Republic of Lebanon
Ministry of Environment

LEBANON'S
4TH NATIONAL COMMUNICATION ON CLIMATE CHANGE

MINISTRY OF ENVIRONMENT
2022

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LEBANON'S
4TH NATIONAL COMMUNICATION
TO THE UNFCCC

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FOREWORD MINISTRY OF ENVIRONMENT

Six years after Lebanon's Third National Communication under the United Nations Framework Convention on Climate Change, I have the honor of presenting the Fourth National Communication as a serious and determined commitment of the Lebanese Government to this global challenge.

During the period between the two national communications, Lebanon has ratified the Paris Agreement through Law 115/2019, produced and submitted 3 Biennial Update Reports and has updated its Nationally Determined Contribution in 2021 putting forward ambitious mitigation goals and adaptation priorities. The NDC update, which has been synchronized with the government economic plans and reforms, aims at driving sustainable, low emission growth as well as increasing the resilience of the economy, communities and ecosystems to sustain any future shocks, including climate events.

Lebanon's Fourth National Communication goes beyond the reporting commitments as a Non-Annex I country, by developing a Greenhouse Gases Inventory for 1994-2019, by updating the climate change risks and impacts based on the most recent scientific findings of the IPCC 6th assessment report and by transparently reporting Lebanon's gaps and needs to improve the implementation and reporting of its climate agenda.

By expressing my highest consideration for the valuable support and collaboration of UNDP and GEF and the extended working group in preparing the Fourth National Communication, I hope this document is a valuable contribution to the achievement of the objectives under the United Nations Framework Convention on Climate Change in particular, and the global climate agenda in general.

Nasser Yassin, PhD
Minister of Environment

FOREWORD UNDP

Climate change is the most challenging crisis of our times, and its adverse impacts pose significant threats to the sustainable livelihoods, security and wellbeing of the people in Lebanon. The United Nations Development Programme (UNDP) has never stopped seizing every opportunity to advocate for urgent action to tackle the impacts of climate change and to mobilize the global community to strengthen its response by supporting the Paris Agreement.

UNDP is proud to provide continuous support to the Government of Lebanon to fulfill its reporting obligation as a Party to the United Nations Framework Convention on Climate Change (UNFCCC). Since the development of its initial National Communication on climate change in 1999 to the publication of this Fourth National Communication 23 years later, UNDP continuously supports the Ministry of Environment in its efforts to improve the climate change agenda.

The efforts exerted by the staff of the ministry and other stakeholders that were engaged in the process of preparing this report and in collecting climate data show the strong engagement of the Lebanese Government on issues related to climate change. In Lebanon, National Communications are moving from a mere reporting exercise to an essential reference document aiming at developing nationwide awareness, building efficient institutional arrangements, and guiding decision makers to address more coherent policies and strategies on climate change. Climate risks and adaptation recommendations stated in the national communication reports have been taken into advisement in the development of the Ministry of Water and Energy's 2020 updated National Water Sector Strategy as well as in the Ministry of Agriculture's National Agriculture Strategy for 2020 – 2025.

The Fourth National Communication is an important report that addresses not only the progress Lebanon is achieving in climate change but also underlines the main gaps and priority needs to further rally support, such as lack of data and knowledge to accurately assess Lebanon's vulnerability, and weak institutional arrangements to systematically identify and quantify the technical, financial and capacity building needs in Lebanon. It also offers Lebanon the opportunity to provide high level information and technical studies integrating climate change into appropriate social, economic, and environmental policies and actions.

Just as, in over 140 countries worldwide, UNDP will continue supporting the Government of Lebanon to overcome the climate challenge. Aligned with the Paris Agreement, UNDP believes that climate action benefits poverty eradication, gender balance, food security and many other sustainable development goals enabling countries to move towards a low-emission climate resilient world.

Melanie Hauenstein
UNDP Resident Representative

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS

AC	Alternative Current
ACE	Action for Climate Empowerment
AD	Activity Data
AFD	Agence Française de Développement
AFOLU	Agriculture and Forestry and Other Land Uses
AMI	Advanced Metering Infrastructure
ASIF	Activity, Structure, Intensity, and Fuel (ASIF) framework
ASI	Avoid-Shift-Improve Approach
AR	Assessment Report
AUB	American University of Beirut
BAU	Business-As-Usual
BECCS	Bioenergy with Carbon Capture and Storage
BEV	Battery Electric Vehicles
BRT	Bus Rapid Transit
BTR	Biennial Transparency Report
BUR	Biennial Update Report
CAS	Central Administration of Statistics
CBIT	Capacity Building Initiative on Transparency
CCXG	Climate Change Expert Group
CA	Conservation Agriculture
CCS	Carbon Capture and Storage
CCU	Carbon Capture and Use
CD	Cartagena Dialogue
CDD	Consecutive Dry Days
CDR	Council for Development and Reconstruction
CEDAW	Convention on the Elimination of all forms of Discrimination Against Women
CEDRE	Conférence Economique pour le Développement par les Reformes avec les Entreprises
CEDRO	Country Energy Efficiency and Renewable Energy Demonstration for the Recovery of Lebanon
CFU	Consecutive Frost Days
CHP	Combined Heat and Power
CGIAR	Consultative Group on International Agricultural Research
CMU	Cash Management Unit
CoM	Council of Ministers
CoP	Conference of Parties
CSP	Concentrated Solar Power
CSO	Civil Society Organizations
CSU	Consecutive Summer Days
CTCN	Climate Technology Center and Network
CVF	Climate Vulnerable Forum
CWD	Consecutive Wet Days
DG	Distributed Generation
DJF	December – January – February
DMFAS	Debt Management and Financial Analysis System
DNA	Designated National Authority
DNI	Direct Normal Irradiation
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
DSP	Distribution Service Providers
DSM	Demand Side Management
EDL	Electricité du Liban
EF	Emission Factor
EMEP	European Monitoring and Evaluation Programme
EMME	Eastern Mediterranean & Middle East

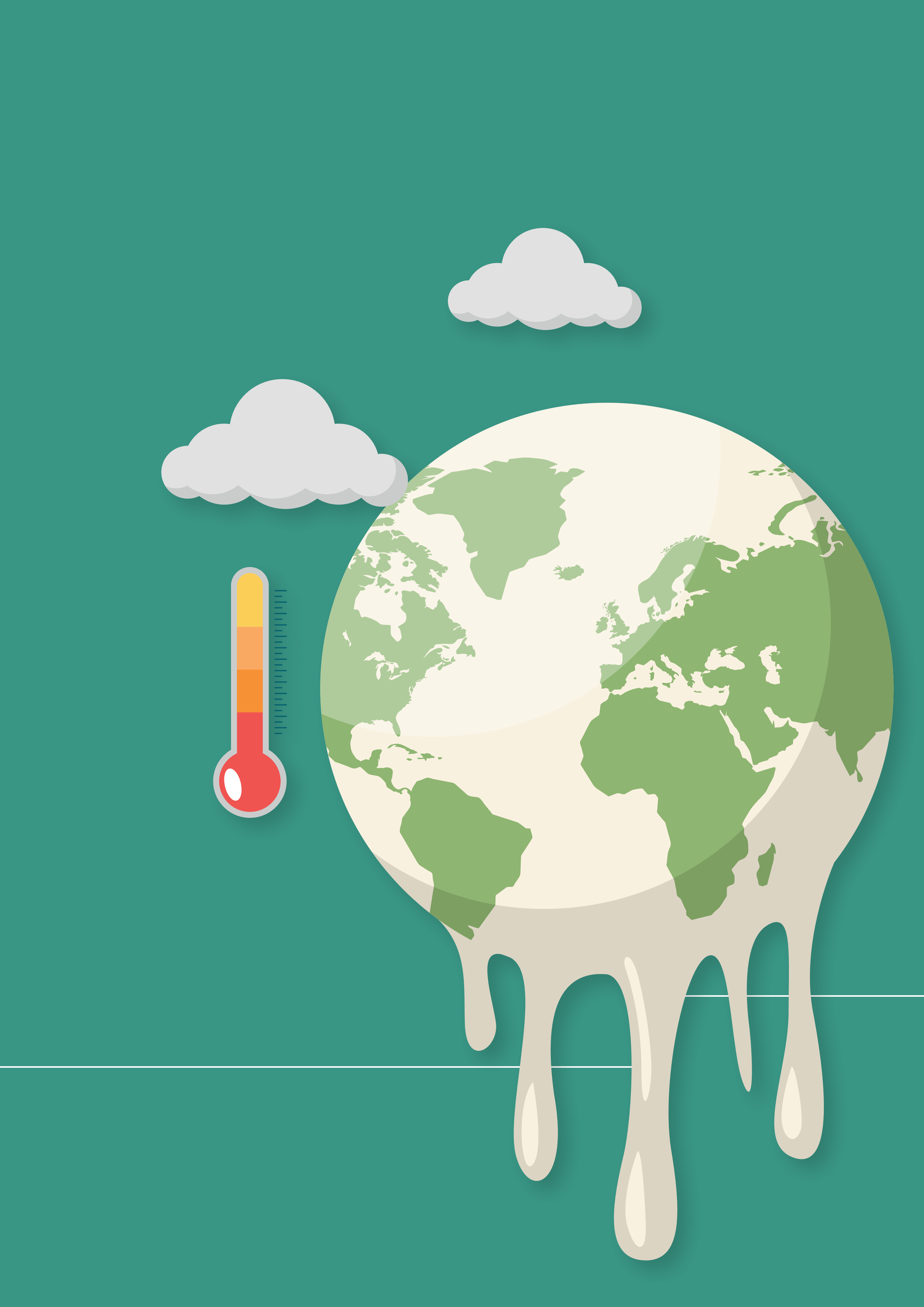
EPC	Energy Performance Contracting
ESI	Evaporative Stress Index
ESS	Energy Storage Systems
ESCOs	Energy Service companies
ESCWA	United Nations Economic and Social Commission for Western Asia
ETF	Enhanced Transparency Framework
EU	European Union
FAO	Food and Agriculture Organization
FES	Friedrich Ebert Stiftung
FIT	Feed-In-Tarif
FOD	First Order Decay
FOLU	Forest and Land Use
ForFITS	For Future Inland Transport Systems
FSV	Facilitative sharing of views
GBA	Greater Beirut Area
GCF	Green Climate Fund
GCM	Global Circulation Model
GDO	Gas Diesel Oil
GDP	Gross Domestic Product
GEF	Global Environment Facility
GEFF	Green Economy Financing Facility
GHG	Greenhouse Gas
GIS	Geographical Information System
GoL	Government of Lebanon
GPP	Geothermal Power Plants
GSHP	Ground Source Heat Pumps
GWP	Global Warming Potential
HD	Heating Degree Days
HCW	Healthcare Worker
HDV	Heavy-Duty Vehicles
HEC	Hybrid Electric Vehicles
HFC	Healthcare Facilities
HFO	Heavy Fuel Oil
HSDI	Heat Stress Duration Index
HWDI	Heat Wave Duration Index
HWFI	Heat Wave Frequency Index
HYPE	Hydrological Predictions for the Environment
IAEA	International Atomic Energy Agency
IAM	Integrated Assessment Pathways
ICA	International Consultation and Analysis
ICE	Internal Combustion Engine
ICARDA	International Center for Agricultural Research in Dry Areas
ICAT	Initiative for Climate Action Transparency
ICT	Information & Communication Technology
IEA	International Energy Agency
IFAD	International Fund for Agricultural Development
IFI	Issam Fares Institute for Public Policy and International Affairs
ILO	International Labour Organization
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
IPM	Integrated Pest Management
IPPU	Industrial Processes and Product Use
IPTEC	IPT Energy Center
IRENA	International Renewable Energy Agency
ISWM	Integrated Solid Waste Management
IWMI	International Water Management Institute

