# CEDRO

CEDRO, with energy efficiency on our mind

# GREEN HOUSE GAS AUDIT

## *FINAL REPORT*

***Presented to***

United Nations Development Programme – UNDP

BEIRUT, LEBANON

***Prepared by***

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Redefining Environmental Strategies.

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# CONTENTS

# ACRONYMS

| | |
|---|---|
| ASDC: | Atmospheric Science Data Center |
| BDL: | Bank Du Liban |
| CDR: | Council for Development and Reconstruction |
| CEDRO: | Country Energy Efficiency and Renewable Energy Demonstration |
| CFL: | Compact Fluorescent Lamps |
| $CO_2$: | Carbon Dioxide |
| EDL: | Electricite Du Liban |
| EF $CO_{2e}$: | Emission Factor in Carbon dioxide equivalent |
| EF: | Emission Factor |
| $EF_e$: | Emission Factor from production of Electricity |
| EU: | European Union |
| Gg: | Gegagrams |
| GHG: | Greenhouse Gas |
| GHG-P: | Greenhouse Gas Protocol |
| HPS: | High Pressure Sodium |
| IL: | Incandescent Lamp |
| IPCC: | Intergovernmental Panel for Climate Change |
| ISC: | Integral Storage Collectors |
| kg: | Kilogram |
| kW: | Kilowatt |
| Kg $CO_{2e:}$ | Kilogram of Carbon dioxide equivalent |
| kWh: | Kilowatt Hour |
| LCECP: | Lebanese Center for Energy Conservation |
| LED: | Light Emitting Diode |
| MoE: | Ministry of Environment |
| MoEW: | Ministry of Energy and Water |
| MoF: | Ministry of Finance |
| MW: | Mega Watt |
| NCV: | Net Calorific Value |
| NEEREA: | National Energy Efficiency and Renewable Energy Action |
| O&M: | Operations and Maintenance |
| PV: | Photovoltaic |
| RE: | Renewable Energy |
| SNC: | Second National Communication |
| Sq.m: | Square Meters |
| SWH: | Solar Water Heater |
| $TCO_{2e}$: | Tonnes of $CO_2$ equivalent |
| TJ: | Tonnes of Joules |
| UNDP: | United Nations Development Programme |

# EXECUTIVE SUMMARY

To overcome power shortages, generate clean energy and promote the renewable energy sector in Lebanon, three UNDP managed projects were launched. The Lebanese Center for Energy Conservation (LCECP) includes the National Energy Efficiency and Renewable Energy Action (NEEREA), Country Energy Efficiency and Renewable Energy Demonstration Project for the Recovery of Lebanon (CEDRO) and Global Solar Water Heating Market Transformation and Strengthening Initiative Project (GSWH). These programmes are designed to implement renewable energy (RE) projects utilizing solar water heater and photovoltaic systems, as well as energy efficiency systems that aim to reduce power demand in the country.

This report calculates the Greenhouse Gas (GHG) emission reduction from the above programmes according to the GHG Project Protocol recommendations, which are developed by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD). The total GHG emission reduction attained from the above noted programmes is 104,070 $TCO_{2e}$ since the projects' respective commissioning date. The CEDRO programme portion of the GHG emission reduction is 884.3 $TCO_{2e}$; the LCEC programmes contributed to GHG reduction of 103,636 $TCO_{2e;}$ while the GSWH programme contributed to 127.0 $TCO_{2e}$. LCEC's project contributed to 99% of the total GHG emission reduction while the GHG reduction from the installation of Solar Water Heaters doubled from 2011 till 2013 (87 tons and 161 tons, respectively).

To achieve a better understanding of the GHG emission reductions from the implemented projects as well as comply with the recommendations of GHG Project Protocol, V4 Advisors took the liberty to make recommendations to be incorporated for future projects.

