vehicle based on the quantity of diesel fuel imported into the Republic and the number of vehicles;
  The diesel fuel consumption rate in Yerevan was determined based on the number of diesel vehicles and the yearly average consumption rate of one vehicle.

Energy consumption of private and commercial passenger vehicles and load-carrying trucks for the period of 2010-2012 is calculated based on the above-mentioned methodology and presented in Table 3.10.

*Table 3.10 Energy consumption of private and commercial vehicles*

| Energy carrier | Measurement unit | Value | | | Conversion factor |
|---|---|---|---|---|---|
| | | 2010 | 2011 | 2012 | |
| Petroleum | thousand litres | 156,296 | 142,389 | 117,045 | |
| | MWh | 1,437,924 | 1,309,979 | 1,076,815 | 9.20 kWh/l |
| Diesel fuel | thousand litres | 55,592 | 54,173 | 59,120 | |
| | MWh | 555,917 | 541,729 | 591,195 | 10.0 kWh/l |
| CNG | thousand $m^3$ | 37,933 | 49,290 | 59,734 | |
| | MWh | 348,448 | 452,774 | 548,717 | 9.186 kWh/m3 |
| **Total** | **MWh** | **2,342,288** | **2,304,482** | **2,216,727** | |

In the private and commercial transport subsection the share of petroleum reduced from 61.4% to 49.0% during the three years concerned. During the same period, in the context of a slight change in the share of diesel fuel, the role of CNG has significantly increased and reached 24.4% from 14.8%. Thus, the annual average rate of growth in the use of CNG amounted to more than 23%. In general, in this subsection the energy consumption rate reduced for about 5% during the three-year period. Mainly the consumption of petroleum was reduced, whereas the consumption of diesel and CNG increased.

Motor fuels consumption tendencies are shown in Figure 3.5 where the share of each energy carrier in the total energy consumption is presented in percentages.

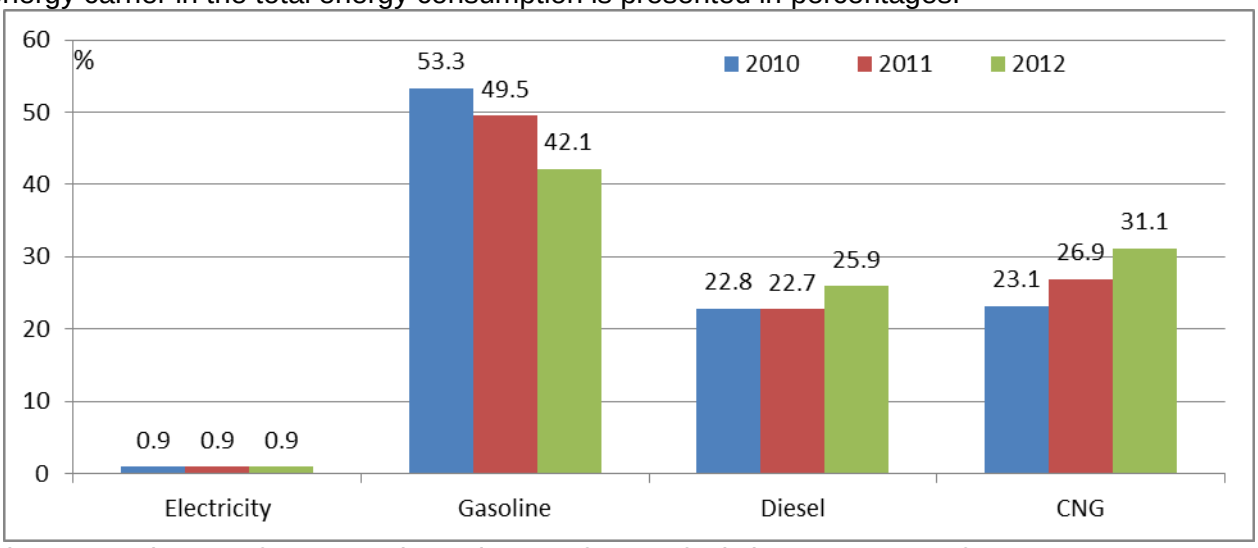



*Figure 3.5 Change of consumption volumes of motor fuels in percentages, for 2010, 2011, 2012*

The more detailed energy consumption trends are presented below.

*Table 3.11. Energy consumption of all vehicles of the City of Yerevan for 2010-12, MWh*

| Name | Electrical energy | | | Petroleum | | | Diesel fuel | | | Compressed gas | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2010 | 2011 | 2012 | 2010 | 2011 | 2012 | 2010 | 2011 | 2012 | 2010 | 2011 | 2012 |
| Karen Demirchyan Yerevan Metro | 18,131 | 18,411 | 17,712 | | | | | | | 579 | 1,075 | 1,075 |
| Electrified land transport | 6,075 | 6,552 | 6,042 | | | | | | | 135 | 124 | 105 |
| City minibuses | | | | | | | 21,350 | 18,682 | 11,342 | 252,069 | 241,675 | 235,828 |
| City buses | | | | | | | 36,600 | 40,302 | 64,770 | 12,413 | 9,811 | 7,008 |
| **Total, public** | ***24,206*** | ***24,963*** | ***23,753*** | | | | ***57,951*** | ***58,983*** | ***76,113*** | ***265,197*** | ***252,684*** | ***244,015*** |
| AD passenger vehicles | | | | 2,797 | 3,442 | 5,150 | | | | | | |
| Passenger vehicles of commercial organizations | | | | 3,010 | 2,797 | 2,316 | | | 3 | 31 | 104.4 | 191.5 |
| Load-carrying trucks of commercial organizations | | | | 677 | 609 | 526 | 501 | 435 | 212 | 686 | 607 | 601 |
| Various vehicles of support services | | | | 1,079 | 1,154 | 1,610 | 100 | 867 | 1,130 | 541 | 638 | 717 |
| Vehicles of healthcare institutions | | | | 3,656 | 3,619 | 3,837 | 22 | 9 | 0 | 15 | | |
| Garbage-removal trucks | | | | 5,270 | 5,281 | 5,345 | 2,036 | 2,040 | 2,065 | 9,541 | 9,541 | 9,541 |
| ***Total, municipal*** | | | | ***16,489*** | ***16,902*** | ***18,783*** | **2,659** | **3,351** | **3,407** | ***10,814*** | ***10,890*** | ***11,051*** |
| **Private and commercial vehicles** | | | | 1,437,889 | 1,309,979 | 1,076,815 | 556,139 | 541,729 | 591,195 | 347,765 | 452,774 | 548,717 |
| **Total, private** | | | | ***1,437,889*** | ***1,309,979*** | ***1,076,815*** | ***556,139*** | ***541,729*** | ***591,195*** | ***347,765*** | ***452,774*** | ***548,717*** |
| **Grand total (public, municipal and private)** | **24,206** | **24,963** | **23,753** | **1,454,378** | **1,326,881** | **1,095,598** | ***558,798*** | ***545,080*** | ***594,602*** | ***358,579*** | ***463,664*** | ***559,768*** |

## 3.2 Transport sector emissions

The emissions in the transport sector as per types of energy carriers are presented below.

*Table 3.12. GHG emissions by the transport sector*

| **Total energy consumption in the transport sector** | | | | | GHG emission factor (tonne/ MWh) | $CO_2$ emissions in tonnes 2012 |
|---|---|---|---|---|---|---|
| Name of the energy carrier (fuel) | Measurement unit | Value | | | | |
| | | 2010 | 2011 | 2012 | | |
| Electrical energy | MWh | 24,206 | 24,963 | 23,754 | 0.222 | 5,273 |
| Petroleum | thousand litres | 158,161 | 144,282 | 119,107 | | 272,804 |
| | MWh | 1,455,122 | 1,327,396 | 1,095,599 | 0.249 | |
| Diesel fuel | thousand litres | 62,179 | 60,922 | 67,575 | | 179,081 |
| | MWh | 621,790 | 609,223 | 670,717 | 0.267 | |
| Compressed natural gas | Thousand nm3 | 68,643 | 78,759 | 88,309 | | 162,364 |
| | MWh | 630,555 | 723,476 | 803,783 | 0.202 | |
| Liquefied petroleum gas | thousand litres | 4 | 4 | 4 | | 7.037 |
| | MWh | 31 | 31 | 31 | 0.227 | |
| **Total** | **MWh** | 2,731,704 | 2,685,089 | 2,593,884 | | 619,530 |

## 3.3 Mitigation measures in the transport sector

Within the scope of Yerevan SEAP seven measures and fifteen sub-measures are considered upon the quantitative results of energy saved and emissions avoided. The resulted amounts are summarized in ***Table 3.22*** for the year of 2020 (at the end of the section), and in terms of time series for 2012-2020 — in Figure 3.6.

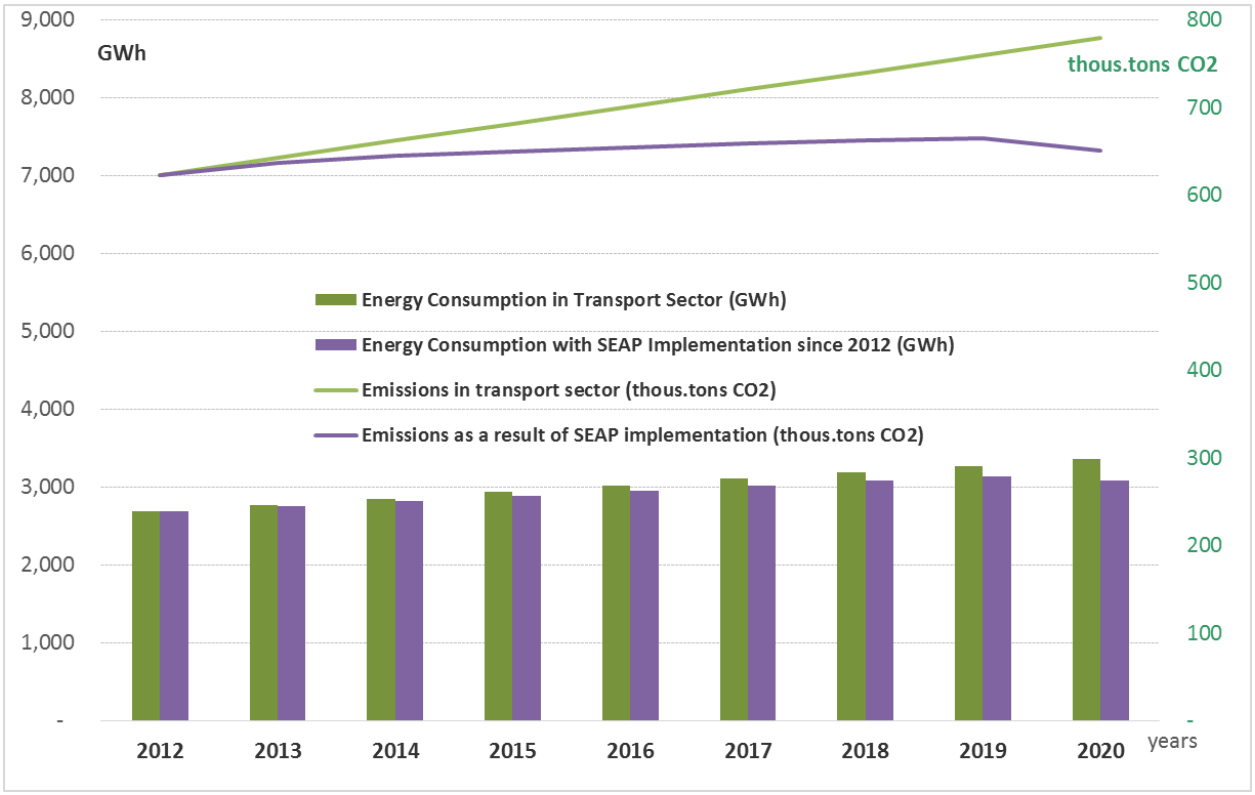



*Figure 3.6. Total energy saved yearly in the transport sector for 2012-2020 (GWh), and yearly $CO_2$ emissions avoided yearly (thousand t $CO_2$)*

The energy saved as a result of seven Activities in the transport sector in 2020 will be about 370,8 thousand MWh, and the avoided $CO_2$ emissions will equal to 168,9 thousand tonnes. From the energy-saving perspective the most significant one among the activities concerned is the implementation of Activity "Strategy program for the optimization of public transport (PT)" (Activity T1). By 2020 it will ensure 39% of the total energy saved and 20% of $CO_2$ emissions avoided in the transport sector.

In this context, the second one in term of importance is Activity T5 (Road infrastructure development, new roads, including bypass roads, new road junctions). It will ensure about 57% of the total energy saved and about 32% of $CO_2$ emissions avoided in the transport sector.

At the same time, from the perspective of avoided $CO_2$ emissions, major significance has Activity T4 (Promoting conversion of PT and private vehicles to CNG through allocation of sites for gas refuelling stations in Yerevan administrative districts, definition of safety requirements). It will ensure about 47% of the total $CO_2$ emissions avoided. This Activity is of key importance mostly for its impact from the point of view of reducing emissions of harmful substances into the atmosphere and providing accessible mobility to the population of Yerevan. The quantitative assessment of this impact is beyond the scope of the SEAP program. Taking into account the fact that Activity T4 assumes change in the type of fuel, it may not result in energy saving.

### 3.3.1 Activity T.1. Strategy program for the optimization of public transport (PT)

This Activity implies PT pool renewal, management and technical optimization, modernization of the ticket system and schedules. The program underlying this Activity was elaborated during the years of 2004-2005 and started to be implemented since 2015. The program comprises two groups of activities which are as follows:

1. Modernization of Yerevan PT pool, optimization of the staff, increase of effectiveness of activities;
2. Optimization of the PT routes network, transition to a common ticket system, installation of electronic schedules in PT stops, power supply of schedule boards and advertising boards by solar photovoltaic energy.

Elaboration of a new routes network is based on the principle of ruling out any overlapping routes which, in its turn, will provide optimal routes classified in diagonal, link and radial functional groups inter-coordinated both among each other and with other types of public transport, such as the underground, land electrical transport. A route network elaborated based on such principle (the example of which is shown below) will enable to significantly reduce the number of vehicles even in the context of the same passenger flow, raise the service attractiveness and alleviate the road and traffic load which day after day becomes a more urgent issue for the capital city.

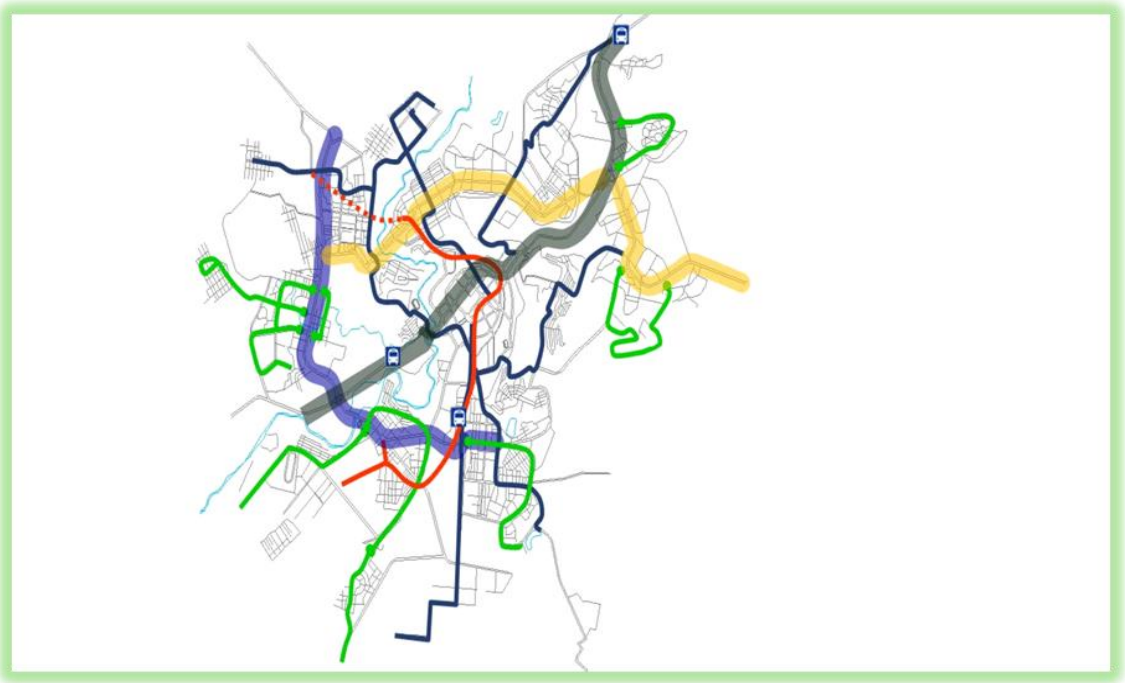


*Figure 3.7. Example of the new route network (Source: "Yerevan 2025" international conference reports[19])*

The assessment of the deliverables (saved energy in MWh, avoided $CO_2$ emissions in thousand t) to be achieved as a result of implementation of the program is based on the measures of the program aimed at optimization of Yerevan PT pool and increase in efficiency of PT routes within the scope of the 3rd phase of implementation of the program. In particular, the number of route minibuses operated in the previous phases of this program has reduced from 3,258 to 1,900 during the period of 2005-2014. Moreover, their pool renewal and route adjustment were also achieved (see: Figure 3.6). In parallel, the number of city buses raised and reached 350 in 2012 instead of 146 recorded in 2005. In this case also PT bus pool was renewed and the routes were adjusted.

The planned indicators of this process, that still continue the tendencies of previous years, have been taken as a basis for the 3rd phase of implementation of the Strategy program for 2015-2020 (see: Figure 3.6).

[19] See: "Improvements in the public transport system" report, V. Nikoyan, Deputy Mayor of Yerevan, available at: https://www.yerevan.am/uploads/media/default/0001/27/1d835edc5df46836d0aad08c7258f771ba7485c2.pdf

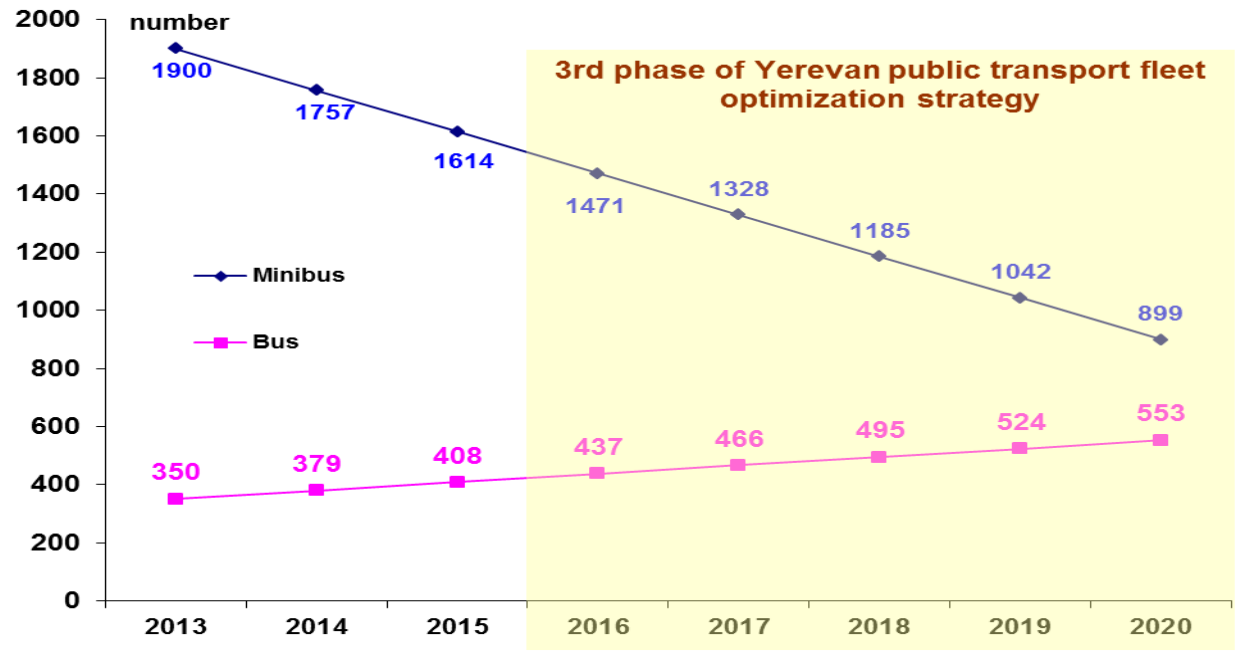



*Figure 3.8. The number (items) of minibuses and city buses operational in Yerevan PT, 2013-2020*

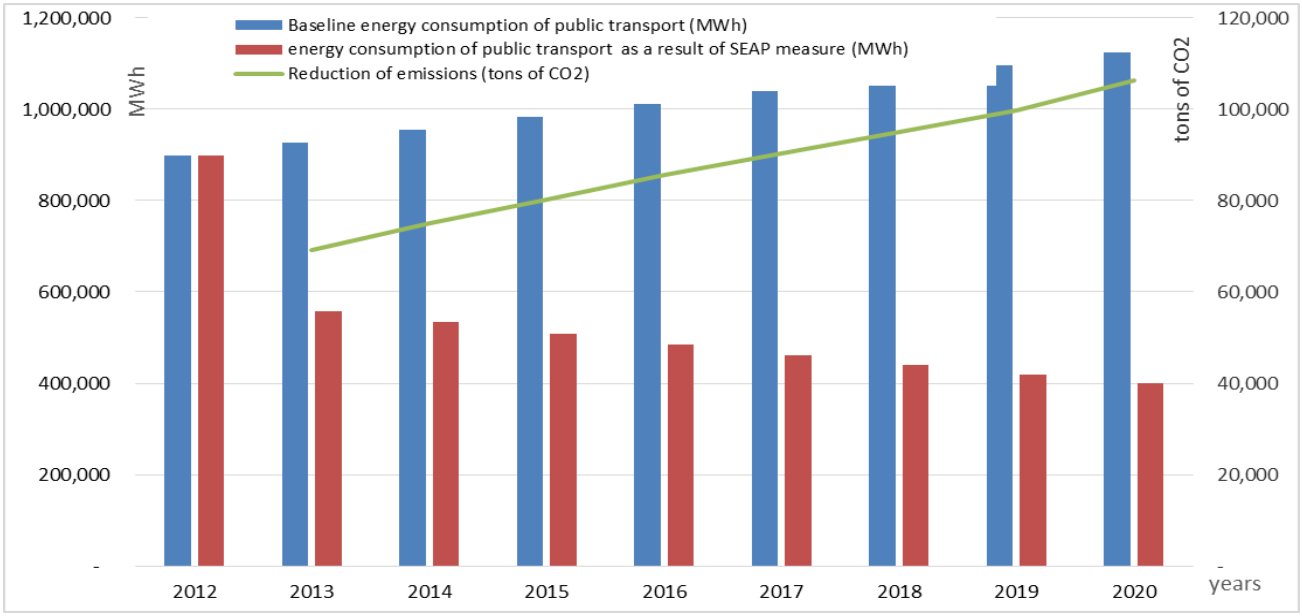



*Figure 3.9. Energy saved and $CO_2$ emissions avoided as a result of Activity T.1*

As a result of implementation of the Strategy the PT traffic efficiency has significantly increased, and at the same time, the yearly mileage of PT pool has essentially reduced. This, in its turn, has caused reduction of motor fuel consumption rates and, accordingly, energy saving and avoided emissions. Figure 3.7 shows the assessments for the energy saved (thousand MWh, on the left) and $CO_2$ emissions avoided ($CO_2$ thousand t, on the right) by the Yerevan PT as a result of implementation of this Activity.

*Table 3.13. Activity T.1. PT optimization results*

| Source of financing, cooperating structures | Value, thousand Euros | Energy saved, MWh/year | Reduction of $CO_2$ emissions | Investment years |
|---|---|---|---|---|

| | | Petroleum | Diesel fuel | Natural gas | , in tonnes, 2020 | |
|---|---|---|---|---|---|---|
| YM, "YerevanProject" CJSC, IFI, other government | 17,200 | | 58,116 | 87,174 | 33,139 | 2013-2020 |
| | | 145,340 | | | | |

### 3.3.2 Activity T.2. Re-equipment of public electric transport (trolleybuses) pool and infrastructures

The Activity is planned to be implemented at the account of the State Budget and EBRD loan funds. It is anticipated to be implemented during 2018–2019. The Activity focuses on the following 6 sub-measures:

***Activity T.2.1.*** Modernization of the trolleybus pool. Currently the pool comprises 79 trolleybuses (9 Renault, 36 LiAZ and 34 Skoda models), from which 22 are out of order. Within the scope of the Activity 50 new trolleybuses are planned to be acquired instead of 43 trolleybuses with an approximate average price of 200 thousand Euros for one trolleybus.
***Activity T.2.2***. Renovation and modernization of the overhead contact system. From 133500 m of trolleybus overhead contact system 66750 m (50%) need capital repair; besides, 8 feeding stations are planned to be added as well.
***Activity T.2.3.*** Modernization of traction substations. All the 24 traction substations in the system are subject to modernization.
***Activity T.2.4***. Renovation and improvement of the cable network. The existing cable network measures 102,000 m in total from which ALS type cables, measuring 50,000 m, need to be replaced.
***Activity T.2.5.*** Reduction of heat losses in buildings and premises of the system. For the purposes of achieving energy saving, out of buildings and premises with a total surface of 13178$m^2$ capital repair works will be carried out, as well as doors and windows will be replaced in premises with a surface of 7200$m^2$ (pursuant to the loan request submitted to EBRD).
***Activity T.2.6***. Improvement of the lighting system in production buildings and premises of the system by installing energy-efficient lamps.

The planned impact of this Activity is presented in Table 5.17 which is based on the timetable of EBRD loan agreement provided for this Activity and energy saving assessments. It should be noted that the Yerevan public transport optimization program, which is to be elaborated with the assistance of ADB, provides for measures aimed at usage and commercialization of the trolleybus services such as new route system for the public transport, ruling out of routes overlapping with trolleybus routes, integrated tariffs, common ticket system and other measures the impact of which is assessed within the scope of Activity T.1.

*Table 3.14 Implementation timetable for Activity T2 by "yearly saved energy" indicator, MWh (according to EBRD loan request assessments)*

| Name | Description | 2018 | 2019 | 2020 |
|---|---|---|---|---|
| **Activity T.2.1** | Modernization of the trolleybus pool | 808.3 | 808.3 | 808.3 |
| **Activity T.2.2** | Renovation and modernization of the overhead contact system | 269.4 | 269.4 | 269.4 |
| **Activity T.2.3** | Modernization of traction substations | 538.9 | 538.9 | 538.9 |

| | | | | |
|---|---|---|---|---|
| **Activity T.2.4** | Renovation and improvement of the cable network | 808.3 | 808.3 | 808.3 |
| **Activity T.2.5** | Improvement of the lighting system in administrative buildings and premises by installing energy-efficient lamps | 66.8 | 66.8 | 66.8 |

*Table 5.18. Activity T.2. Description of the Activity for re-equipment of public electric transport (trolleybus) pool and infrastructures*

| Source of financing, cooperating structures | Value, thousand Euros | Energy saved, MWh/year | Reduction of $CO_2$ emissions, in tonnes, 2020 | Investment years |
|---|---|---|---|---|
| | | Electrical energy | | |
| **YM, "Yerevan electric transport" CJSC, EBRD** | 28,000 | 2,558 | 567 | 2018-2019 |

### 3.3.3 Activity T.3. Re-equipment of public electric transport (Yerevan Metro)

The Activity is planned to be implemented at the account of the State Budget and EBRD loan funds. It is anticipated to be implemented during 2018–2019. The Activity focuses on the following 7 sub-measures:

***Activity T.3.1.*** Construction of a drainage tunnel measuring 932 m in length for the purpose of lowering the groundwater level that will provide for:

***Activity* T.3.1.1.** Partial shutdown of pumping stations during 2018-2019;

***Activity* T.3.1.2.** Shutdown of submersible pumps of the drainage system after the drainage tunnel is put into operation starting from 2019;

***Activity T.3.2.*** Modernization of 15 escalators;

***Activity T.3.3.*** Installation of additional ventilation equipment;

***Activity T.3.4.*** Replacement of 6kW cable network measuring 35 km in length, re-equipment of substations, modernization of the lighting system in the station halls by installation of energy-efficient lamps;

***Activity T.3.5.*** Re-equipment, renovation of the rolling-stock depot, modernization of the rolling stock.

The planned timetable for the implementation of this Activity is presented in Table 5.19 which is drawn up based on the timetable of EBRD Agreement. As the Table shows, the key activities from the perspective of energy saving (construction of a drainage tunnel measuring 932 m in length, lowering of the groundwater level) are planned to be completed in 2019. While before that, during the years of 2016-2018, there will be partial shutdown of drainage system pumping stations (for technical safety purposes) reaching 100% performance efficiency in 2019. At the same time, shutdown of submersible pumps of the drainage system will be possible only after the drainage tunnel is put into operation. Though the measures are focusing solely on technical safety measures, however, they will have a significant energy-saving impact (see: Table 3.15).

*Table 3.15. ActivityT.3. Deliverables expected from the re-equipment of Yerevan Metro (based on the EBRD loan request)*

| Source of financing, cooperating structures | Amount, thousand Euros | Energy saved, MWh/year | Reduction of $CO_2$ emissions, in tonnes, 2020 | Investment years |
|---|---|---|---|---|
| | | Electrical energy | | |
| **YM, Yerevan Metro CJSC , EBRD, government structures** | 21,000 | 3,727 | 827 | 2017-2018 |

### 3.3.4 Activity T.4. Conversion of Yerevan public and private vehicles to CNG

This Activity focuses on promoting the conversion of Yerevan public and private vehicles to CNG through allocation of sites for gas refuelling stations in Yerevan administrative districts, definition of safety requirements, etc.

It should be noted that in terms of $CO_2$ emissions optimization of the PT sector has double effect, *i.e.*, reduction of emissions as a result of both energy saving and change of the fuel used. As mentioned above, Armenia is exceptional in the world in using CNG in the transport sector. Already at the end of 2006 the volume of CNG use in the Republic exceeded the use of diesel fuel and starting from 2013 exceeded also the use of petroleum. The same trend is observed also in the capital. Figure 3.8 shows the data on the use of motor fuel by vehicles in Yerevan and illustrates the trends of their use. The same dynamics is expected in the long-term perspective for the transition from petroleum to CNG (linear trend) conditioned by the relative price advantage of CNG and the fuel type used by petroleum vehicles still existing in the pool and newly imported every year.

Greenhouse gas emission rates as a result of using CNG are essentially lower than the emissions from using petroleum and diesel fuel. Thus, the assessments of avoided $CO_2$ emissions from the use of CNG in the Yerevan transport sector for 2010-2020 are demonstrated in Figure 3.9 (see also the respective line in Table 3.15). As becomes evident from this Figure, as a result of this Activity avoided $CO_2$ emissions from the use of CNG in the transport sector will be around 80 thousand tonnes in 2020.

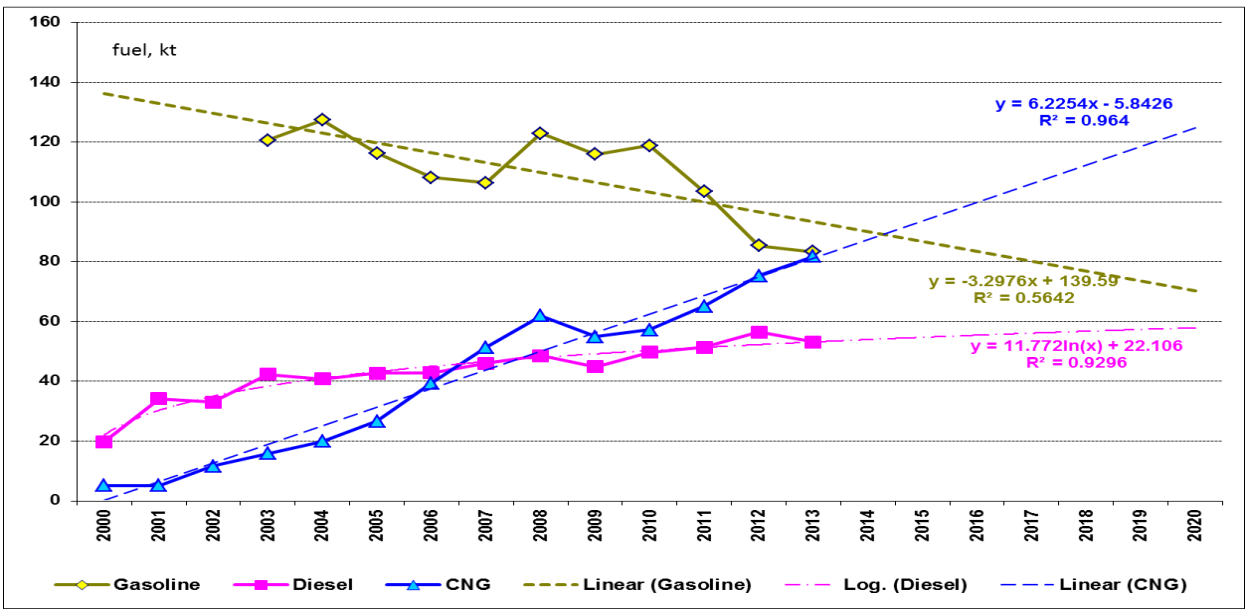



*Figure 3.10 Motor fuels consumed by Yerevan public and private vehicles, thousand t. Factual situation and trend assessment for 2012-2020*

**This Activity is financed at the account of** private investments, generated from own resources of citizens and legal entities, or at the account of "green" and energy efficiency loans provided by international financial organization (EBRD, GGF, IFI) through local financial organizations.