IsDB	Islamic Development Bank
IUCN	International Union for Conservation of Nature
JJA	June – July – August
KPI	Key Performance Indicators
LA	Level Assessment
LARI	Lebanese Agriculture Research Institute
LBP	Lebanese Pound
LCA	Lebanon Climate Act
LCoE	Levelized Cost of Energy
LCEC	Lebanese Center for Energy Conservation
LCV	Light Commercial Vehicles
LCRP	Lebanon Crisis Response Plan
LDV	Light-Duty Vehicles
LDN	Land Degradation Neutrality
LEDS	Low Emission Development Strategy
LEEREFF	Lebanon Energy Efficiency and Renewable Energy Finance Facility
LEPAP	Lebanon Environmental Pollution Abatement Project
LEV	Lebanon Economic Vision
LFG	Landfill Gaz Management
LGIF	Lebanon's Green Investment Facility
LPG	Liquefied Petroleum Gas
LRA	Litani River Authority
LRI	Lebanese Reforestation Initiative
LTS-LERD	Long-Term Strategy for Low-Emission and Resilient Development
LULUCF	Land Use, Land Use Change and Forestry
MENA	Middle East and North Africa
MCA	Multi-Criteria Analysis
MCM	Million Cubic Meters
MDV	Medium Duty Vehicles
MCV	Medium Commercial Vehicles
MISCA	Management Information System for Climate Action
MoA	Ministry of Agriculture
MoE	Ministry of Environment
MoEW	Ministry of Energy and Water
MoF	Ministry of Finance
MoFA	Ministry of Foreign Affairs and Emigrants
MoI	Ministry of Industry
MoIM	Ministry of Interior and Municipalities
MoPWT	Ministry of Public Works and Transport
MPG	Modalities, Procedures and Guidelines
MRV	Measuring, Reporting and Verifying
MRVCE	Measuring, Reporting and Verifying Coordinating Entity
MSW	Municipal Solid Waste
NA	Not Applicable
NAMA	Nationally Appropriate Mitigation Action
NAP	National Adaptation Programme
NCLW	National Commission for Lebanese Women
NC	National Communication
NCC	National Control Center
NDC	Nationally Determined Contribution
NDCSP	Nationally Determined Contribution Support Programme
NDWI	Normalized Difference Water Index
NE	Not Estimated
NEEAP	National Energy Efficiency Action Plan
NEEREA	National Energy Efficiency and Renewable Energy Action
NFP	National Forest Plan
NGO	Non-Governmental Organization
NMVOC	Non-Methane Organic Volatile Compound
NMT	Non-motorized Transport
NO	Not Occurring
NWSS	National Water Sector Strategy
O&M	Operation and Maintenance
ODS	Ozone Depleting Substances

OECD	Organization for Economic Co-operation and Development
OEM	Original Equipment Manufacturer
PATPA	Partnership on Transparency in the Paris Agreement
PC	Passenger Cars
PCM	Presidency of the Council of Ministers
PHES	Pumped Hydro Energy Storage
PP	Partnership Plan
PT	Parabolic Trough
PV	Photovoltaics
QA	Quality Assurance
QC	Quality Control
R&D	Research and Development
RCP	Representative Concentration Pathway
RE	Renewable Energy
RPTA	Railway and Public Transport Authority
SCF	Sub-national Climate Fund
SCADA	Supervisory Control and Data Acquisition
SDG	Sustainable Development Goal
SDII	Simple Daily Intensity Index
SEDAC	Socioeconomic Data and Applications Center
SEA	Strategic Environmental Assessment
SLMQ	Sustainable Land Management in the Qaraoun Watershed Project
SMHI	Swedish Meteorological and Hydrological Institute
SNC	Second National Communication
SOER	State of the Environment Report and Future Outlook
SOP	Standard Operating Procedures
SON	September – October – November
SPEI	Standardized Precipitation Evapotranspiration Index
SPI	Standardized Precipitation Index
SSP	Shared Socioeconomic Pathways
SU	Summer Days
SWDS	Solid Waste Disposal sites
SWH	Solar Water Heaters
SWM	Solid Waste Management
TA	Trend Assessment
TACCC	Transparency, Accuracy, Completeness, Comparability and Consistency
Toe	Tonne-oil-equivalent
TNA	Technology Needs Assessment
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNRWA	United Nations Relief Works Agency
UfM	Union for the Mediterranean
UNHCR	United Nations High Commissioner for Refugees
USAID	United States Agency for International Development
USD	United States Dollar
USFS	United States Forest Service
VIC	Variable Infiltration Capacity
WASH	Water Supply, Sanitation and Hygiene
WE	Water Establishments
WEF	World Economic Forum
WHO	World Health Organization
WFP	World Food Programme
WRF	Weather Research and Forecasting
WUA	Water Users 'Association
WWTP	Wastewater Treatment Plant

CHAPTER 1

NATIONAL CIRCUMSTANCES



SUMMARY OF KEY POINTS

- Lebanon's national circumstances changed drastically between 2019 and 2022, due to an unprecedented economic, financial, monetary, banking crises and amidst the global COVID-19 pandemic.
- Lebanon has been a Party to the United Nations Framework Convention on Climate Change (UNFCCC) since 1994 (Law 359/1994) and ratified both the Kyoto Protocol (Law 738/2006) and the Paris Agreement to the UNFCCC (Law 115/2019 and Decree 5599/2019).
- No major legislation directly addresses climate change in Lebanon, other than the Nationally Determined Contribution (NDC), as dictated by the Paris Agreement. Lebanon submitted its first NDC in 2015 and the updated version in 2021.
- The NDC update has put forward an ambitious mitigation target of 20% emission reduction as an unconditional target by 2030 with clear sector-specific objectives and an enhanced section on Lebanon's adaptation guiding principles and priorities.
- The Ministry of Environment has been appointed as the official NDC coordinator and an inter-ministerial committee was formed in 2017 (Council of Ministers' decision 33/2017) to follow-up on the implementation of Lebanon's NDC.
- Lebanon has been seeking to improve the gender responsiveness of its climate policies and climate action. To support this, a Gender Analysis was carried out to assess various aspects of the governance, policy and planning processes related to climate change and gender equality. Prioritized sectors included energy, waste, and water.
- Lebanon has also been mainstreaming climate change into education and awareness activities targeted not only to schools/university students and local communities, but also to government institutions, private sector, and syndicates and associations.
- Building on the momentum of the COP26 in Glasgow, Lebanon has been increasing the involvement of youth in climate change related activities and policies. 3 Youth representatives joined the official Lebanese delegation to the COP27 in 2022.

Lebanon's Fourth National Communication presents an update of the country's GHG inventory for the 2016 – 2019 period, an overview of institutional arrangements related to MRV, an update of the climate change risks and vulnerabilities to the country as per the last global and regional assessments, in addition to an overview of the main needs and gaps needed to improve climate reporting and climate action in Lebanon.

However, it is worth noting that while this report is being prepared in 2022, Lebanon's national circumstances changed drastically between 2019 and 2022, due to an unprecedented economic, financial, monetary, banking crises and amidst the global COVID-19 pandemic.

An accumulation of large budget deficits throughout the years has significantly increased the debt-to-Gross Domestic Product (GDP) ratio. Moreover, the Lebanese Pound has devalued by as much as 95% by September 2022, while inflation rates soared, impacting the Purchasing Power Parity of Lebanese citizens. The fact that Lebanon relies on imports for most of its food and energy supplies has aggravated the situation even further. The cost of fuel increased drastically since 2018, which significantly changed the domestic, institutional, and industrial pattern of fuel consumption for electricity and heat generation as well as transport. The COVID-19 pandemic has further exacerbated conditions whereby the government-imposed lockdowns that lowered economic activity even more.

On August 4th, 2020, the port of Beirut explosion damaged the Port infrastructure, and surrounding area, with a cost of damage estimated between USD 3.8 and 4.6 billion. This further sets back an already struggling economy and has halted a large area of commercial activity and essential services; the consequent physical capital losses of the blast resulted in an additional decline in GDP, estimated at 0.4 to 0.6 percentage points (World Bank, 2020a).

Furthermore, Lebanon has been dealing with a crippling humanitarian crisis since 2011 due the displaced Syrian population, which has stretched an already fragile public infrastructure with demands exceeding the capacity of institutions to meet the required needs.

1.1 GEOGRAPHIC AND CLIMATE PROFILE

Lebanon is located on the eastern basin of the Mediterranean sea, with a surface area of 10,452 km^2, a coastline extending over 225 km and a landscape characterized by mostly mountainous areas separated by the Bekaa Valley (Figure 1).

Lebanon has a Mediterranean-type climate characterized by hot and dry summers (June to September) and cool and rainy winters (December to mid-March). Spring and autumn are warm and pleasant. The average annual temperature is 15°C.

Along the coast, summers are hot and humid with temperatures crossing 35°C in August. But due to the moderating effect of the sea, the daily temperature range is narrower than it is inland. January is the coldest month, with temperatures around 5 to 10°C. The mean annual rainfall on the coast ranges between 700 and 1,000 mm and about 70% of the average rainfall in the country falls between November and March.

Figure 1: Map of Lebanon

1.2 POPULATION AND SOCIAL PROFILE

The population of Lebanon is estimated at 6 million in 2019 and is characterized by a high density of around 496 persons/ km^2, including foreign workers, Palestinian refugees and Syrian displaced (the latter estimated at 932,619 in 2019). The working age population (15+ years) accounts for around 3.7 million person and the total labor force participation rate is 48.8% with a large difference between men (70.4%) and women (29.3%). The general unemployment rate is estimated at 11.4% in 2018, with differences observed between women (14%) and men (10%), and with a high rate of 23.3% among youth (15–24 years old). The public sector share of employment (ministries, public administration, and government-owned institutions) in Lebanon is 14% while the private sector accounts for the remaining 86%.

Most of the population is concentrated in the biggest cities of the country along the coastline. The estimated total number of households is around 1.266 million. The most common kind of household composition is of 4 persons on average; just 10% of households are composed of only one person.

Lebanon's educational attainment is relatively high compared to the region. Only 2% of residents aged 3 years and above are not enrolled in education and 7% are illiterate. The percentage of residents holding a university degree is 21%, with almost no difference between women and men (CAS, 2020; UNRWA, 2020; UNHCR, 2020).

Gender Lens

Women comprise 51.6% and men 48.4% of the total resident's population. Among women of working age, the labor force participation rate is 29.3%. Despite the relatively high degree of gender occupational segregation (index = 43.8%), the proportion of women in managerial positions (28.9%) is roughly in proportion to their overall share in total employment. Women benefit from a relative gender equality status when it comes to access to education and jobs, but some legislative aspects undermine their possibility to exercise their rights like men (i.e., impossibility to pass on the Lebanese nationality to foreign husbands and their offspring, unequal rights when it comes to divorce, inheritance or child custody).

Along with the Convention on the Elimination of All Forms of Discrimination Against Women (CEDAW), the Rio Convention, Sendaï Framework on Disaster Risk Reduction and the UNFCCC set a solid ground for Lebanon to implement policies that are in line with gender equality and women's empowerment in climate actions. In addition, Lebanon's constitution mentions the equality between all its citizens.

1.3 ECONOMIC PROFILE

Lebanon's Gross Domestic Product (GDP) has been fluctuating in the recent years, due to the economic crisis that Lebanon has been facing during the recent period. In 2019, the nominal GDP stood at USD 51.6 billion which dropped to 18.08 billion in 2021 with a GDP annual growth of -10.15% (World Bank, 2022a).

The Lebanese economy is service oriented with over 79.3% of GDP generated from services in 2019 and 81.27% in 2020. Agriculture and industry/construction contributed to 3.17% and 12.5% respectively in 2019, with an increase of 8.94% for agriculture and 17.64% in industry in 2020 (CAS, 2022)

Lebanon's fiscal policy coupled with regional instability have restrained the country's economic activity as the public debt to GDP ratio stood at 171% in 2019, the largest budgetary shortfall of the decade. Lebanon's vulnerable economy has been further hit by compounded crises, beginning with an economic and financial crisis, followed by COVID-19 and lastly the explosion at the Port of Beirut (IMF, 2022).

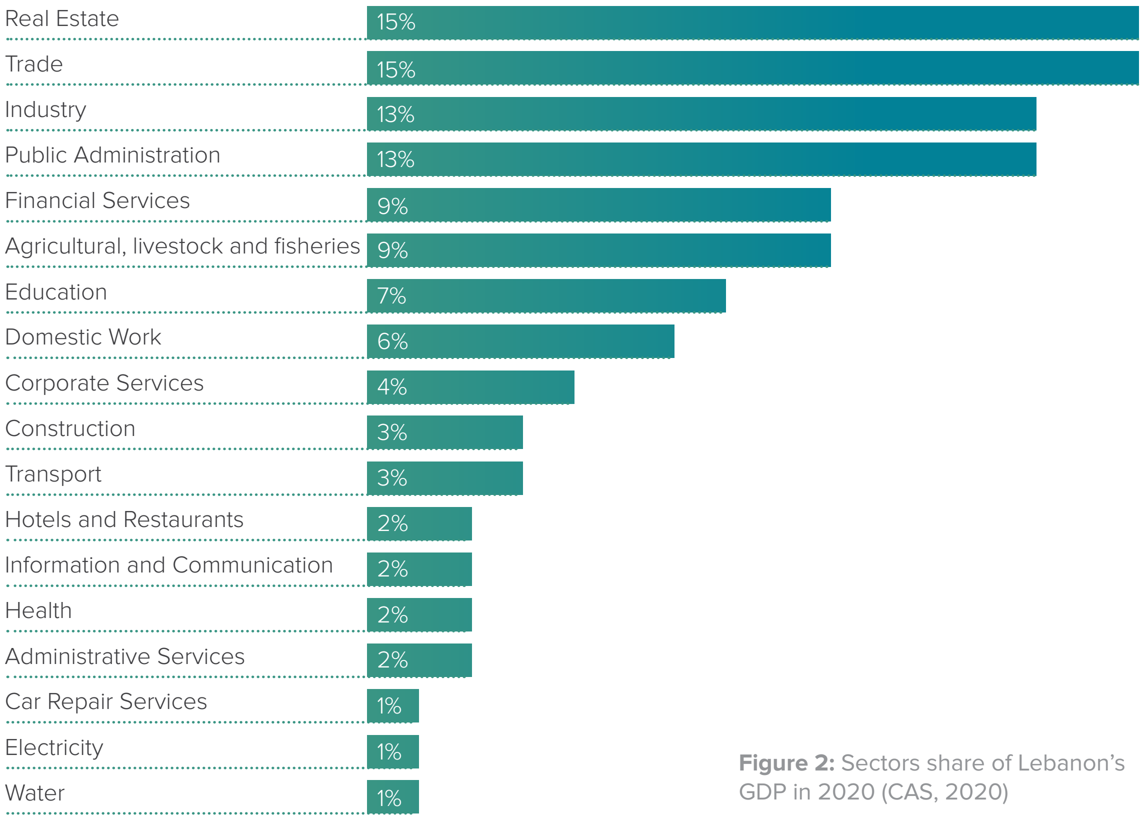


Figure 2: Sectors share of Lebanon's GDP in 2020 (CAS, 2020)

1.4 GOVERNANCE IN CLIMATE CHANGE

Lebanon has a democratic political system, with the Parliament as the legislative body, the Council of Ministers as the executive body and the President as the head of state and the commander-in-chief of the Lebanese Armed Forces and security forces.

