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NATIONAL GREENHOUSE GAS INVENTORY REPORT AND MITIGATION ANALYSIS
FOR THE ENERGY SECTOR IN LEBANON

2015 MINISTRY OF ENVIRONMENT

National Greenhouse Gas Inventory Report and Mitigation Analysis for the Energy Sector in Lebanon

May 2015

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National Greenhouse Gas Inventory Report and Mitigation Analysis for the Energy Sector in Lebanon

Reference projects

Enabling Activities for the Preparation of Lebanon's Third National Communication to the UNFCCC

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Foreword

Ministry of Environment

Through the publications of Lebanon's Initial and Second National Communications to the United Nations Framework Convention on Climate Change, and the Technology Needs Assessment for Climate Change, the Ministry of Environment drew the large climate change picture in the country. The picture shed the light on a number of climate change matters: Lebanon's contribution to global greenhouse gas emissions, the sectoral share of national emissions, the socio-economic and environmental risks that the country faces as a result of climate change, and the potential actions that could and should be undertaken to fight climate change both in terms of mitigation and adaptation.

Through these series of focused studies on various sectors (energy, forestry, waste, agriculture, industry, finance and transport), the Ministry of Environment is digging deeper into the analysis to identify strengths, weaknesses, threats and opportunities to climate friendly socio-economic development within each sector.

The technical findings presented in this report (National Greenhouse Gas Inventory Report and Mitigation Analysis for the Energy Sector) will support policy makers in making informed decisions. The findings will also help academics in orienting their research towards bridging research gaps. Finally, they will increase public awareness on climate change and its relation to each sector. In addition, the present technical work complements the strategic work of the National Climate Change Coordination Unit. This unit has been bringing together representatives from public, private and non-governmental institutions to merge efforts and promote comprehensive planning approach to optimize climate action.

We are committed to be a part of the global fight against climate change. And one of the important tools to do so is improving our national knowledge on the matter and building our development and environmental policies on solid ground.

Mohamad Al Mashnouk

Minister of Environment

Foreword

United Nations Development Programme

Climate change is one of the greatest challenges of our time; it requires immediate attention as it is already having discernible and worsening effects on communities everywhere, including Lebanon. The poorest and most vulnerable populations of the world are most likely to face the harshest impact and suffer disproportionately from the negative effects of climate change.

The right mix of policies, skills, and incentives can influence behaviour and encourage investments in climate development-friendly activities. There are many things we can do now, with existing technologies and approaches, to address it.

To facilitate this, UNDP enhances the capacity of countries to formulate, finance and implement national and sub-national plans that align climate management efforts with development goals and that promote synergies between the two.

In Lebanon, projects on Climate Change were initiated in partnership with the Ministry of Environment from the early 2000s. UNDP has been a key partner in assisting Lebanon to assess its greenhouse gas emissions and duly reporting to the UN Framework Convention on Climate Change. With the generous support of numerous donors, projects have also analysed the impact of climate change on Lebanon's environment and economy in order to prioritise interventions and integrate climate action into the national agenda. UNDP has also implemented interventions on the ground not only to mitigate the effects of climate change but also to protect local communities from its impact.

This series of publications records the progress of several climate-related activities led by the Ministry of Environment which UNDP Lebanon has managed and supported during the past few years. These reports provide Lebanon with a technically sound solid basis for designing climate-related actions, and support the integration of climate change considerations into relevant social, economic and environmental policies.

Ross Mountain

UNDP Resident Representative

Acknowledgements

The climate change team at the Ministry of Environment gratefully acknowledges all individuals and organizations who provided various forms of support for the preparation and successful completion of the national greenhouse gas inventory of the energy sector in Lebanon. Particular mention has to be made to the Ministry of Energy and Water, the Central Administration of Statistics, the UNDP-CEDRO project and the Lebanese Center for Energy Conservation.

Our utmost appreciation goes to Mr. Karim Osseiran whose role and involvement has significantly improved the preparation of this inventory and mitigation analysis. His knowledge and experience were essential for the acquisition of energy-related data and the elaboration and analysis of potential scenarios for emissions reduction.

The climate change team would also like to thank Dr. Toni Issa and the IPTEC team for their collaboration in generating data on the end-use of fuel in Lebanon and highlighting the importance of the involvement and engagement of the private sector in developing environmentally sound policies.

Finally, the Ministry of Environment would like to thank UNDP/GEF for funding the whole greenhouse gas inventory exercise.

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Acronyms

BAU	Business as Usual
BCM	Billion Cubic Meters
CAS	Central Administration of Statistics
CC	Combined Cycle
CFL	Compact Fluorescent Lamps
CCGT	Combined Cycle Gas Turbine
CCPP	Combined Cycle Power Plants
CEDRO	Country Energy Efficiency and Renewable Energy Demonstration Project for the Recovery of Lebanon
CF	Capacity Factor
CoM	Council of Ministers
DO	Diesel Oil
EDL	Electricité Du Liban
EEZ	Exclusive Economic Zone
ENS	Energy not Supplied
EPC	Engineering, Procurement and Construction
FSRU	Floating Storage and Regasification Unit
GBA	Greater Beirut Area
GDO	Gas Diesel Oil
GDP	Gross Domestic Product
Gg	Gigagram or 1,000 tonnes
GHG	Greenhouse Gas
GoL	Government of Lebanon
GWh	Gigawatt hour
GWP	Global Warming Potential
HFO	Heavy Fuel Oil
HPS	High Pressure Sodium
HRSG	Heat Recovery Steam Generator
IATA	International Air Transport Association
ICE	Internal Combustion Engine
INC	Initial National Communication
IPCC	Intergovernmental Panel on Climate Change

IPP	Independent Power Producer
ISIC	International Standard Industrial Classification
kWh	Kilowatt hour
LCEC	Lebanese Center for Energy Conservation
LED	Light Emitting Diode
LPG	Liquefied Petroleum Gas
LRF	Lebanon Recovery Fund
MMBTU	Million British Thermal Units
MoEW	Ministry of Energy and Water
MW	Megawatt
MWh	Megawatt hour
NEEAP	National Energy Efficiency Action Plan
NEEREA	National Energy Efficiency and Renewable Energy Action
NG	Natural Gas
NMVOCs	Non-Methane Volatile Organic Compounds
NPO	Net Power Output
OCGT	Open Cycle Gas Turbine
PER	Public Expenditure Report
PG	Private Generation
PP2010	Policy Paper 2010
PPA	Power Purchase Agreement
PV	Photovoltaic
SC	Simple Cycle
SFOC	Specific Fuel Oil Consumption
SNC	Second National Communication
SWH	Solar Water Heater
TJ	Terajoule
TNC	Third National Communication
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
VOLL	Value of Lost Load

Executive summary

In the framework of Lebanon's Third National Communication (TNC) to the United Nations Framework Convention on Climate Change (UNFCCC), Greenhouse Gas (GHG) emissions resulting from the energy sector in Lebanon were estimated from 1994 to 2011. Calculations were made using the Revised 1996 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories and the Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. The GHG emissions from the energy sector, namely carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), along with the indirect GHGs (carbon monoxide (CO), nitrogen oxides (NO_x), sulphur dioxide (SO_2) and Non-Methane Volatile Organic Compounds (NMVOCs)) have been calculated in order to be reported to the UNFCCC. In addition, this report provides an overview of most of the mitigation activities that have been initiated and implemented during the period 2005-2012 and proposes new mitigation scenarios to further reduce GHG emissions from the energy sector.

Inventory

In 2011, total GHG emissions from the energy sector in Lebanon amounted to 12,471 Gg (Gigagram or 1,000 tonnes) of carbon dioxide equivalent (Gg CO_2eq.) (12.4 million tonnes CO_2eq.). Energy is mainly responsible for carbon dioxide emissions, while it also contributes to methane and nitrous oxide emissions and other air pollutants such as CO, NO_x and SO_2. In 2011, 99.63% of the emissions from the energy sector were CO_2, 0.12% CH_4 and 0.25% N_2O. The contribution of each source to the total of the sector is presented in Figure i.

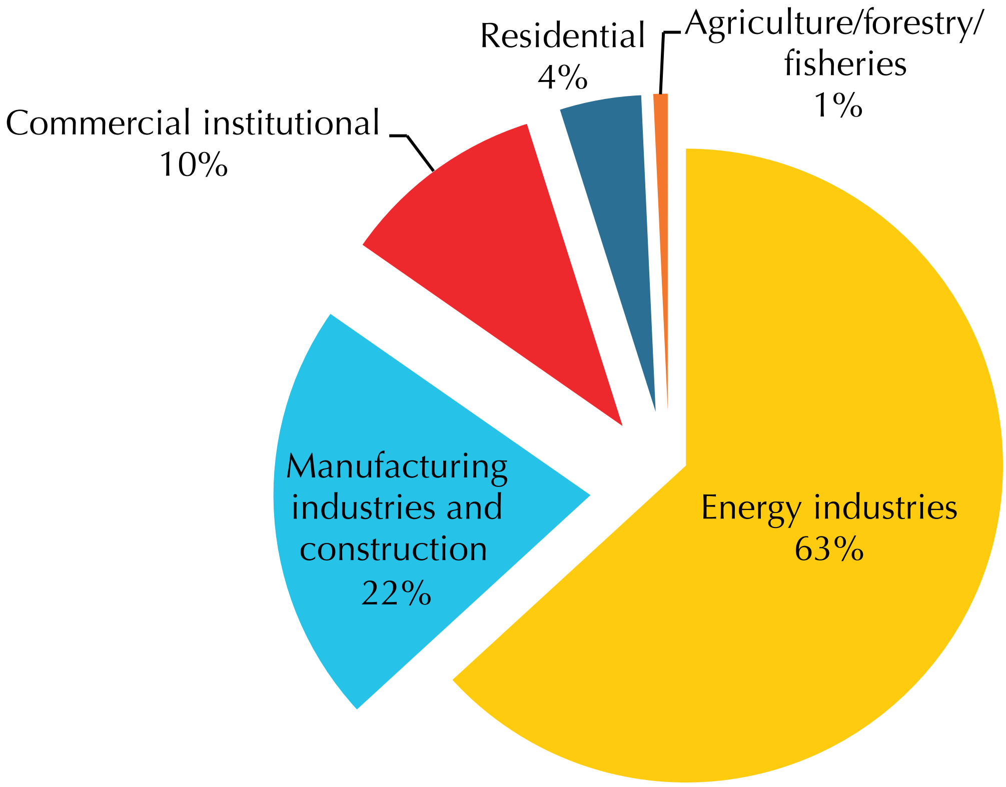


Figure i: Contribution of energy emission sources to the sector's total for 2011

Since electricity generation from public power plants (energy industries) is the main fuel consumer, it is responsible for 63% of the sector's emissions followed by manufacturing industries (22%), and commercial/institutional (10%).

Indeed, public electricity generation is the largest contributor to the sector's emissions due to the fact that more than 88% of imported fuel oil and 53% of imported gas diesel oil are used in thermal power plants for public electricity generation.

It is estimated that the Zahrani, Deir Aamar and Zouk plants are the highest emitters of greenhouse gases, given that they are the biggest power plants in terms of capacity, electricity generation and fuel consumption. However the Hrayche and Tyre power plants are considered as the most polluting installations, with the lowest operation efficiency and the highest emission intensity, generating around 1,000 tonnes CO_2eq. per GWh (Gigawatt hour) of electricity produced (Figure ii).

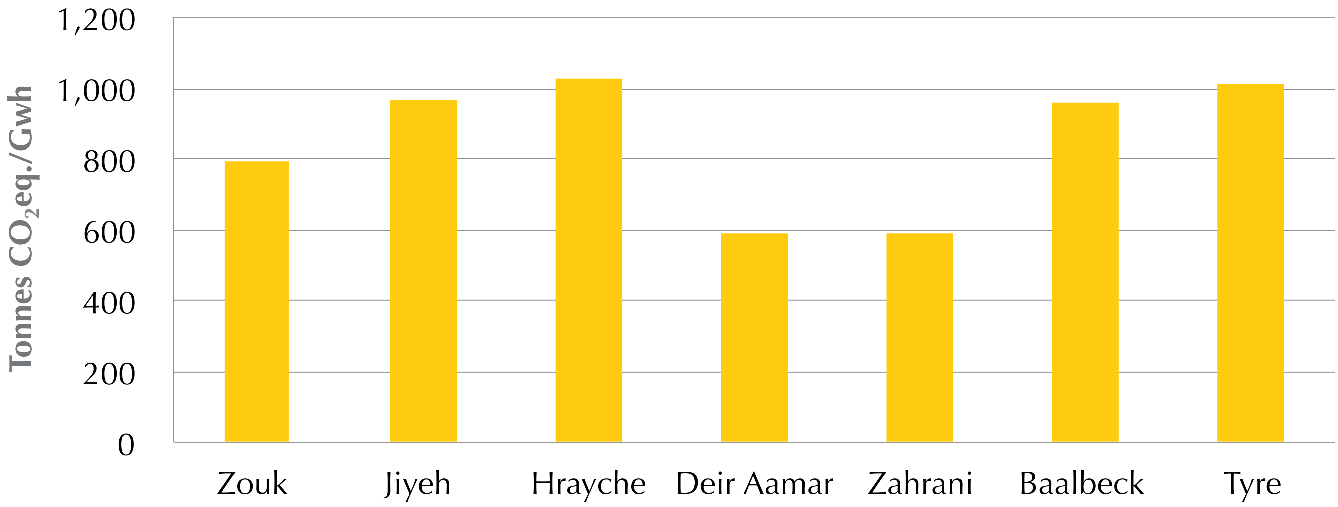


Figure ii: Emission intensity of thermal power plants

In 2011, private electricity generation emitted 2,370 Gg CO_2eq. accounting for 19% of total GHG emissions from energy activities. It is estimated that on average generating electricity from private generators emits less than generating electricity from public thermal power plants. Indeed, while public power plants emit on average 847 tonnes CO_2eq. per GWh produced, private generators emit only 713 tonnes CO_2eq. In addition, in absolute terms, public energy generation produces more GHG emissions than private generation since it produces more electricity and consumes more fossil fuel.

Mitigation

Several projects in Lebanon aim at increasing energy production while decreasing GHG emissions. These projects, implemented by the Ministry of Energy and Water, the Lebanese Center for Energy Conservation, the CEDRO project and other private entities, have induced an estimated 262,712 tonnes CO_2eq. abatement. If these activities are well sustained, it is expected to have a minimum of 119,184 tonnes CO_2eq. per year. This does not take into account the implementation of other additional planned activities across the sector.

In order to further reduce emissions from the energy sector, the mitigation scenario that is proposed includes the full implementation of the Energy Policy Paper (PP2010) of the Ministry of Energy and Water (MoEW) updated as per the actual situation at the end of 2014. The mitigation scenario assumes that the existing plants are rehabilitated and upgraded, and large investments are made to increase the generation capacity to meet demand within 2018. The private generation and purchasing gradually decrease when production reaches the demand level and natural gas will become available by the end of 2018.

The implementation of the Energy Policy Paper inflicts a cumulative decrease of 83 million tonnes CO_2eq. from 2009 to 2030, with an average annual decrease of 3.8 million tonnes Gg CO_2eq. per year as compared to the Business as Usual (BAU) scenario. Starting 2019, a noticeable drop of 38% in emissions is observed, mainly due to the switch of most power plants from heavy fuel oil and diesel oil use to natural gas. The introduction of additional production capacity by Independent Power Producers (IPPs) contributes to reducing even further CO_2 emissions in 2024, 2027 and 2029.

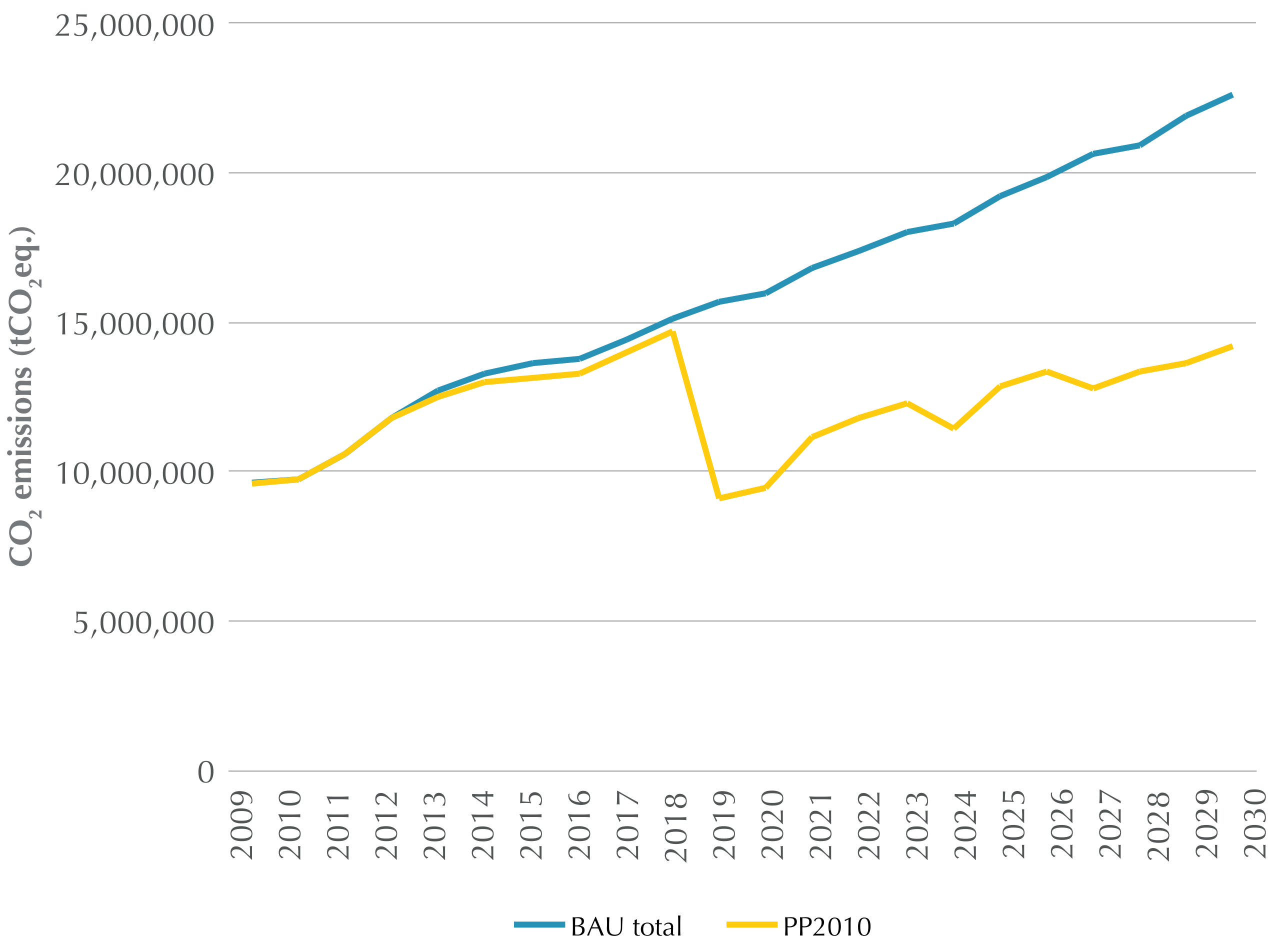


Figure iii: Emission reduction potential from implementing mitigation scenario PP2010

