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Rapport Final

ACTION 4

CONTRIBUTION AU DÉVELOPPEMENT DU PLAN D'ACTION ENERGIE DURABLE (PAED) DE DEUX MUNICIPALITÉS LIBANAISES

PARTIE II : HAMMANA

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L13

Par :
Sabine Saad
Adel Mourtada

Action 4. Contribution au développement de Plan d'Action d'Energie Durable (PAED) de deux municipalités au Liban

Cette action vise l'assistance à deux municipalités libanaises « Hamana » (jumulée avec Macon en France) et la fédération de municipalités de « Shouf Souayjani » dans l'élaboration de leur Plan Action d'Energie Durable (PAED) en vue de leur adhésion à la Convention des Maires. Finalement le choix s'est porté sur la Fédération de municipalités de « Shouf Souayjani » car elle couvre 8 municipalités de population totale plus importante que celle de « Lehfed ». Cependant « Lehfed » reste associée à ce projet dans le cadre des activités de formation et de sensibilisation.

En effet, la Convention des Maires est une initiative européenne qui concrétise l'engagement formel volontaire des ensembles des communes, villes et régions qui aura comme but de réduire les émissions de CO2 de plus de 20% à travers la mise en œuvre de plans d'action en faveur de l'énergie durable (PAED) qui constituera une stratégie locale en matière d'énergie et de climat et qui répondra à leurs propres problématiques. Ce travail est en cours de réalisation en coordination avec les municipalités concernées et l'Université Libanaise (qui voudrait faire participer ses étudiants et ses chercheurs à cette activité).

Afin d'élaborer le PAED et pour montrer ainsi comment atteindre les objectifs de réduction des émissions de gaz polluants imputables à la production et à la consommation d'énergie, il est nécessaire de recourir à des méthodologies reconnues.

Cependant, il y a un manque d'outils adaptés aux conditions des villes de Sud Méditerranée pour évaluer les émissions de base de gaz à effet de serre ainsi que l'impact des PAED sur ces émissions.

Cette action s'intéresse: (1) à évaluer les approches classiques de calcul des émissions de gaz à effet de serre au niveau municipal ainsi que l'impact de PAED (2) à développer les outils méthodologiques et techniques pour combler les lacunes et aboutir à une approche plus développée (par secteur), plus généralisée (les municipalités de Sud-Méditerranée qui souhaiteraient adhérées à la convention des maires) et adaptée au contexte régional.

I. Elaboration de PAED pour une municipalité libanaise et une fédération de municipalités

Un inventaire des sources d'émission de CO2 a été réalisé au niveau municipal (pour les municipalités choisies) avec des mesures sur le terrain et enquêtes dans les secteurs : Bâtiments, Industrie, Transport, Production d'électricité, Déchets solides, Eaux usées, Agriculture.

Le PAED sera développé pour les municipalités choisies, expliqué discuté et mis à leur disposition pour qu'il soit signé et présenté pour l'adhésion à la convention des maires.

Ce projet sera de grand intérêt pour les villes de SUD-Méditerranée et contribuera à impliquer davantage les conseils municipaux à l'élaboration de Plan d'Action d'Energie Durable visant la réduction des émissions de gaz à effet de serra et de la pollution.

Des réunions fréquentes avec les équipes municipales ont eu lieu. Un séminaire national pour la dissémination des résultats (méthodologie et outils) est prévu dans le cadre de cette étude.

Cette activité est menée en étroite coordination avec les Conseils Municipaux de Hamana et de la fédération de municipalités Shouf Souayjani et en partenariat avec l'Université Libanaise et l'Université USJ (à travers l'implication des stagiaires et des doctorants). La Municipalité de Lehfed est aussi intéressée par le développement d'un PAED mais qui sera réalisé dans le futur et non plus dans le cadre de cette convention avec l'ADEME

II. Séminaire nationale « Municipalités et Politiques d'Energie Durable »

Un Séminaire nationale « Municipalités et Politiques d'Energie Durable » est prévu dans les prochains mois. Ce séminaire vise à sensibiliser les municipalités libanaises à adhérer à la Convention des Maires et de renforcer leurs capacités à calculer les émissions de base à effet de serre et à développer leur PAED.

Durant ce séminaire seront présentés:

- La Convention des Maires.
- Les outils d'évaluation des émissions de gaz à effet de serre adaptés au cas du Liban.
- L'étude d'évaluation des gisements d'évitement, des potentiels de réduction de déchets et des impacts environnementaux évités réalisée par l'ADEME.
- Le PAED de la ville de Hamana
- Le PAED de la fédération des municipalités Shouf Souayjani.
- Plan d'action pour sensibiliser les autres municipalités libanaises à adhérer à la Convention Des Maires.

Dans ce rapport la méthodologie de développement de PAED est présentée en Français. Cependant, à la demande des municipalités les PAED ont été réalisés en Anglais. Vu le travail énorme pour leur élaboration il serait très difficile et coûteux en temps de les traduire en Français. Donc ils sont présentés en anglais dans ce rapport.

Le rapport intermédiaire concernant l'action 4 est divisé en 2 parties :

1. Rapport méthodologique
2. Elaboration du « plan d'Action d'Energie Durable, PAED » de la ville de Hammana.

Le PAED de la fédération de municipalités de « Shouf Souayjani » fera l'objet d'un rapport indépendant qui sera finalisé dans les prochains mois.

Il est à noter que les travaux de collecte de données et d'enquête sur le terrain ont été conduits par des étudiants de la faculté de génie de l'université libanaise (Jaafar Berjawi, Imad Aoun et Elie Wehbe) supervisés par Dr. Mazen Ghandour (Université Libanaise), Madame Sabine Saad (Doctorante, USJ/UL) et Dr. Adel Mourtada (ALMEE).

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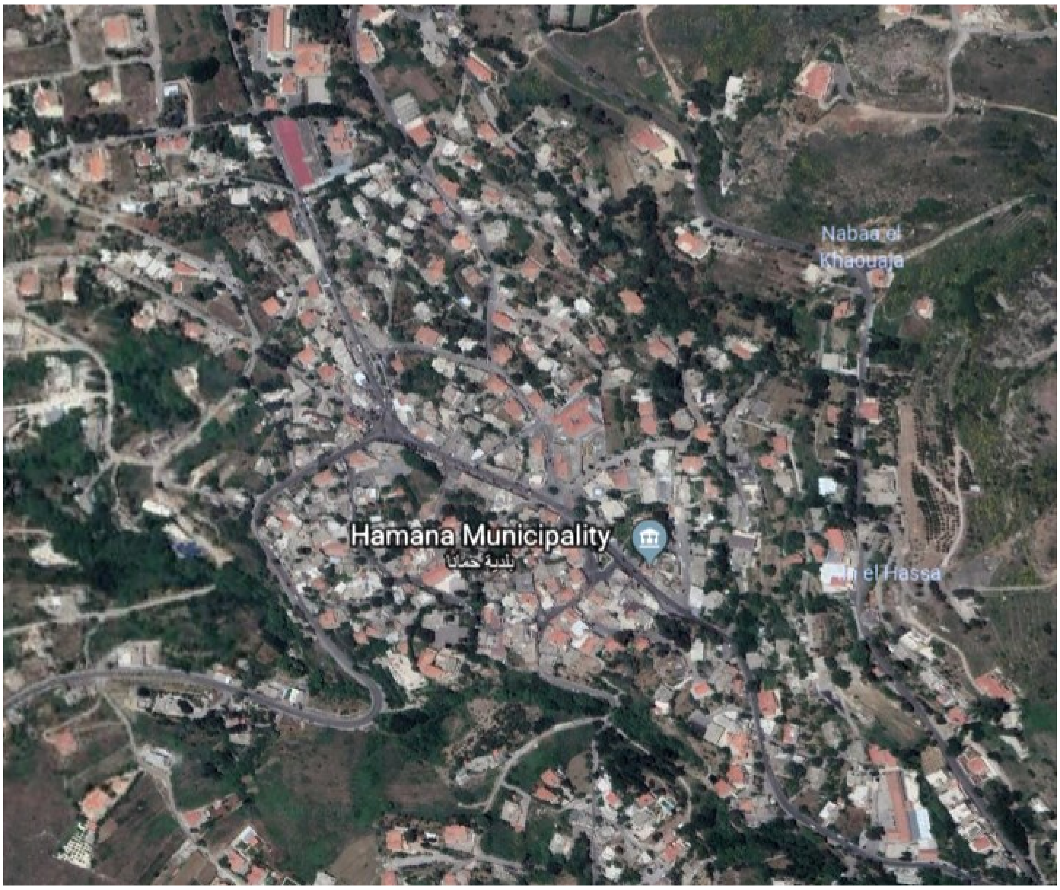
ELABORATION OF A SUSTAINABLE ENERGY ACTION PLAN FOR THE MUNICIPALITY OF HAMMANA



1. Presentation of the Municipality of Hammana and General Data

The Municipality of Hammana is a Lebanese local authority which is located in Baabda District (Qada'a), an administrative division of Mount Lebanon Governorate (Mohafazah). The municipality is member of Federation of Matn El Aala Municipalities. [16] It lies on an altitude ranging from 800 meters to 1600 meters and the municipal building is 1120 meters above sea level.

Its total area is 883 hectares. [16]

The total population of Hammana is 5700 according to the total number of possible voters, while almost 800 citizens are permanent in all seasons and about 3000 citizens live there only in summer. In addition, there are 1500 Syrian refugees who live in the territory in all seasons. By comparing the number of possible voters between the last two elections (2016 and 2018), the yearly population increase is 150 citizens per year.

Hammana contains 1200 households of which 900 are summer only residents, while the maximum number of floors in each building is regulated to 3. It contains 3 hotels, 4 schools, one of which is public, 200 clothing stores, 50 grocery stores, 2 banks, 4 restaurants, 2 health centers, 10 churches, a mosque, 2 theatres, 3 military facilities and 1 civil defense center.

The buildings owned by the municipality are in addition to the municipal building, a waste water treatment plant, a public library, the public school, a sports center, 2 storage shops and a cultural center. [17]

The climate of this territory is classified as hot-summer Mediterranean climate. The table following table shows some of the climate characteristics of Hammana:

Data Source: en.climate-data.org

Table 1.1: Climate Characteristics of Hammana

	Rainfall (monthly)	Average Temperature (°C)	Minimum Temperature (°C)	Maximum Temperature (°C)
January	269	5.4	2	8.8
February	231	6	2.5	9.5
March	193	8.3	4.2	12.4
April	82	12.2	7.5	16.9
May	33	15.9	10.8	21.1
June	2	19.6	14.4	24.9
July	1	21.6	16.4	26.8
August	1	22.4	17.2	27.6
September	5	19.8	14.6	25
October	28	16.7	11.7	21.7
November	116	12.4	8.1	16.7
December	215	7.7	4.2	11.3

1.1. Renewable Energy Potential

1.1.1. Solar Potential

In Lebanon, in order to capture the maximum sun radiation during the year, especially during the less sunny month:

the inclination angle = site latitude ° = 34° = optimal angle

- Nominal power of the PV system: 1.0 kW (crystalline silicon)
- Estimated losses due to temperature and low irradiance: 10.7% (using local ambient temperature)
- Estimated loss due to angular reflectance effects: 2.6%
- Other losses (cables, inverter etc.): 14.0%
- Combined PV system losses: 25.2%

Table 1.2: Solar Irradiance and Output Energy in Hammana

Month	Ed	Em	Hd	Hm
Jan	2.52	78.1	3.18	98.6
Feb	2.71	75.9	3.47	97.2
Mar	3.8	118	4.96	154
Apr	4.22	127	5.6	168
May	4.75	147	6.42	199
Jun	5.12	154	7.02	211
Jul	5.04	156	7	217
Aug	5.02	156	7	217
Sep	4.71	141	6.48	194
Oct	4.14	128	5.55	172
Nov	3.52	106	4.58	137
Dec	2.78	86.2	3.52	109
Year	4.03	123	5.41	165
Total For Year		1470		1970

1.1.2- Wind Potential

Wind power is to convert air flow through wind turbines to mechanically power generators for electricity. Wind power, as an alternative to burning fossil fuels, is plentiful, renewable, widely distributed, clean, produces no greenhouse gas emissions during operation, uses no water, and uses little land. The net effects on the environment are far less problematic than those of nonrenewable power sources.