# Introduction

Lebanon ratified the United Framework Convention on Climate Change (UNFCCC) on the 15th of December 1994 and submitted its Initial National Communication in 1999. The Country's total GHG emissions in year 2000 were 18.5 $MtCO_{2e}$, recorded to be increasing from the 1994 baseline. Lebanon's Second National Communication (SNC) to the UNFCCC submitted in March 2011 presented information on Lebanon's GHG emissions for each sector totaling 20.299 $MtCO_{2e}$. Lebanon's GHG inventory breakdown revealed that the energy production is the main source of GHG emissions, accounting for 53.45% of the total national emission. The country's demand for power is continuously increasing, thus putting additional pressure on Electricite Du Liban's (EDL) installed capacity that already can't meet Lebanon's power needs. The shortages have and will continue to be met by high polluting and low efficient diesel-powered generators. On the other hand Lebanon enjoys a total of 4,435 hours of sunlight (NASA 2013), which could be utilized for power generation and water heating, resulting in reducing the country's GHG emission and meeting its target of 12% renewable energy by 2020.

Consequently, several national programmes addressing renewable energy and energy efficiency installations / projects were implemented in Lebanon; projects that aimed to prepare the Lebanese clean energy market to accelerate and promote sustainable market transformation. The Country Energy Efficiency and Renewable Energy Demonstration Project for the Recovery of Lebanon (CEDRO project), The Lebanese Center for Energy Conservation (LCECP) and Global Solar Water Heating Market Transformation and Strengthening Initiative (GSWH) are some of these programmes that were done in partnership with the relevant Lebanese ministries and other local development agencies; managed by the United Nations Development Programmes (UNDP).

V4 Advisors have been appointed to quantify the GHG emission reduction of the UNDP programmes according to the GHG Project Protocol. The GHG Project Protocol is internationally adopted standard as a policy-neutral accounting tool for quantifying the GHG benefits of climate change mitigation projects. It is the result of a four-year dialogue among business, environmental, and government experts led by World Resources Institute and the World Business Council for Sustainable Development.

The data and information for the GHG emission reduction auditing were provided by the respective project leaders, which covered periods from 2009 till Sept of 2013.

## COUNTRY ENERGY EFFICIENCY AND RENEWABLE ENERGY DEMONSTRATION PROJECT FOR THE RECOVERY OF LEBANON (CEDRO PROJECT):

CEDRO is a United Nations Development Project (UNDP) managed project with a five-year mandate ending in October 2013. CEDRO is a partnership between the Ministry of Energy and Water (MoEW), the Ministry of Finance (MoF) and the Council for Development and Reconstruction (CDR). CEDRO project has a total budget of 9.3 Million USD and funded by the Lebanon Recovery Fund (LRF) through international donations. CEDRO aims to: 1) install 120 energy efficiency and Renewable Energy (RE) projects in public facilities throughout the country, 2) ensure technology transfer as well as encouraging the private sector to invest in various RE sources and 3) create an enabling environment to adopt a national sustainable energy policy.

## SOLAR WATER HEATER SYSTEMS (SWH)

SWH systems use solar energy to heat water for domestic and industrial uses. The collected heat is transferred to a storage tank through a fluid system, where it will heat the water.

SWH systems have two main units: a solar collector and a storage tank. Depending on the circulation of the fluid between these two units, SWH systems can be classified into passive and active systems:

- Passive SWH systems, also known as thermo-siphon, are designed whereby the fluid circulates by heat convection to the tank that is located above the collectors. Passive SWH systems are inexpensive and easy to install.
- Active SWH systems use a pump to circulate hot water from the collector to the storage tank; this type of system has higher efficiency, but is more expensive and difficult to install.

