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MINISTRY OF ENVIRONMENT

MAPPING
NEW DIRECTIONS

A survey of transport patterns & emissions for 2020-2022

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Contents

List of figures 6

List of tables 6

List of acronyms 7

Executive Summary 8

1. Introduction 9

2. National circumstances 9

3. Statistical survey design 13

4. Results of the survey 15

    4.1 New transport patterns for 2022 15

    4.2 Greenhouse Gas Emissions for 2022 18

    4.3 GHG Emissions for the period 2020 – 2021 19

5. Emission uncertainty 22

6. Conclusion 25

7. References 26

8. Annexes 27

    8.1 Annex 1: Parameters used 27

List of Figures

Figure 1 - Contribution of energy emission sources to the energy sector's total emissions for 2019 ... 9

Figure 2 - Distribution of Vehicle Fleet in 2019 ... 10

Figure 3 - Lebanese fleet categories across the years from 1994 till 2019 ... 10

Figure 4 - Gasoline price per 20-liter in LBP and USD (using black market exchange rate) in Lebanon ... 11

Figure 5 - Number of fuel-efficient vehicles imported to Lebanon ... 11

Figure 6 - Emission factor per vehicle type and use ... 13

Figure 7 - Distribution of the sample per city and type of vehicle (1) ... 16

Figure 8 - Distribution of the sample per city and type of vehicle (2) ... 17

Figure 9 - Share of CO_2 eq. (in ktonnes) of each vehicle category in 2022 and 2019 ... 18

Figure 10 - Number of Passenger Cars considered for the 2020-2021 period along their resulting Vehicle Kilometer Traveled (VKT) ... 19

Figure 11 - New daily COVID-19 cases in Lebanon along with the median PC VKT during the crises ... 20

Figure 12 - Gasoline price in Lebanon along with the median PC VKT during the crises ... 20

Figure 13 - Gasoline price in Lebanon along with the median PC VKT during the crises ... 21

Figure 14 - Frequency plots obtained following the Monte Carlo simulations for the emissions of the GHG for the year 2022 ... 23

Figure 15 - Sensitivity chart from Monte Carlo assessment ... 24

List of Tables

Table 1- Description of the vehicle categories used ... 13

Table 2 - The adopted sample size along with the distribution of vehicles ... 14

Table 3 - Sample distribution of vehicle categories in each region (95% CI and 3% margin of error) ... 15

Table 4 - Subject disposition ... 16

Table 5 - Comparison between 2019 and 2022 kilometers driven per year per vehicle category ... 18

Table 6 - Statistics of the Monte Carlo assessment for the year 2022 ... 22

List of Acronyms

BEV	Battery Electric Vehicles
BUR	Biennial Update Report
CH_4	Methane
CI	Confidence level
CO_2	Carbon Dioxide
CO_2 eq.	Carbon dioxide equivalent
GHG	Greenhouse Gases
HDV	Heavy-Duty Vehicles
HEV	Hybrid Electric Vehicles
IPCC	Intergovernmental Panel on Climate Change
LBP	Lebanese Pound
LCV	Light-Commercial Vehicles
N_2O	Nitrous oxide
NCV	Net Calorific Value
PC	Passenger Cars
PDF	Probability Density Functions
PHEV	Plug-In Hybrid Electric Vehicles
PMU	Project Management Unit
SD	Standard Deviation
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollars
VKT	Vehicle Kilometer Traveled

Executive Summary

The economic crisis and pandemic that hit Lebanon, primarily in 2020 and 2021, caused several lockdowns and disrupted the road transport sector, especially driver behavior, kilometers driven, etc. Accordingly, the main purpose of this report is to collect information on transport patterns in Lebanon for the years 2020 to 2022, and accordingly, update Lebanon's Greenhouse Gases (GHG) Inventory for this period.

A survey was conducted during the year 2022 acquiring data from 1,271 vehicles all over Lebanon, following a statistical design and sampling plan. Results showed that in 2022, passenger cars (PC) and two-wheelers were back to their pre-crisis yearly distance travelled (around 12,000 kms/year), with reference to the year 2019, while taxis, Light-Commercial Vehicles (LCV), vans, trucks, and buses showed a 75% decrease in some cases. This back-to-normal situation for Passenger cars and two-wheelers is mainly due to the fact that enterprises gradually started coping with inflation, and providing full or partial dollarized salaries in 2022, which enabled employees to overcome the financial restrictions impacting their commuting decisions.

The data collected for the years 2020 and 2021 showed that only two-wheelers maintained their distances traveled per year in 2020 and 2021 as per the pre-crisis year 2019; two-wheelers were the only vehicle category that was not affected during the crisis and post-crisis and maintained its activity during the COVID-19 pandemic. The Passenger Vehicle Kilometer Travelled (VKT) during this period decreased by around 25-30%, while vans, light commercial vehicles, buses, and trucks experienced a 30-50% decrease.

As a result, greenhouse gas emissions, namely CO_2 eq., decreased by 35% in 2020, 30% in 2021, and 13% in 2022, compared to 2019. The uncertainty assessment using the Monte Carlo simulation for the year 2022 showed values between -64% and +140%, which is mainly due to the wide range of the kilometers driven for Passenger Cars and to a lower extent light commercial vehicles and trucks.

1. Introduction

As a result of Law 359 that was issued in 1994, Lebanon has been a Party to the United Nations Framework Convention on Climate Change (UNFCCC) and has ratified both the Kyoto Protocol and the Paris Agreement following the issuance of Laws 738 and 115 in 2006 and 2019, respectively. Consequently, Lebanon submitted four National Communications and four Biennial Update Reports, the most recent one being the Fourth National Communications in 2022.

These communications and reports base their assessment and action plans on the Greenhouse Gas (GHG) emissions inventory. The main sector that emits GHG is the energy sector, which includes transportation (MoE/UNDP/GEF, 2021). Between 1994 and 2018 and in terms of GHG emissions, road transportation grew by more than 350%.

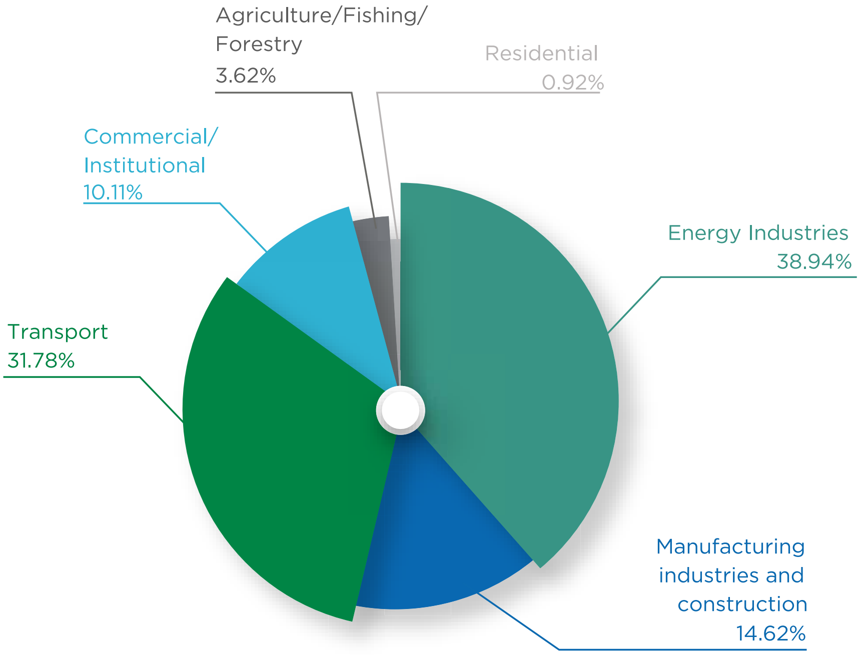


Figure 1 - Contribution of energy emission sources to the energy sector's total emissions for 2019

In October 2019, Lebanon witnessed protests and road blockages which were a result of the economic crisis that intensified and manifested soon after. In addition, the COVID-19 pandemic enforced several lockdowns in 2020 and 2021. These events disrupted the transport sector, especially driver behavior, kilometers driven, etc.

Accordingly, the main purpose of this report is to collect information on transport patterns in Lebanon for the years 2020 to 2022, and accordingly, update Lebanon's Greenhouse Gases (GHG) Inventory for the period that relates to the GHG Inventory calculation.

2. National circumstances

In the absence of a developed and functioning public transportation sector and infrastructure for railway or other urban or national public networks, Lebanon's transport fleet consists mainly of passenger cars (Figure 2). Only a few bus lines currently exist; they are managed by the private sector (individuals or companies). Based on data gathered from the Ministry of Interior and Municipalities – Traffic, Truck and Vehicle Management Authority, the operational national fleet distribution for 2019 consisted of 2,111,879 vehicles with 81% of them being passenger cars (PC) (Figure 2 – Figure 3).

Additionally, internal combustion engines work inefficiently due to the continuous stop-and-go driving patterns resulting in high levels of fuel consumption and pollutant emissions (Mansour et al., 2011).