In order to provide an indication of the approximate amount of energy in Lebanon that could be generated by a single turbine installed at a given location, the indicative annual energy output for each power density band displayed in the supplied power density maps has been calculated. As no specific turbine model has been specified at this stage, the figures displayed relate to a generic 1.5 MW turbine model with an 80 m hub height.

Data Source: The National Wind Atlas of Lebanon, CEDRO

Table 1.3:Annual Energy Output of an 80 m Hub

Power density (W/m2)	Annual Energy Output (GWH/year)
650	2.7
600	2.6
550	2.5
500	2.5

450	2.4
400	2.3
350	2.2
300	2.1
250	1.9
200	1.7
150	1.4
100	1.1
50	0.6
0	0

The output for a single turbine within a larger wind farm development is likely to be lower than theses values.

Source: The National Wind Atlas of Lebanon, CEDRO

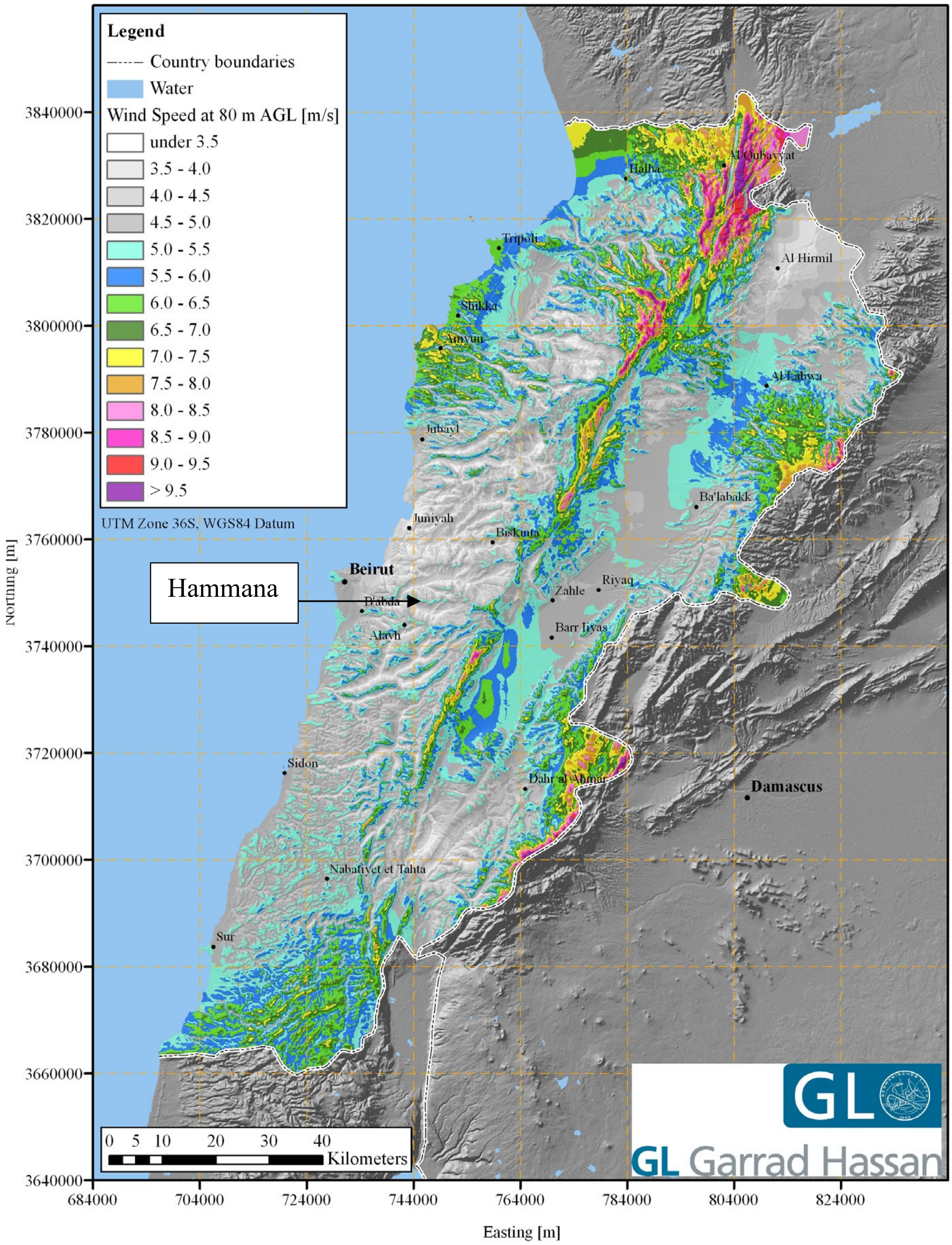


Figure 1.1: Wind speeds at 80 m height

In Hammana it is estimated that the wind speed is around 5 m/s with air density $\rho \cong 1\ kg/m^3$ at 50 m above ground giving a specific power of 120 W/m2.

$$P_s = \frac{1}{2}\rho V^3 \times \frac{\pi}{6}$$

2. Building the Inventory

In this chapter we are going to introduce the important concepts for building a BEI. Then, start by collecting all the necessary data about energy consumption on the territory, classify them into the different sectors and energy form showing the percentage distribution. Finally, calculate the CO2 emissions of each sector followed by the calculation of the total CO_2 emissions and their distribution according to the different sectors and energy forms.

2.1. Introduction

The Baseline Emission Inventory (BEI) quantifies the amount of CO2 emitted due to energy consumption in the territory of the local authority in the baseline year. It allows to identify the principal anthropogenic sources of CO2 emissions and to prioritize the reduction measures accordingly. The local authority may include also CH4 and N2O emissions in the BEI. Inclusion of CH4 and N2O depends on whether measures to reduce also these greenhouse gases (GHGs) are planned in the Sustainable Energy Action Plan (SEAP), and also on the emission factor approach chosen (standard or life cycle assessment (LCA)). For simplicity, we mainly refer to CO2, but it can be understood to mean also other GHGs like CH4 and N2O in the case that the local authority includes them in the BEI and SEAP in general.

Elaborating a BEI is of critical importance. This is because the inventory will be the instrument allowing the local authority to measure the impact of its actions related to climate change. The BEI will show where the local authority was at the beginning, and the successive monitoring emission inventories will show the progress towards the objective. Emission inventories are very important elements to maintain the motivation of all parties willing to contribute to the local authority's CO2 reduction objective, allowing them to see the results of their efforts.

The overall CO2 reduction target of the Covenant of Mayors Signatories is at least 20 % reduction in 2020 achieved through the implementation of the SEAP for those areas of activity relevant to the local authority's mandate. The reduction target is defined in comparison to the baseline year which is set by the local authority.

According to the principles laid out in the Covenant of Mayors, each signatory is responsible for the emissions occurring due to energy consumption in its territory. Therefore, emission credits bought or sold on the carbon market do not intervene in the BEI. However, this does not prevent signatories to use carbon markets and related instruments to finance their SEAP measures.

The BEI quantifies the emissions that occurred in the baseline year. In addition to the inventory of the baseline year, emission inventories will be compiled in the later years to monitor the progress towards target. Such an emission inventory is called Monitoring Emission Inventory (MEI). The MEI will follow the same methods and principles as the BEI. The acronym BEI/MEI is used when describing issues which are common for both BEI and MEI.

2.2. Setting up an inventory:

2.2.1. Key concepts

In the compilation of BEI/MEI, the following concepts are of utmost importance:

Baseline year: Baseline year is the year against which the achievements of the emission reductions in 2020 shall be compared. The EU has committed to reduce the emissions 20 % by 2020. To be able to compare the emission reduction of the EU and the Covenant signatories, a common base year is needed, and therefore 1990 is the recommended baseline year of the BEI. However, if the local authority does not have data to compile an inventory for 1990, then it should choose the closest subsequent year for which the most comprehensive and reliable data can be collected. The year 2016 was chosen as a baseline year.

Activity Data: Activity data quantifies the human activity occurring in the territory of the local authority. Examples of activity data are:

- Oil used for space heating in residential buildings [MWhfuel];
- Electricity consumed in municipal buildings [MWhe];
- Heat consumed by residential buildings [MWhheat].

Emission factors: Emission factors are coefficients which quantify the emission per unit of activity. The emissions are estimated by multiplying the emission factor with corresponding activity data. Examples of emission factors are:

- Amount of CO2 emitted per MWh of oil consumed [t CO2/MWhfuel];
- Amount of CO2 emitted per MWh electricity consumed [t CO2/MWhe].

2.2.2. Boundaries, scope and sectors

The geographical boundaries of the BEI/MEI are the administrative boundaries of the local authority. The baseline CO2 inventory will essentially be based on final energy consumption, including both municipal and non-municipal energy consumption in the local authority's territory. However, also those other than energy-related sources may be included in the BEI.

The BEI quantifies the following emissions that occur due to energy consumption in the territory of the local authority:

i. Direct emissions due to fuel combustion in the territory in the buildings, equipment/facilities and transportation sectors.
ii. (Indirect) emissions related to production of electricity.
iii. Other direct emissions that occur in the territory.

The main sectors to be included in the BEI are:

i. Municipal buildings, equipment / facilities.
ii. Tertiary (non-municipal) buildings, equipment / facilities.
iii. Residential buildings.
iv. Municipal public lighting.
v. Transportation (public and private).
vi. Local electricity production (electric generators).

2.3. Emission factors

2.3.1. Choice of emission factors: standard (IPCC) or LCA

Two different approaches may be followed when selecting the emission factors:

i. **Using 'Standard' emission factors** in line with the IPCC principles, which cover all the CO2 emissions that occur due to energy consumption within the territory of the local authority, either directly due to fuel combustion within the local authority or indirectly via fuel combustion associated with electricity within their area. The standard emission factors are based on the carbon content of each fuel, like in national greenhouse gas inventories in the context of the UNFCCC and the Kyoto protocol. In this approach, CO2 is the most important greenhouse gas, and the emissions of CH4 and N2O do not need to be calculated. Furthermore, the CO2 emissions from the sustainable use of biomass/biofuels, as well as emissions of certified green electricity, are considered to be zero.

ii. **Using LCA (Life Cycle Assessment) emission factors**, which take into consideration the overall life cycle of the energy carrier. This approach includes not only the emissions of the final combustion, but also all emissions of the supply chain. It includes emissions from exploitation, transport and processing (e.g. refinery) steps in addition to the final combustion. This hence includes also emissions that take place outside the location where the fuel is used. In this approach, the GHG emissions from the use of biomass/biofuels, as well as emissions of certified green electricity, are higher than zero. In the case of this approach, other greenhouse gases than CO2 may play an important role. Therefore, the local authority that decides to use the LCA approach can report emissions as CO2 equivalent. However, if the methodology/tool used only counts CO2 emissions, then emissions can be reported as CO2 (in t).