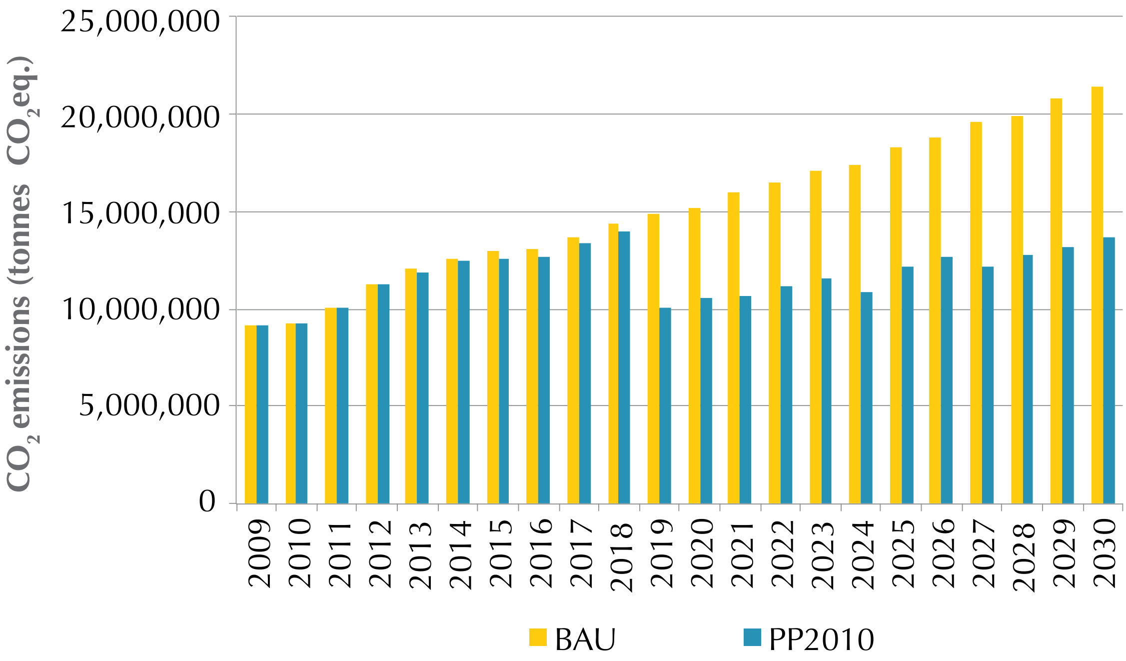


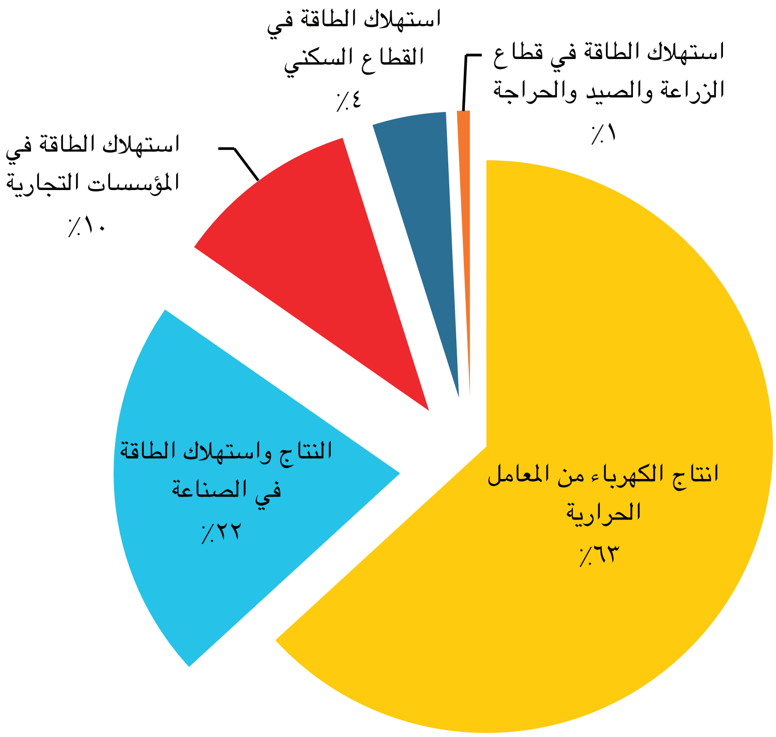
Figure iv: CO_2 emissions under BAU and PP2010 scenarios

الملخص التنفيذي

في إطار البلاغ الوطني الثالث للبنان إلى اتفاقية الأمم المتحدة الإطارية بشأن تغير المناخ، تم تقدير انبعاثات غاز الاحتباس الحراري (الغازات الدفيئة) الناجمة عن قطاع الطاقة في لبنان خلال الفترة ١٩٩٤–٢٠١١. وتمت العملية الحسابية باستخدام المبادئ التوجيهية (للهيئة الحكومية الدولية المعنية بتغير المناخ) المنقحة عام ١٩٩٦ لإعداد قوائم الجرد الوطنية للغازات الدفيئة وإرشادات الممارسات الجيدة وإدارة حالات عدم التيقن في قوائم الجرد الوطنية لغازات الدفيئة (٢٠٠٠). كما تم احتساب انبعاثات الغازات الدفيئة الناجمة عن قطاع الطاقة، وهي ثاني أكسيد الكربون والميثان وأكسيد النيتريك، إضافة إلى انبعاثات الغازات الدفيئة غير المباشرة (أول أكسيد الكربون وأكاسيد النتروجين وثاني أكسيد الكبريت ومركبات عضوية متطايرة غير ميثانية) بهدف رفع التقارير بها إلى اتفاقية الأمم المتحدة الإطارية بشأن تغير المناخ. وبالإضافة إلى ذلك، يقدم هذا التقرير لمحة عامة عن معظم أنشطة التخفيف التي استهلت ونفذت خلال الفترة ٢٠٠٥–٢٠١٢، كما يقترح سيناريوهات جديدة لزيادة التخفيف من انبعاثات الغازات الدفيئة من قطاع الطاقة.

جردة انبعاثات الغازات الدفيئة

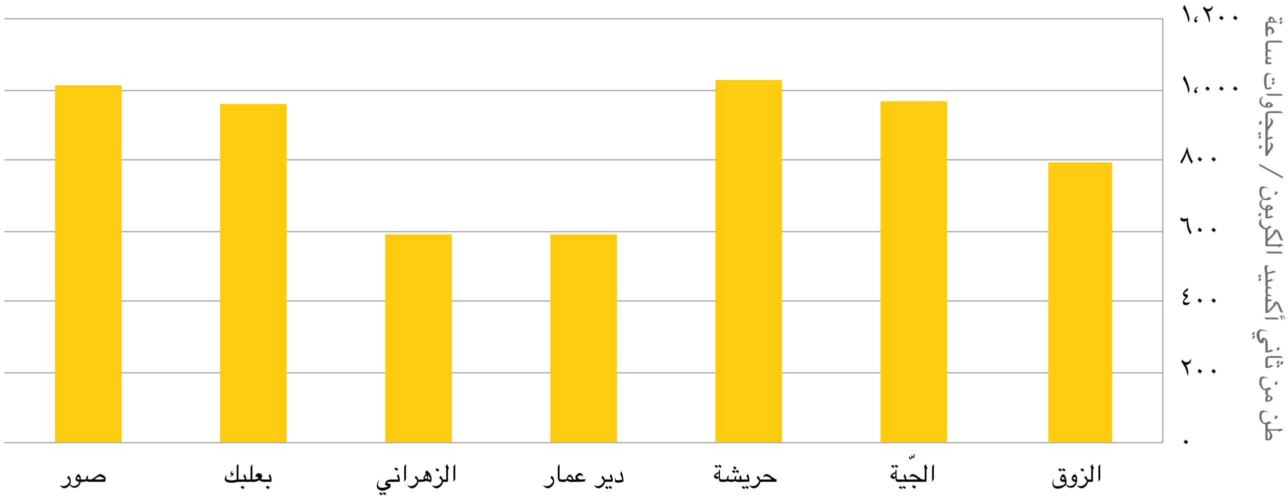
في العام ٢٠١١، بلغ مجموع انبعاثات الغازات الدفيئة من قطاع الطاقة في لبنان ١٢،٤٧١ جيغاغرام من ثاني أكسيد الكربون (١٢,٤ مليون طن). أما مصادر انبعاثات الغازات الدفيئة من الطاقة ومساهمتها فكانت: انبعاثات ثاني أكسيد الكربون ٩٩,٦٣٪، أكسيد النيتروجين ٠,٢٥٪ وانبعاثات الميثان ٠,١٢ ٪ (الشكل أ).



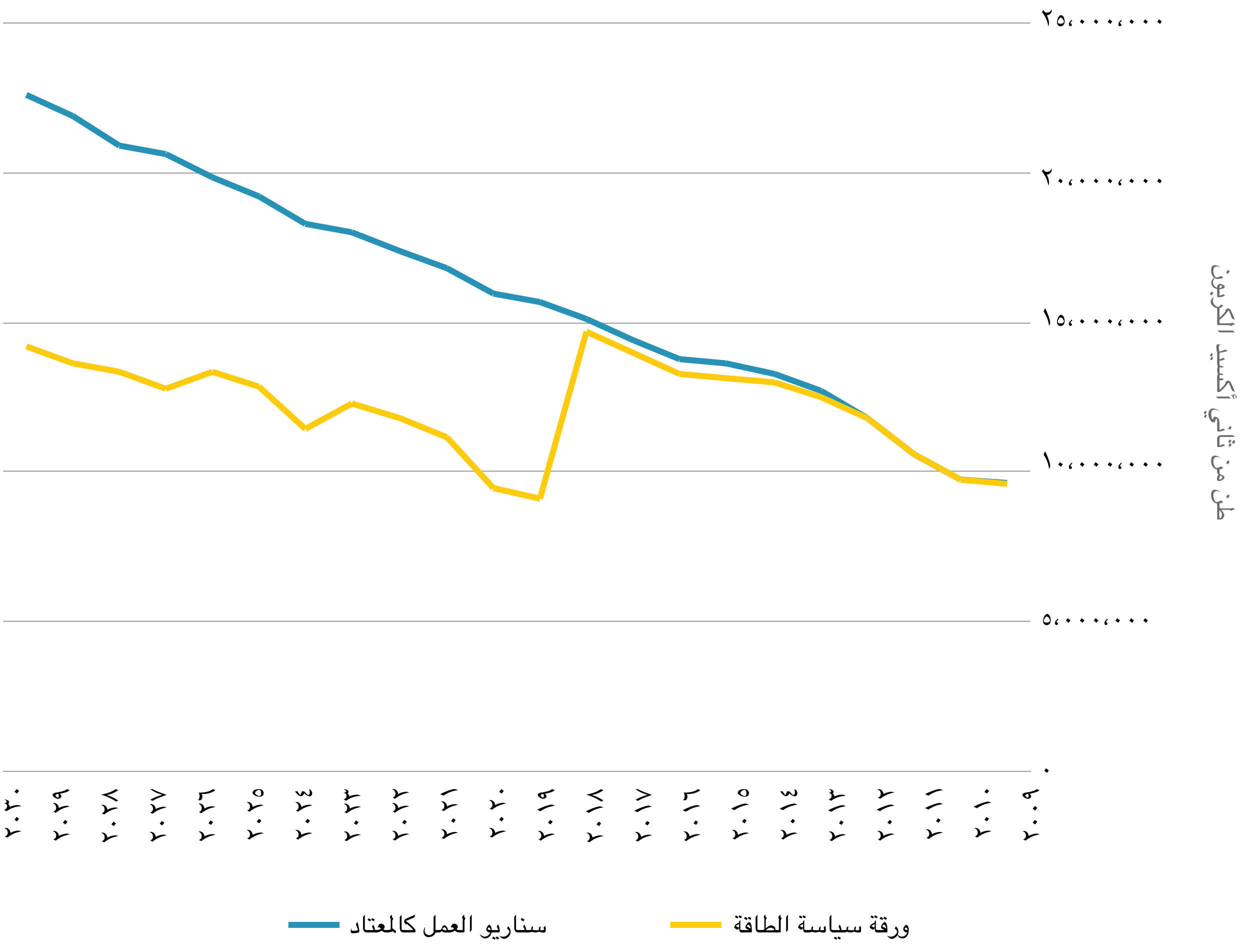
الشكل أ: مصادر انبعاثات الغازات الدفيئة من قطاع الطاقة في لبنان (٢٠١١)

شكّلت الانبعاثات الناتجة من توليد الكهرباء من المحطات الحرارية التابعة لكهرباء لبنان ٦٣٪ من إجمالي انبعاثات قطاع الطاقة فيما كانت الانبعاثات الناتجة عن انتاج واستهلاك الطاقة من القطاع الصناعي تشكل ٢٢٪ ومن القطاع التجاري ١٠٪ من إجمالي انبعاثات قطاع الطاقة. فإن توليد الكهرباء هو أكبر مساهم في انبعاثات القطاع حيث أن أكثر من ٨٨٪ من الفيول أويل و ٥٣٪ من الديزل يستخدم في المحطات الحرارية لتوليد الكهرباء.

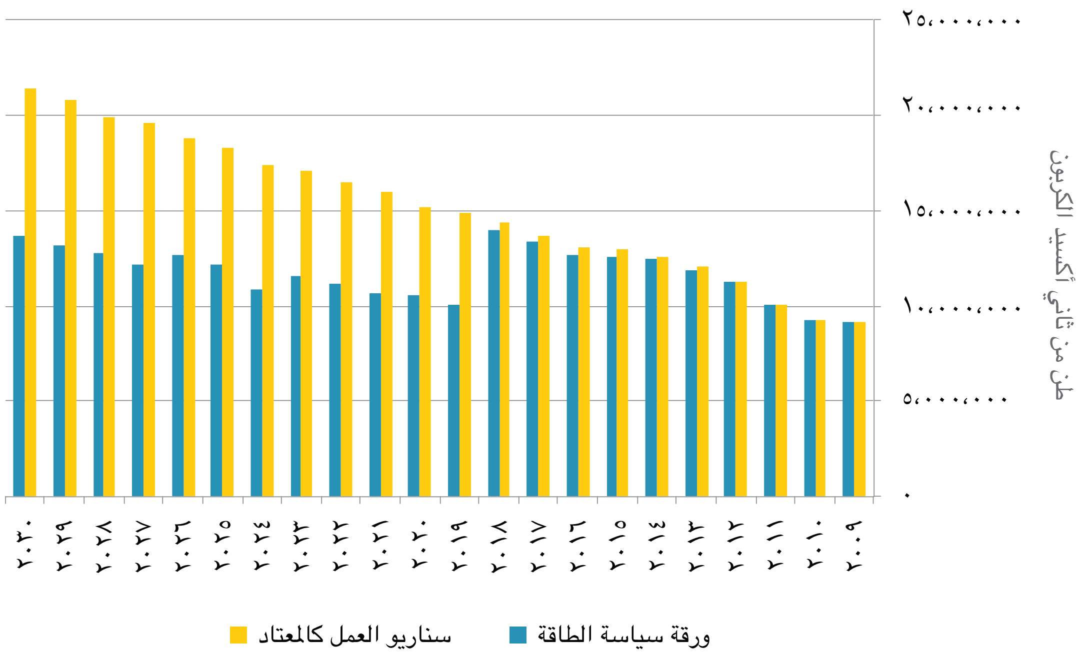
وتشير النتائج إلى أن معامل الزهراني ودير عمار والزوق تشكل اكبر نسبة انبعاثات غازات الدفيئة، حيث انها تعتبر أكبر محطات توليد الكهرباء في لبنان، كما تشير الى أن معملي الهريشة وصور هما الاكثر تلويثاً للبيئة حيث انهما يتميزان بكفاءة تشغيل منخفضة حيث انه ينبعث منهما حوالي ١،٠٠٠ طن من ثاني أكسيد الكربون لكل جيجاوات ساعة من الكهرباء المنتجة.



الشكل ج: انخفاض في انبعاثات الغازات الدفيئة من جراء تنفيذ ورقة سياسة الطاقة



الشكل د: انبعاثات الغازات الدفيئة من جراء تنفيذ ورقة سياسة الطاقة بالمقارنة مع سيناريو العمل كالمعتاد



الشكل ب: انبعاثات الغازات الدفيئة من انتاج الكهرباء في كل من المعامل الحرارية

في عام ٢٠١١، انتاج الكهرباء من المولدات الخاصة تسبب بانبعاث ٢،٣٧٠ مليون طن من ثاني أكسيد الكربون، وهو يشكل ١٩٪ من إجمالي انبعاثات غازات الدفيئة من قطاع الطاقة. ويشار على أنه توليد الكهرباء من المولدات الخاصة يسبب انبعاثات بنسبة أقل مقارنة بتوليد الكهرباء من المعامل الحرارية. في حين تنبعث من المحطات الحرارية ٨٤٧ طن من ثاني أكسيد الكربون عن كل جيجا واط ساعة، تنبعث من المولدات الخاصة فقط ٧١٣ طن من ثاني أكسيد الكربون.

تخفيف الانبعاثات

وتهدف العديد من المشاريع في لبنان إلى زيادة انتاج الطاقة وتقليص انبعاثات الغازات الدفيئة. وتنفذ هذه المشاريع من قبل وزارة الطاقة والمياه، المركز اللبناني لحفظ الطاقة، مشروع CEDRO وجهات خاصة. قد ساهمت هذه المشاريع في تخفيض نحو ٢٦٢،٧١٢ طن من ثاني أكسيد الكربون وإذا استمرت هذه الأنشطة، من المتوقع أن تساهم في تخفيض ١١٩،١٨٤ طن من ثاني أكسيد الكربون سنوياً.

من أجل مواصلة خفض الانبعاثات الناتجة عن قطاع الطاقة، يتم اقتراح سيناريو يشمل التنفيذ الكامل لورقة سياسة قطاع الكهرباء في لبنان (٢٠١٠) لدى وزارة الطاقة والمياه، المحدثة في ٢٠١٤. وقد يبني السيناريو على إعادة تأهيل وتحسين المعامل الحرارية القائمة، وتنفيذ استثمارات كبيرة لزيادة انتاج الكهرباء وتلبية الطلب بحلول عام ٢٠١٨. انتاج الكهرباء من خلال المولدات الخاصة وشراء الكهرباء من سوريا ومصر ينخفض تدريجيا ويصبح والغاز الطبيعي متاح للاستعمال في نهاية عام ٢٠١٨.

سوف يساهم تنفيذ ورقة سياسة الطاقة(PP٢٠١٠) بتخفيض ٨٣ مليون طن من ثاني أكسيد الكربون في الفترة الممتدة من ٢٠٠٩ الى ٢٠٣٠، أي ٣،٨ مليون طن سنويا بالمقارنة مع سيناريو العمل كالمعتاد(BAU) . من الملحوظ أن ٣٨٪ في تخفيض الانبعاثات تقع ابتداء من ٢٠١٩، وذلك من جراء تحويل معظم محطات توليد الكهرباء من الفيول اويل إلى الغاز الطبيعي كما يلحظ أن انتاج الكهرباء من خلال منتجين مستقلين يساهم في زيادة الحد من انبعاثات ثاني أكسيد الكربون في ٢٠٢٤، ٢٠٢٧ و ٢٠٢٩.

Part 1: Inventory

1. Scope

As a Party to the United Nations Framework Convention on Climate Change (UNFCCC), Lebanon is recommended to report its emissions on a periodic basis, according to decisions 17/CP.8, 2/CP.17 and articles 4 and 12 of the Convention. According to the Second National Communication (MoE/UNDP/GEF, 2011), the energy sector is the main contributor of Greenhouse Gas (GHG) emissions in Lebanon, with a share of 54% of national emissions in the year 2000.

This report presents the inventory of the greenhouse emissions of the energy sector in Lebanon for the year 2011 with a trend analysis of the sector's emissions for the period 2000-2011. It includes direct greenhouse gases i.e. carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) as well as indirect GHGs such as nitrogen oxide (NO_x), carbon monoxide (CO), Non-Methane Volatile Organic Compounds (NMVOCs) and sulphur dioxide (SO_2).

2. National circumstances

The Lebanese electricity sector is run by the Electricité du Liban (EDL), an autonomous state-owned (and therefore, a public monopoly) power utility that generates, transmits, and distributes electricity to all Lebanese territories. In 2011, most of the electricity was generated through 7 major thermal power plants and 3.5–4.5% through hydropower plants. When circumstances permit, direct power was purchased from Syria and Egypt (around 7 to 11%).

Almost all of Lebanon's primary energy requirements are imported, since the country does not have any indigenous energy sources with the exception of a small share of hydropower. Out of the 7 thermal power plants in Lebanon, 3 operate on Heavy Fuel Oil (HFO) and 4 on gas diesel oil. The Deir Aamar and Zahrani power plants use the Combined Cycle Gas Turbines (CCGT) and can therefore operate on Natural Gas (NG) once available. Currently, there is no supply of natural gas to Lebanon although a gas pipeline has been connected and a natural gas station has been constructed at the Tripoli installations. Natural gas was only imported for one year during 2010. Recent studies and surveys conducted in the deep offshore Exclusive Economic Zones (EEZ) have shown very promising seismic conditions for hydrocarbon deposits, mainly natural gas with some oil. As a result of that, Lebanon had already started the development phase for the exploration and production era which is expected to have a positive economic impact on the country.

Thermal generation

Although available capacity reached 2,670 MW (Megawatts), actual availability of electricity has varied from as low as 1,500 MW to a maximum of 2,000 MW due to several shortcomings. In the case of the thermal plants, these include plant failures and rehabilitation work, fuel supply and interruption of imported electricity from both Syria and Egypt. In the case of hydropower, rainfall variations, and subsequently water levels variations as well (Kabakian et al., 2015). In addition, the transmission and distribution networks face 3 types of problems: technical losses in the range of 15%, non-technical losses (e.g., theft) amounting to 20% and uncollected bills in the range of 5%.

Thermal capacity is divided into heavy fuel oil-fired steam-turbines at Zouk, Jiyeh and Hrayche, and diesel-fired CCGT at Beddawi and Zahrani and diesel-fired Open Cycle Gas Turbine (OCGT) at Tyre and Baalbeck. The energy produced from these plants is on average 92% of the total production.

Zouk is considered Lebanon's largest thermal power plant, and is located in a highly populated residential area. Its low efficiency (30% below design value) has caused the plant to be a significant environmental and economic issue in the last several years.

Jiyeh is the oldest operating thermal plant also characterized by a high difference of fuel efficiencies compared to the design value (35%). Similarly, the deviation has caused several economic and environmental problems.

Both Zouk and Jiyeh have already reached the end of their design life time and have no emissions abatement technology installed. In addition, both plants suffer from old combustion systems and poor firing operating conditions thereby further increasing their environmental impact in terms of emissions. It is anticipated that such thermal conventional plants may even manage to stay running for 5 additional years, in cases where the plants are well maintained and overhauls are conducted on time. As provided in the policy paper, the life of both Zouk and Jiyeh plants could, through a substantial rehabilitation program, be prolonged by about ten more years.

Zahrani and Deir Aamar, the two most recently constructed power plants are combined cycle gas turbines. The decision to commission these plants was based on an agreement to import pipelined natural gas from Syria in the mid-1990s. These plants make up about half of Lebanon's generation capacity and are estimated to be in a relatively good condition compared to other thermal plants. The operation and maintenance of these plants are outsourced through contracts. The concern is that they are not operating under optimal conditions as they are firing Diesel Oil (DO). The agreement initially provided for sufficient NG to supply both plants (around 1.5 Billion Cubic Meters (BCM) per year at 80% load factor). However, only small quantities of natural gas were received and were enough to fire only one gas turbine at Deir Aamar at a load factor at 80%. But since the end of 2010, natural gas has stopped being available. The Zahrani power plant had never been connected to the NG pipeline.

