Ministry of Nature Protection of the RA
Ministry of Urban Development of the RA

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Overview of Achieved Results and Lessons Learned

Green Urban Lighting UNDP-GEF/00074869 Project

GREEN URBAN LIGHTING

YEREVAN – 2018

The present report is developed in the frames of "Green Urban Lighting" UNDP-GEF/00074869 Project

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Executing agency	**UN Development Programme**
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Hovhannes Nunyan	**Expert on Economic Assessment and Financial Mechanisms**
Artur Tsughunyan	**Expert on Energy Auditing and Evaluation of the EE Potential**

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Arsen Karapetyan	**Expert on Codes and Standards**
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Gurgen Khostikyan	**Local Expert on Education and Capacity Building**

Partner and contractor organizations

- **Ministry of Energy and Natural Resources**
- **Yerevan Municipality**
- **"Shinsertificate" LCC**
- **American University of Armenia**
- **R2E2 Fund**
- **National Institute of Standards**
- **Yerevan Illumination Company CJSC**
- **Design for Lighting LTD, UK**
- **Economic Development and Research Center**
- **Russian Lighting Research Institute named after S.I. Vavilov**
- **"World Vision Armenia" International Relief and Development Organization**
- **Center for Light Emitting Diode and Optic-Electronic Technologies of the NA of Sciences of Belarus**
- **National Polytechnic University of Armenia**
- **Scientific Research Institute of Energy**

ABBREVIATIONS

ADB	Asian Development Bank
ATDF	Armenia Territorial Development Fund
AUA	American University of Armenia
CCIC	Climate Change Information Center of Armenia
CFL	Compact Fluorescent Lamp
CJSC	Closed Joint-Stock Company
CNCO	Community Non-Commercial Organization
EBRD	European Bank for Reconstruction and Development
EE	Energy efficiency
GEF	Global Environmental Facility
GHG	Greenhouse gases
G2iA	Armenia-France Inter-Professional Network
GUL	Green Urban Lighting
HPS	High-Pressure Sodium (lamps)
KM	Knowledge management
LED	Light Emitting Diodes
LLC	Limited Liability Company
MEPS	Minimum Energy Performance Standards
MoEDI	Ministry of Economic Development and Investments of RA
MoNP	Ministry of Nature Protection of RA
MoEINR	Ministry of Energy Infrastructures and Natural Resources of RA
MV	Mercury vapor
NPUA	National Polytechnic University of Armenia
PR	Public relations
RA	Republic of Armenia
RACN	Construction Norms of the Republic of Armenia
R2E2 Fund	Armenia Renewable Resources and Energy Efficiency Fund
RV	Revolving Fund
SARM	National Institute for Standards of Armenia
STAP	Scientific and Technical Advisory Panel (UNEP, GEF)
TA	Technical assistance
UNDP	United Nation Development Program
YIC	Yerevan Illumination Company CJSC
YM	Yerevan Municipality

UNITS OF MEASURE

W	Watt
kg	kilogram
kW	kilowatt (10^3 W)
kWh	kilowatt per hour
Lm	Lumen
Lx	Lux
MWh	megawatt per hour (10^3 kilowatt per hour)
m	meter
m^2	square meter
m^3	cubic meter
Mm	millimeter
t	ton
°C	degrees centigrade

Contents

Introduction

Lighting sector accounts for around 19% of total energy consumption globally, according to the data of International Energy Agency. As a result, this sector is among major sources of greenhouse gas emissions. While application of properly designed modern and energy efficient lighting and control systems (predominantly based on LED technology that has a significant advantages over conventional ones), allows reducing essentially installed capacity and power consumption of indoor and outdoor lighting, thus, reducing operation, maintenance and energy costs, as well as contributing to greenhouse gas emissions reduction. Along with the mentioned benefits, energy efficient modernization leads to improvement of illumination quality contributing to better living and working conditions, comfort and traffic safety.

Therefore, transition to efficient lighting may deliver energy saving and quality improvement benefits, combined with favorable payback, as well as contribute greatly to climate change mitigation strategy.

Wide use of inefficient technologies and equipment in the lighting sector in Armenia, as well as insufficient awareness of key beneficiaries (e.g. state and local authorities, decision-makers, private sector, general public, etc.) on EE technologies result in continuous growth of power consumption and associated greenhouse gas emissions in the sector. This is true both for indoor lighting (e.g. municipal and residential sectors) where inefficient incandescent lamps are still widely used and for outdoor lighting (e.g. streets and parks) where sodium and even mercury lamps of low quality and efficiency are predominantly used. The situation is particularly complicated in municipal lighting sector as due to use of low quality equipment the operation and maintenance costs of lighting systems increase notably while making a significant share in community budgets.

In order to facilitate improvement of energy performance and quality of municipal illumination in Armenia as well as to reduce its carbon footprint, UNDP-GEF "**Green Urban Lighting**" full-sized project (hereafter: "the Project") was launched in January 2014. The overarching goal of the project is to save energy and to reduce emissions of greenhouse gases by increasing energy efficiency of municipal lighting in the cities of Armenia via implementation of municipal investment programs and national policies. This objective is to be achieved via a number of interrelated activities including energy audits of municipal lighting systems, development of modernization proposals, piloting and demonstration of modern energy efficient lighting solutions, establishment of financial and institutional mechanisms for replication of new technologies, improvement of legislative and regulatory framework, awareness raising and capacity building.

The Project is financed by Global Environmental Facility, co-financed by UN Development Programme and Government of the Republic of Armenia. The project implemented by UNDP under coordination of the Ministry of Nature Protection closely cooperated with ministries and state agencies, institutions and NGOs, private sector, expert society and other stakeholders. Main beneficiaries of the project were Yerevan Municipality and other 20 smaller municipalities.

The Project is implemented by a team of proficient local and international experts and under direct oversight of Climate Change Program Coordinator Mrs. Diana Harutyunyan.

The local team of long-term experts consists of: Mr. Artem Kharazyan, Senior Expert on Energy Efficiency, responsible for supporting the Program Coordinator in leading, supervising, and monitoring the project implementation, staff recruitment and task formulation, provision of technical backstopping to and ensuring timely delivery of outputs of the expert team; Mr. Armen Gulkanyan, Expert on Energy Efficient Lighting Market and Technologies, responsible for baseline data collection and analysis, monitoring of lighting systems, development of specifications and organization of procurement of new lighting equipment, provision of technical consultation to the project and stakeholders; Mr. Karen Sargsyan, Local Expert on Lighting System Audit, responsible for audit of municipal lighting systems, verification and analysis of baseline data, development of assessment reports and technical recommendations on lighting system modernization, development of statistics on results of completed projects and provision of technical consultation; Mr. Hovhannes Nunyan, Local Expert on Economic Assessment and Financial Mechanisms, responsible for evaluation of economic feasibility of proposed pilot projects, analysis of financial baseline data on municipal lighting systems, development of a concert of municipal revolving fund for replication of pilot projects, and Mr. Artur Tsughunyan, Expert on Energy Auditing and Evaluation of EE Potential, responsible for energy audits,

evaluation of energy saving potential of the proposed pilot projects, development of a methodological guide on energy audit of lighting systems.

Successful implementation of the project has been achieved also thanks to the contribution of the team of international Consultants: Mr. Steve Coyne, International Expert on Energy Efficient Lighting for Inception Phase, Mr. John Rands, International Consultant on Roadway Tunnel Illumination Systems and Mr. Vesa Rutanen, International Expert on Energy Efficiency. Mr. Andrej Djuretic, Mr. Anatoli Shevchenko, Mr. Andrey Dodonov and Mr.Konstantin Petrenko contributed to the capacity building activities and shared their experience in the course of the workshops and trainings. The short-term local experts provide their input in achieving project results through developing tailored studies and regulatory documents. The project management team was supported by Rubina Stepanyan Programme Associate, Ms. Marianna Arzangulyan, Expert Team Assistant and Mr. Vahan Mardirosyan, Driver/Monitor.

This report provides overview of the major results achieved under each of the project's four components, including:

(i) establishment of an extensive database of information on actual technical condition and performance of public lighting systems, obtained as a result of audits carried out in 21 municipalities;
(ii) building capacities of more than 200 specialists from municipalities and private sector on proper audit, design, procurement, testing, installation and operation of EE lighting systems via organization of numerous trainings and through publication of manuals and guides;
(iii) demonstration of quality improvement and cost saving benefits of modern EE light emitting diodes based lighting technologies via implementation and further promotion of street lighting upgrade projects in 19 municipalities;
(iv) ensuring compliance testing for light sources (e.g. light bulbs and luminaries) via establishment of a modern photometric laboratory, also serving as a training center for university students or practitioners who are taking courses on energy efficient lighting;
(v) securing sustainability and replication of achieved benefits through establishment of 16 municipal revolving funds, where savings from project pilots have been measured, reported and reinvested into 15 new street lighting upgrade projects;
(vi) improvement of regulatory framework for lighting design, by incorporation of MEPS into the acting technical norms and corresponding revision in the Renewable Energy and Energy Efficiency Law of the Republic of Armenia and public procurement rules;
(vii) ensuring high visibility of the project results and facilitation of stakeholder behavior change via regular publications on the project website and project Facebook page, as well as through a media outreach campaign.