Gender Lens

Women representation in decision making bodies

Although the Lebanese Constitution, amended on 21/9/1990, stresses the principle of equality among the Lebanese and the commitment to international instrument, and despite having a parliamentary democracy with a free political environment and electoral system, the situation of women has not been strengthened enough for them throughout the years to have an equal role in decision making.

Lebanon has one of the highest overall gender gaps in the world, ranking 119th out of 149 countries in the World Economic Forum Global Gender Gap report (WEF, 2022). However, when compared to Arab countries, Lebanon ranks 2nd after the United Arab Emirates, and scores the highest level of parity for ministerial positions, with the share of women at that level amounting to 32% of seats (WEF, 2022). In the 2022 elections, 157 out of the 1,043 running candidates were women, which represented 15% of the overall candidacies. However, the results showed that only one woman for every 18 men (5%) was elected to the Lebanese parliament. Based on the findings and recommendations of lessons learned from the 2018 and 2022 parliamentary elections, UN Women and UNDP developed and are implementing a joint action plan which aims at increasing the number of women represented in elected bodies.

Despite some encouraging numbers, more efforts are required to further address the country's systemic gender issues and to fully achieve gender equality and the empowerment of all women in decision making.

Lebanon has been a Party to the United Nations Framework Convention on Climate Change (UNFCCC) since 1994 (Law 359/1994) and ratified both the Kyoto Protocol (Law 738/2006) and the Paris Agreement to the UNFCCC (Law 115/2019 and Decree 5599/2019).

No major legislation directly addresses climate change in Lebanon, other than the Nationally Determined Contribution (NDC), as dictated by the Paris Agreement. Lebanon submitted its first NDC in 2015 and the updated version in 2021 in accordance with Articles 4.9 and 4.11 of the Paris Agreement.

The NDC update has put forward an ambitious mitigation target of 20% emission reduction as an unconditional target by 2030 (Table 1), with clear sector-specific objectives and an enhanced section on Lebanon's adaptation guiding principles and priorities. The NDC updated targets and activities has also been linked to wider socio-economic benefits, which offer entry-points to prioritize potential investments. Linkages with economic drivers such as job creation, increased productivity, reduction of financial burden, improved private sector contribution and innovation enhancement (Figure 3).

Table 1 **Lebanon's NDC 2015 vs. 2020**

Unconditional targets 2015[1]	Unconditional targets 2020[2]
A GHG emission reduction of 15% compared to the Business-As-Usual (BAU) scenario in 2030 (amounting to 6,222 Gg. CO_2eq.).	A GHG emission reduction of 20% compared to the Business-As-Usual (BAU) scenario in 2030, (amounting to 7,790 Gg. CO_2eq.).
15% of the power and heat demand in 2030 is generated by renewable energy sources.	18% of the power demand (i.e., electricity demand) and 11% of the heat demand (in the building sector) in 2030 is generated by renewable energy sources.
A 3% reduction in power demand through energy-efficiency measures in 2030 compared to the demand under the BAU scenario.	A 3% reduction in power demand through energy-efficiency measures in 2030 compared to the demand under the BAU scenario.
Conditional targets 2015[3]	**Conditional targets 2020[3]**
A GHG emission reduction of 30% compared to the Business-As-Usual (BAU) scenario in 2030 (amounting to 11,860 Gg. CO_2eq.).	A GHG emission reduction of 31% compared to the Business-As-Usual (BAU) scenario in 2030 (amounting to 12,075 Gg. CO_2eq.).
20% of the power and heat demand in 2030 is generated by renewable energy sources.	30% of the power demand (i.e., electricity demand) and 16.5% of the heat demand (in the building sector) in 2030 is generated by renewable energy sources.
A 10% reduction in power demand through energy-efficiency in 2030 compared to the demand under the BAU scenario.	A 10% reduction in power demand through energy-efficiency in 2030 compared to the demand under the BAU scenario.

[1] GHG emission reductions recalculated as per the 2006 IPCC Guidelines and AR5 GWPs. Numbers reflect rounding.

[2] The unconditional mitigation scenario includes the impacts of mitigation actions which Lebanon can nationally implement, and through international support in the form of loans or other repayable instruments.

[3] The conditional mitigation scenario covers the mitigation actions under the unconditional scenario, as well as further mitigation actions which can be implemented upon the provision of additional international support in the form of grants.

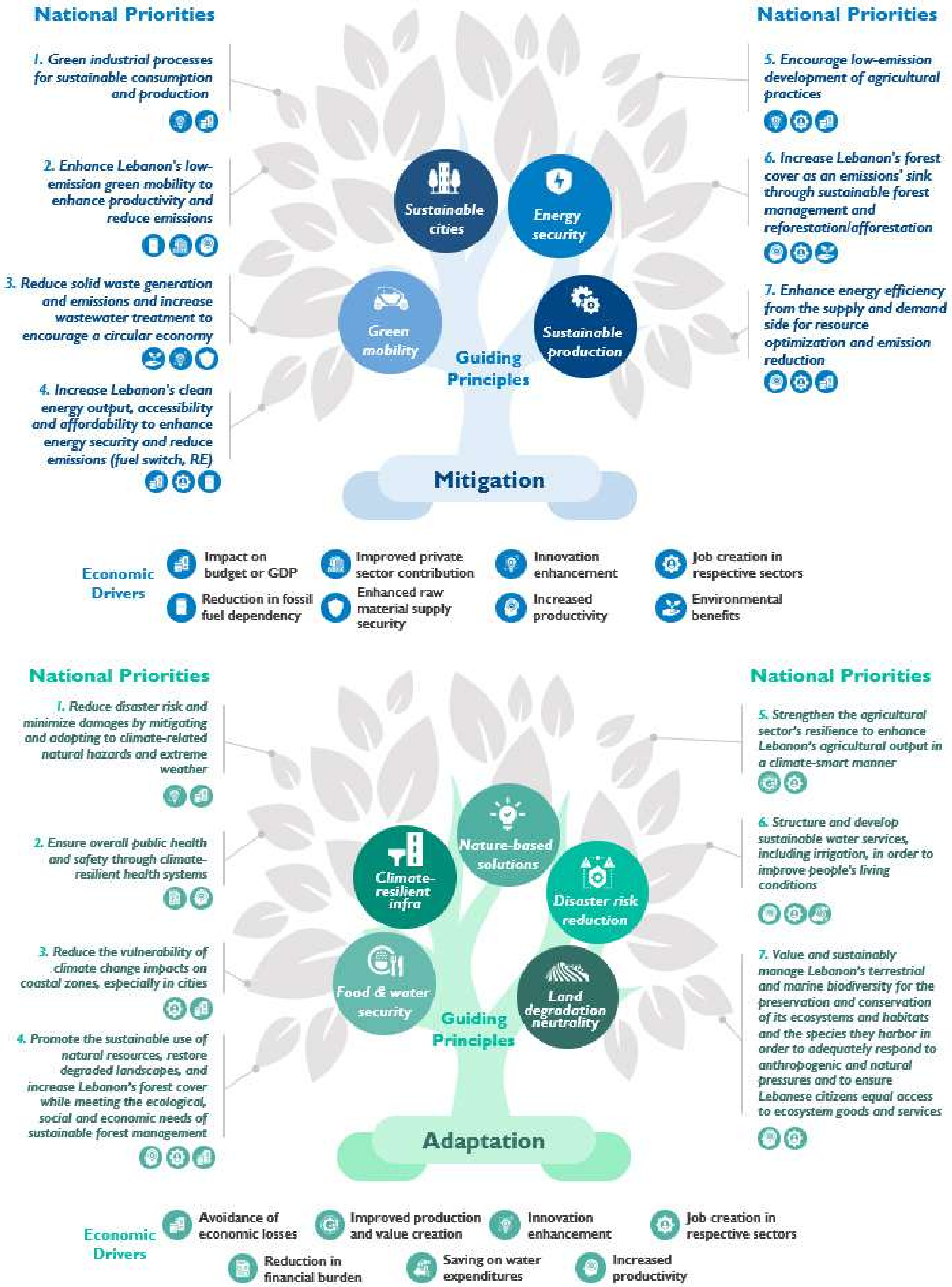


Figure 3: Socio-economic benefits of Lebanon's Nationally Determined Contribution 2021 (MoE/GCF, 2022b)

Lebanon's NDC is intended to align climate mitigation and adaptation measures with the country's economic recovery effort. To this end, it recognizes that effective climate action must be based on robust governance mechanisms, regulations and partnerships, setting out six key Climate Action Enablers to advance this goal:

- Improved governance and institutional capacities
- Incentivized action and fiscal reform – such as tax incentives for clean technology uptake
- Strengthened Partnerships – collaboration with the private sector and civil society organizations
- Innovative Research and Development Encouraged – including partnership with academic bodies, and encouraging innovation labs
- Comprehensive Integration – including gender institutions, youth groups and vulnerable communities
- Enhanced Monitoring and Transparency

To follow-up on the implementation of Lebanon's NDC, the Ministry of Environment has been appointed as the official NDC coordinator and an inter-ministerial committee was formed in 2017 (Council of Ministers' decision 33/2017). The committee is chaired by the Minister of Environment and includes nominated representatives from the Ministry of Energy and Water, Presidency of the Council of Ministers, Electricité du Liban, Ministry of Public Works and Transport, Ministry of Agriculture, Ministry of Interior and Municipalities, Ministry of Foreign Affairs and Ministry of Finance, Central Administration of Statistics and Ministry of Public Health, Council for Development and Reconstruction, National Commission for Lebanese Women, the Center for National Scientific Research and the Lebanese Petroleum Administration.

The mandate of the NDC committee includes:

- Update on the progress of the ministries and institutions' plans and strategies that make up Lebanon's Nationally Determined Contribution
- Implement the UNFCCC decisions related to the NDC and related transparency of action and support requirements
- Assess gaps and needs related to the implementation of sectoral and cross-cutting activities under the NDC and related to the reporting of progress (needs could be financial support, capacity-building support, technology support or technical support)
- Update Lebanon's NDC to move to a more ambitious target every 5 years
- Find linkages and opportunities to better implement Lebanon's NDC and relevant Sustainable Development Goals
- Ensure that the implementation of Lebanon's NDC respects human rights and gender equality
- Prepare the report on the NDC progress and communicate it to the Council of Ministers periodically

Despite the fact that there is no specific climate change legislation in Lebanon, there has been increased integration of climate change mitigation and adaptation into governmental decisions and sectoral plans such as the National Health Strategy (2021), the Ministry of Agriculture Strategy (2020), the Renewable Energy Outlook (2020), the draft National cooling plan (2020), the draft Disaster Risk Management strategy (2020) and the National Strategy for Women in Lebanon (2019). In 2021, the newly formed Government concretely included in its declaration and action plan the "support of a green economy [...] and the commitment to the Paris Agreement".

In addition, the Strategic Environmental Assessment studies that have been prepared recently for the Offshore Petroleum Sector and Updated Water Sector Strategy are taking into consideration climate change impacts and opportunities and are abiding by Lebanon's NDC targets for 2030.

Climate change mitigation and adaptation is also being indirectly tackled through the enforcement of other legislations such as the air quality strategy, the Minister's decisions on emission limit values and carbon reporting mechanism as well as the tax incentives on hybrid and electric cars.