A standard emission factor was chosen for CO2 emissions calculation.

2.3.2. Greenhouse gases included: CO2 or CO2 equivalent emissions:

The greenhouse gases to be included in the BEI/MEI depend on the choice of sectors and also on the choice of emission factor approach (standard or LCA).

If the standard emission factors following the IPCC principles are chosen, it is sufficient to report only CO2 emissions, because the importance of other greenhouse gases is small. In this case, the box 'CO2 emissions' is ticked in the SEAP template, in point 'emission reporting unit'. However, also other greenhouse gases can be included in the baseline inventory if the standard emission factors are chosen. For example, the local authority may decide to use emission factors that take into account also CH4 and N2O emissions from combustion. Furthermore, if the local authority decides to include landfills and/or wastewater treatment in the inventory, then the CH4 and N2O emissions will also be included. In this case the emission reporting unit to be chosen is 'CO2 equivalent emissions'.

In the case of the LCA approach, other greenhouse gases than CO2 may play an important role. Therefore, a local authority that decides to use the LCA approach will likely include also other GHGs than CO2 in the inventory, and select the emission reporting unit 'CO2 equivalent emissions'. However, if the local authority uses a methodology/ tool that does not include any other GHGs than CO2, then the inventory will be based on CO2 only, and the emission reporting unit 'CO2 emissions' is chosen.

The emissions of other greenhouse gases than CO2 are converted to CO2-equivalents by using the Global Warming Potential (GWP) values. For example, one kg of CH4 has a similar impact on global warming than 21 kg of CO2, when considered over a time interval of 100 years, and therefore the GWP value of CH4 is 21.

In the context of the Covenant of Mayors, it is suggested to apply the GWP values that are used in the reporting to the UNFCCC and the Kyoto Protocol. These GWP values are based on the IPCC's Second Assessment report (IPCC, 1995).

However, the local authority may decide to use other GWP values of the IPCC, for example depending on the tool they use.

These GWP values are based on the IPCC's Second Assessment report (IPCC, 1995), and are presented in the table below:

Table 2.1: Conversion of GHG to CO2-equivalents

Conversion of CH_4 & N_2O to CO_2-equivalent units	
Mass of GHG as t compound	Mass of GHG as t CO_2-equivalent
1 t CO_2	1 t CO_2-equivalent
1 t CH_4	21 t CO_2-equivalent
1 t N_2O	310 t CO_2-equivalent

2.3.3. Electricity

In order to calculate the CO_2 emissions to be attributed to electricity consumption, it is necessary to determine which emission factor is to be used. The same emission factor will be used for all electricity consumption in the territory, including that in rail transportation.

Because the estimation of emissions from electricity is based on electricity consumption, the emission factors are expressed as t/MWhe. Therefore, the corresponding activity data to be used has also to be in the form of MWhe, i.e. in MWh of electricity consumed.

Lebanon's emission factor is 0.65 tCO_2/MWH as given by the ministry of environment.

2.4. Data collection

The data was collected by doing field trips to Hammana and by collaborating with the local authority.

All the data collected covers all sectors included in the BEI.

The data collected will be split into six sectors:

i. Municipal
ii. Transport
iii. Public lighting
iv. Electric generators
v. Residential
vi. Non-residential (Commercial, tertiary, service…)

There is a necessity in Lebanese municipalities to add a new sector which is the back-up diesel generators sector due to the continuous black-outs that Lebanon suffers from.

It varies from electricity consumption of all buildings/facilities to oil/fuel consumed for heating, transport, electric generators and more.

2.4.1. Residential Sector

- **Methodology**

Energy consumption in residential sector are mainly for using end-user electric appliances, getting hot water, cooking and space heating in winter.

Statistics were done on a number of houses to collect electricity bills, diesel, wood and gas consumption. A copy of the distributed survey will be found at the end of the report.

Hammana contains 1200 houses that are divided into two categories: [17]

i. Summer inhabited houses which count 900.
ii. Summer and winter inhabited houses which count 300.

The electricity consumption of each resident was taken from their respective electricity bills directly and the total was calculated across the year.

Almost all residents have BDG subscriptions and consume electric energy produced from burning diesel. However, a separate section later in the report will handle energy consumption by BDG and their emissions later on.

Liquid propane gas cans are used for cooking; each can weigh 10 kg of liquid compressed propane giving a volume of 17.3 liters by taking 1kg of liquid propane is equal to 1.73 liter in volume. Another form is used for cooking which is electric energy. This consumption will be included in the bills.

It is estimated that one kg of liquid propane liberates 13.6 kwh of energy [21], thus each 10 kg can which is equivalent to 17.3 liters in volume liberates 136 kwh of energy during the combustion.

So, the energy consumed by a residence due to cooking gas can be given by the following formula:

$$E_g = \frac{N \times 10 \times 13.6}{1000}$$

Where:

- E_g is the energy consumed in MWH.
- N is the number of gas cans consumed per year.
- 10 kg is the mass of propane in each can
- 13.6 kwh is the energy liberated by the combustion of 1 kg of propane
- 1000 is to convert from kwh to MWH

Hammana's residents use diesel, wood, propane gas, electricity or any combination between these types of energies for space heating.

Propane gas energy consumption will be calculated by the same formulation above and electric energy will be included in the bills. It is estimated that one liter of diesel is equivalent to 9.98 [22] kwh in terms of energy when it burns and one kg of wood liberates 4.5 kwh [22] of energy.

So, the total energy consumed by burning diesel can be given by the following equation:

$$E_d = \frac{V \times 9.98}{1000}$$

Where:

- E_d is the energy consumed by burning diesel in MWH.
- V is the volume of diesel fuel consumed in liters.
- 9.98 kwh is the energy liberated from the combustion of one liter of diesel fuel.
- 1000 is to convert from kwh to MWH.

And the total energy consumed by burning wood can be given by the following equation:

$$E_w = \frac{M \times 4.5}{1000}$$

Where:

- E_w is the energy consumed by burning diesel in MWH.
- M is the mass of wood consumed in kg.
- 4.5 kwh is the energy liberated from the combustion of one kg of wood.
- 1000 is to convert from kwh to MWH.

For getting hot water the residents mainly use electric energy, while some of the residents use solar energy, get their hot water from diesel fuel or use a combination between these forms of energies.

Electric energy will be included in the bills and the same calculation method above will be used for diesel heat energy consumption. Solar energy is a clean energy or a zero emission energy.

- **Results:**

The distributions of the different energy types used in the residential sector are shown in the following figures.

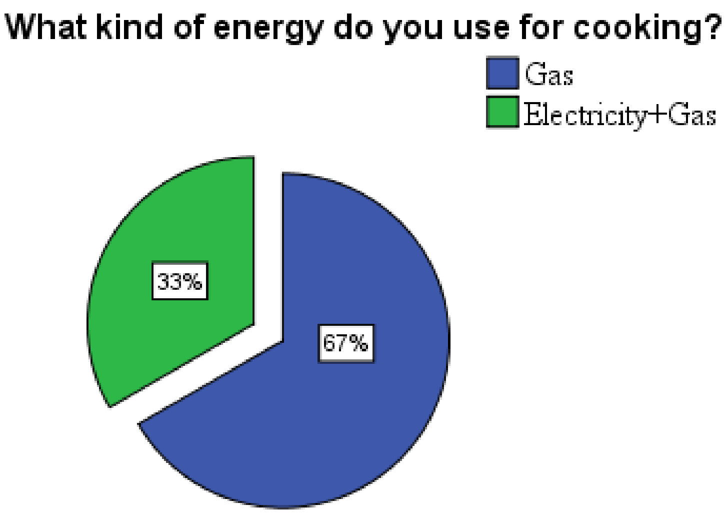


Figure 2.1: Cooking Energy Type Distribution in the Residential Sector

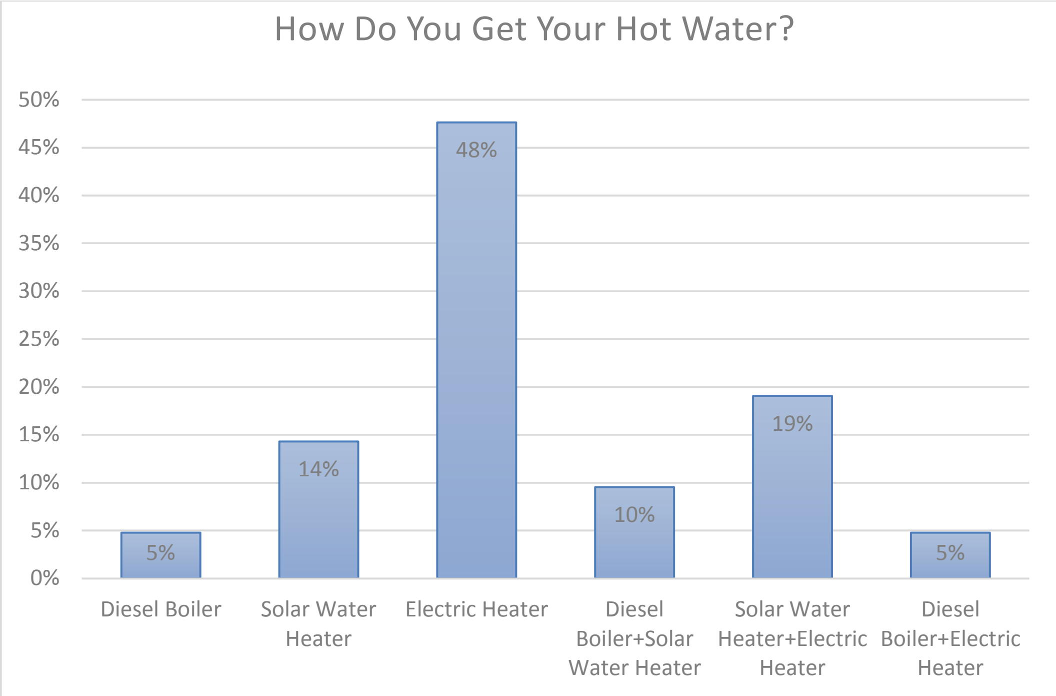


Figure 2.2: Distribution of Hot Water Energy in the Residential Sector

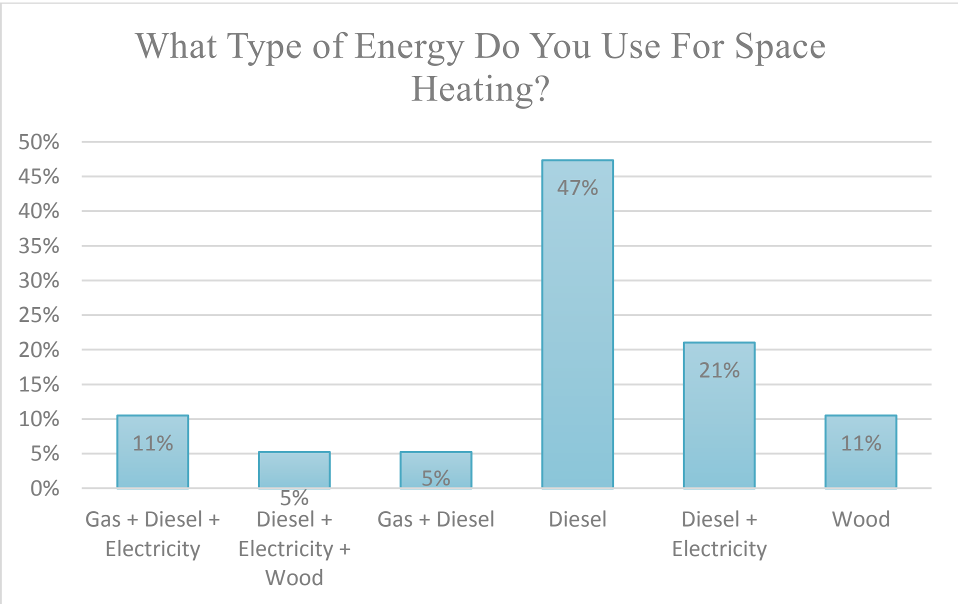


Figure 2.3: Distribution of Space Heating Energy in the Residential Sector

The final energy consumption in the residential sector is shown in the table below:

Table 2.2: Final Energy Consumption in the Residential Sector (MWH)

Electricity Consumption	Diesel Energy Consumption	Wood Energy Consumption	Gas Energy Consumption	Total
3060.95	7875.93	803.57	1527.86	13268.32

It is important to note that our results on electricity consumption verified the estimation done by Isabella Ruble and Sami Karaki in their paper: “Introducing mandatory standards for select household appliances in Lebanon: A cost-benefit analysis” in which they estimated the daily use of electricity for the average Lebanese resident by 14.77 KWH. Our average was 14.81 KWH per day.