Hrayche unit 5 was part of a larger plant that existed in the past and was owned by Kadisha Company which is now a subsidiary of EDL. Hrayche thermal power plant unit 5 consists of an HFO boiler steam power plant in operation since 1982 and designed for a power output of 75 MW. Currently, unit 5 has reached its economic lifetime and shows relatively low performances due to a lack of spare-parts and maintenance.

Private and self-generation

In 2009, the average capacity and imports were 1,500 MW while the average demand was 2,100 MW with an instantaneous peak of 2,450 MW in the summer. The total energy demand was 15,000 GWh (Gigawatt hour) whereas the total production and purchases were 11,522 GWh resulting in energy not supplied (deficit) of 3,478 GWh (23%). The supply of energy averaged 21.22 hours for Greater Beirut Area (GBA) and 15.79 hours for the South with an average of 18 hours (75%) for the whole country.

The energy not supplied by public utilities is being supplied by privately owned generators, providing an estimated 33% of total electricity demand (World Bank, 2009). This share has reached 37% in 2012 (Kabakian et al., 2015). Most commonly, individual or community-based back-up generators are used, kicking-in when EDL's supply is unable to meet demand. Parallel distribution lines are routed using the existing infrastructure of EDL connecting homes to a centralized set of diesel generators. With time, back-up generation has evolved to become a business based on service providers. It was reported that the private generation tariff had exceeded in many cases 45 US¢/kWh compared to the average utility tariff of 9 US¢/kWh. In essence, most consumers retain a connection both to EDL and to an alternative supply point. According to the policy paper, the self-generation bill had exceeded USD 1.7 billion in 2010 and the value is subject to increase if the load utilization factor of the backup generation keeps increasing whilst the utility utilization factor decreases.

Losses to the national economy

The failure of the Government of Lebanon (GoL) to reform the electricity sector is causing an annual deficit of USD 1.5 billion on the public purse and losses on the national economy estimated at not less than USD 2.5 billion per year. This crisis is caused by the lack of worthy investments, high fuel bill (62-75%), the operating status of power plants (half of which are old and inefficient and the other half uneconomical), high technical and commercial losses in transmission and distribution, improper tariff structure and low average tariff, deteriorating financial, administrative, technical and human resources of EDL.

Topping this, the presence of convoluted legal and organizational frameworks exacerbate the exiting deteriorating situation. The legal framework for privatization, liberalization and unbundling of the sector (law 462) exists but is not applied. In parallel, the law implemented by decree 16878/1964 and 4517/1972 which gives EDL exclusive authority in the generation, transmission, and distribution areas is still being applied.

The cost of energy not supplied (Value of Lost Load (VOLL)) has been estimated by Electricité De France and the World Bank in the Public Expenditure Review (PER) to vary between 200 and 2,000 USD/MWh. An average value of USD 700 per MWh not supplied (which includes the cost of private generation) has been used to show losses of USD 2.5 billion in 2009 for the Lebanese economy, which is divided between USD 1.3 billion for private generation and USD 1.2 billion for direct consumer losses.

As for the tariff, the energy policy paper calls for a gradual increase until EDL's fiscal budget is balanced. This is integrated with the improvement in electric service hence eliminating the need for private generators which results in featuring a lower net cost on the consumers. According to the policy, this is achieved through abolishing the financial burden resulting from the high cost of unregulated diesel generators. The policy also calls for the implementation of a modern tariff structure through the adoption of special tariffs and fees for low income consumers and productive sectors and through the implementation of a time of use tariffs in conjunction with the implementation of smart meters.

Renewable energy

Given the current condition of electricity supply in Lebanon, the share of renewable energy is slowly but steadily increasing. In the 2009 Copenhagen Climate Summit, the GoL made a voluntary commitment to develop renewable energy production capacity to reach 12% of the total electricity supply by 2020. That commitment was reaffirmed by the government through introducing this target as a major milestone in the policy paper for the electricity sector in 2010.

Various initiatives have been put in place by the government of Lebanon in order to increase the share of renewable energy, and meet the 12% target by 2020. Currently, the major contributor to the renewable energy mix in the country is hydro power, producing around 4.5% of the country's total energy production. However, Lebanon has a significant wind potential, especially in the North with wind speeds of 7-8 m/sec and an abundant solar resource with an average annual insolation of 1,800–2,000 kWh/m^2. The CEDRO wind atlas results showed an "extremely optimistic" potential of 6,200 MW and a more "realistic" one of 1,500 MW. Due to some constraints related to the electricity grid, land ownership and others, it is believed that the "most realistic" target for wind energy in Lebanon by 2020 is 400 MW (El-Khoury, 2012). Currently, the Ministry of Energy and Water is in the final stages of the evaluation of a 50-100 MW wind farm project tender, which will subsequently be submitted to the Council of Ministers (CoM) for approval.

Solar water heating is well established in the country. Although technologies for solar power generation are becoming cheaper and more competitive, they are still relatively expensive and are currently only used at the micro level and for specific applications like street lighting, water heating and other municipal use. Lebanon has embarked on a national initiative to develop the solar water heating market and to install 1,050,000 m^2 of solar systems by 2020 (El-Khoury, 2012).

As for other renewable energy technologies, the Ministry of Energy and Water is also developing the small, decentralized, grid-connected renewable energy power generation market in Lebanon through a UNDP/GEF project. The target is to facilitate the installation of at least 1.75 MW of new decentralized renewable energy and to pave the way for larger renewable energy power plants (UNDP, 2015).

3. Greenhouse gas emissions inventory of the energy sector

3.1. Methodology

The calculation of greenhouse gas emissions is based on the Revised 1996 Intergovernmental Panel on Climate Change (IPCC) Guidelines for the Preparation of National Greenhouse Gas Inventory (IPCC, 1997) and the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000). According to these guidelines, the source category "Energy" covers all combustion sources of CO_2, CH_4 and N_2O emissions and fugitive emissions associated with the production, transport and distribution of fossil fuels.

Fuel combustion activities are further divided in two main categories, on the basis of the characteristics of the methodology applied for the calculation of emissions:

- Stationary combustion, including energy industries, manufacturing industries and construction and other sectors (agriculture, residential, commercial/institutional and agriculture/forestry/fisheries).

- Transport, including domestic civil aviation, road transport, and domestic navigation.

In this report, only emissions from stationary combustion are presented. Emissions from fuel combustion in the transport sector are published in a separate report[1] (MoE/UNDP/GEF, 2015a).

Table 1: Energy sector - stationary combustion subcategories

Energy industries sector comprises emissions from fuel combustion for electricity generation from main electricity producers, mainly public entities. In Lebanon, this category includes all thermal power plants of Electricité du Liban.
Manufacturing industries and construction sector comprises emissions from combustion of fuels for electricity or heat generation for own use in industries. In Lebanon, emissions from community-based generators are accounted under this category.
Commercial/institutional sectors comprises emissions from fuel combustion for electricity generation, space heating and cooking activities in commercial and institutional buildings.
Residential sector comprises emissions from fuel combustion for space heating and cooking activities.
Agriculture/forestry/fisheries sector comprises both stationary and mobile emissions from fuel combustion in agriculture, forestry and fishing. Related activities include fish farms, water pumps, grain drying, agricultural greenhouses, traction vehicles on farm land and in forest in addition to inland, coastal and deep sea fishing.

Use of the sectoral approach and the reference approach

According to the IPCC guidelines, carbon dioxide emissions from the energy sector are calculated using both the reference and the sectoral approach.

The reference approach is a top-down approach using a country's energy supply data (fuel import) to calculate the emissions of CO_2 from combustion of fossil fuels. The reference approach is a straightforward method that can be applied on the basis of relatively easily available energy supply statistics, leading to the calculation of apparent fuel consumption and consequently CO_2 emissions.

[1] Available on http://climatechange.moe.gov.lb

The sectoral approach is a bottom-up method, using detailed information on the fuel consumption in each distinct sub-sector (power and thermal energy production, processing and construction industry, different ways of transport, institutional and residential sectors, etc.). It is a more complicated approach, relying heavily on statistical sectoral data.

The application of the reference approach can be considered as a quality control procedure, as the deviation of estimations between the 2 approaches should not be significant. In Lebanon, calculation using both approaches shows a difference of less than 2% which is within the acceptable range of error.

3.2. Emission factors and other parameters

Due to the lack of country specific emission factors and emissions measurements, tier 1 methodologies are adopted for the calculation of all GHG emissions from stationary combustion. CO_2, CH_4 and N_2O emission factors and other parameters used in the calculation are based on default values of the Revised 1996 IPCC Guidelines and the IPCC Good Practice Guidance. CH_4 and N_2O emission factors are differentiated by technology and fuel, while CO_2 emission factors are differentiated only by fuel.

Information on the net calorific value per imported fuel for Lebanon is mainly provided by the Ministry of Energy and Water.

Table 2: Carbon content, net calorific value and other parameters by fuel type

Fuel type	Net calorific value (TJ[2]/ktonnes)	Carbon content (tonnes C/TJ)	Oxidation factor (%)	Fraction of carbon stored[3]
Gasoline	44.8	18.9	0.99	0
Jet kerosene	44.59	19.5	0.99	0
Kerosene	44.75	19.6	0.99	0
Diesel oil	43.33	20.2	0.99	0
Heavy fuel oil	40.19	21.1	0.99	0
Liquefied petroleum gas	47.31	17.2	0.99	0
Lubricants	40.19	20	0.99	0.5
Bitumen	40.19	22	0.99	1
Petroleum coke	31	27.5	0.99	0
Natural gas	48	15.3	0.995	0
Biomass	15	29.9	0.98	0

[2] TJ = Terajoule

[3] Assumption is made that no carbon is stored, except for bitumen and 50% of lubricants, as per the IPCC default values.

Table 3: CH_4 and N_2O emission factors

		CH_4 emission factor (kg/TJ)			N_2O emission factor (kg/TJ)		
		Natural gas	Oil	Biomass	Natural gas	Oil	Biomass
Energy industries		1	3		0.1	0.6	
Manufacturing industries and construction			2			0.6	
Transport	Gasoline		20			0.6	
	Diesel		5			0.6	
Commercial/institutional			10	300		0.6	4
Residential			10	300		0.6	4
Agriculture/forestry/fisheries			10	300		0.6	4

3.3. Activity data - stationary combustion

The main reference for the calculation of GHG emissions from the energy sector was the data on fuel import reported by the Ministry of Energy and Water. As per MoEW records, the data of gas diesel oil and heavy fuel oil is divided between public use (i.e. for power plants operated by EDL) and private use, without further disaggregation indicating the amounts of fuel used by industries, by private generators, by the residential or commercial sector or in transport. Therefore, different initiatives were undertaken by the Ministry of Environment and United Nations Development Programme (UNDP) to collect information on the specific fuel consumption of the different subcategories in the energy sector (Table 4, Table 5 and Table 6).

Table 4: Methodology of data collection

Subcategory	Data collection
Energy industries	Official contact was established with the Ministry of Energy and Water, data on energy production and fuel combustion in every EDL thermal power plants was collected and used for this inventory.
All subcategories	In collaboration with IPT, one of the main fuel importers and distributers in Lebanon, a categorization of fuel consumption per end-use was preformed based on the sale of fuel from IPT stations to private entities. Although the survey was conducted over one year (2013), it is assumed that the percent distribution remains constant across the years.
Manufacturing industries and construction	In collaboration with the Ministry of Industry, a survey of 180 major industries in Lebanon was undertaken by the climate change project at the Ministry of Environment to estimate fuel consumption on a disaggregated level and by industry type. The survey sample covered the largest industries in terms of production from each International Standard Industrial Classification (ISIC) category. The collected data was checked and supplemented by information provided by IPT.
Commercial and institutional sectors	A survey of 868 establishments covering different sub-sectors (schools, hospitals, commercial centers, retail shops, hotels, etc.) and all geographical areas was undertaken by the climate change unit at the Ministry of Environment to collect data related to fuel consumption for different institutions. Data was then extrapolated following statistically reliable and representative methods.

Table 5: Description of fuel used in Lebanon

Fuel type	Description	End-use
Gasoline	It is a light hydrocarbon oil for use in internal combustion engines such as motor vehicles and in aviation turbine power units.	- Road transport - Air transport
Jet kerosene	It is a medium distillate used for aviation turbine power units with particular specifications established by the International Air Transport Association (IATA).	- Air transport
Gas diesel oil	Several grades of gas diesel oil are available depending on uses: diesel oil for diesel compression ignition (cars, trucks, marine, etc.) and light heating oil for industrial and commercial uses.	- Road transport - Marine transport - Electricity production in thermal power plants and private generators - Space heating in residential, commercial and institutional sectors
Heavy fuel oil[4]	It comprises a family of oils that make up the distillation residue, including those obtained by blending.	- Electricity production in thermal power plants - Energy production in some manufacturing industries - International navigation
Liquefied petroleum gas	This is the light hydrocarbon fraction of the paraffin series, derived from refinery processes, crude oil stabilization plants and natural gas processing plants. They are normally liquefied under pressure for transportation and storage.	- Cooking in residential, commercial and institutional sectors - Energy production in some manufacturing industries
Bitumen	Solid, semi-solid or viscous hydrocarbon, being brown to black in color, often referred to as asphalt.	- Road paving and asphalt roofing[5]
Lubricant	It is a hydrocarbon produced from distillate or residue; they are mainly used to reduce friction between bearing surfaces.	- Maintenance of machinery and equipment
Petroleum coke	It is defined as a black solid residue, obtained mainly by cracking and carbonizing of petroleum derived feedstock, vacuum bottoms, tar and pitches.	- Energy production in cement industries
Natural gas	It includes blended natural gas with other gases derived from other primary products.	- Electricity production in thermal power plants

[4] Also referred to as residual fuel oil

[5] Emissions of bitumen use are not reported under the energy sector inventory but under the industrial sector. A separate report is available on http://climatechange.moe.gov.lb

Table 6: Quantities of fuel imported for the period 2005-2011

Fuel type (1,000 tonnes)	2005	2006	2007	2008	2009	2010	2011
Gasoline	1,273.10	1,224.61	1,306.82	1,401.17	1,617.67	1,594.94	1,598.42
Jet kerosene	145.52	103.36	139.73	166.69	174.57	220.95	223.88
Gas diesel oil	1,587.67	1,596.28	1,363.19	1,802.74	2,595.36	2,252.01	2,448.07
Heavy fuel oil	1,360.18	1,039.72	1,258.70	1,213.52	1,422.46	1,356.08	1,347.36
Liquefied petroleum gas	154.83	161.12	180.67	163.18	199.14	163.57	196.67
Bitumen	59.88	43.86	72.78	73.92	88.30	105.06	59.19
Lubricants	33.91	29.86	34.34	34.34	34.34	36.90	35.24
Petroleum coke	249.47	477.86	114.20	306.70	357.60	151.70	335.60
Natural gas					35	186	-

Source | MoEW, 2014

Based on the results of the surveys conducted (please refer to Table 4), Table 7 and Figures 1, 2 and 3 present the fuel distribution percentages adopted for the preparation of this inventory.

Table 7: Distribution of fuel consumption by end-use

Fuel type	Consumption
Gas Diesel Oil (GDO)	
Energy industries (EDL)	Fluctuating annual amount, depending on production need
Road transport	14% of total GDO import
Private generation	80% of energy not supplied
Manufacturing industries and construction	49% of private generation
Commercial and institutional sectors	51% of private generation
Residential sector	52% of remaining GDO
Agriculture/forestry/fisheries	48% of remaining GDO
Heavy Fuel Oil (HFO)	
Energy industries (EDL)	Fluctuating annual amount, depending on production need
International navigation	Fluctuating annual amount, depending on need
Manufacturing industries and construction	Remaining amount of fuel oil
Liquefied Petroleum Gas (LPG)	
Residential sector	72% of total import
Manufacturing industries and construction	13% of total import
Commercial and institutional sectors	15% of total import
Gasoline	
Domestic aviation	Fluctuating annual amount, depending on need
Road transport	Remaining amount of gasoline
Jet kerosene	
International aviation	100% of total import
Petroleum coke	
Cement industries	100% of total import
Natural gas	
Energy industries (EDL)	100% of total import
Lubricants	
Energy industries (EDL)	100% of total import

Source | MoEW, 2014 and IPTEC, 2014

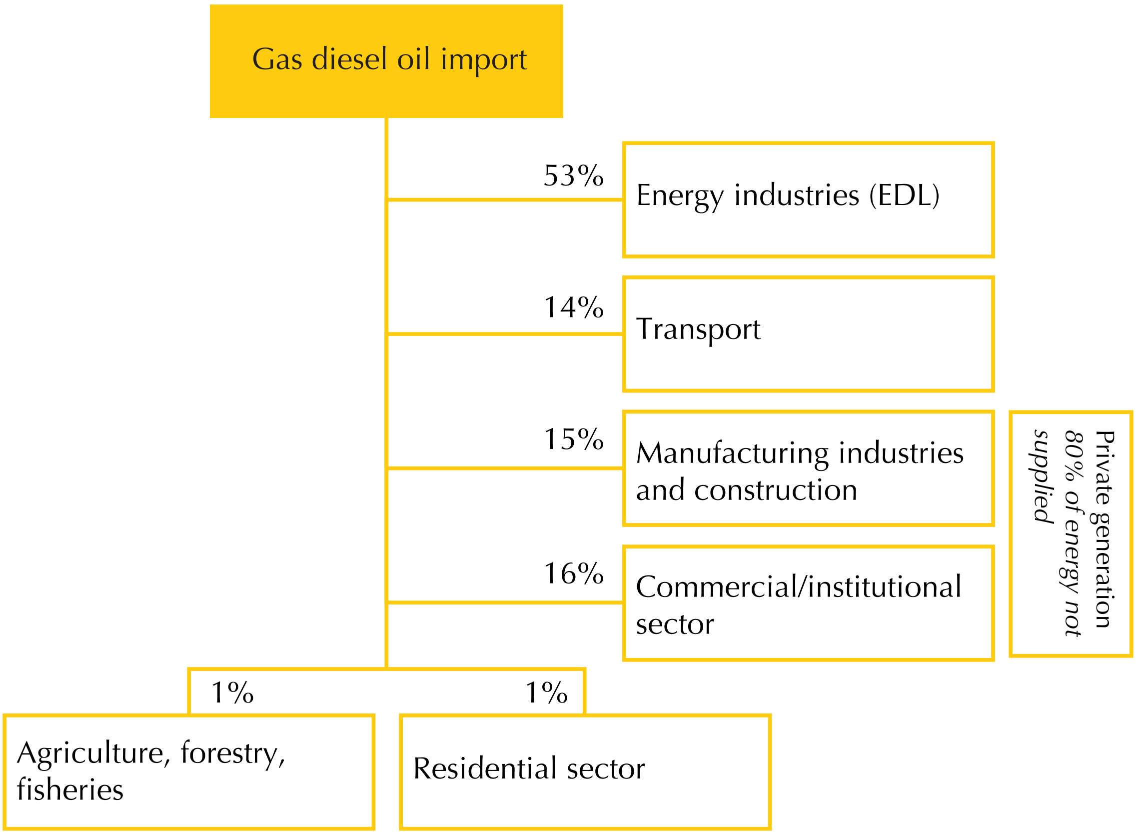


Figure 1: Distribution of gas diesel oil by end-use category (2011)

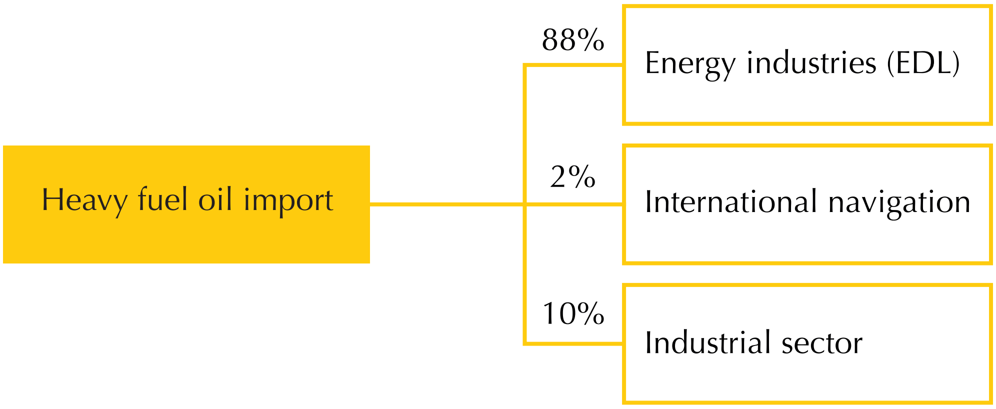


Figure 2: Distribution of heavy fuel oil by end-use category (2011)

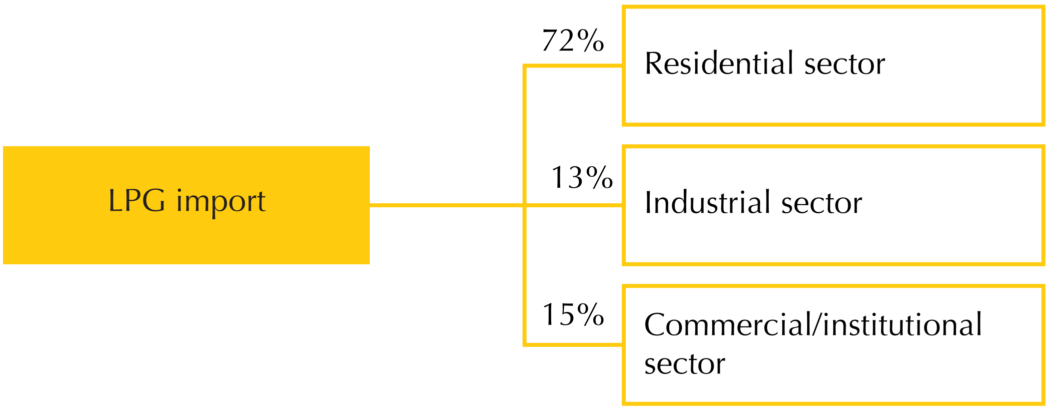


Figure 3: Distribution of LPG by end-use category (2011)

3.3.1. Energy industries - public electricity and heat production

The fuel consumption used under the energy industries category for the estimation of GHG emissions is presented in Table 8. Data for fuel consumption for electricity production is obtained from the Ministry of Energy and Water, which is maintaining consumption data of fuel oil and gas diesel oil for each installation. Limited amounts of natural gas were imported and used in Lebanon in 2009 and 2010.