Along with description of the above-mentioned major achievements that contributed to the overall success of the project, the report incorporates lessons learned and technical experience gained by the expert team within the course of the project implementation. This information may serve as a good starting point for project developers and implementers not only in Armenia but also internationally, as many aspects of energy efficient lighting are common throughout the world. A separate chapter is devoted to description of the methodology applied for calculation of GHG emission reduction benefits of the project and key assumption made during the calculation process.

Map of communities where the lighting system energy audits demonstration projects were implemented

Summary of achievements

The project has managed to successfully implement the vast majority of the planned activities, and deliver high results in each of its components. As a result, the project reached and overcame its overarching goal of direct and indirect energy saving and reduction of greenhouse gases in target sectors. In this chapter, overview of key activities as per each component is presented.

Component I: Municipal energy audits and technical capacity-building

The following key activities were implemented under this task:

- Methodology for (audit) assessment of technical condition and performance of public lighting systems is developed and tested through the pilot site monitoring process. Key outcomes of the audits, including revealed gaps and recommendations on improvements, are summarized and duly communicated to administrations of 21 target municipalities via audit reports. As a result of this activity a methodology guide on Street Lighting Audit has been developed and published.
- An extensive database of information on actual condition and performance of indoor and outdoor lighting systems is created based audit results in target municipalities(Yerevan, Abovyan, Alaverdi, Akhtala, Aparan, Ararat, Dilijan, Gavar, Goris, Gyumri, Kajaran, Kapan, Masis, Meghri, Sevan, Spitak, Stepanavan, Talin, Vanadzor, Vayk, Tashir) and 2 rural (Ararat and Avshar villages).
- In total 29 energy audits (20 for outdoor street and park systems and 9 for indoor systems).
- A study tour for key sector actors on advanced technologies in urban lighting was organized jointly by UNDP Armenia and Schréder Company with visits to the company's testing and design hub in Belgium and production premises in Spain.
- A modern photometric laboratory that enables checking the technical parameters of light sources to confirm their conformity with the declared and/or required parameters, is established, put into operation and made available for all interested stakeholders (see below for more information).
- Educational laboratories on lighting are established at the premises of the National Polytechnic University and its Gyumri Branch (see below for more information).
- More than 200 specialists from municipalities, ministries, design and construction institutions were trained in municipal lighting system technologies, lighting standards, lighting system design and testing, tunnel lighting specifics (list of conducted events is presented in Table 1 below).
- A number of educational, training and capacity building materials are developed, presented to the key stakeholders and published (list of published materials are presented in Table 2 below).
- More than 170 media releases, published in printed media, and broadcasted on TV coverage, including a seventeen-minute reportage on project results and spots on pilot project results, available on YouTube https://www.youtube.com/watch?v=zyxTy5t1pFU
- A major awareness rising event "Green Lighting Week" advertised by 4 TB channels is held and attended by about 3400 participants, available on YouTube https://youtu.be/IeWratgmhpY
- The project page at CCIC website (www.nature-ic.am) is maintained and thematic group in the Facebook periodically updates to share project news, documents and publications.
- Presentation of the project objectives and achievements are delivered at 6 international events and during 2 international study tours.

Table 1: List of awareness raising and capacity building efforts and events

N	Event	Topics and provided information
1.	Seminar on "Energy Efficient Lighting"	Types and parameters of EE lighting equipment.
2.	Presentation of educational module for college students	Key information on energy efficient technologies in lighting sector.
3.	Workshop on "Energy Efficient Lighting for Communities"	Experience in improving the lighting system in urban communities, perspectives of LED technology application expansion and lighting market development issues.
4.	Inauguration event on "Yerevan city energy efficient street lighting pilot project"	Presentation of the pilot project as setting new standards for street lighting and expected to become scaled-up through upgraded EE standards for street lighting and via the municipal revolving fund.
5.	Pavilion at the Energy Week 2014 Energy Efficiency Expo	Objectives and toolkit of the project were presented and discussed with the participants, including legislative reforms, technological innovations, funding opportunities, etc.
6.	Opening ceremony of Zoological Garden of Yerevan City	Presentation of the pilot project as a particular case of park illumination effort, as Yerevan Zoological Garden serves as a facility for natural sciences, environmental protection and educational purposes, especially for children and youth.
7.	"Earth Hour" – an international environmental event	This internationally recognized "lights-off event" event is held worldwide annually since 2007 on the last Saturday in March. At 8.30pm the participating cities, organizations, households turn off their non-essential lights for one hour thus contributing to highlighting the importance of global climate change issue and reduction of greenhouse gas emissions.
8.	Opening ceremony of urban lighting pilot project in Spitak town	Within the consultation marking the opening of the upgraded system, the Mayor emphasized the improved illumination quality of the pilot streets, higher road visibility and thus traffic safety as well as renovated or replaced lighting poles. UNDP Deputy Resident Representative appreciated the effective cooperation with the town authorities, stressing that as a key to successful pilot implementation and replication/upscaling.
9.	Erebuni-Yerevan Expo celebrating the 2797th birthday of Yerevan city	The UNDP Climate Change Program presented its "Improving Energy Efficiency in Buildings" and "Green Urban Lighting" projects at the open-air Erebuni-Yerevan Expo organized by Yerevan Municipality as a part of the Armenian capital's 2797th birthday celebrations. The energy efficiency concept was promoted by presenting the project's ongoing and completed activities and pilot/demonstration projects.
10.	Training on "Proper installation and operation of modern street lights"	Introduction of modern EE street lighting technologies, training on proper handling and installation of LED luminaires, etc.
11.	Seminar on "Technical regulation and establishment of a national testing laboratory"	Identification of need for establishment of modern photometric laboratories in Armenia and to engaging Armenian companies in the network of national testing laboratories of lighting products.
12.	Seminar on "Modern lighting technologies, lighting norms and standards and measuring equipment"	Experience exchange on modern energy efficient lighting implementation, lighting norms and standards improvement, measuring equipment application.
13.	Lectures on "Energy saving in lighting" for secondary and high school students	Presentations on basics of EE in lighting for students of 5 educational institutions, followed by a contest aiming to strengthen the acquired knowledge through practice. Two kinds of contests and awards provided to students for improvement lighting EE based on assessment of saving potential in homes of students and in school buildings.
14.	Workshop on "Design and Implementation of Energy Efficient Lighting of Road Tunnels"	Presentation of modern solutions for energy efficient lighting design and implementation for roadway tunnels. The "Guide to the Lighting of Road Tunnels" was distributed.
15.	Seminar on "Introduction of Contemporary Energy Efficiency	Presentation of new building code on lighting energy efficiency in Armenia, "Artificial and Natural Lighting" RACN 22-03-2017 with

N	Event	Topics and provided information
	Norms and Standards in the Lighting Sector of Armenia"	experience and development prospective of EurAsian Economic Union, European Union and Russian Federation presented by UNDP International expert with extensive experience in the sector Mr. Anatoli Shevchenko.
16.	Training on "Basics of Energy Management, Design Features of Modern Lighting Systems, and Green Procurement Opportunities"	UNDP International expert with extensive experience in the sector, Mr. Andrey Dodonov led the training and presented theoretical and practical principles of urban energy management and the RF experience in energy. Management with significant portion of time and resources of the workshop allotted to group work.
17.	Round table on "Ensuring availability and applicability of relevant methods and techniques for upgrading street lighting systems"	UNDP International expert Mr. Anatoli Shevchenko led the event with presentation and discussion on the sector's legal and regulatory framework in the Russian Federation and their experience in implementation of lighting system upgrade projects, estimation techniques for defining energy consumption amounts, adjusting lighting systems' parameters to achieve higher energy saving, a review of functions and capacities of the available measurement equipment.
18.	An eighteen-minute movie on the main achievements of the project[1]	Overview of the project key objectives, capacity building on the current EE solutions in urban lighting in Armenia, demonstration of energy and cost saving results of the implemented pilots, stressing benefits for communities.
19.	Awareness rising campaign "Green Lighting Week"	Awareness raising on energy saving and environmentally sound lighting solutions, featured a series of high-pitched events and distribution of information and sample LED lamps in selected spots in Yerevan city.
20.	Workshop on "Modelling, design and estimation of lighting systems"	Experienced UNDP specialists presented the toolkit for modelling/design and estimation of indoor and outdoor lighting systems, as well as specific features of energy efficiency lighting systems design to representatives of specialized organizations, design institutions, architectural studios, public authorities, and academia.
21.	Energy Week 2017 Energy Efficiency Expo	The Expo was used as a platform to present the project's results and discuss replicability of the successfully implemented demonstration projects. The Energy Week 2017 series of events are organized by Armenia Renewable Energy and Energy Efficiency Fund in Yerevan.

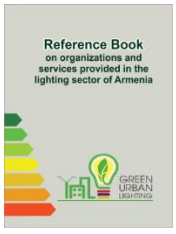
Table 2: List of published materials

Pilot Project Factsheets

Factsheets with information on completed pilot projects and highlights on improved technical parameters of modernized lighting systems were prepared for 25 pilot projects. The factsheets are available from the project website and are distributed at thematic events and relevant working meetings with stakeholders.