Table 2 **Environmental legislations relevant to climate change**

Legislation/strategy	Description and linkages with climate change
Emission limit value for air pollutants - MoE decision 16/1 (2022)	- Provides emission limit values for air pollutants from a range of sources including power plants, private generators, industries, waste plants, etc. - Limiting air pollutants to internationally accepted standards will consequently limit emission of greenhouses.
Tax incentives on environmental products and services - Decree 167 (2017), MoE decision 1281/1 (2017), MoF decisions 18/1 (2020), 35/1 (2021).	- Provides customs reductions on environmental products including equipment related to energy efficiency, renewable energy, waste recycling, etc. - Provides tax break to companies undertaking environmental actions/projects including climate-related projects - Encourages the deployment of climate-friendly technologies and services
Vehicle tax reduction- Article 55 of budget law 79 (2018) Article 95 of budget law 10 (2022)	- Provides tax reduction and/or exemption (customs, etc.) for hybrid and electric vehicles - Encourages the deployment of low emission vehicles - Tax exemption has been maintained throughout the period of 2019-2022
Air Quality Law 78 (2018)	- Provides a legal framework for air quality monitoring and assessment, control and surveillance, information management and research and capacity building promotion, as well as financial provisions and liabilities and sanctions - Endorses the National Strategy for the Ambient Air Quality Management - Tackles emissions from mobile and stationary sources and fuel quality, which will have a direct impact on the reduction of GHG emissions

The National Strategy for the Ambient Air Quality Management 2015-2030 (2017)	- Provides a vision and long-term goals for the implementation of the strategy by 2030, in addition to proposed modalities for the implementation, monitoring and evaluation and information sharing. - Aligns goals with the NDC targets
Carbon reporting mechanism - MoE decision 99/1 (2013)	- Provides a framework and tool for the private sector to report annually their greenhouse gas emissions (on a voluntary basis) – and receive a reporting certificate from the MoE

Over the years, Lebanon has been engaged in several platforms tackling climate change mitigation and adaptation, among which the Cartagena Dialogue for Progressive Action, the Climate Vulnerable Forum, the Partnership on Transparency in the Paris Agreement (PATPA), the NDC Partnership, the Union for the Mediterranean (UfM), and the OECD Climate Change Expert Group (CCXG).

1.5 LINKAGES WITH SUSTAINABLE DEVELOPMENT

Climate change is one of the greatest threats to sustainable development. If left unmitigated at the global level, it has the potential to severely undermine national efforts in meeting their own development goals. Consequently, the achievement of the SDGs and low-emission resilient development should be integrated to reduce risks and enhance livelihoods and ecosystems beyond 2030 until the second half of the century.

When looking at the climate crisis through the security lens in Lebanon, additional impacts emerge: the reduced availability of resources will spur local and transboundary competition. Moreover, migration due to lack of resources or extreme weather events may exacerbate the current crisis already ongoing in Lebanon. This will cause more food insecurity and impact on basic services infrastructure. This multiplier effect puts Lebanon on a risky path and less likely to secure peace. Therefore, adverse climate impacts will add an additional layer of challenges and will set back any improvement in the Lebanese socio-economic status.

Addressing sustainability and risk reduction at all levels of policy-making and planning from the government to non-state actors is urgently needed, to enhance prosperity. In Lebanon, climate action would heavily contribute to economic growth and job creation for example, which sets the stage for an economic and environmental transition:

In addition to the prioritization of sustainable economic growth in several ministerial strategies, Lebanon has developed 3 national plans to pave the way to its recovery from these crises and define future growth:

- **The 3-year development plan:** to overcome short-term financial challenges through USD 10-15 billion in external financing among other financial measures. The plan also outlines structural reforms including grid modernization, anti-corruption, and social protection measures.
- **Lebanon Economic Vision (LEV):** to outline a national strategy for reviving the economy

through targeted investments in the 5 sectors it has identified as core engines of growth: agriculture, industry, tourism, financial services, and the knowledge economy. It aims to increase GDP growth to 6% within three years of implementation and cut the unemployment rate by 50% in five to seven years.

- **The CEDRE-CIP (Conférence Economique pour le Développement par les Réformes avec les Entreprises - Capital Investment Plan):** to outline infrastructure projects that both align with national development goals and create opportunities for economic growth in the short and medium term. These projects cover infrastructure projects in transport, water and irrigation, wastewater, electricity, telecommunications, solid waste, tourism and industrial sectors. For each sector, the programme plan presents an assessment and gap analysis, and identifies how the sector's infrastructure needs line up against SDGs.

Although these plans, if implemented, may put Lebanon back on the path to economic recovery, there is a need to ensure they do not jeopardize the country's GHG emission trajectory under the NDC. A climate proofing methodology has been developed to identify synergy opportunities and showcase how these development plans can achieve their aforementioned objectives while delivering GHG mitigation and building resilience to climate change. Lebanon is also drafting its Long-Term Strategy for Low-Emission and Resilient Development (LTS-LERD), which aims at harmonizing economic growth with reduced ecological impact in 2050 by aligning with concepts of sustainable development and green economy (UNDP, 2021).

Furthermore, in order to synchronize the preparation, update and tracking of Lebanon's NDC, an NDC-SDG assessment was conducted to explore opportunities for complementarity of climate action and sustainable development implementation and support, under the Nationally Determined Contribution Support Programme (NDCSP). The assessment had important implications for Lebanon's NDC update, which merges climate action under the NDC with the SDGs, along with a green and blue economy, leaving no one behind.

Under the synchronization exercise, the mitigation and adaptation strategies that constitute Lebanon's NDC were matched with the different Sustainable Development Goals (SDGs) sub-targets, using the SDG Climate Action Nexus tool (SCAN-tool), developed under the umbrella of the NDC Support Cluster. This tool identifies the climate mitigation and adaptation actions that may impact specific SDG targets. By linking 12 strategies with the 169 SDG sub-targets, the main findings show a high rate of synchronization between climate action and sustainable development in Lebanon, making the achievement of SDG 13 (Climate Action) an enabler for the implementation of other SDGs. It was also found that a large number of linkages were made with non-environment SDGs, such as SDG 3 (Good Health and Well-Being) and SDG 8 (Decent Work and Economic Growth), among others.

For each strategy/sector (energy, waste, transport, water, biodiversity, industry) a guidance document was produced to showcase the primary SDG linkage, along with other important linkages, based on the tool's matching properties. Moreover, the guidance document recommended further possible linkages with SDGs, to be taken up in the next policy-making cycle.

Examples of linkages include:

- Agriculture is a primary source of income and employment in rural areas reaching up to 25% of the labor force and representing

80% of its GDP. Socio-economic stability can be maintained for low-income workers through introducing more sustainable agricultural processes that reduce environmental impact, increases resiliency, and uses water and land resources more efficiently (SDGs 1, 2, 6 and 12).

- Renewable energy technologies such as hydro, solar and wind power, can greatly reduce greenhouse gas emissions and greatly reduce premature deaths from air pollutants. Deploying cleaner energy sources that enable the phasing out of diesel generators can therefore have a significant impact on SDGs 3.4 and 3.9 which relate to achieving more positive health outcomes by reducing harmful pollutants.
- Mass transit strategies can reduce transport cost as part of the household budget by providing public transit as an alternative to car ownership, which could potentially positively impact low-income families (SDG 1) and household income (SDG 4). Further, mass transit that aims to increase mobility and accessibility can greatly improve access to jobs and income potential and provide more equitable access to other important places such as schools, hospitals, and shopping (SDG 10).

1.6 SECTORS OVERVIEW

Energy sector

In 2019, Lebanon generated 13,888 GWh of electricity from its 7 power plants and the 2 power rental barges, operating on heavy fuel oil (grade A and B) and diesel oil; 1,116 GWh from renewable energy sources and 90.77 GWh purchased electricity from Syria, bringing the country's total supply to 15,095 GWh (MoEW, 2020). With a demand estimated at 23,781 GWh and technical losses at 13.30%, the gap between supply and demand is partially met by diesel-operated private generators, used at neighbourhood levels as well as the commercial, industrial, institutional, and residential levels. Over the years, these created a complex informal economy that has been resistant to regulations and government oversight, but have also been a conventional off-grid power solution, because of their relatively low upfront capital costs (Ayoub et al., 2021; Ahmad, 2020). However, this has also widened the market of renewable energy, specifically decentralized PVs, which increased

from 56.50 MWp in 2018 to 78.65 MWp in 2019 (LCEC, 2022).

After 2019 and amidst the compounded crises, public electricity supply has drastically decreased due to the shortage of foreign currency at the Central Bank of Lebanon which has threatened fuel supply and hindered the national electric utility Electricte Du Liban (EDL) to perform its day-to-day operations, pay its dues, or obtain equipment and spare parts for maintenance. This has further increased the gap between electricity supply and demand, which is being covered by private diesel generators that are dispersed almost everywhere in the country.

Besides electricity generation, imported fossil fuels are also used in Lebanon for energy purposes such as heavy fuel oil, petcoke and Liquified Petroleum Gas (LPG) for industrial activities, and LPG for cooking and heating at the commercial, institutional, and residential levels.

Transport sector

In 2019, around 2.1 million vehicles were in circulation in Lebanon, recording an increase of 4% since 2018. Passenger cars account for 81% of the fleet as seen in Figure 4 and most of the cars are 12 to 17 years old (Figure 5).

Since 2019, as a result of the consecutive lockdowns imposed for COVID-19 pandemic and the economic and monetary crisis, transport characteristics, patterns and parameters significantly changed. According to the Lebanese Association of Car Importers, the registration of new cars dropped by 73% with 6,101 newly registered cars by November 2020, compared to 22,528 cars at the time of the year in 2019. Gasoline prices skyrocketed as authorities removed subsidies on fuel imports, making 20 liters of gasoline worth half the minimum wage in Lebanon. Moreover, as car insurance and spare parts are priced in dollars, road safety has become at risk, since car maintenance has become less of a priority, as well as insurance. The combined effect of the pandemic and the economic crisis has had a drastic change in the country's car-centric culture and consumer travel choice preferences and priorities, which has yet to be identified for current period.

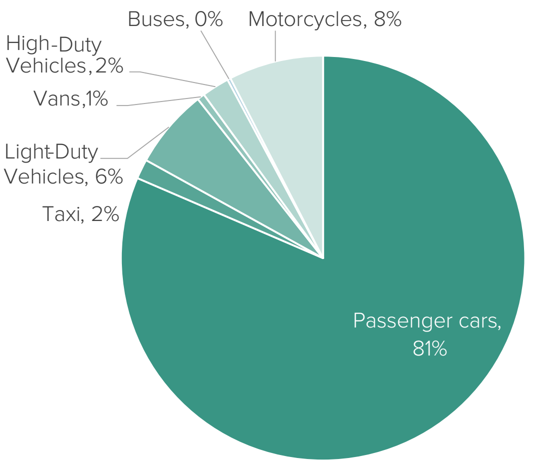


Figure 4: Categorization of Lebanon's 2019 vehicle fleet

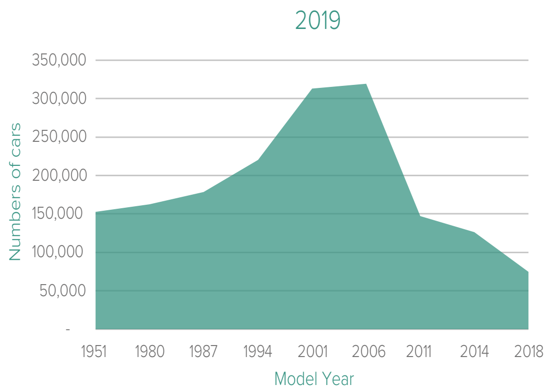


Figure 5: Categorization of fleet by age of car

Forestry

Forests occupy approximately 13% of the total area of the country, in addition to 10% of Other Wooded Lands (FAO, 2015). According to the latest land cover land use map (CDR/CNRS, 2017), the main natural green landcover categories are pasture (154,000 ha), scattered forests (138,500 ha), dense forests (79,200 ha) and grassland (84,200 ha).

Lebanon's location in the Mediterranean basin makes it fertile for forest fires, especially in the warm and dry season. It is estimated that, every year, forest fires ravage areas and burn over 4,000 hectares of land throughout the fire season. The year 2019 witnessed one of the highest numbers of fires in Lebanon, burning 3,155 ha of forestland in one year (Mitri, 2019).