Lubricants are used in thermal power plants to grease and maintain equipment and machinery. It is assumed that all imported lubricants are used under the energy industries category since only an insignificant undetermined amount is used in manufacturing industries and transport.

Table 8: Activity data for fuel consumption in energy industries

Fuel type	Quantity (1,000 tonnes)		
	2009	2010	2011
Heavy fuel oil	1,132.72	994.29	1,305.67
Gas diesel oil	1,227.69	1,283.36	1,186.78
Natural gas	34.92	186.32	-
Lubricants	34.34	36.90	35.24

Source | MoEW, 2014

3.3.2. Manufacturing industries and construction

This category includes GHG emissions from fuel consumption in the 2 following activities:

1- Production of electricity, steam and process heat by industries: the industrial sector is one of the major sectors consuming energy. However, due to the intermittent electricity supplied by EDL and the constant power shortages, most industries in Lebanon generate their own energy from in-house generators. Gas diesel oil and fuel oil are bought either directly from the Ministry of Energy and Water or from private fuel distributors and are used in the premises. Unfortunately no data is recorded on these quantities. Petroleum coke is consumed only in cement industries and imported quantities are delivered directly to the industries' locations after receiving approval from the Ministry of Environment.

2- Private generation: due to the frequent power shortages of EDL, community-based back-up generators have flourished in Lebanon, supplying electricity to households during cut-off hours (which range from 3 to 15 hours a day depending on the region). All these generators work on gas diesel oil which is bought either directly from private fuel distributors or from gas stations. Unfortunately, no data is available on the number, capacity or quantity of fuel used for private generators in the country. It is assumed that the gap between public electricity supply and demand in Lebanon is being met at 80% by community-based generators and commercial institutions' generators.

Table 9 presents the quantities of fuel used in manufacturing industries and construction from 2009 to 2011, based on the following assumptions:

- The gas diesel oil consumed for private generation is divided more or less equally between community-based generators and privately owned generators by commercial institutions (49% and 51% respectively). It is assumed that 1 liter of diesel oil generates 3.65 kWh.

- The heavy fuel oil used in manufacturing industries is estimated to be the difference between the total fuel oil imported to Lebanon minus the amount consumed by public utilities and the amount consumed for international navigation.

- The LPG used in this sector is estimated at 13% of the total LPG import to Lebanon.

Table 9: Activity data for fuel consumption in manufacturing industries and construction

Fuel type	Quantity (1,000 tonnes)		
	2009	2010	2011
Gas diesel oil	302.70	304.31	361.89
Heavy fuel oil	170.77	46.72	133.59
LPG	25.89	21.26	25.57
Petroleum coke	357.60	151.70	335.60

Source | MoEW, 2014

3.3.3. Transport

GHG emissions from road, air and marine transport are presented in a different report published by the Ministry of Environment (MoE/GEF/UNDP, 2015a).

3.3.4. Other sectors

This category includes the GHG emissions caused by fuel combustion in the commercial/ institutional sectors (hotels, schools, universities, retail shops, commercial centers, etc.), residential sector and agriculture/forestry/fisheries. Different types of fuel are considered under this category and are mainly used for electricity generation, cooking, heating, fishing and in other mobile equipment.

Burning of wood for heat generation is under the residential sector's category. However, only CH_4 and N_2O emissions from burning of biomass are reported in the inventory. According to the IPCC guidelines, CO_2 emissions are not included in the national total in a country's emission inventory but are reported as memo items in the reporting tables (IPCC, 1997).

Since no activity data is available on a disaggregated basis to allocate energy use to each subcategory, specific assumptions are made as presented in Table 10, Table 11and Table 12.

Table 10: Activity data for fuel consumption in the commercial and institutional sectors

Commercial/institutional sectors					
Fuel type	**Quantity (1,000 tonnes)**			**End-use**	**Assumptions**
	2009	**2010**	**2011**		
Gas diesel oil	317.65	319.34	379.76	- Electricity generation - Space heating - Water heating	51% of the fuel used for private generation is consumed by the commercial/institutional sectors.
LPG	29.87	24.54	29.50	- Cooking - Space heating - Water heating	15% of the total LPG imported to Lebanon is used by the commercial/institutional sectors.

Source | MoEW, 2014

Table 11: Activity data for fuel consumption in the residential sector

Residential sector					
Fuel type	**Quantity (1,000 tonnes)**			**End-use**	**Assumptions**
	2009	**2010**	**2011**		
Gas diesel oil	247.79	164.94	30.02	- Space heating - Water heating	52% of the remaining quantity of GDO after consumption in energy industries, transport and private generation is used by the residential sector.
LPG	143.38	117.77	141.61	- Cooking - Space heating - Water heating	72% of the total LPG imported to Lebanon is used by the residential sector.

Note: gas diesel oil used for electricity generation in households has been accounted for under the category manufacturing industries and construction – private generation.

Source | MoEW, 2014

Table 12: Activity data for fuel consumption in agriculture/forestry/fisheries

Agriculture/forestry/fisheries					
Fuel type	**Quantity (1,000 tonnes)**			**End-use**	**Assumptions**
	2009	**2010**	**2011**		
Gas diesel oil	154	102	19	Mobile equipment	48% of the remaining quantity of GDO after consumption in energy industries, transport and private generation is used by agriculture/forestry/fisheries.
	77.61	51.66	9.40	Fishing boats	

Source | MoEW, 2014

3.3.5. Feedstock and non-energy use of fuels

Some of the imported fuels are used as raw materials for the production of other products. In chemical industry and metal production, or the use of fuels for non-energy purposes such as bitumen and lubricants (HS code used for Lebanon is HS 27.10.19.90). Since these fuels are not combusted, their carbon content is totally or partially stored in the product and is not oxidized into carbon dioxide for a certain period of time. The CO_2 released from the use or decomposition of the product is not reported under the energy sector's inventory but under the industrial sector's inventory (MoE/UNDP/GEF, 2015b).

The calculation of carbon dioxide emissions from non-energy use of fuels is based on the relevant consumption by fuel type and the fraction of the carbon stored by fuel type (50% for lubricants and 100% for bitumen).

3.4. Gaps and constraints identified by INC and SNC

Some gaps and needs for the calculation of GHG emissions from the energy sector were identified in the Initial National Communication (INC) and Second National Communication (SNC) as summarized in Table 13. They mainly consist of (1) the underdeveloped institutional arrangement for energy data monitoring and collection, (2) the unavailability of specific data and/or the inaccessibility of existing data for adopting tiers 2 and 3 methodologies, and (3) the use of default emission factors from IPCC guidelines instead of Lebanon fuel-specific emission factors. Some of these constraints were tackled in the preparation of this inventory, as part of the improvements introduced in the Third National Communication (TNC). However, many challenges still remain, mostly linked to data availability and institutional arrangements.

Table 13: Gaps and needs for the calculation of GHG emissions from the energy sector identified in the INC and SNC

		INC	SNC
Gaps	Underdeveloped data collection for the inventory	- Lack of institutional arrangement for data monitoring and reporting. - Absence of an energy balance. - Absence of disaggregation of fuel use per subcategory.	
	Unavailable and/or unshared specific data for tiers 2 and 3 calculations	Missing information on technological specifications of public power plants and private generators.	
	Use of IPCC default emissions factors	No fuel-specific emission factors elaborated for Lebanon.	
Needs	Enforce specific activity data collection for the preparation of the inventory	Create a national institutional arrangement for the preparation of the GHG inventory, empowering the Central Administration of Statistics (CAS), the relevant ministries and concerned public authorities to develop an energy balance and monitoring indicators of energy activity data.	
	Share of data	Standardize/centralize data reporting and develop protocols for data accessibility.	
	Develop Lebanon's fuel-specific emission factors and methodologies	- Conduct measurements campaigns in order to elaborate specific emission factors representative of the Lebanese used fuel. - Develop GHG emissions estimation models with local research institutes to create Lebanon-specific methodologies using advanced bottom-up approaches for inventory preparation.	

3.5. Results and discussion

The results of the GHG emissions from the energy sector include emissions from energy industries, manufacturing industries and construction, commercial/institutional sectors, residential sector and agriculture/forestry/fisheries for the year 2011 and present a trend analysis for the period 2000-2011. Although transport is considered to be a subcategory of the energy sector as per the Revised 1996 IPCC Guidelines, it is not reported in this publication. Due to the importance of the sector and its contribution to GHG emissions, the inventory of the transport sector has been published as a separate report (MoE/UNDP/GEF, 2015a[6]).

3.5.1. Energy sector GHG inventory for 2011

In 2011, the energy sector's GHG emissions were estimated at 12,471 Gg (Gigagram or 1,000 tonnes) CO_2eq. (12.4 million tonnes CO_2eq.), representing 51% of the total greenhouse gas emissions in Lebanon. Energy is mainly responsible for carbon dioxide emissions, while it also contributes to methane and nitrous oxide emissions and other air pollutants such as CO, NO_x and SO_2. In 2011, 99.63% of the emissions from the energy sector were CO_2, 0.12% CH_4 and 0.25% N_2O. The contribution of each source to the total of the sector is presented in Table 14 and Figure 4. The transport sector is not included in these calculations.

Table 14: GHG emissions from energy by source category and gas for 2011

Categories	Emissions			
	CO_2 (Gg)	CH_4 (Gg)	N_2O (Gg CO_2eq.)	Total* (Gg CO_2eq.)
Total energy	**12,425.76**	**14.66**	**30.96**	**12,471.38**
Energy industries	7,853.04	6.66	19.66	**7,879.36**
Manufacturing energy and construction	2,675.10	1.37	6.08	**2,682.55**
Other sectors	1,897.63	6.63	5.22	**1,909.48**
Commercial/institutional	1,293.72	3.75	3.32	**1,300.79**
Residential	513.67	2.62	1.67	**517.96**
Agriculture/forestry/fisheries	90.23	0.26	0.23	**90.72**

* For the calculation of the emissions in terms of CO_2eq., the Global Warming Potential (GWP) of CH_4 and N_2O were adopted from the IPCC Second Assessment Report (GWP CH_4=21 and GWP N_2O=310).
Numbers may reflect rounding.

[6] Available on http://climatechange.moe.gov.lb/

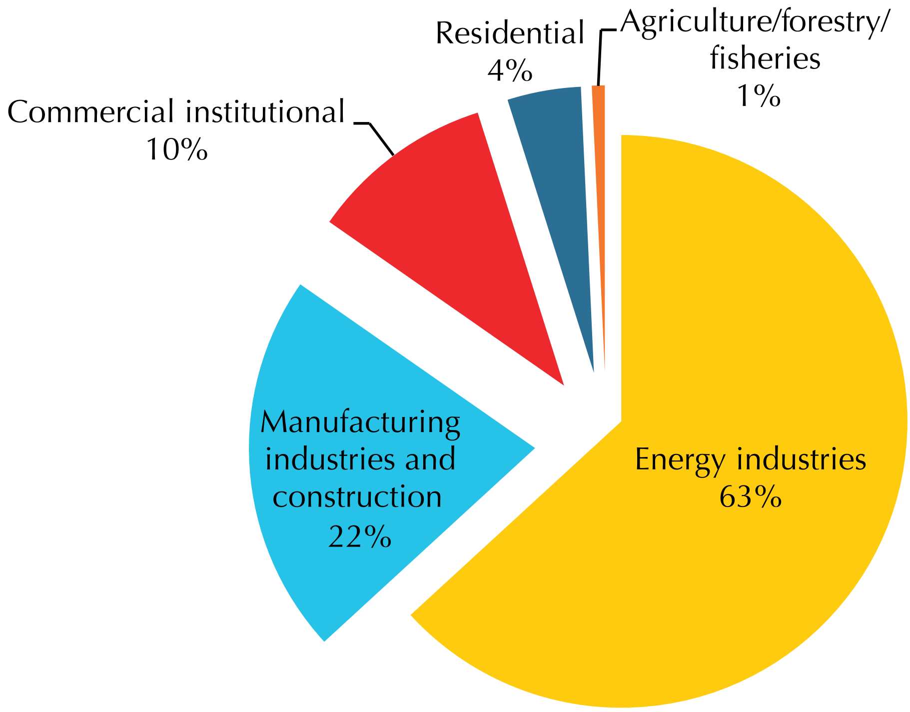


Figure 4: Contribution of energy emission sources to the sector's total for 2011

Energy industries

The energy sector relies on fossil fuel combustion for meeting the bulk of energy requirements in Lebanon. The final consumption in 2011 amounted to approximately 254,252 TJ. Since electricity generation from public power plants (energy industries) is the main fuel consumer; it is responsible for 63% of the sector's emissions followed by manufacturing industries (22%) as illustrated in Figure 4.

Indeed, public electricity generation is the largest contributor to the sector's emission due to the fact that more than 88% of imported fuel oil and 53% of imported gas diesel oil are used in thermal power plants for public electricity generation (Figure 5).

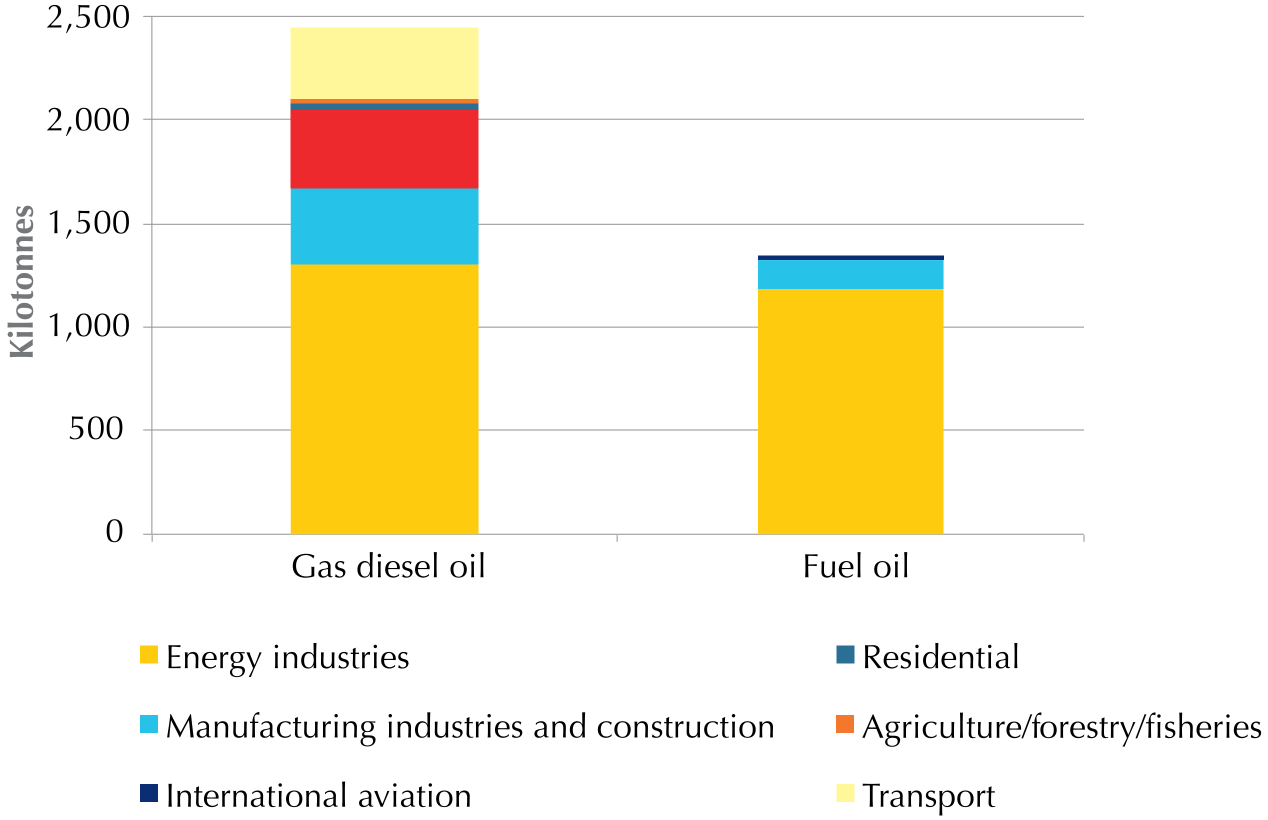


Figure 5: Consumption of gas diesel oil and fuel oil per subcategory

In terms of the share of each power plant to the reported emissions, it is estimated that the Zahrani, Deir Aamar and Zouk plants are the highest emitters of greenhouse gases, given that they are the biggest power plants in terms of capacity, electricity generation and fuel consumption (Table 15).

However, due to the high efficiency of the Zahrani and Deir Aamar installations (Figure 7), both plants are characterized by low emission intensity, generating around 590 tonnes CO_2eq. per GWh of electricity produced (Figure 6) while Zouk has a relatively high emission intensity, emitting 791 tonnes CO_2eq. per GWh electricity produced. In fact, the Zahrani and Deir Aamar power plants are the most recent installations and make up about half of Lebanon's generation capacity, although not operating under optimal conditions. The two plants are equipped with diesel-fired combined cycle gas turbines, which are designed to best operate using natural gas. Their switch to natural gas is expected to drastically reduce their emissions as well as emission intensity.

As for the Zouk power plant, its actual operation efficiency is below the design value by as much as 30%, leading to significant impacts on the fuel bill and greenhouse gas emissions. On the other hand, the Hrayche and Tyre power plants seem to be the most polluting installations, with the lowest operation efficiency (3.01 and 3.16 GWh/tonnes of fuel used respectively as per Figure 7) and the highest emission intensity, generating around 1,000 tonnes CO_2eq. per GWh of electricity produced (Table 15 and Figure 6). The Hrayche power plant is a relatively small installation using heavy fuel oil in steam-turbines to produce around 3% of the country's total electricity production. The plant was built in 1982 and is showing relatively low performances due to a lack of spare-parts and maintenance, hence justifying its high emission intensity. As for the Tyre power plant, it operates on open cycle gas turbines since 1996 and is only used at peak demand due to its low efficiency and high cost of generation.

Table 15: Electricity production and CO_2 emissions per thermal power plant for 2011

	Fuel type	Fuel used (tonnes)	Production (GWh)	CO_2 emissions (tonnes CO_2eq.)	Emission intensity (tonnes CO_2eq./ GWh)
Zouk	Fuel oil	614,242	2,398	1,896,951	791
Jiyeh	Fuel oil	472,557	1,509	1,459,388	967
Hrayche	Fuel oil	93,893	282	289,969	1,027
Deir Aamar	Gas diesel oil	535,918	2,895	1,708,509	590
Zahrani	Gas diesel oil	576,009	3,130	1,836,319	587
Baalbeck	Gas diesel oil	60,348	201	192,390	958
Tyre	Gas diesel oil	106,258	336	338,751	1,009
Average					847

Numbers may reflect rounding.