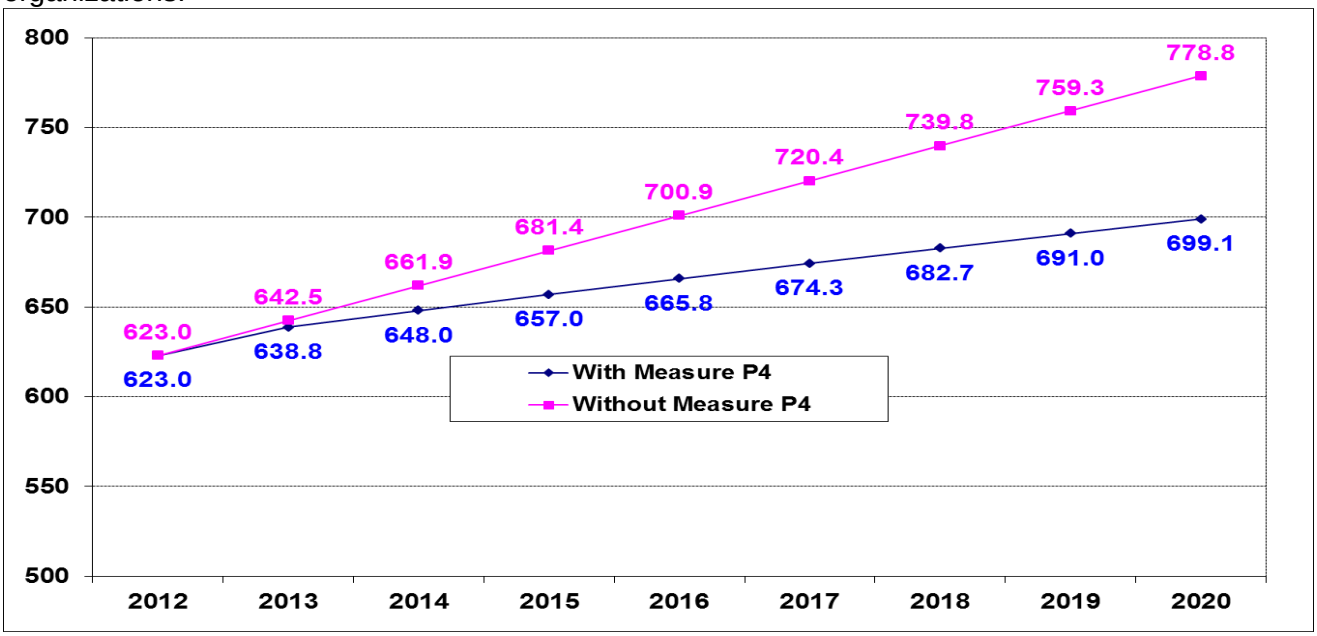



*Figure 3.11 Avoided $CO_2$ emissions achieved as a result of conversion of Yerevan public and private vehicles to CNG. Actual situation for 2012-2015 and assessments for 2016-2020*

Initially, the major user of CNG in vehicles was the private sector and the motives for its use were purely of economic nature. The relatively low price of the natural gas was the reason that the use of CNG was 2.5-3.0 times cheaper than the use of petroleum. Starting from 2005 Yerevan Municipality promoted the use of CNG in public transport by allocating special sites for gas refuelling stations and assisting in development of respective regulatory standards and safety rules. This resulted in that during the years of 2005-2008 the level of use of CNG in Yerevan transport sector (public and private) started to increase more rapidly annually by around 16-17% (see Figure 3.8).

*Table 3.16 Description of the Activity for conversion of Yerevan public and private vehicles to CNG*

| Source of financing, cooperating structures | Value, thousand Euros | Energy saved, MWh/year | Reduction of $CO_2$ emissions, in tonnes, 2020 | Investment years |
|---|---|---|---|---|
| **YM, private companies, other government structures** | N/A | Not applicable | 79,690 | 2013-2020 |

### 3.3.5 Activity T.5. Improvement of road infrastructure

The program focusing on enlargement of the road and street network, construction of road junctions on various levels, construction of new bypass and through traffic roads is one of the consistent programs implemented with the aim of unloading the road and street network of the capital. The annual programs provide for construction of overhead pedestrian crossings and implementation of operation and maintenance activities for the purposes of ensuring pedestrian traffic safety and preventing interruptions of transportation flows.

Three key directions are highlighted by the municipality in terms of improvement of the road and street network of Yerevan:

- 
- 
- unloading the city centre;
  improvement of the road and street network of the city centre;
  arrangement of primary roads bypassing the City of Yerevan.

Currently activities are carried out jointly with the Asian Bank of Development to divert traffic from the centre of Yerevan by way of design, construction and re-construction of a number of primary roads and their junctions bypassing the centre of Yerevan.

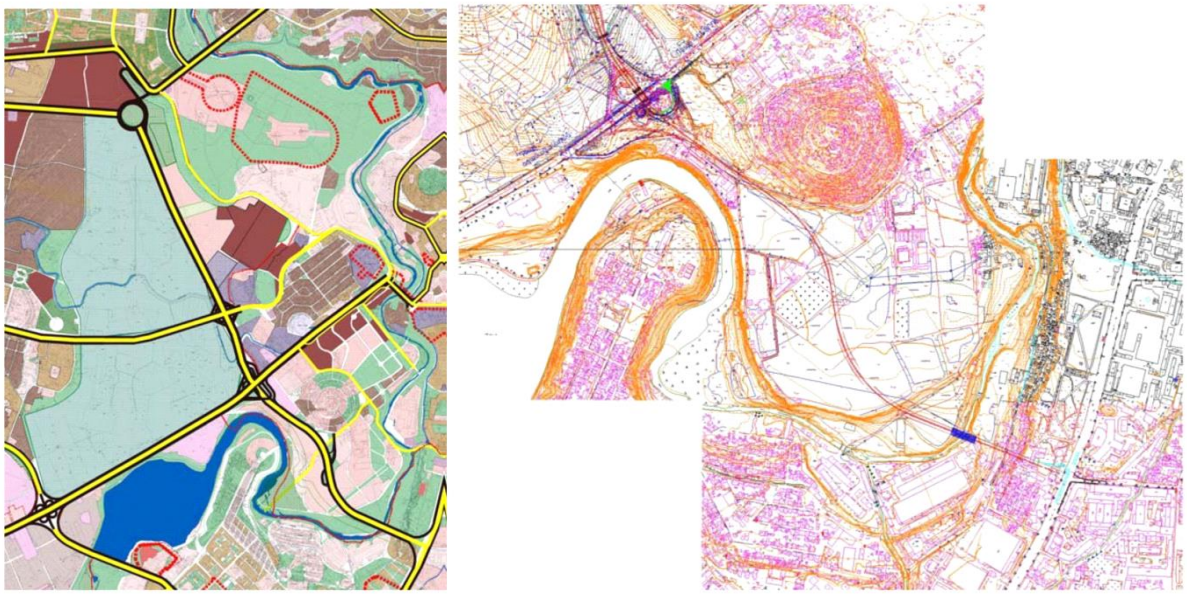


*Figure 3.12 Leningradyan Street – Isakov Avenue – Arshakunyats Avenue city primary road (on the left). The layout of city primary road extending from Isakov Avenue to Arshakunyats Avenue (on the right).*

The main impact of this complex program, as well as all other similar infrastructure projects on cities will be the improved urban road network, reduction of the duration of individual routes, as well as reduction of fixed and variable amortization, operation and maintenance costs of vehicle in the amount of u to 40%. For private passenger vehicles and load-carrying trucks the fuel costs comprise 30-50% of the operation and maintenance costs, moreover, these costs are even higher for load-carrying trucks since they mostly use diesel fuel. It should be noted that the measures aimed at bypassing the city centre will be beneficial both for private vehicle owners that will be able to drive from one suburb of the city to another without entering the city centre and for load-carrying trucks that are engaged in cargo transportation activities using Yerevan for transit purposes.

The Government of the RA received a loan from the Asian Development Bank (ADB) — Sustainable Urban Development Investment Program, Tranche 1 and Tranche 1 for financing this Activity and a number of other measures. Taking into account that the ADB has not yet assessed the quantitative indicators of the above-mentioned urban development projects, in particular, reduction of the time spent on traffic, the impact of these new solutions and roads on Yerevan private and commercial transport is estimated within the scope of SEAP based on the international experience in impact assessment of similar programs.

*Table 3.17. Expected reduction in fuel consumption and $CO_2$ emissions as a result of improvement of Yerevan road and street network (Activity T5)*

| Implementing entity | Value, thousand Euros | Energy saved, MWh/year | | | Reduction of $CO_2$ emissions, in tonnes, 2020 | Investment years |
|---|---|---|---|---|---|---|
| | | Petroleum | Diesel fuel | Natural gas | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| **YM, private, ADB, SUDIP** | 82,800 | 129,217 | 70,943.4 | 10,974 | 53,334 | 2015-2020 |
| | | 211,136 | | | | |

### 3.3.6 Activity T.6. Optimization of municipal transport and improvement of management efficiency (including in terms of garbage-removal and sanitary cleaning vehicles and machinery)

The Municipality of Yerevan adopted a policy of improving the management efficiency within the scope of which the garbage collection and sanitary cleaning services in Yerevan Municipality (11 administrative districts, except for Avan AD) are provided by SANITEK Company which was awarded the contract as a result of the competition held for this purpose.[20]

For efficiency purposes the vehicle pool of the Municipality was also reduced by a certain number of vehicles.

*3.3.6.1 Activity 6.1. Optimization of sanitary cleaning vehicle and machinery pool*

Improvement of management efficiency of garbage collection services will address not only sanitary issues but will also have an immediate impact on fuel costs of garbage-removal trucks.

Since 2013 as a result of investments made by “SANITEK” Company a sufficient quantity of completely new European vehicles and machinery were imported. Cost efficiency is achieved by consolidation of previously operating organizations and improvement of operational efficiency. The Company was required also to provide its services by introducing and applying new standards and new control mechanisms (equipment of garbage-removal trucks with the GPS system, organization of works by using specific maps, etc.) which enabled making the whole process of garbage collection even more effective.

The above-mentioned measures are expected to cover all the administrative districts and ensure transition to more efficient management and provision of garbage collection services by modernized vehicles and machinery. Reduction in fuel costs already recorded before 2015 and expected further up to 2020 is presented below in Figure 3.13.

[20] See Agreement No EQ-BYTsDzB-13/71 [ԵՔ-ԲԸԾՁԲ-13/71] on “Procurement of services for garbage collection and sanitary cleaning in the City of Yerevan, including in winter months” signed between Yerevan Municipality and “SANITEK” Company on 17 September 2013

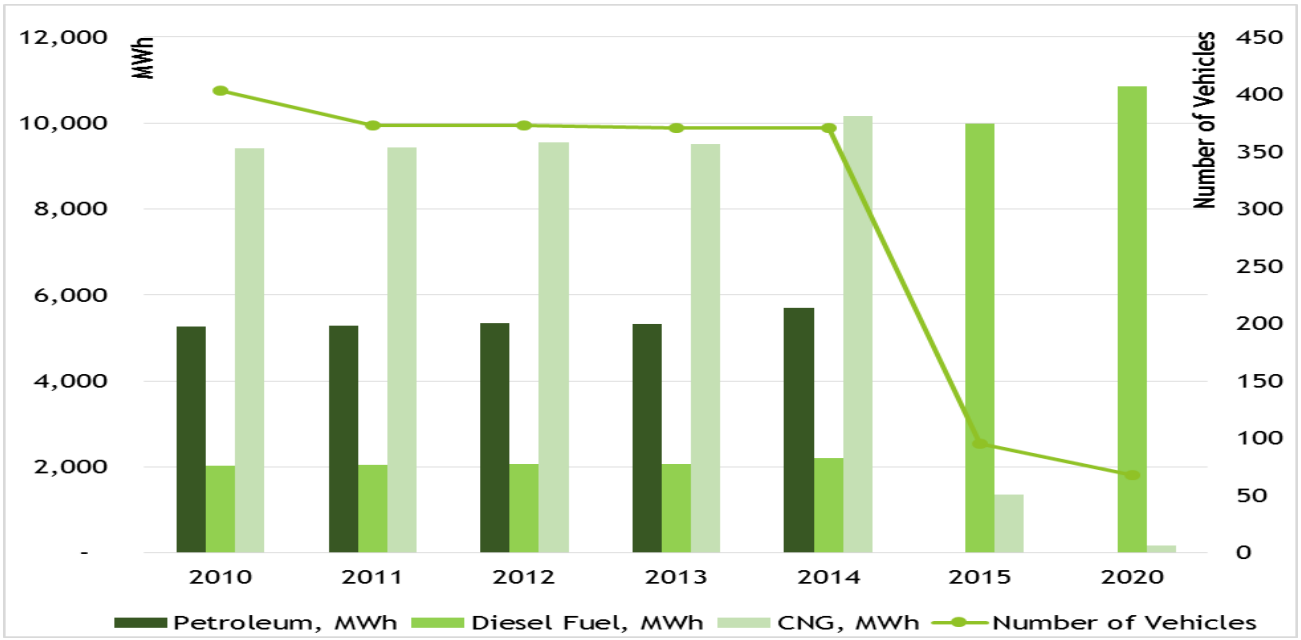



**Figure 3.13. Quantitative indicators of vehicles and machinery used in sanitary cleaning services and fuel consumption rates, 2010-2020**

Greenhouse gas emissions have also reduced alongside with the reduction of fuel consumption rates.


**Figure 3.14. Reducing energy consumption and GHG emissions resulting from increasing the efficiency of sanitary cleaning services, 2010-2020**

*Table 3.18. Expected reduction of fuel consumption and $CO_2$ emissions rates as a result of reducing the number of sanitary cleaning vehicles and machinery, Activity T .7.1.*

| Implementing entity | Value, thousand Euros | Energy saved, MWh/year | | | Reduction of $CO_2$ emissions, in tonnes, 2020 | Investment years |
|---|---|---|---|---|---|---|
| | | Petroleum | Diesel | CNG | | |
| **YM,** | 10,000 | 5,345 | (8,785) | 9,365 | 877 | 2014-2020 |

| | | | | |
|---|---|---|---|---|
| **«SANITEK» Company** | | 5,925 | | |

*3.3.6.2 Activity T.6.2. Reduction of municipal transport*

In May 2016 the number of Yerevan municipal vehicles was reduced by 26 within the scope of measures aimed at increasing the management efficiency.[9] The average annual fuel consumption rate for a municipal passenger vehicle is estimated as equivalent to about 152 MWh. Accordingly, the reduction of 26 vehicles will entail reduction of energy consumption in 1,950 MWh annually which, in case of petroleum, will be equivalent to reduction of 983 tonnes of $CO_2$ emissions.

*Table 3.19 Expected reduction of fuel consumption and $CO_2$ emissions rates as a result of reducing the number of Yerevan municipal vehicles, Activity T 7.1.*

| Implementing entity | Value, thousand Euros | Energy saved, MWh/year (Petroleum) | Reduction of $CO_2$ emissions, in tonnes, | Investment years |
|---|---|---|---|---|
| **YM** | -//- | 1,950 | 983 | 2016-2020 |

The outcomes of mitigation measures T. 7 are summarized below.

*Table 3.20. Expected reduction of fuel consumption and $CO_2$ emissions rates as a result of optimization of Yerevan municipal transport and improvement of management efficiency (Activity T.7.)*

| Implementing entity | Value, thousand Euros | Energy saved, MWh/year | | | Reduction of $CO_2$ emissions, in tonnes, 2020 | Investment years |
|---|---|---|---|---|---|---|
| | | Petroleum | Diesel | CNG | | |
| **YM** | **10,000** | 7,295 | (8,785) | 9,365 | **1,363** | **2014-2020** |
| | | **7,875** | | | | |

## 3.3.7 Activity T.7. Modernization of the transport pool of Yerevan Municipality; Yerevan Municipality Strategy Program for promotion of electric vehicles (EV)

Currently the use level of electric-powered vehicles is growing rapidly in all developed and almost all developing countries. In technological terms the most popular vehicles are purely electric cars, i.e., battery electric vehicles (BEV) and plug-in hybrid electric vehicles (PHEV). It is noteworthy, that electric-powered vehicles are widely used especially in countries where there are nuclear power plants and where the nuclear power generation has an essential (France, Japan, USA) or a significant (the Netherlands) proportion in the total power generation balance. The fact is that both the use of electric-powered vehicles and the operation of electric transport, in general, extensively enhance the efficiency of all energy systems in which the proportion of power generated by nuclear power plants comprises more than 10%. Accordingly, in the Republic of Armenia, where the share of nuclear power generation reaches 25-30% in the total balance, this process will have a more pronounced impact.

- The key purposes of promoting electric cars in Armenia are the following:
- Reducing dependency on imports of fossil fuel in the transport sector;
  Reducing GHG and hazardous emission in the administrative district of the City of Yerevan;

- Direct energy saving owing to more efficient fuel energy conversion typical to electric cars energy conversion;
  Indirect energy saving owing to: (a) daily load levelling of the overall energy system in the RA (night charging); (b) seasonal load levelling of the energy system and increasing the efficiency of base load power stations (seasonal levelling effect):

Presumably, for the purposes of implementation of this Activity, individual transport sector development programs will be harmonized under a common approach aimed at considerable development of public electric transport and promotion of electric cars, mainly BEVs and PHEVs under the present Activity T6 in line with the priorities in the public transport sector. In particular, the given Activity will most probably launch within the scope of the comprehensive national strategy for promotion of electric cars proposed in Armenia NEEAP. As the first step of the national strategy, it is proposed to develop a plan for the promotion of electric cars in the City of Yerevan which will be implemented in two phases. The pilot phase will extend from 2017 to 2020. Under proper control and monitoring the first 72 EVs will be put into experimental operation. Provisions will be made for outlining the national strategy for the promotion of electric cars and drafting the strategy for the development of infrastructure for charging and maintenance of the EV pool. Armenia will join the Electric Vehicles Initiative of the International Energy Agency (IEA EVI) and will become a member of IEA Hybrid and Electric Vehicle Implementing Agreement (IEA-IA).

In the long-term perspective the plan will advance in 2021-2030, and the EV pool will grow reaching 446 units.[21]

**EV promotion incentives:** There are numerous strategies and measures stimulating the EV promotion policy. The major part of promotion mechanisms falls within the authority of the state, such as the tax and customs incentives, differentiated tariff policy, environmental tax exemptions and so on.

Within the scope of municipal authority the following incentives may be applied:

- Preferential or zero parking fees for EVs in the centre of Yerevan;
- Prioritised and user-friendly parking lots;
  Allocation of accessible areas for charging stations;
- Introduction of a mandatory requirement in new construction authorizations requiring to provide for charging facilities for EVs;
  Engagement of EVs in municipal transport and so on.

The calculations made within the scope of this Activity to estimate the direct energy saving are based on the comparative analysis of European modern electric and hybrid vehicles, typically BEVs and PHEVs. The outcomes of Mitigation measure T.7 are summarized below.

[21] During a time period extending beyond the time limits of the SEAP, *i.e.*, in 2021-2030, the EV fleet will reach 446 units which will ensure approximately 1000 MWh direct energy saving. A number of steps will be undertaken to promote the Measure ensuring up to 20% annual growth in promotion of BEVs and PHEVs. It should be noted that despite the optimistic forecast in the T6, such pace is internationally accepted as market penetration velocity for a successful technology which is possible in case of availability of a favorable environment for business and services and various stimulating mechanisms. Beyond the SEAP domain, as well as beyond the competence of the Yerevan municipality, this measure could result in indirect energy saving and $CO_2$emissions avoidance, if an optimal energy tariffs system is developed (basic / semi-peak / peak electricity) to encourage night charging of EVs. The time period of implementation of this phase of the Strategy will include the commissioning of the new unit of the Armenian Nuclear Power Plant which is planned for 2026-2027. The mentioned circumstances will facilitate the promotion of private and public EVs and will lead to 15-20% annual growth of their promotion. This indirect effect is not estimated within the SEAP but falls within the scope of NEEAP of the Republic of Armenia.

*Table 3.21. Activity 7.1. Description of the Yerevan Municipality Strategy Program for promotion of electric vehicles (EV)*

| Source of financing, cooperating structures | Value, thousand Euros | Energy saved, MWh/year | | | Reduction of $CO_2$ emissions, in tonnes, 2020 | Investment years |
|---|---|---|---|---|---|---|
| | | Petroleum | Diesel fuel | Natural gas | | |
| **YM, other government structures, IFIs** | 1,700 | 47.5 | 39.2 | 84.4 | 79.2 | 2017-2030 |
| | | 171.1 | | | | |

## 3.4 Consolidated Data of Activities in the Transport Sector

Investment indicators of the transport sector, the overall energy and environmental results are summarized in Table 3.21.

*Table 3.22. Key indicators of transport sector activities*

| Activity index | Sector/ Activity | Source of financing, cooperating structures | Implementation timeframe (start - end) | Estimated value (thousand Euros) | Expected energy saving [MWh/year] | | | | | Reduction of $CO_2$ emissions, in tonnes, 2020 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Electrical energy | Natural gas | Petroleum | Diesel fuel | Total | |
| **Activity T.1** | Public transport (PT) optimization program: Modernization of Yerevan PT pool, optimization of the staff, optimization of routes, common ticket system | YM, other government structures, ADB / SUDIP | 2013-2020 | 17,200 | - | 87,174 | - | 58,166 | 145,340 | 33,139 |
| **Activity T.2** | Re-equipment of public electric transport (trolleybuses) pool and infrastructures | YM, other government structures, EBRD | 2018-2019 | 28,000 | 2,492 | 67 | - | - | 2,558 | 567 |
| **Activity T.3** | Re-equipment of public electric transport (Yerevan Metro) | Yerevan Metro CJSC, EBRD, EIB, YM | 2017-2018 | 21,000 | 3,726 | - | - | - | 3,726 | 827 |
| **Activity T.4** | Promoting the conversion of public and private vehicles to CNG by allocation of sites for gas refuelling stations in Yerevan administrative districts, definition of safety requirements | YM, Ministry of Territorial Administration of the RA, Private business, Green/Energy efficiency loan facilities | 2013-2020 | - | - | - | - | - | - | 79,690 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Activity T.5** | Road infrastructure development (new roads, including bypass roads, new road junctions) | YM, ADB, SUDIP | 2015-2020 | 82,800 | - | 10,974 | 129,218 | 70,943 | 211,136 | 53,334 |
| **Activity T.6** | Optimization of municipal transport and improvement of management efficiency (including in terms of garbage-removal and sanitary cleaning vehicles and machinery) | YM | 2014-2020 | 10,000 | - | 9,365 | 7,295 | (8,785) | 7,875 | 1,363 |
| **Activity T.7** | Modernization of urban transport pool; Yerevan Municipality Strategy Program for promotion of electric vehicles | YM, other government structures , RA Ministry of Energy and Natural Resources, donors | 2017-2020 pilot phase | 1,700 | - | 84 | 48 | 39 | 171 | 79 |
| **Total in the transport sector** | | | | 160,700 | 6,218 | 124,126 | 1,184 | 6,218 | 107,665 | 136,560 |

# 4 Public buildings

More than 40% of public buildings (1,190 buildings, of which 501 are under municipal control or administration) are located in Yerevan and occupy a total area of approximately 5.7 million $m^2$. Schools, universities, colleges, preschools, medical institutions and sports establishments make up 92% of all public institutions in the capital.

A considerable part of public buildings in the City of Yerevan is under the state patronage, control and direct financing. The respective sectoral ministries exercise management of and control over the respective institutions assigned to them and are responsible for their maintenance and renovation in accordance with the defined procedure (for example, the RA Ministry of Healthcare is responsible for medical institutions, the RA Ministry of Education and Science is responsible for schools, etc.). Along with state and municipal institutions there are already a considerable number of private institutions functioning in the educational sector.

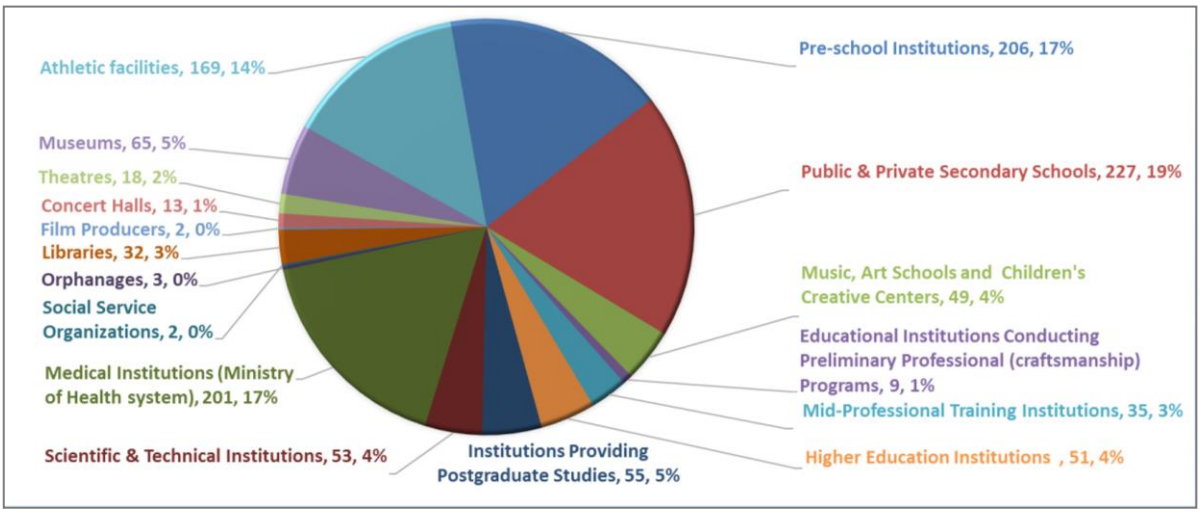



Figure 4.1. Quantitative and percentage proportion of public buildings in Yerevan, 2012

The SEAP domain covers public buildings falling under control or management of the Municipality of Yerevan, including management of part of the above-mentioned medical institutions, educational institutions and other public buildings the administration of which has been delegated to the Municipality of Yerevan.

The two buildings of the Municipality of Yerevan, the administrative buildings of all the 12 administrative districts, 8 CJSCs engaged in transportation, design, culture activities, 13 CJSCs engaged in urban landscaping and maintenance services, 2 municipal non-commercial organizations (MNCO) dealing with construction and providing special services to the population are under municipal ownership. The Municipality and administrative districts carry out also the management of 160 preschool educational institutions having the status of MNCOs, 31 healthcare institutions having the status of CJSCs (2 of 33 institutions are transferred to trust management), as well as of a vast number of music and art schools, libraries, museums, theatres, children and youth creative centres, cultural centres, sports schools.

The funding of all the preschool education institutions (preschools), art, music and fine-art schools, children and youth sports schools is provided from the municipal budget of the city. The funding of senior, secondary and basic schools is provided from the State Budget.

The distribution of 160 preschools, by administrative districts, that fall under control of the Municipality is presented below.

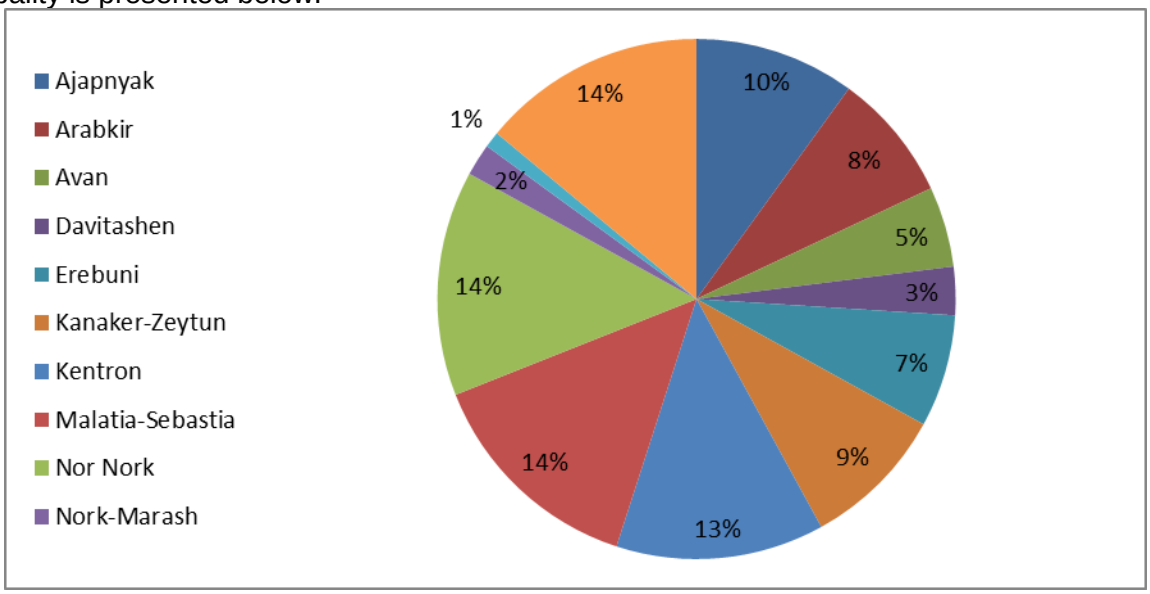



*Figure 4.2. Proportional distribution of preschools by administrative districts*

Funds are allocated regularly from the budget of the City of Yerevan for renovations of preschool institutions and schools, acquisition of property for these institutions including energy-consuming equipment, such as computers, household appliances, etc.

The Municipality of Yerevan has 159 general education schools falling within the scope of its competence: 145 basic schools, 2 special schools and 14 secondary schools. The mentioned 14 secondary schools include one evening school for blind people and two educational complexes.

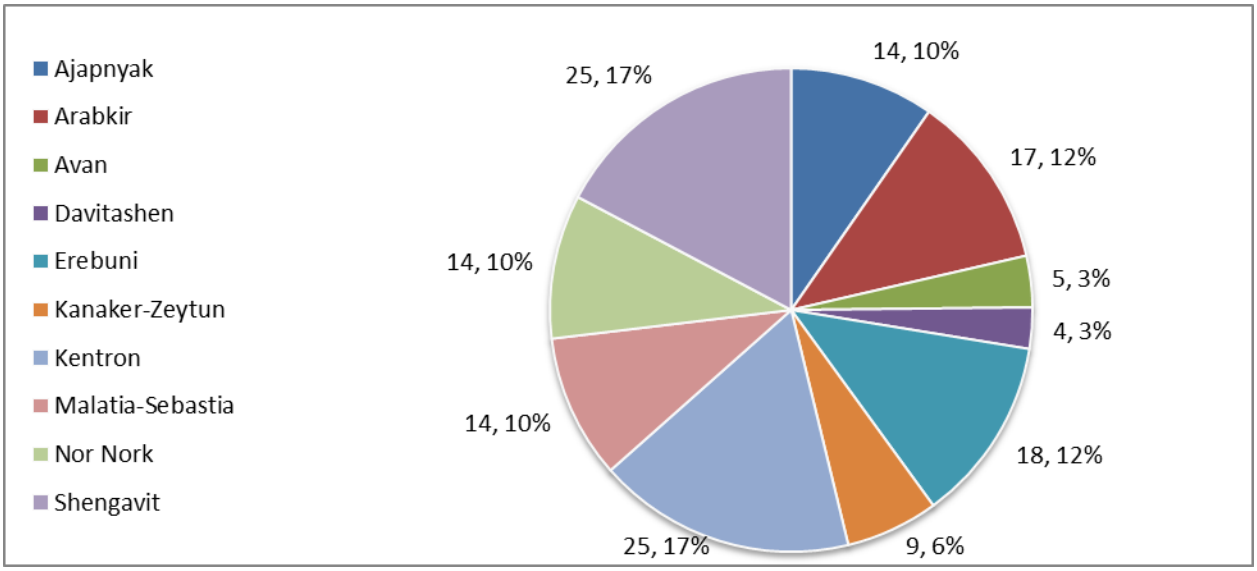



*Figure 4.3 Distribution of Yerevan schools by administrative districts*

It should be noted that according to the findings of a research carried out in 12 typical schools in 2014, out of 12 schools 7 were estimated as needing major capital repairs, and the remaining 5 were in good or satisfactory condition.[22]

[22] See Open Society Foundations – Armenia, the report is available at: http://www.osf.am/wp-content/uploads/2013/11/Analysis-of-Financial-Management-of-12-Yerevans-Mainstream-Schools.pdf

## 4.1 Energy Consumption of Public Buildings

### 4.1.1 Energy Consumption of Administrative Buildings

Electrical energy and natural gas comprise the main energy sources used in 2 administrative buildings of the Municipality of Yerevan and in total 14 administrative buildings of 12 administrative districts. The funding of all the mentioned buildings is provided from the municipal budget. The volumes of electrical energy and natural gas consumed in those buildings during 2010-2012 are summarized in Table 4.1.