Reference book on "Acting organizations and rendered services in the lighting sector of Armenia"

The reference book was developed and published in English and Armenian languages. The document presents specification of lighting equipment available in the local market, and provides information on companies that produce and import them. The publication was distributed among municipalities, national and local stakeholders and financial organizations and placed on the project web-site.



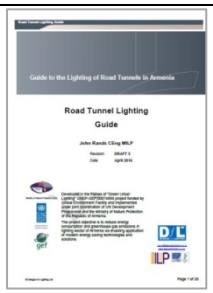
[1] This and other project related videos are available online via "Climate Change Armenia" YouTube channel.

Guide on Energy Efficient Lighting

Informational brochure “Guide on Energy Efficient Lighting” for high school students and specialized educational institutions students is aimed to increase awareness of students on indoor lighting technologies via comparison of their advantages and disadvantages as well as on key parameters. The objective of the Guide is to facilitate well informed decision making for selection of lighting technologies.

Road Tunnel Lighting Guide

The aim of this guide (Armenian and English) is to illustrate processes involved in the development, design and analysis of road tunnel lighting, current best practice recommendations for the lighting schemes and potential equipment involved in achieving energy efficiency for the installation. From the guide the reader will be able to understand some of the complexities that can occur in producing a compliant road tunnel lighting scheme.

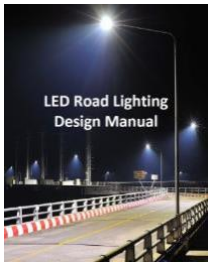


Residential Energy Consumption Survey

The report, developed by Economic Development and Research Center (EDRC) as per request of the Project, was aimed to obtain reliable data on energy consumption by urban and rural communities in Armenia, as well as to describe and analyze the current energy consumption picture in the country. The study (2600 respondents) provides the most recent, relevant and unique information on the current situation with indoor illumination in residential sector of Armenia.

LED Road Lighting Design Manual

To build the capacity of local municipalities and specialists of design institutions, the project analyzed the available guidelines and manuals on modern lighting technologies and selected as most applicable, the “LED Road Lighting Design Manual” commissioned by Philips Lighting (2015). The manual was localized and published in Armenian language. The objective of this manual is to provide municipal authorities and other stakeholders a useful tool to integrate LED road lighting solutions into relevant energy, transport, urban and rural development projects

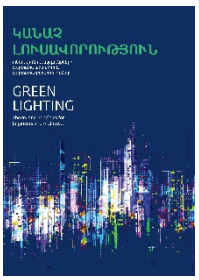


Construction norms “Artificial and Natural Lighting” RACN 22-03-2017

The norms determined the requirements for minimum permissible levels of illumination and brightness for outdoor and indoor lighting, meeting modern international requirements for comfort, and safety, determined the maximum allowable power (capacity) of lighting systems necessary to meet the standards as well as determined the indicators for using natural lighting in general lighting.

Green Lighting: Theory and Principles for Engineers and Architects

This bilingual textbook for engineers and architects is a brief summary on the physical, biological and aesthetical principles, as well as standards, economic approaches, software, and environmental aspects underlying the lighting technologies. The authors specifically emphasize the energy efficient solutions that help to mitigate climate change, one of the challenges of the modern world, and is applicable for governments to achieve energy independence and for individuals and businesses to increase savings.



Establishment of the first modern photometric laboratory in Armenia

The light testing laboratory established by the project in the Yerevan Illumination Company. It is equipped with integrating sphere and spectroradiometer, as well as necessary ancillary devices, including calibrated digital AC and DC power sources, digital power meter, and standard instrument cabinet for installation of equipment. For calibration of measuring unit a set of etalon light sources is provided. The installed equipment allows checking and measuring technical parameters of light sources such as luminous flux (Lm), luminous efficacy (Lm/W), spectrum, color temperature (K) and color rendering index.

The laboratory can provide services to all interested parties from private and public sectors. At the same time, the laboratory may serve as a training center for university students or practitioners who are taking courses on energy efficient lighting. In order to ensure sustainability of the laboratory operation, the Yerevan Illumination Company has appointed a specialist responsible for maintenance of the equipment and testing process. Technical team of the project provided necessary consultancy and practical support to the appointed specialist.

Within the reporting period about 100 samples (different type of light bulbs as well as luminaries), provided by more than 10 lighting companies and organizations (Concel LLC, Electrica Group LLC, El Gen LLC, Eurotechnolight LLC, Light and More LLC, Energy Saving LLC, Yerevan Municipality, etc.). Was tested compliance of actual parameters of the tested samples with the declared (labeled) data. The laboratory tested also about 4000 LED light bulbs procured for installation in frontier village of Armenia within the scope of UNDP Territorial Development Programme.

Establishment of an educational laboratory

Within the scope of the Statement of Intent signed between UNDP and National Polytechnic University of Armenia (NPUA) an educational laboratory on efficient light sources was established at the premises of the University. The project provided the newly established laboratory with lamp testing stands (portable and stationary) that allows simultaneous operation of different types of lamps (incandescent, halogen, compact fluorescent, LED), visual testing of their brightness and color range and measurement of their parameters, namely, wattage, amperage, etc.

The stands demonstrate advantages of the different lighting technologies and along with the testing stands, and posters on energy performance of different lighting technologies and on equipment for light source testing and equipment for audit of lighting systems contribute to improved curricula of educational establishment. The same equipment and informational materials were provided to similar educational laboratory established in the Gyumri branch of the University.

Results of the Component I in numbers:

- **29** audits for public lighting systems (outdoor and indoor) in **23** municipalities conducted
- **28** reports with recommendations on municipal lighting system improvements issued
- **1** modern photometric and **2** educational laboratories established
- **2** study tours on advanced EE lighting technologies is organized
- project achievements presented at **6** international events
- more than **200** specialist trained on EE lighting aspects
- **32** awareness raising and capacity building events conducted or co-financed
- **10** publications on informational and training materials prepared
- more than **170** media releases organized
- **3400** people covered by “Green Lighting Week” awareness rising event

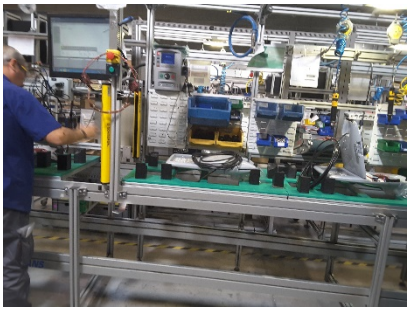


Audit of street lighting systems and meeting with pilot municipalities



Establishment of a modern photometric laboratory for lighting sources





A study tour for key sector actors on advanced technologies in urban lighting



Capacity building raising events



“Green Lighting Week” awareness rising event

Component II: Demonstration projects

Drawing upon results of energy audits described in the previous chapter, the project has provided both technical assistance and incremental direct investments to support the implementation of selected pilot projects for EE public lighting in Yerevan and other selected urban and rural communities. This is one of the most important components of the project as it is to demonstrate not only energy, cost and GHG emissions reduction but also comfort and safety improvement benefits from introduction of new LED based efficient lighting technologies and solutions, as well as to provide technical, procedural and financial insight for replication of the proposed approaches through municipal programs and associated financial support.

Within the scopes of this component 34 outdoor and street lighting (Table 3, 8), and 11 indoor (Table 5) EE lighting projects (replacement of MV and HPS lamps by LED lamps and luminaries) financed by the UNDP-GEF project and co-financed by target municipalities and third parties, were implemented. As main beneficiary of the Project Yerevan municipality was refurbished key avenue linking International airport to the center. The savings from this first project was accumulated in the Municipal revolving fund and later used for refurbishment of the lights on Mashtots avenue (50% from GEF grant and 50% from fund) – 2.56 km, and later for Atenk street and Tsiternakaberd avenue (3.5 km) and the in last one was Arshakunyats avenue (4.0 km).

Table 3: List of pilot projects in outdoor lighting systems

N	Municipality	Length of pilot objects, km	Luminaires quantity, pcs		Installed capacity, kW		Reduced capacity, kW	Annual energy saving, MWh	Annual GHG emission reduction, t CO_2
			before	after	before	after			
1	Yerevan	10.14	959	684	261.48	90.96	170.52	618.58	274.65
2	Alaverdi	2.42	92	92	26.19	4.79	21.40	33.13	14.71
3	Spitak	1.76	78	78	21.49	8.03	13.46	23.62	10.49
4	Abovyan	1.69	141	106	40.08	7.74	32.34	59.20	26.28
5	Sevan	1.10	62	62	17.68	4.65	13.02	23.83	10.60
6	Goris	3.80	112	112	34.72	16.24	18.48	32.44	14.40
7	Ararat (and 2 rural commu-nities)	5.09	190	193	54.08	11.24	42.84	76.87	47.79
8	Stepanavan	2.43	99	99	28.31	10.21	18.09	31.76	14.10
9	Kapan	1.55	70	70	20.00	5.25	14.75	27.93	18.46
10	Kajaran	1.38	76	76	21.53	3.20	18.34	73.29	32.54
11	Gavar	1.58	53	53	15.22	4.80	10.42	18.29	8.12
12	Akhtala	1.02	40	40	6.84	1.68	5.16	11.30	5.00
13	Masis	2.20	87	87	24.80	6.79	18.01	39.44	17.50
14	Talin	1.20	44	44	11.40	3.73	7.67	11.20	4.97
15	Tashir	2.40	80	80	22.80	8.56	14.24	20.79	9.20
16	Aparan	2.58	86	86	24.51	9.20	15.31	27.94	12.40
17	Sevan Penensula*	1.14	65	65	11.12	2.28	8.84	16.13	7.16
Total		**43.48**	**2,334**	**2,027**	**642.25**	**199.35**	**442.89**	**1,145.74**	**528.37**

*Note: *) The project implemented jointly with the Ministry of Nature Protection of RA*

The Table 4 below summarizes information on total resources invested by GEF and co-financing mobilized from target municipalities and third parties for implementation of pilot projects in municipal outdoor (street and public areas) lighting, as well as on the total number of implemented pilots.