The figure below shows the distribution of energy forms consumed in the residential sector.

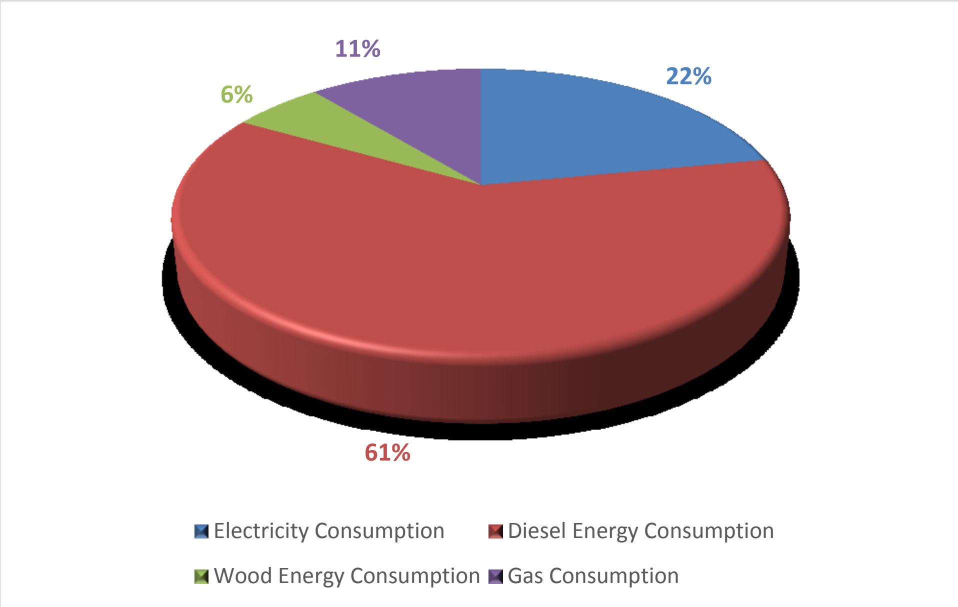


Figure 2.4: Distribution of Energy Forms in the Residential Sector

We notice that diesel heat energy is the main energy consumed in the residential sector, electricity comes second, gas is the third and wood comes in the final place.

2.4.2. Public lighting

- **Methodology**

In Hammana light bulbs are installed in almost all primary and secondary streets. These lights consume electricity from the main grid.

They operate from seven in the evening till five in the early morning giving them ten hours of operating hours per day. They function for 3650 hours in one year.

The total energy consumed by each lamp over a given year can be calculated using the following formula:

$$E = \frac{P \times T}{10^6}$$

Where:

- E is the total energy consumed in MWH.
- P is the total power of the light bulbs in watts.
- T is the number of operating hours per year.
- 10^6 is to convert from wh to MWH.

- **Results:**

The main streets contain 250 W lamps counting 481 while the secondary streets contain 1182 150 W lamps.

The total energy consumed by the public lighting sector is shown in the table below:

Table 2.3: Final Energy Consumption in the Public Lighting Sector (MWH)

Number of Light Bulbs	Power (W)	Total Runtime (hours)	Energy (MWH)	Total Energy
481	250	3650	438.91	1086.06
1182	150		647.15	

The total energy consumed by the public lighting sector is 1086.06 MWH which is completely electrical taken from the main EDL grid.

2.4.3. Municipal Sector

- **Methodology**

The municipal sector includes all the facilities owned and run by the municipality. These include the municipal building, a water treatment plan and a public school. However, the water treatment plant's energy is 100% clean which is solar.

So our statistics covered only the municipal building and the public shcool which consumed energy in the form of electricity from the main grid, propane gas for cooking and diesel for space heating. In addition to electricity from the BDG supplier which will be discussed further in this report.

The same methodology that was used in the residential sector for calculating energy consumption was used here.

So, the electricity consumption was taken directly from electricity bills, heat energy from burning propane gas was calculated using the following equation:

$$E_g = \frac{N \times 10 \times 13.6}{1000}$$

Where:

- E_g is the energy consumed in MWH.
- N is the number of gas cans produced per year.
- 10 kg is the mass of propane in each can.
- 13.6 kwh is the energy liberated by the combustion of 1 kg of propane.
- 1000 is to convert from kwh to MWH.

And heat energy from burning diesel for space heating was calculated using the following equation:

$$E_d = \frac{V \times 9.98}{1000}$$

Where:

- E_d is the energy consumed by burning diesel in MWH.

- V is the volume of diesel fuel consumed in liters.
- 9.98 kwh is the energy liberated from the combustion of one liter of diesel fuel.
- 1000 is to convert from kWh to MWH.

➢ **Results**

It was found that the total electricity consumption over the span of the year was 5.43 MWH, that the municipality consumes 8 propane gas tanks per year and that it consumes 5000 liter of diesel for space heating.

The public school consumed 34.96 MWH of electricity from the main grid, 233.53 MWH of thermal energy from diesel for space heating, 42.91 MWH of thermal energy for electricity production and 3.36 MWH from BDG which we won't include to avoid double counting of BDG energy.

By calculating energy consumptions of propane gas and diesel by the previous formulas, the final energy consumption of the municipal sector is shown in the table below

Table 2.4: Final Energy Consumption in the Municipal Sector (MWH)

Electricity	Diesel	Cooking Gas	Total
40.39	326.85	1.09	368.32

The figure below shows the distribution of energy forms consumed in the municipal sector.

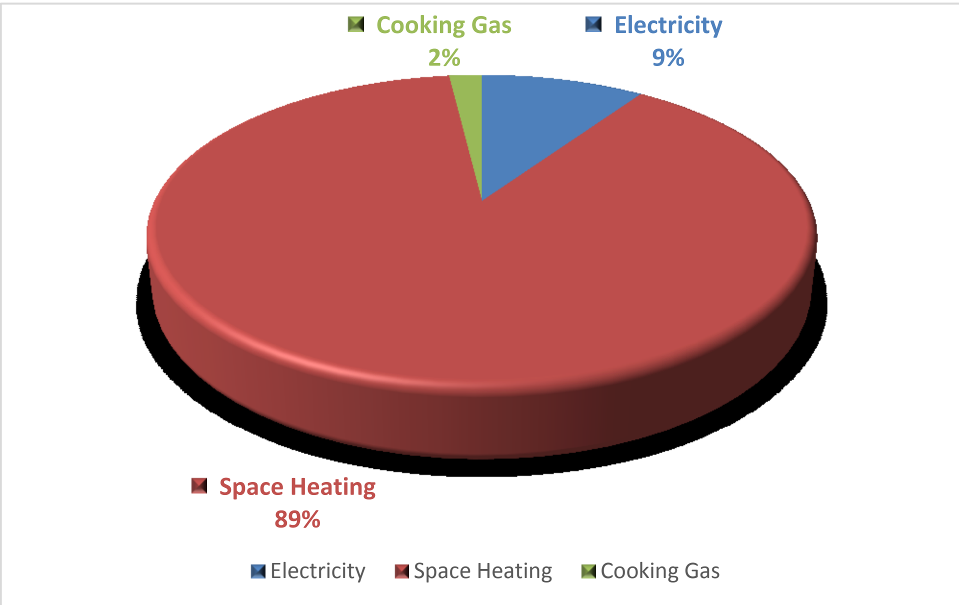


Figure 2.5: Distribution of Energy Forms in the Municipal Sector

2.4.4. Transportation Sector

➢ **Methodology:**

The transport sector varies from public to private and commercial transportation in addition to the municipal fleet. Mainly small cars and SUVs runs on gasoline when delivery and class 8 trucks run on diesel as a source of energy.

It is estimated that one liter of diesel produces 9.98 kwh of energy and one liter of gasoline produces 9.2 [22] kwh of energy.

The normal consumption of each these vehicles is measured by how many tanks are consumed during a certain period of time, knowing that one tank of gasoline or diesel is equivalent to 20 liters.

In the BEI the fuel combustion to be included must be done within the territory we are working on. In our survey a question was asked about the fuel consumption for transportation in general and the fuel consumption restricted to the municipal territory. The result was that almost nobody could estimate his fuel consumption in the territory, so we took a different approach to solve the problem.

Field trips and traffic counts were done on the village square which is a connection of 3 two-ways main streets. An average of the number of cars was calculated per hour. However, our counts were done in summer time, so in order to calculate the total traffic count over the year we multiplied our calculated average by 0.3 knowing that 25% of the total residents are inhabited over the whole year.

The total traffic count on each road was calculated using the following formula:

$$C_i = (0.3 \times A \times 10 \times 185) + (A \times 12 \times 180)$$

Where:

- C_i is the total traffic count over the year on main street i by a certain type of vehicles.
- A is the calculated average traffic count per hour.
- 0.3 is the factor taking into account the winter inhabitation.
- 10 is the number of day hours in winter.
- 12 is the number of day hours in summer.
- 185 is the number of winter days.
- 180 is the number of summer days.

To calculate the total distance covered on each road by a certain type of vehicle, we multiplied the average count by the road. Road 1 measures 3.3 Km while roads 2 and 3 measure 1.3 Km. So, the total distance covered in the territory by a certain type of vehicles can be calculated using the following formula:

$$E = \sum \frac{C_i \times d_i \times KMPT \times 20 \times EPL}{1000}$$

Where:

- C_i is the total traffic count over the year on main street i by a certain type of vehicles.
- di is the total distance of road i.
- KMPT is the number of Km per tank of fuel consumed by a certain type of vehicles.
- 20 is the number of liters per tank.
- EPL is the calorific value of the fuel per liter which is 9.98 kWh/l for diesel fuel and 9.2 kWh/l for gasoline.