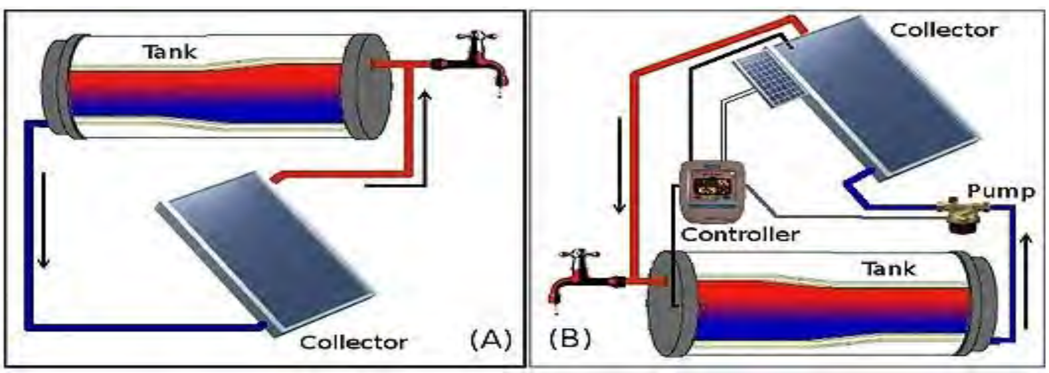


**Figure 1: Types of Solar Water Heater (SWH) systems. A) Passive SWH system. B) Active SWH system**

There are several types of SWH systems:

- Glazed non-selective surface flat plate
- Glazed selective surfaced flat plate
- Unglazed plastic collectors
- Evacuated tubes

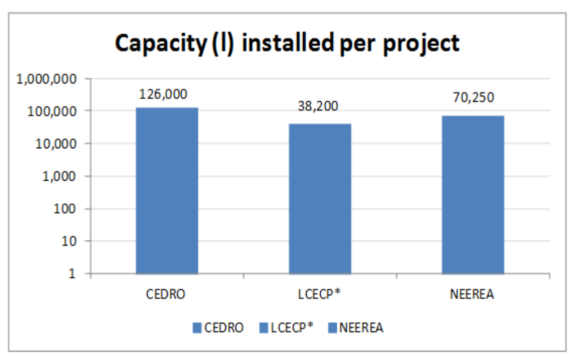


**Figure 2: Total capacity of installed SWH per project. *Due to data limitation, 800 units of 300 l each were excluded in this report**

SWHs were installed in Lebanon to provide hot water to hospitals, jails and other public buildings / facilities. The SWH systems are placed in parallel to existing conventional heating units or in series to reduce diesel consumption in the existing conventional boilers systems. The total installed capacity by CEDRO was 126,000 liters (Figure 2).

## PHOTOVOLTAIC (PV)

Photovoltaic (PV) converts solar radiation into direct current electricity (Figure 3). PV systems are made from the following materials monocrystalline silicon, polycrystalline silicon, amorphous silicon, cadmium telluride and copper indium gallium selenide / sulfide.

This report has quantified the GHG emissions from the 304.2 MWh produced by CEDRO till the 1st of September 2013.

**Figure 3: two PV projects installed by CEDRO**

## EFFICIENT LIGHTING DEVICES:

Efficient lighting devices include Light Emitting Diodes (LEDs), Compact Fluorescent Lamps (CFL), Ceramic Metal Halide (CMH), electronic ballasts, and retrofitting of lighting systems. The high efficiency of the above noted bulbs in comparison with the conventional incandescent lamp (IL), results in giving the same amount of light (lumens) for less kWh.

**Electrical power equivalents for differing lamps (EnergyStars)** [2]

| Minimum light output (lumens) | Electrical power consumption (Watts) | | |
|---|---|---|---|
| | Incandescent | Compact fluorescent | LED |
| 450 | 40 | 9–13 | 4–9 |
| 800 | 60 | 13–15 | 10–15 |
| 1,100 | 75 | 18–25 | 17 |
| 1,600 | 100 | 23–30 | 22 |
| 2,600 | 150 | 30–52 | Not available |

**Table 1 summarizes the lumens production from the 3 types of light bulbs**

[2] Energystar.gov. http://www.energystar.gov/index.cfm?c=cfls.pr_cfls_lumens

## GENERAL DESCRIPTION OF CEDRO

Since 2009, the CEDRO programme has installed a total of 67 PV cell systems, attaining power production of 104,175 Wp; 16 SWH units with a total capacity of 126,000 L of water and; 539 street lighting systems (LED bulbs, PV poles, induction floodlight). Table 3 summarizes the total number of accomplished projects per governorate.