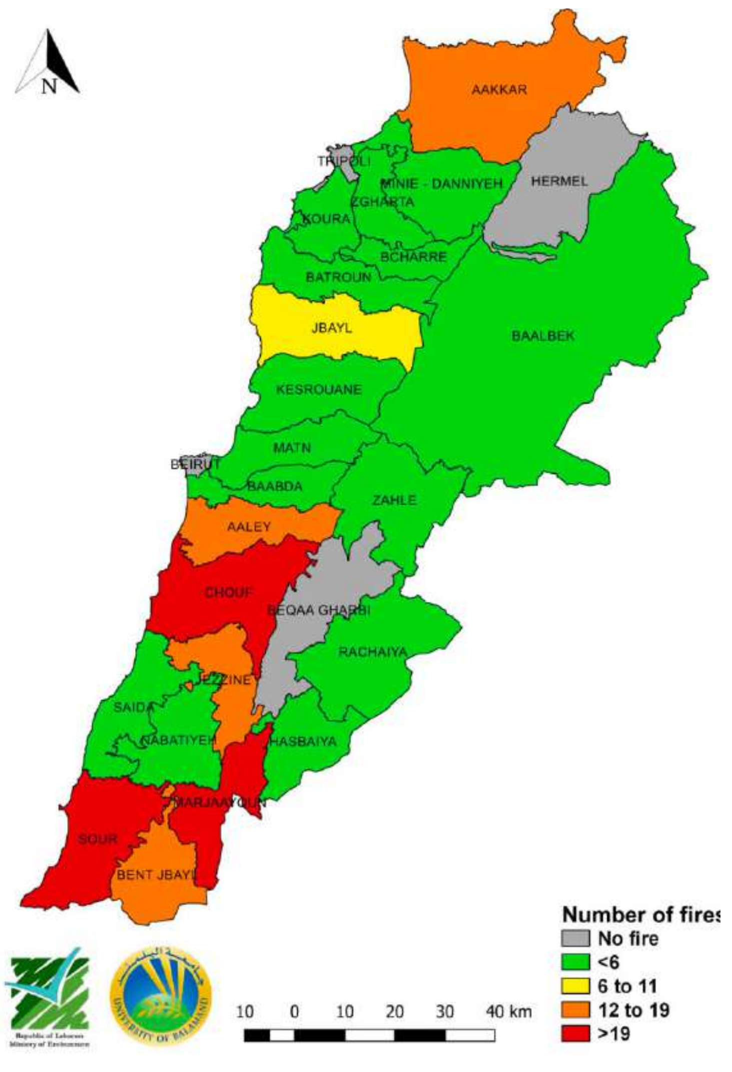


Figure 6: Fire occurrence per Caza in 2019

18 nature reserves have been created in Lebanon since 1992 to protect natural habitats and endemic and endangered species, among which one is a UNESCO biosphere reserves, one is a Barcelona Convention Special Protected Area two are Specially Protected Area of Mediterranean Importance under the Barcelona Convention and 2 are RAMSAR sites.

Agriculture

With its small contribution to the national GDP, agriculture (including fishing and forestry) accounts for 20% of Lebanon's active population, and agricultural workers are regarded as the poorest workers among all employment sectors, with 40% considered poor (UNHCR, 2020; FAO, 2020a). Most of the rural population is dependent on agriculture as a primary or secondary source of income.

Lebanon can produce a wide variety of crops due to a favourable climate as well as localized conditions stemming from its diverse topography. Agricultural areas comprise 232,200 ha (23% of the country) and include permanent crops, temporary crops, and greenhouses. Permanent crops represent 54% of the total cultivated area. Temporary crops include cereals, pulses, vegetables, fodder crops, and industrial crops, and include 44% of cultivated areas. The remaining crop areas are in greenhouses (Verner et al., 2018).

Most field crops agriculture is found in the Bekaa area, with minor distribution in the South and North. Olives and deciduous fruit trees and citrus are mostly concentrated in the North with minor distribution in the South on the coast, with olive production expanding inland in the Southeast of Lebanon. Protected agriculture is mostly distributed on the coast in the Keserwan and North area; vineyards are in the Bekaa and Zahle area and banana is mainly produced on the coast in the South of Lebanon (Figure 7).

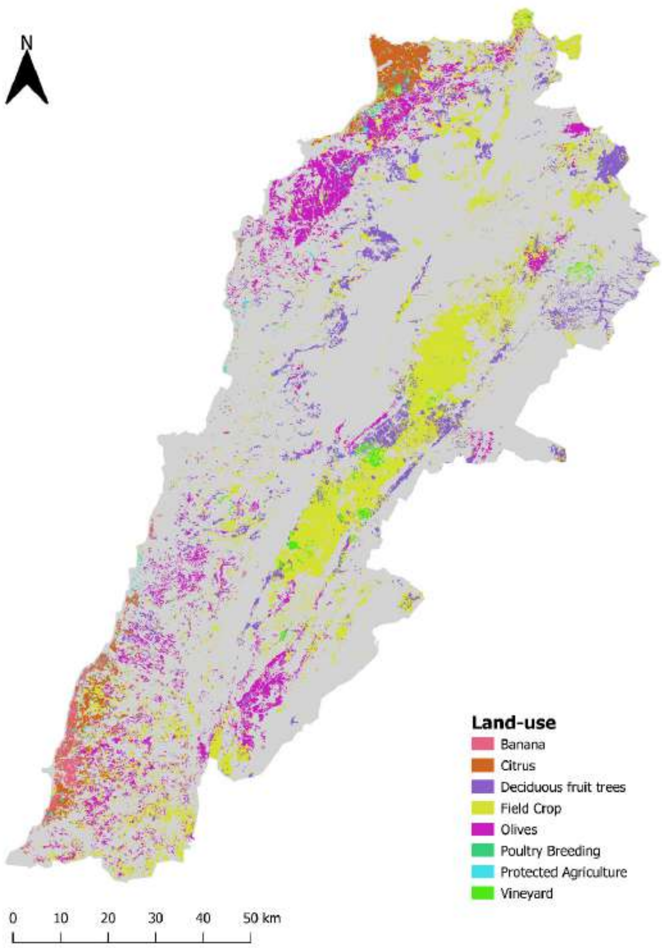


Figure 7: Land-use map of Lebanon highlighting agricultural divisions and classifications.

Water sector

Ensuing the 2019 economic crisis in Lebanon, which was further exacerbated by the COVID-19 pandemic, Lebanon's water sector suffered both at the financial and operational level, increasing pressure on water establishments to deliver. The challenges to the water sector worsened with the devaluation of the Lebanese pound (LBP) combined with inadequate tariff, low collection and subscription rates, unpaid debts, and high non-revenue water, which undermined the financial viability of the four water establishments and impaired their ability to cover operation and maintain expenditures to ensure basic service to households. Additionally, the devaluation of the LBP impacted public sector servants within the water establishments, where technical staff was already lacking, hindering the water establishments' ability to maintain daily operations.

The lack of fuel has exacerbated these issues. Since 2019, public water supplies have fallen significantly, from an average of 125 liters per capita per day to below the necessary daily quantity per person of 35 liters. Over 70% of the Lebanese population currently faces critical water shortages. These are especially severe in regions that are already more remote and have historically received less investment in public infrastructure, like the Bekaa Valley and North Lebanon (Ferrando, 2022). The lack of electricity has also caused frequent shutdowns of several wastewater treatment facilities, discharging untreated sewage into the already heavily polluted rivers.

In addition, the sudden expansion of population following the Syrian crisis in 2011 has significantly increased domestic water stress in the country. It is estimated that 2.45 million people are currently suffering from extreme water stress (compared to 2.1 million before the crisis) and 3.2 million inhabitants are suffering from high water stress (compared to 2.5 million before the crisis), most of whom live in major cities (Figure 8) (Jaafar et al., 2020).

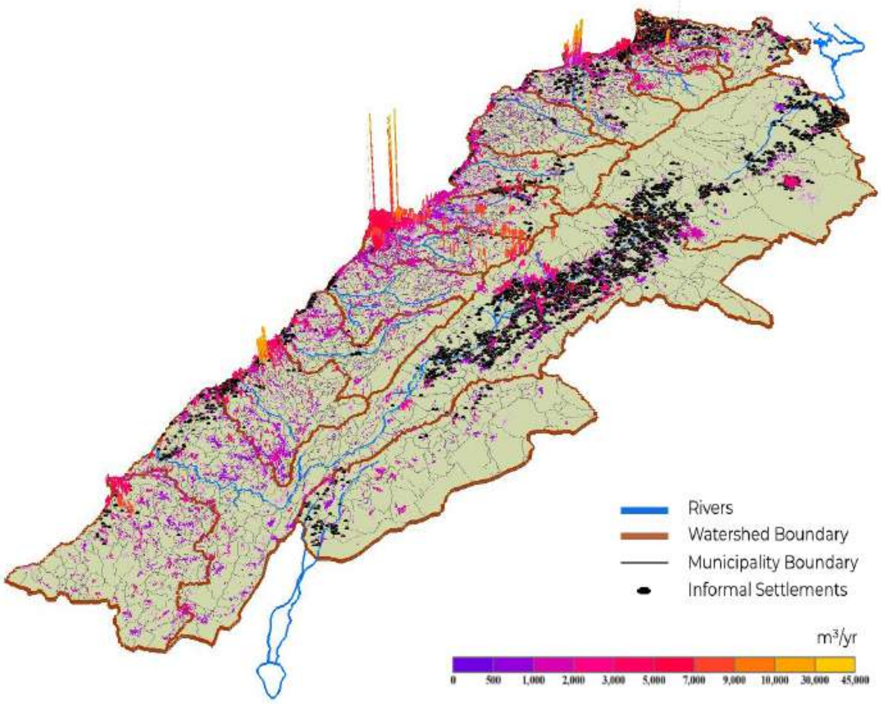


Figure 8: Spatially distributed domestic water demand in m^3/yr (adapted from Jaafar, 2021)

Keeping in mind that the national water coverage is around 80%, an estimated 65% of the population does not have access to safely managed drinking water. As stated above and reiterated by the updated National Water Sector Strategy (NWSS) developed by the Ministry of Energy and Water, regional water establishments are not financially or technically equipped to efficiently manage water supply and they are not achieving cost recovery (non-revenue water at 45% nationwide, metered connections are only 10%, and around 30% tariff collection rate) (MoEW, 2020).

There are eight major aquifers in Lebanon, with a total estimated volume of 1,360 Mm^3 annually. Although there have been several studies to evaluate the extent, hydrologic associations, storage capacity, quality, and retention time of groundwater aquifers in Lebanon, data availability is still limited. Studies on groundwater resources in Lebanon have estimated groundwater extraction rates in public wells at 249 Mm^3/yr., without accurate estimates for private wells. Overall average groundwater extraction rate was reported to range between 400 to 1,000 Mm^3 annually in earlier reports (UNDP, 2014).

In terms of water demand, the total annual demand was estimated at 1,473 Mm^3 in 2010, divided between the agricultural (58%), domestic (31%) and industrial (11%) sectors. Current agricultural demand is estimated to be higher, where around 71% goes to agriculture while the remaining covers domestic and industrial uses (SOER, 2020). Although there is no deficit between water demand and supply, the issue is linked to the mismatch between the geographical distribution of water resources and the increasing bulk of demand.

As for water consumption, the 2019 water sector strategy revised the water consumption rates that were used in the policy paper of 2012 from 160 l/d/capita in urban and 140 l/d/capita in rural zones to 125 l/d/capita. The strategy also estimated the average irrigation water requirement at around 8,400 m^3/ha/year, with a total of 878.3 Mm^3 need for irrigation water per year (MoEW, 2020). Main irrigated crops include cereals, potatoes, citrus, and vegetables. About 45% of croplands depend upon surface irrigation, primarily basin and furrow type. Typically, such schemes use diversion or intake structures on streams or springs with canals. Sprinkler irrigation is practiced in about 20% of croplands, particularly where sugar beet and potatoes are grown in the Bekaa Valley. Other areas, such as the coastal region, uses localized irrigation. Public irrigation development includes dams and surface water reservoirs, pipelines, and canals.

1.7 GENDER-RESPONSIVENESS OF CLIMATE ACTION

Gender and its relationship to climate change is a relatively new aspect in Lebanon and the concept remains unclear for a majority of stakeholders. To understand men and women's different situations and needs with regards to climate change, sex disaggregated data is essential. It informs on development gaps and allows the identification of adequate actions towards sustainable development and mainstreaming gender into climate related policies.

In 2017, the UNFCCC's Gender Climate Action Plan affirmed the importance of supporting women's full and equal participation in the UNFCCC process and prioritized the gender-responsiveness of climate change policies and measures. It is within this context that Lebanon has been seeking to improve the gender responsiveness of its climate policies and climate action. To support this, a Gender Analysis was carried out to assess various aspects of the governance, policy and planning processes related to climate change and gender equality and specifically analyzed data collection, existing technical capacities, institutional mechanisms, and gender mainstreaming opportunities.

The Gender Analysis on climate change, which was conducted under the Nationally Determined Contribution Support Programme (NDCSP), relied on secondary data regarding the legal, social, economic, and political aspects of gender relations in Lebanon, and has prioritized the energy, waste, and water sectors to undertake capacity building and gender mainstreaming activities to better support gender-sensitive climate action. The selection of these three sectors was based on the impact, status, opportunity, human resources and external support, as presented in Table 3 (MoE/UNDP/NCLW, 2021).