The number of kilometers per tank was calculated the number of miles per gallon MPG taken from EPA's numbers (Environmental Protection Agency). The following figure shows the average miles per gallon equivalent:

Data Source: Environmental Protection Agency

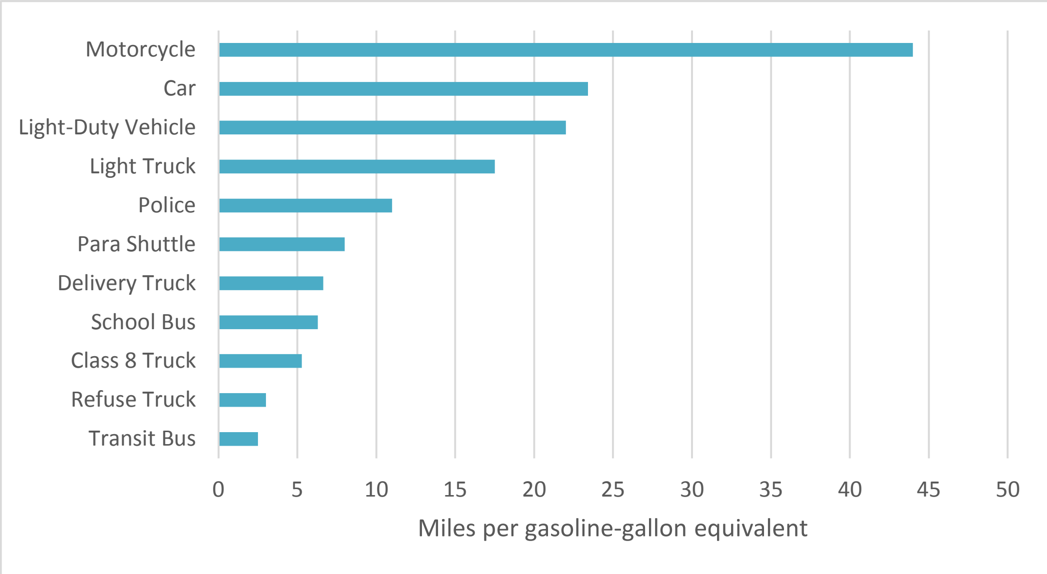


Figure 2.6: Average Fuel Economy of Major Vehicle Categories

Knowing that one tank of fuel is equivalent to 5.29 US gallons and that one mile is equivalent to 1.6 Km, thus:

$$KMPT = MPG \times 5.29 \times 1.6$$

The average of kilometers covered by consuming one tank of fuel by each type of vehicles are given in the following table:

Table 2.5: Average Kilometers per Tank for Each Type of Vehicles

	MPG	**KMPT**
Car	23.41	198.14
Bus	6.30	53.32
Class 8 Truck	5.29	44.77

The municipal fleet energy consumption was calculated by getting the total consumed fuel over the span of the year by the following formulas:

$$E_d = \frac{V_d \times 9.98}{1000}$$

Where:

- E_d is the energy consumed by burning diesel in MWH.
- Vd is the volume of diesel fuel consumed in liters.
- 9.98 kWh is the energy liberated from the combustion of one liter of diesel fuel.
- 1000 is to convert from kWh to MWH.

$$E_G = \frac{V_G \times 9.2}{1000}$$

Where:

- E_G is the energy consumed by burning gasoline in MWH.

- VG is the volume of diesel fuel consumed in liters.
- 9.2 kWh is the energy liberated from the combustion of one liter of gasoline.
- 1000 is to convert from kWh to MWH.

➢ **Results:**

It was found that the municipal fleet consumes 11650 and 7400 liters of gasoline and diesel fuel respectively.

The traffic counts showed that the average cars per hour was 250, the average class 8 truck per hour was 4.55 and the average buses per hour was 1.33 in each of the three main roads.

The final energy consumption in the transportation sector is shown in the table below:

Table 2.6: Final Energy Consumption in the Transportation Sector (MWH)

Cars	Trucks	Fleet Gasoline	Fleet Diesel	Buses	Total
3716.09	324.58	105.99	74.60	79.95	4301.22

2.4.5. Back-Up Diesel Generators

➢ **Methodology:**

The demand for electric generators have been increasing rapidly due to the continuous electric blackout happening all over the country. Thus electric generators running on diesel fuel has become a necessity in our daily lives. A generator is a device that converts mechanical energy to electrical energy for use in an external circuit. The source of mechanical energy may vary widely from a hand crank to an internal combustion engine. In our case, three phased generators that runs on diesel fuel are used to produce electricity and assumed to be running at full load.

A generator's capacity is given in KVA (Kilovolt Ampere). To get the total electrical energy consumed by the generator's power grid we use this formula:

$$E = \frac{KVA \ \times \cos(\varphi) \times T}{1000}$$

Where:

- E is the total electrical energy consumed in MWH
- KVA is the total power (capacity) of the generator in Kilovolt. Ampere
- T is the total runtime over the year in hours.
- $\cos(\varphi)$ is the power factor of the load considered 0.8.
- 1000 to convert from KWH to MWH.

In Hammana there are two BDG suppliers they have a total capacity of 400 KVA in winter and 800 KVA in summer. The generators have an average runtime of 300 hours per month.

➢ **Results:**

By substituting the numbers supplied by the BDG suppliers we find that the total energy consumed from BDG is 576 MWH in winter and 1152 MWH in summer.

The table below shows the final energy consumption from BDG:

Table 2.7: Final Energy Consumption from BDG (MWH)

Summer	Winter	Total
1152	576	1728

2.4.6. Non-Residential Sector

The data from non-residential sector was unavailable.

2.4.7. Total Energy Consumption in Hammana

- **Classification by Sector:**

The total energy consumption classified by sector is shown in the following table:

Table 2.8: Final Energy Consumption Classified by Sector (MWH)

Residential Sector	Municipal Sector	Transportation Sector	Public Lighting	BDG	Total
13268.32	368.32	4301.22	977.45	1728.00	20643.31

The total energy consumption in the municipality of Hammana is 21002.57 MWH.

The distribution of energy consumption by sector is shown in the figure below:

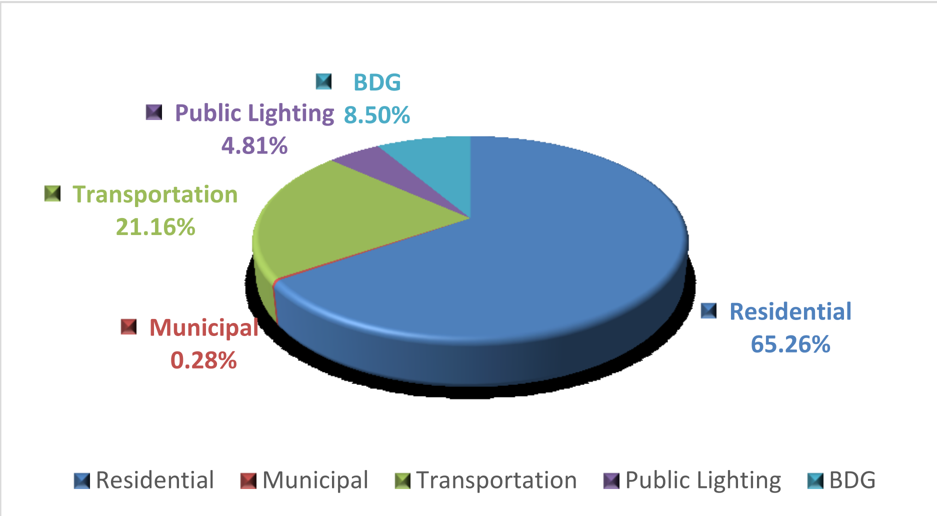


Figure 2.7: Distribution of Energy Consumption by Sector

The major energy consumer is the residential sector, transportation comes second, BDG third with 8.23% and the other sectors follow.

- **Classification by Energy Form:**

The total energy consumption classified by energy form is shown in the table below:

Table 2.9: Final Energy Consumption by Form (MWH)

Electricity	Diesel	Wood	Gas	Gasoline	BDG	Total
4078.79	8681.91	803.57	1528.95	3822.09	1728	20643.31

The distribution of energy consumption by form is shown in the following figure:

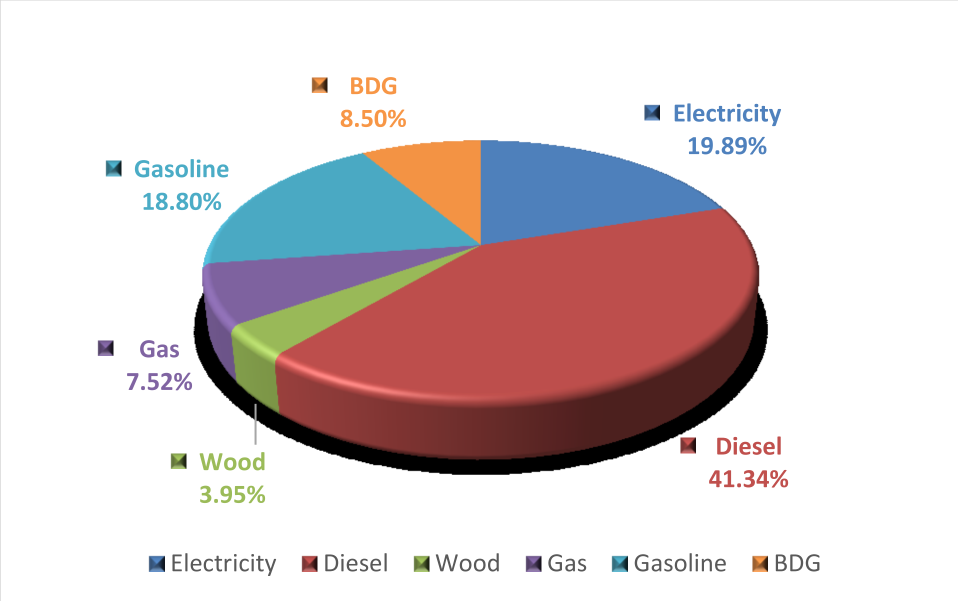


Figure 2.8: Distribution of Energy Consumption by Form

Diesel energy is the most consumed energy where electricity comes second, gasoline third, BDG and gas fourth while wood is the least consumed energy.

2.5. CO_2 Emissions

After calculating the energetic consumptions of the different sectors, we will convert them into tones of CO_2 emissions by using conversion factors issued by the Ministry of Environment in Lebanon. Standard emission factors were used.