Table 4: Invested resources and implemented projects in community outdoor lighting systems

Total amount of investment (US dollar)	Including					Number of pilots
	UNDP-GEF project	From revolving fund	Community co-financing		Other (3rd-pary) investment	
			For luminaires purchasing	For installation & improvement		
1 185 396.4	**652 989.7**	**239 675.9**	**16 611.3**	**273 314.5**	**2 805**	**34**

Table 5 below provides information on demonstration (pilot) projects implemented in indoor lighting systems under GEF and municipal co-financing.

Table 5: List of pilot projects in indoor lighting systems

N	Project / Activity	Area of pilot sites, m^2	Bulbs or luminaires quantity, pcs		Installed capacity, kW		Reduced capacity, kW	Annual energy saving, MWh	Annual GHG emission reduction, t CO_2
			before	after	before	after			
1	Nature Museum (Yerevan)	950	240	204	8.92	4.14	4.78	8.00	3.50
2	Kanaker Social House (Yerevan)	2,400	646	656	32.78	7.21	25.65	19.36	8.60
3	Gumri Mush kindergarten	480	48	63	4.28	1.66	2.62	4.10	1.82
4	Geology Museum (Yerevan)	500	95	90	4.70	2.12	2.58	2.16	1.16
5	Yerevan Municipality	16,082	3,914	3,523	151.88	50.43	101.45	152.18	67.57
6	Yerevan History Museum	3,105	398	398	23.01	6.70	16.31	24.74	10.86
7	Masis Community	1,683	148	148	12.85	3.20	9.65	10.59	4.70
8	PR Campaign	-	3,000	3,000	180.00	27.00	153.00	223.38	99.20
9	Special school (Yerevan)	1,170	90	90	9.00	1.32	7.68	7.68	3.41
10	MoEDI	6,800	682	682	25	7.7	17.3	43.14	19.2
11	MoNP	14,500	2554	2554	121.3	37.9	83.3	208.36	92.5
Total		**47,670**	**11,815**	**11,408**	**695.02**	**149.38**	**424.32**	**703.69**	**312.52**

The Table 6 below summarizes information on total resources invested by GEF and co-financing mobilized from target municipalities for implementation of pilot projects in municipal indoor.

Table 6: Invested resources and implemented projects in community indoor lighting systems

Total amount of investment (US dollar)	Including			
	UNDP-GEF project	Community co-financing		Other (3^{rd}-pary) investment
		Luminaires	Installation and improvement	
85,000	**65,586**	**19,414**	**(not monetized)**	**--**

Results of the Component II in numbers:

- **21** urban and **2** rural communities (with over **1.5 mln** population) covered by the project
- **34** outdoor and **11** indoor illumination systems modified
- Illumination of **44 km** of pilot streets/areas and **47,700 m^2** of buildings improved
- about **2,000** LED outdoor luminaries and **11,400** indoor LED lamps and luminaires installed
- about **867 kW** of installed capacity of lighting systems reduced
- **1.85 GWh** of electricity saved (**75%**) and **841 tons of CO_2** emissions reduced annually
- conformity with Illuminance level and uniformity norms ensured
- traffic comfort and safety as well as better living/working conditions ensured
- over **$718,600** of GEF funding spent and over **$259,100** of co-financing mobilized



Modernization of street lighting system on Isakov Avenue in Yerevan



Energy efficient upgrade of lighting system of Yerevan ZOO



Complete renovation of the street lighting system in Spitak municipality



Test and acceptance of LED street luminaries the pilot project in Alaverdi municipality



Upgrade of indoor lighting system in the social house in Yerevan and in the kindergarten Mush in Gyumri Municipality

Component III: Replication via municipal lighting programs and associated financial instruments

Successful implementation of the pilot projects on EE modernization of public lighting has demonstrated immediate cost-saving and energy saving benefits, and contributed substantially to changing of decision-makers perception of the street illumination as sector, where drastic improvement of public services can be achieved through cost-effective investments into energy efficient technologies available on the local market.

The number of municipalities interested in piloting new lighting systems or willing to expand already implemented pilots is increasing; however, shortage of municipal funds, limited access to loans, unattractiveness of municipal sector for private capital because of lack of regulations and high risks as well as other factors are limiting capabilities of local governances to realize these plans.

Therefore, the project team was tasked to develop a set of financial, institutional and legal proposals aimed at overcoming the mentioned barriers and facilitating investments in municipal energy efficient lighting.

The following activities have been implemented within the scope of this component:

Establishment of municipal revolving funds in 16 municipalities

Municipal revolving funds (off-budget special accounts) to support investments for replication of energy efficient activities in public lighting sector have been established in Yerevan and 15 other municipalities.

Project has developed the concept and charter of the municipal revolving funds. The funds establishment were approved by the city councils and the permission to open extra budgetary accounts was granted by the Ministry of Finance. In Yerevan, the special account was opened in Yerevan Illumination Company by the order of Mayor.

The funds will serve to accumulate actual savings (electricity, operation and maintenance) achieved via implementation of GEF financed pilot projects as to reinvest findings into design (10% of resources) and implementation (90% of resources) of public lighting modernization projects based on EE technologies. The resources of the funds are managed by the fund management councils. Each month the energy savings were monitored and reported by the city administration and verified by project expert.

In the Table 7 below information on established revolving funds, estimated annual savings and resources accumulated as of August 2018 is presented.

Table 7: Information of municipal revolving funds established by the project

N	Municipalities	Estimated annual savings (USD)	Resources accrued as of 01.09.2018 (USD)	Including				Fund operated since
				2015	2016	2017	2018	
1	Yerevan	115296.1	273073	35465	65580	101459	70569	30.07.2015
2	Abovyan	8663.1	17009	--	5303	6255	5452	17.03.2016
3	Alaverdi	3328.1	11552	1732	2957	4210	2653	01.12.2015
4	Ararat (urban)	2670.7	3981	--	393	1888	1700	27.03.2017
5	Ararat (rural)	3209.1	3707	--	600	1401	1706	10.11.2016
6	Gavar	2058.8	3187	--	0,0	1674	1513	21.02.2017
7	Goris	3050.9	7175	--	2086	3137	1953	23.09.2016
8	Kajaran	9466.6	10306	--	898	4353	5055	06.12.2016
9	Kapan	3159.0	4857	--	253	2531	2073	13.01.2017
10	Masis	3425.5	2215	--	0,0	302	1914	02.11.2017
11	Sevan	2404.8	6707	--	2643	2540	1525	04.05.2016
12	Spitak	2206.2	6950	246	1747	3056	1901	18.04.2016
13	Talin	977.7	818	--	0,0	0,0	818	16.03.2018

N	Municipalities	Estimated annual savings (USD)	Resources accrued as of 01.09.2018 (USD)	Including				Fund operated since
				2015	2016	2017	2018	
14	Stepanavan	3905.5	10299	--	840	4427	5032	03.02.2017
15	Tashir	1815.2	--	--	--	--	--	19.04.2018
16	Aparan	2423.9	596	--	--	--	596	19.07.2018
TOTAL		**168,061.2**	**361,836**	**37,443**	**83,300**	**137,233**	**103,864**	

Scaling-up municipal EE lighting projects via revolving funds

Replication of the piloted EE lighting modernization projects has been financed through the resources of the revolving funds in 10 municipalities, resulting in about 840 kWh of energy saving and 394 tCO2 emission reduction annually. The project team provided technical assistance to the municipalities for design, tender and implementation of street lighting modernization follow-up (replication) projects.

Total amount of resources reinvested from the revolving funds for replication of pilot projects during the project implementation period is **239,676 USD**.

Information on replication projects implemented in outdoor lighting systems and financed via energy efficiency revolving funds is summarized in the table below.