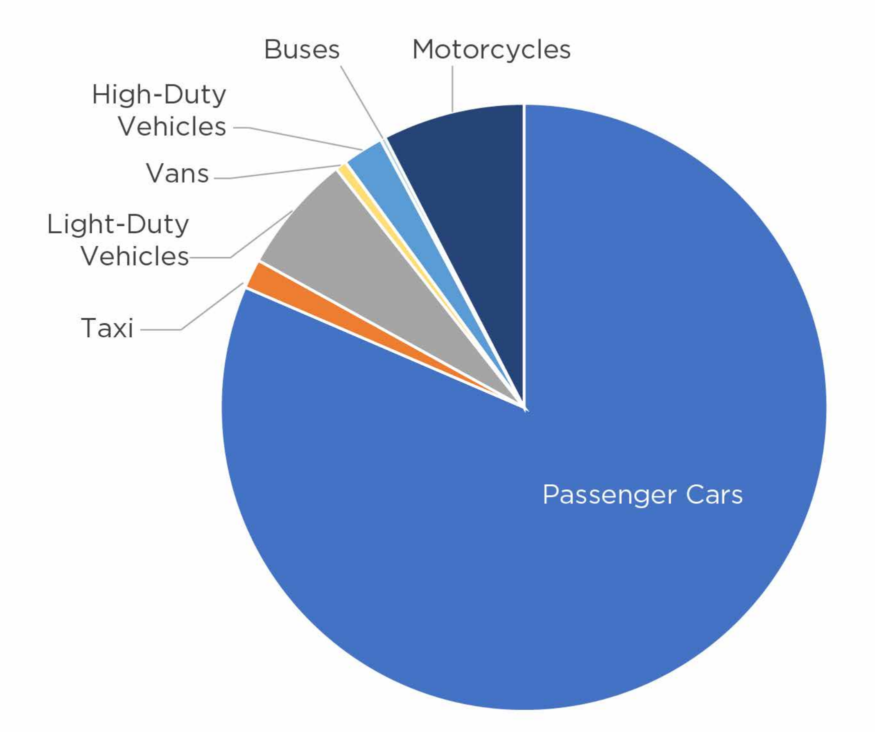


Figure 2 - Distribution of Vehicle Fleet in 2019

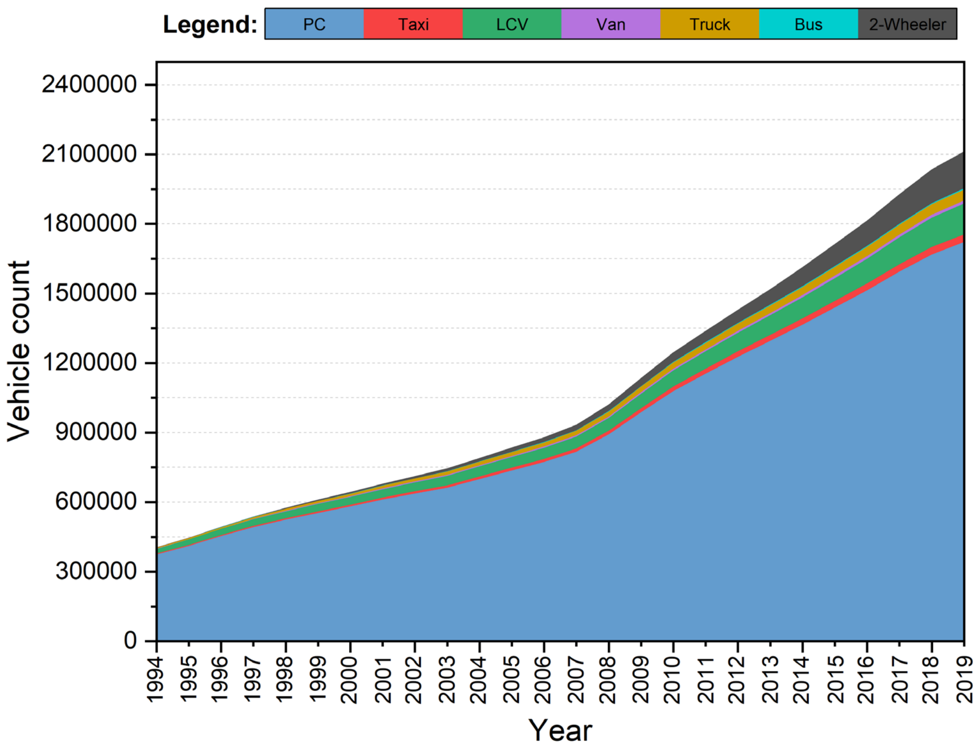


Figure 3 - Lebanese fleet categories across the years from 1994 till 2019

The main fuel type used in road transport in Lebanon is gasoline; only Heavy-Duty Vehicles (HDV), vehicles with more than 3.5 tonnes capacity, such as trucks and big buses, run on diesel. In 2002, Decree No. 7858/2002 banned the use of diesel fuel for light and medium-duty engines (Afif et al., 2008). The transport fleet age was 20 years in 2019, and was characterized by a high percentage of vehicles that are not equipped with catalysts (approx. 35%); however, a fraction of this 35% originally had catalysts which were probably removed without being replaced, as part of a common practice to avoid high maintenance costs in the absence of effective law enforcement banning such practices (Waked and Afif, 2012; Waked et al., 2012).

With the exacerbation of the economic crisis which began in 2019 and the consequent devaluation of the Lebanese Pound (LBP), the Lebanese government removed all gasoline and diesel subsidies, while the minimum wage remained the same at 675,000 LBP (in 2022). Consequently, the price of 20 liters (in LBP) of gasoline increased by more than 3000% from mid-2019 till end of 2022 (Figure 4).

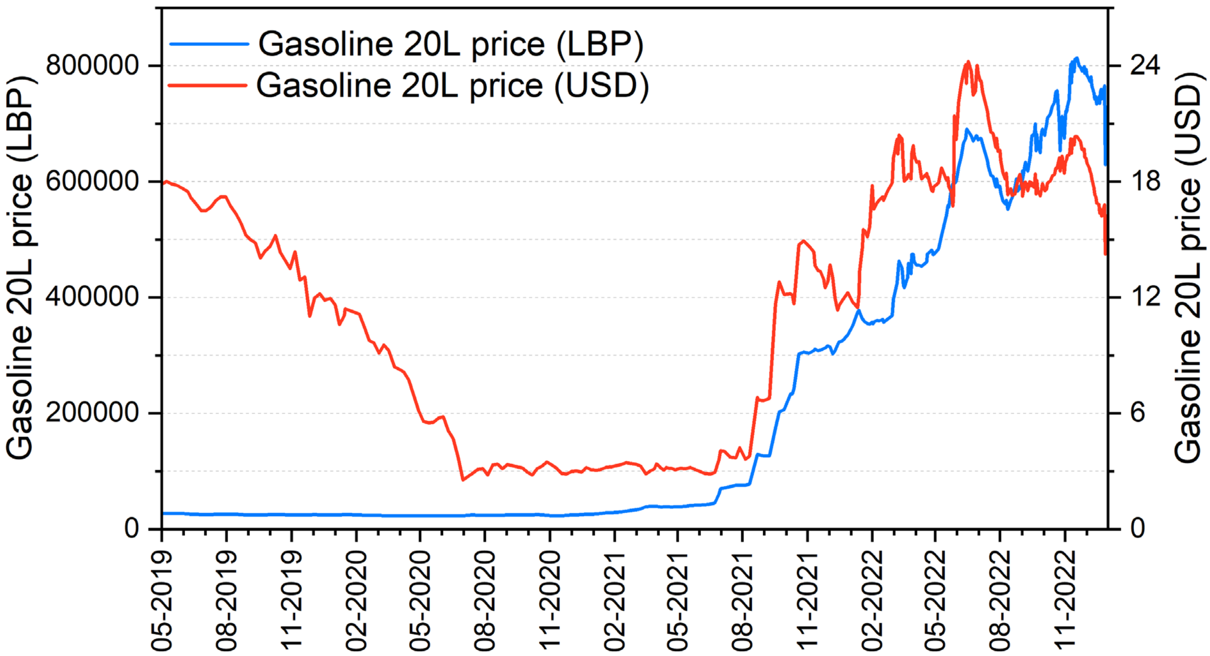


Figure 4 - Gasoline price per 20-liter in LBP and USD (using black market exchange rate) in Lebanon

The increase in fuel prices, compounded by petrol shortages during the summer of 2021 sparked a surge in the acquisition of fuel-efficient vehicles post-2019. In addition, the tax incentive associated with hybrid and electric cars, introduced in the budget laws of 2018-2024 and effective until 2029, incentivized consumers to pivot towards hybrid and electric car purchases. Customs data reveal the importation of 3,910 hybrid cars and 3,248 electric cars into Lebanon between 2015 and 2023 (Figure 5) (Lebanese Customs Administration, 2023).

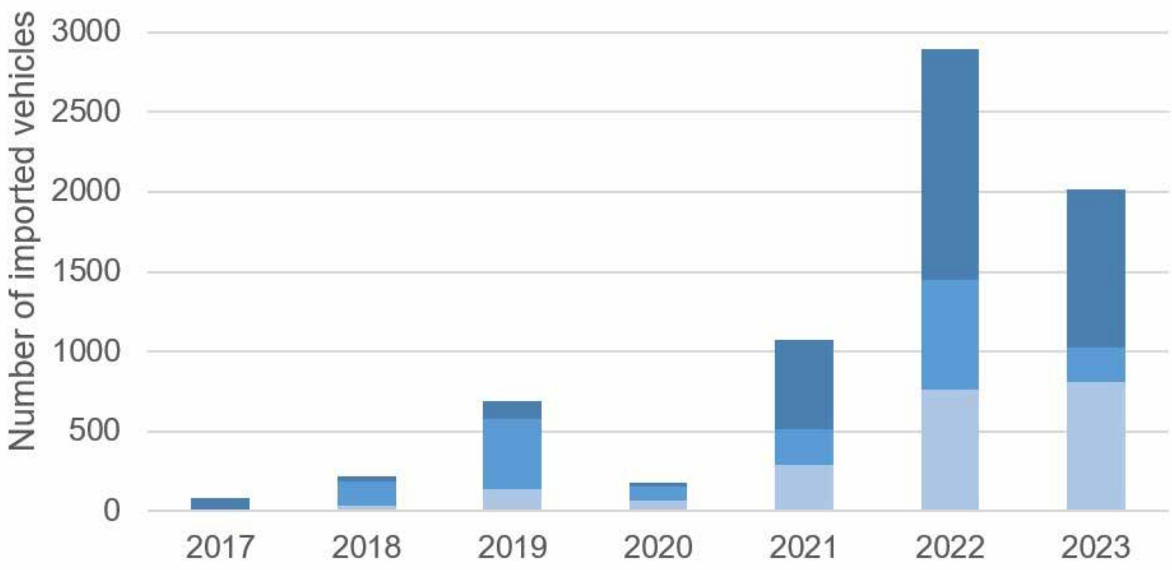
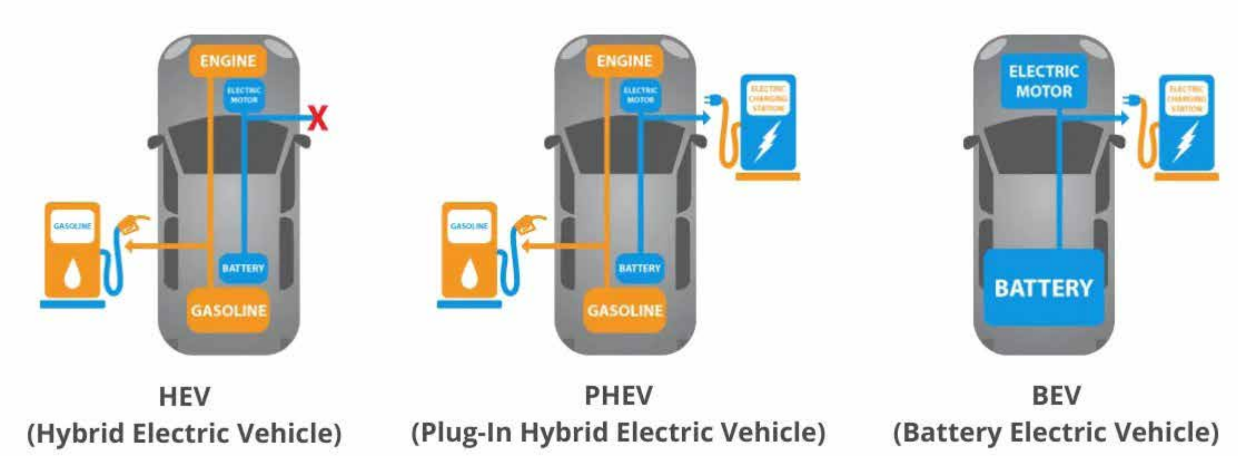