| | North | Mount Lebanon | South | Bekaa | Beirut |
|---|---|---|---|---|---|
| PV (n) | 20 | 14 | 14 | 17 | 2 |
| PV (Wp) | 31500 | 23625 | 4500 | 25200 | 19350 |
| SWH (liter of water) | 17500 | 64500 | 16000 | 28000 | - |
| Street Lighting | 22 | 262 | 45 | 210 | - |

**Table 3: Summary of the CEDRO implemented projects**

## SOLAR WATER HEATERS (SWH)

From 2009 till 2013 CEDRO installed 16 projects of SWH with a total capacity of 126,000 liters of hot water in all governorates except for Beirut. The cumulative number of operating days till 1st of September 2013 was 13,161 days.

Table 4 and Figure 4 show the installed capacity and cumulative number of operating days since commissioning per governorate. Around half of the total capacity was installed in 6 locations in Mount Lebanon (64,500 liters).

In all projects, it was estimated that the temperature of water will increase from 20°C to a maximum of 45°C, and that the circulation of water will be via a pump of 20 Wp.

| | Number of days since commissioning | | | | |
|---|---|---|---|---|---|
| | North | Mount Lebanon | South | Bekaa | **Total** |
| Dec-11 | 1369 | 426 | 2099 | 943 | **4837** |
| Dec-12 | 2680 | 1797 | 3410 | 1522 | **9409** |
| Sep-13 | 3656 | 3109 | 4386 | 2010 | **13161** |

**Table 4: Number of commissioning dates per governorate**

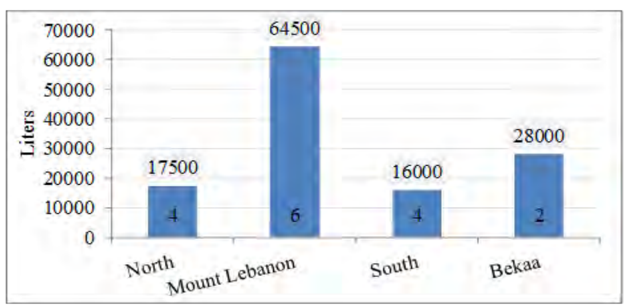


**Figure 4: Installed capacity per governorate**

After accounting for the power consumption of all pumps, the overall reduction of $CO_{2e}$ till 1st of September 2013 was calculated to be 52 $TCO_{2e}$. According to the "Evaluation for Community energy Efficiency and Renewable Energy \ Demonstration project for the Recovery of Lebanon CEDRO II" auditing report of CEDRO II,

2006 IPCC Guidelines for National Greenhouse gas inventories
Project 7214 : The Lebanese CFL Replacement CDM Project – South Lebanon

it was noted that some sites had installed SWH that were either damaged and / or not utilized. Therefore, the total GHG emission reductions could be 26% below the calculated number (Roumieh Prison alone accounts for 25% of the total installed capacity).

In some sites or seasons, the base temperature of 20°C is incorrect and will require higher boiler utilization, therefore, an increase in the GHG emission of 1°C change will directly affect the total emission by an average of 0.15 kg of $CO_{2e}$ per 1°C.

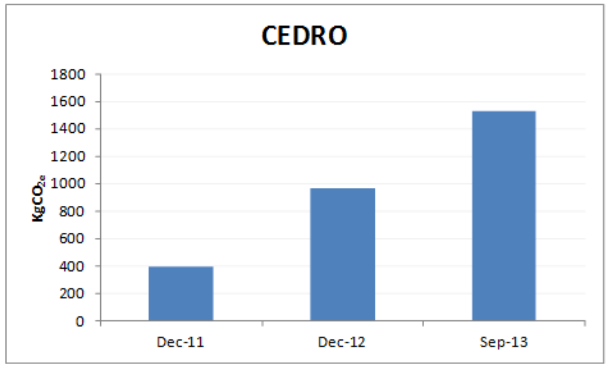

**Figure 6: Total avoided GHG emissions in Kg of $CO_{2e}$ from CEDRO per installed liter per fiscal year**

Taking the above assumptions into consideration, the daily average GHG emission reductions from all implemented SWH systems is 4 kg of $CO_{2e}$ / day.