Table 8: Projects of outdoor illumination financed by energy efficiency fund

Municipality	Length of street, km	Luminaires quantity, pcs		Installed capacity, kW		Reduced capacity, kW	Annual energy saving, MWh	Annual GHG emission reduction, t CO_2
		before	after	before	after			
Yerevan	9.26	1,129	676	303.43	95.98	207.45	703.45	312.33
Alaverdi	0.50	20	20	5.73	1.19	4.54	7.03	3.00
Spitak	0.20	10	10	2.68	0.75	1.92	3.38	1.50
Abovyan	0.91	95	95	27.18	6.20	20.98	38.39	17.04
Ararat (urban)	1.03	34	34	9.76	1.88	7.88	15.71	22.68
Ararat (rural)	1.26	42	42	11.97	2.31	9.66	20.49	9.1
Stepanavan	0.61	28	28	7.89	1.58	6.31	11.08	4.92
Kapan	0.38	13	13	3.65	1.15	2.50	5.47	7.90
Kajaran	0.90	33	33	9.53	1.78	7.76	31.00	13.76
Gavar	0.30	12	12	3.02	0.72	2.30	4.04	1.79
Total	15.35	1,416	963	384.84	113.54	271.3	840.04	394.02

Support in development of municipal lighting upgrade program and mobilization of funds in Yerevan

In May 2015, EBRD, the Ministry of Finance of Armenia and the Municipality of Yerevan city signed an agreement to allocate a co-financing grant of 2.2 million USD to support the modernization of street lighting in the city of Yerevan. The grant was provided by the E5P fund (Eastern Europe Energy Efficiency and Environment Partnership), which is managed by the EBRD and pools donor contributions from the European Union and a number of donor countries including Armenia, and supplemented EBRD 4 million USD loan committed by the Bank for modernization of Yerevan's street lighting system by introducing new energy-efficient technologies that will benefit the city's residents. Totally about €6 million has been secured for renovation and energy efficient modernization of lighting system of 28 streets in Yerevan based on LED technology.

As it was later acknowledged by the Yerevan municipality and officially communicated to the UNDP Armenia (the letter of Mr. Kamo Areyan, First Deputy Mayor of Yerevan) that the positive experiences from the UNDP-GEF supported pilot projects and related awareness raising and built trust of the key decision makers in EE LED technology contributed significantly to the approval of the EBRD loan by the National Assembly of RA.

Facilitation of public lighting modernization programs in other cities in Armenia

As mentioned before, audit of public lighting systems in 23 partner municipalities were carried out by the project. Obtained results provide ground for preparation of optimal technical proposals for energy efficient modernization of entire municipal street lighting systems for each of the community. The basic technical solution proposed for all municipalities (and tailored for each municipality based on its specificities) is replacement of existing inefficient lighting systems composed of MV, HPS and CF lamps with efficient LED street luminaries. The proposals also contain assessment of investments needed for procurement of the luminaires, energy and cost saving benefits and simple pay-back. The reports are aimed to help municipalities to mobilize funds for implementation of proposed activities.

Contribution to mobilization of financing for lighting system upgrade initiatives

The following resources have been mobilized by IFIs, funds and private sector to invest in EE modernization of lighting systems in Yerevan and regions:

- ADB has prepared a 48.6 million USD loan for the 60 mil USD Sustainable Urban Development Investment Program that includes energy efficient street lighting component (ca 2 million USD).
- EBRD is implementing a 28 million USD project "Gyumri Urban Roads" that has a major component on modernization of street lighting.
- Armenian Territorial Development Fund is preparing 8 million USD funding for municipal infrastructure modernization, with a main demand from municipalities being energy efficient public lighting.
- Other similar initiatives and projects in the sector are implemented by various stakeholders (e.g. SGP, GCP, Bright Border, etc.).

Results of the Component III in numbers:

- **16** municipal revolving energy efficiency lighting funds established
- **361,836 USD** accumulated in the funds during the project implementation
- **239,676 USD** reinvested from the fund in replication of **10** pilot projects, **14 km** of roads
- about **1,416** luminaries replaced and **271 kW** of installed capacity reduced via replication
- **840 GWh** of electricity saved and **394 tons of CO_2** emissions reduced annually
- **10** municipalities received assistance for design and tender documentation preparation for street lighting upgrades

Component IV: National policies, codes, and standards on lighting

The following key activities were implemented within the scope of this component.

Law of RA "On making an amendment and an addition into the RA law "On energy efficiency and renewable energy"

The project team jointly with "Improving Energy Efficiency in Buildings" UNDP-GEF project participated in development of the draft Law of RA "On making an amendment and an addition into the RA law "On energy efficiency and renewable energy", proposing a package whose adoption enables the following:

- Besides voluntary principle for energy saving also application of compulsory norms, so as to create legislative bases of stipulating energy efficiency requirements on buildings and lighting equipment/lamps in legal acts (e.g. via adoption of the respective technical regulations);
- Stipulating mandatory requirements on energy efficiency and energy saving for the newly constructed residential multi-apartment buildings, as well as for facilities being constructed (reconstructed, renovated) under the public funding;
- Identification of economy sectors of the Republic of Armenia as featuring high, medium and low energy intensity which will enable to implement regular organization of statistics on energy consumption in lighting systems and buildings;
- Adoption of labeling of energy consuming equipment and devices and identification of label form to contribute to wider use of those (including lamps and lighting equipment) in buildings, outdoor lighting and other systems;
- Clarification of regulatory issues for energy audit implementation;
- Compilation of a list of energy efficient devices, appliances and other products identified as hazardous for human life and/or environment (containing dangerous substances), as well as procedure for circulation of those in the RA internal consumer market and utilization of those upon disposal, including issues relevant to mercury containing lamps.

The Law was adopted by the National Assembly of RA on 12 May 2016.

Decision of RA Government "On implementation of energy saving and energy efficiency improvement measures in facilities being constructed under the state funding"

The project team participated in developed of the decision of RA Government "On implementation of energy saving and energy efficiency improvement measures in facilities being constructed (reconstructed, renovated) under the public funding". The decision was adopted by the RA Government on December 25, 2014, decision #1504-N.

The list of the proposed energy saves and energy efficiency measures mandates, among other measures, application of energy saving heating, ventilation, air conditioning, hot water supply, lighting systems and equipment in all facilities being constructed (reconstructed, renovated) under the public funding.

Adoption of Technical Standard RA CN 22-03-2017 "Natural and Artificial Lighting"

The building norms in force at the beginning of the project were approved in 1996 and updated in 2004. The norms did not reflect the current lighting requirements in Europe and Russia, and therefore did not provide for security requirements. On the other hand, construction norms allowed ensuring energy saving by reducing comfort conditions.

The project revised and updated Technical standard RA CN 22-03-2017 "Natural and Artificial Lighting" to incorporate minimal energy performance standards required for lighting. The introduction of new norms allowed to limit the minimum permissible levels of illumination required for certain classes of roads. On the other hand, the norms have limited the maximum permissible capacity of the system to ensure the required level of illumination, thereby stimulating the use of the most energy-efficient lighting systems.

Development of Green Procurement Guide

In the course of the Project interactions with specialists from municipalities who are responsible or involved in lighting systems design, as well as operation and maintenance was revealed their insufficient technical competence in terms of proper selection and procurement of lighting equipment.

To address this issue, a green procurement guide (package of green procurement documents) was prepared, outlining the legislative framework governing the public procurement process and presenting a guide to the principles and criteria for choosing lighting equipment. The Guide was formally submitted to the Ministry of Territorial Administration and Development for distribution as recommended practice to municipalities.

Greenhouse gas emissions reduction

In line with GEF requirements, the impact of climate change mitigation projects on greenhouse gas emissions have to be estimated using methodologies developed by the Scientific and Technical Advisory Panel (STAP) and recommended by GEF:

- Manual for Calculating GHG Benefits of GEF Projects: Energy Efficiency and Renewable Energy Projects (2008)
- Calculating Greenhouse Gas Benefits of the Global Environmental Facility Energy Efficiency Projects, Version 1.0. (2013)

Usually, only one out of the mentioned two methodologies is used for calculation of GHG emission reduction. The 2013 methodology ensures more rigor and consistent GHG analysis and simplified the application for GEF agencies, by providing a more complete, and easy-to-use Excel spreadsheet Tool that embeds more standardized guidance in the form of algorithms and conservative default factors[2].

Nevertheless, taking into consideration some specific aspects of the current project components (described below in the text) and in consultation with international consultants, it has been agreed to apply "combined" approach based on both methodologies. However, the overall climate change mitigation (GHG abatement) contribution of the project is assessed by applying 2013 methodology.

Explanation of calculation process and key assumptions made by the project team as well as results of calculations are introduced below.

General assumptions

- Out of 4 project components only three (demonstration projects, municipal programs & financial mechanism and regulation) are considered for calculation of energy saving and GHG emission reduction benefits, while the fourth one (audits, awareness raising and capacity building) is rather contributes to achievement of the projects ultimate objectives indirectly. Accordingly, calculations are made for the following modules provided by the 2013 Methodology: (1) Standards and Labeling, (3) Demonstration and Diffusion and (3) Financial Instruments. The second module, "Building Codes", is not applied as project activities do not strictly comply with its applicability conditions and intervention type[3].

The project components has been conditionally arranged into respective groups and classified as per the above-mentioned modules in the following way.

Activity Component	Sector/Subsector	Module/Intervention Type
EE upgrade of outdoor lighting of streets in Yerevan	Street Lighting	Demonstration & Diffusion
EE upgrade of outdoor lighting of streets in Regions	Street Lighting	Demonstration & Diffusion

[2] *Calculating Greenhouse Gas Benefits of the Global Environment Facility Energy Efficiency Projects. Version 1.0. Scientific and Technical Advisory Panel, Global Environment Facility, March 2013.*

[3] Applicability conditions: "Projects that systematically address residential, public, or commercial sector building efficiency through codes or other policy instruments"; Intervention types: "Building code establishment; enhanced code enforcement".