Figure 5 - Number of fuel-efficient vehicles imported to Lebanon



A Hybrid Electric vehicle combines an electric motor and battery pack to the internal combustion engine in conventional vehicles.

A plug-in hybrid electric vehicle is an extended version of a hybrid vehicle, which utilizes rechargeable batteries that can be restored to full charge by connecting a plug to an external electric power source.

A PHEV shares the characteristics of both a conventional hybrid electric vehicle and a battery electric vehicle, having a plug to connect to the grid.

Battery electric vehicles have no internal combustion engines and derive all their power using an electric motor exclusively from rechargeable battery packs.

While these vehicles do not produce tailpipe GHG emissions, emissions result from the power plants while generating the electricity needed to power these vehicles.

In Lebanon, a gasoline car emits 0.194 kg CO_2/km (MoE/UNDP/GEF, 2022), while a hybrid car emits 42% less at 0.113 kg CO_2/km, and an electric car emits 33% less at 0.129 kg CO_2/km, based on the 2019 electricity mix. Due to its exclusive reliance on fossil fuels, a gasoline car naturally exhibits the highest emission factor. Nevertheless, it's noteworthy that under current Lebanese conditions, the emission factor of an electric car surpasses that of a hybrid car. This discrepancy arises from the fact that electric cars draw power from the national grid, which predominantly relies on fossil fuels, leading to a relatively high national grid emission factor of 0.663 kg CO_2/kWh. As such, the efficacy of an electric vehicle, in terms of reducing overall emissions, is compromised within the present context of Lebanon (MoE/UNDP/GEF, 2022).

In terms of emissions per car, it varies according to the nature of the vehicle's use and its technology. A private gasoline car emits 2,328 kg CO_2/car/year while a gasoline taxi emits 9,700 kg CO_2/car/year due to the difference in distance travelled between the two car types (12,000 kms for a private car versus 50,000 kms for a taxi). The same applies to hybrid and electric Taxis, as presented in the figure below (Figure 6).

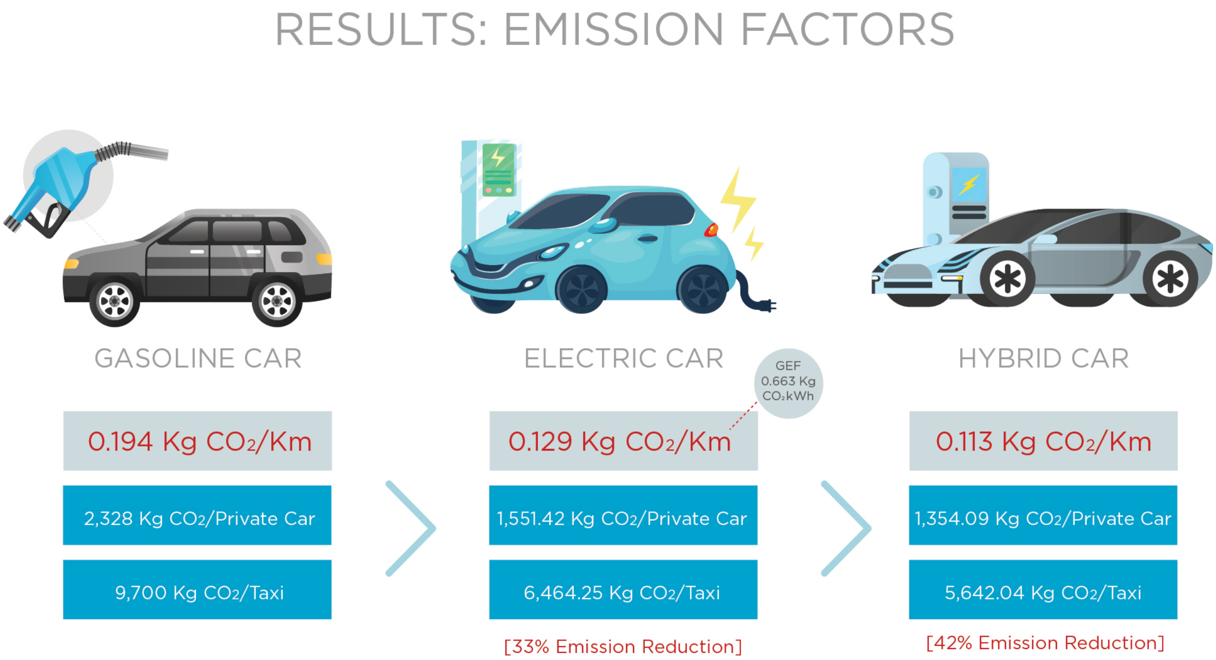


Figure 6 - Emission factor per vehicle type and use, including Grid Emission Factor (GEF)

3. Statistical survey design

The survey design applies to the Field and Follow-up surveys. The statistical design consists of different steps.

1. Sample Size Estimation

The survey was designed in a way to determine the smallest sample size of vehicle records whose mean and standard deviation are reasonably close to the "true" mean and standard deviation of the whole population. To attain high precision and determine the minimum sample sizes needed, knowledge of the targeted vehicles was required. Additionally, data from 2019 presented in Table 2 was considered to determine the sample size and characteristics and collect information for the period 2020-2022.

The stratified sampling method was used for evaluation, specifically "univariate stratification," taking into consideration only one variable of classification that is the type of vehicle (PC, taxi, LCV, vans, trucks, buses, and motorcycles) (table 1). Additionally, this method can further reduce the required sample size for precisely determining the fleet-wide average gap; also providing sufficient representation of sub-populations of interest, and requires a priori knowledge of the population.

Table 1 - Description of the vehicle categories used

Vehicle category	Description
Passenger Cars (PC) and Taxi	Private personal gasoline cars and taxis used for mobility including Sport Utility Vehicles (SUV).
Light Commercial Vehicles (LCV) and Vans	Gasoline Light Commercial Vehicles with rated gross weight less than 3,500 kg including light trucks designed for the transportation of cargo, and gasoline vans for the transportation of passengers.
Heavy Duty Vehicles (HDV) incl. trucks and buses	Diesel Heavy Trucks vehicles with rated gross weight exceeding 3,500 kg designed for transportation of cargo and diesel buses for the transportation of passengers.
Motorcycles	Includes a mixture of 2-stroke and 4-stroke engines as well as mopeds having an engine less than 50cc.

Based on the 2019 fleet that is equivalent to around 2,111,879 vehicles, and per the sample size evaluation based on the total population size, Table 2 presents the scenario for this study with 95% confidence levels (CI) and 3% precision or margins of error for the 2022 data (Bolbol et al., 2012). A total of 1,067 vehicles were sampled across Lebanon.

Table 2 - The adopted sample size along with the distribution of vehicles

Stratification variable	PC	Taxi	LCV	Vans	Trucks	Buses	Moto.	Total
Vehicles fleet 2019	1,720,534	33,146	133,833	12,561	46,451	5,400	159,954	2,111,879
Proportion (per type)	81.47%	1.57%	6.34%	0.59%	2.20%	0.26%	7.57%	100%
Sample size 95% CI - 3% i	869	17	68	6	23	3	81	1,067

As for the years 2020 and 2021, records will be collected for the highest number possible of vehicles. Splicing techniques were used where needed.

2. Derived Variables

The analysis of the collected data determined the following key parameters for the year 2022:

- Number of kilometers driven at a national level per category, namely PC, taxis, LCV, vans, trucks, buses, and motorcycles.
- Percentage of catalyst removed in vehicles
- Age and sex of conductor
- Fuel consumption for PC & taxi, LCV & vans, and trucks & buses

3. Additional practical considerations

Practical actions were undertaken in addition to the aforementioned points. A comprehensive field survey was conducted across various locations in Beirut, Tripoli, Zahleh, and Saida, with an equitable distribution of records from each region. Table 3 illustrates the minimum number of vehicles per vehicle category in each region, ensuring a 95% confidence level and a 3% margin of error. Sampling was carried out randomly at diverse sites such as supermarkets, university campuses, school parking lots, places of worship, and intersections, as well as through networks of relatives, friends, and colleagues. Additionally, a Google Form, endorsed by UNDP, was developed and made available online, comprising a questionnaire designed to gather the following essential information:

- Surveyed #: shall be unique and provided during data entry
- Name of surveyed
- Gender: Male/Female
- Phone number of surveyed to be able to conduct the Follow-up Survey
- Age of conductor
- Brand of the vehicle
- Type of the vehicle: PC, taxi, LCV, van, big bus, trucks, motorcycle

- Production year of vehicle
- Year of registration in Lebanon
- Fuel consumption in liters per km, liters/100 km, L/mile, km/20L, km/L, etc.
- Kilometers driven per year
- Current odometer in km during survey
- Presence of the Catalytic convertor[1]: yes, no, I do not know
- Available records of the years 2019, 2020, & 2021: yes, no

Data on distance traveled during the 2019-2022 period was collected based on the sample of annual maintenance booklet and supplemented by one of the main car importers in Lebanon, who agreed to compile and share odometer data. Consequently, data from 1,000 vehicles were collected for the 2019-2022 period trying to fully cover the years 2020 and 2021, while little data was available for other vehicle categories. Additionally, people that participated in the 2022 field survey were contacted to try and get qualitative information on their annual odometers, lockdown periods, work hours, etc. Private Cars data was linearly interpolated to accommodate for monthly averages.