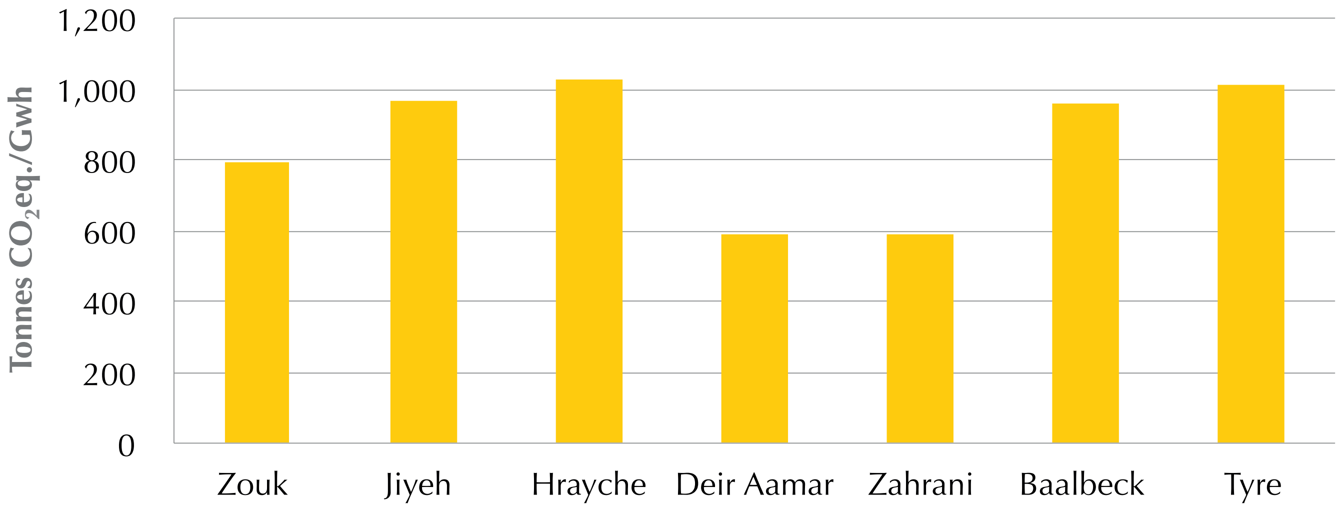


Figure 6: Emission intensity of thermal power plants

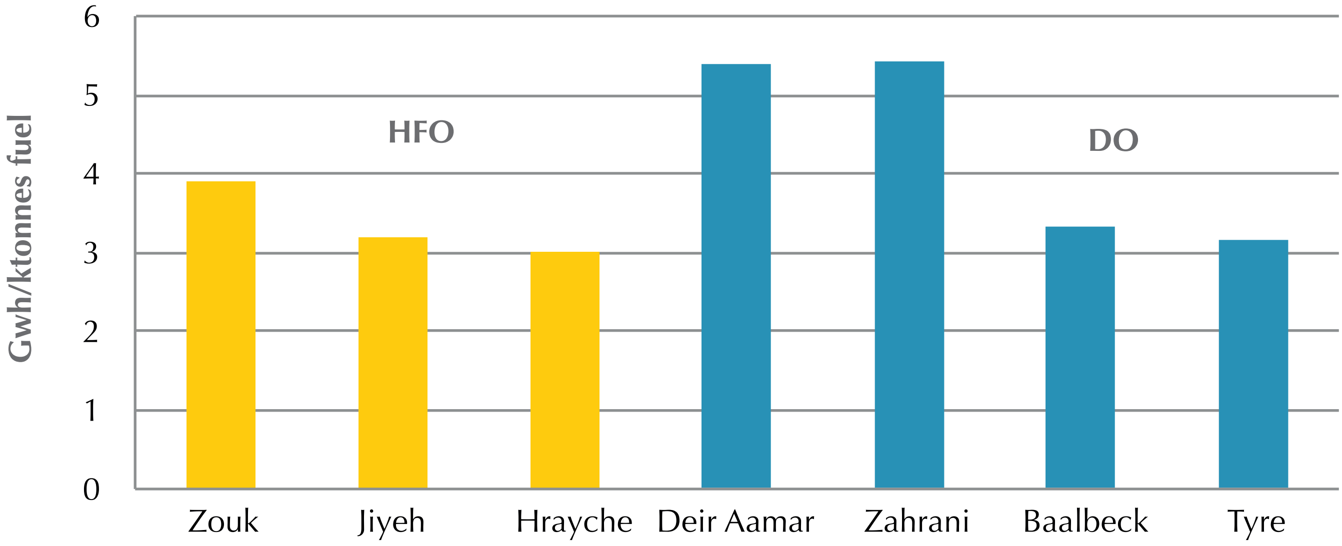


Figure 7: Thermal power plants efficiency

Manufacturing industries and construction and commercial/institutional sectors

Other high-emitting subcategories in the energy sector are manufacturing industries and construction and the commercial/institutional sectors since they cover all combustion activities related to the private generation of electricity. Due to a high difference between electricity supply and demand, electricity is being produced through generators in the industrial, commercial, institutional and residential sectors either through privately owned generators or through neighborhood generators. In 2011, 741,651 tonnes of gas diesel oil were used for private electricity generation, representing more than half the amount used in EDL diesel-fired power plants and constituting 30% of total import of gas diesel oil (Figure 8).

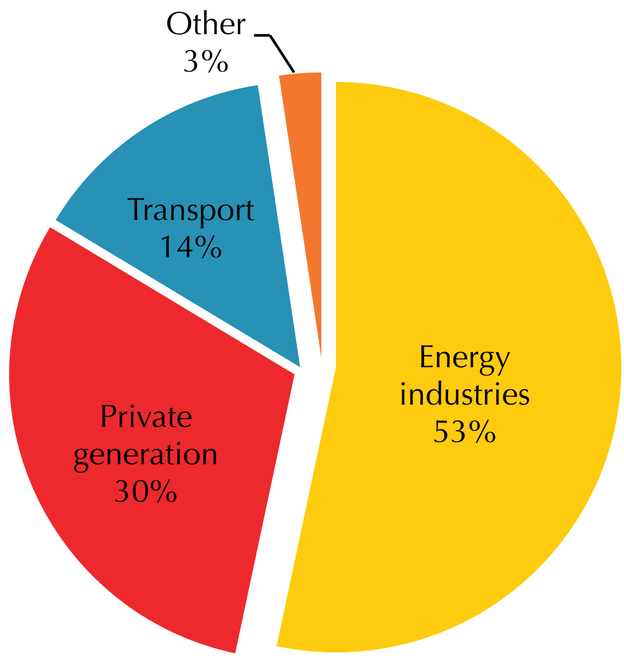


Figure 8: Consumption of gas diesel oil per end-use

Out of the 3,983.34 Gg CO_2eq. emitted from the manufacturing industries and construction and commercial/institutional sectors in 2011, private electricity generation emitted 2,370 Gg CO_2eq. accounting for 13% of total GHG emissions from energy activities. These emissions are closely linked to the quantity of gas diesel oil used in the generators. As illustrated in Table 16 and Figure 9, it is estimated that on average generating electricity from private generators emits on average less than generating electricity from public thermal power plants. Indeed, while public power plants emit on average 847 tonnes CO_2eq. per GWh produced, private generators emit only 713 tonnes CO_2eq. per GWh. In addition, in absolute terms, public energy generation produces more GHG emissions than private generation since it produces more electricity and consumes more fossil fuel (Figure 9 and Figure 10).

Table 16: Fuel consumption and GHG emissions of private generation for 2011

	Gas diesel oil consumed (tonnes)	GHG emissions (tonnes CO_2eq.)	Estimated Production (GWh)	Emission intensity (tonnes/GWh)
Private generation	741,651	2,370,931	3,326	713

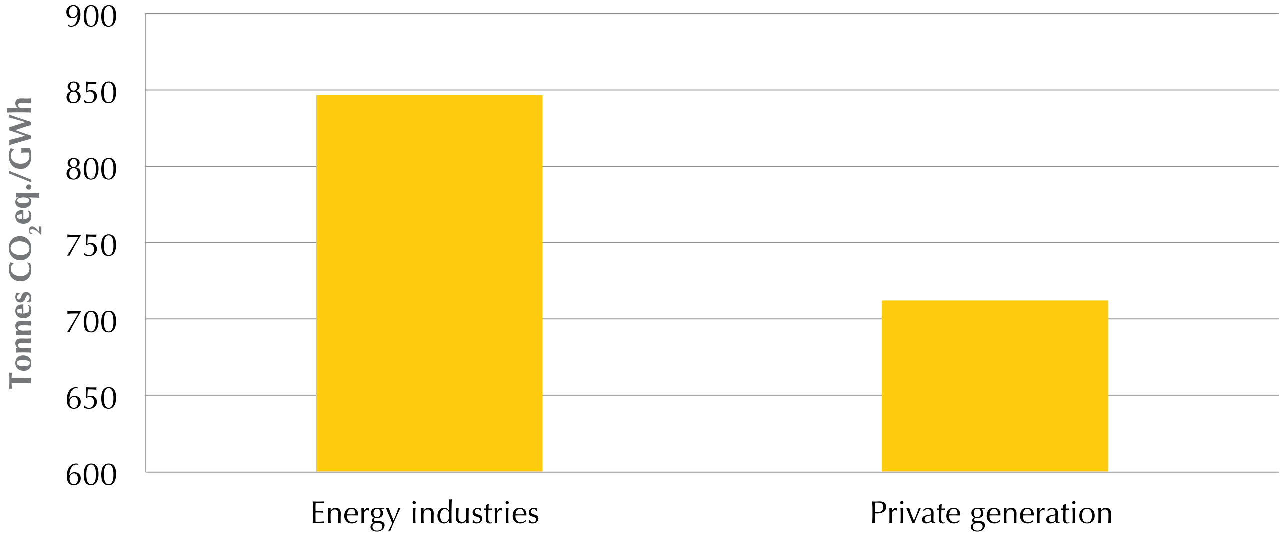


Figure 9: Emission intensity in tonnes CO_2eq./GWh of energy industries versus private generation in Lebanon

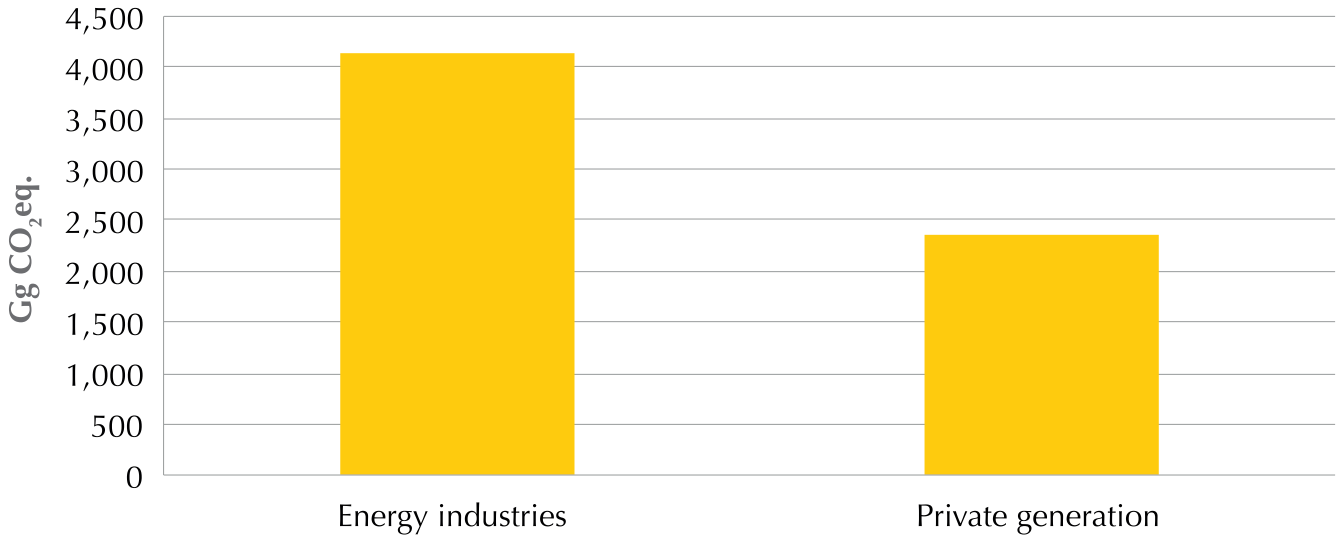


Figure 10: GHG emissions of energy industries versus private generation in Lebanon in 2011

Residential sector

In the residential sector, Liquefied Petroleum Gas (LPG) is estimated to be the main source of GHG emissions (421 Gg CO_2eq.), followed by gas diesel oil that is used for space and water heating in households (Figure 11). Emissions from the use of private generators in residential buildings are not allocated in this category to avoid double counting from private generation under the manufacturing industries and construction category.

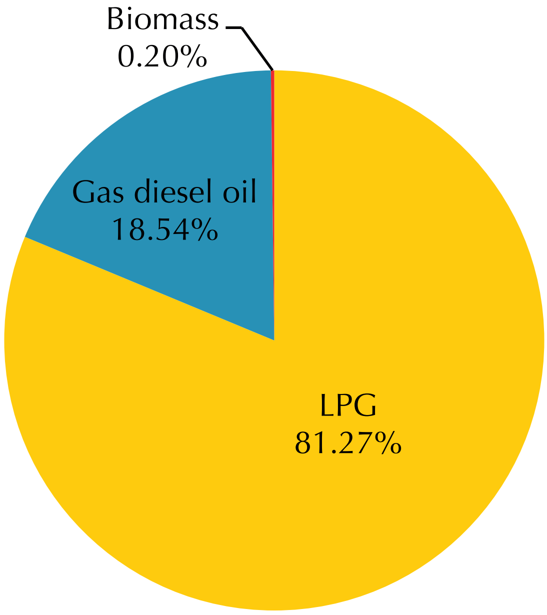


Figure 11: Distribution of GHG emissions in 2011 per fuel type used in the residential sector

Numbers may reflect rounding.

3.5.2. Trends in Lebanon's GHG emissions for the energy sector: 2000-2011

The GHG emissions of the energy sector increased by 12%, between 2000 and 2011, from 11,171 Gg CO_2eq. in 2000 to 12,471 Gg CO_2eq. in 2011.

The key driver behind this increase is the growing demand for energy caused by population growth and economic development, as illustrated in Figure 12 and Figure 13. However, this increase in energy demand was not met by a proportional increase in energy production from public utilities at EDL. Indeed, as shown in Figure 14, the trend in total emissions does not follow the trend of emissions from energy industries, reiterating the fact that electricity production from public utilities preserved a constant growth during the 2000-2011 period. Consequently, the emission gap specifically from 2009 to 2011 is caused by private generators. This is further confirmed in Figure 15 where it is notable that the increase in emissions is mainly due to the increase in gas diesel oil import, which is the main fuel used in private generators whereas heavy fuel oil imports, which are mainly used in public thermal power plants, witnessed a shy growth with a clear disproportion to the increase in emissions.

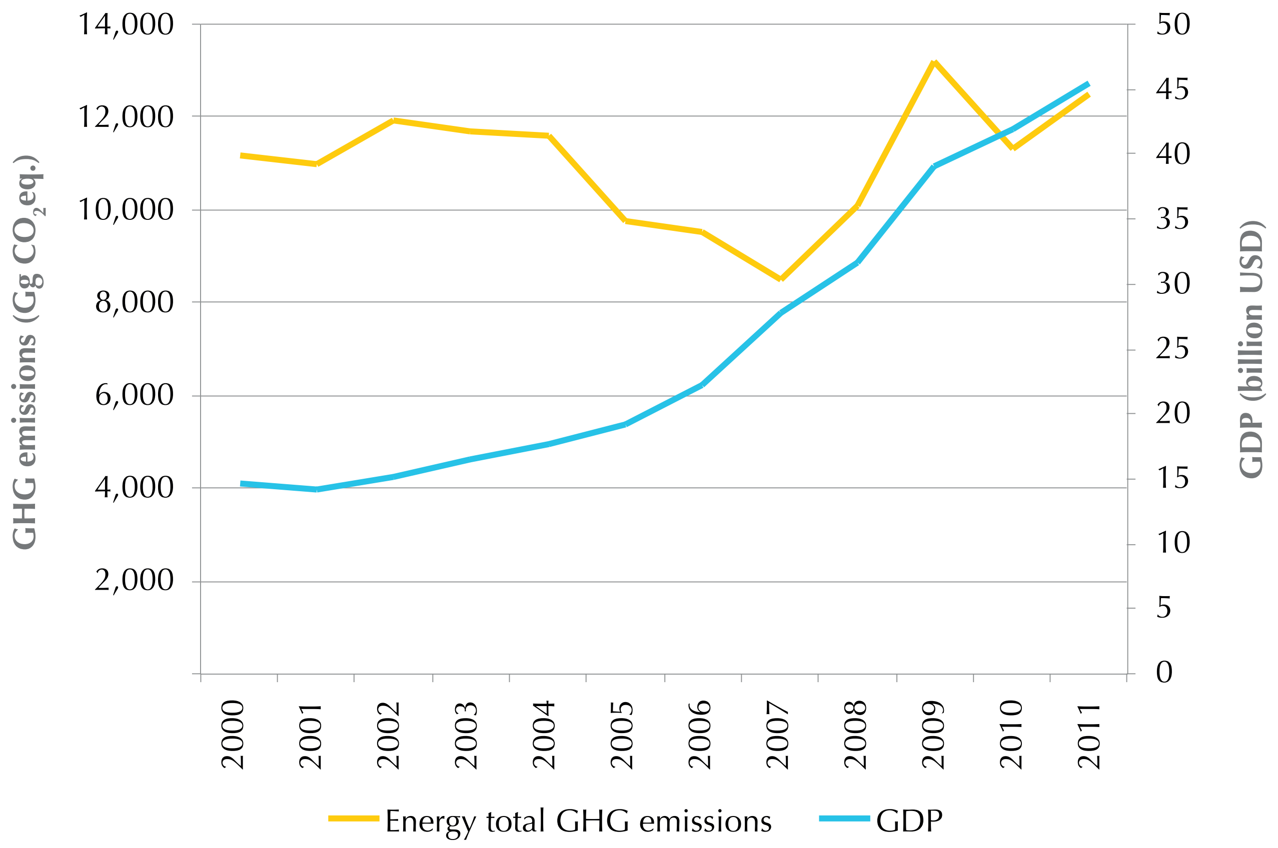


Figure 12: Gross Domestic Product (GDP) growth and GHG emission trends from the energy sector