Activity Component	Sector/Subsector	Module/Intervention Type
EE upgrade of Indoor lighting	Indoor Lighting	Demonstration & Diffusion
EE updated of outdoor lighting of Yerevan Zoo	Lighting of Public Spaces	Demonstration & Diffusion
Establishment of Municipal Revolving Fund	Street Lighting	Financial Instrument
Development of a new standard on EE lighting (outdoor) and (indoor)	Indoor and Outdoor Lighting	Standards and Labeling
	Indoor and Outdoor Lighting	Standards and Labeling

- Maximum lifetime for applied LED based lighting technologies is 20 years in line with guaranteed lifetime of technology announced in supplier's technical information.

- National grid electricity emissions factor – 0.4 tCO2/MWh (in line with the Report on Grid Emission Factor for the Electricity System of the Republic of Armenia prepared by UNDP and MoNP).

Module 1: Standards and Labeling

- This module is applied to calculate energy saving and GHG emissions reduction effect to be achieved through development and enforcement of a new standard on energy efficient lighting (Technical standard RA CN 22-03-2017 "Natural and Artificial Lighting"). For the purposes of calculation, impact of this activity on transformation of outdoor and indoor lighting markets is assessed separately, thus, it has been conditionally broken down into the following two outcomes: outdoor and indoor

- For outdoor lighting sector it is assumed that LED technology is replacing outdated HPS and MV lamps, as the most wide-spread technologies applied in the sector (based on the results audits carried out by the project).

- Other assumption made for outdoor lighting sector and respective justifications are summarized in the table below (based on survey results, data from custom authority).

Parameter (unit)	Value	Notes
Technology Specifications		
Power Consumption: LED Lighting (W)	95	Average capacity of LED luminaries to replace existing HPS and MV lamps, calculated based on information on supplied and installed LED luminaries from in technical specifications and instructions of luminaries.
Power Consumption: HPS and Mercury (W)	298	Average capacity of HPS and MV lamps for outdoor lighting, calculated based on statistical information on street luminaries in Yerevan and regions available in the Project Document.
Daily Usage (hour/day)	6	Average daily usage of outdoor lighting based on the project's statistics, calculated based on information on daily usage of street lighting systems in Yerevan and regions.
Days Used Each Year (days/year)	365	Annual usage of street lighting systems.
Market Assumptions		
Annual Sales in Year 2014	26,000	Information on import of HPS and MV lamps for 2014. (Custom Authority of RA.)
Annual Sales Growth Rate	5%	Expert judgment on conservative growth rate of lighting market
Baseline Assumptions		
Market Share of LED Lighting in Year 2014	2%	Information received from municipalities during PPG stage of the project as well as updated data from Yerevan Municipality
Baseline Annual Increase in LED Lighting Market Share	5%	Expert judgment on conservative growth rate of LED lighting market (consistent with STAP default value)
Annual reduction in energy consumption: LED Lighting	5%	Average annual improvement of efficiency of technology (manufacturer data)
Annual reduction in energy consumption: HPS and MV	1%	Default value proposed by the STAP methodology

- In Market Assumption section, the annual sale of luminaries in 2014 (first year of the project) is 26,000. This data reflects information received from the Custom Authority for 2014. In the same section it is assumed that annual sale rate growth is 5%. This two figures result in about 84,000 luminaries at the end of the analysis period (2038) which seems to be reasonable amount given that in 2014 total number of street lighting points was about 70,000. The project did not make projections of the annual sales growth rate based on Custom Authority data published for subsequent years, as they show very dramatic (inconsistent) changes and might be "misinterpreted" by the Tool.
- For street lighting, it is assumed that the Standard adopted in 2017 would have conservative influence, so that 60% of new sales on street lighting luminaries are compliant with the Standard. This is average percent for twenty-year time horizon (assuming that it starts from 20% and ends with e.g. 80%). This is quite a conservative assumption, as assortment of LED luminaries already dominating in majority of advanced lighting shops. On the other hand, this assumption takes into account an influence of "dynamic baseline" (likelihood of accuracy of the projected effect in a business-as-usual scenario without GEF intervention). Hence, the proposed average 60% of influence seems to be reasonable.
- For indoor lighting sector it is assumed that LED technology is replacing outdated incandescent lamps, as the most wide-spread technology applied in residential sector (based on the results of surveys).
- Other assumption made for outdoor lighting sector and respective justifications are summarized in the table below.

Parameter (unit)	Value	Notes
Technology Specifications		
Power Consumption: LED Lighting (W)	10	Average capacity of LED luminaries to replace existing incandescent lamps.
Power Consumption: Incandescent (W)	60	Average capacity of incandescent lamps for indoor lighting.
Daily Usage (hour/day)	3.5	Average daily usage of indoor lighting based on UNFCCC methodology.
Days Used Each Year (days/year)	365	Annual usage of indoor lighting systems.
Market Assumptions		
Annual Sales in Year 2014	18,000,000	Information on import of technology provided by the Custom Authority of RA
Annual Sales Growth Rate	1%	Expert judgment on conservative growth rate of lighting market.
Baseline Assumptions		
Market Share of LED Lighting in Year 2014	5%	Lighting market survey carried out by the project (survey)
Baseline Annual Increase in LED Lighting Market Share	5%	According to the lighting sector survey carried out in 2015 and 2017 (consistent with STAP default value)
Annual reduction in energy consumption: LED Lighting	5%	Average annual improvement of efficiency of technology (manufacturer data)
Annual reduction in energy consumption: incandescent	1%	Default value proposed by the STAP methodology

- For indoor lighting it is assumed that the Standard adopted in 2017 has less influence than that for street lighting because procurement of street luminaries is mainly organized through public procurement procedures (i.e. are more influenced by the norms). This, more conservative assumption is made foreseeing that only 30% of new sales of indoor lamps (systems) will be compliant with the new standard.

Based on Project data input and assumptions, the Tool provides the following results:

Standards and Labeling Module	Cumulative			Annual			
	Total	2014-2018	2019-2038	2014	2018*	2025	2035
Direct Electricity Savings (MWh)	3,764,179	311,712	3,452,467	0	**188,209**	188,209	188,209
Direct GHG Emission Savings (tCO2)	**1,505,672**	124,685	1,380,987	0	**75,284**	75,284	75,284
Direct PP GHG Emission Savings (tCO2)	**152,911**		152,911	0	0	8,511	8,511
Indirect BU Emission Savings (tCO2)							

**) Year of project end*

The target set of the "national policy" component of the project is as follows: "Indirect energy savings of 125 GWh per year from implementation of national lighting policy (50,000 tons of CO_2 emissions)". Taking into consideration the specificity of the Tool (it does not provide indirect emission saving results for this module), annual savings for 2018 (end of the project) are considered.

As it is seen from the table above, the target was achieved at **150%** (188,209 GWh direct energy saving vs. 125 GWh stated in ProDoc and 75,284 tCO_2 direct GHG reduction vs. 50,000 tCO_2 in the ProDoc.

Module 3: Demonstrations and Diffusion

- This module is applied to calculate energy saving and GHG emissions reduction effect to be achieved not only through implementation of GEF project financed pilot projects, but also through replication of piloted technologies via municipal programs financed from municipal budgets and by third parties (replication projects financed through revolving funds is considered in the next module). For the purposes of calculation, all implemented activities have been conditionally divided into the following four groups of outcomes of EE upgrades:
  1. Outdoor lighting of streets in Yerevan city.
  2. Outdoor lighting of streets in other communities
  3. Indoor lighting
  4. Outdoor lighting public spaces (Yerevan Zoo)
- Assumptions are made on the dynamic baseline i.e. Percent of Activities Implemented in the Baseline (without GEF). For all outcomes 1% has been used except for component 3 where 5% has been applied.
- Assumptions are made regarding replication of pilots "Number of Replications Post-project as Spillover". Assumptions on number of replications of the pilot activities are based on available information on activities of various stakeholders, such as EBRD (Yerevan and Gyumri), ATDF (Dilijan), ADB (North-South highway and Yerevan Road projects), etc.

Based on data input and assumptions, the Tool provides the following results.

Demonstrations and Diffusion Module	Cumulative			Annual			
	Total	2014-2018	2019-2038	2014	2018*	2025	2035
Direct Electricity Savings (MWh)	31,275	4,562	26,713	0	**1,564**	1,564	958
Direct GHG Emission Reduction (tCO2)	**12,510**	1,825	10,685	0	**625**	625	383
Direct PP GHG Emission Savings (tCO2)							
Indirect BU Emission Savings (tCO2)	**117.753**		117.753				

**) Year of project end*

The target set for the "Demonstration projects" component of the project is as follows: "Direct energy savings of 1.2 GWh per year from demonstration projects (474 tons of CO_2 emissions)".

Following the logic explained above, results on 2018 (end of the project) was achieved at about **130%** or 1.564 GWh direct energy saving (vs. 1.2 GWh stated in ProDoc) and 625 t CO_2 direct GHG reduction vs. 474 tCO_2 in the ProDoc.