2.5.1. Conversion Factors

The ministry of environment in Lebanon have issued a paper with the conversion factors of each type of energetic compound, this paper includes: [23]

- One MWH of electricity is equivalent to 0.65 tons of CO2.

$$1\ MWH_{electricity} = 0.65\ t_{CO_2}$$

- One MWH of electricity produced by an electric generator emits 1.3 tons of CO2.

$$1\ MWH_{BDG} = 1.3\ t_{CO_2}$$

- One liter of diesel is equivalent to 0.002637 tons of CO2.

$$1\ l_{diesel} = 0.002637\ t_{CO_2}$$

- One MWH of energy is produced by burning 100 liters of diesel fuel oil and it emits 0.2637 tons of CO2 into the atmosphere.

$$1\ MWH_{diesel} = 0.2637\ t_{CO_2}$$

- One liter of gas is equivalent to 0.54 kg in mass and produces 0.001595 tons of CO2.
  One MWH of energy is liberated by burning 73.5 kg of gas which is equivalent to approximately seven cans and it is equivalent to 0.2171 tons of CO2.

$$1\ MWH_{gas} = 0.2171\ t_{CO_2}$$

- One MWH produced by burning wood for space heating produces 0.39 tons of CO2.

$$1\ MWH_{wood} = 0.39\ t_{CO_2}$$

- One MWH of energy produced from burning gasoline emits 0.249 tons of CO2.

$$1\ MWH_{gasoline} = 0.249\ t_{CO_2}$$

2.5.2. Residential Sector

The CO_2 emissions of each energy form with its respective emission factor of the residential sector is shown in the table below:

Table 2.10: CO2 Emissions of the Residential Sector

	Electricity	Diesel	Wood	Gas	Total
Energy (MWH)	3060.95	7875.93	803.57	1527.86	13268.32
Emission Factor (tCO2/MWH)	0.65	0.2637	0.39	0.2171	Total
CO2 Emissions (tCO2)	1989.62	2076.88	313.39	331.70	4711.59

2.5.3. Public Lighting:

The total CO_2 emissions of public lighting is shown in the table below:

Table 2.11: CO2 Emissions of Public Lighting

Energy (MWH)	977.45
Emission Factor (tCO2/MWH)	0.65
CO2 Emissions (tCO2)	635.34

2.5.4. Municipal Sector:

The CO_2 emissions of each energy form with its respective emission factor of the municipal sector is shown in the table below:

Table 2.12: CO2 Emissions of the Municipal Sector

	Electricity	Diesel	Cooking Gas	Total
Energy (MWH)	40.39	326.85	1.09	368.32
Emission Factor (tCO2/MWH)	0.65	0.2637	0.2171	Total
CO2 Emissions (tCO2)	**26.25**	**86.19**	**0.24**	**112.68**

2.5.5. Transportation Sector

The CO_2 emissions of each energy form with its respective emission factor of the transportation sector is shown in the table below:

Table 2.13: CO2 Emissions of the transportation Sector

	Gasoline	Diesel	Total
Energy (MWH)	3822.09	479.13	4301.22
Emission Factor (tCO2/MWH)	0.249	0.2637	
CO2 Emissions (tCO2)	951.70	126.35	1078.05

2.5.6. Back-Up Diesel Generators:

The total CO_2 emissions of public lighting is shown in the table below:

Table 2.14: CO2 Emissions of BDG

Energy (MWH)	1728
Emission Factor (tCO2/MWH)	1.3

CO2 Emissions (tCO2)	2246.4

2.5.7. Total CO2 Emissions:

The total CO2 emitted in the municipality of Hammana is 8865.30 tCO2.

2.5.8. Emissions by Sector:

The total CO2 emissions of the municipality of Hammana classified by sector are shown in the table below:

Table 2.15: Total CO2 Emissions by Sector (tCO2)

Sector	Residential	Municipal	Transportation	Public Lighting	BDG	Total
CO2 Emissions	4711.59	208.3	1078.05	635.34	2246	8865

The distribution of CO2 emissions by sector are shown in the figure below:

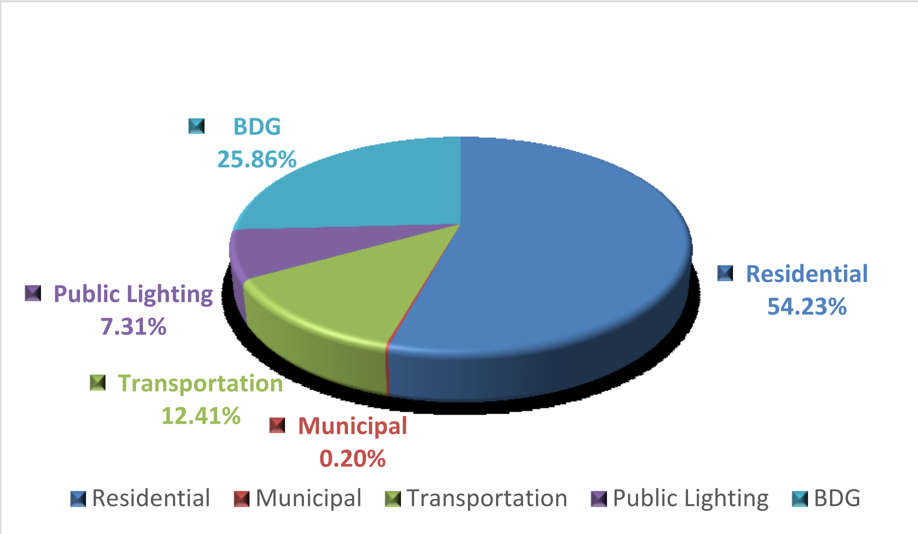


Figure 2.9: CO2 Emissions Distribution by Sector

2.5.9. Emissions by Energy Form:

The total CO2 emissions of the municipality of Hammana classified by energy form are shown in the table following:

Table 2.16: Total CO2 Emissions by Energy Form

	Electricity	Diesel	Wood	Gas	Gasoline	BDG	Total
Energy	4078.79	9076.12	803.57	1529	3822.09	1728	20643.31
Emission Factor	0.65	0.2637	0.39	0.2171	0.249	1.3	Total
CO2 Emissions	2628	2393.37	313.39	332	951.70	2246	8784.07

The distribution of CO2 emissions by energy form is shown in the figure below:

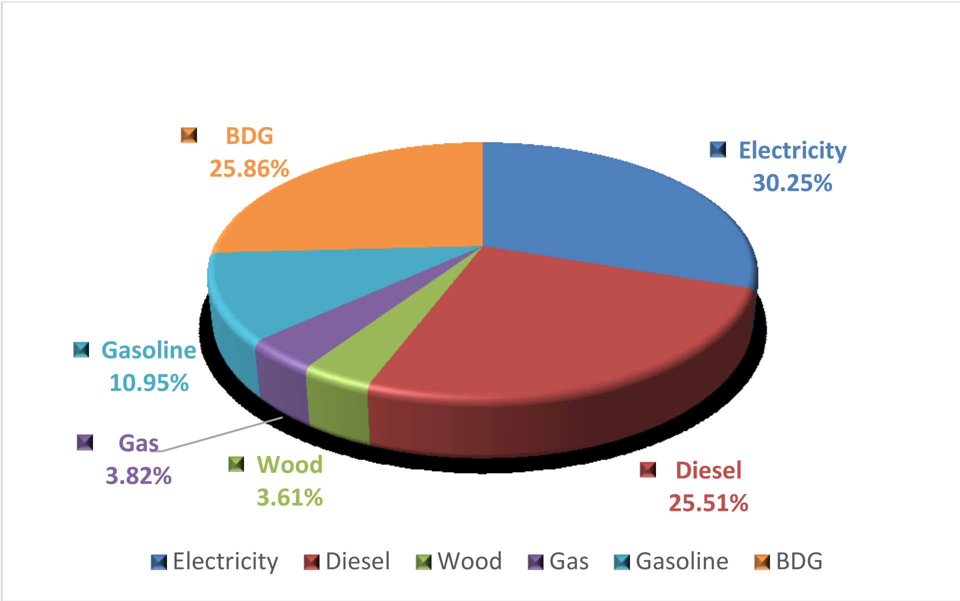


Figure 2.10: CO2 Emissions Distribution by Energy Form

3. SEAP Implementation and Reducing Emissions

In this chapter we are going to propose mitigation actions to reduce the CO_2 emissions in the territory to verify the goal of 20% reduction set by the covenant of mayors, quantify the effect of these actions one by one and their total effect on the whole territory's emissions.

3.1. Introduction:

This chapter is intended to describe the technical measures taken to reduce the amount of CO2 emitted into the atmosphere.

A sustainable energy action plan is set to reduce CO2 emissions by 20% by the year 2020.

3.2. SEAP elaboration

After calculating the amount of CO2 emitted into the atmosphere by different sectors, we will describe the steps taken to reduce these emissions by 20%. In what follows all of the CO2 emissions and reduction are given per current year. Reduction of CO2 is given by the following formula:

$$\%\, Reduction = \frac{CO_{2_b} - CO_{2_a}}{CO_{2_t}} \times 100$$

Where:

- CO_{2b} is the CO2 emission before the installation of the new system.
- CO_{2a} is the CO2 emission after the installation if the new system.
- CO_{2t} is the total CO2 emissions of the (sector, energy form, municipality, etc.)

Our main strategy will be to work on public buildings trying as much as possible to introduce the use of renewable energy, specifically solar, in these buildings because funding public projects is easier due to the presence of several organizations that provide loans for such projects.

3.2.1. Public Street Lighting:

Our first step in reducing the CO2 emissions of the territory will target the public lighting sector. As mentioned previously, this sector is responsible for 7.23% of Hammana's total CO2 emissions, which makes it an important contributor. Also, public lighting is visible by all the residents and an action on this sector will show a sign of dedication from the municipality that will be transferred to the stakeholders. Our action will be to replace all the street lights in Hammana with solar powered 40 W lamps. This actions will nullify the emissions of this sector, reducing the total CO2 emissions of the territory by 635.34 tCO2. The tables below show the effect of this action on the territory:

Table 3.1: Energy Consumption and CO2 Emissions in the Territory Before Installing the PV Powered Lamps

Energy Form	Electric	Diesel	Gasoline	LPG	Wood	BDG	Total
Energy	4079	8405	3822	1529	804	1728	20643
Emission Factor	0.65	0.2637	0.249	0.2171	0.39	1.3	Total
CO2 Emissions	2651	2217	952	332	313	2246	8784

Table 3.2: Energy Consumption and CO2 Emissions of the Old Traditional System

Energy Form	Electric	Total
Energy	977.45	977.45
Emission Factor	0.65	Total
CO2 Emissions	635.34	635.34

Table 3.3: Energy Consumption and CO2 Emissions of the New PV Powered Lamps

Energy Form	PV	Total
Energy	218.52	218.52
Emission Factor	0	Total
CO2 Emissions	0.00	0.00

Table 3.4: Energy Consumption and CO2 Emissions of the Territory After Installing the New System

Energy Form	Electric	Diesel	Gasoline	LPG	Wood	BDG	PV	Total
Energy	3101	8682	3822	1529	804	1728	218.52	19884
Emission Factor	0.65	0.2637	0.249	0.2171	0.39	1.3	0	Total
CO2 Emissions	2016	2289	952	332	313	2246	0	8149

The reduction in CO2 emissions is found to be 635 tCO2 and the percentage of reduction is 7.23% of the overall CO2 emissions in the territory.

3.2.2. Municipal Sector:

The municipality plays a crucial role in implementing the sustainable energy action plan, which represents the pilot project for the municipality and stakeholders. To be successful, SEAP should be developed in close cooperation between the local authorities and stakeholder groups who will be involved in implementing new actions. This would allow them to expertise the changes in consumption and giving positive feedback on the attitude of the staff and visitors.

In order to achieve this objective, we managed to consider two actions. The first one is to harvest solar PV energy to satisfy electric and BDG needs of the municipal building. The second action which is directly related to the first action was to switch the municipal fleet to electric vehicles.

For the first action and from the chapter before we know that the municipal building consumes 5.43 MWH of electricity per year. While no direct data was available as to how much energy they consume from the BDG, we supposed this value to be equal to that of electric energy from EDL because of Lebanon's blackouts which are equal in time as the supply hours, so the total energy required by the PV system is 10.87 MWH making and average daily demand of 29.78 KWH.