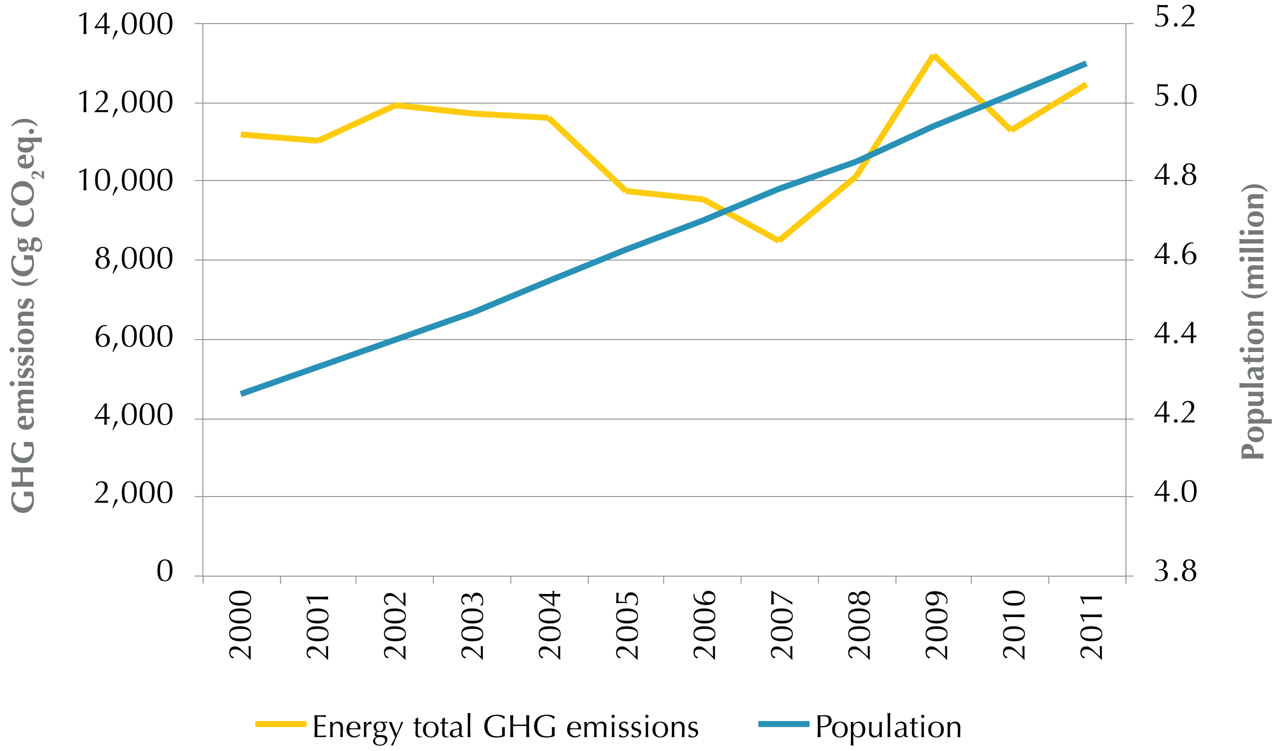


Figure 13: Population growth and GHG emission trends from the energy sector

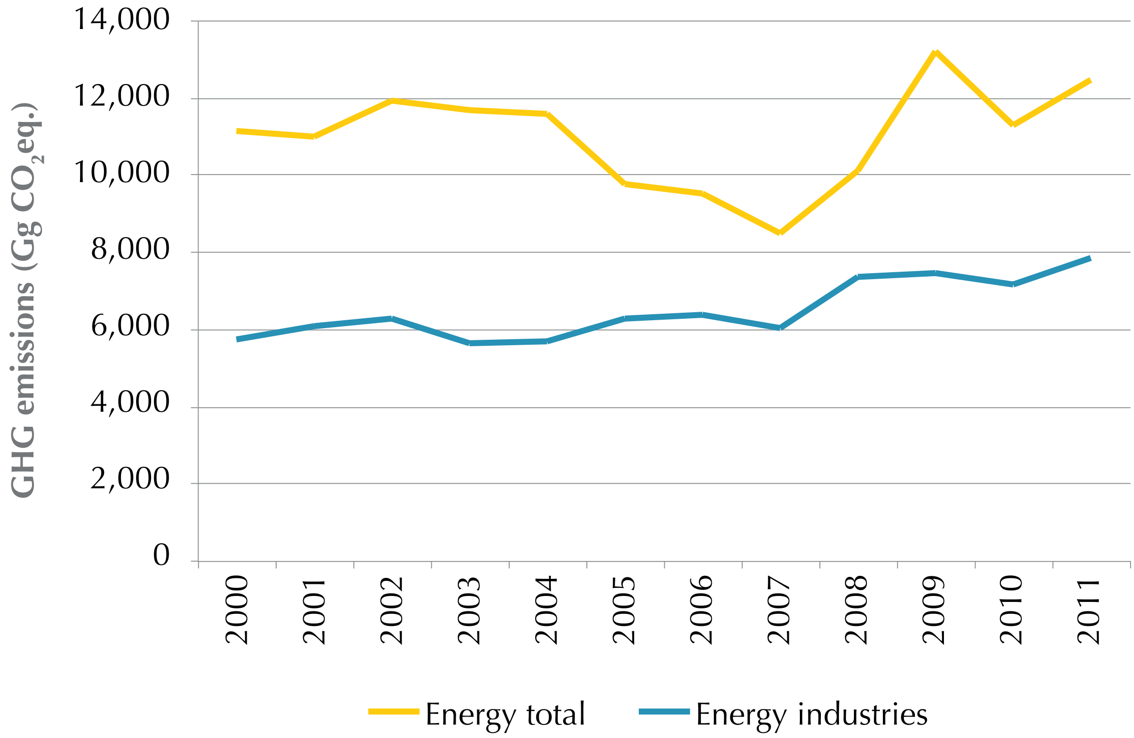


Figure 14: Trend of GHG emissions from energy industries

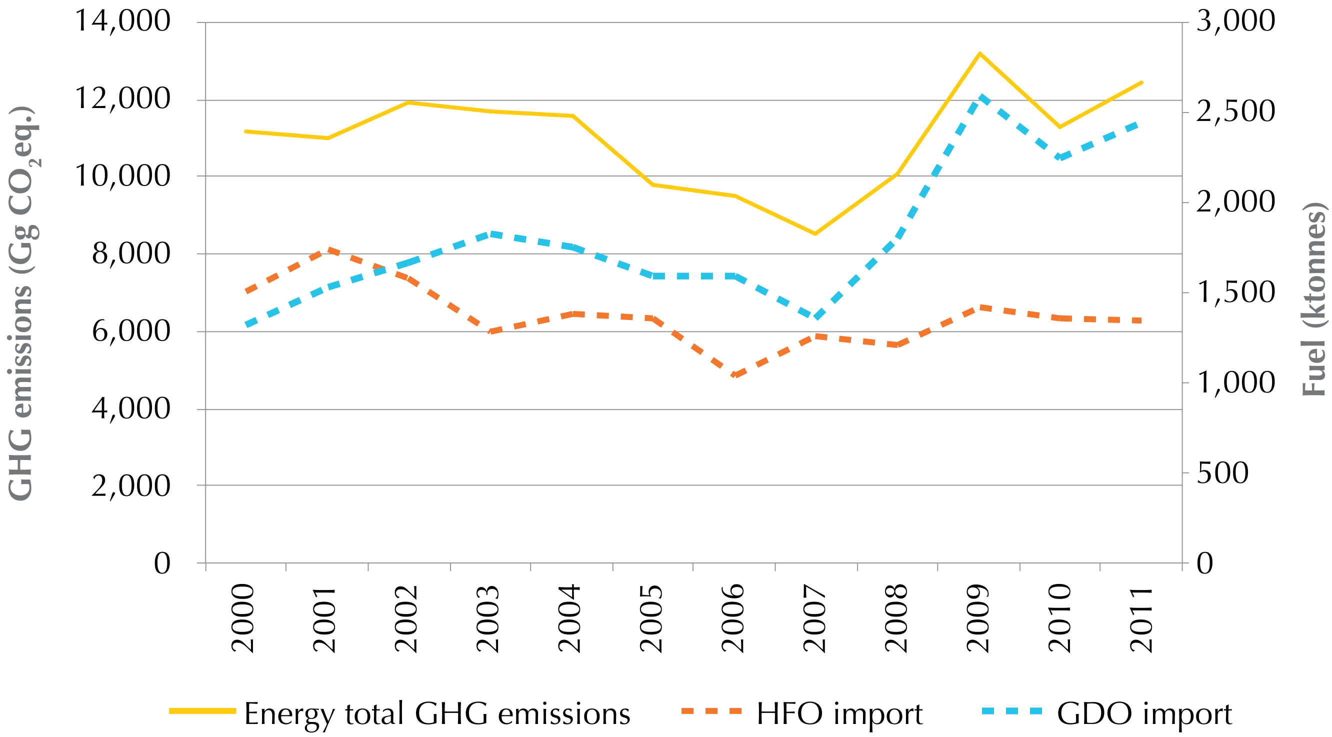


Figure 15: Fuel import and GHG emissions trends of the energy sector

Emission growth did not follow a stable trend, as it witnessed 2 detectable drops in 2007 and 2010 in addition to one significant increase in 2009. The drop in the emission trend in 2007, mainly driven by a similar drop in gas diesel oil import is an indirect result of the July 2006 war where significant damage to the road network and electricity infrastructure was inflicted. Indeed, due to the impairment of the electricity distribution network, it was impossible to distribute all the electricity produced and consequently thermal power plants were operating at partial load during the year 2007. The rehabilitation of the infrastructure extended over 2 years, and it wasn't until 2009 that power plants started to run on full capacity again, hence explaining the peak in GHG emissions in 2009. As for the decrease in emissions observed in 2010 which is proportional to the decrease in gas diesel oil import, it is mainly caused by (1) the use of natural gas in the Deir Aamar plant in 2010 thus consuming 40% less gas diesel oil, (2) the increase in hydropower production by 34% from 2009 to 2010 and (3) the decrease in production of the Tyre plant (consuming 30% less gas diesel oil).

Lebanon's emission factors from electricity production has slightly changed during the last years with 2010 having the lowest emission factor due to the provision and use of natural gas during this year (Table 17).

Table 17: Lebanon's emission factors from the electricity sector

	Emission factor (tonnes CO_2eq./MWh)			
	2009	**2010**	**2011**	**2012**
Electricity produced by EDL (thermal and hydro)	0.697	0.660	0.678	0.676
Electricity produced by EDL and private generation (assumed at 80% of energy not supplied)	0.693	0.647	0.668	0.657

3.5.3. Trends in indirect GHGs and SO_2 for the energy sector: 2000-2011

The role of carbon monoxide (CO), nitrogen oxides (NO_x) and Non-Methane Volatile Organic Compounds (NMVOCs) is important for climate change as these gases act as precursors of tropospheric ozone. In this way, they contribute to ozone formation and alter the atmospheric lifetimes of other greenhouse gases. Sulphur dioxide (SO_2) also has an indirect impact on climate, as it increases the level of aerosols with a subsequent cooling effect. Therefore, emissions of these gases should be taken into account in national inventories.

Emissions of non-CO_2 gases are calculated based on tier 1 methodology by applying emission factors (Table 18 and Table 19) to fuel statistics which are organized by sector. In reality, emissions depend on the fuel type used, combustion technology, operating conditions, control technology and on maintenance and age of the equipment. However, since such detailed data is unavailable in Lebanon, the use of more detailed methodologies was not possible.

Table 18: Emission factors of indirect greenhouse gases

	NMVOCs emission factor (kg/TJ)			NO_x emission factor (kg/TJ)			CO emission factor (kg/TJ)		
	Natural gas	**Oil**	**Biomass**	**Natural gas**	**Oil**	**Biomass**	**Natural gas**	**Oil**	**Biomass**
Energy industries	5	5		150	200		20	15	
Manufacturing industries and construction		5			200			10	
Other sectors		5	600		100	100		20	5,000

Table 19: Emission factors and other parameters of SO_2 emissions

	Heavy fuel oil	**Diesel oil**
Sulphur content of fuel (%)	2	1
Sulphur retention in ash (%)	1	1
Abatement efficiency (%)	1	1
Net calorific value (TJ/Ktonnes)	40.19	43.33
SO_2 emission factor (kg/TJ)	975.47	452.39

In Lebanon, the main gases emitted by the energy sector for the period 2000-2011 are SO_2, which is mainly caused by the sulphur content in burnt fuel, and NO_x, which is mainly generated through the combustion processes in thermal power plants. CO and NMVOCs are emitted at lower rates (Table 20).

The trend analysis of these emissions shows a notable increase in NO_x emissions (34%) and SO_2 emissions (16%) from 2000 to 2011. These are primarily caused by the increased consumption of both heavy fuel oil and gas diesel oil during this period. The highest values of emissions for both NO_x and SO_2 were recorded in 2009 due to a peak in fuel combustion while the lowest values were recorded in 2007 due to the indirect impacts of the July 2006 war (Figure 16).

Table 20: Indirect GHG emissions and SO_2 emissions from the energy sector

	Emissions (Gg)			
	NO_x	**CO**	**NMVOCs**	**SO_2**
2000	22.64	1.82	0.62	86.57
2001	26.90	2.06	0.72	103.27
2002	26.72	2.05	0.72	99.63
2003	25.76	2.01	0.71	91.2
2004	26.14	2.02	0.71	93.42
2005	23.96	1.91	0.65	84.35
2006	23.47	1.81	0.62	76.29
2007	21.35	1.69	0.57	73.78
2008	25.42	1.96	0.67	83.12
2009	30.69	2.67	0.87	105.89
2010	26.82	2.34	0.76	92.37
2011	30.38	2.45	0.83	100.29

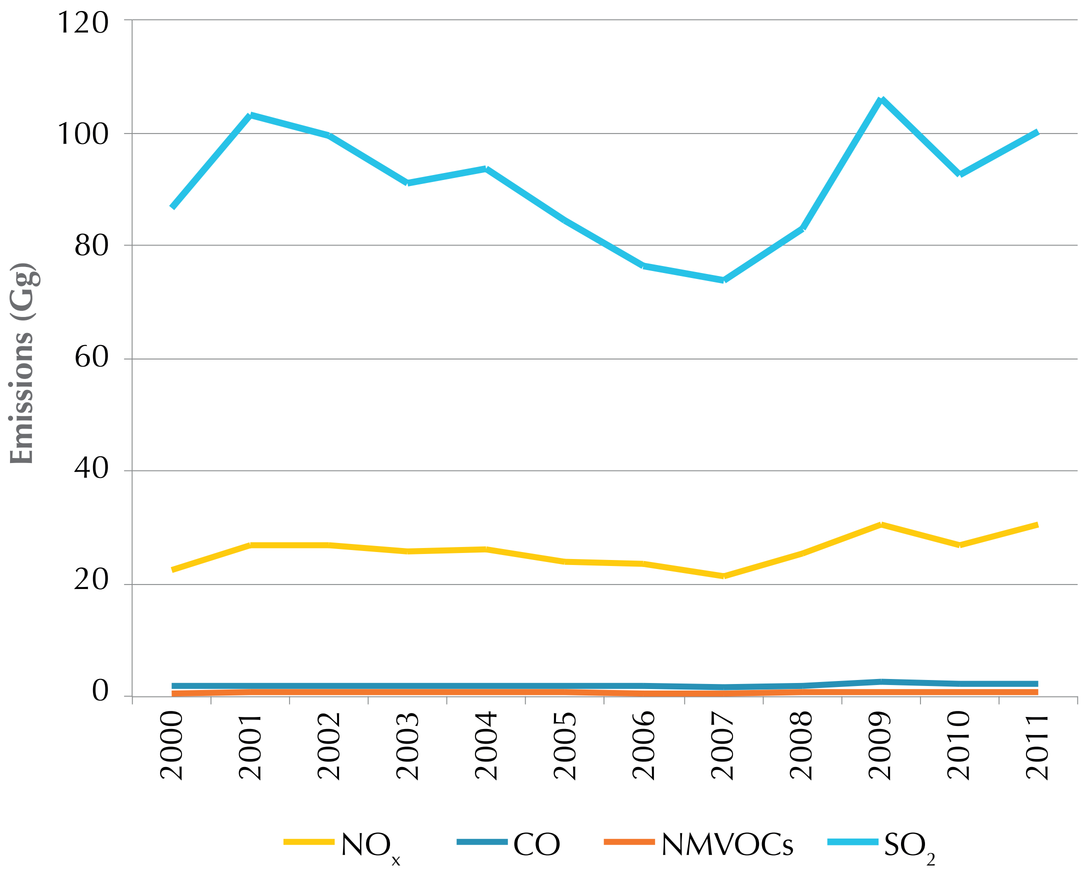


Figure 16: Indirect GHG emissions and SO_2 emissions from the energy sector

Part 2: Mitigation analysis

4. Scope

Energy production through fossil fuel heavily contributes to GHG emissions. Climate mitigation measures in this sector play an important role in achieving positive environmental, economic, and social impact through demand side management and clean energy production. The implementation of mitigation measures helps in reducing the country's GHG emissions through reducing the electricity purchased from EDL, reducing fuel consumption from onsite generation of electricity as well as water and space heating.

5. Existing mitigation actions

This section presents an overview of most of the activities initiated and/or funded either by the government or by international organizations for the period 2005-2012 in reporting tables through:

- Shifting electrically driven hot water systems to renewable energy/solar thermal systems;
- Producing electricity through renewable resources such as solar, wind, geothermal, biomass, and hydro;
- Demand side management through the implementation of energy efficiency measures such as energy efficiency lighting, green roofs, boiler performance enhancement, and other energy performance measures.

The implementation of these mitigation measures has induced an estimated 262,712 tonnes CO_2eq. abatement. If the described activities are well sustained, it is expected to have a minimum of 119,184 tonnes CO_2eq. per year. This does not take into account the implementation of other additional planned activities across the sector.

However, in the absence of any data related to privately funded energy efficiency and renewable energy projects, only a limited number of activities completed by major commercial institutions were considered. These measures contribute to mitigation by displacing private generation which has high emissions due to its high consumption of diesel oil and low quality of emissions control equipment. It is worth noting that the calculation of the GHG emissions reduction is based on the assumption that the mitigation actions are being used at full capacity all the time. The dispatching rules, and operating conditions are disregarded in the calculation.

Table 21 and Table 22 present the main energy related activities that reduce GHG emissions, initiated either by the Ministry of Energy and Water, or by the Lebanese Center for Energy Conservation (LCEC) and the UNDP "Country Energy Efficiency and Renewable Energy Demonstration project for the Recovery of Lebanon" (CEDRO) whose work is mandated by MoEW in addition to some private initiatives. Table 23 to Table 28 present full information including information on objectives and goals, coverage, budget, GHG reduction potential, and any other information on the progress of implementation of the mitigation action.

Table 21: Mitigation actions in the energy sector

Existing activities or under execution
1. Installation of Photovoltaic (PV) systems 2. Installation of Solar Water Heaters (SWH) 3. Installation of efficient lighting 4. Microwind and microwind-PV 5. Replacement of Compact Fluorescent Lamps (CFL) 6. Energy saving measures implemented self-financed by the private sector

Table 22: Summary of mitigation activities for the period 2005-2012

Sector	Activity	Achieved outcome	Estimated reduction of GHG emissions (tonnes CO_2eq.)	Yearly emission reduction (tonnes CO_2eq./ year)
Energy	Installation of PV	Total of 1,936 kWp of capacity installed Annual savings of 2,877.12 MWh	5,046 for the period 2010 - 2012	1,682
Energy	Installation of SWH	Total of 126,000 liters and 1,800 m^2 installed	7,960 for the period 2005-2012	995
Energy	Light Emitting Diode (LED) street lighting	Annual savings of 10,965 MWh	7,434 for 2012	7,434
Energy	Mircowind and microwind-PV	16 kWp of capacity installed Annual savings of 23.77 MWh	36 for the period 2010-2012	12
Energy	Replacement of incandescent lamps with CFL	3,025,000 incandescent lamps replaced in 1,415,000 households across Lebanon	90,036 per year for 2012	90,036
Energy	Energy saving measures implemented self-financed by the private sector	184,700 liters of SWH capacity installed 20,440 MWh saved every year from energy efficiency measures	152,200 for the period 2005-2012	19,025
Total			**262,712**	**119,184**

Table 23: Installed PV systems

Installed PV systems	
General information: PV systems are used to deliver electricity from solar power. The PV systems installed displace grid electricity and reduce the use of diesel backup generation. The systems were mostly installed in public schools, municipalities and community centers.	
Implementing agencies	UNDP-CEDRO project LCEC
Geographical coverage	All regions of Lebanon
Budget	CEDRO: USD 1.05 million LCEC: USD 5.9 million
Timeframe	2007-2013
Sources of funding	Spanish Government, via the Lebanon Recovery Fund (LRF) National Energy Efficiency and Renewable Energy Action (NEEREA)
Goals	Assist in establishing small-scale PV power in the market in Lebanon.
	Various capacity building and awareness raising initiatives on the technology.
	Make various public institutions benefit from this technology.
Achievements or progress	All sites completed, equal to 1,936 kWp of capacity Annual savings around 2,877.12 MWh
GHG emission reduction expected	1,682 tonnes of CO_2eq./year
Methodology	Revised 1996 IPCC Guidelines
Assumption	GHG emission reduction is calculated from reduction of EDL usage and diesel electricity generation.
Enabling environment	The implementation of a feed-in-tariff is necessary for the PV installations development.

Table 24: Installed solar water heating

Installed solar water heating	
General information: 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 water will be heated. 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. Various initiatives were undertaken to provide hot water to schools, hospitals, jails and other public buildings/facilities.	
Implementing agencies	UNDP-CEDRO project LCEC
Geographical coverage	All regions of Lebanon
Budget	CEDRO: USD 1.26 million LCEC: USD 1.44 million
Timeframe	2007-2011
Sources of funding	Spanish Government, via the LRF National Energy Efficiency and Renewable Energy Action (NEEREA)
Goals	Assist in establishing commercial solar hot water market in Lebanon.
	Various capacity building and awareness raising initiatives on the technology.
	Make various public institutions benefit from the technology.
Achievements or progress	Totally installed 126,000 liters and 1,800 m^2
GHG emission reduction expected	995 tonnes of CO_2eq./year
Methodology	Revised 1996 IPCC Guidelines
Assumption	GHG emission reduction is calculated from the difference between using conventional fuel sources to produce hot water and producing it using renewable energy sources.
Enabling environment	The existing set-up being implemented by LCEC is giving very good results in terms of solar water heating market expansion.

Table 25: LED street lighting

LED street lighting	
General information: LED street lighting fixtures replace High Pressure Sodium (HPS) street lighting fixtures. It reduces approximately 35% of electricity demand in comparison to the HPS.	
Implementing agencies	UNDP-CEDRO project LCEC
Geographical coverage	All regions of Lebanon
Budget	CEDRO: USD 360,000 LCEC: USD 3.61 million
Timeframe	2007-2011
Sources of funding	Spanish Government, via the LRF National Energy Efficiency and Renewable Energy Action (NEEREA)
Goals	Assist in establishing energy efficiency street lighting.
	Make various public institutions benefit from this technology.
Achievements or progress	All street lighting fixtures (replacing HPS) sites are completed. Annual savings around 10,965 MWh
GHG emission reduction expected	7,434 tonnes of CO_2eq./year
Methodology	Internal calculations
Assumptions	100 watt LED replaces 150 watt HPS (saving 50 W). Operational from 8 pm to 6 am (10 hours).
Enabling environment	The cost of LED Lighting is still very high and there are many brands in the market that have performances lower than the expectations. The market needs to be controlled by qualifying the good products and introducing incentives to foster the LED installations.

Table 26: Microwind and microwind-PV

Microwind and microwind-PV	
General information: Microwind and microwind-PV systems are used to deliver electricity. The systems installed by CEDRO displace grid electricity and reduce the use of diesel backup generation. The systems mostly were installed in public schools, municipalities and community centers.	
Implementing agency	UNDP-CEDRO project
Geographical coverage	All regions of Lebanon
Budget	CEDRO: USD 9.76 million Allocated to microwind and microwind-PV: approximately USD 100,000
Timeframe	2007-2013
Source of funding	Spanish Government, via the LRF
Goals	Assist in establishing small-scale microwind power in the market in Lebanon.
	Various capacity building and awareness raising initiatives on the technology.
	Make various public institutions benefit from this technology.
Achievements or progress	All sites completed, equal to 16 kWp of capacity. Annual savings around 23.77 MWh
GHG emission reduction expected	12 tonnes of CO_2eq./year Assumed 8 years maximum (cumulative): 96 tonnes of CO_2eq.
Methodology	Internal calculations
Assumption	GHG emission reduction is calculated from reduction of EDL usage and diesel electricity generation.
Enabling environment	The implementation of a feed-in-tariff is necessary for the PV installations development.