Figure 6 shows the cumulative total GHG emissions reduction per fiscal year from CEDRO project.

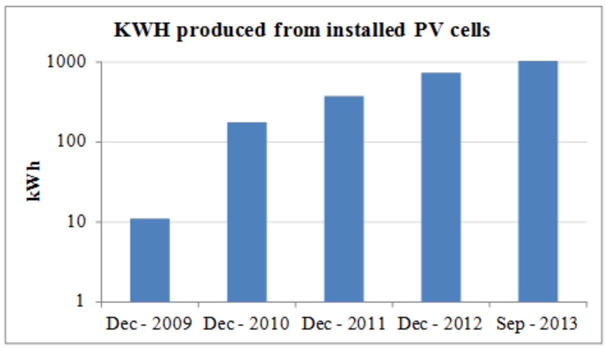

**Figure 7: kWh produced from installed PV units per year**

## Photovoltaic Cells (PV)

A total installed capacity of 104,175 Wp was put online since December 2009, generating a total of 1,046 MWh assuming an average of 12.15 hours of sunlight per day. Up till the 1st of September 2013, the cumulative operating number of days from commissioning is 56,021.

680 tons of $CO_{2e}$ were reduced from the power generated from the PV systems up till 1st of September 2013.

One may account for 20% lower GHG emission reductions assuming that 20% of the installed PV systems are not properly working or fully utilized.

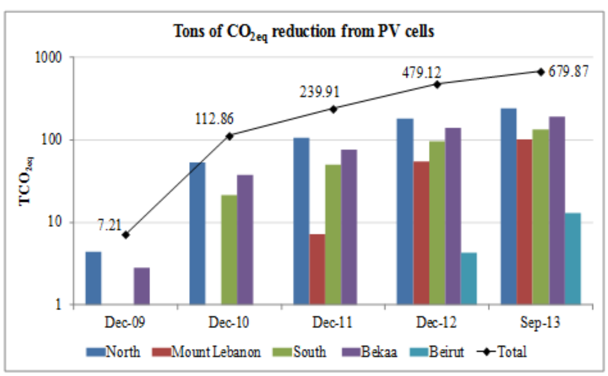

**Figure 8: Tons of $CO_{2e}$ reduction from PV Cells**

The daily average GHG emission reduction from all PV systems installed varied from 12.1 kg of $CO_{2e}$ to 13.1 Kg of $CO_{2e}$ from December 2009 till 1st of September 2013 respectively.

## STREET LIGHTS

In October 2009 CEDRO commenced implementing energy efficiency projects targeting street lights. A total of 539 street light bulbs were replaced by more efficient bulb types up till the 1st of September 2013, leading to energy reduction of 234 MWh.

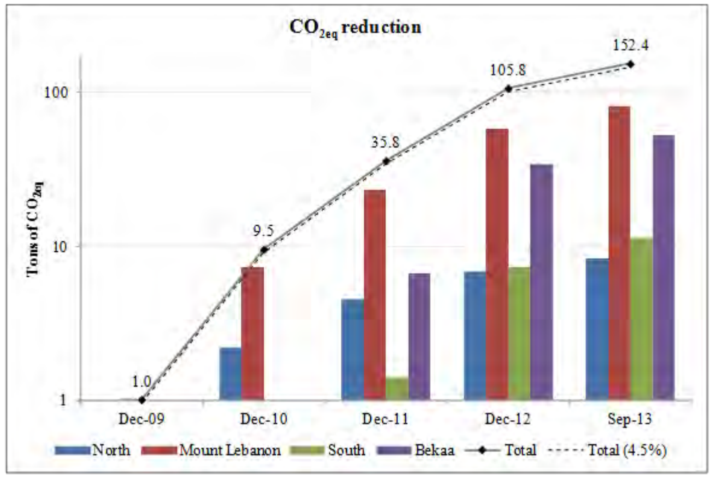


Figure 9: $CO_{2e}$ reduction per year and per governorate from all Street

From a GHG emission reduction perspective, a total of 152.4 $TCO_{2e}$ were reduced in 9,957 days of use. Accounting for failure rates of 4.5% (according to CEDRO), the average daily amount of GHG reduction is 15.3 Kg of $CO_{2e}$ per day.