To find the size of the PV system we take into consideration that summer days are sunnier than winter day, so we sized our system upon winter sunny hours. This leads to an excess of energy in the summer days which we will use to charge the electric vehicles in summer months. The following figure shows the solar irradiation and energy output of a 1 KW_p PV system in Hammana:

Table 3.5: Energy Output and Irradiance of a 1KWp PV module in Hammana

Month	Ed	Em	Hd	Hm
Jan	2.52	78.1	3.18	98.6
Feb	2.71	75.9	3.47	97.2

Mar	3.8	118	4.96	154
Apr	4.22	127	5.6	168
May	4.75	147	6.42	199
Jun	5.12	154	7.02	211
Jul	5.04	156	7	217
Aug	5.02	156	7	217
Sep	4.71	141	6.48	194
Oct	4.14	128	5.55	172
Nov	3.52	106	4.58	137
Dec	2.78	86.2	3.52	109
Year Average	4.03	123	5.41	165
Total For Year		1470		1970

Where:

- E_d: Average daily electricity production from the given system (KWH)
- E_m: Average monthly electricity production from the given system (KWH)
- H_d: Average daily sum of global irradiation per square meter received by the modules of the given system (KWH/m^2)
- H_m: Average sum of global irradiation per square meter received by the modules of the given system (KWH/m^2)

The least sunny month is January with irradiance of 3.18 KWH/m^2 and having an output energy of 2.52 KWH.

$$KW_p = \frac{Total\ Daily\ Demand}{Daily\ Energy\ Supply\ of\ the\ Least\ Sunny\ Month}$$

According to the equation above, the size of the system will be 12 KW_p, producing an average of 4.03 KWH daily and a sum of 17.65 MWH yearly, resulting in an excess of 6.78 MWH.

For the second action we need to assume that the global efficiency of a gasoline vehicle is 20%, that of a diesel vehicle is 30% and that of an electric vehicle is 60%.[1]

The total diesel energy consumed by the municipal fleet is 74.6 MWH which corresponds to 22.38 MWH of mechanical energy while the total gasoline energy consumption of the fleet is 105.99 MWH which corresponds to 21.2 MWH of mechanical energy. So, the total mechanical energy consumed is 43.58 MWH which in turn requires 72.63 MWH of electric energy. 6.78 MWH of this electric energy is taken from the PV system leaving 65.85 MWH to be taken from the grid.

The following tables show the effect of these actions on the total emissions of the territory:

Table 3.6: Energy Consumption and CO2 Emissions in the Territory Before Applying the Actions

Energy Form	Electric	Diesel	Gasoline	LPG	Wood	BDG	Total
Energy	4079	8682	3822	1529	804	1728	20643
Emission Factor	0.65	0.2637	0.249	0.2171	0.39	1.3	Total
CO2 Emissions	2651	2289	952	332	313	2246	8784

[1] https://www.fueleconomy.gov/feg/evtech.shtml

Table 3.7: Energy Consumption and CO2 Emissions of the Municipal Building Before Applying the Actions

Energy Form	Electric	Diesel	Gasoline	BDG	Total
Energy	5	75	106	5	192
Emission Factor	0.65	0.2637	0.249	1.3	Total
CO2 Emissions	4	20	26	7	57

Table 3.8: Energy Consumption and Emissions After Applying the Actions

Energy Form	Electric	PV	Total
Energy	66	18	84
Emission Factor	0.65	0	Total
CO2 Emissions	43	0	43

Table 3.9: Energy Consumption and CO2 Emissions in the Territory After Applying the Actions

Energy Form	Electric	Diesel	Gasoline	LPG	Wood	BDG	PV	Total
Energy	4139	8607	3716	1529	804	1723	18	20535
Emission Factor	0.65	0.2637	0.249	0.2171	0.39	1.3	0	Total
CO2 Emissions	2690	2270	925	332	313	2239	0	8770

The application of these two actions will lead to a reduction of 14 tons of CO2 emissions representing a 0.16% reduction. The main disadvantage of this action is that our electricity has a relatively high emission factor (0.65 tCO2/MWH) so, the effect of switching to electric vehicles backfired. If we only switch to EV we will practically increase in the CO2 emissions, so we need to install the PV system before. Then we switch to EV hoping that someday our electricity sector would be fixed and we no longer have to suffer the environmental and economic consequences of the high electricity cost.

3.2.3. Public School PV

In the SEAP we tried as much as possible working on public buildings or buildings that are run by the municipality. One of these buildings is the public school which contains an elementary school, a high school and a technical school in three separated buildings sharing the same electric meter but each gets their backup electricity from a different source.

The school consumes an overall of 34.96 MWH of electricity from the main grid yearly emitting 22.72 tons of CO2. They consume 3.36 MWH from BDG supplier, 233.53 MWH from diesel for space heating and 42.91 MWH from the same source of energy to produce electricity.

The total energy consumption of the public school is 314.76 MWH emitting 99.99 tons of CO2.

Our action will be producing all the electric energy for the three schools from PV cells. The total electric consumption is 69.92 MWH which should be produced by the PV system. As mentioned in the action before the total peak power of the system is calculated according to the least sunny month of the year which is January in Hammana, averaging 3.18 sunny hours per day with our proposed crystalline silicon system producing 2.52 KWH per day.

The total peak power of the system is 77 KW_p producing 113.26 MWH of energy yearly. The remaining excess energy which will be produced in summer when the school is closed will be delivered to the grid by using the net metering technology currently available in Lebanon according to the Ministry of Water and Energy. This excess will be used in winter for space heating. The efficiency of an electric resistance heater is 100%[2] while the efficiency of a typical diesel fired boiler is around 75%[3]. This action will save 54.18 MWH of diesel thermal energy for space heating added to the energy required to electricity production.

The following tables show the effect of this action on the total emissions of the territory:

Table 3.10: Total Territory Energy Consumption and CO2 Emissions Before Installing the PV System

Energy Form	Electric	Diesel	Gasoline	LPG	Wood	BDG	Total
Energy	4079	8682	3822	1529	804	1728	20643
Emission Factor	0.65	0.2637	0.249	0.2171	0.39	1.3	Total
CO2 Emissions	2651	2289	952	332	313	2246	8784

Table 3.11: Total Public School Energy Consumption and CO2 Emissions Before Installing the PV system

Energy Form	Electric	Diesel	BDG	Total
Energy	34.96	276.45	3.36	314.76
Emission Factor	0.65	0.2637	1.3	Total
CO2 Emissions	22.72	72.9	4.37	99.99

Table 3.12: Total Public School Energy Consumption and CO2 Emissions After Installing the PV System

Energy Form	Diesel	PV	Total
Energy	179.35	113.26	292.61
Emission Factor	0.2637	0	Total
CO2 Emissions	47.29	0	47.29

Table 3.13: Total Territory Energy Consumption and CO2 Emissions After Installing the PV system

Energy Form	Electric	Diesel	Gasoline	LPG	Wood	BDG	PV	Total
Energy	4044	8585	3819	1529	804	1725	113	20535
Emission Factor	0.65	0.2637	0.249	0.2171	0.39	1.3	0	Total
CO2 Emissions	2629	2264	951	332	314	2242	0	8731

The total reduction in CO2 emissions is 59.69 tons yearly making a percentage of 0.6% of the total CO2 emissions of the territory.

The application of this action and the actions before will set an example for the stakeholders to follow the path of their local authority and try to harvest the solar energy for their houses, schools and markets…

3.2.4. 250 KW Solar Farm

In this action we will try to reduce CO2 emissions from BDG with installing a 250 KW solar farm which will supply electricity for residents upon the blackouts of the main grid electricity.

[2] https://www.energy.gov/energysaver/home-heating-systems/electric-resistance-heating

[3] https://www.energy.gov/energysaver/home-heating-systems/furnaces-and-boilers

This action will have also economic effect on the residents due to the high bill people pay to get their backup electricity. The main reason is that the municipality will be the provider of this electric energy and its goal won't be to achieve profit but merely to get back the cost of installation and the running cost of the system, so people surely will be happy to switch from the traditional BDG suppliers to the clean energy provided by the municipality for financial reasons.

This action will have a great effect on the CO2 emissions of the territory because the environmental bill of the BDG is very high emitting 1.3 tons of CO2 for every MWH of electricity produced. Another advantage as to use this energy is that Hammana is mainly a summer residence where 75% of its housing units are summer residences during the sunniest months of the year producing the most energy, so no or very little energy is wasted in this process.

As mentioned in the actions before, the average daily production of our proposed crystalline silicon panel is 4.03 KWH per KW_p, so the total energy produced by the whole 250 KW_p system will be 367.74 MWH yearly that will be reduced from the energy consumption of BDG making it 1360.26 MWH.

The following tables show the effect of this action on the total emissions of the territory:

Table 3.14: Territory Energy Consumption and CO2 Emissions Before Installing 250 KW PV Farm

Energy Form	Electric	Diesel	Gasoline	LPG	Wood	BDG	Total
Energy	4079	8682	3822	1529	804	1728	20644
Emission Factor	0.65	0.2637	0.249	0.2171	0.39	1.3	Total
CO2 Emissions	2651	2289	952	332	313	2246	8784

Table 3.15: Energy Consumption and CO2 Emissions of the BDG Sector

Energy Form	BDG	Total
Energy	1728.00	1728.00
Emission Factor	1.3	Total
CO2 Emissions	2246.40	2246.40

Table 3.16: Energy Consumption and CO2 Emissions of the BDG Sector After Installing 250 KW PV Farm

Energy Form	BDG	PV	Total
Energy	1360.26	367.74	1907.35
Emission Factor	1.3	0	Total
CO2 Emissions	1768.34	0.00	1815.64

Table 3.17: Territory Energy Consumption and CO2 Emissions After Installing 250 KW PV Farm

Energy Form	Electric	Diesel	Gasoline	LPG	Wood	BDG	PV	Total
Energy	4079	8861	3822	1529	804	1360	368	20823
Emission Factor	0.65	0.2637	0.249	0.2171	0.39	1.3	0	Total
CO2 Emissions	2651	2337	952	332	314	1768	0	8354

The total reduction in CO2 emissions in the territory will 478.06 tons of CO2 which represents 5.44% of the total CO2 emissions of the territory.

The long term goal is to nullify the energy consumption from BDG which we will work on accomplishing when this action is completed and it regained its cost.

3.2.5. Solar Water Heaters for Residential Sector:

The target of this sector will be the residential sector. Supposing a form of funding is found for the residents, a 200-liter solar water heater will be installed for all the residents.

Our statistics estimated that 14 houses used diesel and electricity for getting hot water, 14 used diesel only, while 29 used solar and diesel energies to get their hot water. A total of 33600 liters of diesel is used each year to get hot water producing 335.33 MWH of heat and emitting 88.43 tons of CO2 to the atmosphere. In addition to the residents using diesel, we found that 743 houses used only electric heaters and 229 houses used electric heaters in addition to a solar water heater. An average of 5 hours per day of running the electric water heater was calculated.

An average electric water heater has a power of 1.5 KW [24] and operates for 300 days per year for winter and summer residents, and 100 days in summer residences.

The total electric energy used for getting hot water in the territory is 1060.71 MWH emitting 689.46 tons of CO2 to the atmosphere. The installation of 200-liter solar water heater for all the residents will reduce the use of electric heaters to 1 hour for 100 days only for the winter residents while the summer residences won't use the electric heaters at all reducing the electric energy to 45 MWH and nullifying the diesel energy.

The following tables show the effect of this action on the total CO2 emissions of the territory:

Table 3.18: Territory Energy Consumption and CO2 Emissions Before Installing Solar Water Heaters

Energy Form	Electric	Diesel	Gasoline	LPG	Wood	BDG	Total
Energy	4079	8682	3822	1529	804	1728	20644
Emission Factor	0.65	0.2637	0.249	0.2171	0.39	1.3	Total
CO2 Emissions	2651	2289	952	332	313	2246	8784

Table 3.19: Hot Water Energy Consumption and CO2 Emissions Before Installing Solar Water Heaters

Energy Form	Electric	Diesel	Total
Energy	1061	335	1396
Emission Factor	0.65	0.2637	Total
CO2 Emissions	689	88	778

Table 3.20: Hot Water Energy Consumption and CO2 Emissions After Installing Solar Water Heaters

Energy Form	Electric	Diesel	Total
Energy	45	0	45
Emission Factor	0.65	0.2637	Total
CO2 Emissions	29	0	29

Table 3.21: Territory Energy Consumption and CO2 Emissions After Installing Solar Water Heaters

Energy Form	Electric	Diesel	Gasoline	LPG	Wood	BDG	Total
Energy	3063	8347	3822	1529	804	1728	19293
Emission Factor	0.65	0.2637	0.249	0.2171	0.39	1.3	Total

CO2 Emissions	1991	2201	952	332	314	2246	8036

Applying this action will reduce the CO_2 emissions by 748.64 tons which represent 8.52% of the total CO_2 emissions of the territory.