Table 27: Replacement of CFL

Replacement of CFL	
General information: The purpose of the CFL replacement project is to replace 3,025,000 working incandescent lamps with 23 Watt (W) CFL in approximately 1,415,000 households. CFL were distributed door-to-door by the electricity bill collectors to residential electricity subscribers. Each household involved in the project received CFL free of charge in exchange for working incandescent lamps in operation at the household up to a maximum of 3 CFL. The project resulted in CO_2 emission reductions by saving electricity from the Lebanese power grid.	
Implementing agencies	Ministry of Energy and Water (MoEW) LCEC
Geographical coverage	All regions of Lebanon
Budget	USD 7 million
Timeframe	2012
Source of funding	Government of Lebanon
Goals	Replace incandescent lamps with CFL
	Reduce GHG emissions
Achievements or progress	3,025,000 incandescent lamps replaced in 1,415,000 households across Lebanon
GHG emission reduction expected	90,036 tonnes CO_2eq. per year
Methodology	Internal calculations
Assumptions	-
Enabling environment	-

Table 28: Energy saving measures implemented self-financed by the private sector

Energy saving measures implemented self-financed by the private sector	
General information: This includes energy efficiency measures and initiatives implemented by some institutions from the private sector through their own funding.	
Implementing agency	Private sector
Geographical coverage	All Lebanon
Budget	Not available
Timeframe	2005-2012
Source of funding	Private funding
Goal	Aims at reducing the electricity consumption at the facility through the implementation of various energy saving measures such as solar water heaters, energy efficient lighting, power factor correction, and other measures.
Achievements or progress	Totally installed: - Solar water heaters: 184,700 liters - Energy efficiency measures: 20,440 MWh/year
GHG reduction	Annual GHG emission reduction: 19,025 tonnes CO_2
Emission reduction expected by completion of action	Not available
Methodology	Revised 1996 IPCC Guidelines
Assumptions	Emission factors: - EDL: 0.65 kg/MWh - Genset: 1.3 kg/kWh - Diesel heating: 0.25 kg/kWh (carbon trust) - Water heating: 70% electrical, 30% diesel and gas (LCEC, 2014) - Electricity: 65% EDL, 35% Genset (EDL data)

6. Planned mitigation actions

Fuel sourcing

The energy Policy Paper 2010 (PP2010) came in to resolve the future fuel debate and had selected Natural Gas (NG) as the primary strategic energy source for the country. The fuel sourcing statement as provided in the policy is based on diversity and security where 2/3 of the fuel mix is based on natural gas with multiple sources of supply, 12% are renewable energies, and the remaining from other sources of fuel while selecting power generation technologies that work on both natural gas and fuel oil.

As per the energy policy paper, NG will be imported from multiple sources, to reduce the risk of supply outages. The strategy is to consider both NG through pipelines from neighboring countries and NG imported through Liquefied Natural Gas (LNG). To accommodate this, the policy defined the infrastructure requirements as follows:

1. Pipeline along the coast: The pipeline will feed all power plants from Deir Aamar to Tyre and will be used for industrial and residential gas distribution as well as for potential NG vehicles. The pipeline will be laid to follow the railway track to cut expropriation costs. The considered sources of NG are, among others, Turkey, former Soviet republics, Russia, Syria, Egypt, Qatar, and Algeria. This is not withstanding that the potential of finding natural gas in the territorial waters of Lebanon may be considered for domestic use, especially for power generation.

2. LNG terminal (Floating Storage and Regasification Unit (FSRU) or onshore terminal): According to Poten and Partners (2009), offshore FSRU is the preferred technology for Lebanon LNG imports and Deir Aamar is the preferred location. The rental of an FSRU will be done for a limited period of 12 years, allowing domestic natural gas to eventually supply the gas demand in Lebanon during the next decade if the coming offshore drillings are successful. It is estimated that Lebanon will require up to 3.5 million tonnes per year of LNG to meet longer-term power generation requirements, including at the existing Zahrani and Deir Aamar plants (870 MW), new CCGT at Beddawi (450 MW), reciprocating engines at Zouk and Jiyeh (278 MW), and additional 1.6 GW Independent Power Producer (IPP) development as required to sustain electricity demand growth in Lebanon. Poten and Partners have also estimated the expected LNG prices. At projected oil prices of around 90 USD/barrel in 2015, Lebanon can expect to pay long-term LNG prices in the 11 to 14 USD/MMBTU range (MMBTU is Million British Thermal Units). At 120 USD/barrel oil price, the range increases to 13 to 16 USD/MMBtu. The main competition to Lebanon for the next 10 years will come from Asia and Continental Europe.

According to the paper, the FSRU is expected to be deployed by the end of 2016 and thus the GoL should act promptly targeting the first delivery of LNG in early 2017. This date is in line with the development of the pipeline and the IPP power plants and any delay may cause cascaded damage on the planned projects.

Renewable energy and energy efficiency

For the past few years, Lebanon witnessed some acceptable developments in the energy efficiency and renewable energy sectors. The Ministry of Energy and Water had provided subsidized loans for the citizens to install solar water heating systems and remove electric heaters from the grid. Another initiative was the replacement of 3 million incandescent lamps with compact fluorescent lamps, an investment worth USD 7 Million.

In 2012, MoEW announced the national action plan for energy efficiency and renewable energy, (referred to as NEEAP, National Energy Efficiency Action Plan) which was considered a strategic document to pave the way for the overall national objective of 12% of renewable energy by 2020. A new NEEAP was prepared in 2015 to prepare the roadmap of the energy sector from 2015 to 2020.

Other initiatives have been put in place by the government of Lebanon in order to increase the share of renewable energy, and meet the 12% target by 2020. Currently, the Ministry of Energy and Water is in the final stages of the evaluation of a 50-100 MW wind farm project tender, which will subsequently be submitted to the Council of Ministers (CoM) for approval. In addition, the market of small, decentralized, grid-connected renewable energy power generation is being developed with a target to facilitate the installation of at least 1.75 MW of new decentralized renewable energy and to pave the way for larger renewable energy power plants (UNDP, 2015).

Increased production

As part of the policy paper's short term immediate and urgent plan, MoEW was able to start the investment process of increasing the installed capacity by 1,200 MW at a cost of USD 1 billion. This is the first large scale investment Lebanon has experienced in the power sector in 15 years. This capacity is a mix of rental power for a limited period of time, upgrades of existing units and new power plants of different technologies. The completion of this short term expansion plan is foreseen to be by the end of 2015.

In the summer of 2012, the GoL represented by MoEW entered into a contract agreement with KARKEY, a Turkish subsidiary of Karadeniz Holding, for renting 270 MW of reciprocating engines mounted on floating barges. The first power barge, moored at the existing Zouk thermal station, started operation in the winter of 2013 and is supplying a total capacity of 188 MW to the 150 kV network. The second barge, moored at Jiyeh thermal station, started operation in the summer of 2013 and is supplying a total capacity of 82 MW to the 150 kV network. According to the contract, this is an Energy Conversion Agreement under which the risk and security of fuel supply are on the GoL's behalf. According to the policy, these rental units are aimed at supplying the required additional power in the summer as well as to act as a standby capacity needed for 2-3 years to rehabilitate the existing units at Zouk and Jiyeh.

Currently, there are two reciprocating engines power plants under construction at the sites of Zouk and Jiyeh. The Danish Engineering, Procurement and Construction (EPC) contractor, Burmeister & Wain Scandinavian Contractor, in alliance with engines OEM MAN BandW started the procurement process for the erection of a 194 MW at the site of Zouk and 78.2 MW at the site of Jiyeh. The engines are designed to run on tri-fuel basis of HFO, Diesel Oil (DO) and NG when available. To boost efficiency, these units will run in Combined Cycle (CC) mode, Heat Recovery Steam Generators (HRSG) will be installed at the exhaust of the engines collecting waste heat to generate steam and run small steam turbine. According to the contract this is a fast track construction job were the full capacity is expected to be online 18 months after the official starting date.

MoEW had also entered into an EPC contract agreement with a Greek company, J&P Avax, for the erection of 565 MW CCGT power plants at the land extension of the existing Deir Aamar CCGT. The plant is composed of three GE frame 9E units, three heat recovery steam generators and one steam turbine. The plant is designed to run on a dual fuel basis and shall fire HFO at a de-rated capacity of 539 MW until NG is available to the plant. Actual construction works are expected to start soon. Similar to previous contracts this is a fast track construction job where the full capacity is expected to be online within 26 months after the official starting date.

As part of an operation and maintenance contract awarded to a Malaysian YTL Power Services, EDL had managed to upgrade packages sequentially for the V94.2 gas turbines at Zahrani and Deir Aamar. The upgrade plan was completed by the end of summer 2013. The upgrades added up a capacity of at least 63 MW in total in addition to enhancements in efficiency and lifetime extensions.

After the completion of the short term plan which aims to re-enforce the generation infrastructure providing confidence for the private sector in the utility capability, and enhancing creditworthiness of the sector to attract senior debits and reliable financiers, MoEW is planning to start the process of increasing the installed capacity by 1,500 MW and later by an additional 1,000 MW using the modality of IPP.

Amongst the projects that are still under the development phase are the rehabilitation of the existing units at Jiyeh and Zouk thermal stations and the conversion of the Tyre and Baalbeck open cycle power plants into combined cycle.

Gaps in mitigation actions

From the preliminary review of the relevant documentation, some gaps were identified with respect to the mitigation options which require further attention by the GoL. The gaps are presented in a general manner but are deemed to be essential aspects to be considered for a successful development of mitigation actions.

Fuel sourcing: Fuel sourcing for the new generation capacity needs to be seriously taken into consideration. Notwithstanding the fact that Lebanon is expected to have its own domestic sources of natural gas available for the next decades. Until the domestic natural gas will become readily available, ensuring the supply of natural gas in sufficient quantities at a competitive price is a challenging task as Lebanon has to face market challenges in economies of scale, solvency and suitability of legal framework to achieve this target. The GoL would suffer from significant financial problems with the policy paper planned IPPs should the fuel quantities or quality be at risk.

Fuel distribution: Even though the policy paper has foreseen the construction of a domestic natural gas pipeline along the Lebanese sea shore for the natural gas distribution to all the facilities located on the sea shore, the project implementation is being delayed and might be even reconsidered. In case of replacement by single FSRUs for each plant located along the sea shore, the advantage of supplying natural gas to the cities and other facilities will be lost. Also the loss of the possibility to extend the network by supplying natural gas to the internal parts of the country as the Bekaa puts a limitation on the number of potential sites for future power plants developments.

Technical constraints: Not all plants can be converted to natural gas, specifically Zouk and Jiyeh old plants as well as Hrayche plant. Thereby mitigation scenarios must be adapted accordingly. An alternative to natural gas would be to select the most appropriate abatement technology for these plants and use combustion improvement technologies as HFO conditioning.

Legal and regulatory framework: The present lack of clarity of the regulatory and legal standing of the private sector participation and the absence of an experienced regulatory authority to manage IPPs might hinder the progress of an IPP development which is relied on for future developments. This represents a major risk as the future 2,500 MW addition is all planned to be under the IPP scheme.

Political risk: Mitigating political risk is a major aspect to consider, especially with the surrounding conflicts, uncertainties and the fragility of the Lebanese regime. This aspect would be a major obstacle for reliable world class private investors to come in and invest in such a capital intensive infrastructure.

The financial standing of the GoL: The current negative financial standing of the country to attract world class developers and financiers categorizes it as non-creditworthy for reliable investors and lenders to think of mobilizing funds and invest in the energy sector in Lebanon.

EDL fragility: The national utility is being exposed by the lack of coherence of the decisions of the GoL. EDL is not being allowed to raise the tariffs in a way to cover its costs, nor to freely recruit as needed, and is unable as a result to invest adequately in its fleet maintenance and development. The prevailing situation might lead to a total collapse of the national utility thereby hindering most of the plans in the energy sector.

Hydropower: There are many old concessions in the hydro sector that have rights on the energy produced from water. These concessions have old Power Purchase Agreements (PPA) with EDL at reduced tariffs and are expected to expire mostly within the next 15 years. This situation constitutes a major barrier for the development of the hydro sector as neither the concessions owners are able to invest (i.e. due to the low tariffs and the short remaining duration), nor the GoL is able to do the same unless it decides to buy back the concessions.

7. Proposed mitigation option analysis

The energy sector is one of the main sources of GHG emissions in Lebanon, accounting for more than 51% of national emissions, mainly due to the high reliance on fossil fuel as the main source of energy for electricity production and the poor performance of the existing thermal generation system. The government of Lebanon has already embarked on a series of projects to increase production capacity and improve the generation conditions.

This section explores the full implementation of the policy paper as mitigation options aiming at further reducing GHG emissions from this sector. The proposed scenario is compared to a Business as Usual (BAU) scenario in order to estimate its potential GHG emissions reduction potential for the years 2020 and 2040. In the BAU scenario, no actions are expected to take place and the GHG estimation for this scenario will follow the same trend as identified in the inventory report; on the other hand, the scenario will take into consideration the full implementation of current policies, strategies, or plans considered and approved at the national level.

7.1. Methodology

The Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 1997) have been used for the calculation of the GHG emissions from the energy sector based on the fuel consumption of each electricity producing source.

The GHG emissions are calculated in terms of CO_2 equivalent, which includes emissions of CO_2, CH_4 and N_2O, based on the IPCC Second Assessment report values of Global Warming Potential (GWP) for 100 years ($N_2O = 310$, $CH_4 = 21$).

CO_2eq. emissions

$$= \frac{[\text{quantities of fuel x net calorific value x carbon content x fraction of carbon oxidized x (44/12)}]}{1{,}000}$$

$$+ \left[\frac{\text{quantities of fuel x net calorific value x } CH_4 \text{ emission factor}}{1{,}000} \right] \text{x GWP } CH_4$$

$$+ \left[\frac{\text{quantities of fuel x net calorific value x } N_2O \text{ emission factor}}{1{,}000} \right] \text{x GWP } N_2O$$

The specific equations for the GHG emissions from the use of heavy fuel oil, diesel oil and natural gas are as follows, Q being the consumption in tonnes:

Emissions from consumption of heavy fuel oil

$$tCO_2 = \frac{[Q \times 40.19 \times 21.2 \times 0.99 \times (44/12)]}{1{,}000} + \left[\frac{Q \times 40.19 \times 0.003}{1{,}000}\right] \times 21 + \left[\frac{Q \times 40.19 \times 0.0006}{1{,}000}\right] \times 310$$

Emissions from consumption of diesel oil

$$tCO_2 = \frac{[Q \times 43.33 \times 20.2 \times 0.99 \times (44/12)]}{1{,}000} + \left[\frac{Q \times 43.33 \times 0.003}{1{,}000}\right] \times 21 + \left[\frac{Q \times 43.33 \times 0.0006}{1{,}000}\right] \times 310$$

Emissions from consumption of natural gas

$$tCO_2 = \left[\frac{Q \times 48 \times 15.3}{1{,}000}\right] \times 0.995 \times (44/12)$$

The **Availability** factor of a power plant is the amount of time that it is able to produce electricity over a certain period, divided by the amount of the time in the period:

Availability is defined as "a percentage measure of the degree to which machinery and equipment is in an operable and committable state at the point in time when it is needed." This definition includes operable and committable factors that are contributed to the equipment itself, the process being performed, and the surrounding facilities and operations. This statement incorporates all aspects of malfunctions and delays relating to equipment, process, and facility issues.

$$AF = \frac{[\text{Time the plant is able to produce}]}{\text{Time}}$$

The availability of a power plant varies greatly depending on the type of fuel, the design of the plant and how the plant is operated. The availability factor does not reflect the periods at which the plant is running at partial loads. This is why for the purposes of calculations in the tables, we have taken into account the net Capacity Factor (CF).

The net **Capacity Factor** of a power plant is the ratio of its actual output over a period of time, to its potential output if it were possible for it to operate at full nameplate capacity continuously over the same period of time. To calculate the capacity factor, the total amount of energy the plant produced during a period of time is divided by the amount of energy the plant would have produced at full capacity.

$$CF = \frac{[\text{net actual energy produced}]}{\text{net continuous energy at full nameplate capacity}}$$

The Capacity Factor accounts for partial load and also for periods in which the plant is shutdown for convenience (i.e. as in the case of Tyre and Baalbeck due to the high operating cost). The Capacity Factor is usually lower than the availability factor.

The **Energy Cost** is the sum of costs (USD) over the sum of net generation (kWh). It is usually expressed in US¢/kWh:

$$\text{Energy Cost} = \frac{[\text{sum of costs in US¢}]}{[\text{sum of net generation in (kWh)}]}$$

The **Specific Consumption** of a plant is an expression of efficiency and is the ratio of the fuel consumption in grams over the net generation (kWh):

$$\text{Specific Consumption} = \frac{[\text{sum of fuel consumed in g}]}{[\text{sum of net generation in (kWh)}]}$$

The **Net Energy Production** per year of a plant is expressed in MWh/year and is calculated as follows:

Net Energy Production = [net MW plant capacity] x [365 x 24] x [CF]

The Energy Not Supplied (ENS) is determined by the difference between Production and Demand.

ENS = production + purchasing - demand

7.2. Business as usual scenario

The BAU scenario shows no large investments in the power sector from the government. The status of the existing power plants is subject to increased wear and tear, whereas the increase in demand is estimated at 3% per year with private generation increasing as needed while maintaining a supply of 80% of the Energy Not Supplied (ENS) (i.e., assuming that 20% of the ENS remains not served in accordance to the policy paper assumptions) and purchasing from Syria and Egypt decreasing as a result of the Syrian conflict. Emissions related to purchased energy are attributed to the country of origin and thus not accounted in Lebanon's total emissions. The BAU scenario assumes that natural gas will not be available before 2020.

Assumptions

Conventional steam thermal power plants

The actual decay in the plants of Zouk, Jiyeh and Hrayche is currently slightly worse than the norm for the same type of plants as EDL is often unable to perform the overhauls and maintenance activities in a timely manner, thereby leaving room for further loss of performances. The reasonable assumptions taken for each plant are thereby also based on the historical data.

The degradation of conventional steam plants is reflected by a Net Power Output (NPO) decrease of 1.06% per year, a specific consumption increase between 2% to 4% per year and a Capacity Factor decrease by 1% to 2% per year.

Combined cycle gas turbines power plants running on diesel oil

The wear and tear behavior of diesel oil fired Combined Cycle Power Plants (CCPP) similar to the ones of Zahrani and Deir Aamar is not well documented as most CCPP usually run on natural gas. The reasonable assumptions taken for each plant are thereby also based on the historical data.

Simple cycle gas turbine plants running on diesel oil

The power plants of Tyre and Baalbeck are usually running in simple cycle and have fuel costs that are higher than the other plants as these are being supplied by truck tankers only. They are thereby being used only as peak units when needed. The reasonable assumptions taken for each plant are thereby also based on the historical data.

Hydropower plants

The hydro production has been simulated based on historical data from the last 4 years assuming a similar rainfall pattern every 4 years will repeat itself. Lebanon had during these years one very dry year and one abundant year, the others being in between which reflects the full range of changes in rainfall quantities. The loss of production caused by the implementation of the Conveyor 800 project on the Litani River is reflected starting from year 2018.

Private generation

The private generation is calculated to be 80% of the ENS in line with the policy paper assumptions. The Private Generation (PG) is assumed to be 100% from DO generation and the specific consumption used in the calculations corresponds to a medium size new generator unit.

Share of renewable energy

The share of renewable energy in the BAU scenario is limited to the power generated by hydropower.

Table 29: Assumptions for BAU scenario

Assumptions for BAU scenario

Zouk thermal power plant
Specific Consumption increases by 2% per year.
Capacity Factor drops around 1% per year.
NPO decreases 1.06% per year.

Jiyeh, Hrayche thermal power plant
Specific Consumption increases by 4% per year for Jiyeh.
Capacity Factor drops around 2% per year.
NPO decreases 1.06% per year.

Baalbeck and Tyre
Specific Consumption increases by 0.5% per year.
Capacity Factor drops around 1% per year.
NPO decreases 0.04% per year.

Zahrani combined cycle
Specific Consumption increases by 1.75% per year.
Capacity Factor follows identical 4 years cycles.
NPO decreases 0.04% per year.

Deir Aamar combined cycle I
Specific Consumption increases by 1.75% per year.
Capacity Factor follows identical 4 years cycles.
NPO decreases 0.04% per year.

Deir Aamar combined cycle II
Capacity Factor follows identical 4 years cycles.
NG price is fixed at 6.01 USD/MMBTU.
NG becomes available in 2019.
NG Density is 0.7035 kg/m^3.
NPO decreases 0.04% per year.
Simple Cycle (SC) increases 1.75% per year.

Hydropower
Same pattern of rainfall every 4 years.

Private generation
PG is calculated to be 80% of the ENS.
The specific consumption used corresponds to a Medium Size new PG Unit.

In all the scenarios, the fuel prices for the simulated period is assumed to be constant at USD 740/tonne for the heavy fuel oil, USD 1,000/tonne for the diesel, and USD 15/MMBTU for the NG.

Table 30 summarizes the data simulation for the BAU scenario. The years 2009 till 2012 are filled in with actual recorded data, whereas the data for the years 2013 till 2030 is simulated based on the assumptions that are specific to each technology and each particular plant.

Table 30: CO_2 emissions under BAU scenario

	2009	2010	2011	2012	2015	2020	2025	2030
Demand (MWh/year)	15,000	15,956	16,564	18,433	20,637	23,924	27,735	32,152
Production + purchase (MWh/year)	11,522	12,460	12,406	10,969	11,013	10,815	9,352	9,535
Private generation (MWh/year)	2,782	2,797	3,326	5,971	7,699	10,487	14,706	18,093
Share of renewable energy	4.95%	6.35%	5.73%	7.63%	4.67%	4.72%	1.14%	1.65%
CO_2eq. (tonnes CO_2eq.)	9,093,019	8,745,369	10,086,667	11,231,083	12,948,453	15,128,302	18,242,128	21,415,102
Average CO_2eq./MWh (tonnes CO_2eq./MWh)	0.689	0.624	0.678	0.676	0.715	0.745	0.791	0.804

7.3. Energy Policy Paper 2010 scenario

The Energy Policy Paper 2010 (PP2010) scenario maintains the same demand growth assumptions as the BAU scenario with the full implementation of the Energy Policy Paper 2010 initiatives updated as per the actual situation at the end of 2014 (i.e. taking into account the various slippages in the time schedule). The update of the Policy Paper initiatives as of December 2014 is summarized in Table 31.