*Table 4.1. Energy consumption of administrative buildings in 2010-2012*

| Name of the administrative unit | Electrical energy, MWh | | | Natural gas, thousand $nm^3$ | | |
|---|---|---|---|---|---|---|
| | 2010 | 2011 | 2012 | 2010 | 2011 | 2012 |
| 1. Municipality, 1st building | 880.4 | 941.3 | 960.2 | 61.5 | 128.0 | 139.8 |
| 2. Municipality, 2nd building | | | 585.6 | | | 54.6 |
| 3. Ajapnyak | 108.6 | 111.9 | 138.8 | 14.1 | 17.2 | 15.3 |
| 4. Avan | 145.3 | 190.0 | 214.4 | 27.5 | 46.8 | 24.9 |
| 5. Arabkir | 347.8 | 434.6 | 417.8 | 32.6 | 44.3 | 39.0 |
| 6. Davitashen | 99.6 | 76.9 | 81.5 | 14.7 | 21.1 | 24.6 |
| 7. Erebuni | 169.6 | 191.5 | 191.2 | 44.9 | 70.8 | 50.9 |
| 8. Kentron | 562.8 | 601.4 | 439.0 | | | 22.5 |
| 9. Malatia-Sebastia | 142.3 | 163.7 | 170.6 | 16.8 | 19.5 | 20.8 |
| 10. Nor Nork | 362.8 | 391.4 | 423.2 | 44.4 | 60.7 | 52.4 |
| 11. Nork-Marash | 37.1 | 25.8 | 22.1 | 8.1 | 16.0 | 13.3 |
| 12. Nubarashen | 19.6 | 29.5 | 29.2 | | | |
| 13. Shengavit | 249.2 | 268.6 | 225.5 | | | |
| 14. Kanaker-Zeytun | 188.4 | 173.4 | 212.5 | 26.4 | 29.7 | 31.5 |
| **Total** | **3313.5** | **3600.1** | **4111.7** | **291.0** | **454.2** | **489.6** |
| **Total, without the new 2nd building of the Municipality** | **3313.5** | **3600.1** | **3526.1** | **291.0** | **454.2** | **434.9** |

During the three-year period, as described in the table, the total energy consumption of administrative buildings was constantly growing. Moreover, the average annual growth in electricity consumption amounted to about 7%, whereas the annual natural gas consumption rates grew by more than 21%. This increase is explained by enlargement of municipal buildings. In particular, the reason for the increase in energy consumption is the new building of the Municipality of Yerevan which was commissioned in 2012. Apart from the energy consumption rates of the new building (as described in the last line of Table 4.1) the basic energy consumption rates did not grow after 2012 but slightly decreased instead (as compared to the data recorded in 2011 the consumption of electrical energy and natural gas decreased relatively by 2% and 4% respectively in 2012 and 2013).

More explicitly, it is shown in Figure 4.4. Within the three-year period consumption rates of natural gas exceeded the electrical energy consumption.

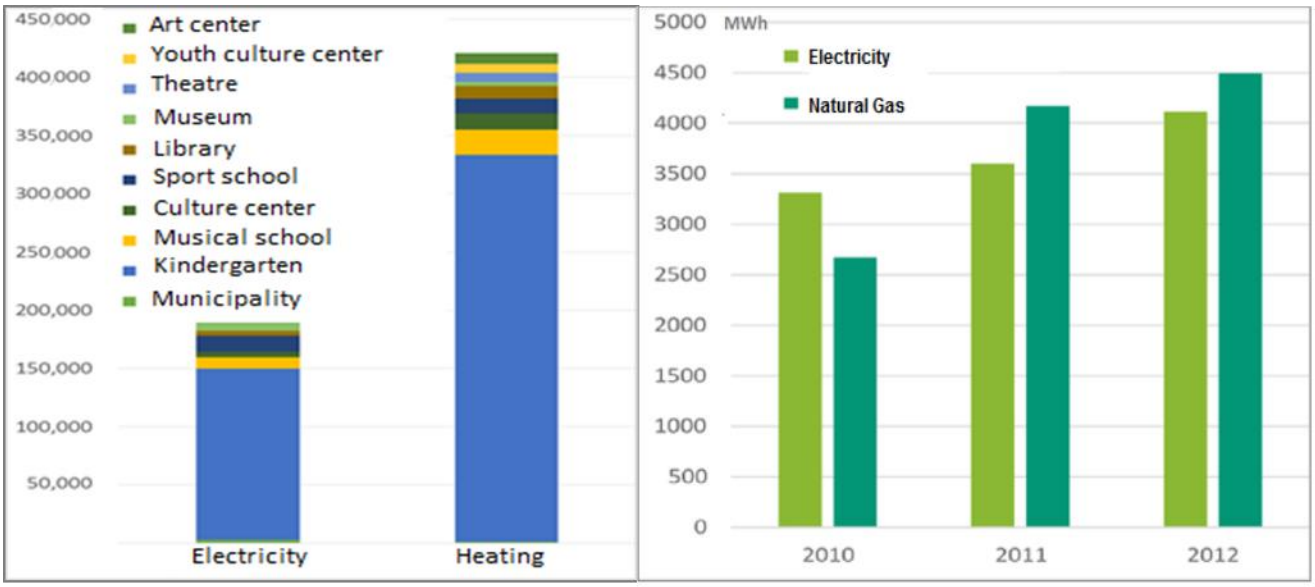



*Figure 4.4 Yearly energy consumption of administrative buildings*

The internal lighting systems in the administrative buildings normally consume 27-30% of the total electricity. The study of the lighting systems enabled to identify the types of luminaires used, their energy efficiency and the illumination level of the structure surfaces used. In general, the electric power consumption of lamps per each 1m2 of those surfaces is 8 W/m2 which is quite high. For the administrative building of Kanaker-Zeytun administrative district this indicator equals to 19.2 W/m2 since incandescent light bulbs are used there. 94% of electric power consumption of the internal lighting system falls on such lumps in case when the indicator of the total number of incandescent light bulbs in all administrative buildings makes up 40%, the remaining 54% is accounted for luminescent lamps, and 3% for LED lamps. See Figure 4.5.

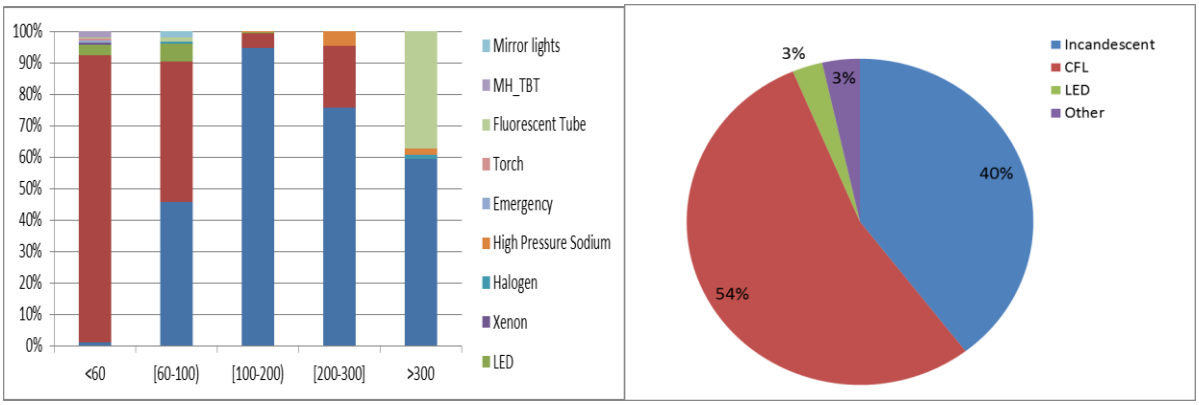



*Figure 4.5. The quantitative structure of illuminating lamps*

### 4.1.2 Energy consumption by support service providers under municipal control

The energy consumption of administrative buildings of the closed joint stock companies under municipal control, *i.e.*, Karen Demirchyan Yerevan Metro and "Yerevan electric transport", are estimated in the "Energy consumption of public transport" subsection. These companies are funded from the State Budget by 45% and 58% respectively. "Yerevantrans" and "Yerevan Bus" CJSCs operate on their own funds and recommendations for the improvement of their energy consumption are of rather a consultative character. "Yerqaxluys" [Yerevan City Light] CJSC is an entity funded from the municipal budget. Thirteen urban landscaping and maintenance services CJSCs fully and two construction and special services MNCOs partially are funded from the

municipal budget. Except for CJSCs dealing with electrified transport, the volumes of consumption of electrical energy and natural gas by the rest of the CJSCs and two MNCOs are summarized in Table 4.2.

*Table 4.2. Electricity consumption by support service providers under municipal control (except for electrical transport)*

| Electrical energy, MWh | | Natural gas, thousand $nm^3$ | | Total energy consumption, MWh | |
|---|---|---|---|---|---|
| 2011 | 2012 | 2011 | 2012 | 2011 | 2012 |
| 1,014.81 | 897.37 | 44.02 | 41.52 | 1,419.18 | 1,278.77 |

The major consumers of electrical energy are the "YerevanProject" and "Yerevantrans" companies which in 2012 consumed about 350 MWh electrical energy or 39% of the overall energy consumed by all the companies considered in the section. Only five companies used natural gas. The double dominance of consumption rates of natural gas as compared to electricity consumption (expressed in MWh) is quite characteristic to the consumers in this group.

### 4.1.3 Energy consumption of preschool education institutions

The two preschool education institutions under direct control of the Municipality and 158 preschool education institutions (preschools) under control of administrative districts are the major consumers of electrical energy and natural gas. The funding of these institutions is provided from the municipal budget; their energy consumption volumes for 2010-2012 are presented in Table 4.3 and Figure 4.7. The share of preschools is 65% in the overall energy consumption and 79% in natural gas consumption of administrative buildings.

As the data in Table 4.3 show, at the end of the period concerned the natural gas consumption in these institutions has stabilized at the level of about 2.5 million $nm^3$/year, while electricity consumption decreased by around 2.3% annually over the past three years.

*Table 4.3. Electrical energy and natural gas consumption of preschool education institutions in 2010-2012*

| № | Administrative district | Quantity | Numbers | Natural gas, thousand $nm^3$/year | | | Electrical energy, MWh/year | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | 2010 | 2011 | 2012 | 2010 | 2011 | 2012 |
| 1 | Ajapnyak | 16 | 35-50 | 105.5 | 302.6 | 333.4 | 462.4 | 545.1 | 584 |
| 2 | Avan | 7 | 51-57 | 51.3 | 96.9 | 98.2 | 200.7 | 238.2 | 282.2 |
| 3 | Arabkir | 13 | 22-34 | 70.3 | 168.1 | 160.7 | 404.8 | 474 | 392.8 |
| 4 | Davitashen | 5 | 58-62 | 16.1 | 118.5 | 175.3 | 185.3 | 141.7 | 254.4 |
| 5 | Erebuni | 13 | 63-75 | 53.5 | 164.3 | 262.1 | 228.5 | 250.6 | 264.7 |
| 6 | Kentron | 21 | 1-21 | 37.1 | 133.2 | 175.7 | 622.1 | 574.9 | 554.3 |
| 7 | Malatia-Sebastia | 22 | 76-97 | 172.1 | 624.1 | 417 | 369.6 | 474.3 | 798.4 |
| 8 | Nor Nork | 23 | 98-120 | 118.4 | 373.2 | 373.8 | 694.3 | 818.4 | 643.6 |
| 9 | Nork-Marash | 4 | 121-124 | 34.1 | 30.7 | 27.9 | 31.8 | 55.5 | 46.1 |
| 10 | Nubarashen | 1 | 125 | 6.7 | 6.6 | 5 | 16.7 | 17.8 | 7.2 |
| 11 | Shengavit | 21 | 127-147 | 56.8 | 279.3 | 272.1 | 601.8 | 896.6 | 566.3 |
| 12 | Kanaker-Zeytun | 14 | 148-162 | 90.4 | 181.3 | 171.4 | 199.7 | 229.6 | 259.3 |
| | **Total** | **160** | | **812.2** | **2,479.0** | **2,472.6** | **4,017.8** | **4,716.6** | **4,653.1** |

At the beginning of the period presented in the table the natural gas consumption is marked by extremely low rates. During the transition period in 2010-2011 owing to replacement of heating systems in the municipal buildings many institutions shifted to the use of natural gas in

larger volumes for heating and hot water generation purposes which resulted in that the consumption rate of that energy carrier increased drastically in almost three times (Figure 4.7).

In general, the annual energy consumption by preschools of the two main energy carriers in the future, in 2011-2012, was stabilized reaching approximately 27.5 thousand MWh /year.

Incandescent light bulbs dominate in the interior lighting systems of preschool institutions; their share in the preschools of 10 administrative districts (minus Avan and Arabkir districts) is about 70%. This indicator is higher in preschools of Kanaker-Zeytun municipality reaching 89.4%. The institutions of Nubarashen and Nork-Marash administrative districts use exclusively luminescent lamps, and the average lighting level of the used (heated) areas as per the electric power of luminaries is only 1 W/m$^2$.

The average level of lighting as per electric power of luminaires in the total premises of institutions reaches an average of 7.43 W/m$^2$ which is a rather high indicator. The most "extravagant" illumination in terms of energy consumption is used in preschools of Kentron and Shengavit administrative districts, 14.25 W/m$^2$ and 11.27 W/m$^2$, respectively. In some cases, the lighting level was 1 W/m$^2$, and in the other cases it reached 43.4 W/m$^2$ (see Figure 4.6).

Such radical difference in indicators is an evidence of a number of existing problems, such as the insufficient lighting level or the extremely high energy consumption rates when trying to provide comfortable lighting level due to inefficient luminaires (there are still a large number of incandescent light bulbs in a considerable number of preschools), lack of standard norms for lighting quality and control over the compliance with these norms, as well as the possible deficiencies of statistical data which is unacceptable for efficient energy management.

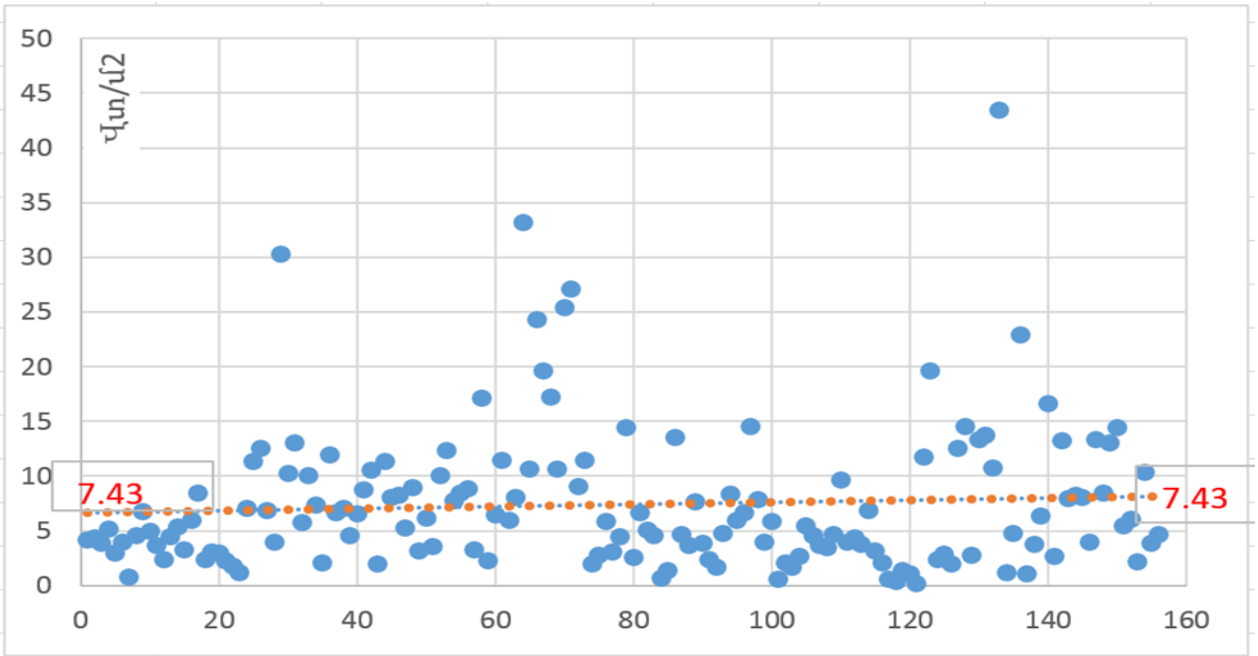



*Figure 4.6. The specific illumination level of premises in 160 preschools of Yerevan (W/m$^2$)( above); normalized illumination energy intensity based on benchmarking (below) .*

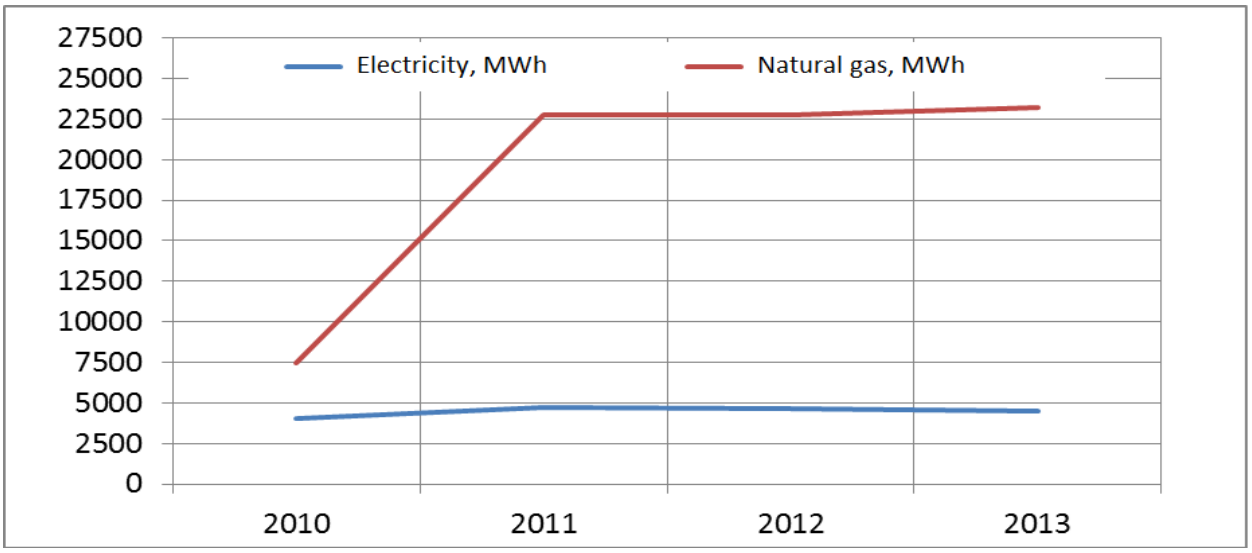



*Figure 4.7.Overall dynamics of main energy consumption in preschools*

The stabilization of consumption volumes of the basic energy carriers, natural gas and electrical energy, in preschool education institutions of the Coty of Yerevan during the period from 2011 to 2013 is explicitly shown in Figure 4.7.

During the drafting process of the SEAP an attempt was made to carry out energy benchmarking for preschool institutions aimed at comparing the energy consumption of all the preschools normalized to a standard unit, and in the given case in terms of annual energy consumption in kWh normalized to $1m^2$.

As shown in Figure 4.8 the energy consumption indicators of 160 municipal preschools normalized to $1m^2$ are largely dispersed. The average energy consumption amounts to 142 kWh/$1m^2$/year (standard deviation=144). Moreover, consumption of 50% of preschools falls below the benchmark level of 115 kWh/$1m^2$/year, whereas the consumption rates of others exceed this indicator and in some cases even multiple times. The 115 kWh/$1m^2$/year benchmark level marks out those preschools which are the most energy-consuming and require immediate intervention. It should be noted that these data will be more complete and reliable where an energy management system is established by the municipality.

The analysis in Figure 4.8. is indicative and aims at showing the energy management and benchmarking options

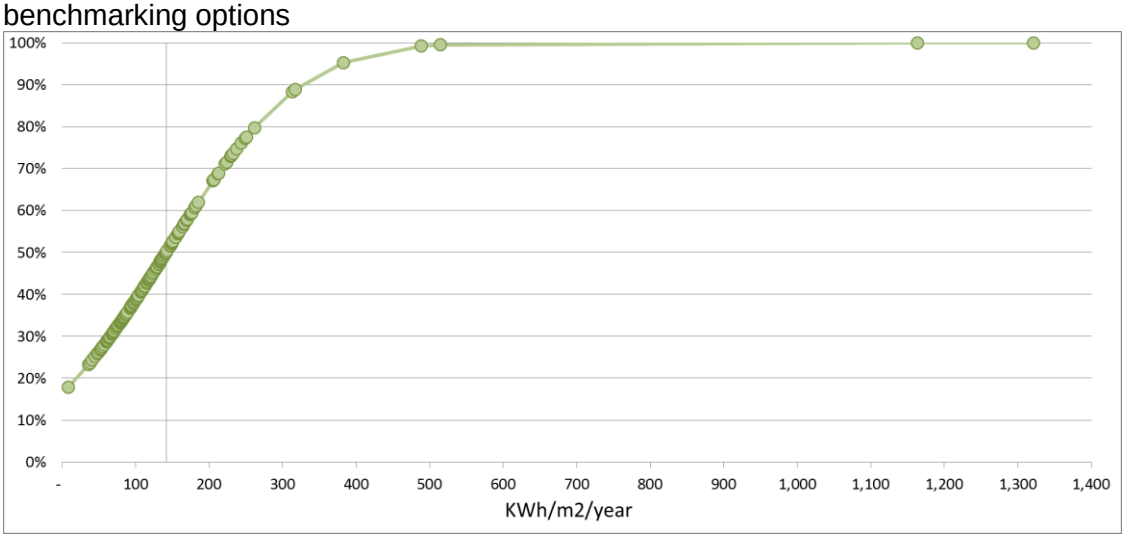



**Figure 4.8. Normalized energy consumption of preschool institutions**

Figure 4.9. indicates that the data regarding preschools in the upper part need to be verified as a matter of priority, and, if confirmed, immediate energy efficiency measures should be undertaken for saving

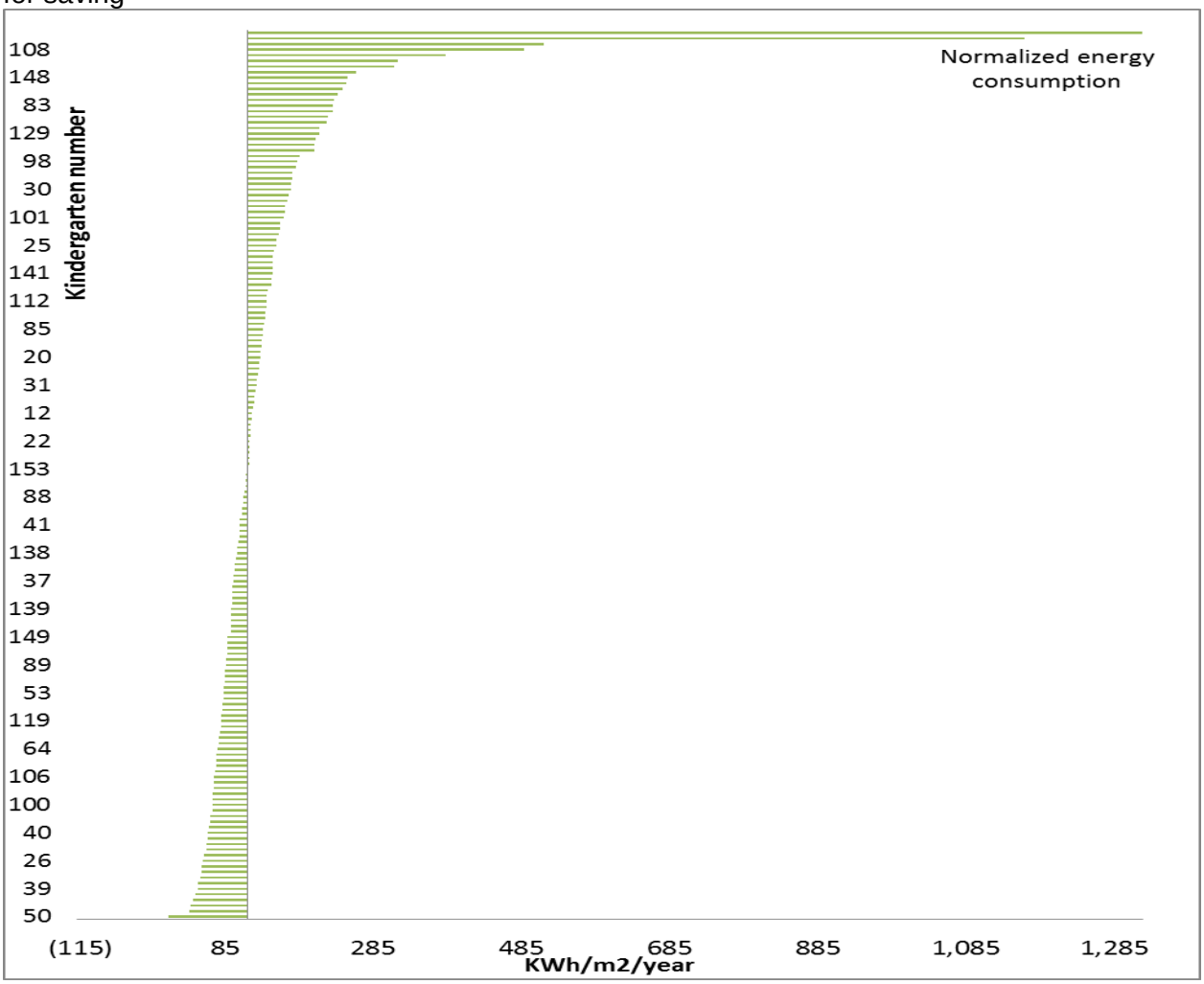



Figure 4.9. Normalized energy consumption of preschool by individual preschools

### 4.1.4 Energy consumption of cultural, art, sports centres, sports and cultural, children and youth creative centres

Music and art schools, cultural centres, children and youth creative centres and libraries in the administrative districts are funded from the municipal budget. Museums and theatres, the energy consumption of which is also covered in this subsection, are funded from the means of the State Budget. These institutions also use mainly electrical energy and natural gas. In this group of consumers the electrical energy consumption volumes constitute almost 1/3 of the volume consumed by all other institutions in the cultural and creative field. In general, museums and theatres have a share of about 25-30% in the total consumption volume in the given sector.

The data on the consumption of electrical energy and natural gas for the years of 2011 and 2012 are summarized in Table 4.4.

Music and art schools, as well as cultural centres recorded a substantial reduction in energy consumption in 2012 as compared to the previous year. As a result, the total energy consumption by these institutions comprised only 90.8% of the previous year consumption.

The situation is quite the opposite in the case of natural gas since the consumption rates in 2012 exceeded the consumption of the previous year by almost 25% which is due to the transition from electricity to natural gas for heating purposes.

*Table 4.4. Consumption of electrical energy and natural gas by cultural, creative institutions and sports schools in 2011 and 2012, MWh/year*

| Type of the building | Electrical energy | | Natural gas | | Total energy consumption | |
|---|---|---|---|---|---|---|
| | 2011 | 2012 | 2011 | 2012 | 2011 | 2012 |
| Music schools | 443.5 | 339.7 | 882.8 | 1,328.3 | 1,326.3 | 1,668.0 |
| Art schools | 206.3 | 148.8 | 434.5 | 677.9 | 640.8 | 826.7 |
| Libraries | 128.4 | 128.6 | 336.2 | 493.3 | 464.6 | 621.9 |
| Children and youth creative centres | 170.4 | 204.2 | 392.2 | 507.1 | 562.6 | 711.3 |
| Cultural centres | 781.8 | 711.7 | 432.7 | 497.9 | 1,214.5 | 1,209.6 |
| Museums and theatres | 561.7 | 550.4 | 1,146.40 | 1,006.20 | 1,708.10 | 1,556.60 |
| Sports schools և sports and cultural centres | 321.14 | 312.72 | 912.35 | 1,036.24 | 1233.49 | 1,348 |
| | | | | | | |
| **Total** | **2,613.24** | **2,396.12** | **4,537.15** | **5,546.94** | **7,150.39** | **7,943.06** |

Music schools have the biggest share in this group of consumers; these are followed by museums and theatres and then by sports schools and sports and cultural centres.

Libraries are the most “modest” consumers of both the electricity and natural gas the share which in the total consumption ranges between 5-10%. Taking into account the surface of their premises, this is indicative of poor heating.

Under the conditions state funding energy consumption indicators of museums and theatres in 2012 are lower by about 9% from the indicators of the previous year. However, the energy consumption volumes of theatres and museums showed signs of stabilisation in the years following the year of 2012.

Sports schools, children and youth complex sports schools and sports and cultural centres, in total 35 consumers, are functioning both under the direct control of the Municipality of Yerevan (including “Yerevan Sports Committee” MNCO) and all the administrative districts of the city.

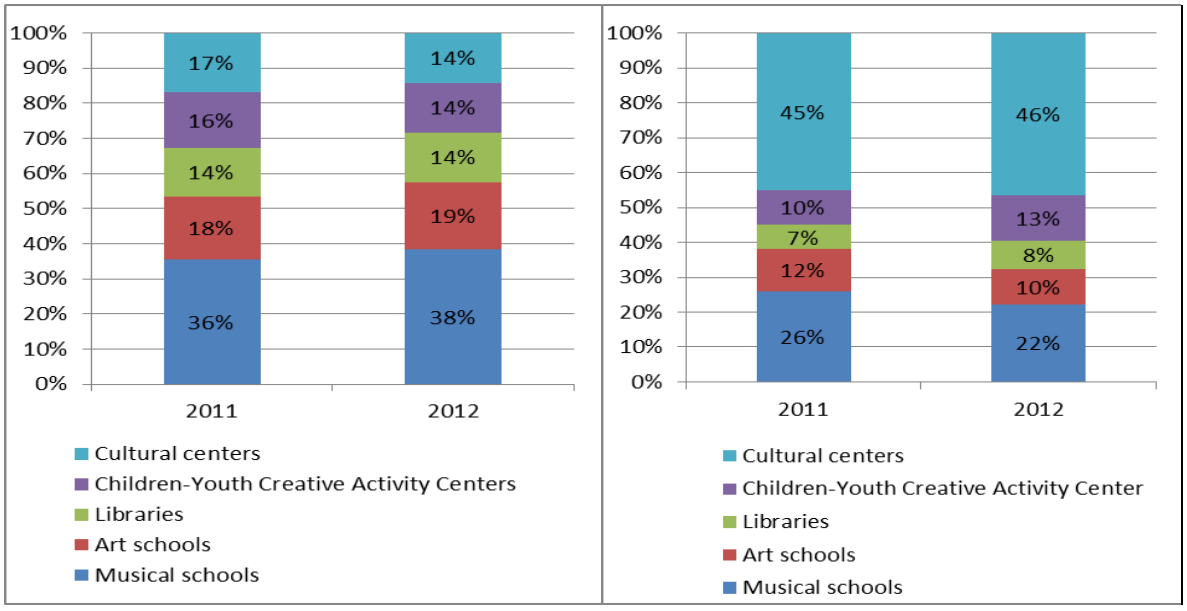


*Figure 4.10 Consumption of natural gas (on the left) and electricity (on the right) by cultural and creative enters in 2011 and 2012, MWh/year*

As of 2012 many of the sports schools and sports and cultural centres still used electrical energy for heating purposes. Information on electrical energy yearly consumption volumes was received from 30 MNCOs, whereas the information on the volumes of natural gas covers only 12 MNCOs. Some of these institutions also use electricity for heating and hot water generation purposes, although sports schools should ensure a higher level of comfort. In the base year at least 7 of all 30 sports schools still continued to use electric heaters solely or used them in as heating devices in combination with others. Buildings are not using energy efficient lamps in lighting devices. Although incandescent light bulbs comprise only 31% of all the lamps used, however with their installed capacity they make up 78% in the total.

In the heating period and during the remaining period of the year some sports schools have considerably unequal consumption of electrical energy which evidences that the electrical energy is used for thermal purposes. This is especially obvious in the case of R. Karapetyan Children and Youth Complex Sports School and A. Azaryan Children and Youth Gymnastics School of Olympic Reserve of Yerevan. The diagrams illustrating the electrical energy consumption volumes (MWh/month) in these two schools are presented in Figure 4.11.

The average monthly consumption for around 5 winter months exceeds the average monthly consumption for the remaining 7 months 4.2 times in the case of the first school and more than 5 times in the case of the second school. Such a huge difference for children and youth sports schools that use natural gas may hardly be explained only by the impact of daylight time in winter period. Such a high level of consumption of electrical energy may be due to electric heating, which is the most expensive heating option taking into account the energy tariff system currently effective in the Republic of Armenia.