Table 3 Prioritized ranking of sector impact on gender

Sector	Impact	Status	Opportunity	Human Ressources	Sub-Total	External Financial support	Total
Agriculture	High	Medium	High	High	11	Yes	8
Biodiversity	Low	Low	Unknown	Low	3	No	6
Disaster Risk Reduction	High	Medium	High	High	11	Yes	8
Energy	High	Low	High	Low	8	No	11
Land degradation neutrality	Low	Unknown	Low	Low	3	Yes	0
Land change, Land-use change, forestry	Low	High	Low	High	8	Yes	5
Public Health	Medium	Unknown	Low	Unknown	3	No	6
Transport	High	Low	Low	Low	6	No	9
Tourism	High	Low	Low	Low	6	No	9
Waste	High	Low	Medium	Low	7	No	10
Water	High	Low	High	Low	8	No	11

The main challenges in mainstreaming gender into climate change policies and actions identified in the gender analysis report include:

- Cultural barriers to gender equality and women's participation in decision-making;
- Misunderstanding of the concept of gender which hinders its effective consideration and prioritization in policies;
- Difficulties in understanding the linkages between gender and climate change;
- Lack of capacity-building on climate change in institutions;

- Lack of systematic mainstreaming of gender into climate change policies and planning (integration is irregular and varies across sectors);
- No dedicated budget for gender-related activities;
- Lack of adequate data to perform informed policy-making on gender integration;
- Lack of coordination for data collection between the relevant ministries, public institutions and academic institutions.

As a result, most policies and strategies related to climate change and included in Lebanon's NDC do not thoroughly address gender dimensions as illustrated in Figure 9. Gender integration seems more advanced in the agriculture and forestry sectors in terms of gender integration, while the biodiversity, energy and water sectors' policies do not have gender considerations at all. As for transport and waste, gender was briefly mentioned in the respective strategies but lacked transformative action.

Figure 9: Gender inclusion by sector policies (MoE/UNDP/NCLW, 2021)

National Commission for Lebanese Women

The National Commission for Lebanese Women (NCLW) is the public institution responsible for mainstreaming gender into national policies or administrations. The General Assembly of NCLW is composed of 24 members appointed by the Council of Ministers. Established in 1998, the NCLW is mandated to promote women's rights in the Lebanese society and enhance gender mainstreaming in public institutions. The NCLW administers a Gender Focal Points network where members are designated by each Minister and their role is to make sure that gender considerations are taken into account in planning processes and policies, to identify gaps and obstacles for gender mainstreaming and to communicate regularly with other Focal Points to share experience and reinforce their capacities.

The Gender Focal Points have received capacity building in gender equality and climate change concepts and linkages, in sectoral aspects of gender and climate change, and in best practices for mainstreaming gender across all levels of a ministry. In fact, in Lebanon, a Gender Focal Point has been nominated to the UNFCCC to participate in gender climate negotiations and to further mainstream climate change in national policies. This provides good exposure and participation of the NCLW in international climate negotiations and consequently, linking global discussions to national gender-responsiveness.

Under the 12 strategic objectives of the National Strategy for Women (2011-2021), climate change is indirectly referred to twice under objective 9 ("Enhancing the contribution of women to environmental protection") and 11 ("Protecting girls and women in situations of emergency, armed conflict, war and natural disaster"). The document highlights the positive role that women can play along with men to improve social behaviors to mitigate climate change and to adapt to its impacts because of the gender role they hold for household management and education of children to eco-friendly behaviors. It also mentions climate change impacts and the importance of including women in DRR planning, action and capacity building.

Additional to the gender analysis report, a set of Standard Operating Procedures (SOPs) have been developed to assist ministries in integrating gender into policies and strategies and climate reporting and planning. Figure 10 provides the summary of the SOPs for integrating gender at the sector level.

Moreover, the SOPs mandate the establishment of regular impact assessments which can include indicators such as the increase (%) in women's participation in decision-making related to climate planning and action, the increase (%) in number of women-led organizations in climate related action and the decrease in inequality regarding access to and control over resources (Table 4). Based on the proposed SOPs, several capacity-building sessions were organized for gender focal points in different institutions to enhance awareness on climate change, gender, and their integration into the policy-making process. Moreover, this exercise has also allowed for improved gender integration in Lebanon's updated NDC, prioritizing it in mitigation and adaptation, as well as listing it as a climate action enabler.

A AT THE INITIAL STAGE OF THE POLICY MAKING PROCESS

1. Involvement of relevant actors

To facilitate gender integration, it is crucial to involve a range of actors who will ensure this inclusion because of their knowledge or their mandate. Involving them at an earlier stage can ensure that gender is well-mainstreamed and increases the chances for building gender-responsive policies and strategies.

2. Assessment of the situation

To integrate gender in any policy or strategy, an overview of men and women's roles in the related sector will inform the specific aspects that need to be included.

3. Collection of data

After the situation has been assessed in light of available data, and once the need for additional data has been identified, a data collection system can be planned. The data collection system can be prepared in partnership with other national institutions, academic institutes, civil society actors and international organizations. It is also beneficial to build upon existing data collection systems.

4. Conduct data analysis

Analyzing data can inform several factors within a specific sector regarding economic, social or political related aspects such as understanding the difference in access to and control over resources and availability of opportunities for women and men in rural and urban settings.

5. Study the gaps and differences and why they occur

Identifying trends and gaps in the studied sector helps understand how public policies affect men and women differently.

B IN THE POLICY MAKING PROCESS

1. Involve all relevant actors

Build capacities of women at the ministry level and promote their participation to enhance their role in the policy-making process. Women should be involved in the policy-making process at all levels and roles (decision makers/ consultation role/ advisory role / and as part of the process).

2. Be proactive in integrating gender

Reinforce the role of Gender Focal Points in ensuring they are involved at all stages of the policy making process, and organize workshops with gender institutions to increase knowledge of policy makers on gender mainstreaming. Involve donors, if applicable, and ask for external expertise if needed.

3. Gender Focal Points review policy drafts

Ensure that Gender Focal Points are able to review and comment on drafts of policy/ strategy/ plan/etc.

Figure 10: Steps from SOPs to integrate gender into climate relate policies and strategies

Table 4 Proposed indicators to assess gender integration in sectoral policies

	Energy indicators	Waste indicators	Water indicators
Gender role in the sector	• Type of energy used and consumption of energy by users (by sex) • Level of awareness of energy efficiency practices	• Type of tasks related to the waste sector (sex-disaggregated) • Number of employees in the waste sector disaggregated by position, type of work and sex	• Number of M/F trained members of Water Users Association (WUA) • Share of women in WUA • Number of water users satisfied by WUA (sex disaggregated)
Participation in the sector	• Number of women-headed businesses in the energy sector • Number of women engineers working in the energy sector	• Number of women represented at local and national levels in discussion on Solid Waste Management (SWM) • Number of women-headed companies working in SWM • Increase (%) of women's participation in SWM activities (type of activity to be defined) • % of women taking part in decision related to treatment and disposal strategies for SWM	• Number of woman-headed private companies involved in water distribution and Operations and Maintenance (O&M) • Number of women at managerial positions in private companies working in water management
Capacity building and awareness	• % of women taking part in awareness activities • % of women having access to information on financing options, energy efficiency mechanisms, and renewable energy	Number of municipality and ministry M/F employees enrolled in capacity building activities on SWM • Number of M/F participants by type of training delivered • Number of capacity building activities organized by municipalities (include number of participants, type and sex) • Number of municipalities where a partnership between civil society actors and SWM actors exist • Type of public targeted by media campaign (by age, socio-economic profile, sex)	• Number of M/F participating in awareness activities and education programs on conservation initiatives • Share of women in education programs • Number of M/F involved in awareness campaigns on irrigation techniques (sex disaggregated)
Finance	• % of women accessing green loans		

Based on the SOPs, several recommendations were put forward to accelerate the integration of gender in climate change policies and actions including:

- Strengthen the Gender Focal Points network through two-way capacity-building: gender training for climate stakeholders and climate change training for Gender Focal Points
- Raise awareness of public institutions on the benefit of women's participation in decision-making
- Involve women-led organizations in sectoral workshops, events and trainings
- Build a strong CSO network, including women-led organizations and academia, to reinforce national capacities on climate change and gender
- In key NDC sectors, take advantage of policy revision processes as and when they arise to integrate climate and gender considerations
- Allocate specific budget lines in ministries and project to work on linkages between climate change and gender
- Advocate for the SOPs to be adopted by the Council of Ministers and utilize them to mainstream gender in NDC priority sector policies, strategies, plans, and in climate planning and reporting, including NDC, UNFCCC communications, NAMAs, NAPs, and LEDS
- Adopt and further develop the SOPs and indicators to understand the level of participation of the women in institutional processes and include them in climate transparency mechanisms
- Include identified sector indicators in the Enhanced Transparency Framework that Lebanon intends to implement
- Utilize international frameworks to support sectoral gender mainstreaming, such as the UNFCCC Gender Action Plan and its national implementation, where relevant and applicable
- Reinforce existing national capacities in data collection including the role of Central Administration of Statistics in the coordination of data collection process and the DRM unit in collecting sex-disaggregated data on climate change aspects

Pursuant to the gender and climate change decision 3/CP.25, paragraph 11, Lebanon officially nominated to the UNFCCC National Gender and Climate Change Focal Points from the Ministry of Environment as well as the NCLW.

The latest Labour Force and Household Living Conditions Survey 2018-2019 organized by the Central Administration of Statistics and supported by the ILO and the EU, provided disaggregated gender data related to the share of women and men in the total residential population, martial status, head of households, educational attainment, participation in labour market including the informal sector, unemployment rates and health and disability (CAS, 2020). Although this is considered as a significant improvement towards gender mainstreaming, there still is a need to expand such studies to understand how gender roles are distributed and inform climate change policies in this regard. Additional information to be collected can include:

- Share of women and men in rural/urban population
- Share of men and women working in each sector (agriculture, industry, energy, forestry, transport, public institutions)
- Type of unpaid activities and time spent for each activity by sex
- Number of land-owners by sex
- Behavioral studies on water use, transportation pattern, food consumption, etc. by sex
- Access to loans and financial possibilities for renewable energy by sex

1.8 EDUCATION AND CLIMATE CHANGE AWARENESS

Several initiatives have been launched and established in Lebanon to raise awareness on climate change and mainstream it into the education system. The Ministry of Environment with the support of UNDP has been leading on such activities and has been providing tailored awareness sessions not only to schools/university students and local communities, but also to government institutions, private sector, and syndicates and associations. Guidebooks such as the "Teacher's guide on climate change" (2015) and "How to create value from climate change: A guide for your company in Lebanon" (2016) have been used by various institutions to mainstream climate change in their workplans. UNICEF, in collaboration with the Issam Fares Institute for Public Policy and International Affairs, has also developed climate change modules for youth training and disseminated to partners and other stakeholders to integrate and complement climate change related topics into existing and new education programs.

However, due to the economic, and social crisis, and the emergence of new national challenges and priorities, the momentum for mainstreaming climate change in the education sector has slowed down during the recent years. Awareness activities are still scattered and demand-driven, and a complete strategy on Action for Climate Empowerment (ACE) to accelerate climate solution through education, training and public awareness is yet to be developed in Lebanon.

1.9 YOUTH ENGAGEMENT IN CLIMATE CHANGE

Building on the momentum of the COP26 in Glasgow, Lebanon has been increasing the involvement of youth in climate change related activities and policies. A youth engagement and consultation session has been organized post COP26 with the support of the UK Embassy in Lebanon to define and determine the role that Lebanese youth and innovators has to play in terms of climate change negotiations at the global level, and national decision making at a local level. As a result, 3 youth representatives have been selected from Lebanon to participate in the Climate Youth Negotiator Programme and have officially joined the Lebanese delegation in COP27 in Sharm el Sheikh.

1.10 PRIVATE SECTOR ENGAGEMENT IN CLIMATE ACTION

The engagement of Lebanon under the United Nations Framework Convention on Climate Change (UNFCCC) from national reporting requirements to the submission of the updated Nationally Determined Contributions (NDC) under the Paris Agreement, created national momentum for mainstreaming climate change in sectoral policies and across different types of stakeholders, including the private sector. The latter had already been invited to consider the environmental consequences of its activities through project requirements; namely Environmental Impact Assessments (EIA) under decree 8633-2012, and Strategic

Environmental Assessments (SEA) under decree 8213-2012. Some companies extended their engagement by taking part in voluntary initiatives such as reporting their carbon footprint to the Ministry of Environment under Decision 99/1, and joining the Lebanon Climate Act (LCA); a platform promoting knowledge exchange and capacity building on climate change among non-state actors, and acknowledging the reporting efforts of companies by granting a reputational award of "climate champions".

Lebanon also introduced income tax breaks for environmental industry activities and a reduction of custom tariffs on environmentally friendly goods (decree 167 of 2017), tax exemptions on hybrid and electric cars by virtue of Article 55 of Budget Law 79/2018. These various forms of engagement allowed participating businesses to benchmark their emissions across the years and observe linkages between emission reduction and cost reductions. Some capitalized on this benefit by developing a climate action plan and identifying their climate risks and opportunities including investing in climate-friendly measures, namely reduction of industrial pollution, renewable energy and energy efficiency. In addition, few loan-based financial and technical mechanisms such as the Lebanon Environmental Pollution Abatement Project (LEPAP), the National Energy Efficiency and Renewable Energy Action (NEEREA), among others, with the support of the Lebanese central bank were implemented.