Figure 10 shows the GHG emissions from one installed led bulb per year.

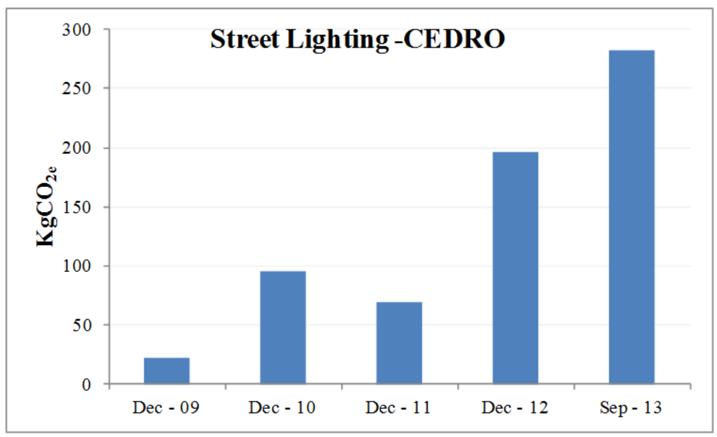


Figure 10: GHG emission reductions from installed LED bulbs per year

## TOTAL GHG EMISSION REDUCTION FROM THE CEDRO PROJECT

The total reduction of GHG emissions from CEDRO's installation of RE systems is 884.3 $TCO_{2e}$; a daily average of 32 kg $CO_{2e}$.

# RECOMMENDATIONS

In order to achieve a better understanding of the GHG emission reductions from the implemented projects, and to comply with the recommendation of GHG Project Protocol, the following should be taken into account:

- Information related to distances travelled to install and maintain the RE systems should be provided and included in the GHG emission calculation
- The exact date for commissioning should be provided to accurately calculate the emissions of the RE installation, including the ones that were not accounted for due to complete absence of the information
- The rate of failures, capacity usage should be registered and incorporated in the GHG calculation
- Some background information on the availability of electricity and offsetting the outage should be available
- Utilization of the RE systems should be improved and accurately reported
- Regular maintenance and check-ups for the installed equipments should be provided to assure the continuity of these units

V4 Advisors used the guidelines of the GHG protocol as well as adopted the IPCC calculation methodologies to quantify the GHG emission reductions attained from the installation of SWH, PV and efficient bulbs. The emission reductions were primarily achieved from the difference of fossil fuel used pre and post the installation of the RE and energy efficient systems.

## GHG EMISSION REDUCTIONS FROM SOLAR WATER HEATERS

To reiterate the SWH systems that were installed in Lebanon by the CEDRO programs are all active types.

As the passive SWH systems do not require electricity or any other source of energy, their GHG emissions is zero. The active SWH systems, on the other hand, require the installation of a pump that is powered by electricity; and as a result emits GHG emissions equal to the amount of power used by the pump.

GHG emission reduction is calculated from the difference of using conventional fuel source to produce hot water from producing it using RE sources.

$$\text{GHG saving} = \text{GHG}_{\text{boilers}} - \text{GHG}_{\text{SWH}}$$

## GHG EMISSION FROM BOILERS

The GHG emissions emitted by boilers using conventional fuel source is computed using the following formula that is in accordance to the IPCC guidelines[5]:

$$GHG_{\ boiler\ (tCO_{2eq})} = Diesel_{\ (l)}\ x\ D_{CO_2\ (tCO_2/TJ)}\ x\ NCV_{\ (TJ/Gg)}\ x\ D_{diesel\ (kg/l)}\ x\ 10^{-6}{}_{\ (Gg/kg)}$$

Where:

$D_{CO_2}$ ($tCO_2/TJ$) is the emission factor of diesel which is equal to 74.1 $tCO_2/TJ$
Diesel (l) is the amount of diesel used in liter
NCV: Net Calorific Value of Diesel which is equal to 43.3 TJ/Gg
D diesel x $10^{-6}$ is the density of Diesel equal to 0.85 Gg/l

To compute the GHG emissions from boilers which are emitted by the production from the energy produced due to the heating process of water, the formula below was used:

$$\text{GHG}_{\text{ boilers}} = \text{Q}_{\text{ heating kWh}} \times GHG_{\text{1kWh}}$$

Where:

$Q_{heating}$ is energy (W) produced in warm a certain amount of water from initial temperature ($t_i$) to final temperature ($t_f$). Consequently,



$$Q_{heating} = Kg_{\ water} \times SHC_w \times (t_f - t_i)/T_s$$

Where

Kg water is the amount of heated water in Kg,

$SHC_W$ is the Specific Heat Capacity of water = 4,180 J $Kg^{-1}$ $K^{-1}$,

$T_s$ is the required time of heating in second

The GHG emitted from the production of 1kWh was computed using the IPCC methodology and found to be: 1 kWh produces 2.93 Kg of $CO_{2e}$.

## GHG EMISSION FROM ACTIVE SWH SYSTEMS

In the case of a forced circulation (Active SWH), the $GHG_{pump}$ is equal to the emission emitted from the electricity used to drive the pump. The GHG emitted is computed based on the IPCC methodology:

$$GHG_{pump} = \mathrm{CE}_{\ (\mathrm{kWh})} \times 10^{-3} \times EF_{Elec\,(tCO_{2e}/MWh)}$$

Where:

CE is the amount of Consumed Electricity in kWh $_{\text{consumed}}$

$EF_{Elec}$ is the Emission factor of Electricity in Lebanon expressed in $TCO_{2e}$ per MWh it is equal to 0.65

## GHG EMISSION FROM 1°C INCREASE IN THE INLET / OUTLET TEMPERATURE

To compute the effect of 1°C change in the inlet / outlet per year, the following formula is used:

$$GHG_{\ (1°C)} = {GHG_{(year)}}/{D} * \delta t$$

Where:

GHG 1°C is the emission from an increase of 1°C in inlet / outlet

GHG (year) is the cumulative GHG emission emitted from commissioning till end of the fiscal year considered in this report

D is the total number of days till from commissioning till end of the fiscal year considered in this report

δt is the temperature between inlet and outlet in °C

## GHG EMISSION FROM ELECTRICITY CONSUMPTION

The total GHG emission from electricity consumption in $TCO_{2e}$ is computed as per the following formula:

2006 IPCC Guidelines for National Greenhouse gas inventories

Where:

GHG electricity in $TCO_{2e}$ is the amount of GHG emitted due to electricity consumption

CE in kWh is the consumption of electricity

$10^{-3}$ to convert from kWh to MWh

$EF_{Elec}$ is the Emission factor of Electricity in Lebanon expressed in $TCO_{2e}$ per MWh it is equal to 0.65

## GHG EMISSION FROM STREET LIGHTING

In CEDRO project the street lighting projects were based on replacing conventional bulbs with LED. Therefore, the calculation of GHG emission reductions was calculated using the following formula

The total GHG emission from light bulbs is computed as per the following formula:

$$GHG_{lightbulbs} = W_{(Watt)} \times H_{(h)} \times D_{(day)} \times 10^{-3} \times EF_{Elec}(tCO_{2eq}/MWh)$$

Where:

GHG $_{lightbulb}$ is the amount of GHG emitted from the electricity consumed by light bulbs

W in Watt is the wattage of the light bulb

H in hours number of hours of use per day

D in number of day of usage per year

$10^{-3}$ to convert from kWh to MWh

$EF_{Elec}$ in $TCO_{2e}$ per MWh is the Emission factor of Electricity in Lebanon, is equal to 0.65 $TCO_{2e}$ / MWh

The GHG emission reductions were computed from the difference of electricity used to produce the same lumens from incandescent as opposed to other energy efficient bulbs.