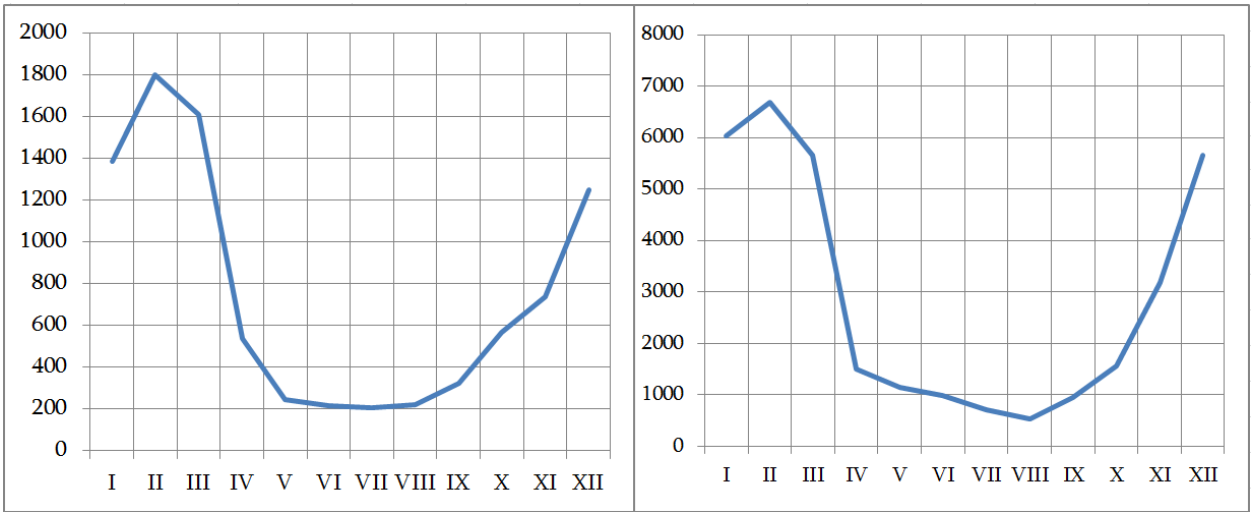



*Figure 4.11. Electrical energy consumption schemes in R. Karapetyan (on the left) and A. Azaryan CYCS schools, 2012.*

The specifications of internal lighting systems in the buildings of sports schools, children and youth complex sports schools and sports and cultural centres were also reviewed. The relevant information was received from almost all the institutions. The electric power consumption of general internal lighting systems in the institutions referred to in Table 4.1 equals to 164.68 kW; 68% of the luminaires are low-efficient incandescent light bulbs. The aggregate power consumption of luminescent lamps is around 53 kW.

In most of sports institutions the internal lighting systems provide energy efficient illumination. In this regard quite high indicators are recorded in Yerevan Sports Committee, 4.53 W/m$^2$, A. Azaryan sports school, 3.04 W/m$^2$, V. Zatikyan sports school in Malatia-Sebastia

administrative district, 3.63 W/m$^2$, etc. The absolute leader is the Children and Youth Complex Sports School of Nork-Marash administrative district with an indicator of 2.40 W/m$^2$. The internal lighting of the sports school is provided by luminescent lamps.

The situation is quite unsatisfactory in the Children and Youth Complex Sports School of Arabkir administrative district with the indicator amounting to 12.55 W/m$^2$ and in the Fencing School named after A. Grigoryan with the indicator amounting to 17.60 W/m$^2$, which makes obvious the fact of exceeding the installed electric power capacity of interior lighting systems.

The above-mentioned analysis was carried out purely on the basis of data concerning the power consumption of illumination lamps and the surfaces illuminated. Moreover, there are no data in the municipal procurement system and in the reports that are necessary for assessing the efficient illumination level (lux or lumen normalized surface data). Such situations urge that defining respective technical conditions in procurement processes for energy efficiency purposes is very important and this — together with the energy management information mechanism — will enable to regularly estimate not only the energy consumption volumes but also its efficacy and optimal quality.

The actual volumes of consumption of electrical energy and natural gas, as well as GHG emissions in 2012, which is a base year in terms of greenhouse gas emissions cadastre, are presented in

Table ***4.5***.

*Table 4.5. Energy consumption and GHG emissions by cultural, art, sports centres, sports and cultural, children and youth creative centres in 2012 by administrative districts*

| Name of the administrative district | Electrical energy | Natural gas | Total energy consumption | GHG emissions (tonnes of $CO_2$) |
|---|---|---|---|---|
| | MWh/year | | | |
| **1. Ajapnyak** | 197.8 | 516.0 | 713.8 | 148.2 |
| **2. Avan** | 193.2 | 317.3 | 510.5 | 107.0 |
| **3. Arabkir** | 208.5 | 689.1 | 897.6 | 185.5 |
| **4. Davitashen** | 163.3 | 293.3 | 456.6 | 95.5 |
| **5. Erebuni** | 252.3 | 410.9 | 663.2 | 139.0 |
| **6. Kentron** | 162.9 | 305.8 | 468.7 | 97.9 |
| **7. Malatia-Sebastia** | 186.5 | 489.7 | 676.2 | 140.3 |
| **8. Nor Nork** | 244.6 | 578.1 | 822.7 | 171.1 |
| **9. Nork-Marash** | 141.2 | 207.0 | 348.2 | 73.2 |
| **10. Nubarashen** | 145.0 | 273.9 | 419.0 | 87.5 |
| **11. Shengavit** | 288.6 | 808.5 | 1,097.0 | 227.4 |
| **12. Kanaker-Zeytun** | 212.4 | 658.0 | 870.4 | 180.1 |
| **Total** | **2,396.4** | **5,547.5** | **7,944.0** | **1,652.6** |

### 4.1.5 Energy consumption of municipal healthcare institutions

More than three dozens of healthcare institutions are functioning under the control of the Municipality of Yerevan. All the institutions in this group have the status of closed joint stock companies. State Budget funding is provided to 30 them, 3 of them have been transferred to trust management. Natural gas and electrical energy are the main energy carriers used by these

institutions. The vehicles used by these institutions, including also vehicles for special services, naturally motor fuel. Costs related to transport services of health institutions are reviewed in the transport energy consumption section.

The annual consumption rates of electrical energy and natural gas of 31 public healthcare institutions for the period of 2010-2012 are summarised in Table 4.6 below.

"Kanaker-Zeytun" medical centre and Scientific Research Institute of Cardiology in Kanaker-Zeytun administrative district are the most major consumers of electrical energy from among the considered institutions which, for example, in 2011 consumed around 45% of the total electrical energy consumed by all 31 entities; as regards outpatient clinics, here clinics No 12 and No 19 may be distinguished. In general, in 2010-2012 the electricity consumption varied in the range of 7200-8100 MWh/year limits. The predominance of electrical energy consumption volumes over the natural gas consumption volumes is quite characteristic of this group of consumers. At the end of the period observed, the ratio amounted to 1.46.

Initially natural gas was used only in 9 institutions but starting from 2012 the number of customers drastically grew reaching 17. "Nork Marash" and "«Sourb Astvatsamayr" medical centres are the major consumers of natural gas. The overall natural gas consumption volumes in healthcare institutions during the period of 2011-2012 were quite stable and varied in the range of 580-630 thousand $nm^3$ limits.

*Table 4.6. Electrical energy and natural gas consumption volumes in healthcare institutions[23]*

| Type of consumed energy | 2010 | 2011 | 2012 |
|---|---|---|---|
| Electrical energy, MWh | 7,246.6 | 8,084.7 | 7,750.4 |
| Natural gas, thousand $nm^3$ | 378.3 | 600.7 | 578.2 |
| Total, MWh | 10,721.66 | 13,602.73 | 13,061.75 |

Besides, assessment was also carried out to estimate the level of illumination of healthcare institution premises. Almost 2/3 of around 970 kW installed capacity of internal lighting systems in the institutions fall on low-efficient incandescent light bulbs. Therefore, this stands for the high volumes of electrical power consumption which amounts to 9.02 $W/m^2$ for a surface measuring 1 $m^2$. In some institutions this indicator reaches up to 18 W ("Kanaker-Zeytun" Medical Centre) or even up to 28 W (Endocrinological Dispensary).

*Table 4.7. Energy consumption in public buildings, 2012, MWh*

| Type of the building | Electrical energy | Natural gas | Total energy consumption |
|---|---|---|---|
| | | | |
| **Administrative buildings** | 4,111.7 | 4,497.0 | 8,608.7 |
| **General educational institutions** | 4,653.1 | 22,713.7 | 27,366.7 |
| **Cultural and creative centres** | 1,533.0 | 3,505.8 | 5,042.5 |
| **Sports schools** | 312.7 | 1,036.2 | 1,345.2 |
| **Support service providers (MNCOs, CJSCs)** | 897.4 | 381.4 | 1,278.8 |
| **Museums and theatres** | 550.4 | 1,006.2 | 1,556.6 |
| **Schools** | 75,750.3 | 113,625.4 | 189,375.6 |
| **Healthcare institutions** | 7,750.4 | 5,311.2 | 13,061.6 |
| **Total** | 95,558.9 | 152,077.0 | 247,635.8 |

[23] Note: The factor 9.186 $kWh/nm^3$ was used for converting the natural gas consumption indicators from physical units to energy units.

## 4.2 GHG emissions of public buildings

The overall quantitative indicators of energy consumption in 2011 and 2012 as per the types of institutions, together with the respective data on GHG emissions, are summarized below.

*Table 4.8. GHG emissions indicators in public buildings in 2011 and 2012 as per the type of institutions*

| Type of the building | $CO_2$ emissions (tonnes) | |
|---|---|---|
| | 2011 | 2012 |
| **Administrative buildings** | 1,629.8 | 1,834.6 |
| **Preschools** | 1,987.0 | 9,643.5 |
| **Cultural and creative centres, including museums** | 992.1 | 1,819.4 |
| **Sports schools** | 63.3 | 209.3 |
| **Support service providers (MNCOs, CJSCs)** | 406.6 | 166.8 |
| **Schools** | 32,586.7 | 36,066.0 |
| **Healthcare institutions** | 3,360.4 | 2,297.9 |
| **Total** | **40,963.2** | **51,933.6** |

In relative terms, natural gas has a predominant role in the energy consumption scheme of consumers of this group the share of which in the total energy supply services increased from 58.8% reaching 69.6% in 2011 with equivalent emissions as from 2012. The growth in the level of emissions may be explained by the growing number of gas heating systems installed by the efforts of the Municipality which, although caused an increase in energy consumption and emission levels, but similarly contributed to the increase in quality of municipal services and level of comfort in public buildings.

The energy efficiency in most public buildings is very low which is largely due to the age of the buildings, poor state of the building envelope, as well as the lack of proper energy management. Generally, such buildings have 10-70% energy saving potential. Energy costs of the majority of public institutions make up 5-20% of current expenditures, while they still provide only about 40% of the average comfort level.

Energy efficiency will enable allocating funds for this sector from the limited public budget. Without energy efficiency the impact of fluctuations in energy prices will increase the demand for public budget allocations.

## 4.3 Energy efficiency measures in public buildings

### 4.3.1 Activity P.1. Introduction of the energy manager institute in public institutions

This Activity is aimed at creating a position of an energy manager in each administrative district with involvement of a professional specialist with adequate experience and skills and specialization in any field of energy industry.

Energy managers of administrative districts submit recommendations, at their discretion, on cost-effectively reducing the energy consumption level of the most energy-intensive institutions of the district. Energy managers carry out monitoring to identify and evaluate energy saving potentials within the given institution. Subsequently, energy managers develop recommendations for optimization of the institution's energy balance, submit them to the AD management and follow up their implementation.

Presumably, introduction of the energy manager institute will allow achieving 7-8% saving of energy carriers over the next 4-5 years as compared to the base year consumption volumes. In

2012 The quantities of electrical energy and natural gas consumed by budget-funded organisations amounted to 19,808.6 MWh and 38,451.6 MWh respectively.

The energy efficiency and environmental benefits expected to result from the implementation of the Activity are illustrated in the table below.

*Table 4.9. Activity P.1 Outcomes of energy management Activity*

| Source of financing, cooperating structures | Value, thousand Euros | Energy carriers saving, MWh/year | | Reduction of emission, tonnes | Investment years |
|---|---|---|---|---|---|
| | | Electrical energy | Natural gas | | |
| YM and AD | 34.0 | 1585.0 | 3100.0 | 978.5 | 2017 - 2018 |
| | | 4,685.0 | | | |

Cooperation between the staffs of institutions falling within the scope of municipal competence and control is important for supporting the activities of the AD energy manager. A program is proposed to develop for voluntary participation in the energy management process for institutions within municipal competence. As a first example, it is proposed to announce a competition for developing an energy management program for general education schools based on a previously designed and provided format. Participating schools within the scope of their own capacities will submit a respective energy management program together with their planned energy saving measures. In order to stimulate participation of schools the Municipality of Yerevan will undertake promoting measurers. One of the possible incentives may be the best program (or programs) being included in the development plan for the next year of the Municipality for the purpose of implementation of the proposed measures. Actually, so long as it is possible to direct money savings resulting from various municipal energy efficiency programs to the municipal energy efficiency revolving fund, the implementation of such promoting measures may be funded regularly from this fund.

The energy savings from the above-mentioned energy management voluntary program are not quantitatively estimated within the SEAP.

### 4.3.2 Activity P.2. Thermal protection in municipal buildings

The purpose of this Activity is to ensure thermal protection during the heating season in the building structures of institutions with involvement of small scale investments. The minimal expenditures needed for the implementation of the Activity are connected to the purchase of widely used and affordable materials and tools. Employees of institutions themselves may be involved in the process of carrying out primitive works and those not requiring higher qualification. Such weatherization measures of buildings may include the following:

- installation of back reflectors for heaters of the building heating system;
- weatherization of external doors and windows with the help of widely used and easily accessible materials, such as silicone, polyurethane foam, insulating foam sealant, sponge rubber tape, foam rubber, etc.;
- thermal insulation of indoor heat pipes;
- installation of automatic door closers;
- constructing small sized vestibules for entrance doors.

Such measures will result in around 5-8% reduction in energy consumption of the heating season. The relevant calculations are summarized in the table below.

*Table 4.10. Activity P.2. Outputs of measures aimed at thermal protection in municipal buildings*

| Source of financing | Value, thousand Euros | Energy carriers saving, MWh/year | | Reduction of $CO_2$ emissions, tonnes | Investment years |
|---|---|---|---|---|---|
| | | Electrical energy | Natural gas | | |
| YM and AD | 12.0 | 1188.0 | 2300.0 | 728.0 | 2017-2018 |
| | | 3,488 | | | |

### 4.3.3 Activity P.3. Using energy efficient luminaires in the internal lighting systems of public buildings

Almost 40% of the luminaires used in the internal lighting systems of administrative buildings are low-efficient incandescent light bulbs totalling 17.255 in quantity. Their replacement with contemporary and energy efficient luminaires may be carried out with relatively small investments. The total energy consumption of all the administrative buildings in the base year of 2012 totalled 4,112 MWh, from which around 25% falls on the consumption of the internal lighting system. Replacement of incandescent light bulbs with compact luminescent lamps or light-emitting diode lamps will allow reducing for least four times the costs of electrical energy consumption for lighting purposes.

Within the next 4-5 years all the incandescent light bulbs now used in administrative buildings are expected to be completely replaced with energy-efficient luminescent or LED lamps which will result in annual savings of electrical energy in the amount of $\Delta E = 0.5 \cdot 4111.17 \cdot 0.25 \cdot 0.75 = 385.4$ MWh.

*Table 4.11. Activity P.3. Outcomes of using energy efficient luminaires in the internal lighting systems of public buildings*

| Source of financing | Value, thousand Euros | Energy carriers saving, MWh/year | | Reduction of $CO_2$ emissions, tonnes | Investment years |
|---|---|---|---|---|---|
| | | Electrical energy | Natural gas | | |
| YM | 69 | 385 | - | 86 | 2017-2020 |

### 4.3.4 Activity P.4. Energy efficiency oriented programs in public buildings falling within the scope of competence of Yerevan

In public institutions the current per capita financing scheme (per patient in hospitals, per student in educational institutions) allows using borrowed funds for energy-efficient modernization and pay back the investments from money savings. Such energy efficiency projects are successfully implemented by the Armenia Renewable Resources and Energy Efficiency Fund (R2E2 Fund) in 2012.[24] Since 2013 this process involved also public buildings of Yerevan.

First of all, the experience of R2E2 Fund in modernization of public buildings for energy efficiency purposes made it obvious that these buildings are in a poor state of repair and maintenance where around USD 17-20 of additional investments are needed per square meter (this is equivalent to around 10% of the amount calculated based on USD 200 spent per square meter of reconstruction of the entire building) to achieve double reduction in the consumption of natural gas used for heating, thus achieving a double reduction in greenhouse gas emissions.

[24] The Governemnt of the Republilc of Armenia approved an EE project (cost of the projeot estimated USD 10.7 million dollar) through the financing of the World Bank and implemented by the R2E2 Fund. The objective of the project was to implement energy saving activities in public buildings in order to reduce the level of energy consumption by social and other public structures.

The primary heating energy demand, calculated based on 120-126 kWh/m2/year, provides only 40-50% comfort level. Despite existing budgetary constraints EE measures enabled improving the comfort level up to an acceptable level. After the installation of an energy efficient heating system an additional increase in EE is possible to achieve through comprehensive, including thermal insulation of walls, replacement of doors and windows, replacement of windows with walls (reduction of translucent surfaces) and thermal insulation of the roof. The energy efficiency indicators of seven public buildings in Yerevan (mainly general education schools) resulting from the relevant measures implemented in these buildings are summarized below.

*Table 4.12. Activity P.4. Outcomes of energy efficiency oriented programs in public buildings falling within the scope of competence of Yerevan*

| Source of financing, cooperating structures | Value, thousand Euros | Energy carriers saving, MWh/year | | Emission reduction, tonnes of $CO_2$ | Investment years |
|---|---|---|---|---|---|
| | | Electrical energy | Natural gas | | |
| R2E2 Fund | 289 | - | 2534 | 512 | 2013-2020 |

### 4.3.5 Activity P.5. Using renewable energy in public buildings

The use of renewable energy sources, such as solar energy, municipal solid and liquid waste, pruning of trees in recreation and walk areas, is quite realistic in urban conditions. This section focuses only on measures using solar energy.
The following main parameters of terrestrial solar irradiation of the City of Yerevan are used for estimating the technical indicators of measures: total solar radiation on a horizontal surface under medium cloud cover — 1690 kWh/($m^2$.year), annual average share of direct radiation under the same conditions — 62 %.

#### *4.3.5.1 Activity P.5.1. Installation of solar water heaters in preschool institutions*

The use of solar water heaters in preschools (kindergartens) could, in addition to environmental and energy benefits, contribute to building a caring attitude among children towards the nature and energy from early childhood. Since in these institutions water is heated by using electricity or natural gas, it is desirable to use solar hot water generation systems in combination with the existing facilities as a hybrid system component. In this case, the solar water heating could constitute the base of the overall water heating system having a high efficiency, and could annually provide about 850-900 kWh/$m^2$ useful thermal energy.

Presumably, in eight administrative districts with the highest number of preschools it will be possible during the next 4-5 years to introduce solar water heating in at least 50 of these institutions (totalling 160) with active area of collectors amounting to about 30 $m^2$ in each. In that case the annual amount of thermal energy generated by solar subsystems will total $\Delta Q = 50 \cdot 30 \cdot 900 = 1350.0$ MWh/year, the equivalent saving of natural gas in case of 85% efficiency of gas water heater will total $\Delta B = 1350/0.85 = 1588.2$ MWh/year.

*Table 4.13. Results of Activity P.5.1*

| Implementing entity | Value, thousand Euros | Energy saving, MWh/year | | Reduction of emissions, tonnes of $CO_2$/year | Investment years |
|---|---|---|---|---|---|
| | | Electrical energy | Natural gas | | |
| YM | 525.00 | - | 1588.2 | 320.8 | 2018 - 2020 |

*4.3.5.2 Activity P.5.2. Installation of solar energy plants in healthcare institutions*

In the baseline year the indicators of energy consumption in 31 budget-funded medical institutions under the control of the Municipality are the following: electrical energy — 7750.39 MWh; natural gas — 5311.20 MWh. For the next 3-4 years the following is planned to carry out in 23 medical institutions in different administrative districts of the city:

- install solar water heating systems each with 50 $m^2$ of active absorber area, adapted to existing hot water generation systems, as initial heating level for preheating the water supplied;
- install solar direct conversion panels for lighting of yard and porch areas of 31 institutions equipped with 260 W watt-peak photovoltaic PV-modules. The market value of the module, including energy efficient luminaires, inverter, accumulator, sensor and installation works are estimated at around EUR 800.

By the year of 2020 it is planned to install solar water heaters with 1150 $m^2$ of active surface area in 23 healthcare institutions in total and photovoltaic PV-modules in all 31 institutions each with up to 1 kW watt-peak.

As a result of operation of solar energy plants the expected annual saving in the energy consumed will be the following:

- natural gas saving for water heating: $\Delta B = 1150 \cdot 900/0.85 = 1217.6$ MWh/year (assuming that initially hot water is generated by gas water heater with 85% of efficiency);
- electrical energy saving: $\Delta E = 31 \cdot 1 \cdot 1600 = 49.6$ MWh/year.

The overall result of these activities is the 9.7% reduction of total 13061.6 MWh energy consumption in the baseline year.

*Table 4.14. Results of Activity P.5.2.*

| Implementing entity | Value, thousand Euros | Energy saving, MWh/year | | Reduction of emissions, 2020, t $CO_2$/year | Investment years |
|---|---|---|---|---|---|
| | | Electrical energy | natural gas | | |
| YM, other government structures | 490.00 | 49.6 | 1217.6 | 256.7 | 2018 - 2020 |

*4.3.5.3 Activity P.5.3. Installation of solar energy plants in sports schools and children and youth complex sports schools*

During the baseline year 28 municipal budget-funded MNCOs and 2 State Budget-funded MNCOs consumed 312.72 MWh of electrical energy and 1036.25 MWh of natural gas. Moreover, the analysis of electrical energy consumption schemes shows that the use of electrical energy for heating purposes is not uncommon in these institutions. Solar water heating and direct energy production plants are planned to be used in these facilities as well, just like in healthcare institutions.

By the year of 2020 in each of at least 20 sports institutions solar water heaters with 12 $m^2$ of active surface area and 520 W of watt-peak photovoltaic modules are planned to be installed. Given the peculiarities of these institutions useful solar energy may be expected in the amount of about 500 kWh/($m^2$.year).

As a result of operation of solar energy plants the expected annual saving in energy consumed by sports institutions will be the following:

- natural gas or electrical energy saving for water heating: $\Delta B = 12 \cdot 20 \cdot 500/0.85 = 141.17$ MWh/year,
- natural gas saving for water heating: $\Delta E = 20 \cdot 0.52 \cdot 1600 = 16.64$ MWh/year.

The overall result of these two renewable energy activities is the 11.7 % reduction of total 1349.0 MWh energy consumption in the baseline year in all 30 MNCOs.

*Table 4.15. Results of Activity P.5.3.*

| Implementing entity | Value, thousand Euros | Energy saving, MWh/year | | Reduction of emissions, 2020, tonnes of $CO_2$/year | Investment years |
|---|---|---|---|---|---|
| | | Electrical energy | Natural gas | | |
| YM and sports schools | 90.00 | 16.64 | 141.17 | 32.20 | 2018 - 2019 |
| | | 157.81 | | | |

*4.3.5.4 Activity P.5.4. Installation of solar energy plants in administrative buildings*

The total energy consumption of administrative buildings of the Municipality of Yerevan and 12 administrative districts during the baseline year of 2012 amounted to: electrical energy — 4111.7 MWh, natural gas — 489.55 thousand $nm^3$ or 4497.0 MWh. The possibilities of using renewable energy resources in administrative buildings are more realistic owing to the organizational and performance discipline. Besides, initiative of local authorities may have an advertising and promotional impact both on population and business circles.

Presumably, given the peculiarities of arrangement of buildings in the city a solar water heating project may be implemented in at least 10 administrative buildings from 14 of them in total by the year of 2020. Besides, flat-plate or tubular collectors with about 35 $m^2$ of active surface area will be possible to install in each building; these collectors, operating as preheating level of the existing water heating system, will be able to annually produce 800 kWh of useful thermal energy thus replacing the natural gas consumption.

In such circumstances, the amount of natural gas saved (replaced) as a result of installation of the solar water heating system will annually total $\Delta B = 10 \cdot 35 \cdot 800/0.85 = 329.4$ MWh/year. Such saving constitutes about 7.3% of the initial amount of natural gas consumed by all administrative building.

*Table 4.16. Results of Activity P.5.4.*

| Implementing entity | Value, thousand Euros | Energy saving, MWh/year | | Reduction of emissions, 2020, tonnes of $CO_2$/year | Investment years |
|---|---|---|---|---|---|
| | | Electrical energy | Natural gas | | |
| YM | 122.00 | - | 329.4 | 66.54 | 2018-2020 |

Overall results of using renewable energy in municipal buildings are summarized below.

*Table 4.17. Activity P.5. Results of using renewable energy in municipal buildings*

| Implementing entity | Value, thousand Euros | Energy saving, MWh/year | Reduction of emissions, 2020, | Investment years |
|---|---|---|---|---|

| | | Electrical energy | Natural gas | tonnes of $CO_2$/year | |
|---|---|---|---|---|---|
| YM | 1,227.0 | 66 | 3,343 | 690 | 2018-2020 |
| | | 3,409 | | | |

### 4.3.6 Activity P.6. Investments for construction repair works within energy efficiency activities in municipal buildings

In medium-term programs of the Municipality of Yerevan the measures planned for 2017 and implemented since 2012 up to now cover also replacement of doors and windows in municipal buildings, replacement of heating systems, renovation of boiler installations, as well as repair of roofs, that have at least 8-10% energy saving effect.

*Table 4.18. Activity P.6.Results of investments for construction repair works within energy efficiency activities in municipal buildings*

| Implementing entity | Value, thousand Euros | Energy saving, MWh/year | | Reduction of emissions, 2020, tones of $CO_2$/year | Investment years |
|---|---|---|---|---|---|
| | | Electrical energy | Natural gas | | |
| YM | 5,396 | - | 9,788 | 1,977 | 2013 - 2020 |

### 4.3.7 Activity P.7. “De-risking climate investments: Thermal Rehabilitation and EE in buildings” project for public buildings

For promoting activities targeted at improving the energy efficiency in public buildings and multi-apartment residential buildings, the Municipality of Yerevan in 2015 initiated consultations with the UNDP and European Investment Bank (EIB). As a result a joint investment project was developed providing EIB loan investments in Yerevan municipal buildings and multi-apartment buildings with co-financing from the municipal budget. Considering the numerous constraints connected to investments in this sector, as well as the financial problems constantly faced by both the community and the residents, it was necessary to make such investments more accessible and implement them not as pilot but large-scale projects. To this end, the “De-risking climate investments: Thermal Rehabilitation and EE in buildings” project document was developed jointly with the UNDP and communicated to the Green Climate Fund for financing purposes (grant). This grant will enable reducing the loan investment related risks. In 2016 the development and implementation of a feasibility project targeted at improving the energy efficiency in public buildings and multi-apartment residential buildings in the City of Yerevan stated with the support of the UNDP and European Investment Bank.

The project will include components aimed at thermal insulation of building envelopes, installation of entrance doors in staircases, replacement of windows, reconstruction of heating/cooling, air ventilation and air conditioning systems and renewable energy sources integration components.

Given the fact that, according to preliminary estimations, during the entire duration of the project it will include around 160 municipal buildings, while the number of residential buildings will respectively amount to 6000 residential houses and 290 multi-apartment buildings, this Activity is covered in this section on the part of public buildings, and it is covered in the Residential Sector subsection on the part of residential buildings. Note that 20% is taken as a degree of market penetration of public buildings by 2020.

*Table 4.19. Activity P.7. Results of "De-risking climate investments: Thermal Rehabilitation and EE in buildings" project in municipal buildings*

| Implementing entity | Value, thousand Euros | Energy saving, MWh/year | | Reduction of emissions, 2020, tones of $CO_2$/year | Implementation timeframe |
|---|---|---|---|---|---|
| | | Electrical energy | Natural gas | | |
| YM, EIB, GCF, UNDP | 1,724 | | 35,819 | 7,235 | 2016-2020 |

### 4.3.8 Activity P.8. Modernisation of household appliances in preschools

A significant portion of energy-consuming household appliances installed in preschools are old, and the volumes of gas and electricity consumed for their operation increases every year. Since 2015 refrigerators, ovens and household appliances of preschools are being replaced by the efforts of the YM. In some cases this replacement fails to entail energy efficiency (for example, when additional or a larger number of refrigerators are provided to cover extra needs) but results in improving the quality of municipal service.

In 2013 the Municipality replaced 129 electric ovens in 110 preschools (budget totalling AMD 70.8 million), hence achieving in these preschools reduction of the overall electrical energy consumption by 2 MWh, and reduction of natural gas consumption by more than 87 thousand cubic meters (equivalent to about 800 MWh). Thus, the replacement of ovens resulted in reduction of the total energy consumption by 7% or 802 MWh, which is equivalent to 162 tonnes of $CO_2$ emissions avoided. The replacement of the remaining ovens will require investments of about AMD 43 million and is planned to be implemented by 2020. This investment will bring about 392 MWh/year additional energy saving and reduction of about 79 tonnes of $CO_2$ emissions. Thus, the already completed and further planned modernization will result in total 1,194 MWh/year of energy saving and 241 tonnes of $CO_2$ emissions reduction (total investment equalling to AMD 115 million or EUR 216.4 thousand).

*Table 4.20. Activity P.8. Results of modernization of household appliances in preschools*

| Source of financing, cooperating structures | Value, thousand Euros | Energy saving, MWh/year | | Reduction of emissions, 2020, tones of $CO_2$/year | Investment years |
|---|---|---|---|---|---|
| | | Electrical energy | Natural gas | | |
| **YM** | 401 | 1,191 | 3.14 | 265 | 2013-2020 |
| | | 1,194 | | | |

## 4.4 Consolidated Data of Activities in the Public Buildings Sector

Investment indicators of the public buildings sector, the overall energy and environmental results are summarized in *Table **4.21***.

*Table 4.21. Key indicators of public buildings sector activities*

| Index | Activity | **Possible source of financing, cooperating structures** | Implementation timeframe (start - end) | Estimated value (thousand Euros) | Expected energy saving [MWh/ year] | Reduction of emissions, 2020, tones of $CO_2$/year |
|---|---|---|---|---|---|---|

| | | | | | | |
|---|---|---|---|---|---|---|
| **P.1** | Introduction of the energy manager institute in municipal institutions | YM | 2017-2018 | 34.0 | 4,685 | 978 |
| **P.2** | Measures aimed at thermal protection in buildings of institutions | YM | 2017-2018 | 12.0 | 3,488 | 728 |
| **P.3** | Using energy efficient luminaires in the internal lighting systems of administrative buildings | YM | 2017-2020 | 69.0 | 385 | 86 |
| **P.4** | Energy efficiency oriented investment in public buildings falling within the scope of municipal competence of Yerevan | YM | 2013-2020 | 289.1 | 2,534 | 512 |
| **P.5** | Using renewable energy in municipal buildings | YM, RA MH | 2018-2020 | 1,227.0 | 3,409 | 690 |
| **P.6** | Investments for construction repair works within energy efficiency activities in municipal buildings | YM | 2013-2020 | 5,396.0 | 9,788 | 1,977 |
| **P.7** | "De-risking climate investments: Thermal Rehabilitation and EE in buildings" | YM | 2016-2020 | 1,723.9 | 35,819 | 7,235 |
| **P.8** | Modernisation of household appliances in preschools | YM | 2013-2020 | 400.8 | 1,194 | 265 |
| | ***Total*** | | | **9,152** | **61,302** | **12,471** |

# 5 Municipal Solid Waste

Household waste collected in the municipal administrative territory of Yerevan is removed to Nubarashen, Jrvezh, Masis landfills and Spandaryan industrial dump site in Ajapnyak administrative district. According to the SEAP Guidelines, in addition to energy and transport sectors other sources of greenhouse gas emissions may also be considered in the Action Plan provided, that the measures fall within the scope of competence of the Municipality of Yerevan and may lead to additional reduction of GHG emissions from these other sources. Since only the Nubarashen landfill is involved in terms of planning activities by 2020, consequently only Nubarashen solid waste landfill is included in the baseline GHG emissions cadastre and mitigation measures.

Nubarashen landfill is one of the largest landfills of municipal solid waste (MSW) located in the territory of the similarly named administrative district of Yerevan. It started to be used as

landfill since 1950 and is located about 9-10 kilometres to the south-east from the centre of the capital city occupying an area of approximately 52.3 hectares.[25]

## 5.1 GHG Emissions from Yerevan Nubarashen Municipal Landfill

The share of GHG emissions from Nubarashen landfill, which is covered below, has been identified based on the findings recorded in waste section of 2012 GHG National Inventory. The calculations were made by using all those design and default factors that were used in preparing the 2012 GHG National Inventory of the Republic of Armenia in accordance with the IPCC Guidelines.