Table 3 - Sample distribution of vehicle categories in each region (95% CI and 3% margin of error)

Stratification variable	PC	Taxi	LCV	Vans	Trucks	Buses	Moto.	Total
Beirut	218	5	17	2	6	1	21	270
Saida	218	5	17	2	6	1	21	270
Tripoli	218	5	17	2	6	1	21	270
Zahleh	218	5	17	2	6	1	21	270
Design sample number	872	20	68	8	24	4	84	1,080

4. Results of the survey

4.1 New transport patterns for 2022

The analysis and results for the year 2022, based on the survey data, are presented as follows: The survey was executed in two phases:

- Phase I involved data collection through a survey administered in the field, and via a Google Form.
- Phase II comprised of follow-up phone calls conducted 1.5 to 5 months after the initial data collection.

Fieldwork took place from April to November 2022 (Table 4). The first round of odometer data collected on-site was categorized as either prospective (reflecting the current displayed odometer) or retrospective in cases where discrepancies emerged after the second round of odometer data collection during the follow-up.

1 A catalytic converter is an emission control device which, through a redox reaction, reduces by almost 90% toxic gases and pollutants in exhaust gases emitted by internal combustion engines.

The survey predominantly comprised of male subjects, accounting for 82% of the participants, as subjects were randomly selected in the field; the primary interest focused on the type of vehicle. Participants' age ranged from 18 to 87 years old, with an average age of approx. 37 years ± 12 years.

The distribution of vehicles across each city compared to the planned distribution outlined in the study design is summarized in Figure 7 and Figure 8.

Table 4 - Subject disposition

First survey completed - Phase I	April 2022
Last survey completed - Phase II	November 2022
Total number of subjects	1,271
Number of subjects enrolled in Beirut	325
Number of subjects enrolled in Zahleh	339
Number of subjects enrolled in Tripoli	286
Number of subjects enrolled in Saida	321

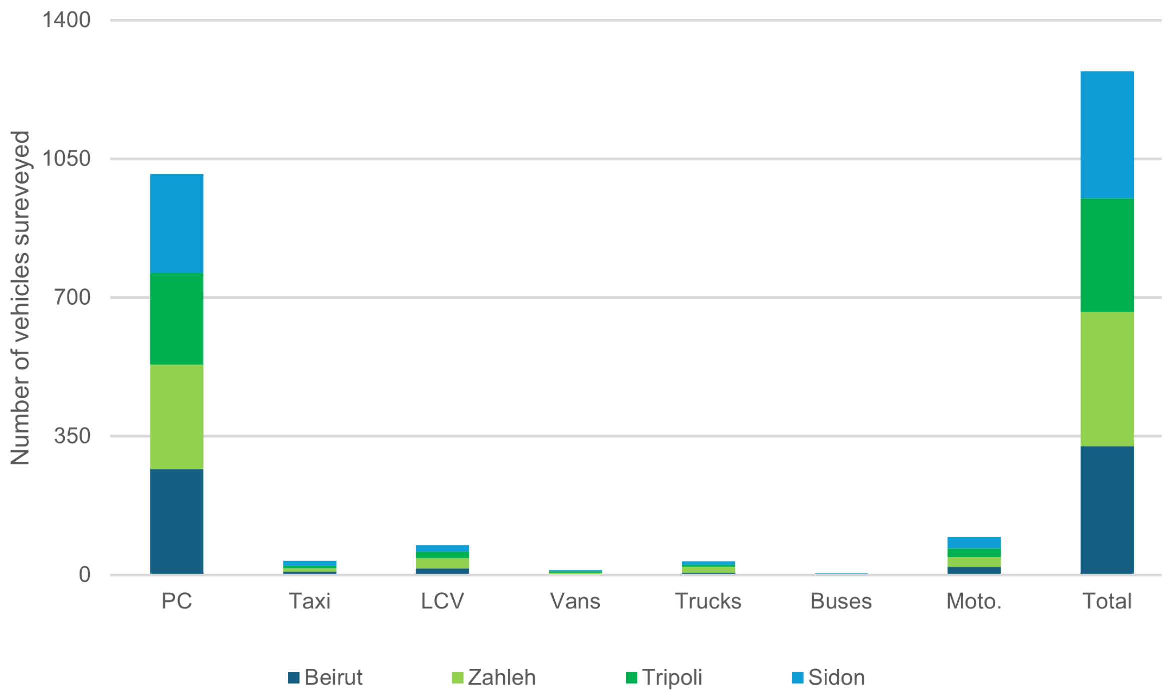


Figure 7 - Distribution of the sample per city and type of vehicle (1)

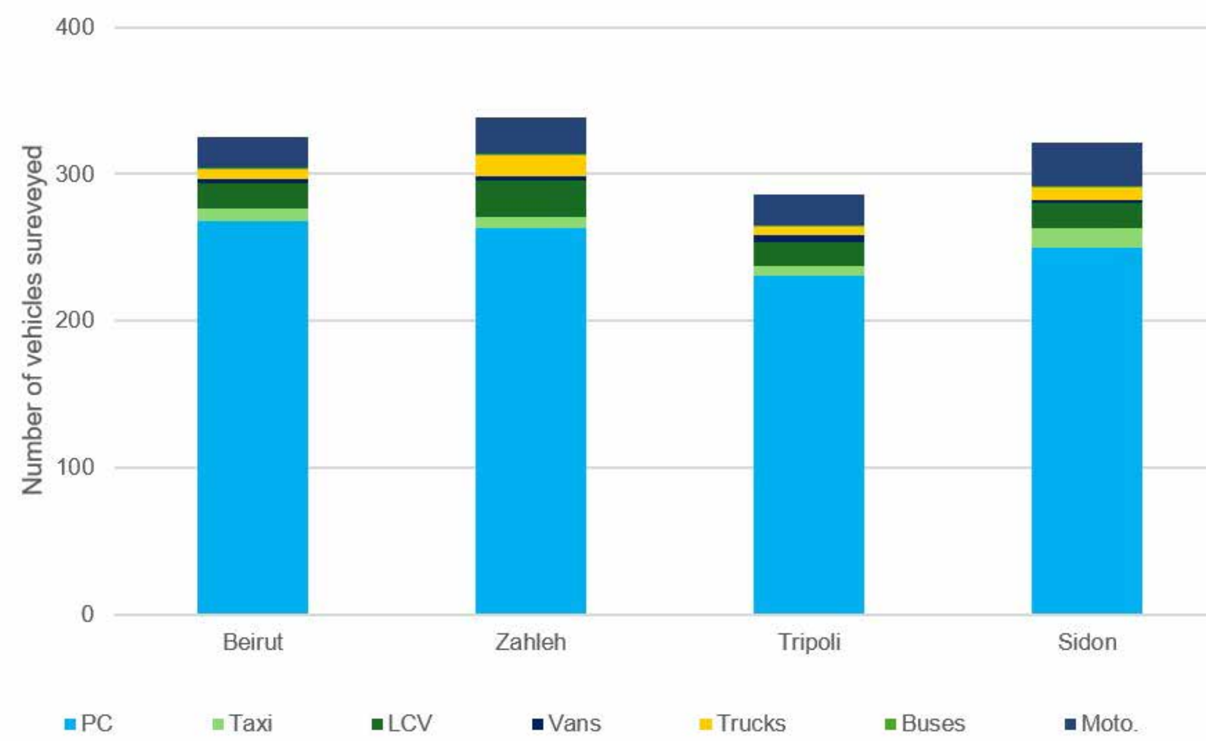


Figure 8 - Distribution of the sample per city and type of vehicle (2)

For analytical purposes, the six distinct categories of vehicles were consolidated into four groups as follows: "PC & Taxi," "LCV & Vans," "Trucks & Buses," and "Motorcycles." Among passenger cars, Mercedes emerged as the most prevalent brand among surveyed participants, comprising approximately 15% of the total, while Toyota and BMW followed closely behind with approximately 9% each. In evaluating the eco-friendly attributes of vehicles, participants were questioned about the presence of a catalytic converter. Notably, a significant portion, accounting for 14.24%, indicated uncertainty regarding whether their vehicle was equipped with this component. For vehicles with a year of production beginning 1992, 78% of PC, 38% of LCV, 47% of HDV, and 49% of Motorcycles had catalyst available.

The distribution of kilometers driven per year, categorized by vehicle type and region, has been documented in Table 5, alongside a comparison to data from 2019. Results underscore the wide variability in the data, with instances where vehicles have accumulated zero kilometers per year to others operating for more than eight consecutive hours per day. This variance is likely attributed to the ongoing economic crisis and the surge in fuel prices in Lebanon since 2019.

Further analysis reveals that only passenger cars and motorcycles have reverted to a "business-as-usual" scenario compared to 2019, while other vehicle categories have experienced reduction ranging from 30% to 75%.

Furthermore, fuel consumption data was collected for passenger cars, taxis, light commercial vehicles, vans, trucks, buses, and motorcycles. Responses indicating a range of fuel consumption were standardized to a single value, while "don't know" responses were treated as missing data. The median fuel consumption values for 2022 were determined as 180 km/20L for PC & Taxi, 195 km/20L for LCV & Vans, 90 km/20L for Trucks & Buses, and 440 km/20L for Motorcycles. These values align with those considered in the BUR 4 (MoE/UNDP/GEF, 2021).

The kilometers driven during the year 2022 exhibited discernible fluctuations primarily among commercial vehicle categories such as vans and trucks, whereas private vehicle mileage remained relatively static. Notably, private cars exhibited a marginal variance (12,000 kilometers in 2019 from BUR 4 compared to 12,893 kilometers in 2022), whereas buses, vans, and trucks experienced substantial reductions in travel, marking a decline of 54%, 66%, and 75% respectively. This trend likely stems from the increase in fuel prices and removal of subsidies following the economic crisis post-2019, prompting enterprises to streamline or curtail their commercial operations. This decrease including the intensity has been confirmed by additional vehicle owners of these categories through informal interviews post-survey.