3.2.6. Changing People's Attitude:

A proposed action will be working on changing people's attitude towards climate change and energy consumption. The following figures can give us an idea of how the residents think and behave about the climate change and the energy crisis our world is suffering from:

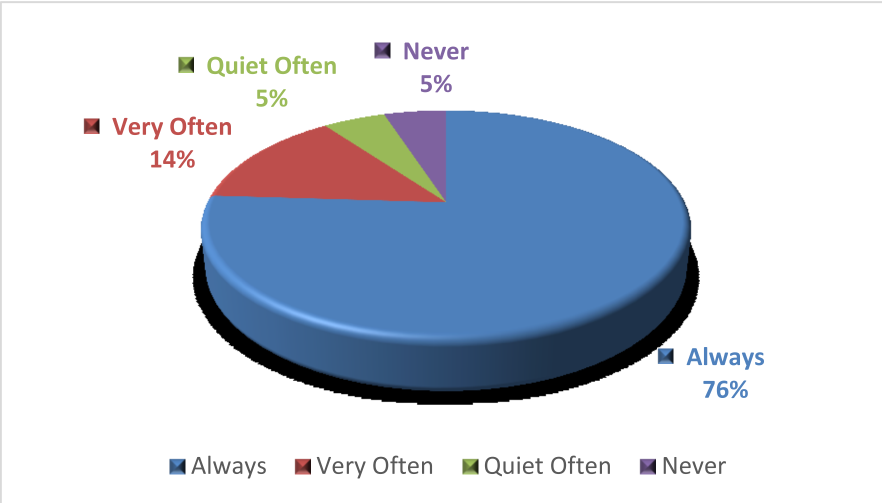


Figure 3.1: How Often Do You Switch the Lights Off When Not in the Room?

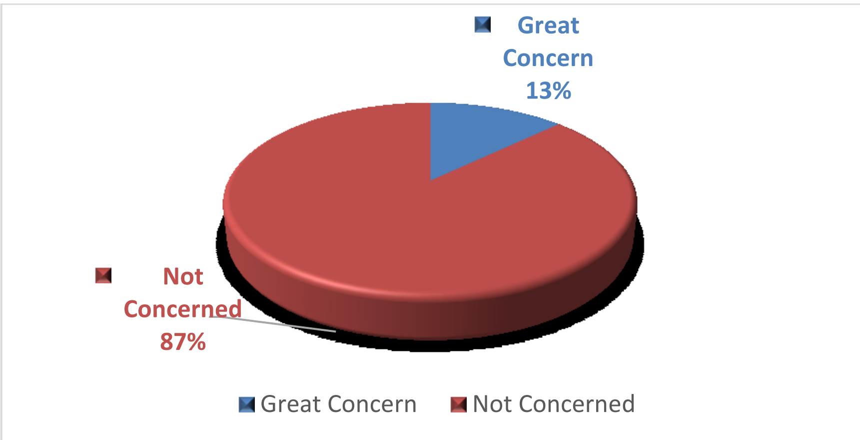


Figure 3.2: How Concerned Are You About Climate Change Concern?

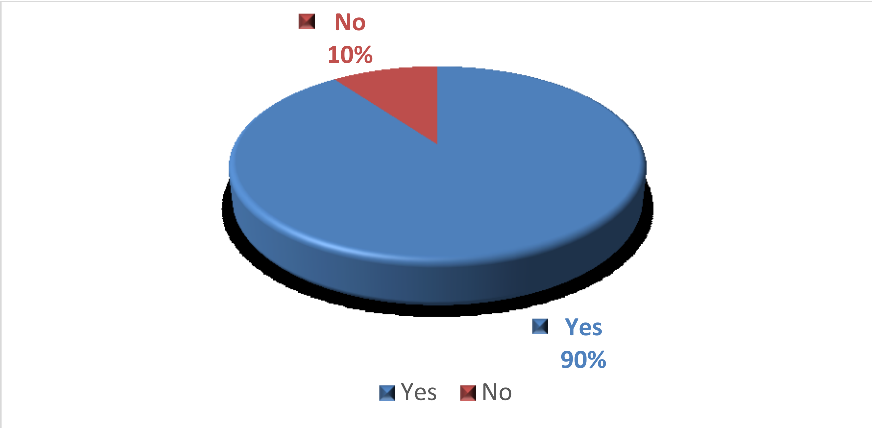


Figure 3.3: Would You Be Interested in Participating in Energy Saving Activities in the Future?

The figures above show that not all the people have concern about climate change, that 24% of people do not always switch off the lights when they are not in the room and most importantly they showed that 90% of the people would be interested in participating in energy saving activities.

In addition to the general population the municipality should target its staff starting with itself before trying to change others. An energy engineer should be hired to oversee the implementation of the plan and to train the municipal staff and employees to reduce their energy consumption. An energy saving account can be established for the staff including bonuses for the most energy efficient employee. Another possible role for this engineer will be to perform free energy audits to the residents proposing ways to reduce energy consumption and shedding the light on places where energy is wasted.

We recommend that at every event hosted by the municipality, a short segment showing the consequences of climate change to be held. This will help introduce people to the severity of the problem and make them involved in trying to reduce their energy consumption as much as possible.

3.2.7. Total Reduction:

The total reduction in CO_2 emissions after applying the first 5 actions will be 1928.59 tons representing 21.94% of the total CO_2 emissions in the territory which meet the target of 20% reduction set by the covenant of mayors before 2020.

The last action will help increase this percentage further but we can't yet estimate how much it would reduce emissions. However, we would be able to estimate its effect in the later MEI.

4. Conclusion

Climate change and global warming are affecting our daily lives, threatening all the living species on the planet and leading us toward extinction, so we must commit ourselves on reshaping the structure of our daily routine and taking a step closer to save the planet from total annihilation. Each one of us must shape his thoughts into seeing the entire planet as a one huge living organism protecting us and helping us to survive, and our survival depends on it. CO2 and CO2 equivalents such as methane gas and NO2 are some of the main contributing factors of global warming, thus reducing emissions is our key step for saving our lives. The commitment taken by the covenant of mayors will take us a step closer toward reducing CO2 emissions.

After collecting and analyzing all the data about energy consumption and organizing them into a specific framework and categories, we were able to calculate the total CO2 emissions by each sector.

Six measures were proposed in order to reduce these emissions, solar powered street lights, 200-liter solar water heater for each residence, PV systems were proposed in order to satisfy the electric needs of the municipal building, along with replacing the municipal fleet with a new electrically power one, and the public school, along with reducing the fossil thermal needs with electrical heaters. Most importantly we proposed hiring an energy engineer to supervise the implementation of the plan and educate municipal staff and citizens about the importance of our step by launching different launching energy saving activities

The sustainable energy action plan developed for Hammana will reduce the total CO2 emissions of this territory by 22% exceeding the target set by the Covenant of Mayors by 2%. This reduction won't just require the commitment of the municipality, but the commitment of each individual leading evolution toward a better life for the sake of our children's.

Annex 1: Questionnaire developed to collect data of the residential sector

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خلال سنة **2016**

استهلاك الطاقة

استهلاك الكهرباء المباشر من شركة **كهرباء لبنان** (KWH) Triphasé Monophasé

كانون الثاني ___	نيسان ___	تموز ___	تشرين الأول ___
شباط ___	ايار ___	آب ___	تشرين الثاني ___
آذار ___	حزيران ___	أيلول ___	كانون الاول ___

استهلاك الكهرباء المشترك من **المولدات الخاصة** (KWH) Triphasé Monophasé

كانون الثاني ___	نيسان ___	تموز ___	تشرين الأول ___
شباط ___	ايار ___	آب ___	تشرين الثاني ___
آذار ___	حزيران ___	أيلول ___	كانون الاول ___

وسائل النقل

ما عدد السيارات التي تملكها؟ ___ ما هو متوسط استهلاك الوقود؟ ___ (تنكة)

والتي تستهلكها فقط داخل البلدة؟ ___

نوع الوقود: بنزين ديزل

ما هو استهلاكك للطاقة في الطبخ؟

غاز ___ قارورة

كهرباء ___ ساعة في اليوم

حديقة:

ما مساحة التشحيل؟ (م2) ___

عدد مرّات التشحيل في السنة ___

أسئلة متنوّعة

يقال اننا نعيش في أزمة طاقة. هل تعتقد ذلك؟ نعم لا

كم مرة تطفئ الأضواء عندما لا تكون في الغرفة؟ دائما في كثير من الأحيان في بعض الأحيان أبدا

كيف تحصل على مياه الشرب الخاصة بك؟ و ما هي حاجتك اليومية؟ ___

هل تفرز النفايات الخاصة بك بشكل صحيح؟ نعم لا

ما مدى قلقك . بشأن الاحترار العالمي / تغير المناخ؟ ___

هل تهتم بالمشاركة في أنشطة توفير الطاقة في المستقبل؟ نعم لا

خلال سنة **2016**

استهلاك الطاقة

هل تنتج كهربائك بنفسك؟ كيف وما هو إستهلاكك للطاقة؟

- طاقة شمسية PV ____ (KWH)
- طاقة هوائية ____ (KWH)
- طاقة مائية ____ (KWH)
- مولّد كهربائي صغير
  - بنزين ____ برميل
  - مازوت ____ برميل

كيف تحصل على مياه ساخنة؟

- سخان على المازوت ____ ليتر في الشهر
- سخّان شمسي ____ سعة المياه
- سخان كهربائي ____ عدد ساعات التشغيل في اليوم
- سخان على الغاز ____ قارورة في السنة
- سخان على الحطب ____ كيلو في الشهر

كيف تدفئ منزلك في فصل الشتاء؟ حدد إستهلاكك

- مركزي
- محلّي

عدد الغرف ____

غاز ____ قارورة

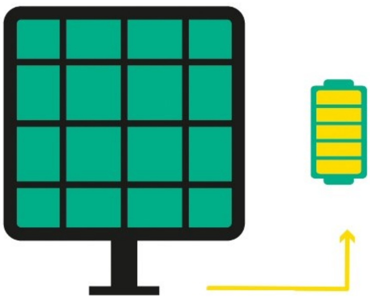
مازوت ____ ليتر

كهرباء ____ ساعة في اليوم

حطب ____ كيلو

ما هي صفات البناء؟

- كسوة حجرية
- جدار مزدوج
- عزل حراري
- سقف قرميد
- المنيوم



منوعات

هل تملك ○ شقّة ○ بيت منفرد

ما هي مساحة المنزل؟ ____ م2

ما هو عدد سكّان المنزل؟ ____ شخص

ما هي عدد ساعات الوجود في المنزل؟ ____ ساعة في اليوم

ما هي عدد أيام الوجود في السنة؟ ____ أيام في السنة

ما هو عدد المصابيح الكهربائية؟ ____ ○ تقليدي ○ لمبات التوفير أو LED

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