However, these financing mechanisms launched by the Central Bank are today suspended due to the country's economic and financial crisis. Several activities initiated by and for the private sector and local communities were put on hold to cater for the new challenges and needs that emerged recently. New financing and technical support initiatives have been established in hopes of offering new entry points to the private sector, including the CEDRO 5 Industry Applications for Renewable Energy and Energy Efficiency Installations with Cedar Oxygen Fund for partial grants for industrial facilities. The Subnational Climate Finance (SCF), in collaboration with Pegasus Capital, the GCF and the Ministry of Environment, is also looking to invest in infrastructure projects, such as sustainable energy, waste and sanitation, regenerative agriculture, and nature-based climate solutions.

In addition, with the exacerbation of the energy crisis in 2021 and 2022 and the removal of fuel subsidies, investments in decentralized renewable energy by the commercial and residential sector have witnessed a sharp growth and it is expected that this growth remains in the upcoming years to mitigate electricity shortages and increased prices.

While Lebanon has yet to develop a comprehensive and integrated framework for private sector climate action, these different initiatives and legislations could serve as entry points for private sector engagement in climate action and financing.

Sub-national Climate Finance

Main funding agency: Green Climate Fund

Implementing entities: Fund managed by Pegasus Capital Advisors, technical assistance provided by the International Union for Conservation of Nature (IUCN), Regions of Climate Action (R20) and Gold Standard.

Beneficiaries: 42 developing countries, including Lebanon

Finance modality: Blend of concessional and conventional capital with technical assistance grants

Commercial USD 600 million

Concessional USD 150 million (GCF)

Grant for technical assistance USD 28 million

Timeframe: 2020-2040

Objectives:

The Subnational Climate Finance initiative (SCF) is a global blended finance initiative that aims to invest in and scale mid-sized (USD 5 to 75 Million) sub national infrastructure projects in the fields of sustainable energy, waste and sanitation, regenerative agriculture and nature-based solutions in developing countries. The SCF targets local and subnational institutions and provides support on how subnational climate projects should be structured, de-risked, and funded by both public and private investors, while monitored and benchmarked in accordance with agreed standards.

More information on : https://www.subnational.finance/scf-fund/

A study on the corporate engagement of Lebanese businesses with climate action and financing was conducted in 2022 under the GCF readiness project (MoE/GCF, 2022a) based on 3 private sector dialogues and a pulse survey of 80 companies representing the various economic sectors in Lebanon. The study confirms that while climate change is not a new topic among Lebanese companies, and while many are aware about related risks and opportunities on their businesses, climate change has yet to be integrated and prioritized in corporate strategies where climate action and investments can be measured, tracked and associated to wider targets for a transformational shift in the private sector towards sustainability. This will necessitated the update of development of related policies and institutional arrangements to enable green investments and reduce costs (eliminating all fossil fuel subsidies, enabling cost recovery from waste generation, exploring the feasibility of a cap-and-trade system), strengthening regulations around carbon footprint reporting, scaling up research around private climate action and investments, and incorporating the topic in academic business curriculums.

The pulse survey results showed that there was still an interest from Lebanese companies to incorporate climate change related activities in their corporate strategies and associate them to wider sustainability targets. Opportunities are being spotted at all levels, including the bottom line (consumer-line) and the private sector is exploring solutions for its value chain such as investments in solar energy following the oil prices fluctuations, removals of subsidies on fuel and electricity shortage in Lebanon.

Survey respondents reported mostly feeling the impacts of climate change on the availability of raw materials and affordability of key resources (for instance, the scarcity of grape yields due to unfavorable weather events jeopardizes wine production) as well as the increase of physical risks on assets, transitional (regulatory) risks and disruptions along the supply chain. They also cited political and economic instability of the country, the lack of financial instruments, high investment costs and weak public support and institutional set-up as main reasons of hampered climate investments.

More details of the pulse survey results are available in the below figures.

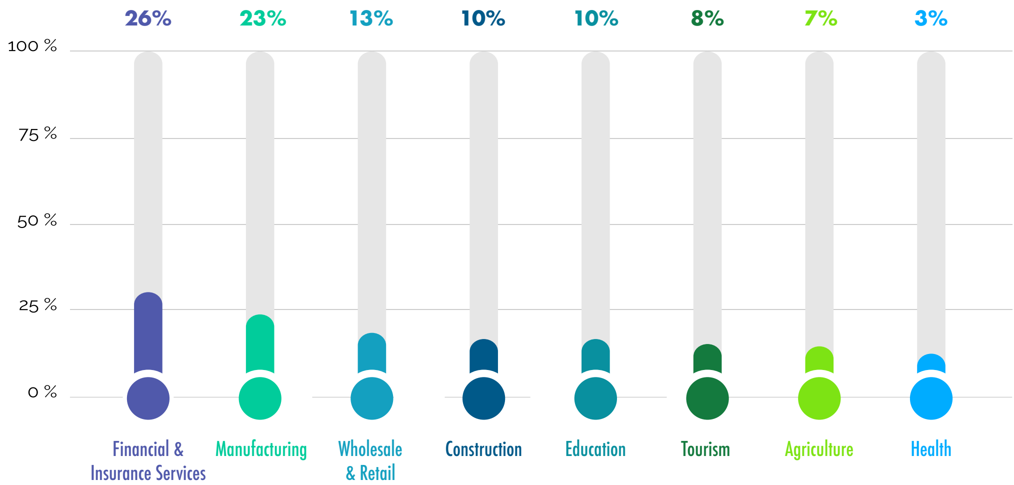


Figure 11: Sample composition of pulse survey

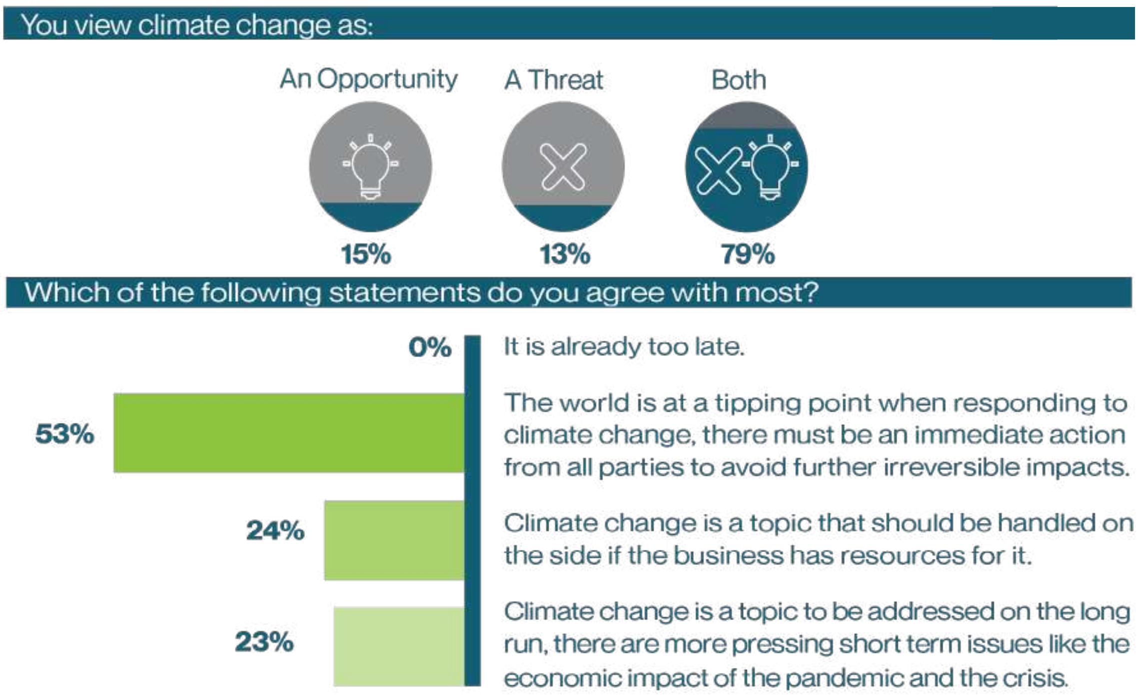


Figure 12: Businesses views of climate change

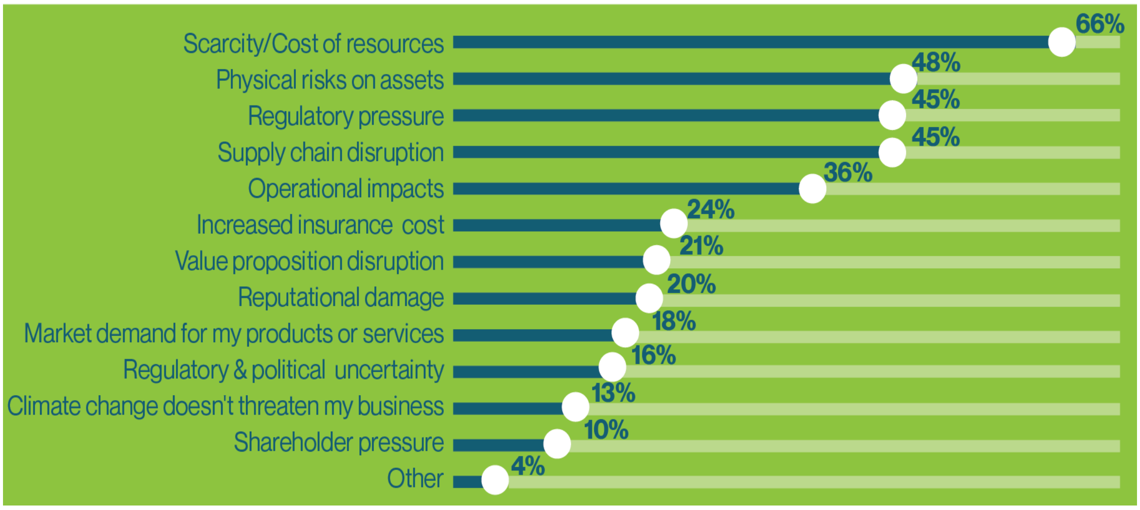


Figure 13: Perceived negative impacts of climate change on businesses

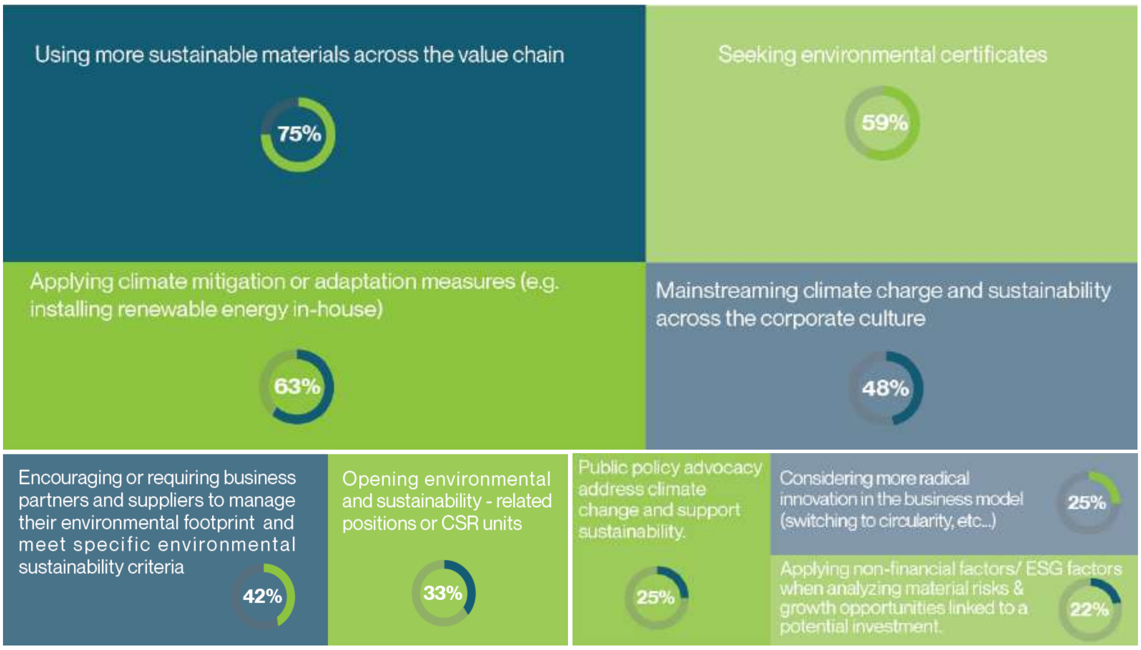


Figure 14: Types of climate change and sustainability initiatives deployed by the private sector


3
GOOD HEALTH
AND WELL-BEING
Selfie

CHAPTER 2

INSTITUTIONAL ARRANGEMENTS RELATED TO MRV

SUMMARY OF KEY POINTS

- In Lebanon, the Ministry of Environment (MoE) is the national focal point for climate change and is also the focal point of the following climate change related international organizations, centers, initiatives and funding bodies.
- A climate change project team, supported by multilateral funds, works under the Service of Environmental Technology at the Ministry of Environment, and is responsible amongst other, for the preparation and submission of the National Communications (NC).
- In order to prepare and submit NCs on a continuous basis, institutional arrangements have been put in place according to the preparation of GHG inventories, undertake mitigation analysis, update and assess climate risks and vulnerabilities, update Technology Needs Assessments and report on gaps, constraints and related financial, technical and capacity building needs.
- Lebanon has no specific methodology for monitoring the progress of climate action and for tracking and reporting on support received, as limited information is available to estimate the overall support that Lebanon is receiving for climate action.
- As part of the CBIT project, an MRV Coordination Entity is to be established to set a mechanism to track climate action and finance flows, through its network or partners or through a regular donor coordination process. In addition, the operationalization of an MRV platform will facilitate the exchange of data between Ministries, among which progress indicators and financial flows.