Table 5 Comparison between 2019 and 2022 kilometers driven per year per vehicle category

	PC N=1012	Taxi N=36	LCV N=76	Vans N=12	Trucks N=35	Buses N=4	Motorcycles N=96
Km driven in 2019 (BUR 4)	12,000	50,000	25,000	50,000	50,000	50,000	5,000
Km driven in 2022	12,894	32,993	15,343	16,999	12,372	22,682	5,289
Percent change	+7%	-34%	-396%	-66%	-75%	-55%	+6%

4.2 Greenhouse Gas Emissions for 2022

The data and parameters collected from the sample survey, such as travelled distances per category, technology removal (catalyst) share, were extrapolated and used for the entire vehicle fleet of 2022 to update the GHG emission inventory for road transport. Assumptions related to vehicle efficiency, emission factor, etc. were adopted in previous inventories to ensure time-series consistency (Annex 1).

Accordingly, GHG emissions from road transport were estimated at 6,509.72 Gg of CO_2, 1.47 Gg of CH_4, and 0.42 Gg of N_2O, with a national total equivalent to 6,663 Gg of CO_2 eq. This is considered as a decrease -9.9% from 2018 (7,392 Gg CO_2 eq.) and -12.7% from 2019 (7,635 Gg CO_2 eq.).

Although emissions in 2022 decreased compared to years before the economic crisis (e.g., 2019), the emissions of PC and two-wheelers increased compared to 2019, while all other vehicle categories exhibited a decrease in their emissions, making passenger cars by far the main contributor to emissions in 2022 (Figure 9). Trucks have been largely impacted with their emissions in 2022 being around 28% of those in 2019.

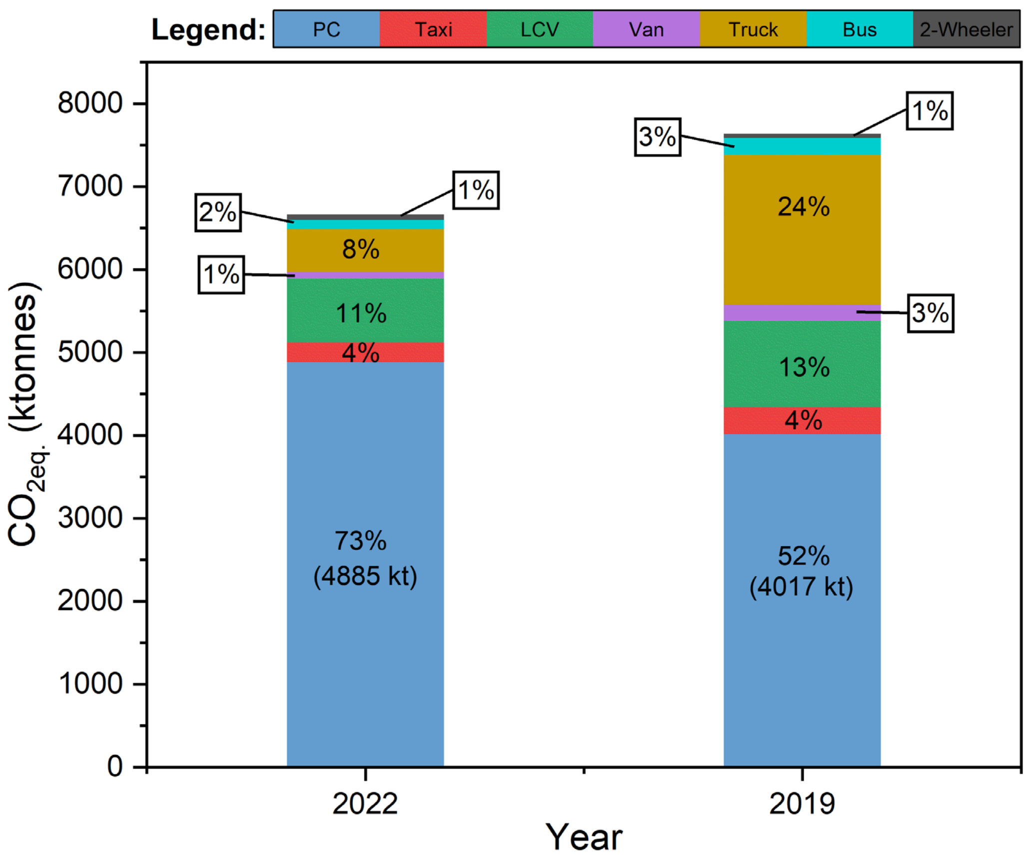


Figure 9 - Share of CO_2 eq. (in ktonnes) of each vehicle category in 2022 and 2019

4.3 GHG Emissions for the period 2020 – 2021

The transport sector's greenhouse gas emissions in 2020 and 2021 were profoundly influenced by the substantial socio-economic shifts following 2019, compounded by the COVID-19 pandemic during those years. In March 2020, the airport, sea, and land entry points were temporarily closed, followed by the enforcement of curfews, primarily during the night. In October and November 2020, towns and villages experienced another round of lockdowns, leading to a nationwide lockdown in Lebanon. The subsequent months in 2021 saw the introduction of vaccines in April, after which full lockdowns ceased, replaced by ongoing measures and occasional curfews for the remainder of the year. All COVID-19 restrictions were lifted in 2022 as the virus was deemed to be contained. These successive lockdowns, coupled with rising inflation rates (reaching up to 155% in 2021) and the gradual reduction of gasoline subsidies, resulted in decreased mobility among the populace.

Based on the odometer data collected for passenger cars, Figure 10 illustrates a decline in kilometers traveled following the peak observed in the summer of 2019, prior to the onset of the economic crisis and the pandemic. The summer peaks persisted in 2020 and 2021, followed by a notable increase in 2022, resulting in a business-as-usual Vehicle Kilometer Traveled (VKT) trend. In 2020, the median VKT stood at 9,000 km, while in 2021, it increased to 9,400 km. (Figure 10 exclusively displays months where the number exceeded 500 and their respective average and median monthly averages.)

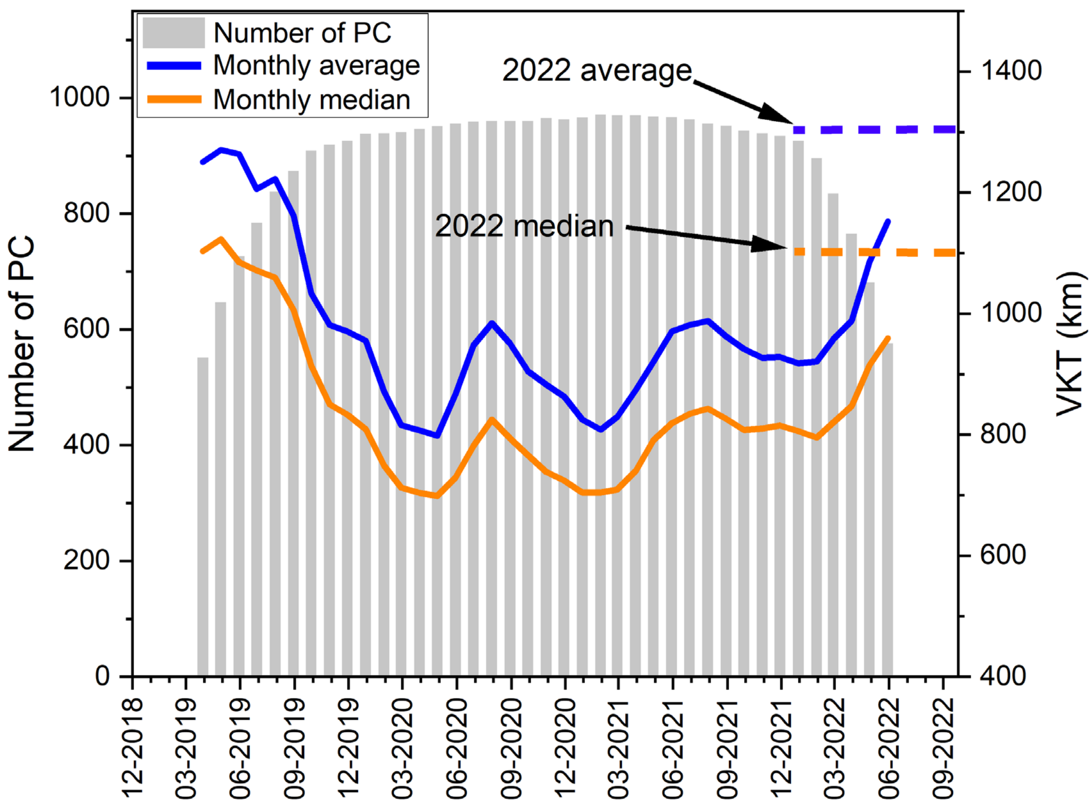


Figure 10 - Number of Passenger Cars considered for the 2020-2021 period along their resulting Vehicle Kilometer Traveled (VKT)

Based on phone surveys with taxis, vans, LCV, trucks, buses, and two-wheeler owners from the 2022 survey, qualitative results show that the Vehicle Kilometres Travelled (VKT) for taxis decreased between 0-30% compared to 2019, while vans, LCV, buses, and trucks experienced a 30-50% decrease. However, two-wheelers maintained their VKT, and some even increased, resulting in an increase between 0-20%.

On one hand, the concurrent occurrence of the economic and health crises posed challenges in determining the respective impacts on the decline in Vehicle Kilometers Traveled (VKT). Figure 11 and Figure 12 illustrate that the reduction in VKT post-summer 2020 primarily resulted from COVID-19 measures, with the increase in fuel prices having a minor effect. The decline in VKT was more pronounced in 2020 compared to 2021, attributed to the relaxation of measures following vaccine distribution and the emergence of less severe COVID-19 strains. On the other hand, businesses exhibited resilience to inflation, increasingly compensating their employees with additional funds in dollars, facilitating easier travel for workers.