Table 31: Updated schedule of Energy Policy Paper 2010

Initiative	**Planned production date**	**Rescheduled production date**	**Remarks**
Power wheeling	2010	**2010**	Done
Barges	2010	**2013**	Done
Zouk 194 MW Internal Combustion Engine (ICE) plant	End 2014	End 2015	In progress
Jiyeh 78.2 MW ICE plant	Mid 2014	Mid 2015	In progress
Deir Aamar II CCPP 539 MW	End 2016	End 2017	In suspension
Rehabilitation of Zouk and Jiyeh thermal power plants	End 2015	End 2018	Under procurement
Upgrade of Zahrani and Deir Aamar CCPP	2013	**2014**	Done
CC Add On of Tyre and Baalbeck power plants	2012	2018	Under study
IPP 1,500 MW	2015	2018	Under study
IPP 1,000 MW	2018	2021	Under study
Hydro 40 MW	2015	2018	Under study
Wind 60 MW	2013	2017	Under procurement
Waste to energy	2014	2017	In progress

The generation part of the energy policy was targeting a total installed capacity of 4,000 MW by 2014 and 5,000 MW thereafter. 2,500 MW of the target capacity is due using Independent Power Producers (IPPs) modality.

The PP2010 scenario assumes that the existing plants are rehabilitated and upgraded, and large investments are made to increase the generation capacity to meet demand within 2018. The private generation and purchasing gradually decrease when production reaches the demand level.

Private generation is estimated to be 80% of the ENS in accordance with the Policy Paper assumptions (i.e.: 20% of the ENS remains not served).

Purchasing depends on the availability of the suppliers to give energy and the capability of EDL to receive it. It is thereby unpredictable especially in view of the prevailing situation in Syria and Egypt. Moreover sometimes EDL is unable to purchase even if the energy is available due to cash flow problems. In the PP2010 scenario purchasing is assumed to come back gradually to the 2009 level starting from 2015 after having dropped significantly during the last 3 years. Starting from 2018, after eliminating the purchasing and private generation completely, the plants that have the higher levelized cost of electricity start to be decommissioned as needed in sequence. The PP2010 scenario assumes that natural gas will become available end of 2018.

In 2018 when production becomes close to the demand level, the highest costs plants of Jiyeh and Hrayche are decommissioned, and the load of the barges and the peak plants of Tyre and Baalbeck are being managed by order of merit to meet the demand.

Starting from 2019, the barges are decommissioned and Zouk plant is being used at partial load as needed to meet the demand. Starting from 2028, the plant of Baalbeck is decommissioned or kept in stand-by.

The assumptions pertaining to the simulation of the data of each plant are shown below.

Table 32: Assumptions for PP2010 scenario

Assumptions for the PP2010 scenario

Zouk thermal power plant

HFO conditioning improvements starting 2013.
HFO conditioning decreases consumption around 0.7% on the average.
Plant rehabilitation starting 2018.
One unit is in shutdown during the rehabilitation.
Plant rehabilitation restores efficiency to 39.05% and Availability to 82%.
SC increases by 2% per year before rehabilitation.
SC increases by 0.53% per year after rehabilitation.
Capacity Factor drops around 1% per year.
NPO decreases 1.06% per year after year 2026.

Jiyeh, Hrayche thermal power plant

Jiyeh and Hrayche Thermal Power Plant start to be decommissioned in 2018.

Zouk and Jiyeh ICE plants

Both plants enter in operation on HFO in 2015.
Both plants switch to NG operation in 2019.

Specific Consumption increases by 0.258% per year.
NPO decreases by 0.258% per year.
Capacity Factor drops around 0.001% per year.

Baalbeck and Tyre
Both plants will benefit from the Combined Cycle Add On in 2018.
Both plants will be converted to natural gas in 2019.
NPO becomes respectively 115.07 MW and 103.36 MW with Add On.
Specific Fuel Oil Consumption (SFOC) becomes respectively 222 g/kWh and 211 g/kWh with Add On.
Capacity increases +2.5% on natural gas.
Efficiency increases +1.2% on natural gas.
Capacity Factor drops 0.1% after 2019.
SC increases by 0.5% per year for SC and 1.75% for CC.

Zahrani and Deir Aamar I Combined Cycle
The plants of Deir Aamar I and Zahrani have been upgraded in 2013 and start operating on natural gas in 2019.
Gas turbines upgrades increase plant capacity to 464.5 MW in Deir Aamar and 468.5 MW in Zahrani and reduce specific consumption by 5%.
Capacity increases +2.5% on natural gas
Efficiency increases +1.2% on natural gas

Deir Aamar II Combined Cycle
Deir Aamar II enters into service in 2018 on HFO.
Plant switches to NG operation in 2019.
NPO decreases 0.04% per year.
SC increases 1.75% per year.
Capacity Factor follows identical 4 years cycles.

Hydropower
Production follows the same pattern as the historical data of the previous years (i.e.: similarly to the BAU scenario).
Additional energy produced by Kadesha following the completion of its hydro fleet rehabilitation in 2016 (+37% energy).
Addition of the Janneh hydro plant in 2019.

Private generation
Private generation will be practically eliminated as of 2019.

Barges
The barges started operation in 2013 and are gradually decommissioned starting 2019 following the rehabilitation completion and the reach of a balance between demand and supply. The barges are a policy paper initiative and would never have been brought under BAU conditions.

PV Generation
The PV generation is based on a continuous growth of 725 MWh/year of the small PV installations (i.e. similar to the historical data during the past years).
Addition of the five stages of the Beirut River Snake project respectively in

2015, 2018, 2021, 2025 and 2029 is taken into account.
The energy produced from renewable sources is replacing energy that would have been produced from fossil fired sources.

Independent Power Producers (IPP)
The IPP power plants are gradually introduced as needed to cope with the increasing demand starting from 2019:
IPP1, 545 MW GE Gas Turbines Combined Cycle, on the grid in 2019
IPP2, 474.8 MW Alstom Gas Turbines Combined Cycle, on the grid in 2021
IPP3, 486.6 MW Ansaldo Gas Turbines Combined Cycle, on the grid in 2024
IPP4, 474.4 MW Siemens Gas Turbines Combined Cycle, on the grid in 2027
IPP5, 497.5 MW MAN Reciprocating Engines Plant, on the grid in 2029

7.4. Comparison between BAU and Policy Paper scenarios

The implementation of the MoEW Energy Policy Paper (2010) including recent updates, inflicted a cumulative decrease of 83,796 Gg CO_2eq. from 2009 to 2030, with an average annual decrease of 3,816 Gg CO_2eq. per year as compared to the business as usual scenario (Figure 17).

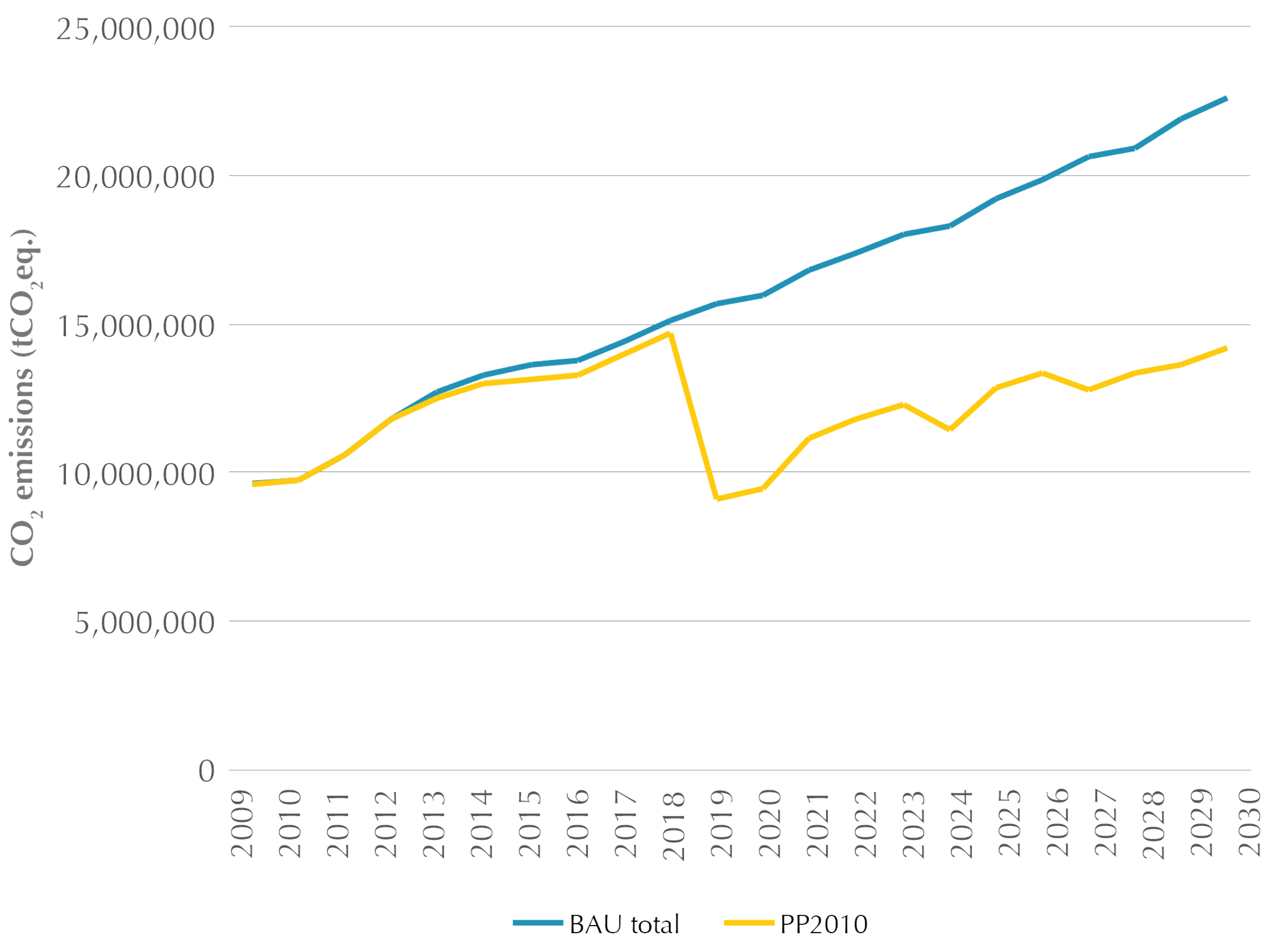


Figure 17: Emission reduction potential from implementing scenario PP2010

Figure 18 clearly illustrates the changes that would result from the implementation of the PP2010 scenario. Compared to the BAU conditions, power production under PP2010 meets demand in the year 2020 while completely eradicating private generation. This is made possible mainly by the switch of most power plants to natural gas by 2019 and by improving the efficiency of power plants, in addition to the increase in the share of hydropower and other renewable energies.

These significant technical changes between both scenarios are reflected in terms of the CO_2 emissions generated by this sector, as presented in Figure 19. Starting 2019, a noticeable drop of 38% in emissions is observed, also mainly due to the switch of most power plants from heavy fuel oil and diesel oil use to natural gas. The introduction of additional production capacity by IPPs contributes to reducing even further CO_2 emissions in 2024, 2027 and 2029.

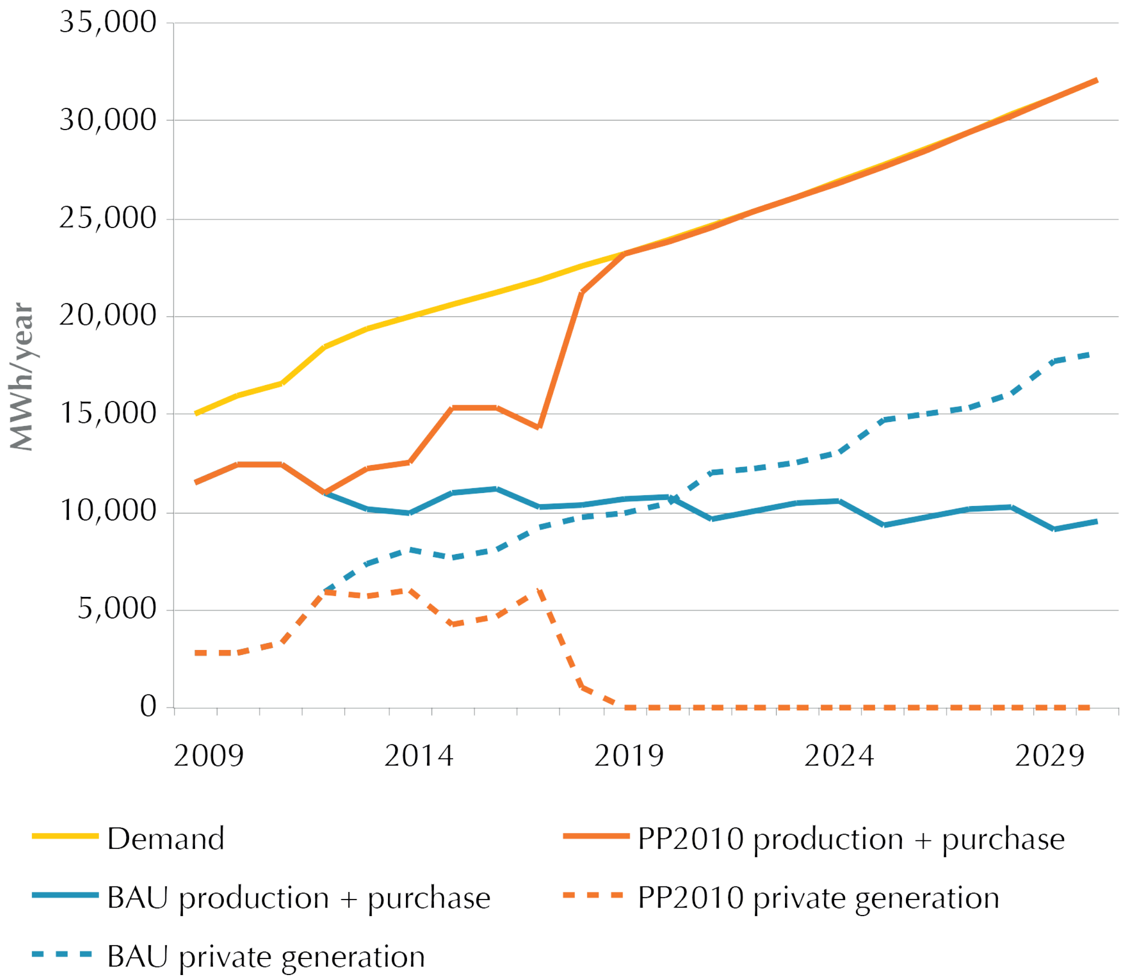


Figure 18: Variations between BAU and PP2010 scenarios

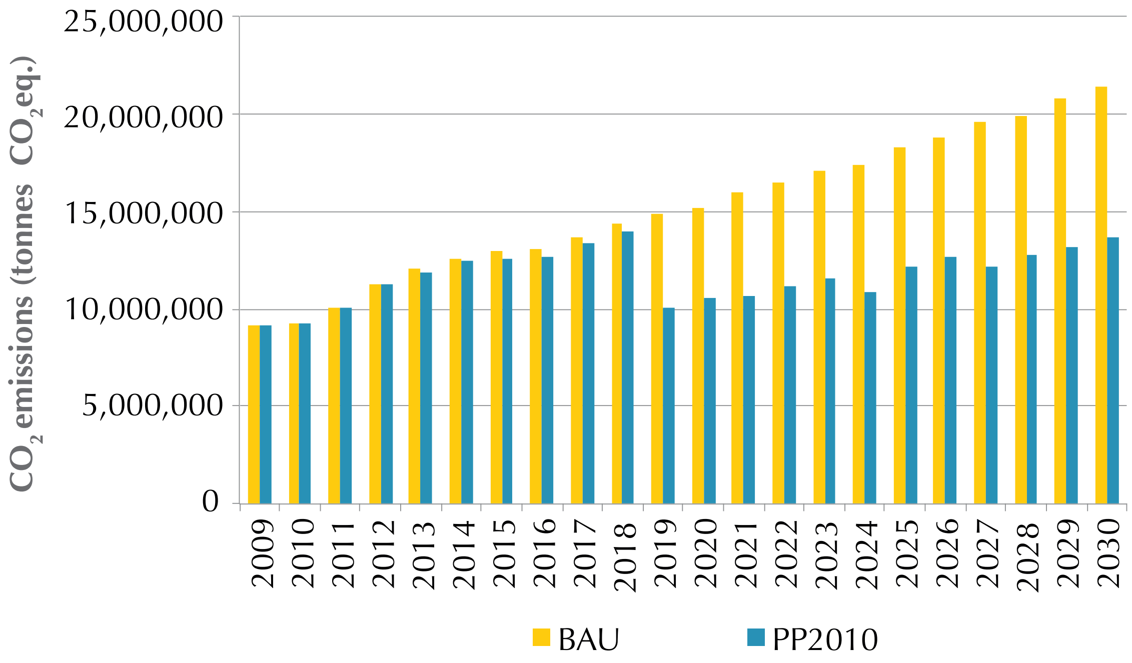


Figure 19: CO_2 emissions under BAU and PP2010 scenarios

It is worth highlighting that in most optimistic scenarios, the contribution of the renewable energies to the improvement of the emission factor in tonnes CO_2eq./MWh remains very modest as shown in Figure 20. This underlines the fact that the main contributor to emissions reduction in the energy sector relies primarily on switching from fossil fuel to natural gas and the improvement of the efficiency of the large scale production technologies.

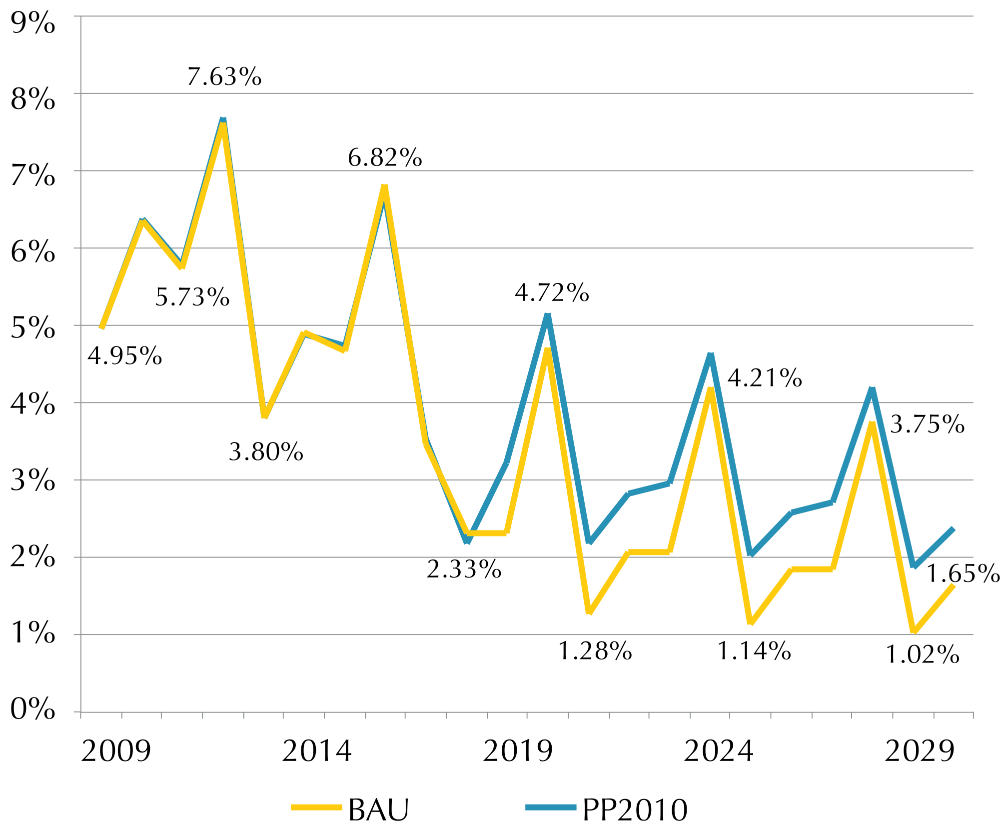


Figure 20: Renewable energy percentage of avoided emissions between BAU and PP2010 scenarios

8. Conclusion

In the current patterns of activities, the Lebanese energy sector generates many environmental and economic burdens on the government and the population. This report highlighted the impact of adopting mitigation measures to lessen these burdens, namely reduce the CO_2 emissions while responding to the energy sector reform needs. Several projects have already been put in place, inducing an estimated 119,184 tonnes CO_2eq. per year. Further significant reductions are expected to be achieved through the full implementation of the Energy Policy Paper of the Ministry of Energy and Water, assuming that the existing plants are rehabilitated and upgraded, and large investments are made to increase the generation capacity to meet demand within 2018.

The analysis of the potential CO_2 emissions and energy use reductions showed a cumulative decrease of 83 million tonnes CO_2eq. from 2009 to 2030, with an average annual decrease of 3.8 million tonnes Gg CO_2eq. per year as compared to the BAU scenario. Starting 2019, a noticeable drop of 38% in emissions is observed, mainly due to the switch of most power plants from heavy fuel oil and diesel oil use to natural gas. The introduction of additional production capacity by IPPs contributes to reducing even further CO_2 emissions in 2024, 2027 and 2029. These emission reductions can only be achieved through the full implementation of the Ministry of Energy and Water electricity policy paper while ensuring the integration of a well-designed portfolio of policies and incentives, and establishing an enabling institutional and legal framework.

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