The considerations herein cover $CH_4$ emissions from municipal solid waste (MSW) in Nubarashen landfill. MSW incineration was not considered at all since this is almost not applicable in the case of the capital.

Currently, in average around 850-900 tonnes of household and other waste is moved per day (200-220 thousand tonnes per year) from the territory of the capital to the urban landfill. Household waste does no undergo sorting and processing operations but rather waste compaction and neutralization through covering by soil layer measuring 25-30 cm.

Under the Clean Development Mechanism of the Kyoto Protocol the Municipality of Yerevan signed a contract on 10 March 2009 with the Japanese Shimizu Corporation on Nubarashen Landfill Gas Capture and Power Generation project which will contribute to reduction of greenhouse gas emissions from the landfill and improvement of environmental and sanitary conditions.

Currently, in the Nubarashen dump site, with about 8 ha surface area, methane gas is collated and transferred to the central vertical pipe (flare) through drilled vertical holes and horizontal gas drains and combusted there. The area is covered with an airtight sheet and a layer of soil. The duration of the project implementation is 16 years. According to calculations the planned certified emission reduction is estimated to be equivalent to 512 thousand tonnes of $CO_2$ gas for the whole period of effectiveness of the contract, that is, up to the year of 2023.

The financing of the project, including financing of system maintenance and operating costs, is provided by the Japanese party. The structure has been transferred under the ownership of the Armenian party, and is operated by “Nor Barekargum” CJSC.

**Figure 5.1.** Distribution of methane extraction wells in Nubarashen landfill “Block B-Western” site (on the left), methane flare plant (FP, on the right)

[25] See Yerevan Development Program for 2015 adopted by Decision of the Yerevan Local Council No 263-N of 23 December 2014.

The yearly methane and carbon emissions from the landfill are controlled and certified by an internationally certified organisation and are registered as Certified Emission Reduction Units. Emissions are shown on Table 5.1.

**Table 5.1**. *Nubarashen MSW emissions, thousand tonnes*

| Emissions | 2010 | 2011 | 2012 |
|---|---|---|---|
| Methane (kt) | 10.8 | 10.8 | 10.9 |
| $CO_2$ equivalent | 225.8 | 227.0 | 228.3 |

## 5.2 Activity M.1. Mitigation measure in the MSW sector, methane extraction project

Expanding the project on closing the Nubarashen landfill and opening of a new landfill and methane extraction is included in Yerevan Development Programs. On 16 October 2015 a Memorandum of Understanding was signed between the Government of the Republic of Armenia, Municipality of Yerevan, European Union and the European Investment Bank on cooperation in municipal solid waste management sector. Taking the aforementioned into account the SEAP also covers measures aimed at mitigation of GHG emissions from Yerevan MSW.

The operating methane extraction plant is located in the "Block B-Western" site of the Nubarashen landfill occupying an area of about 9 hectares (see Figure 5.1, on the left). It consists of 27 vertical extraction (collection) wells. Methane extracted from these wells is collected through radial pipes in 4 key clusters that also have their key wells and condensate collection tanks. Figure 5.2 illustrates the scheme of 27 vertical methane extraction wells in the "Block B-Western" site of the Nubarashen MSW landfill. Thereafter, methane extracted through lateral pipes and dried is transferred to the methane flare plant (FP, see Figure 5.1, on the right) which is manufactured by the Swiss Hofstetter Umwelttechnik AG Company.

Activities of the first phase of implementation of the Project included preparation of 27 vertical wells, installation of extraction pipe network and flare plant. Since August 2009 methane is extracted from the "Block B-Western" site, transferred to the flare plant and exposed to flaring. The Project included also implementation of the 2nd phase focusing on methane combustion in special gas engine generator (GEG) for electrical energy generation purposes, however, this phase of the Project was not implemented due to various reasons.

According to official data of the monitoring carried out within the framework of Clean Development Mechanism (CDM),[26] in the course of the current first phase of Project implementation about 81 tonnes of methane is monthly extracted from the "Block B-Western" site with 9 ha of surface area and flared, which is equivalent to approximately 20.4 kt $CO_2$ emission prevention (81t $CH_4$ x 21 x 12 months).[27]

Taking these data as a basis and taking into account the current projects covering Nubarashen landfill, it is anticipated within the scope of SEAP that by the year of 2020 it will be possible to:

- extend the extraction pipe network currently existing on the "Block B-Western" site with 9 ha of surface area onto the other two sections of the Nubarashen landfill (Block B-Southern and Block C with a total surface area of 10 ha, see Figure 5.4), which will enable to increase monthly extraction volumes and achieve 171 t of methane extraction instead of currently existing indicator of 81 t (or 43.092 kt $CO_2$ equivalent per year),
- install a GEG with installed power capacity of 1.5 MW for the purposes of generation of electrical energy for own needs of the Nubarashen landfill which will operate at plant factor of 0.5 of its installed capacity.

[26] Nubarashen Landfill Gas Capture and Power Generation Project in Yerevan. PDD 0069. 2nd monitoring period – from 01/04/2010 until 31/07/2011. CDM MONITORING REPORT. Version 01. 08/09/2011

[27] The methane to $CO_2$ factor is equal to 21.

Beginning from the starting year of the 2nd phase, *i.e.*, from 2020+, it will be possible to avoid **43.092 kt $CO_2$** equivalent GHG emissions and annually produce about **6.5-7.0 million kWh** of electrical energy. It should be noted that these estimates are conservative. The MSW morphology is changing over time resulting in increase of the biologically decomposed portion, which will lead also the increase of methane generation. This means that the specific portion of methane generated in the new Block B-Southern and Block C sites (t $CH_4$/per hectare) will be no less than the indicators of the "Block B-Western" site.

In March 2016 the assessment activities were completed concerning the key indicators of the project on upgrading/closing the Nubarashen landfill, extraction of methane and generation of electrical energy there which is implemented with the support of the European Investment Bank. According to the estimates, it is expected that the enlarged extraction system of the Nubarashen landfill will allow collect biogas with nominal flow rate of 962 $m^3$/h. This is equivalent to about 436.5 $nm^3$/h of methane flow equal to 50% methane content in biogas currently existing in the landfill.[28] For its useful recovery a gas engine generator with nominal capacity 1.06 MW is proposed to install near the existing flare plant which, according the EIB estimates, starting from 2019 will ensure about **7.63 million kWh** of electrical energy per year.

It should be noted that these estimations from EIB study (14% accuracy) are in line with the above-mentioned assessments in the SEAP. However, it should be added that the EIB's assessment suggests an unusually high rate of installed capacity utilization for Armenia equalling to 0.82, or rated capacity operation of a plant with duration of approximately 7.195 hours per year. Therefore, it is quite realistic to estimate the expected annual output of the expanded program of methane extraction in Nubarashen as prevention of about **44.644 kt $CO_2$** equivalent greenhouse gas emissions and production of **about 7.0 million kWh** of electric power starting from 2019.

*Table 5.2. Activity M.1. Results of methane extraction project in Nubarashen landfill*

| Source of financing, cooperating structures | Value, thousand Euros | Energy carriers saving, MWh/year | | Emission reduction, tonnes of $CO_2$ | Investment years |
|---|---|---|---|---|---|
| | | Electrical energy | Natural gas | | |
| **YM, EIB, E5P** | 293 | 7.000 | | 44,644 | 2018-2020 |

[28] See: Yerevan Solid Waste Assignment. European Investment Bank, ERD / LOT 2 – Solid Waste. LANDFILL CLOSURE CONCEPT NOTE, March 2016, Pages 33-34.

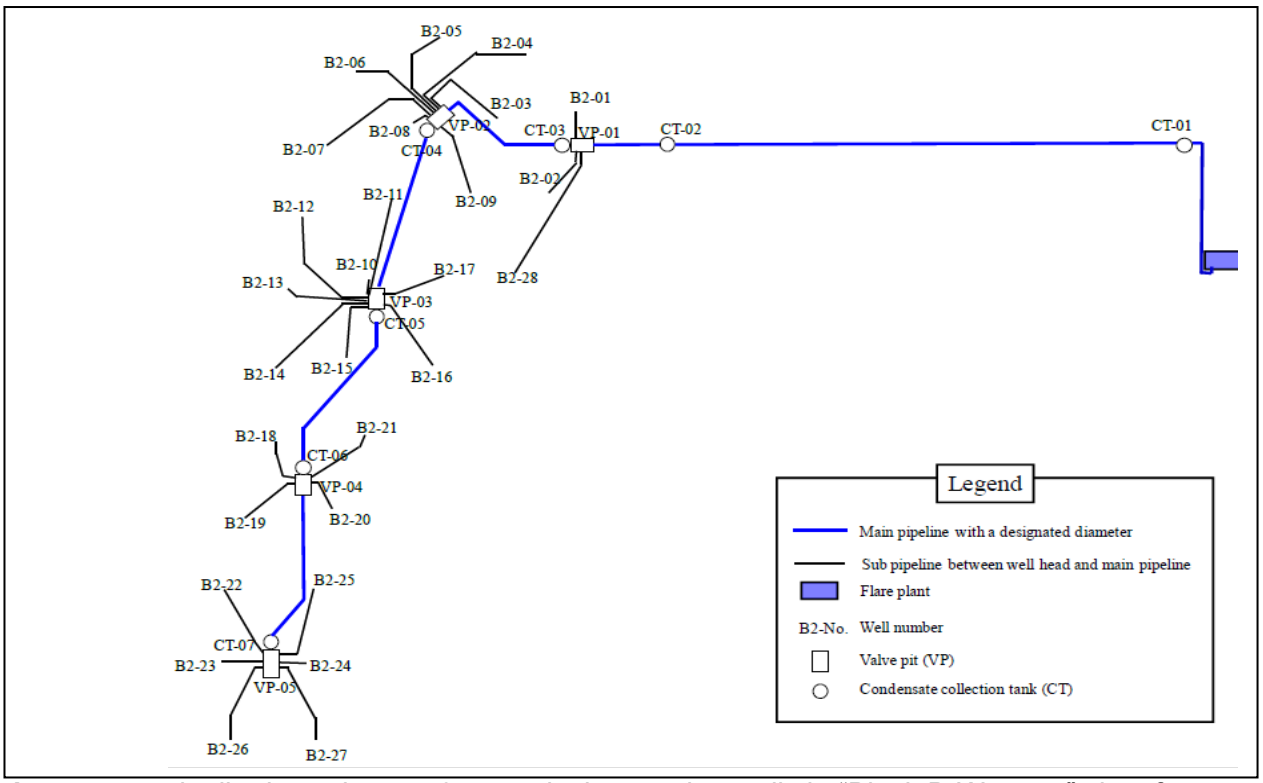



**Figure 5.2.** Distribution scheme of 27 vertical extraction wells in "Block B-Western" site of Nubarashen MSW landfill

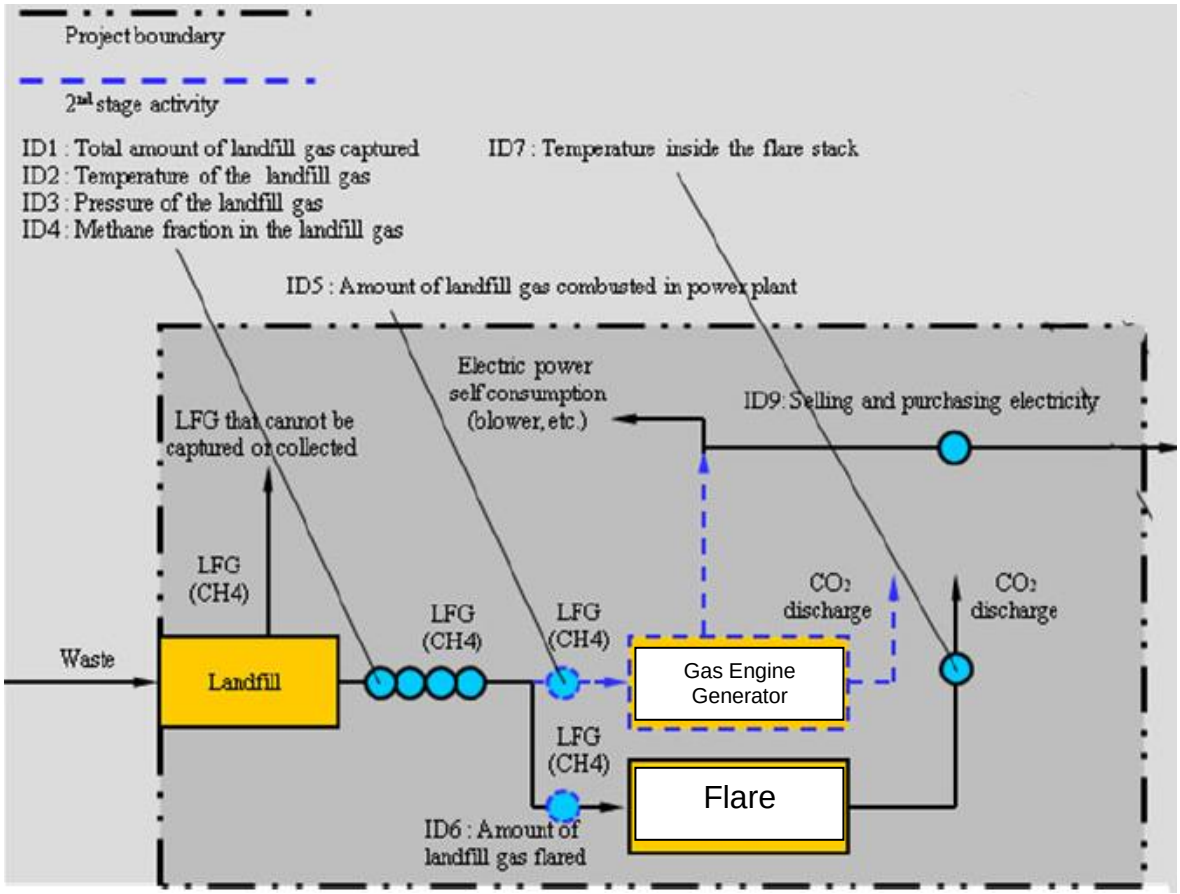



**Figure 5.3.** Methane extraction project's first (extraction and flaring, black line) and second (electrical energy generation by GEG, blue dashed line) phases implemented by Shimizu Corporation

# 6 City Lighting System

## 6.1 Energy Consumption of City Lighting System

Street and outdoor lighting system is financed from the municipal budget and is a large energy consumer. During the last 5-6 years, the outdoor lighting system of Yerevan underwent significant qualitative and quantitative changes. Inefficient mercury light bulbs are no longer used, and after 2012 the lighting systems in a number of streets were equipped with modern energy-efficient luminaries, under various grant and credit programs.

Data on technical inventory of outdoor lighting systems are presented in Table 6.1.

*Table 6.1. Technical characteristics of the outdoor lighting system of Yerevan*

| System component | Unit | Value | | |
|---|---|---|---|---|
| | | 2010 | 2011 | 2012 |
| **1. Number of street light-poles** | count | 26,178 | 27,170 | 28,950 |
| **2. Number of luminaries, including** | count | 48,222 | 49,765 | 51,015 |
| – **incandescent light bulbs** | count | 1,488 | - | - |
| | W* | 100 | - | - |
| – **luminescence lamps** | count** | 5,694 | 4,799 | 2,447 |
| | count*** | | 616 | 751 |
| | W* | 100-400 | 100-400 | 100-400 |
| – **sodium lamps** | count | 41,040 | 44,350 | 46,817 |
| | W* | 100- | 100-400 | 70-250 |
| – **LED luminaires** | count | - | - | - |
| | W* | - | - | - |
| **3. Total length of streets with lighting** | km | 1,174 | 1,196 | 1,226 |

*) The electric power of one lamp / luminaire is provided,
**) mercury lamps,
***) CFLs,
****) The assessment was done based on the information provided by the Municipality.

The total annual power consumption of the street lighting system of Yerevan in 2012 was equal to 34.46 GWh/year; the total installed electric power of all the lamps / luminaries was 12.82 MW. Sodium lamps have the highest percentage in the total number of street luminaries; in the period 2010-2012, the figure ranged from 85% to 90%. Incandescent light bulbs are not used in the street lighting system of Yerevan since 2011.

Energy consumption parameters related to operation of the outdoor lighting system of Yerevan in the period 2010-2012 are summarized in Table 6.2 (source: Yerkaghluis Company).

*Table 6.2 Operational data on outdoor lighting system*

| Parameter | Unit | Value | | |
|---|---|---|---|---|
| | | 2010 | 2011 | 2012 |
| Installed power of the system | kW | 12,755 | 13,033 | 12,820 |
| Hours of operation | hour/year | 2,494 | 2,401 | 2,688 |
| Average duration of daily operation in winter | hour/day | 7.9 | 9.2 | 9.8 |
| Average duration of daily operation in summer | hour/day | 6.3 | 5.8 | 6.2 |
| Annual energy consumption | GWh | 31.8 | 31.3 | 34.5 |

The average annual duration of operation of the street lighting system throughout the last years showed stabilization trends ranging at 2400 – 2700 hours/year.

## 6.2 GHG Emissions Resulting from the Operation of the City Lighting System

Data on GHG emissions resulting from energy consumption by the city lighting system are presented below (source: Yerkaghluis Company).

*Table 6.3 GHG emissions resulting from the operation of the outdoor lighting system of Yerevan City*

| Parameter | Unit | Value | | |
|---|---|---|---|---|
| | | 2010 | 2011 | 2012 |
| Power consumption | MWh | 31,800.0 | 31,300.0 | 34,460.0 |
| $CO_2$ emissions | K ton | 7,059.6 | 6,948.6 | 7,650.0 |

## 6.3 Measures to Improve Energy Efficiency of the City Lighting System

Starting from 2013, with the assistance of donors and international financial institutions, the Municipality is implementing projects on replacing the conventional light-bulbs in the street lighting system of Yerevan City with efficient LED luminaries which are consuming around 60% less electricity while generating the same amount of or even more light.

### 6.3.1 Activity L.1: Improving the Energy Efficiency of the City Lighting System

This activity aimed at improving the energy efficiency and reducing the GHG emissions by increasing the efficiency of the street lighting system is being implemented under Green Urban Lighting Project funded by UNDP-GEF grant (2013-2017). In the 2015-2016 period a number of initiatives on improvement of the energy efficiency of the outdoor lighting system of Yerevan City were implemented under this grant-funded project.

In March 2015 the Project replaced 756 high pressure sodium lamps with 482 efficient LED luminaires on Yerevan Center – Zvartnots International Airport highway[29]; the outcome of this initiative was the reduction of the installed electrical power of the street lighting system by 136.5 kW resulting in 63% energy saving and higher level of illuminance (26 lx instead of the existing 16 lx). The annual energy saving reached 503 MWh/year.

[29] See the brief description of the Project at: http://www.nature-ic.am/wp-content/uploads/2015/01/LED-Isakov-arm.pdf

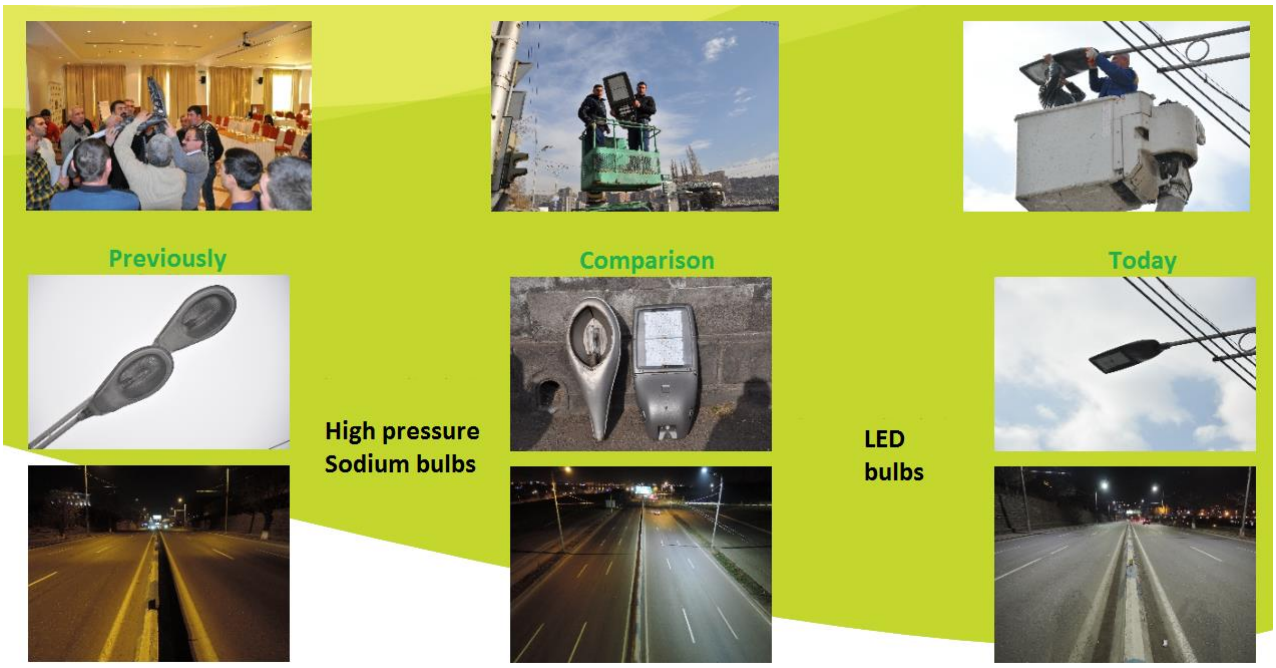



**Figure 6.1** *Demonstration Project on Introduction of Efficient LED Lighting in Yerevan; Green Urban Lighting, UNDP-GEF*

In June 2015, under the same Project, the old luminaires of the Yerevan Zoo were replaced with efficient LED luminaires, resulting in annual energy saving of 21.4 MWh (77%).

The expected aggregate energy saving impact of the above mentioned programs in Yerevan is estimated at 830.4 MWh/year which is equal to 2.42% of the total energy consumption of the sector in the Base Year. One of the important achievements of the Project is the possibility of using the proceeds from savings on electricity bills and maintenance costs for raising a revolving fund (Municipal Energy Saving Revolving Fund of Yerevan) to finance future projects on modernization of the city lighting system.

In April-June 2016, a project on modernization of the street lighting systems in Mashtots Avenue and Haghtanak Bridge was implemented with joint efforts of the Green Urban Lighting Project and the Municipality, supported by funding from the Targeted Fund for Energy Efficiency Improvement of Yerevan Municipality. It is expected that the project will result in annual energy saving of 306 MWh (74%).

In the light of the increasing scope of replication of project results and the trends for reduction of the prices on energy efficient luminaires in the market, the creation of such a revolving fund can have a multiplier effect[30] leading to systemic changes on a long run. The operation of such revolving fund will allow to increase the total annual energy saving by the year 2020 to the level of 2,096 MWh/year[31]. Other project result are summarized in the following table.

[30] Multiplier is a factor measuring the multiplier effect in response to the positive impact on the end result in the controlled sector. Source: http://www.investopedia.com/video/play/multiplier-effect/ . The multiplier effect in this case is related to the generation of a flow of investments resulting from the first successful investment in energy efficiency measures. The internal rate of return from energy saving works actually as a factor (multiplier) that is applied to the initial investment capital.

[31] Multiplier effect was assessed based on the normalized value of the total life-of-project energy saving under the UNDP Green Urban Lighting Project and the principle of full reinvestment of all the saved money, as well as the predetermined internal rate of return (around 24.7%).

*Table 6.4. Activity L.1: Improving energy efficiency of the city lighting system; expected results by the year 2020*

| Source of financing, cooperating structures | Value, thousand Euros | Energy carriers saved, MWh/year | | Emission reduction, tonnes of $CO_2$/year | Investment years |
|---|---|---|---|---|---|
| | | Electrical energy | Natural gas | | |
| **YM, UNDP/GEF** | 490.0 | 2,183* | - | 485 | 2013-2017 |

** - includes the multiplier effect on the revolving fund*

### 6.3.2 Activity L.2 Improving the Efficiency and Reliability of the Street Lighting in Yerevan

The credit program of the European Bank for Reconstruction and Development (EBRD) was initiated in 2015; the Program will be implemented in 2016-2017. The overall credit package is USD 6 million or EUR 5.45 million. One third of the investments (USD 2 million) is financed from the grant provided by Eastern Europe Energy Efficiency and Environmental Partnership (E5P). It is expected that the Program will result in annual energy saving of 2,554 MWh/year, which is equal to around 7.4% of the base year power consumption. Energy efficiency, however, is not the only aim of this Program; the investment part of the Program has a significant infrastructure safety and reliability improvement component. The main energy efficiency and environmental criteria of the Program are presented in the following table.

*Table 6.5. Activity L.2: Improving the Efficiency and Reliability of the Street Lighting in Yerevan; anticipated results in year 2020*

| Source of financing, cooperating structures | Value, thousand Euros | Energy carriers saved, MWh/year | | Emission reduction, tonnes of $CO_2$/year | Investment years |
|---|---|---|---|---|---|
| | | Electrical energy | Natural gas | | |
| **YM, EBRD, E5P** | 5450.0 | 2554.0 | - | 567.0 | 2016-2017 |

### 6.3.3 Activity L.3: Installation of solar batteries for feeding of outdoor lighting systems in multi-apartment residential zones

The purpose of the Activity, that ends in 2020, is to use 260 W solar photovoltaic kits for feeding of the outdoor lighting systems in 1,500 multi-apartment block neighbourhoods.

It is planned to use two kits for each multi-apartment block; the kits will generate electricity for outdoor lighting of the neighbourhood, and if possible also for lighting of the block entrances and staircases (one for each entrance). On average around 4 PV kits will be required for each neighbourhood. The experience shows that a PV kit with 1 kW maximum output can generate around 1,400 kWh electric energy annually in the environment of a standard Yerevan neighbourhood.

The average annual output of photovoltaic kits can be calculated as follows: $\Delta E = 1500 \cdot 4 \cdot 0.26 \cdot 1400 = 2184.0$ MWh; from where we can calculate the reduction of carbon dioxide emission: $\Delta CO_2 = 0.222 \cdot 2184 = 484.8$ ton.

*Table 6.6. Activity L.3: Installation of solar batteries for feeding of outdoor lighting systems in multi-apartment residential zones; anticipated results in year 2020*

| Implementing partner | Value, thousand | Energy saving MWh/year | Emission reduction, | Investment years |
|---|---|---|---|---|

| | Euros | Electrical energy | Natural gas | tonnes of $CO_2$/year | |
|---|---|---|---|---|---|
| **YM, Yerkaghluis Company, donor organizations** | 4,650.0 | 2,184.0 | - | 484.8 | 2018-2020 |

### 6.4 Summary Data on Activities in City Lighting Sector

Data on the activities in the city lighting sector, including investment criteria, energy saving and environmental outcomes are summarized in Table **6.7**.

*Table 6.7. City lighting sector activities; expected results by the year 2020*

| index | Activity | Source of financing, cooperating structures | Deadlines (start – end) | Estimated cost (thous. EUR) | Anticipated energy saving [MWh/year] | Emission reduction by 2020, tonnes of $CO_2$/year |
|---|---|---|---|---|---|---|
| **L.1** | Improving the energy efficiency of the city lighting system | YM, UNDP/GEF | 2013-2017 | 490 | 2183 | 484.63 |
| **L.2** | Improving the efficiency and reliability of the street lighting in Yerevan | YM, EBRD, E5P | 2016-2017 | 5450 | 2554 | 566.99 |
| **L.3** | Installation of solar batteries for feeding of outdoor lighting systems in multi-apartment residential zones | YM, Yerkaghluis Company, donor organizations | 2018-2020 | 4,650.0 | 2,184.0 | 484.8 |
| | **Total** | | | **10,590.0** | **6,921.0** | **1,536.5** |

# 7 Green Spaces and Municipal Greenhouse

## 7.1 Green Spaces and Municipal Greenhouse; Energy Consumption and GHG Absorption Indicators

Development and maintenance of green spaces is one of the priority tasks in Yerevan. The illegal widespread loggings in 90s, that were due to the energy crisis, caused significant damage to the forest and tree cover of the City of Yerevan. The green area per inhabitant of the capital was 7.5 m²/person as of 2012, which is two times lesser than the rate defined by the regulatory standards.

In recent years, large-scale activities were carried out under the program of the Municipality of Yerevan for the expansion of the irrigation system, creation of new systems which in turn

contributed to the improvement, rehabilitation and enlargement of green spaces. In 2010-2012, along with the irrigation network expansion and renovation program, landscaping (tree planting) and decorative flowering of streets, parks and forest parks were carried out.

As of 2012, green spaces of limited access and special purpose occupied correspondingly 3,664 ha and 2,135 ha land area. Of this total area 497 ha was the share of green spaces having the status of “forest-gardens” and148 ha the share of lawns.

*Table 7.1. Green spaces of Yerevan City; year 2012*

| | Description | Surface, ha |
|---|---|---|
| **1** | **Publicly open, including:** | **841.9** |
| | – Parks | 153.0 |
| | – Public gardens | 36.9 |
| | – Forest-gardens | 497.5 |
| | – Lawns | 147.9 |
| | – Flower beds | 6.5 |
| **2** | **Limited access** | **3,664.0** |
| | **Special purpose** | **2,134.8** |
| **3** | **TOTAL** | **6,639.9** |

The following diagram shows the changes in the total surface of publicly open green spaces in the period 1990-2012.

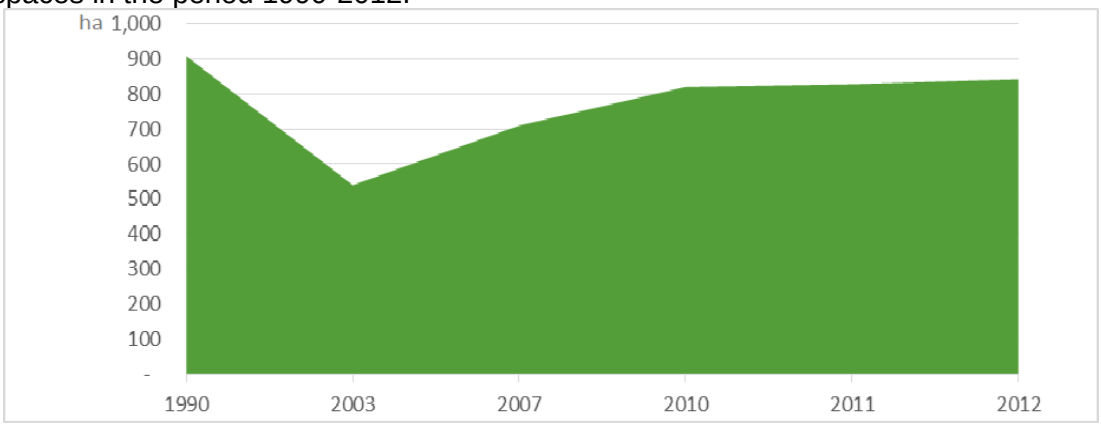



**Figure 7.1 Total green space area in Yerevan; 1990-2012 period**

Data on the surface of land area occupied by lawns, parks, public gardens and forests in the period 2010-2012 are presented graphically in Figure 7.7 below.

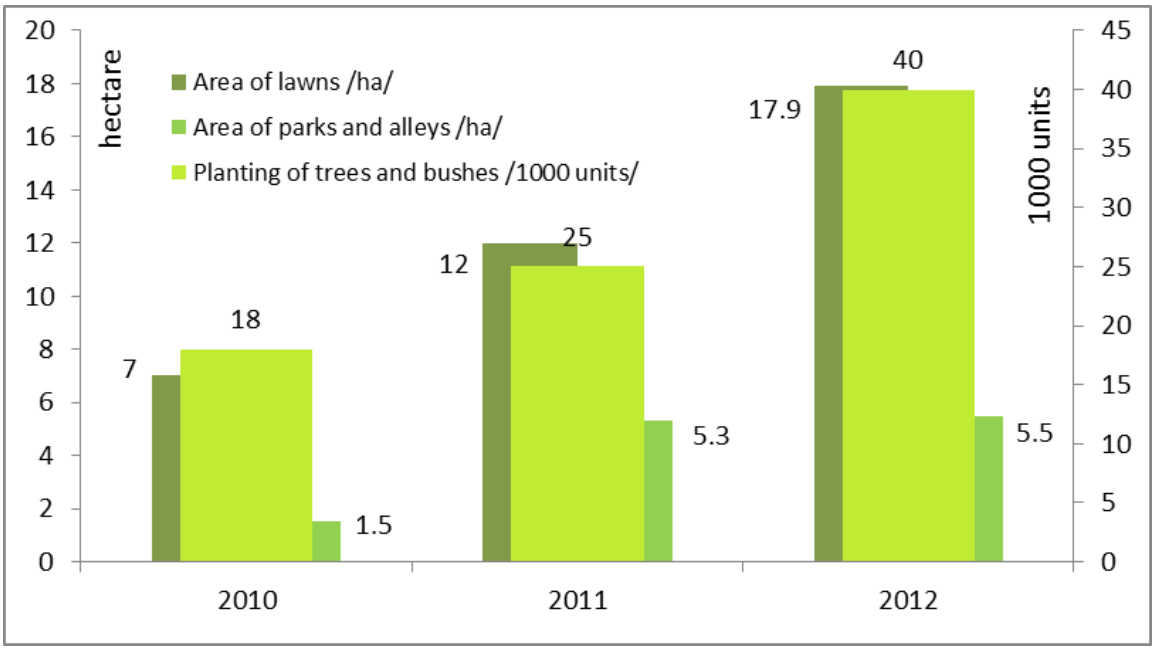



*Figure 7.2. Information on creation and development of green spaces in Yerevan*

Yerevan Municipality is responsible for development and implementation of programs and activities required for implementation of state policies in Yerevan, based on decisions and instructions of the Elders' Council and the Mayor, and after clearance with National Environmental Authorities.