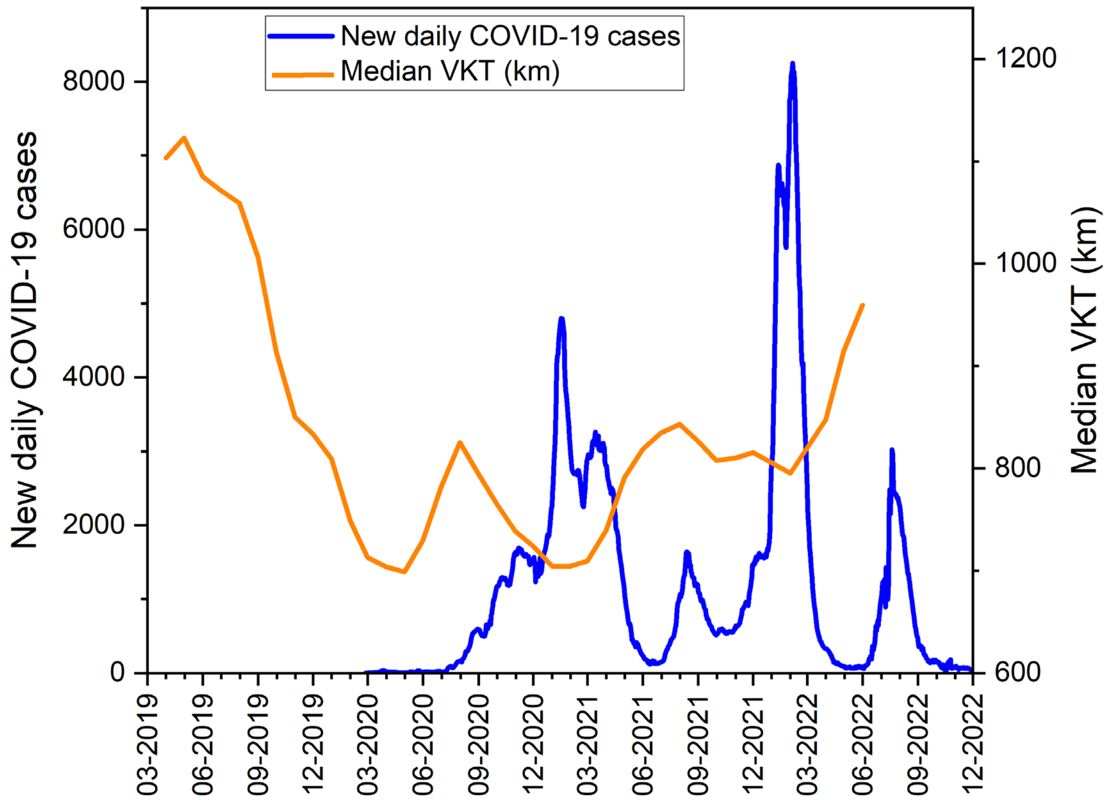


Figure 11 - New daily COVID-19 cases in Lebanon along with the median PC VKT during the crises

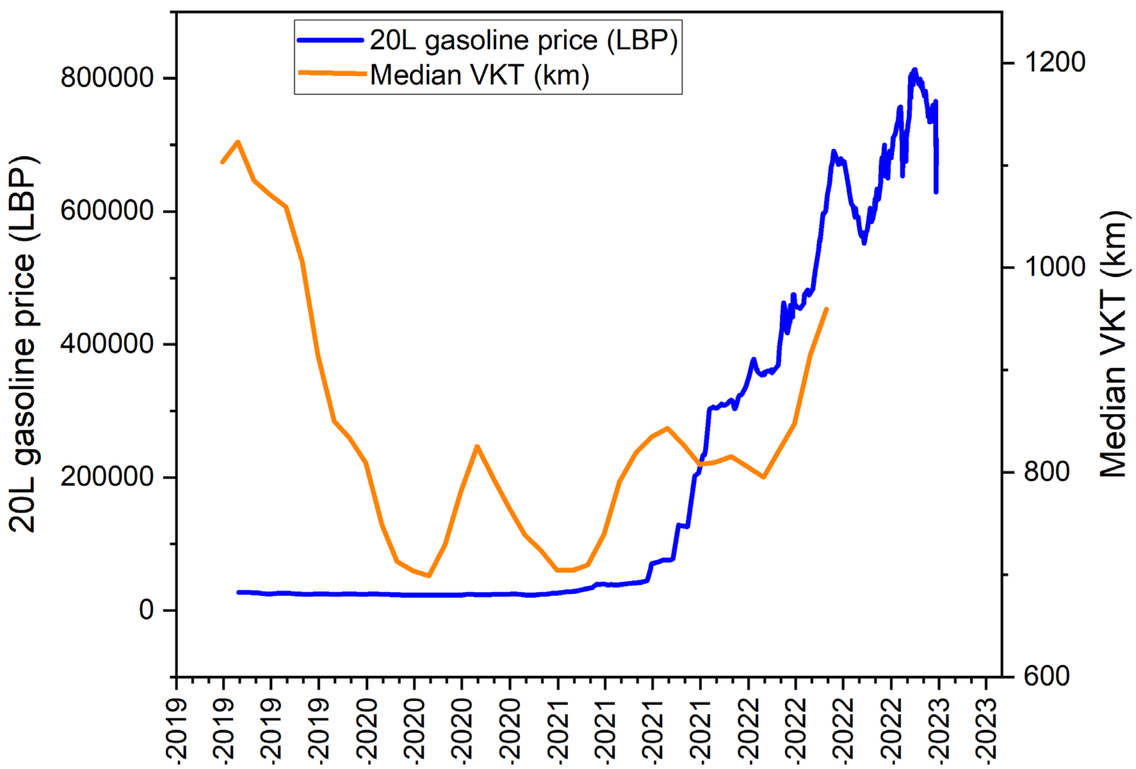


Figure 12 - Gasoline price in Lebanon along with the median PC VKT during the crises

GHG emissions for 2020 and 2021 were estimated using the projected 2020 and 2021 fleet (linear extrapolation using 2015-2019 data), current determined travelled distances per category, technology removal (c.a. the catalyst) share, and the assumption considered in previous inventories and for the year 2022 (Annex 1: Parameters used). Figure 13 presents the different emissions values for CO_2, CH_4, N_2O, and CO_2 eq. while showing the decrease in emissions and the comeback to almost pre-crisis levels which will probably be attained in future years.

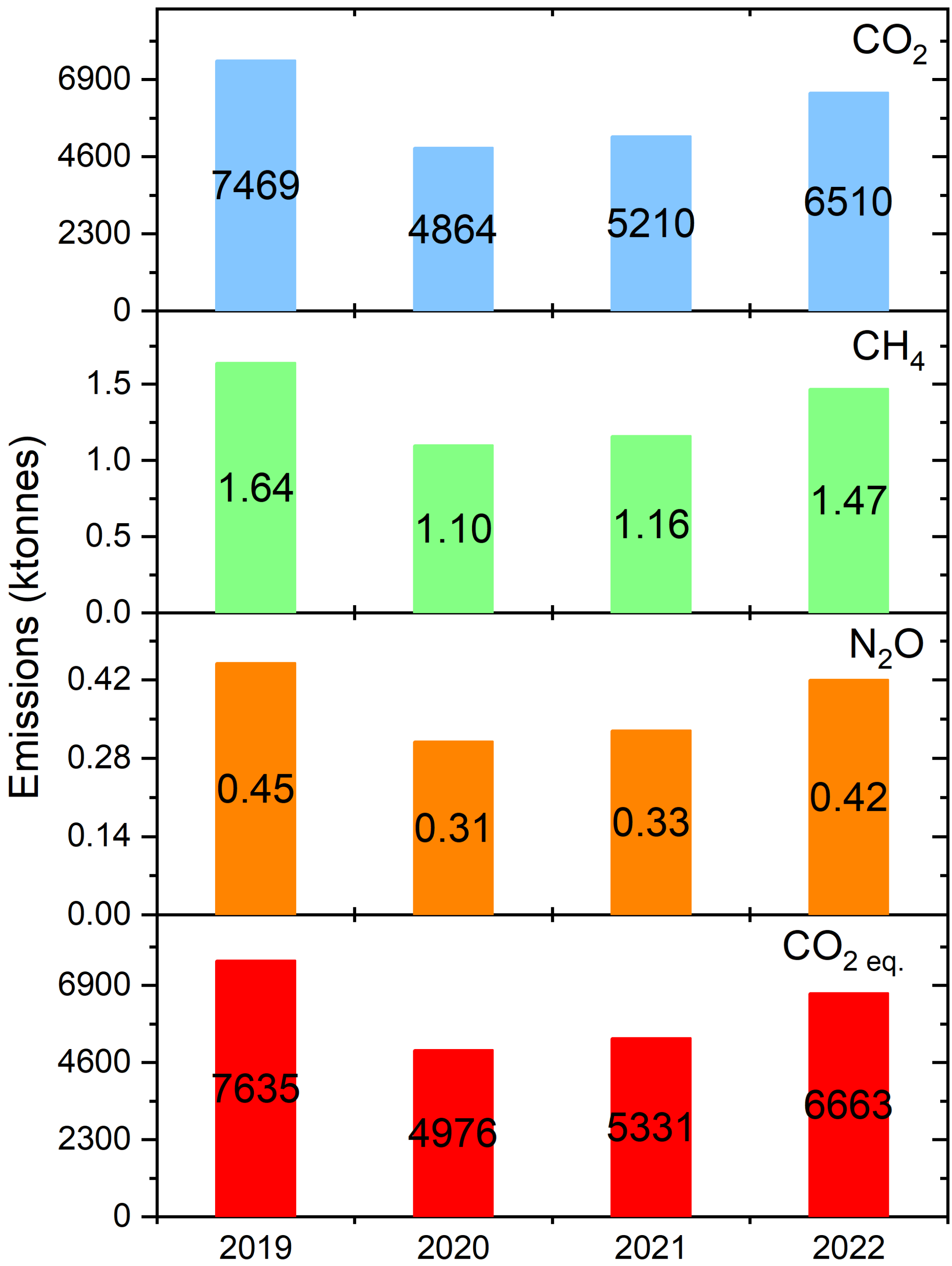


Figure 13 - Gasoline price in Lebanon along with the median PC VKT during the crises.