This component also contributes to achievement of another target of the project set in the Project Document, i.e. "Indirect energy savings of 20 GWh per year from replication of demonstration projects via municipal programs (8,000 tons of CO2 emissions)".

The Tool considers replications of pilots as indirect bottom-up emission savings and provide only cumulative result for 20 years (not annual e.g. for 2018). In the table below it is seen that Indirect bottom-up emission savings (tCO2) due to replication of pilots via municipal programs is **117,753 tCO2**.

In order to "transform" the achieved cumulative (lifetime) emission reduction into annual format to be able to compare it with ProDoc's target of 8,000 tCO_2/a, we propose to divide cumulative Indirect BU Emission Savings (tCO2) by 20 years, thus, conditionally obtaining annual data. As a result of this calculation, annual Indirect BU Emission Savings due to replication of pilots via municipal projects financed from municipal budgets and other sources is 5,888 tCO_2/a, i.e. about **73%** of the total target amount of 8,000 tCO_2/a.

Annual GHG emission reduction benefit achieved via replication projects financed through municipal energy efficient lighting revolving funds is calculated in the next module

Module 4: Financial Instruments

- This module is applied to calculate energy saving and GHG emission reduction effect to be achieved through replication of pilot technologies financed by municipal revolving funds established by the project. For the purposes of calculation, all implemented activities have been integrated into the following group of outcomes:

    1. Establishment of Revolving Fund for Municipal Energy Efficient Lighting.

As already explained above, application of "Financial Instruments" module of the STAP Methodology 2013 is not reasonable, as this Tool is designed for loan finance projects and, thus, does not reflect peculiarities of the Municipal Revolving Funds established under GUL project.

Hence, it has been proposed to apply approach defined in the Methodology 2008 "Manual for calculating GHG benefits of GEF projects: Energy efficiency and renewable energy projects" for calculation of GHG emissions reduction benefits from the establishment and operation of the Municipal Revolving Fund and integrate (to the extent possible) outcomes of this separate calculations into the "Financial Instruments" module of the STAP Methodology 2013.

Below exempts form the mentioned manual are quoted as well as results of calculation are introduced.

Direct Post-project Emission Reduction Effects of GEF-financed Interventions

In some cases, GEF projects put in place a GEF-supported financing mechanism that will continue supporting direct investments after the project's implementation period. A typical example is a revolving fund for up-front financing of energy investments, which is refinanced from user fees or loan repayments. Depending on the leakage rate and the speed of payback, facilities of this type can multiply the original direct investment and associated emission savings long after the project itself has ended.

These "direct post-project" emissions can be calculated with the same formula as the direct effects that are achieved during project implementation. In fact, as the facility that might have a post-project impact is usually set up and operating during the project, the direct emission savings from the first "turnover" of that facility are factored into the direct emission reductions as discussed above. Assumptions are necessary as to how many more "turnovers" the facility will have after the project is completed.

For a revolving fund, the rates of reflow and leakage determine how many investments can be financed after the supervised implementation period (how often the fund can "revolve"). The emission savings from these investments will be estimated as a multiple of the direct GHG outputs of the project.

The formula is:

CO2 DPP = CO2 direct * tf; with

CO2 DPP = emissions saved with investments supported by post-project financial mechanism

CO2 direct* = direct emission savings to the degree they are supported through the mechanism that causes the post-project impacts

tf = turnover factor, determined for each facility based on assumptions on fund leakage and financial situation in host country.

In the absence of a good turnover rate estimate Direct Post Project emission reduction can be estimated with the following equations:

$$[d * (1 - r ^ (n + 1))/k] – d,$$

where:

d = direct lifetime reduction from investments made during the project supervision from the financial mechanism only,

n = years of fund operation after project close (typically 5-10 years),

k = leakage rate after the project close,

r = 1 – k = reflow rate after project close.

According to the statistical information available at the Project, direct (cumulative) CO_2 emission reduction achieved within the scope of the project as a result of replication of pilot projects financed by the fund only is 474 tCO_2 (equivalent to 1,185 MWh), while annual CO_2 emission reduction effect achieved via the replication of pilots after completion of the project is 315.6 tCO_2/a (equivalent to 789 MWh/a).

In order to calculate "d" i.e. direct lifetime reduction from investments made during the project supervision from the financial mechanism only, it is necessary to sum total emission reduction achieved during implementation period of the project (2017-2018) to cumulative emission reduction to be achieved after completion of the project (in 2019-2038). For the purpose of this calculation average lifetime of measures is 18 because certain pilots were implanted not at the end of the project (i.e. in 2018) but earlier (i.e. in 2016-2017), thus, the average duration of measures staring from the end of 2018 is about 18 years.

As a result, "d" = 474 + (315.6 x 18) = 6,154.8 tCO_2.

If assumed that the fund's operation period is 12 years; and given that the fund started its full operation on the third year of the project implementation, it is assumed that after completion of the project the fund will operate 10 more years.

Leakage rate after the project closure is assumed to be 5%.

Based on the above assumptions, Direct Post Project CO2 emission saving is:

$$DPP = [d * (1 - r ^ (n + 1))/k] – d = [6154.8 * (1 – 0.95 ^ (10 + 1))/0.05] – 6154.8 = 46924.2\ tCO_2$$

Turnover factor (tf) is 46924.2 / 6154.8 = 7.6

If the above-described approach for transformation of cumulative results into annual is acceptable then we will have the following result:

Direct Post Projects Emission Savings of 46,924.2 tCO2 divided by 20 years gives 2,346 tCO_2/a of annual emission reduction.

As a result of calculations of CO_2 emissions reduction effects of measures implemented under "Demonstration projects" and "Financial Instruments" components, the following results for conditional annual reductions for "replication of demonstration projects via municipal programs" target are achieved:

1. Replication of pilots via municipal programs funded by municipalities and donors: 5,888 tCO_2/a,
2. Replication of pilots via municipal programs funded by the Municipal Revolving Funds: 2,346 tCO_2/a.

Thus, the total annual emission reduction effect of these two measures makes 8,234 tCO_2, hence the "replication of demonstration projects via municipal programs" component the target was achieved at about **103%** (8234 tCO_2/a vs. 8,000 tCO_2/a).

Overall results of calculation of GHG benefits achieved through implementation of all project components are summarized in the table below.

Table 10: Results of GHG emission reduction calculation for all project components

All Components	Cumulative			Annual		
	Total	*2014-2018*	*2019-2038*	*2018*	*2025*	*2035*
Direct Electricity Savings (MWh)	3,810,840	317,459	3,493,381	190,562	190,562	189,956
Direct Total Energy Reduction (GJ)	13,719,025	1,142,853	12,576,173	686,022	686,022	683,840
Direct GHG Emission Reduction (tCO_2)	1,524,336	126,984	1,397,353	76,225	76,225	75,982
Direct PP GHG Emission Reduction (tCO_2)	199,835		199,835	0	8,511	8,511
Indirect BU Emission Reduction (tCO_2)	117,753		117,753			
Indirect TD Emission Reduction (tCO_2)	0		0			

GHG emission reduction benefits of the project in numbers			
Activity	**End of Project Target**	**Calculated GHG Benefits**	**Achievement**
Demonstration projects financed by GEF and co-financed by target municipalities	Direct energy savings of **1.2 GWh/a** and emission reduction of **474 t CO_2/a**	Direct energy savings of **1.564 GWh/a** and emission reduction of **625 t CO_2/a**	The target was achieved at **130%**
Replication of demonstration projects realized through municipal programs finance via RFs and by other donors	Direct energy savings of **20 GWh/a** and emission reduction of **8,000 t CO_2/a**	Direct energy savings of **20.56 GWh/a** and emission reduction of **8,234 t CO_2/a**	The target was achieved at **103%**
Adoption of minimum energy performance standard of lighting appliances compulsory for public sector	Indirect energy savings of **125 GWh/a** and emission reduction of **50,000 t CO_2/a**	Indirect energy savings of **188.2 GWh/a** and emission reduction of **75,284 t CO_2/a**	The target was achieved at **150%**

Conclusions

A number of lessons have been learned within the course of project implementation that can be shared with all interested parties locally and internationally, to serve as a reference and ground for design, and materialization of similar initiatives and projects in energy efficient lighting. This chapter summarizes main lessons learned in each of the respective project components.

- **Audit of lighting systems** organized before and after upgrade, is vital for assessment of an actual baseline situation, thoughtful selection of pilot projects and corresponding technical solutions, as well as for evaluation of energy saving, quality improvement and other benefits to be achieved through implemented measures. Audits shall be provided in line with a pre-agreed procedure (methodology), so that uniformity (comparability) of information collected for different pilots is ensured. Audit team shall be equipped with necessary technical means such as pedometer, lux meter, laser meter, etc. to ensure accuracy of measurements. Along with luminaries and lighting fixtures, attention shall be paid to poles and arms as well as to the electrical wiring, grounding, metering and control equipment, as the success of pilot projects largely depend on the condition of the infrastructure and supply system. It is necessary to properly manage health and safety risks of the audit team, especially during night-time work.