In 2009 the Elders' Council of Yerevan adopted a decision on the procedure for mandatory improvement of the real property and associated common elements in the administrative territory of Yerevan City; the procedure specifies the nature, volume and conditions of activities to be carried out by the owner of real property for improvement of the property and adjacent green spaces of public use.

To reduce the negative impact on the environment, the proceeds from environmental charges collected from the six main polluting industries in the territory of Yerevan are used by the Municipality for rehabilitation and expansion of green (recreation) spaces, within the framework of the RA Law on Targeted Use of Environmental Charges Paid by Companies, adopted in 2010.

As of 2015, the total area of green spaces in Yerevan was equal to 6758.5 ha, including 852,3 ha for public use; the per capita green space area was equal to 7,6 $m^2$. These figures are well below the internationally accepted norms.[32] According to the World Health Organization, the minimum green space area needed to enable healthy environment for a permanent resident is 9 $m^2$, while the preferred surface of green space per resident should be equal to 50 $m^2$/person.[33]

[32] See the Program on Development of Yerevan for 2016, adopted as an annex to the Decision No 432-N of the Local Council of Yerevan on December 23, 2015.
[33] See: ASSESSING PEDESTRIAN ACCESSIBILITY TO GREEN SPACE USING GIS. Tudor MORAR et al. Transylvanian Review of Administrative Sciences, No. 42 E/2014, pp. 116-139

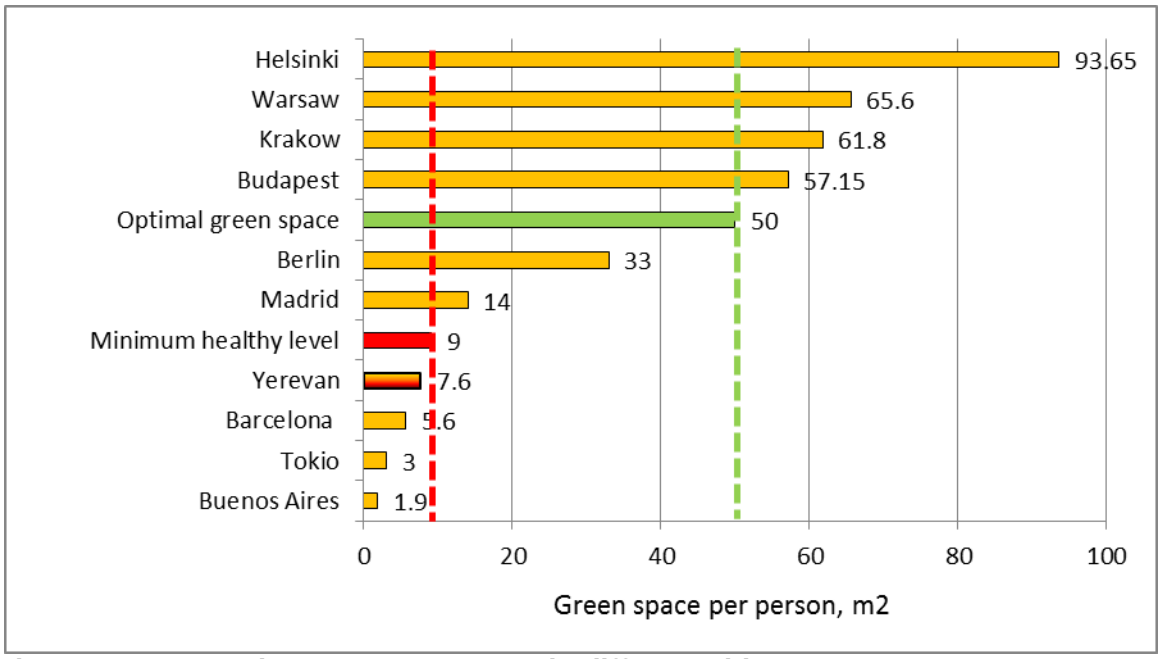



**Figure 7.3. Per capita green space area in different cities**

For development and expansion of green spaces the municipal services are using the rootstock raised in municipal greenhouse. The natural gas consumption by the municipal greenhouse, which has an area of 0.5 ha, was 79 thousand $m^3$ in 2012 (in 2014 the natural gas consumption figure reached the level of 97 thousand $m^3$), which a number of times exceeds the energy consumption standards of modern energy efficient greenhouses. Energy consumption data for the greenhouse in the period 2010-2012 is presented in Table 7.2 below.

*Table 7.2. Energy consumption by the municipal greenhouse in 2010-2012*

| Energy carrier | 2010 | 2011 | 2012 |
|---|---|---|---|
| **Electric energy (MWh)** | 17.5 | 28.3 | 36.9 |
| **Natural gas ($m^3$)** | 18,672.0 | 19,828.0 | 79,006.0 |
| **Total energy (MWh)** | 189.1 | 182.2 | 762.6 |

## 7.2 Energy Consumption and GHG Emissions of the Municipal Greenhouse

GHG emissions caused by the energy consumption of the municipal greenhouse that is used for servicing of the green spaces of the City are quite significant.

*Table 7.3. GHG emissions caused by the energy consumption of the municipal greenhouse in 2012*

| Energy carrier | GHG emissions (tonnes of CO2) |
|---|---|
| **Natural gas** | 146.6 |
| **Electric energy** | 8.2 |
| **TOTAL** | **154.8** |

## 7.3 Activities for Expansion of Green Spaces and Mitigation Measures for Addressing the Energy Consumption by the Greenhouse

The species of trees and plants used in recent years for landscaping purpose in the newly build districts, streets and highways (Isakov-Leningradyan, Saralange, Tevosyan, Davit Bek,

Yeghvard, Sevan, Argavand, and Ashtarak highways) of Yerevan fully correspond to modern landscaping requirements both in terms of aesthetical look and volume of the tree-crown.

### 7.3.1 Activity G.1. Expansion of Green Spaces

The total area of rehabilitated and newly planted parks in 2012 was equal to 190 ha (Figure 7.4). In 2013, during the spring planting season, around 30,000 trees and 10,000 bushes were planted in irrigated areas only. The survival rate for the planted trees was 72%.

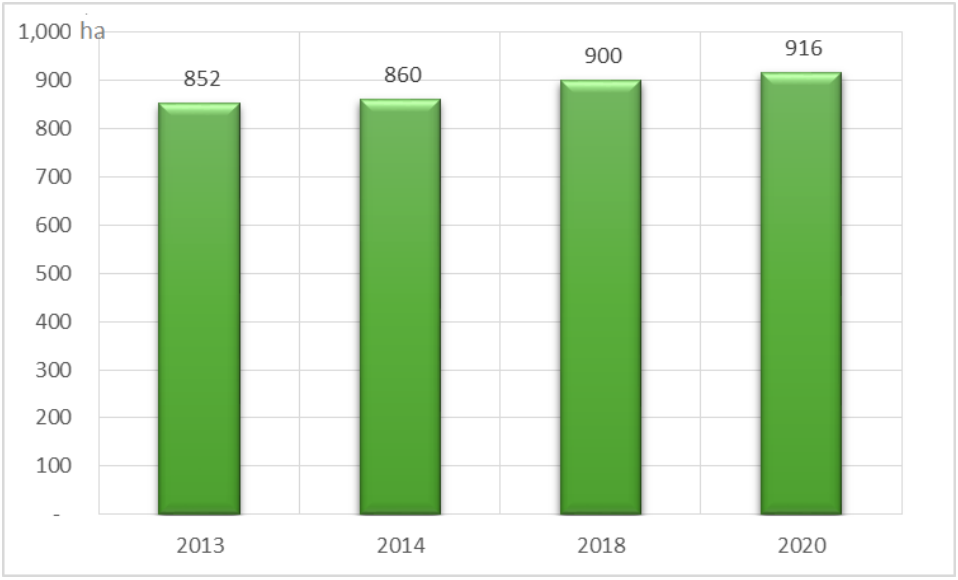



**Figure 7.4. Publicly open green spaces (ha)**

For continuous rehabilitation and expansion of green spaces the Municipality is actively implementing ongoing projects on tree planting, landscaping, and flowering since 2012. The situation is being gradually improved, green spaces are being developed, expanded and rehabilitated in such locations as Yerablur (2014), Paros Forest-Garden, Haghtanak Park (2015), Karmir Blur, Tsitsernakaberd (2016), forest-garden neighbouring the detour tunnel, Saralange (2017).

The publicly open green spaces of the Capital City in 2013-14 were already expanded to 852 ha.[34] Particularly:

- Around 20 ha of lawns, including on road lane separators, sidewalks, parks and public gardens were developed and/or rehabilitated,
- 54,000 trees and bushes were planted,
- 2,700,000 flower rootstock were provided for 7.2 ha flower beds of Yerevan, 120 decorative flower beds were planted,
- An irrigation network consisting of 12km of pipelines and 4 wells was build, enabling the irrigation of 50-55 ha of green space,
- Improvement work has been started in the public park at the section Mashtots Avenue – Saryan Street, including: planting of new trees, expansion of green spaces and restoring of lawns;
- Green spaces of recreational areas were increased by 6.2 hectares.

[34] See the Annual Report of the Yerevan Municipality for 2015

***Figure** 7.5. Images of green spaces in Yerevan*

The practice of using landscaping elements in road construction was successfully applied in Isakov-Leningradyan Highway Project, under which 4.5 hectares of new green spaces were created. To mitigate the negative impact of road transport emissions it was decided to apply this approach as regular practice. All in all 16.7 ha of modern green spaces were created in Yerevan–Sevan, Yerevan–Ashtarak, Yerevan–Yeghvard and Argavand highways, in Arshakuniats Avenue, as well as in Davit Bek and Tevosyan streets.[35]

The objectives of the Four-year Program for Development of Yerevan in 2014-2017 included the expansion of publicly open green spaces to 880 hectares. In the context of expansion of Yerevan's green spaces a program on rehabilitation and expansion of buffer zones in a number of location has been discussed and approved. The Program will be implemented in 2016-2020 and will incorporate large scale tree-planting activities in Paros, Tsitsernakaberd, Yerablur, Karmir Blur, Haghtanak and Tatul Krpeyan parks, in forest-gardens adjacent to Nor Nork Hayordats Tun and Champagne & Wine Factory, as well as in areas adjacent to Argavand Highway (Table **7.4**).

*Table 7.4. Expansion of green spaces; work done in 2013-2015 and plans for 2017-2020*

| | **Project title** | **Completed work** | | | **Planned work** | |
|---|---|---|---|---|---|---|
| | | **2013** | **2014** | **2015** | **2016** | **2017-2020** |
| **1** | **2** | **3** | **4** | **5** | **6** | **7** |
| **1** | **Rehabilitation and expansion of green spaces and forest-gardens in 2013-2020** | | | | | |
| **1.1** | Establishment and | 7.5 | 5.0 | 6.7 | | 15 |

[35] See the following reports on "Yerevan-2025" International Conference: "Prospects for Green Space Rehabilitation and Sustainable Development", by A. Martirosyan, Head of Nature Protection Department of Yerevan Municipality Staff
https://www.yerevan.am/uploads/media/default/0001/27/3b12c25878d24b06bbf48b2ae3765834bf281264.pdf

| | | | | | | |
|---|---|---|---|---|---|---|
| | rehabilitation of parks and public gardens /ha/ | | | | | |
| **1.2** | Lawn repair /ha/ | 12.0 | 12.0 | 12.5 | 12.5 | 60 |
| **1.3** | Planting of trees and bushes /count/ | 40,000 | 60,000 | 54,000 | 40,000 | 100,000 |
| **1.4** | Flowering /count/ | 2,000,000 | 2,200,000 | 2,500,000 | 2,700,000 | 3,000,000 |
| **1.5** | Planting of rose bushes /count/ | 12,000 | 40,000 | 20,000 | 40,000 | 100,000 |
| **2** | **Forest rehabilitation** | | | | | |
| **2.1** | Rehabilitation work | | Yerablur forest-garden, Paros forest-garden | Haghtanak Park | Karmir Blur, Tsitserna-kaberd | Saralange, Detour Tunnel area Park |
| **2.2** | Improvement of per capita green space area /$m^2$/ indicator | **7.0** | **7.6** | **7.8** | **8.0** | **9.0** |

This activity has been included in the list of mitigation measures with certain reservations. The mitigation impact of required investments expressed in tonnes of GHG emission reduction is indirect by its nature.

According to estimates, one hectare of forest, depending on the type of trees and bushes, during one sunny day can absorb from the atmosphere 120-280 kg of $CO_2$ and produce 180-200 kg of oxygen. Since the newly planted green spaces can reach that level of output only after a number of years[36] it can be assumed that by the year 2020 the average effective output of all the green spaces will be around 50% of the maximum estimated output. Thus, one hectare of such space will absorb around 100-120 kg of carbon dioxide in one day.[37]

Based on the actual data of tree-planting activity since 2012, and the estimates for the period 2016-2020, by the year 2020 the tree-covered area of the City will increase by 74 ha (916 ha in 2020, see Figure 7.4). Thus, considering the number of sunny and green days in Yerevan: 365-140=225 days, the amount of carbon dioxide absorbed annually can be assessed as follows:

$$M_{CO2} = 74 \cdot 225 \cdot 110 \cdot 10^{-3} = 1{,}831 \text{ tonnes of CO2}$$

*Table 7.5. Activity G.1. Green space expansion trends and expected results of planned activities*

| Source of financing, cooperating structures | Value, thousand Euros | Saving of energy carriers, MWh/year | | Emission reduction, tonnes of CO2/year | Investment years |
|---|---|---|---|---|---|
| | | Electrical energy | Natural gas | | |
| **YM, public and donor organizations** | 370.0 | 0 | 0 | 1,831 | 2013-2020 |

### 7.3.2 Activity G2. Improvement of Energy Efficiency of the Municipal Greenhouse

[36] This timing varies depending on the tree type.
[37] See the international methodology of calculation adjusted to Armenia conditions at: https://www.americanforests.org/assumptions-and-sources/#carbon

According to the data provided by the private sector, the use of modern technologies in greenhouses allow to achieve around 10-times reduction of the energy consumption and significant saving of irrigation water.[38]

›

Table 7.6 below draws a comparison between the municipal greenhouse and a model facility.

*Table 7.6. Comparison between the YM greenhouse and a model facility (for the present 0.5 ha area)*

| Parameters to compare | Present greenhouse | Efficient greenhouse | Energy saving potential |
|---|---|---|---|
| **Electric energy (MWh)** | 36.9 | 50 | - |
| **Natural gas ($m^3$)** | 79,006.0 | 9,000.0 | 70,006.0 |
| **Total energy (MWh)** | **725.8** | **82.7** | **643.1** |
| **GHG emissions (t $CO_2$)** | **154.8** | **27.8** | **129.9** |

The activities aimed at improving the energy efficiency of the municipal greenhouse, particularly the introduction of efficient heating system, can significantly reduce both energy and operation costs (annual saving = 70,000 $m^3$ of natural gas and around 11 million drams) and the greenhouse gas emissions.

*Table 7.7. Activity G2. Anticipated results from improvement of the energy efficiency of the municipal greenhouse*

| Source of financing, cooperating structures | Value, thousand Euros | Saving of energy carriers, MWh/year | | Emission reduction, tonnes of CO2/year | Investment years |
|---|---|---|---|---|---|
| | | Electric energy | Natural gas, thous. $m^3$ | | |
| **YM, public and donor organizations** | 455.0 | 0 | 643 | 130 | 2019-2020 |

## 7.4 Additional Proposals for Development of Green Spaces and Improvement of Energy Efficiancy

The following activities are for future development programs and therefore are not included in SEAP quantitative assessments and targets. Calculation of their impact will be practically possible only after implementation of a certain number of pilot projects; the mid-term programs of the Municipality do not include such projects yet.

Additional proposals for development of green spaces and introduction of energy efficient technologies include the following activities.

### 7.4.1 Use of Plant Shading for Reduction of Energy Consumption in Public Buildings

Shading can significantly reduce the temperature of shaded surfaces and following layers (up to $20^0$C).[39] Trees on the eastern, southern and western sides of a building reduce the energy demand of the building. The important thing is to select the right type of tree. The most

[38] Source: memo provided by the Armenian Harvest Promotion Center in 2015 for NEEAP development.
[39] See: A.Amirkhanyan, “Green Architecture: energy Efficiency and Renewable Energy”, 2015

appropriate are the deciduous trees that lose their leaves in autumn and winter opening up the way for solar radiation, while in spring they restore their green crown and produce shade. The trees growing near the buildings should be pruned to grow above the building and cover the roof with shade.

Climbing plants can also be used to protect the walls from solar radiation. The tradition in Armenia is to grow climbing vine for this purpose. The leaves of the climbing plants produce shade in summer. The most effective in this sense are the vertical gardens planted on south-western or western sides of buildings. Images and schematics of vertical gardens are provided in Figure 7.6 below.

Such vertical gardens are quite expensive since in addition to plants and media they require sophisticated irrigation and mounting techniques. In European countries a vertical garden can cost up to EUR 100-250 per square meter. Local governments apply this practice primarily for demonstration and awareness raising purposes. If applied in visible places, this practice can be replicated later by private sector.

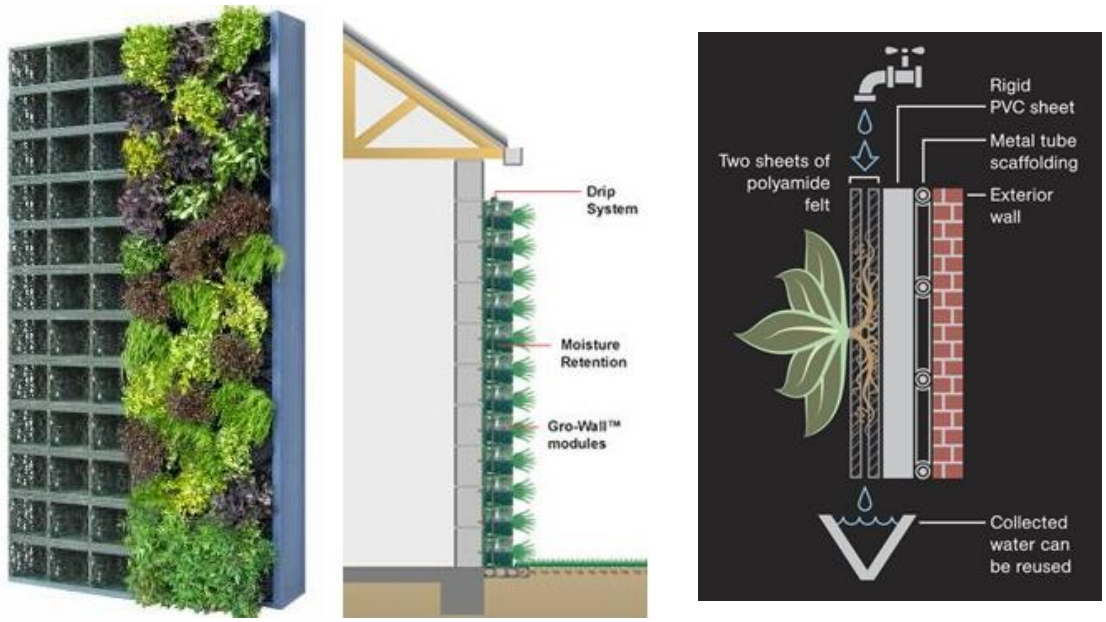



*Figure 7.6. The structure of vertical gardens*

### 7.4.2 Use of Green Roofs

The term “green roof” refers to a roof covered with soil and vegetation. Such roofs have a number of advantages, particularly they: filter rainwater and air from pollutants, reduce the flood flows, reduce the level of noise, create an environment for urban biodiversity. Green roofs are good also for energy efficiency; they keep the heat and reduce energy losses since the green roof layer works as an effective thermal insulator. In summer time they reduce the energy consumption on cooling, while in winter they keep the heat.[40]

## 7.5 Summary Data on the Activities in the Area of Green Spaces

The actual and anticipated results from activities in the area of green space management are summarized in Table **7.8** below.

*Table 7.8. Actual and anticipated results from activities in the area of green space management*

[40] See: A.Amirkhanyan, “Green Architecture: energy Efficiency and Renewable Energy”, 2015

| index | Activity | Source of financing, cooperating structures | Deadlines (start – end) | Estimated cost (thous. EUR) | Anticipated energy saving [MWh/year] | Emission reduction by 2020, tonnes of $CO_2$/year |
|---|---|---|---|---|---|---|
| **G.1** | Rehabilitation and expansion of green spaces and forests | YM | 2013-2020 | 370.4 | - | 1831.0 |
| **G.2** | Application of modern energy efficient technologies in the municipal greenhouse | YM | 2019-2020 | 454.5 | 643.1 | 129.9 |
| | Total | | | 824.9 | 643.1 | 1,960.9 |

# 8 Water-supply System

This section covers only the drinking water supply system and the water structures and fountains of the city. The irrigation system is covered by the "Green spaces and Municipal Greenhouse" section.

## 8.1 Drinking water supply

### 8.1.1 Energy Consumption by the Water-supply System

The water-supply system of the Capital City includes a distribution network with a total length of 1964 km, 23 daily storage reservoirs with a total capacity of 223,5 thousand $m^3$, water mains with a total length of 803 km, 9 water sources, 103 water intake facilities, 81 artesian wells, 5 big pumping stations and 29 boreholes.[41]

Water-supply and wastewater collection services in Yerevan are provided by Yerevan Jur Utility which was established further to a lease contract signed between the government of the Republic of Armenia and the French Veolia Eau - Compagnie Generale des Eaux. This is one of the successful examples of public-private partnerships in Yerevan. Yerevan water-supply system is used to supply drinking water to 332,750 subscribers representing a population of 1,100,000.

During the years of the lease contract the water-supply and wastewater collection systems of the city improved significantly, they became more efficient and manageable. Significant achievements were observed in the areas of pressure zoning of the distribution network, network management, commercial management of the services, prevention of breakages, leakages and illegal connections, and as a result of all these – the improved quality of services, particularly in terms of duration of water supply. These results are presented in Table 8.1 and show a significant energy consumption reduction trend; reduction of energy consumption was one of the performance criteria under the World Bank's Yerevan Water & Wastewater Project (2006-2011).

Yerevan Municipality's Water Structures Company operates and maintains 30 water structures in the city, including 14 fountains, 8 pools, Yerevanyan Reservoir and the Karapi Lich skating rink.

[41] See at: https://www.yerevan.am/am/communal-services/

**Figure 8.1. Water decorations of the capital city: fountains and pools**

To ensure the smooth operation and the proper aesthetical look of water structures hundreds of pumps and lights are kept operating 200-365 days a year. Table 8.1 below provides data on energy consumption of water systems in 2012.

*Table 8.1. Energy consumption by water systems; years 2010-2012*

| Systems | Energy consumption (MWh) | |
|---|---|---|
| | 2011 | 2012 |
| **Yerevan water systems, including:** | **86,200** | **54,800** |
| **Drinking water supply system** | 54,900 | 38,100 |
| **Water structures** | 1,353 | 1,386 |
| **Wastewater collection, irrigation systems** | 29,947 | 15,314 |

It should be noted that only the issues related to energy consumption by drinking water supply systems and water structures were studied carefully within SEAP framework. Lack of data on irrigation and wastewater collection systems limited the possibilities for an inclusive study in these areas.

## 8.2 GHG emissions caused by the operation of the water-supply system

*Table 8.2. GHG emissions caused by the operation of water systems in 2012*

| System | Emissions (tonnes of $CO_2$) |
|---|---|
| **All water systems of Yerevan, including:** | 12,166 |
| **Drinking water supply system** | 8,460 |
| **Water structures** | 308 |
| **Wastewater collection, irrigation systems** | **3,397** |

## 8.3 Mitigation measures in water systems

### 8.3.1 Activity W.1. Mitigation measures in water-supply system

Modernization of the water-supply system of Yerevan is a long-term continuous process. The implementation of programs for improvement of system management and application of best international practices continued also after 2012. For this purpose Yerevan Jur Utility initiated two new credit programs that started in 2014-2015 with the financial assistance of the French Government and the European Bank for Reconstruction and Development.

- The operator developed and implemented a set of interrelated measures to reduce energy consumption in the water supply system, including:

  The 11.59 million EUR project on rehabilitation and improvement of the water supply and wastewater collection networks (completed in 2015). The project include the replacement of

- 107,027 m of corroded distribution pipes and installation of 6,278 water-meter boxes in Noragavit, Shahumyan /Akhparashen/, Kilikia, Kanaker-Zeitun and Davtashen districts of Yerevan.
- The 1.77 million EUR project on installation of remote control temper-proof flow management system (SCADA) in the entire distribution network of the City; the purpose of the system is to prevent breakages and increase the reliability of the network by improving the pressure and flow management.
- The 21 million USD Program (including both credit and grant components) on Priority Investments for Improvement of Water Supply in Yerevan (EBRD - 7 million USD, EIB - 7 million USD, EU Neighborhood Investment Facility (NIF) - 7 million USD grant).
- The EBRD 3-year Program on Improvement of Water-supply in Yerevan initiated on July 19, 2013, further to the Credit Agreement signed between Government of Armenia and the ENRD. The Program includes activities on replacement of around 152 km of network pipes, construction of 30 new booster pumping stations, and repair of individual connections and meter-boxes. Part of the work has been already completed.[42]

As a result of these activities implemented in 2013-2015, the annual energy consumption in the system was reduced by 13,511 MWh. It is expected that the activities planned for 2016-2017 will further increase the annual savings to 14,606 MWh. As we can see from Figure 8.2 below, since the inception of improvement programs in 2012, the energy consumption was reduced by 35% compared to the base year.

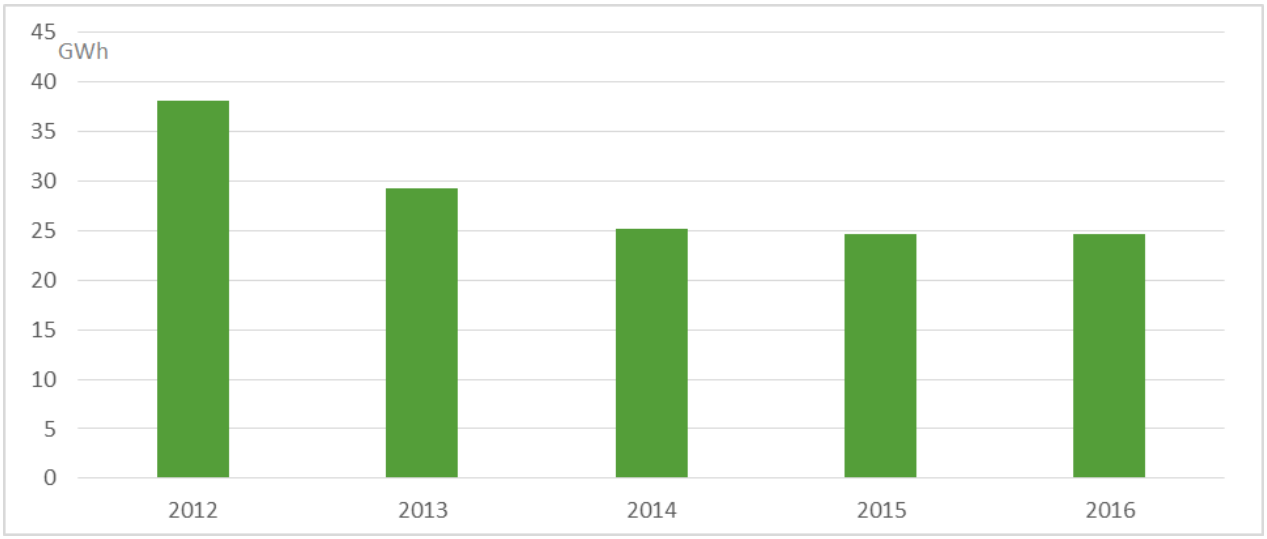



**Figure 8.2. Energy consumption in the drinking water supply system in 2010-2016 (million KWh)**

Table 8.3 below presents the anticipated results from energy saving and emission reduction activities by the year 2020.

*Table 8.3. Activity W.1. Anticipated results from mitigation measures in water-supply sector of Yerevan by 2020*

| Source of financing, cooperating structures | Value, thousand Euros | Saving of energy carriers, MWh/year | Emission reduction, tonnes of CO2/year | Investment years |
|---|---|---|---|---|
| | | Electric energy | | |

[42] The work will be continued until the end of the 10-year agreement in 2017; after that a single operator will be selected and licensed for management of water-supply systems in Yerevan and the rest of the country. Next steps for improvement of the system will be decided with participation of the new operator.

| | | | | |
|---|---|---|---|---|
| **YM, Yerevan Jur, EBRD, EIB, NIF, French Government** | 44,000.0 | 13,510 | 2,999 | 2013-2020 |

### 8.3.2 Activity W.2. Reduction of Energy Consumption in Water Structures and Fountains

Water Structures Company of Yerevan Municipality and Yerevan Jur Utility carried out activities on current repair and improvement of water structures and drinking water fountains. To increase the efficiency of water structures 100 energy efficient lamps were purchased and installed in the period 2013-2015; only this allowed to reduce the annual energy consumption by 25 MWh. The energy efficiency measures will be continued until 2020. The planned activities include:

- Replacement of 40 spotlights with LED luminaires, and
  Replace at least 10 out of 123 pump motors.
- The following additional activities may be required as well:
- Modernization of old and inefficient pump motors;
  Modernization of power supply lines of pumps and lights;
- Replacement of existing power transformers with less powerful ones following the installation of energy efficient lams and pump motors;
  Comprehensive energy audit.

The aggregate impact of the planned activities is presented in the table below.

*Table 8.4. Activity W2. Anticipated results from mitigation measures in water structures and fountains of Yerevan by 2020*

| Source of financing, cooperating structures | Value, thousand Euros | Saving of energy carriers, MWh/year | Emission reduction, tonnes of CO2/year | Investment years |
|---|---|---|---|---|
| | | Electric energy | | |
| YM, Water Structures CJSC, EBRD, IFI | 53,320 | 408 | 91 | 2013-2020 |

## 8.4 Summary Data on Mitigation Measures in the Water Supply Sector

The actual and anticipated results from activities in the area of water-supply, including the operation of water structures, are summarized in Table **10.14** below.

*Table 8.5. Anticipated results from mitigation measures in water-supply sector*

| Index | Activity | Source of financing, cooperating structures | Deadlines (start – end) | Estimated cost (thous. EUR) | Anticipated energy saving [MWh/year] | Emission reduction by 2020, tonnes of $CO_2$/year |
|---|---|---|---|---|---|---|

| | | | | | | |
|---|---|---|---|---|---|---|
| **Activity W1.** | Reduction of water losses and improvement of management in the drinking water supply system of Yerevan | YM, Yerevan Jur, EBRD, EIB, NIF, French Government | 2013-2020 | 44,000 | 13,510 | 2,999 |
| **Activity W2.** | Improvement of energy efficiency of water structures and fountains | YM, Water Structures CJSC, IFI | 2013-2020 | 53,320 | 408 | 91 |
| | **Total** | | | **97,320** | **13,918** | **3,090** |

# 9 Intersectoral, Horizontal Activities

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

## 9.1 Activity H.1. Municipal Energy Planning and Management

The energy manager will be appointed by the municipality and, within the scope of his or her powers, will be responsible for the implementation of the energy policy of the Municipality and will be entitled to perform the following functions:

1. Create an energy information system and ensure its regular updating, analysis and monitoring;
2. Monitor the state of municipal electricity consumers, the amount of fuel and energy consumed by them;
3. Submit periodic analytical reports and recommendations on energy consumption tendencies;
4. Initiate and develop projects related to efficient use of energy, and co-operate 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 the energy consumption of buildings;
6. cooperate with the mass media, private companies and the population in all aspects of energy efficiency to ensure the SEAP visibility and participation, promote initiatives such as the Municipal Energy Days, “Earth Hour”, Car-Free Days/No $CO_2$ Emissions Days, etc.;
7. Involve, if necessary, external consulting services in municipal SEAP implementation, improvement, monitoring processes and other activities requiring professional qualification;
8. Negotiate on behalf of the municipality, consolidate, organize and coordinate daily SEAP activities of foreign labour, project implementation units.

A permanent SEAP task force will be formed from the relevant departments of the Municipality that will provide 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. 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 the SEAP monitoring and provide two-year reporting.