5. Emission uncertainty

The IPCC Approach 2 using Monte Carlo simulations was used for CO_2, CH_4, N_2O, and CO_2 eq. to estimate the overall uncertainty levels for the year 2022.

Proper Probability Density Functions (PDF) were used. The number of iterations was reached at 1100 when the estimate for the 95 percent confidence range was determined to be within ± 1% of the mean; then an adequately stable result was attained. The frequency plots obtained are presented in Figure 14.

The statistics of the Monte Carlo analysis are presented in Table 6. The emission data fits a lognormal distribution. Additionally, the mode (most common value) of the data is closer to the 2.5th percentile (lower end) than the 97.5th percentile (higher end). This suggests that a higher chance of observing lower emission values exists compared to higher ones. In simpler terms, it's more likely to see lower levels of gas emissions than higher levels based on the analysis.

Table 6 - Statistics of the Monte Carlo assessment for the year 2022

Index	CO_2	CH_4	N_2O	CO_2 eq.
Mean (tonnes)	7,640,276	2,230	623	7,868,587
Median (tonnes)	6,700,128	1,834	525	6,904,336
Standard deviation (tonnes)	3,972,583	1,510	368	4,094,757
Uncertainty (%)	-64%; +139%	-71%; +186%	-66%; 157%	-64%; +140%

Based on these results, the level of uncertainty related to CO_2 eq. emissions are fairly similar to the level of uncertainty related to CO_2 emissions, which is expected since the major driver of CO_2 eq. is CO_2 in the case of road transport with a fleet running on gasoline and diesel.

This indicates that the observed CO_2 emissions uncertainty is mostly responsible for the uncertainty of CO_2 eq., while CH_4 and N_2O contributions are minor.

The uncertainty assessment following Approach 1 is not applicable as per the 2006 IPCC guidelines since assumptions/conditions of Approach 1 would not be met.

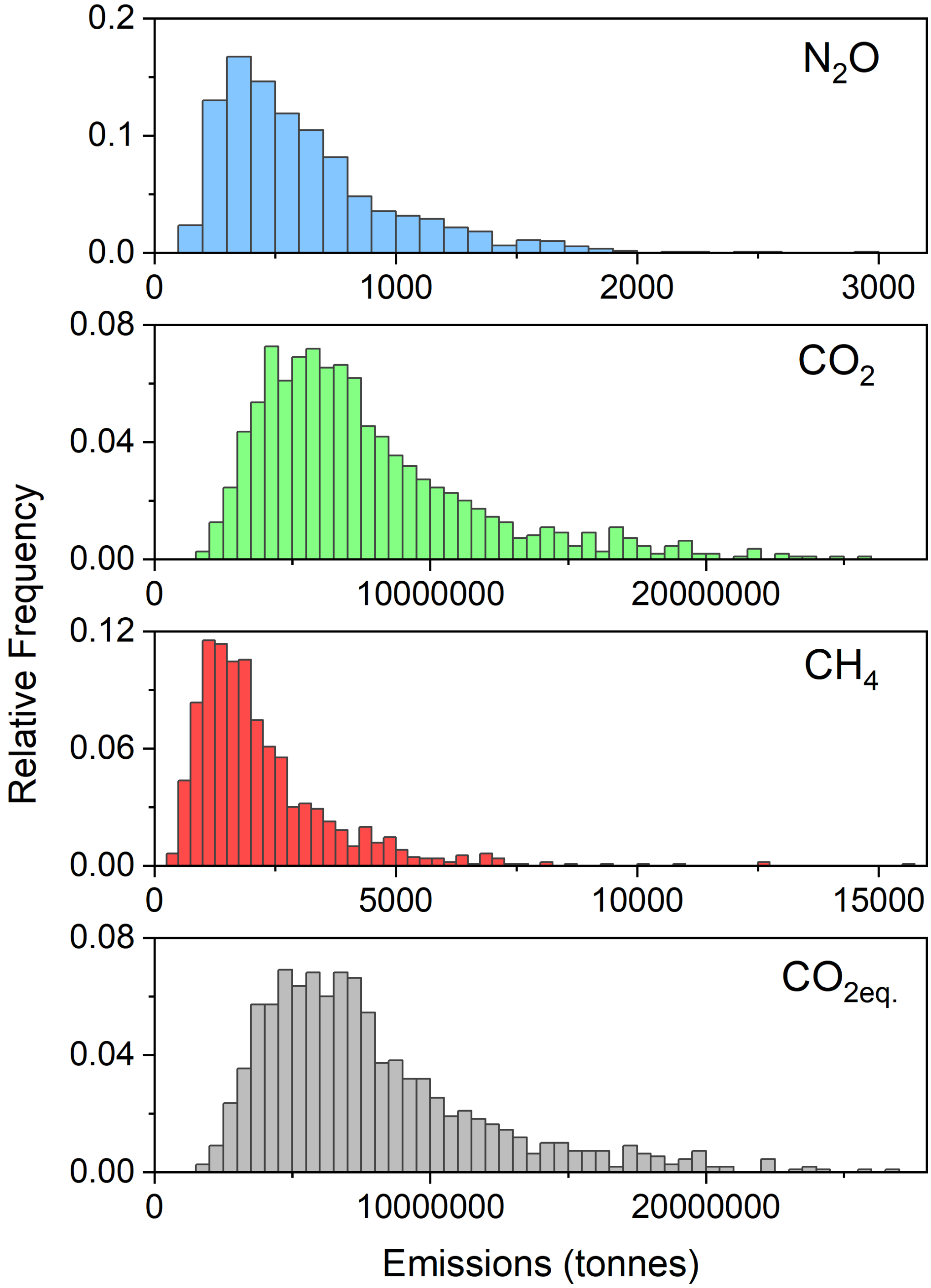


Figure 14 - Frequency plots obtained following the Monte Carlo simulations for the emissions of the GHG for the year 2022

The most relevant parameters for the uncertainty of CO_2 eq. emissions from road transport for the year 2022, measured by the rank correlation coefficient, have been individuated from the application of Monte Carlo (Table 6). These are the Vehicle Kilometre Travelled for PC (VKT1) with a contribution of 88%, LCV (VKT3) and trucks (VKT5) each having a contribution of 2-3%. As far as feasibility is concerned, it is important to reduce the associated uncertainty of VKT1 (Figure 15).

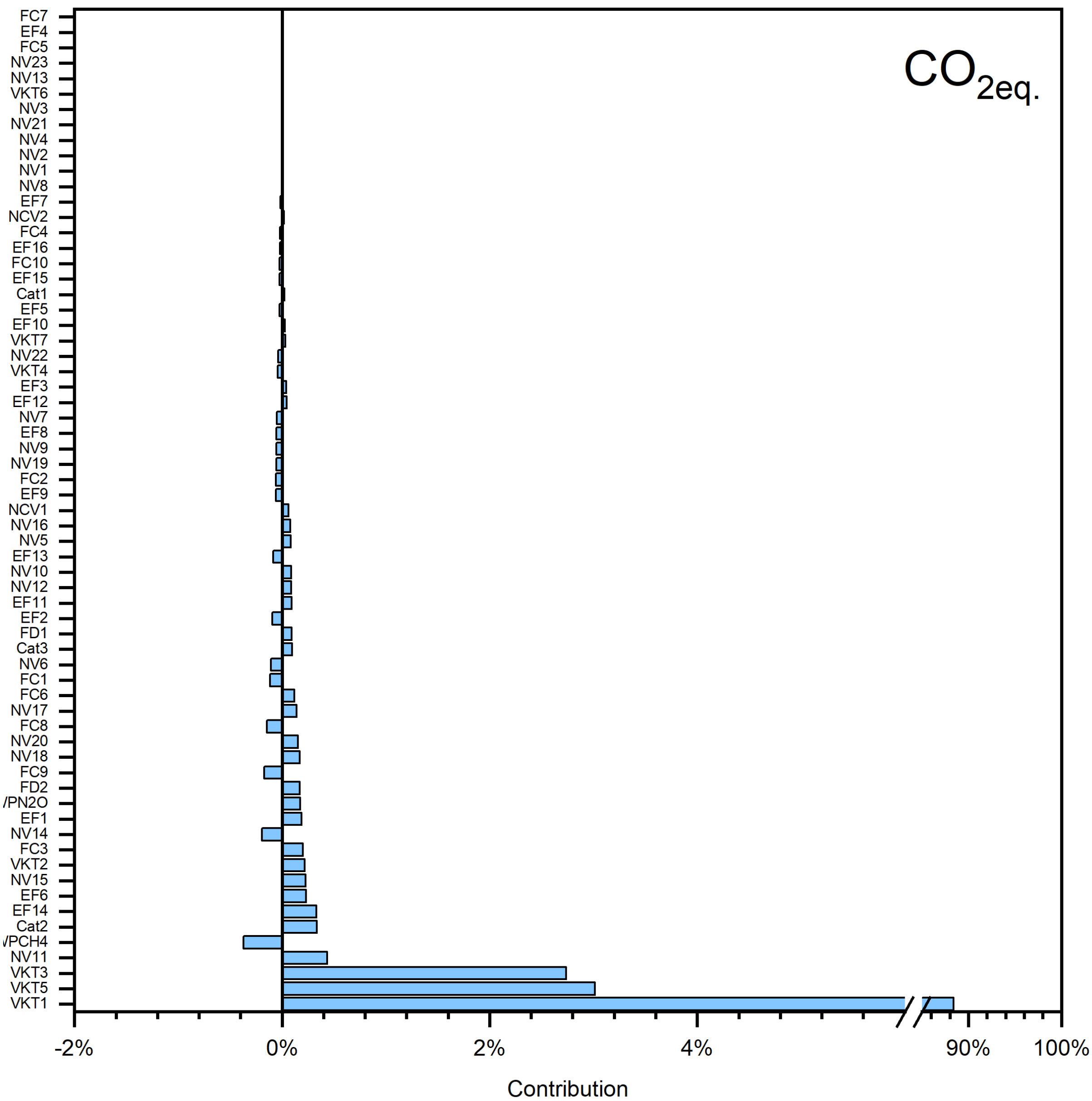


Figure 15 - Sensitivity chart from Monte Carlo assessment

6. Conclusion

The economic crisis and pandemic that hit Lebanon, primarily in 2020 and 2021, caused several lockdowns and disrupted the road transport sector, especially driver behavior, kilometers driven, etc. Accordingly, the main purpose of this report is to collect information on transport patterns in Lebanon for the years 2020 to 2022, and accordingly, update Lebanon's Greenhouse Gases (GHG) Inventory for this period.