$$\text{Reduction of GHG} = \text{Production of GHG}_{\text{Conventional bulbs}} - \text{Production of GHG}_{\text{Energy efficient bulbs}}$$

## GHG EMISSION FROM PV

The total GHG emission reductions attained from the installation of PV systems in $TCO_{2e}$ were computed from the amount of power produced from the PV systems as opposed to EDL or diesel power generators

Where:

Amount of GHG to produce the same amount of electrical power produced from PV is computed using the following formula:

$$\text{Amount of GHG}_{\text{produced}} = \text{Electricity used}_{\text{kWh}} \times \text{Emission Factor Electricity}_{TCO_{2e}/\text{kWh}}$$

## GHG REDUCTION ATTAINED PER ANNUM

V4 Advisors adopted a fiscal year (1st January till 31st of December) as basis for its GHG reductions; consequently the calculations for emission reductions were calculated from commissioning dates till the end of the fiscal year, and on cumulative basis, with the exception of 2013 calculation that was done till 1st of September.

## GHG REDUCTION PER PROJECT AND PER INSTALLED UNIT

To facilitate the comparison between projects, the GHG reduction was computed by installed unit as follow:

$$GHG_{unit} = GHG_{year} / T_{Cap}$$

Where:

GHG unit is the GHG reduced per installed unit

GHG year is the total fiscal yearly emission

$T_{Cap}$ is the total installed capacity in liters for SWH, in W for PV and in light bulb for unit for street lighting

## ASSUMPTIONS

The following assumptions were used in the calculation of GHG emissions:

- The RE equipments: actual condition, efficiency of usage
- Source of electricity: EDL, self-generators supply
- Sunlight times during summer and winter
- SWH were to replace diesel boilers

*The RE equipments*

For the quantification of the GHG emission reductions and taking the technical recommendations from the "Evaluation for Community energy Efficiency and Renewable Energy \ Demonstration project for the Recovery of Lebanon CEDRO II" into consideration, V4 Advisors assumed that all implemented projects with a commissioning date before December 2012 have a utilization of 80%. The utilization percentage takes into account damaged equipments and non optimal / efficient utilization of the RE systems.

For the CEDRO street lighting projects, V4 Advisors calculated the GHG emission reductions in two scenarios. The first scenario having a failure rate of 4.5%, as provided by the CEDRO team and the second scenario assumes no-failure rate.

*Electrical shortage / outage*

Due to Lebanon's continuous increase in electricity demand in peak load, and the decrease in supply provided by EDL, the shortage of electricity is met by the diesel-powered generators that are owned and operated by the private sector in Lebanon. For the sake of comparison, the following two scenarios were considered:

EDL provides power on continuous basis
EDL's electrical shortage not being met by any source or parallel or backup power

*Sunlight availability during summer and winter*

Using data from the Atmospheric Science Data Center (ASDC) NASA Su face meteorology and Solar Energy model (table 2), the yearly average sunlight at an altitude from 10 to 100 m was found to be 12.15 hours per day[7].

**Monthly Averaged Daylight Hours (hours)[7]**

| Month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average | 10.1 | 11 | 11.9 | 13 | 13.9 | 14.3 | 14.1 | 13.4 | 12.4 | 11.3 | 10.4 | 9.96 |

**Table 2: Monthly Average Daylight Hours from Surface Meteorology and Solar Energy model, NASA**

[6] Lebanon's Second National Communication to the UNFCC, MoE, 2011
[7] NASA. Surface meteorology and Solar Energy, a renewable energy resources web site, release 6, https://eosweb.larc.nasa.gov/cgi-bin/sse/sse.cgi?+s01#s01

*SWH were to replace the diesel boilers*

Due to the large capacity of solar water heaters, it was assumed that the baseline scenario of the SWH is diesel consumption, in other words, the SWH were to replace the diesel boilers, but not the electrical dependent boilers.

## LIMITATIONS

Since EDL's power shortages have been inconsistent and unscheduled for the past couple of years in all the regions in Lebanon (with the exception of Beirut), V4 Advisors assumed an average of 12 hours per day across the board and an 8-hour shortage for the governorate of Beirut.