*Table 9.1. Activity H.1. Municipal Energy Planning and Management*

| Possible source of financing, cooperating partners | Value, thousand Euros | Energy carriers saving, MWh/year | $CO_2$ emissions reduction, tonnes | Investment years |
|---|---|---|---|---|
| YM | 100.0 | N/A | N/A | 2017-2020 |

## 9.2 Activity H.2. "Green Procurements" 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 specifying energy efficiency criteria for the products or services procured apart from the principle of low price; for example, when procuring lighting lamps it is necessary to specify the lamp power (W), the amount of light falling on an illuminated surface (lux or lumen/$m^2$), the term of service (thousand hours), or 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 account of municipal funds.

Likewise, prior to design and cost estimation activities 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 are already defined in the RA current legislation (the RA Law "On Energy Efficiency and Renewable Energy", norms and conditions on construction thermo-physics, Decision of the RA Government on approving the procedure for energy expert examination, the RA Standard on energy performance assessment of buildings, certification and labelling, etc.).

The following are necessary for procurement planning:

1. Conducting mandatory energy audits for reconstruction, capital repair and construction of buildings;
2. Specifying and following minimum energy consumption norms and standards by using minimum quality and comfort criteria for every public building or service, such as W/$m^2$ norm for lighting, kW/$m^2$/year norm for thermal energy demand, W/lux/$m^2$ norm for street lighting, etc.);
3. Involving professional services in the initial stage of organising competitive bidding procedures to develop technical specifications, terms of references and/or project orders with verifiable and measurable energy efficiency criteria, such as term of service of lamps, quality of the light emitted, colour, temperature, boiler efficiency, heat transfer coefficient of the wall constructed and so on.

Monitoring of luminaires in terms of their quality and effectiveness will be carried out by the laboratory created with support from UNDP.

*Table 9.2. Activity H.2. "Green Procurements" rules and procedures, inclusion of energy audit in the process of procurement planning*

| Possible source of financing, cooperating partners | Value, thousand Euros | Energy carriers saving, MWh/year | $CO_2$ emissions reduction, tonnes | Investment years |
|---|---|---|---|---|
| YM | 25.0 | N/A | N/A | 2017-2020 |

## 9.3 Activity H.3. Energy Performance Certification of Buildings

The objective of introducing energy certification of buildings is to determine the actual energy intensity of buildings and identify the existing potential for achievable energy saving. This requires monitoring and inspection of buildings, using standardized methods for assessing the external technical condition of the building or other contemporary devices recording the intensity of infrared radiation (thermal imaging or infrared cameras) and identifying the thermal protection value of building envelopes.

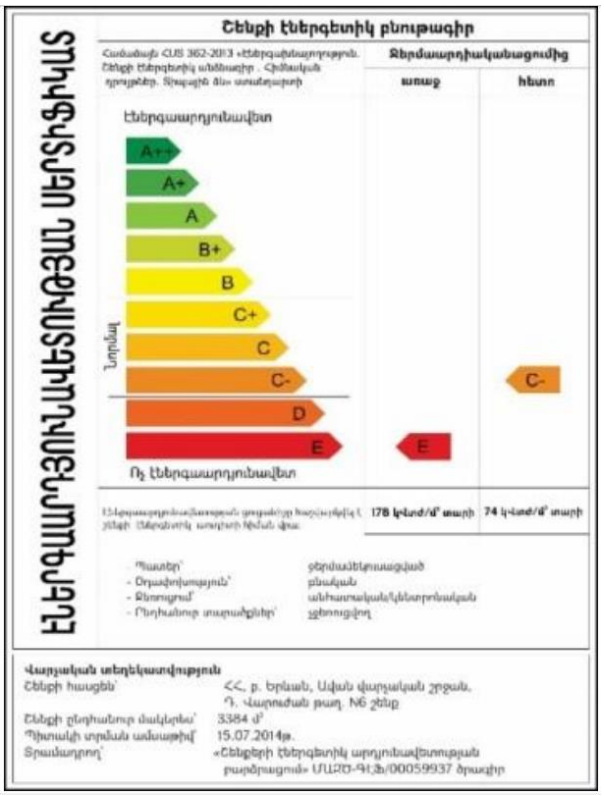



Figure 9.1∃ Sample of energy performance certificate, energy performance rating of building of No 6 in Daniel Varouzhan Street in Avan administrative district of Yerevan

The energy performance certificates enable to assess the baseline condition in terms of improving the thermal protection qualities and the internal lighting system before and after the implementation of energy saving measures. For the purposes of certification the administrative districts will be required to recruit qualified specialists and use appropriate measuring devices. One of the advantages in this situation 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 these buildings. In the course of development of certificates the National Standard “Energy efficiency. Building energy passport. Main provisions. Typical forms” (AST 362-2013) will be taken into consideration.

In addition to being a verification of energy efficiency the energy performance certificate is also an effective tool in building public awareness on the value of the construction in the real estate market. Presumably, after learning about energy certificates every resident of the city will be involved in the processes of energy saving measures and will save electricity consumed on lighting for about 5 minutes per day, and natural gas used for domestic purposes for the same duration. Hence, in view of this we can speak about

$5\ րոպե \cdot 365 օր/24 ժամ/60 րոպե = 1.267$ full day per year.

The volume of electrical energy annually consumed by the population amounts to 193.7 GWh. Around 18% of this amount, *i.e*., 34.87 GWh, is consumed for lighting, which on a daily basis is equal to 95.52 MWh/day. Therefore, the amount of annual electricity savings will be equal to:

$$\Delta E = 1.267 \cdot 95.52 = 121.02 \text{ MWh/year.}$$

On the same principle, assuming that the activity will involve around 60% of the city population, and given the fact that the natural gas consumption volume by the population amounts annually to 443.59 GWh and daily to 1215.3 MWh, the following result will be outlined:

$$\Delta B = 1.267 \cdot 0.60 \cdot 1215.3 = 923.87 \text{ MWh/year.}$$

*Table 9.3. Activity H.3. Evaluating Results of Energy Performance Certification of Buildings, 2020*

| Possible source of financing, | Value, thousand | Energy carriers saving, MWh/year | $CO_2$ emissions reduction, | Investment years |
|---|---|---|---|---|

| cooperating partners | Euros | Electrical energy | Natural gas | tonnes | |
|---|---|---|---|---|---|
| YM, other partners | 34.0 | 121.0 | 923.9 | 213.5 | 2018-2020 |
| | | 1,045 | | | |

## 9.4 Activity H.4. Participation in "Earth Hour" Global Campaign

In various countries of the World this event is usually organized in early March each year and is aimed at raising public awareness on the importance of energy saving. Every year on that day Yerevan, after joining this initiative in 2010, turns off for one hour the street lighting of the city thus saving 17.1 MWh of energy and preventing 3.8 tonnes of $CO_2$ emissions. One of the other objectives of this event is to demonstrate to the population the energy efficiency value of this joint effort when this is just about a joint energy-saving initiative held every year only 1 hour of a single 1 day a year. Moreover, besides street lighting, budget-funded institutions will also join this initiative by turning off power supply for 1 hour subject to strict compliance with safety rules. Effectively organised awareness measures will promote the population and the private sector to join this initiative.

For assessing the hourly consumption rates of consumer groups the following has been taken as a basis:

1. 70% of daily average electricity consumption by the population occurs within 10 hours,
2. 95% of daily electricity consumption by budget-funded institutions occurs within 8 hours;
3. 100% of street lighting occurs within 5 hour.

Thus, proceeding from this assumption and taking into account the average daily consumption volumes of electrical energy by consumer groups, the following values have been arrived at in terms of energy efficiency:

- population — $0.7 \cdot 95.52/10 = 6.686$ MWh,
- budget-funded institutions — $0.95 \cdot 19810/260/8 = 9.048$ MWh,
- street lighting — $1.0 \cdot 31300/365/5 = 17.1$ MWh.[43]

Thus, subject to full participation of the population, this event will enable to achieve 32.9 MWh of electricity saving.

*Table 9.4. Activity H.4. Evaluating Results of Participation in "Earth Hour" Global Campaign, 2020*

| Possible source of financing, cooperating partners | Value, thousand Euros | Energy carriers saving, MWh/year | | Reduction of emissions, tonnes of $CO_2$ | Investment years |
|---|---|---|---|---|---|
| | | Electrical energy | Natural gas | | |
| YM | 6.0 | 32.9 | - | 7.3 | 2017-2020 |

## 9.5 Activity H.5. Participation in European Sustainable Energy Days Event

43 According to the UNDP / GEF " Green Urban Lighting" project assessment, the installed power capacity of municipal lighting systems of Yerevan is 15 MW, and annual consumption of electrical energy amounts to 31,3 million kWh, which is equivalent to 17.15 MWh in case of operation for 5 hours.

The participants of the event include the population and budget-funded institutions, which mostly use electrical energy and natural gas. Energy saving should be achieved by a amore caring attitude towards energy sources especially when using it in food preparation, for household electrical appliances and internal lighting systems. Such days are held within the European co-operation framework and also under the “Covenant of Mayors” initiative.

The “Sustainable Energy Days” event includes numerous mechanisms which may take any creative and innovative format. The following may be proposed as a few examples:

1. Organisation of outdoor Sustainable Energy expos in Yerevan administrative districts on non-working days in the main walk areas of ADs (for example, it may be the Northern Avenue in Kentron AD). The Expo stands may be equipped by manufacturers and importers operating in the Republic of 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, use of renewable energy, etc.).

2. The municipality may acquire or rent an expo bus or truck and equip it as an “Eco-Bus” or “Energy Bus”. Using thematic mobile eco-pavilions is not a new idea, and many such “pavilion-buses” are currently touring various cities in Europe and North America. In cooperation with technical universities this bus will be decorated to have an attractive design, equipped with modern energy efficient construction materials and household appliances, students will be involved who undergo on-the-job training and following a relevant guidance will be able to demonstrate and interpret the opportunities of contemporary energy efficient technologies and alternative energy sources, materials accessible in the market, ways of using them (for example, energy efficient lamps, thermal insulation, solar water heaters, etc.). The bus will be touring in residential districts on non-working days and raising awareness of the population. The items exhibited in the bus will be updated regularly with the aim of maintaining the high efficiency level of the event. This event may be organized also with the involvement of the private sector. Technology suppliers may participate in terms of commercial advertising by providing additional supplies to be exhibited in the bus.

It is assumed that 80% of Yerevan residents are informed about and apply energy saving measures which are implemented only on weekdays and include saving of electricity and natural gas for up to 5 minutes. In this case on the annual basis the event will last:

$$5 \cdot 260/60/24 = 0.903 \text{ full day.}$$

The average daily electricity consumption by the population of Yerevan is equal to 2390.6 MWh/day, this amount is equal to 6016.3 MWh/day in case of natural gas, and 76.18 and 147.89 MWh/day respectively in case of budget-funded institutions (260 is taken as the number of working days). Thus, the amounts of saved electricity and natural gas will be equal to:

1. on the part of population — $0.8 \cdot 0.903 \cdot 2390.6 = 1728.0$ MWh of electrical energy and $0.8 \cdot 0.903 \cdot 6016.3 = 4346.16$ MWh of natural gas,
2. on the part of budget-funded institutions $0.903 \cdot 76.18 = 68.79$ MWh of electrical energy and $0.903 \cdot 147.89 = 133.55$ MWh of natural gas.

*Table 9.5. Activity H.5. Evaluating Results of Participation in European Sustainable Energy Days Event, 2020*

| Possible source of financing, cooperating partners | Value, thousand Euros | Energy carriers saving, MWh/year | | Reduction of emissions, tonnes of $CO_2$ | Investment years |
|---|---|---|---|---|---|
| | | Electrical energy | Natural gas | | |

| | | | | | |
|---|---|---|---|---|---|
| YM | 15.0 | 1,796.8 | 4,479.7 | 1,302.9 | 2017-2020 |

## 9.6 Activity H.6. Involvement of Schools in Sustainable Urban Energy Development Processes

### 9.6.1 Activity H.6.1. Involvement of Schools in Sustainable Urban Energy Development Programs

The purpose of a sustainable energy related event is to build responsible and careful attitude in schoolchildren towards energy and the nature in general, and accordingly such events pursue more future-oriented targets. The event implies creation of the so-called monitoring groups in schools that will participate in “soft measures” development, organization and implementation activities. Various participation formats have been widely used in such programs, such as “school energy auditors squads”, “energy police”, “sustainable energy theatre”, “green school”, “energy efficient schools competition”, “energy efficiency patrol” and other creative formats, and the schoolchildren themselves will actively be involved in choosing one of them

The total number of school-age children comprises about 17% of the urban population according to data of the National Statistical Service of Armenia, or 170 thousand citizens. Supposing that at least 80% of the population is to some extent related to children’s school life (the average number of family members = 3.6), the total number of such citizens will make $170000 \cdot 3.6 \cdot 0.8 \approx 490$ thousand people or 48% of the population of Yerevan. If we assume that these citizens during the day will initiate full saving of electricity and natural gas for at least 5 minutes, then on a yearly basis we can talk about

$$5 \cdot 365/60/24 = 1.267$$ full days.

The energy and environmental calculations of energy and natural gas saving results show the following:

1. electrical energy savings —$1.267 \cdot 0.48 \cdot 2390.6 = 1453.87$ MWh,
2. natural gas savings — $1.267 \cdot 0.48 \cdot 6016.3 = 3658.87$ MWh.

Such events in technologically more advanced format may be carried out among students.

### *9.6.2* Activity H.6.2. Holding Out-of School Activities at Schools on Energy saving and Renewable Energy

Since 2014 the Yerevan Municipality cooperates with the Acopian Center for the Environment of the American University of Armenia in implementation of the “Natural Environment and I” educational program. The program is implemented among middle and high school students from schools throughout Yerevan is aimed at encouraging students to develop a broad appreciation of local, regional, and global environmental issues and to develop capabilities in addressing some of the environmental challenges either as individuals or as a group.

The main goal of the program is to build a more caring attitude among students towards natural resources, which will contribute to the successful implementation of the above-mentioned measures and achievement of the expected effectiveness.

However, the benefits of this initiative will presumably equal to 50% of effectiveness of the European Sustainable Energy Days event with the involvement of less investments.

*Table 9.6. Activity H.6. Evaluating results of Involvement of Schools in Sustainable Urban Energy Development Programs, 2020*

| Possible source of financing, cooperating partners | Value, thousand Euros | Energy source saving, MWh/year | | Reduction of emissions, tonnes of $CO_2$ | Investment years |
|---|---|---|---|---|---|
| | | Electrical energy | Natural gas | | |
| YM, schools, Universities NGOs | 33.5 | 2,253.9 | 5,858.9 | 1,683.9 | 2018-2020 |

## 9.7 Activity H.7. Organising Seminars and Training Courses for Specialists of Budget-Funded Institutions, Enterprises and Companies

The event focuses on relatively new and inexperienced employees, energy managers of institutions, enterprises and companies in terms of raising awareness, development of professional skills and exchange of experience.

Such targeting will fundamentally uphold the opportunities and necessity of energy saving and will enable the involved specialists to develop more substantiated and feasible proposals in the energy efficiency improvement and renewable energy fields.

The direct and immediate assessment of the energy and environmental outcomes of the measure is impossible. Presumably it will have the same quantitative result as the previous measure.

*Table 9.7. Activity H.7. Evaluation of Results of Organising Seminars and Training Courses for Specialists of Budget-Funded Institutions, Enterprises and Companies, 2020*

| Implementing entity | Value, thousand Euros | Energy carriers saving, MWh/year | | Reduction of emissions, tonnes of $CO_2$ | Investment years |
|---|---|---|---|---|---|
| | | Electrical energy | Natural gas | | |
| YM | 7.0 | 800.0 | 2,200.0 | 622.0 | 2018-2020 |

## 9.8 Consolidated Data of Horizontal Activities

Investment indicators of the “soft” measures targeted to the reduction of greenhouse gas emissions, the overall energy and environmental results are summarized Table 9.8.

*Table 9.8. Key Results of Cross-cutting (intersectoral) “Soft” Measures*

| No | Activity | Source of financing, cooperating structures | Implementation timeframe (start - end) | Estimated value (thousand Euros) | Expected energy saving (MWh/year) | Expected reduction of emissions, tonnes of $CO_2$, 2020 |
|---|---|---|---|---|---|---|
| **H.1.** | Municipal Energy Planning | YM | 2017-2020 | 100 | - | - |
| **H.2** | Introducing “Green Procurements” Rules | YM | 2017-2020 | 25 | - | - |

| | | | | | | |
|---|---|---|---|---|---|---|
| **H.3.** | Energy Performance Certification of Buildings | YM, other partners | 2018-2020 | 34 | 1,045 | 213 |
| **H.4** | Participation in “Earth Hour” Global Campaign | YM | 2013-2020 | 6 | 33 | 7 |
| **H.5.** | Participation in European Sustainable Energy Days Event | YM | 2017-2020 | 15 | 6,277 | 1,304 |
| **H.6** | Involvement of Schools in Sustainable Urban Energy Development Processes | YM, schools, Universities, NGOs | 2018-2020 | 34 | 8,113 | 1,684 |
| **H.7** | Organising Seminars and Training Courses for Specialists of Institutions, | YM | 2018-2020 | 7 | 3,000 | 622 |
| **Total** | | | | 221 | 18,467 | 3,830 |

# 10 Housing Sector

In order to meet the urgent housing maintenance costs the Municipality makes certain investments which indirectly lead to energy-saving effect. Maintenance and further operation of the capital's housing sector are among the priorities of the city authorities, and this is the rationale for the growing amount of financing provided every year from the municipal budget for covering the needs of condominiums. Thus, as stated above in the SEAP, this is the reason that the SEAP covers mitigation measures in the housing sector, but that sector is not a part of the baseline inventory of GHG emissions and mitigation targeting.

## 10.1 Urban Housing Stock

The quantitative indicators of the housing stock of Yerevan for 2010-2012 according to forms of management and administrative districts are shown in Tables 10.1 and 10.2. Multi-apartment buildings comprise about 62% of the housing stock of the capital. More than 96% of them are managed by condominiums, trusts and fiduciary managers. The share of housing stock managed by the municipality is gradually reducing as provided for by the public policy in the field of privatization of the housing stock, MAB management.

*Table 10.1. Quantities and total surface areas of apartments in multi-apartment buildings, and of residential houses (private houses)*

| | Housing stock of residential houses | | MAB stock | | |
|---|---|---|---|---|---|
| **Year** | **Count, unit** | **Total surface area, thousand m²** | **Quantity of buildings** | **Quantity of apartments, unit** | **Total surface area, thousand m²** |
| **2010** | 51,792 | 8,444 | 4,731 | 228,666 | 14,429 |
| **2011** | 54,726 | 8,783 | 4,729 | 228,880 | 14,524 |
| **2012** | 55,626 | 8,920 | 4,746 | 230,138 | 14,727 |
| **of which:** | | | | | |
| **(a) managed by condominiums** | | **2010** | 108 | 5,138 | 329,131 |
| | | **2011** | 85 | 4,294 | 282,971 |
| | | **2012** | 75 | 3,024 | 202,980 |
| **(b) managed by condominiums, trust and licenced managers** | | **2010** | 4,623 | 223,528 | 14,100 |
| | | **2011** | 4,644 | 224,586 | 14,241 |
| | | **2012** | 4,671 | 227,114 | 14,524 |

The largest number of multi-apartment buildings (MAB) are located in Kentron administrative district comprising 15.7% of the total number MABs, the smallest number of MABs are in Nubarashen administrative district comprising 0.7% of the total (see Figure 10.1).

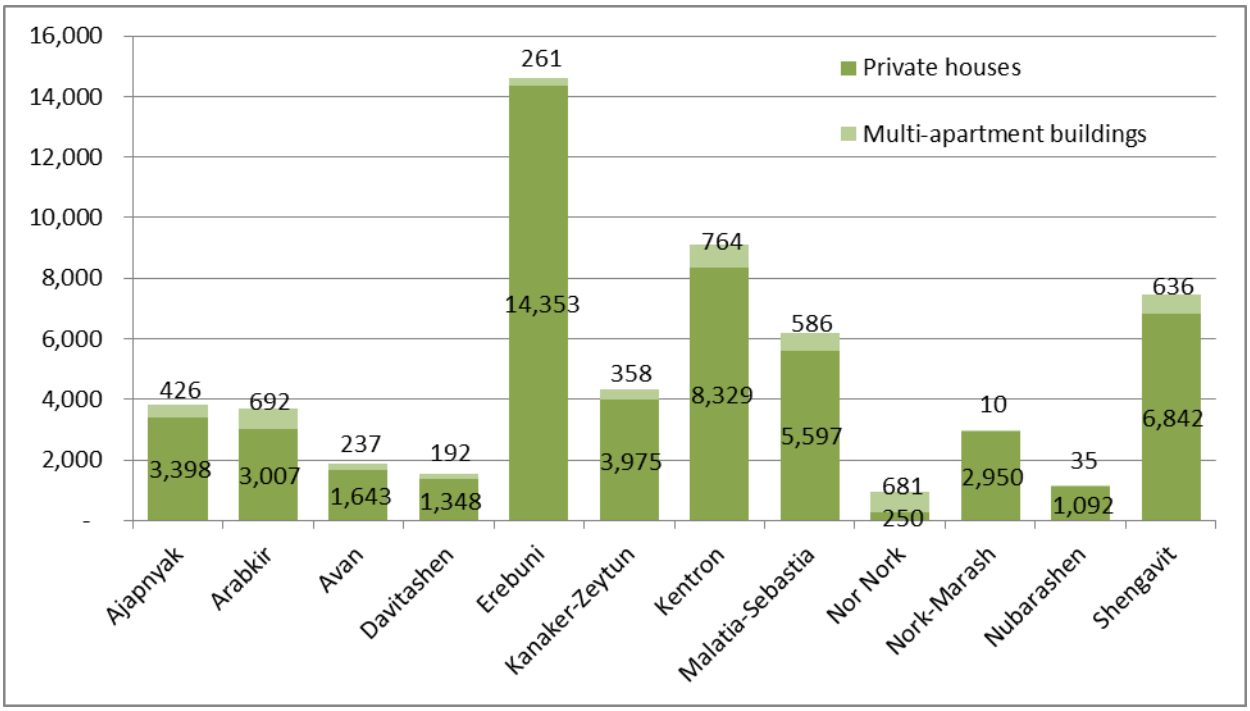



*Figure 10.1. Number of buildings/constructions by administrative districts,* **2015**

During the years of 2010-2012 the housing stock of has increased by approximately 2%, while the housing stock multi-apartment buildings — by 0.8 percent. In general, the average growth of the housing stock in the municipality of Yerevan in those years was 1.27%/year.[44]

*Table 10.2. The number of multi-apartment buildings by administrative districts (including buildings of hostels) by the end of the year, 2010-2012*

| Administrative district | 2010 | 2011 | 2012 |
|---|---|---|---|
| **Ajapnyak** | 425 | 425 | 426 |
| **Avan** | 239 | 240 | 240 |
| **Arabkir** | 667 | 667 | 673 |
| **Davitashen** | 186 | 186 | 188 |
| **Erebuni** | 263 | 262 | 262 |
| **Kentron** | 722 | 731 | 728 |
| **Malatia-Sebastia** | 580 | 580 | 583 |
| **Nor Nork** | 668 | 669 | 669 |
| **Nork-Marash** | 9 | 10 | 10 |
| **Nubarashen** | 37 | 37 | 37 |
| **Shengavit** | 626 | 626 | 626 |
| **Kanaker-Zeytun** | 359 | 360 | 360 |
| **Total** | 4,781 | 4,793 | 4,802 |

*Source: National Statistical Service*[45]

[44] Source: Statement of imformation provided by the Public Utilities Department of the Staff of the YM as of 09.03.2015, and NSS 2015.

[45] The data on the housing stock provided by the YM slightly differ from the data of the National Statistica Service due to the difference of reporting formats. The authors used the data of the YM, with the exception of cases when the data of the required format were present only in NSS documents.

*Table 10.3. Number of buildings/houses and apartments in Yerevan by administrative districts, as of 2015*

| Municipality/Administrative district | Total quantity | | |
|---|---|---|---|
| | MAB | Apartments | Private houses |
| | | | |
| **Ajapnyak** | 426 | 32,800 | 3,398 |
| **Avan** | 237 | 10,851 | 1,643 |
| **Arabkir** | 692 | 34,300 | 3,007 |
| **Shengavit** | 636 | 26,809 | 6,842 |
| **Malatia-Sebastia** | 586 | 27,229 | 5,597 |
| **Erebuni** | 261 | 13,455 | 14,353 |
| **Nubarashen** | 35 | 4,664 | 1,092 |
| **Kanaker-Zeytun** | 358 | 15,447 | 3,975 |
| **Davitashen** | 192 | 9,013 | 1,348 |
| **Kentron** | 764 | 29,056 | 8,329 |
| **Nor Nork** | 681 | 32,700 | 250 |
| **Nork-Marash** | 10 | 179 | 2,950 |
| **Yerevan municipality – total, from which:** | 4,878 | 236,503 | 52,784 |
| ***Information is provided by the Public Utilities Department of the Staff of the YM, as of 09.03.2015** | | | |

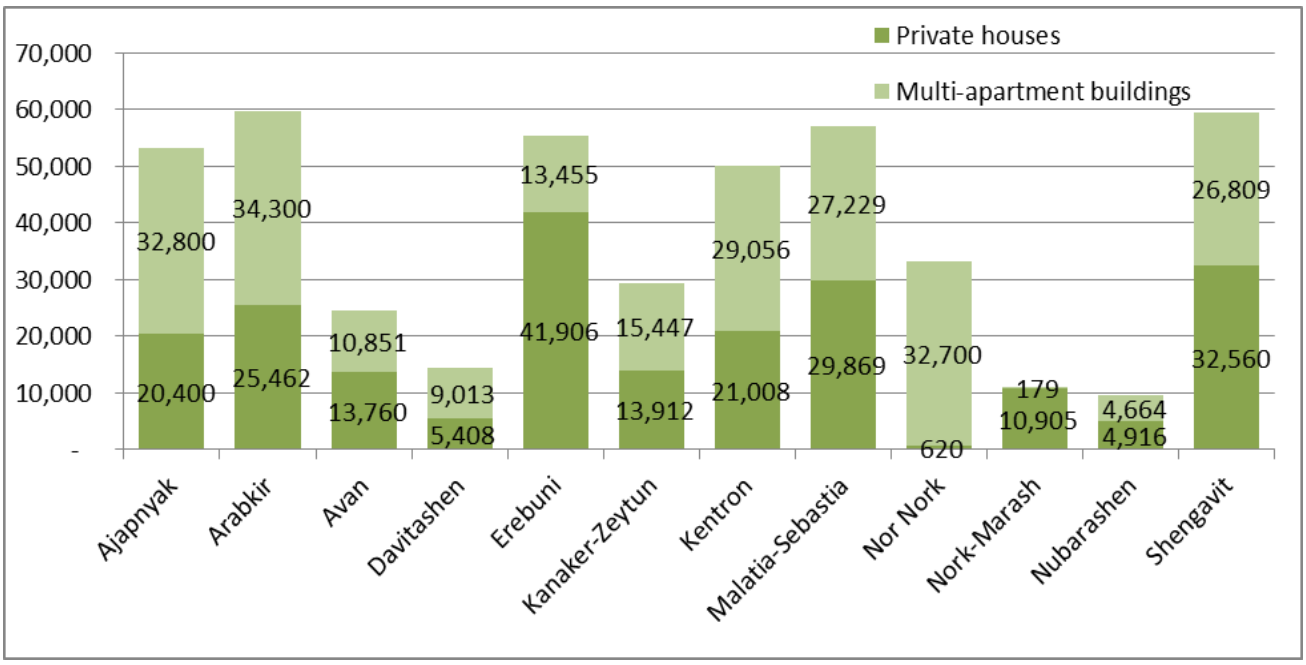



*Figure 10.2. Number of apartments by administrative districts and the type of buildings, 2015*

The major part of the multi-apartment building stock is of more than 30 years of age. Almost 30% of multi-apartment buildings are built by using panel or monolithic concrete. As shown in figure 10.3, almost 40% of the total housing stock has been in service for more than 40 years. Private houses that make up one third of the total residential area are relatively well preserved. Scarce financial resources targeted to maintenance and restoration of the housing stock of the City of Yerevan resulted in reduction of maintenance activities volumes of technical parameters of buildings and in increase of their depreciation.

| Structure of the housing stock by the year of construction | Structure of the housing stock by the number of stores | Structure of the housing stock by the building envelope |
|---|---|---|

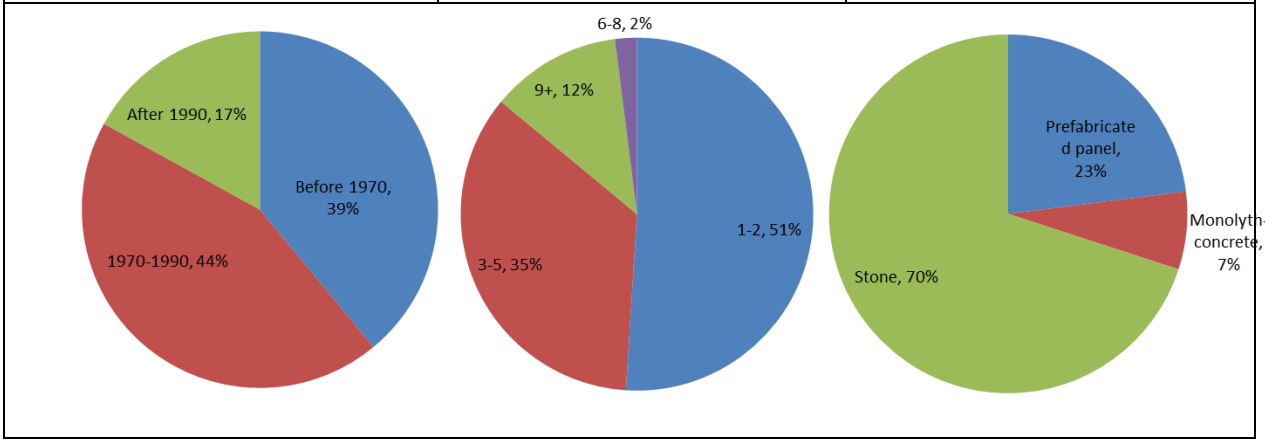



*Figure 10.3. Structure of MABs by the year of construction, number of stores and type of construction material, 2012*

The Law "On Management of Multi-Apartment Buildings", dated 2002, has failed to properly specify the rights and obligations of condominiums; as a consequence repair and maintenance activities of multi-apartment buildings are not adequately performed resulting in year by year deterioration of their condition. The extremely low fees paid for the maintenance of the building fail to cover even the immediate repair work. The situation is no better in term of collection of fees, which hardly amounts to more than 60%. Thus, it is urgently necessary to clarify and redefine the roles and responsibilities of the owner, on the one hand, and of the organizations in charge, on the other hand.

In Armenia the heat conservation indicator of the housing stock is rather low. The expenses made for heating are very high. There are serious problems related to the technical conditions of the basement level, internal networks of water supply and sewerage. The technical condition of buildings has largely deteriorated by the negative impact arising from depreciation of the internal and external networks of water supply and sewerage, damage of waterproof layers of roofs, termination of central heating. Currently a number of multi-apartment buildings and hostels are in an emergency condition of different degrees due to the circumstance that various reconstructions and changes of load-bearing structures have been carried out by residents and owners of non-residential premises, while no capital repair and reinforcement work has been initiated.[46] The existing housing stock of multi-apartment buildings have a high level of physical deterioration, the corridors and roofs, etc. are in need of capital repair.

According to the decision of the RA Government the technical inspection of multi-apartment buildings should be carried out periodically, but no later than once every 10 years; however the lack of financial resources prevented from carrying out technical condition inspections in most multi-apartment buildings. At the same time, the absence of a document on technical condition adversely affects the effective implementation of further management and operation functions.

Since a separate study has not been carried out for the housing stock of Yerevan, we can assume that the analysis indicators for the entire housing stock of the Republic of Armenia may be representative also for Yerevan. According to the assessment carried out in 2012, about 30% of multi-apartment housing stock is estimated to be in a bad condition, 6% is considered to have excellent or good condition, while the condition of 64% is estimated as satisfactory. Technical deficiencies are almost entirely accumulated in the parts falling under common shared ownership.

[46] See https://www.yerevan.am/am/mayors-decisions/2658-a-2/ https://www.yerevan.am/uploads/media/default/0001/34/13d42026a90289de354ffbd9d2bd3a87541fd282.pdf

There are also problems in terms of seismic issues. Building envelopes, including the facade parts of multi-apartment buildings of the housing stock, which are common shared ownership, are in poor condition almost everywhere. Up to now no high priority has been given to the reconstruction of building envelopes since there have been more urgent needs of repairing roofs and rehabilitating drainage systems in the buildings. Almost 75 % of roofs and their drainage systems need urgent repair. Repair work is needed also in about 60% of entrance sections and staircases of multi-apartment buildings.[47]

## 10.2 Energy Consumption by the Population

The city is entirely provided with electricity supply. The level of population access to gas infrastructure makes 95%. Centralized heat supply, which covered the needs of around 85% of multi-apartment buildings in Soviet times, almost entirely practically ceased to operate from the heating season of 2004-2005. A cogeneration-based energy supply system is operating in the territory of Avan administrative district with 4,000 kW of installed capacity, 4400 kW heat capacity and 15.12 MW peak boiler capacity. It provides services to 39 multi-apartment buildings but has been designed to meet the heating and hot water demands of in total 76 MABs in Avan administrative district. Another cogeneration-based system operates in the energy centre of the State Medical University named after M. Heratsi. This system, unlike the first one, is able to provide some of the University's buildings with cold supply by an absorption unit of 1.5 MW capacity. In general, the heating in the housing sector is provided by individual hot water boilers and heating systems, gas and/or wood stoves, electric heaters, while in public/commercial buildings heating is provided only from heating boiler houses.