A survey was conducted during the year 2022 acquiring data from 1,271 vehicles all over Lebanon, following a statistical design and sampling plan. Results showed that in 2022, passenger cars (PC) and two-wheelers were back to their pre-crisis yearly distance travelled (around 12,000 kms/year), with reference to the year 2019, while taxis, Light-Commercial Vehicles (LCV), vans, trucks, and buses showed a 75% decrease in some cases. This back-to-normal situation for Passenger cars and two-wheelers is mainly due to the fact that enterprises gradually started coping with inflation, and providing full or partial dollarized salaries in 2022, which enabled employees to overcome the financial restrictions impacting their commuting decisions.

The data collected for the years 2020 and 2021 showed that only two-wheelers maintained their distances traveled per year in 2020 and 2021 as per the pre-crisis year 2019; two-wheelers were the only vehicle category that was not affected during the crisis and post-crisis and maintained its activity during the COVID-19 pandemic. The Passenger Vehicle Kilometer Travelled (VKT) during this period decreased by around 25-30%, while vans, light commercial vehicles, buses, and trucks experienced a 30-50% decrease.

As a result, the resulting greenhouse gas emissions, namely CO_2 eq., decreased by 35% in 2020, 30% in 2021, and 13% in 2022, compared to 2019. The uncertainty assessment using the Monte Carlo simulation for the year 2022 showed values between -64% and +140%, which is mainly due to the wide range of the kilometers driven for Passenger Cars and to a lower extent light commercial vehicles and trucks

In essence, while the overall trend indicates a positive decline in GHG emissions over the three-year period, the considerable uncertainty underscores the complexity of factors influencing emissions, particularly the varied response of different vehicle categories to crisis conditions. As such, continued monitoring and analysis are essential for understanding and mitigating the environmental impacts of transportation dynamics in times of crisis.

7. References

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8. Annexes

8.1 Annex 1: Parameters used

Activity data, emission factors and other parameters

The following activity data is considered:

- The number of registered vehicles in Lebanon was provided by the Ministry of Interior and Municipalities/Traffic, Truck and Vehicle Management Authority for the year 2019 (MoIM, 2020). The database includes the number of registered vehicles by category, type of use (private or public), production date, circulation date, horsepower, and type of fuel used. No category is allocated for fuel-efficient vehicles in the MoIM database; therefore, their share cannot be determined over the last few years.
- The vehicle fleet was classified per vehicle type, category and European Union (EU) emission control technology (taking into consideration the common practice in Lebanon of removing the emission control catalyst without any replacement. The fraction of each vehicle category for which the catalyst was removed was obtained from a survey conducted in Beirut on 3,000 vehicles (Waked, 2012; Waked and Afif, 2012). The results from this survey were extrapolated to the rest of the vehicle fleet.
- Fuel consumed by each type of car by type of fuel is estimated based on:
  - Number of gasoline vehicles (cars, light duty vehicle, vans, motorcycles)
  - Number of diesel vehicles (assuming only heavy-duty vehicles and buses)
  - Average travelled distance
  - Fuel economy
  - Fuel density
- Gas/diesel oil is only used by heavy-duty vehicles and buses. The amounts used per year were assumed based on average 29.9 l/100km and an annual mileage of 50,000 km/year. The amounts used by passenger cars (taxis in general), LDV, and vans are considered insignificant.
- In the 2006 revised IPCC guidelines, the tier 1 emission factors are shown as a function of kgemissions/TJfuelused. Therefore, the required activity data is fuel consumption per vehicle type and technology, which is estimated by determining the fuel efficiency, the annual travelled Kms for each vehicle and the NCV for each fuel type.
- In the EMEP/EEA 2019 guidelines, Tier 2 emissions factors are expressed in g of emitted pollutant per km driven for exhaust CO, NO_x, SO2, and NMVOC. SO2 emissions require the sulphur content in fuel per fuel type where regulatory limits were used (Decree 3054/2016 for 2017-2019, Decree 8442/2002 for data from 2002 to 2016, and Second National Communication to UNFCCC sulphur content values for 1994 to 2001). Evaporated NMVOC from gasoline fueled vehicles including diurnal emissions, running losses, and hot soaking were accounted for following the Tier 1 methodology for annual averaged temperatures of 10°C to 25°C which is expressed by unit of mass emissions per vehicle per day.
- Default CO_2 emission factors are used for each fuel type from the IPCC 2006 guidelines. For N_2O and CH_4 emissions, default EU emission factors per vehicle type and technology are considered since in Lebanon most of the vehicle fleet is constituted of European vehicles
- Default fuel consumption per vehicle type and per technology was used as per the ForFITS model for the direct GHGs

- HDV diesel consumption for the direct and indirect GHG is assumed to be 29.9 liter of diesel/100km, based on the data provided by IPT on their trucks fleet consumption, and double checked against the GREET Model default value (from Argonne National Laboratory) and compared to the results study conducted by VTT Technical Research Centre of Finland. The consumption value is averaged taking into consideration the loaded and unloaded truck trips.
- Due to field data unavailability, the annual travelled distance per vehicle category is considered using the ForFITS database. ForFITS is a modeling tool intended to evaluate the transport activity, energy use and CO_2 emissions, using transport data collected from different national and international transport related agencies (UNECE, 2014). For countries with mobility characteristics similar to Lebanon, a value of 12,000 km/year is estimated for private passenger cars, 50,000 km/year for taxis, 25,000 km/year for light commercial vehicles, 50,000 km/year for vans and heavy-duty vehicles, and 5,000 km/year for motorcycles.

Default CO_2 emission factors for 1.A.3 Transport

Fuel type	CO_2 emission factor (kg/TJ)
Gasoline	69,300
Diesel oil	74,100
At tier 1, the emission factors assume that 100% of the carbon present in fuel in oxidized during or immediately following the combustion process.	

Source | table 3.6.4 page 3.64 and table 3.5.2 page 3.50 chapter 3, volume 2, IPCC revised 2006 guidelines

Default emission factors for CH_4 and N_2O emissions for 1.A.3 Transport

Type of vehicle	CH_4 emission factor (kg/TJ)	N_2O emission factor (kg/TJ)
Gasoline Private Passenger and Taxis cars		
Uncontrolled	33.00	3.20
Early non-catalyst control	33.00	3.20
Non-catalyst control	33.00	3.20
Oxidation catalyst	25.00	8.00
Three-way catalyst	3.80	5.7
Gasoline LCV and Vans		
Uncontrolled	33.00	3.20
Early non-catalyst control	33.00	3.20
Non-catalyst control	33.00	3.20
Oxidation catalyst	25.00	8.00
Three-way catalyst	3.80	5.70
Diesel Heavy trucks and Buses	**3.90**	**3.90**
Gasoline LCV and Vans		
<50cc	33.00	3.20
2-strokes	33.00	3.20
4-strockes	33.00	3.20

Source | table 3.2.2 page 3.21 chapter 3 volume 2, IPCC 2006 guidelines

Parameters for road transport for 2019

	Average Travelled Distance (km)[1]	Fuel Economy (L/100 km)[2]	Fuel Density (kg/L)[3]	Net Calorific Value (TJ/ktonnes)[4]
Gasoline Private Passenger cars				
Uncontrolled	12,000	11.2	0.74	43.5
Early non-catalyst control	12,000	9.4	0.74	43.5
Non-catalyst control	12,000	8.3	0.74	43.5
Oxidation catalyst	12,000	8.1	0.74	43.5
Three-way catalyst	12,000	8.5	0.74	43.5
Gasoline Taxis				
Uncontrolled	50,000	11.2	0.74	43.5
Early non-catalyst control	50,000	9.4	0.74	43.5
Non-catalyst control	50,000	8.3	0.74	43.5
Oxidation catalyst	50,000	8.1	0.74	43.5
Three-way catalyst	50,000	8.5	0.74	43.5
Light commercial vehicles Gasoline cars				
Uncontrolled	25,000	13.6	0.74	43.5
Early non-catalyst control	25,000	13.6	0.74	43.5
Non-catalyst control	25,000	13.6	0.74	43.5
Oxidation catalyst	25,000	13.6	0.74	43.5
Three-way catalyst	25,000	13.6	0.74	43.5
Vans Gasoline cars				
Uncontrolled	50,000	13.6	0.74	43.5
Early non-catalyst control	50,000	13.6	0.74	43.5
Non-catalyst control	50,000	13.6	0.74	43.5
Oxidation catalyst	50,000	13.6	0.74	43.5
Three-way catalyst	50,000	13.6	0.74	43.5
Diesel Heavy trucks and Buses[5]				
Uncontrolled	50,000	29.9	0.83	41.6
Early non-catalyst control	50,000	29.9	0.83	41.6
Non-catalyst control	50,000	29.9	0.83	41.6
Oxidation catalyst	50,000	29.9	0.83	41.6
Three-way catalyst	50,000	29.9	0.83	41.6

Motorcycles Gasoline cars				
<50cc	5,000	2.4	0.74	43.5
2-strokes	5,000	4	0.74	43.5
4-strockes	5,000	5.1	0.74	43.5

1. Default numbers from ForFITS based on similar countries characteristics
2. MoE/UNDP/GEF (2015c).
3. MoE/UNDP/GEF (2011).
4. Country specific Net Calorific Value
5. Average Travelled Distance for HDV and Buses for the year 2018 is 38,000 km

Emissions from other categories under mobile combustion are calculated with default emission factors available in the 2006 IPCC guidelines for GHG emissions.

Direct GHG default emission factors for international bunkers and domestic aviation

Fuel type	Net Calorific value (TJ/ktonne)	CO_2 emission factor (kg/TJ)	CH_4 emission factor (kg/TJ)	N_2O emission factor
(kg/TJ)	43.5	70,000	0.5	2
Jet kerosene	42.8	71,500	0.5	2
Heavy fuel oil	41.1	77,400	7	2

Source | table 3.6.5 page 3.64 and table 3.5.3 page 3.50 chapter 3 volume 2, IPCC 2006 guidelines

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