- Establishment and maintenance of timely **communication and experience sharing channels with similar initiatives and projects** in other countries (especially those with similar historical and social-economic background). It is essential to avoid issues already faced by the partners, explore new insights and ideas that can be integrated into the project philosophy to yield additional benefits, identify strategic fit and synergy between projects and ensure effective coordination. The Project benefited considerably from cooperation with two similar ongoing UNDP-GEF projects in Russian Federation and in Kazakhstan. The support of partner projects helped in efficient implementation of a number of activities on capacity building, setting of norms, pilot projects design, etc.

- **Timing of implementation** is critical for demand-driven projects involving new technologies that are not yet well known and unaffordable for majority of stakeholders. From that standpoint, the Project was launched very timely, as its start coincided with a period of sizable improvements in LED lighting technologies coupled with decreasing prices. These global trends in lighting sector, contributed substantially to the success of the project through increasing local demand for project results, technical support in proper understanding of light design principles based on LED technologies. Earlier start of the project may have had critical implications because of extremely high initial cost and less advanced performance of LED technology, while later start would have required revision of the demand-driven philosophy of the project to bring it into compliance with the transformed local lighting market.

- **Implementation of demonstration projects at the earlier stage** of the project proved to be the right decision, as it allowed ensuring regular monitoring completed pilots and analysis of achieved results during the project's supervised implementation period. Moreover, this approach helped the project team to provide technical assistance and consultancy on design, implementation and monitoring of replication projects to a greater number of stakeholders, hence, high quality of replication activities and bigger replication effect in terms of GHG emission reduction have been achieved.

- Decision to implement **large number of small demonstration projects** in many municipalities ensured better coverage across the country and involvement of bigger number of stakeholders, suppliers and contractors, thus contributing to better and wider awareness rising of municipalities and population. Besides that the capacity building of large number of municipal specialists through "learning by doing", increased number of replication projects as benefits of new technologies have been demonstrated to a larger number of municipal decision-makers and stakeholders. The mentioned multiple advantages undoubtedly exceed the cost-saving effect (due to economies of scale) in case of implementation of small number of bigger pilots.

- Regardless of the announced goals of Armenian government and donor community to promote sustainable energy development of the country, energy efficiency improvement potential in municipalities remains largely unexplored and unrealized. The lack of significant progress in public lighting sector transformation to energy efficiency technologies was mainly due to certain fundamental barriers such as high initial costs

for LED technologies, limited municipal budgets and lack of access to capital (municipal borrowing). The reduction of LED technologies prices are mitigating the first barrier, while other barriers can be addressed (at least partly) via **municipal energy efficiency revolving funds** established as a separate municipal off-budget accounts. Such funds are not institutionalized as stand-alone organizations with separate budget, staff and administration. Instead, the fund are operated by municipalities based on simple, pre-agreed and transparent procedures. Along with savings from first pilots implemented by the Project support, these funds may "accumulate" resources from other (public, private and donor) sources, as well as savings from other similar EE activities carried out in municipalities, thus, ensuring sustainability of this vehicles. Funds established under the Project in 16 municipalities have been operated successfully, whereas, savings from the first pilots have been used to finance 10 replication projects with annual GHG emissions reduction around 394 t CO_2. Currently municipalities are exploring possibilities to use that funds for accumulation of savings from other energy efficiency and renewable energy projects.

- **Identification and early engagement of stakeholders** on national and local levels is important to ensure good coordinated and successfully implemented project. The Technical Advisory Committee, set under the Project, served as a good platform for presentation of ongoing and planned tasks, discussion of proposed technical solutions, identification of barriers, coordination of activities, etc. Multiple stakeholder participation may substantially increase efficiency of such discussion platforms, provided that relevant stakeholders are involved. The Committee of the Project comprised of representatives of the Ministry of Energy Infrastructure and Natural Resources, Ministry of Urban Development, Ministry of Territorial Administration and Development, Ministry of Economy, Ministry of Nature Protection, the R2E2 Fund, the Scientific Research Institute of Energy, National Institute for Standards and Yerevan State University of Architecture and Construction. Along with these stakeholders, the Committee's meetings were attended by representatives of expert community and private sector.
- **Promotion and dissemination of information** of projects objectives, activities and deliverables through various channels, including website, Facebook page, publications, media, etc. is a necessary precondition for accomplishment of the project tasks and achieving its ultimate objectives. Particularly, promotion of energy and cost saving benefits of the first demonstration projects in street lighting though broad awareness campaigns contributed a lot to dissemination of information among municipal decision makers and facilitated replication of pilots in other communities. Availability of guides and manuals at the website helped to ensure wise public access to these materials. Another important point is that instead of setting a new project-bound website, all information as well as awareness raising and capacity building materials have been hosted at the website of Climate Change Information Center[4], hence, securing "sustainability" of access of information even after project completion.
- At the initial stage the project faced a problem associated with the lack of formal statistical information on public lighting infrastructures, residential (household) energy consumption, market share of traditional and LED lamps, etc. In order to address this informational gap, the project conducted market assessment among key suppliers and sellers of lighting products, organized data collection from 25 municipalities as well as conducted 2 social surveys on residential energy consumption (around 2600 respondents each). These exercise demonstrated that in the absence of formal statistics, **market assessment and surveys** could be relatively reliable means for collect broader and realistic data of the country lighting market and trends.
- Market assessment and tenders, organized under pilot component of the project, revealed presence of a large amount of poor quality lighting products or products that does not comply with parameters set in certificates. Thus, establishment of a **modern photometric laboratory** that enables checking the conformity with the declared and/or required parameters, is vital for building trust to new technology and protect municipalities and other stakeholders from using of poor-quality or inappropriate products.
- In order to ensure bigger coverage of market transformation efforts and wider post project energy saving and GHG emission reduction benefits, it is of utmost importance that relevant minimum energy

[4] *Climate Change Information Center was established in 1997 in the frames of the UNDP/GEF Project "Armenia - Country Study on Climate Change" with a main goal to strengthen the Information Center of the Ministry of Nature Protection.*

performances standards are set and enforced through respective norms. For this reason, the project revised former "Natural and Artificial Lighting" construction standard which was approved by the Urban Development Committee and registered by Ministry of Justice as RA CN 22-03-2017 "Natural and Artificial Lighting" . The construction norm incorporate minimum energy performance requirements for street lighting of 45-60 W/m^2 Lx. The construction norm adopted in 2017 is mandatory for construction and reconstruction projects. However, the standard only is not sufficient to facilitate sustainable market transformation. Thus, within the framework of the "national policy" component, the project participated in development of the Law of RA "On making an amendment and an addition into the RA law "On energy efficiency and renewable energy"(adopted in May 2016) and of Decision of RA Government "On implementation of energy saving and energy efficiency improvement measures in facilities being constructed under the public funding" (adopted in December 2014).

- To achieve maximum demonstration impact the proper pilot **site selection** can ensure **high visibility effect** for all stakeholders and specifically population and decision makers. To achieve the latter objective the vast majority of pilot projects were implemented on central streets with intensive transport and pedestrian traffic and popular public areas. The proper design, selection of high quality LED lighting technologies and continuous monitoring of savings (around 70%) and appropriately organized advertising campaign helped to achieve significant confidence in benefits of new energy efficient LED technologies, which outweighs the initial high investment costs and contributes to popularization of the project and piloted technologies among population and local administrations.

- Based on gained practice, it is recommended that **tender documentation** (technical specifications) for the supply of lighting equipment has to:
  - Make reference to acting standards and norms;
  - Request bidders to propose corresponding technical solutions for illumination of the target object, providing the description of the lighting object parameters (e.g. width of a roadway, class of the road and sidewalks, location and height of poles, etc.), instead of previous practice when the capacity (in kW) and/or light output of the (in Lumens) was used for selection. This approach enables bidders to come up with the most optimal (tailored) solutions, based on lighting equipment that meets the specified requirements.
  - Provide detailed requirements for supplied equipment, e.g.: luminous intensity distribution curve, color temperature, tightness level and impact resistance of electrical and optical blocks, operating temperatures, availability of surge protection, minimum luminous efficacy, guarantee time, etc. Such approach can ensure the reliable quality for procured lighting systems. Insufficiently thought-out and detailed **technical specifications** for procurement of lighting equipment allows certain "unfair" bidders to offer products that do not ensure proper technical solutions.

- **Lack of relevant experience** of engineers involved in the design and upgrade of public lighting systems of municipalities has been identified as a major problem for sustainability of the results achieved by the project. Cooperation with municipalities and specialized organizations revealed that the vast majority of engineers still rely on old practice and solutions in lighting design, while LED technologies have dramatically changed design and implementation solutions within last decade. Consequently, trainings on the principles of modern lighting design with the use of corresponding software (e.g. DIALux, Relux, etc.) shall be incorporated in the capacity building framework activities to address this major gap. The training shall also cover information on modern lighting technologies and solutions.

- **Periodic monitoring of local and international lighting market** enables identification of more advanced and less costly lighting technologies, thus, reducing overall costs and improving the decision making by public and residential sector. This emphasizes importance of having specialized organizations (during the lifetime of the Project that function was provided by the Project expert team), which can analyse and disseminate up-to-date information on the latest technological advances and ensure unbiased advise to municipalities and consumers on most perspective investments in energy efficient lighting systems, provide recommendations for energy efficiency policy decisions and improvement of legal and regulatory framework, as well as support in conducting market surveillance for protection of consumers from low quality products.

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