The Yerevan Thermal Power Plant, the equipment of which has exhausted its operational resources (the 1st unit was launched in 1963), and the new combined steam-and-gas unit of the TPP, which has high energy performance with net electrical efficiency of about 49%, are located in the territory of the urban municipality.

In the residential sector the energy consumption is related mainly to heating, hot water generation and food preparation, lighting, power supply of electrical household appliances. The main energy sources are electricity, natural gas, and also wood in individual houses zones.

Data on electricity and natural gas consumption by the residents of MABs and private houses in Yerevan municipality for the period of 2010-2012 are presented in Table 10.4.

*Table 10.4. Consumption of energy sources on the housing sector*

| Name | Measurement unit | Value | | |
|---|---|---|---|---|
| | | 2010 | 2011 | 2012 |
| **Electrical energy** | MWh/year | 767501.90 | 855292.80 | 872585.70 |
| **Natural gas** | thousand $nm^3$/ year | 194124.75 | 247323.57 | 239054.94 |
| | MWh/ year | 1783229.95 | 2271914.31 | 2195958.68 |
| **- including MAB** | thousand $nm^3$/ year | 126808.50 | 165133.60 | 159613.70 |
| | MWh/ year | 1164862.88 | 1516917.62 | 1466211.54 |
| **- including private houses** | thousand $nm^3$/year | 67316.25 | 82189.93 | 79441.23 |
| | MWh/ year | 618367.07 | 754996.70 | 729747.14 |
| **Firewood** | thousand $m^3$ | 71.12 | 77.21 | 71.96 |
| | MWh/ year | 177692.00 | 192892.10 | 179873.20 |

[47] See Protocol Decision of the RA Government No 38 of 29 September 2011 on "Five-Year Strategy Progame for Improvement of Management, Maintenance and Opetation of the Multi-Apartment Housng Stock of the Republic of Armenia", Annex. http://www.minurban.am/programs/files/29_09_11_n38_h.pdf

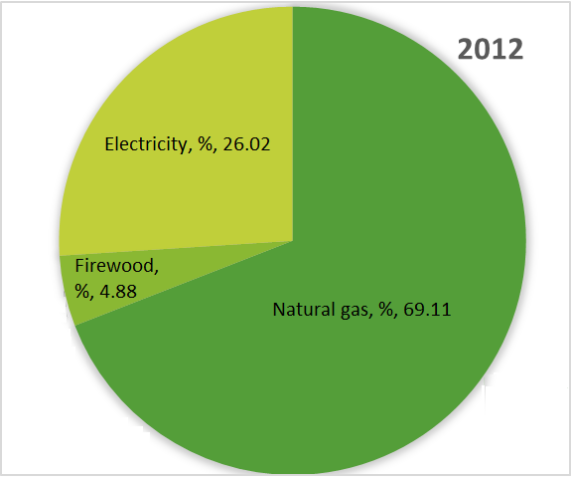
| | | | | |
|---|---|---|---|---|
| **Coal** | tonnes | 930.00 | 930.00 | 930.00 |
| | MWh/ year | 7030.80 | 7030.80 | 7030.80 |
| **Total** | **MWh/year** | **2735454.6** | **3327130.0** | **3255448.1** |

The dominating role of natural gas in the residential sector is also quite obvious. During the years specified in Table 10.4 the share of natural gas in the total energy expenses comprised 66-68%. The natural gas consumption rates in multi-apartment buildings are two times higher than in private houses, which is basically proportionate to the overall residential surface ratio.

The results of the survey conducted within the framework of the United Nations Development Programme were used for assessing the volumes of wood used.[48]

According to the survey data, 5.4% of homeowners in Yerevan municipality consumed wood for heating purposes in 2014-2015. On average one apartment annually uses 4.7 $m^3$ of wood, which in terms of the entire urban community makes 70 thousand $m^3$ per year. Taking into account that the bulk density of wood is about 577 $kg/m^3$, the lower combustion temperature of wood is 3,720 kcal/kg or 4.33 kWh/kg, the energy indicator of wood consumption will be equal to 174.88 GWh/year.:

During the period preceding the year of 2014, the calculations of consumption indicators of wood were based on the results of USAID "Development of Systems for Armenia's National Energy Balance and Greenhouse Gas Inventory" Project reports and UNDP "Residential Energy Consumption Survey" reports. Their comparative analysis shows that about 20% of wood in Armenia was used in the capital. These assumptions served as a basis for estimating wood consumption volumes for the period of 2010-2012 in Table 10.4.




The structure of energy source consumption by the population in 2011 is presented in the form of a diagram Figure 10.4.

The share of wood does not exceed 5% in the total energy balance of 2010-2012 which is somewhat lower than the average indicator in the Republic of Armenia.

***Figure 10.4. Structure of energy consumption in the housing sector, 2012***

## 10.3 GHG Emissions from the Housing Sector

Energy consumption and GHG emissions in the housing sector are summarized below.

[48] Residential Energy Consumption Survey, Analytic Report; Economic Development And Research Center; UNDP; Yerevan, October 2015

*Table 10.5. Consumption of energy sources in the housing sector, MWh/year and volumes of GHG emissions (t $CO_2$/year), 2012*

| Name of energy source | Energy consumption, MWh/year | GHG emissions, t CO2 |
|---|---|---|
| **Electrical energy** | 855,293 | 189,875 |
| **Natural gas** | 2,271,914 | 458,927 |
| **Wood** | 192,893 | - |
| **Coal (stone coal)** | 7,031 | 2,398 |
| **TOTAL** | **3,327,131** | **651,199** |

## 10.4 Measures Aimed at Energy Efficiency and GHG Emissions Reduction in the Housing sector

The municipal community financially supports the measures aimed at maintenance and repair of multi-apartment buildings. In addition to repairs of more than 70 thousand $m^2$ (568 buildings) of flat roofs and more than 32 thousand $m^2$ (501 buildings) of slanting roofs, as well as repairs of entrances in 921 MABs, the Municipality also carried out MAB energy efficiency enhancement measures. For instance, in 2011 more than AMD 78 million, and in 2012 — about AMD 67 million was invested by the Municipality for replacement of doors and windows in entrance areas of MABs (see Table 10.6).

*Table 10.6. Investments made by the Municipality in MAB energy efficiency measures in 2011-2012*

| Replacement of entrance doors | Entrance door, count | Entrance door, average surface area, square meters | Entrance door, surface area, square meters | Amount spent, thousand AMD |
|---|---|---|---|---|
| 2011 | 624 | 2 | 1,248 | 49,920 |
| 2012 | 519 | 2 | 1,038 | 41,520 |
| **Replacement of entrance windows** | **Window, count** | **Window, average surface area, square meters** | **Window, surface area, square meters** | **Amount spent, thousand AMD** |
| 2011 | 11,798 | 0.8 | 9,438 | 28,314 |
| 2012 | 10,695 | 0.8 | 8,556 | 25,688 |

In multi-apartment buildings the system of common shared ownership and the management and maintenance of property considered as common ownership prove to be very inefficient preventing the use of energy saving opportunities by the multi-apartment buildings market; while according to the results of donor-financed pilot projects an average residential building in Armenia has an energy saving potential of 30-50% given the current energy prices. It should be noted that active credit lines are offered to household owners for energy efficiency investments by international and local financial institutions, such as EBRD, International Financial Corporation, Green for Growth Fund (GGF), the French Development Agency (AFD) with its “Jerm Ojakh” [“Warm House”] Social & Energy Efficiency Housing Finance Program. In March 2016 German Development Bank (KfW) also initiated opening of a credit line for house energy efficiency. These credit lines help the residents of the capital to manage their energy demand; promotion of energy efficiency in the municipal sector and creation exemplary precedents may facilitate the distribution of those credit resources, although their results are not included in this SEAP. However, the indirect impact of these credit lines will be reflected in Activity R.5 which will be supported by the Municipality through the provision of appropriate authorisations.

The energy saving potential of building has been estimated for many times. Recent

research and demonstration projects has proved the energy saving potential of this sector. Low-cost measures (repair, weatherization, replacement of entrance front-doors and windows) provide 10-12% of energy saving, while comprehensive measures and those requiring large investments (thermal modernization of the facade, replacement of all windows and doors) may provide up to 58% of energy saving.

In the MAB energy efficiency sector the investments are hindered by a number of legislative, institutional and financial barriers the addressing of which is essential for promoting the flow of large-scale investments in this sector. Relevant reforms, adequate capacity building, social programs and appropriate funding schemes are indispensable for properly targeting the investments in this sector. The RA Law "On condominiums" needs further improvement.

In its medium-term action plans the RA Ministry of Urban Development has specified the necessity of amending or even completely revising the RA Law "On Management of Multi-Apartment Buildings" by making relevant amendments in the RA Civil Code provisions on management of multi-apartment buildings and by revising Decision of the RA Government No 1161-N "On Establishing Mandatory Rules for Maintenance of Common Shared Ownership in Multi-Apartment Buildings".

As to the current situation related to internal lighting in the housing stock it should be noted that as of 2012 the population of Yerevan consumed 855,293 MWh of electricity (*Table 10.4*). According to the household energy consumption survey conducted by the UNDP Green Urban Lighting Project, in summer months average household (HH) lighting costs comprise 18% of the total expenses. Based on this proportion the annual energy consumption for lighting by the population in Yerevan will be equal to 159,352 MWh: The same survey found that incandescent light bulbs are predominantly used in the housing stock for internal lighting purposes. Replacement of incandescent light bulbs with compact luminescent or LED lamps will allow for predictions of about 70-80% of energy savings (see Activity 10.4.5).

The current and several anticipated measures for increasing the energy efficiency of housing stock are described below.

### 10.4.1 Activity R.1. Improving Energy Efficiency in Buildings Initiative

On 12 November 2012 a Letter of Intent was signed between the Yerevan Municipality and UNDP on the "Improving Energy Efficiency in Buildings" project which showed the energy efficiency potential of existing buildings with a view of facilitating the dissemination of experience in implementing similar projects. In the context of achieving the project objectives a demo building of panel type was chosen in 2013 that was connected to the centralized heating system, assessment of the technical condition of the building was carried out, a survey was conducted among the residents according to which the residents gave their consent on involvement of their building in the project.

Construction work aimed at improving the energy efficiency of the multi-apartment building No 6 Daniel Varuzhan area in Avan administrative district chosen under the project was carried out in 2013-2014 and included the following: increase thermal resistance of external walls of the building, by installation of thermal insulating material on the outer surface; replacement of doors and windows in the staircases of the building; installation of windows on basement openings; waterproofing of the roof. This experience of thermal modernisation of a multi-apartment building is the first attempt not only in Yerevan but also throughout the country. After the thermal modernisation, thermal restoration of the facade of the multi-apartment building in Avan district of Yerevan the annual energy consumption for heating needs in the building, that was equal to 178 kWh/m$^2$, reduced up to 74 kWh/m$^2$ (by 58%).[49] See Figure 10.5.

[49] Letter of Intent was signed between UNDP and the Yerevan Municipality on showing the energy loss reduction potencial of a multi-apartment building through increasing the level of thermal conservation of

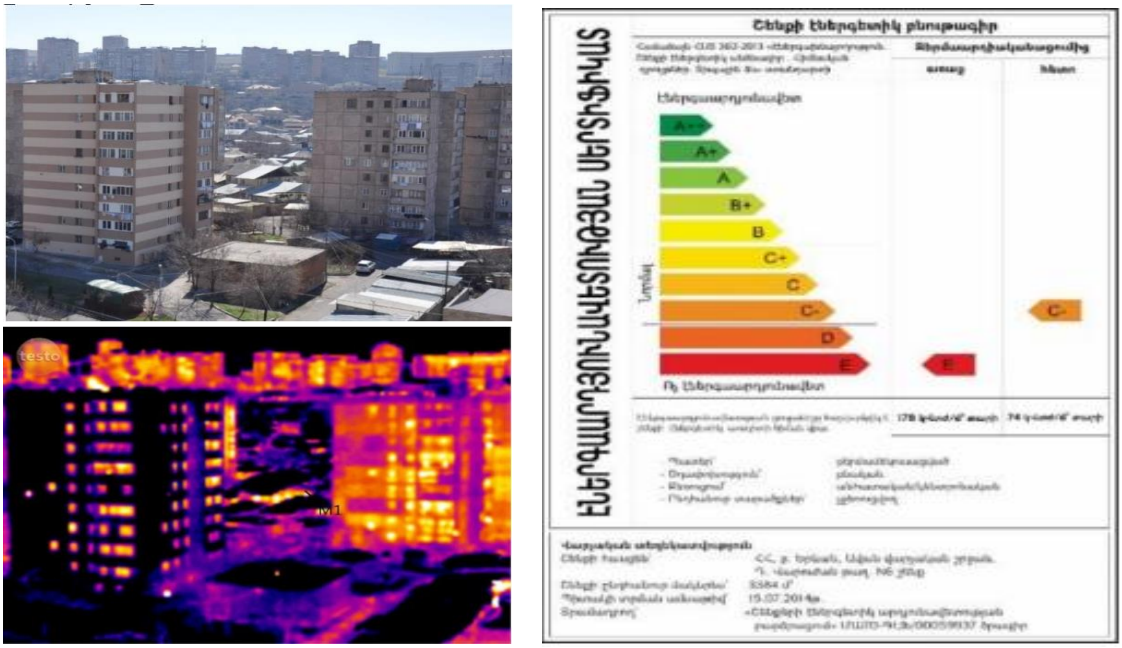


*Figure 10.5. Daylight and infrared image of the demo building after thermal enveloping under the UNDP/GEF and Municipality joint pilot project and the energy performance certificate of the building*

Under another initiative of the UNDP in 2012 a Letter of Intent on cooperation was signed with the constrictor of “Cascade Hills” residential complex in Yerevan, according to which the Project provides consultancy to the developer to ensure the highest possible energy performance of the buildings with new design solutions. Owing to energy efficient solutions the specific value of energy consumption for heating and cooling in the demonstration building made 44 kWh/m$^2$/year instead of with 69 kWh/m$^2$/year in the baseline year.[50]

*Table 10.7. Action R.1. Impact assessment of Improving Energy Efficiency in Buildings initiative, 2020*

| Source of financing, cooperating partners | Value, thousand Euros | Energy saving, MWh/year | | Reduction of emissions, t $CO_2$/year | Investment years |
|---|---|---|---|---|---|
| | | Electrical energy | Natural gas | | |
| **UNDP, YM, Private investor** | 645 | | 406 | 82 | 2013- 2017 |

### 10.4.2 Activity R.2. Loan Mechanisms for Increasing Energy Efficiency in MABs

Habitat for Humanity Armenia (HFHA) has developed a model of providing loans for energy efficiency investments in condominiums, and measures for increasing the energy efficiency of common areas of three typical panel buildings have been implemented through credit

building envelopes. The relevant activities were carried out in A1-451 KP1p/9 type building No 6 Daniel Varuzhan in Avan administrative district. Consolidated indicators of the pilot project are available at: http://www.nature-ic.am/wp-content/uploads/2015/01/Avan-DSK_ENG_FINAL_-20.10.15.pdf

[50] See Brief Description of the Project available at: http://www.nature-ic.am/wp-content/uploads/2016/02/IEEB_Cascade-Hills_arm.pdf

financing. The municipality has co-financed these investments within the framework of a mutual memorandum of understanding with the HFHA for such projects funded by loans. In some cases residents (condominiums) also provided their contribution in the investments made with co-financing.

*Table 10.8. Activity R.2. Impact Assessment of Loan Mechanisms for Increasing Energy Efficiency in MABs, 2020*

| Source of financing, cooperating structures/ Implementing entity | Value, thousand Euros | Energy saving (MWh/year) | Reduction of emissions, 2020, t $CO_2$/year | Investment years |
|---|---|---|---|---|
| | | Natural gas | | |
| **HFHA, YM, USAID** | 1,100 | 5,067 | 1,024 | 2013- 2018 |

### 10.4.3 Activity R.3. [P.7] "De-Risking Climate Investments: Thermal Rehabilitation and EE in Buildings" Project

For promoting activities targeted at improving the energy efficiency in public buildings and multi-apartment residential buildings in 2015 consultations were initiated with the UNDP and European Investment Bank. The project will include components aimed at ensuring seismic stability, thermal insulation of building envelopes, replacement of entrance doors and windows in staircases, reconstruction of heating/cooling, air ventilation and air conditioning and lighting systems and renewable energy sources integration components. To this end, the "De-Risking Climate Investments: Thermal Rehabilitation and EE in Buildings" project document was developed jointly with the UNDP and communicated to the Green Climate Fund for financing purposes (grant). In 2016 it is anticipated to develop and implement a feasibility project targeted at improving the energy efficiency in public buildings and multi-apartment residential buildings in the City of Yerevan is anticipated with the support of the UNDP and European Investment Bank.[51]

*Table 10.9. Activity R.3. [P.7] Impact Assessment of "De-Risking Climate Investments: Thermal Rehabilitation and EE in Buildings" Project, 2020*

| Source of financing, cooperating partners | Value, thousand Euros | Energy saving, MWh/year | | Reduction of emissions, t $CO_2$/year | Investment years |
|---|---|---|---|---|---|
| | | Electrical energy | Natural gas | | |
| **YM, EIB, GCF, UNDP** | 700 | | 6,930.7 | 1,400.0 | 2016-2020 |

### 10.4.4 Activity R.4. Installing Solar Water Heaters in Private Housing Areas

By the year of 2020 6,000 units of solar water heaters are planned to be installed in private residential housing areas each with 2.7-3.0 $m^2$ of active absorber area. In hybrid combination with the existing electric or gas water heating systems, the useful solar energy flow is expected to be within the range of 800-850 kWh/$m^2$.

The possibility of granting incentives in this area will be viewed in the context of issuing construction authorisations. The practice of other advanced cities in this field includes accelerated approval of construction projects with the use of renewable energy technologies, setting of differential tariffs for construction authorisations, preferential local tax rates, in the case of certain sizes or construction zones — binding requirement to use renewable energy, etc.

Owing to solar water heating the natural gas saving will be equal to $\Delta B = 6000 \cdot 2.7 \cdot 800/0.85 = 15245.0$ MWh. This saving of natural gas constitutes only 2.2% of

[51] See Brief description of the Project at: http://www.nature-ic.am/wp-content/uploads/2016/05/GCF-UNDP-prodoc-brief_Arm.pdf

gas consumption in the entire private residential housing area in the base year and 17.3% of annual gas consumption by 6000 private houses involved.

*Table 10.10. Activity R.4. Impact Assessment of Installing Solar Water Heaters in Private Housing Areas, 2020*

| Source of financing, cooperating partners | Value, thousand Euros | Energy saving, MWh/year | | Reduction of emissions, t $CO_2$/year | Investment years |
|---|---|---|---|---|---|
| | | Electrical energy | Natural gas | | |
| **House owners** | 5,700 | - | 15,245 | 3,080 | 2017-2020 |

### 10.4.5 Activity R.5. Providing LED Lamps to Socially Vulnerable Households

Rising energy prices have had a significant impact on access to energy. The tariff for electricity has already exceeded the threshold of affordable access to utility services for families in need. Thus, in socially vulnerable families more than ten percent of the family budget is spent on utility services during the heating season. If energy efficiency measures are subsidized for low-income households, the impact of the 2015 increase of electricity price in 7% may be mitigated. About 40% of electrical energy consumed in low-income households falls on lighting. In order to keep the power consumption volumes within the affordable limits it is recommended to support low-income families by way of replacing inefficient incandescent light bulbs with LED (light-emitting diode) lamps.

On average, by providing 9 LED lamps to every family, the community will help to improve the ability of poor families to pay part of utilities costs by way of reducing their energy consumption costs by at least 5-6 times (by reducing 60 W power lamps with 8-10 W power lamps).

*Table 10.11. Impact Assessment of Activity R.5*

| Implementing entity | Value, thousand Euros | Energy saving, MWh/year | | Reduction of emissions, t $CO_2$/year | Investment years |
|---|---|---|---|---|---|
| | | Electrical energy | Natural gas | | |
| **YM, donor organisations** | 645 | 14700 | - | 3263.4 | 2018-2020 |

## 10.5 Activity R.6. Replacement by the Municipality of Entrance Doors and Windows in the MAB Sector

As mentioned earlier, the Municipality annually allocates funds to condominiums for covering MAB maintenance costs. These sums are spent on different construction and reconstruction measures, including replacement of entrance doors and windows. Since the primary aim of these measures is not energy efficiency, there are no detailed technical data allowing to evaluate the actual energy saving effect of investments already implemented in 2013-2015 and envisaged for 2016-2020 (see Table 10.7). Taking as a basis the net financial data available, the energy efficiency effect was estimated based on the normalised unit value of energy saving measures, relying on the indicators of investment projects implemented in the field.

*Table 10.12 Investments for Replacement by the Municipality of Entrance Doors and Windows in the MAB Sector, estimated energy efficiency and GHG emissions reduction, 2013-2020*

| | Estimated volume of work (unit) | | Volume of investments (thousand AMD) | | Total energy saving, MWh | Reduction of emissions, t $CO_2$ |
|---|---|---|---|---|---|---|
| | Replacement of entrance doors | Replacement of entrance windows | Replacement of entrance doors | Replacement of entrance windows | | |
| **2013** | 755 | 12,746 | 60,400 | 30,591 | 3,714 | 750 |
| **2014** | 700 | 11,135 | 56,000 | 26,724 | 3,376 | 682 |
| **2015** | 546 | 10,561 | 43,680 | 25,347 | 2,817 | 569 |
| **2016** | 357 | 7,570 | 28,560 | 18,168 | 1,907 | 385 |
| **2017** | 650 | 11,875 | 52,000 | 28,500 | 3,286 | 664 |
| **2018** | 650 | 11,875 | 52,000 | 30,591 | 3,371 | 681 |
| **2019** | 650 | 11,875 | 52,000 | 26,724 | 3,213 | 649 |
| **2020** | 650 | 11,875 | 52,000 | 25,347 | 3,157 | 638 |
| **Total** | 4,958 | 89,513 | 396,640 | 211,992 | 24,841 | 5,018 |

The consolidated data of the Activity are summarised below.

*Table 10.13. Impact Assessment of Activity R.6., 2020*

| Implementing entity | Value, thousand Euros | Energy saving, MWh/year | | Reduction of emissions, t $CO_2$/year | Investment years |
|---|---|---|---|---|---|
| | | Electrical energy | Natural gas | | |
| YM | 175 | | 24,841 | 5,018 | 2013-2020 |

## 10.6 Consolidated Data of the Housing Sector Activities

Investment indicators of the housing sector activities, the overall energy and environmental results are summarized in Table 10.14.

*Table 10.14. Key indicators of housing sector activities, 2020*

| Index | Sector/Activity | Source of financing, cooperating structures | Implementation timeframe (start - end) | Estimated value (thousand Euros) | Expected energy saving (MWh/year) | Reduction of emissions (t $CO_2$) |
|---|---|---|---|---|---|---|
| **R.1** | Improving energy efficiency in buildings, drafting secondary legislation regarding energy efficiency, as well as financing the first pilot project on thermal modernisation of a multi-apartment building in Avan municipality | UNDP/GEF, YM | 2013-2017 | 645 | 406 | 82 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **R.2** | Financing energy efficiency, Commercial loan mechanisms for increasing energy efficiency in residential buildings | HFHA, YM, USAID | 2013-2018 | 1,100 | 5,067 | 1,024 |
| **R.3** | De-risking climate investments: thermal rehabilitation and EE in buildings | UNDP, GCF, YM, EIB, MNP | 2016-2020 | 700 | 6,931 | 1,400 |
| **R.4** | Installing solar water heaters in private housing areas | YM | 2017-2020 | 5,700 | 15,245 | 3,079 |
| **R.5** | Providing LED lamps to socially vulnerable households | YM, donor organisations | 2018-2020 | 645 | 14,700 | 3,263 |
| **R.6** | Replacement by the municipality of entrance doors and windows in the MAB sector | YM | 2013-2020 | 175 | 24,841 | 5,018 |
| | **Total** | | | 8,965 | 67,190 | 13,866 |

# 11 Long-Term Recommendations on Using Advanced International Experience in Sustainable Energy Development

Several other measures are also recommended from the international experience in sustainable energy development which, although not expressed in quantitative terms, have qualitatively new effect and will enable to ensure the publicity of the subject matter, raise public awareness, promote behavioural and lifestyle changes. From the long-term perspective the use of such measures would also be desirable and welcomed in the City of Yerevan.

## 11.1 Increasing Public Visibility and Public Involvement in SEAP

Although the main objective of the SEAP is to identify the energy efficiency and energy saving capacities of the Municipality and the investment opportunities and priorities for their implementation, it also constitutes a unique opportunity to raise public awareness about the issues of energy efficiency. The potential for promoting the awareness and support efforts is quite real with wider community and civic involvement. Any option should be used that could promote broader and systemic changes in public thinking and behaviour leading to greater energy efficiency. For example, within the framework of development of SEAP, in March 2016 a seminar was organized in the American University of Armenia with the participation of students from different universities, which allowed raising awareness of the students about this important initiative of the Municipality and also gave them an opportunity to submit innovative proposals related to the SEAP.

## 11.2 Awareness-Building Efforts in Municipalities: Energy-Efficient Architecture and Engineering

A considerable part of the energy consumed in buildings is used for space heating and cooling. Most of this energy is lost through building envelopes. With the participation of students from architecture and engineering departments of universities community exhibitions (expo) and "Do it yourself" demonstrations may be organized concerning building insulation. These measures may also be used to inform neighbourhood residents about energy-efficient versions of energy-consuming devices, such as LED lighting sources, energy-efficient household appliances, energy efficiency oriented behaviour, and so on.

## 11.3 Feasibility Study for Using "Cool Roofs" in Public Buildings

Cool roofs have a colouring with high reflection coefficient (albedo) that reflects most of the sunlight and, therefore, reduces the heat load on the building in summer months. This might be a very good option for public buildings as it reduces the cooling needs of the space and improves thermal comfort. It is often assumed that cool roofs can bring about additional space heating costs in winter months. This should not be a matter of serious concern since the heat surplus is minimal in winter. Moreover, the snow-covered roofs provide the same effect as the cool roof since the heat surplus effect is minimized when snow reflects the sunlight.

## 11.4 Building an "Eco-district"

An "Eco-district" constitutes a circle of sustainability with a commitment to integrate objectives of sustainable development and reduce its own ecological footprint for which more demanding environmental requirements are specified. The district may be certified by a Neighbourhood Development LEED-ND certificate[52] designed to certify exemplary development projects of neighbourhoods that perform well in terms of smart growth, urbanism, and green building. Construction of the first "green" building, Avedisian school in Malatia-Sebastia municipality of Yerevan, was a good precedent, and it became the first LEED certified building in the Republic of Armenia.

The achievements of the pilot project on improving the building envelope and energy efficiency of building No 6 in D.Varouzhan street of Avan AD allow to consider the possibility of creating an Eco-district. In order to put this idea into effect in one of the districts of Yerevan it is necessary to carry out a technical assessment of the existing buildings. In case of a newly built "Eco-district" the respective requirements need to be set and complied with still in the design phase.

## 11.5 Creation of Pedestrian-Friendly Infrastructure

Creation and enhancement of pedestrian-friendly infrastructure is an indispensable part of normal urban development. Yerevan has also undertaken measures in this direction. Such measure include extending sidewalks, creating pedestrian paths, traffic calming measures (narrowing traffic lanes, curb extensions, building speed humps, reducing the traffic speed limits etc.[53]).

## 11.6 Providing Public Transport Accessibility in New Districts

The distance that a person is willing to walk to get to the vehicle is equivalent to about 5 minutes walking distance (400-600 meters). The pedestrian pathways should necessarily be short, direct and continuous. Accessibility of public transport is especially important in the new

[52]For further detail on sustainable neighborhood development please refer to: http://www.usgbc.org/articles/getting-know-leed-neighborhood-development

[53]For a wide variety of taffic calming solutions adopted in cities, see https://en.wikipedia.org/wiki/Traffic_calminghttps://en.wikipedia.org/wiki/Traffic_calming

developing neighbourhoods of the community where pedestrian routes must be concentrated around public transport hubs for easy and comfortable walking. Such conditions contribute to the growth of public transportation and reduced use of private passenger cars.

## 11.7 Developing Bicycle Infrastructure in Yerevan

The transport sector has an extensive share in the emissions footprint in Yerevan. The Municipality of Yerevan has already initiated efforts aimed at construction of bicycle parking lots. Promoting the use of bicycles contributes to reducing the levels of using traditional transport and fuel related to it and, accordingly, enables reducing the subsequent emissions. Promotion of the use of bicycles will allow also reducing the demand for additional transport infrastructure and reducing the traffic load on the roads.

The main focus might be the creation of a combined biking infrastructure both as a recreational and utility network by building inter-community routes. A number of possible options for bicycle infrastructure are the following:

- Bicycle routes on major arterial roads in Yerevan (Tigran Mets,Amiryan, Mashtots, Sayat-Nova, Baghramian, Komitas) or on roads parallel to them. Large intersections of Yerevan allow for safely travelling by a bicycle;
- Creation of “Yerevan Student Cycling Routes” between the Universities;
- Cycling route between the famous sights of Yerevan;
- With the involvement of private investors, creation of parking lots for rented bicycles in higher districts of Yerevan on which cyclists would easily drive down to low-lying districts of the city and there give back the rented bicycles which will be returned to their original parking lot by trucks.

The infrastructure includes bicycle stands in buses, trains, bicycle routes, bike lanes, paths shared with pedestrians, signalized intersections, traffic control systems for cyclists, guiding sings, lighting and trip ending facilities (bicycle racks, stands or panels).

## 11.8 Application of Advanced Information Technologies for Increasing Effectiveness of Using Public Transport

Making detailed and multilingual information available on public transport routes, fares and schedules through innovative applications, electronic schedules, etc. Further efficiency may be achieved by providing in bus stops the information about the location of the public transport by the GPS system, instalment of data transmitting devices at bus stops, which report the number of passengers waiting to the management centre, and so on. This could be valuable resource for tourists. These measures may be line with programs focusing on public transport optimization, common ticketing system, and electronic schedules measures.

The same mechanism may be employed when creating a centralized GPS system for taxi cabs that will enable to improve the cost-efficiency of fuel use by taxis.

## 11.9 Creating Car-Free Zones in the City Centre

Creation of car-free zones may be launched in several parts of the city centre during relatively less intense periods in terms of traffic intensity. Bicycle rentals could operate in such zones with quite attractive tariffs.

## 11.10 Irrigation Schedule Management

Regulation of drip irrigation and intensity of irrigation of urban green areas by readings of specific sensors regarding land and air relative humidity and air temperature.

## 11.11 Feasibility Study for Irrigation of Green Spaces of Yerevan by Using Rainwater

It is proposed to conduct a feasibility study on accumulating rainwater and using it for irrigation of green spaces in Yerevan. This measure will result in reduction of energy consumption for the irrigation system.

## 11.12 Green Roofs

Green roofs are partially or completely covered with vegetation. The layers of a green roof must, like any roof, accommodate drainage and protect the building from the elements with a waterproof membrane; they also must provide irrigation and root protection barriers while staying as light as possible. In general, green roofs have several advantages. They:

- 
- extend the useful service life of a roof;
- reduce energy consumption and related costs for the building cooling;
- improve the aesthetic appearance;
- reduce greenhouse gas emissions;
- absorb carbon dioxide;
- reduce the storm water runoff;
- reduce the urban heat island effect,
  improve air quality by reducing the temperature and absorbing air pollutants;
  supplement the natural environment.

The role of the Municipality in promoting green roofs lies in the formation of an appropriate legislative framework.

## 11.13 Public-Private Partnership in Implementing SEAP Activities

Yerevan Municipality needs to explore those SEAP activities the financing of which may be attractive in terms of investment and beneficial for private investors. Yerevan has already achieved a successful experience in community-private sector partnership in garbage collection sector. This experience should be extended to effective street lighting investment projects, introduction of electric cars and hybrid vehicles, bike rental services, use of energy efficient solutions and technologies operating on renewable energy in the advertising sector and related sectors.

## 11.14 Study and Evaluation of Possibilities of Extracting Energy from Municipal Household and Industrial Wastewater

Anticipate in medium-term and long-term municipal infrastructure development programs possibilities for methane extraction and energy production from liquid waste.

## 11.15 Enhancement of the Potential of Using Green Transport

It is necessary to analyse and discuss the prospects of expanding the services of the present electric transport in Yerevan, including expansion of the metro network, as well as using the rope way as public transport.

In the municipal transport sector promote the use of environmentally clean fuel, maximum use of electric transport.

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