2.1 INSTITUTIONAL ARRANGEMENTS FOR THE PREPARATION OF NATIONAL COMMUNICATIONS

In Lebanon, the Ministry of Environment (MoE) is the national focal point for climate change and is also the focal point of the following climate change related international organizations, centers, initiatives and funding bodies such as:

- United Nations Framework Convention on Climate Change (UNFCCC)
- Intergovernmental Panel on Climate Change (IPCC)
- The Adaptation Fund
- NDC Partnership
- Green Climate Fund (GCF)
- Climate Technology Centre and Network (CTCN)
- Climate Vulnerable Forum (CVF)
- Cartagena Dialogue for Progressive Action (CD)
- Partnership on Transparency in the Paris Agreement (PATPA)
- Initiative for Climate Action Transparency (ICAT)

A climate change project team, supported by multilateral funds, works under the Service of Environmental Technology at the Ministry of Environment, and is responsible amongst others, for the preparation and submission of the National Communications (NC).

Mandate of the climate change project team at MoE

- Prepare National Communications and Biennial Update Reports
- Prepare and update of Nationally Determined Contributions along with implementation follow up,
- Develop climate change policy (i.e., Low-Emission Development Strategy, financial incentives),
- Follow-up and lead on institutional arrangements to enhance national climate action, finance and transparency,
- Follow-up on mainstreaming climate change in national sectoral policies, strategies and institutions including energy, water, transport, agriculture, forestry, solid waste, wastewater, oil and gas, finance, gender, sustainable development, education, research, disaster risk, cities, etc.
- Establish linkages and synergizing work with other international conventions such as the UN Convention to Combat Desertification, the UN Convention on Biological Diversity, the Sendai Framework for Disaster Risk Reduction, the Montreal Protocol on Ozone Depleting Substances, and its Kigali amendments, the Agenda 2030 for Sustainable Development, etc.
- Follow-up on international climate change negotiations, under the UNFCCC,
- Coordinate regional and international climate change related projects,
- Provide technical support to the focal point to the UNFCCC, Green Climate Fund, Adaptation Fund, Global Environment Facility, Climate Technology Center and Network and Intergovernmental Panel on Climate Change.

Accordingly, the Ministry of Environment was responsible for coordinating the preparation of Lebanon's first, second, third and fourth National Communications and Biennial Update reports, with the support of the Global Environment Facility (GEF), and the collaboration of the United Nations Development Programme (UNDP).

In order to prepare and submit NCs on a continuous basis, institutional arrangements have been put in place according to the following elements:

1- GHG inventory: The Ministry of Environment's climate change project team is the lead compiler of the GHG inventory. Various ministries such as the Ministry of Energy and Water, the Ministry of Agriculture, the Ministry of Interior and Municipalities, and research institutions such as the Institute for Environment at the University of Balamand and the IPT Energy Centre, are mainly involved in the provision of activity data and other parameters for the preparation and validation of the GHG inventory.

2- Mitigation analysis: The Ministry of Environment's climate change project team is the entity responsible to analyze and recommend mitigation measures to further reduce national GHG emissions, as part of its national communication reports. The development of business-as-usual scenarios as well as mitigation scenarios for different sectors are undertaken by sectoral experts in close consultation with national stakeholders and decision makers.

3- Risk and vulnerability and adaptation: The Ministry of Environment's climate change project team is the lead author of the risk and vulnerability chapter, where the most recent national and regional research on climate change risks, impacts and sectoral vulnerabilities are compiled and analyzed. An external reviewer is recruited as a Quality Control measure to ensure consistency and completeness of the data. Finally, a set of sectoral recommendation measures are proposed in consultation with relevant stakeholders.

4- Technology Needs Assessment: External consultants are recruited to update Lebanon's TNA for the energy, transport, agriculture and water sectors. Intensive stakeholders' consultations are undertaken to prioritize respective technologies based on multi-criteria decision analysis and to develop technology action plans.

5- Constraints and gaps and related financial, technological, and capacity building needs and support needed and received: Information related to sectoral constraints, gaps and needs are collected through stakeholders' consultations and bilateral meetings with key experts, in addition to a desk review of relevant national reports, plans and strategies that identify and report similar information. A validation exercise is also undertaken with representatives of donor agencies and international organization to ensure no omission of activities. However, the absence of proper institutional arrangements to involve local communities, municipalities and the private sector hinders the completeness and accuracy of the exercise.

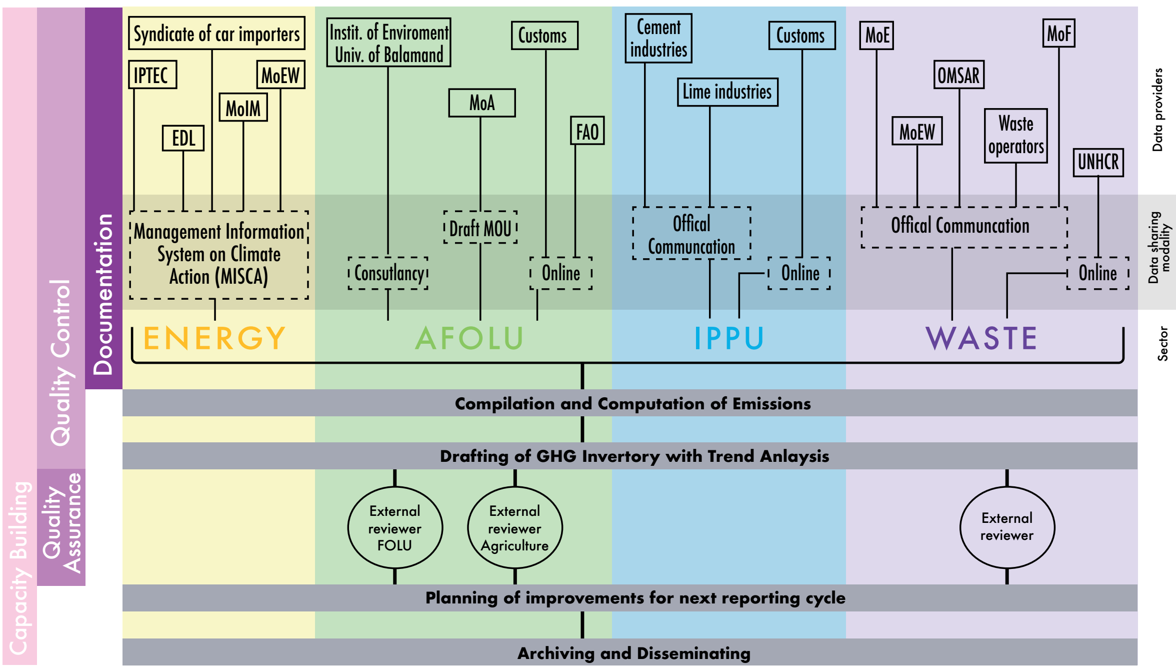
Through the Capacity Building for Improved Transparency (CBIT) project, Lebanon envisages to establish an MRV Coordinating Entity (MRVCE) and a network of partners to enhance the role and engagement of ministries and agencies not only in the preparation of the GHG inventory, but also in collecting data and information for other sections.

2.2 GHG INVENTORY SYSTEM

Lebanon has produced three National Communications (NC) (submitted in 1999, 2011 and 2016) and four Biennial Update Reports (BUR), submitted in 2015, 2017, 2019 and 2021, each containing a national Greenhouse Gas (GHG) inventory. The last GHG inventory, reported as part of Lebanon's 4th BUR, covers a time series from 1994-2018 and was compiled using the 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories and using the IPCC software version 2.54.

The GHG inventory is an integral part of National Communications and Biennial update reports, whose preparation have been undertaken through the Global Environment Facility's (GEF) enabling activity and managed by the United Nations Development Programme (UNDP) in Lebanon. The overall coordination of the GHG inventory is handled by the climate change office, which is part of the Service of Environmental Technology at MoE.

The GHG inventory compilation team is located at the climate change office and is financed on a project basis. The retention of the compilation team therefore depends on the ability to sustain international funding. The compilation team is supported by sectoral experts (transport, FOLU, wastewater) recruited on a needs basis as well as external reviewers. Activity data is collected by the Ministry of Environment - Climate Change project team through data sharing requests with relevant institutions. Intensive stakeholders and key data holders consultations are conducted during the process, building on existing institutional arrangements.



IPTEC: IPT Energy Center; EDL: Electricite du Liban; MoIM: Ministry of Interior and Municipalities; MoEW: Ministry of Energy and Water; MoA: Ministry of Agriculture; MoU: Memorandum of Understanding; FAO: Food and Agriculture Organization; MoE: Ministry of Environment; OMSAR: Office of the Minister of State for Administrative Reform; MoF: Ministry of Finance; UNHCR: United Nations High Commissioner for Refugees.

Figure 15: GHG Inventory preparation process for the inventory of 2019

During the GHG inventory preparation process, attempts to abide by a pre-defined GHG inventory cycle have been compromised by various delays in access to funding, access to data, or enabling political environment. These delays affect the approach of data collection, which is mostly undertaken on an ad-hoc manner (as opposed to having a restrained data collection phase) which decreases the time spent and efforts invested in improving methodologies, data validation, Quality Assurance/ Quality Control (QA/QC) and uncertainty analysis.

Uncertainty assessment has been carried out for this inventory based on the 2006 IPCC guidelines.

Quality Assurance (QA) and Quality Control (QC) measures have been undertaken for the activity data, emission factors and parameters following the recommendations and IPCC 2006 Revised Guidelines. Standardized **documentation and archiving** templates have been used to capture methodologies and data, expert judgements and assumptions, recalculations and improvements made as well as reported issues and potential improvements.

The adoption of the standardized documentation sheets upstream allowed a significant improvement in the tracking of methodological changes, data sources, assumptions, necessary improvements and recalculations. QC roles and responsibilities were clearly allocated, both general and category-specific QC measures were defined and applied, sectoral QA was undertaken and outcomes of QA/QC were documented. Quality assurance for the GHG inventory was performed through an external review by a UNFCCC reviewer.

By adopting this approach, the inventory compilation team intended to bring significant improvement on both the implementation and reporting of QC procedures, while balancing quality control requirements, improved accuracy and reduced uncertainty against requirements for timeliness and cost effectiveness.

2.3 MRV OF MITIGATION AND ADAPTATION ACTIONS AND POLICIES

Currently Lebanon has no specific methodology for monitoring the progress of actions described. Sectoral experts are usually recruited to collect information on mitigation and adaptation activities being undertaken at a national level and consultations with project proponents and main stakeholders help identify mitigation and adaptation actions being implemented or being planned. However, this exercise is not undertaken on a systematic and regular basis and linkages between sectoral policies and actions and climate change are still not well clarified. Indeed, institutionalized communication and reporting channels are crucial to avoid double counting, assign specific activities to specific plans and/or commitments, and identify the multitude of actors working on mitigation and adaptation actions beyond the sectoral actors. For example, the private sector and municipalities are responsible for a significant part of climate action reduction, however, due to the unavailability and scattering of relevant data, their activities are not completely covered under this reporting exercise. The current approach to assessing impacts of mitigation and adaptation actions does not allow filtering through different levels of information to identify cluster of information.

Based on the above, tracking climate actions accurately and comprehensively has become an important need to better assess emission reduction progress against committed targets and the impact of adaptation action on beneficiaries.

Lebanon plans to enhance the robustness and institutionalization of reporting mitigation actions through 2 main workstreams:

1- Mapping of planned and implemented activities through the NDC Partnership: Lebanon became a member of the NDC Partnership in 2019, and as the main focal point, the Ministry of Environment has coordinated with several ministries to develop sectoral Partnership Plans (PPs) for the energy, transport, waste, water and wastewater, agriculture, and forestry sectors. These plans present Lebanon's priorities related to climate change actions in a framework that allows tracking progress against results. It will therefore present new and planned climate action work as well as ongoing projects and programs, including sectoral barriers and needs with corresponding enabling technical and financial assistance activities. The Partnership Plans are being re-evaluated by respective ministries in 2021 to reflect the recent national circumstances and have been shared with the NDC Partnership partners in order to mobilize relevant support.

2- Institutionalized tracking of activities through the Capacity Building Initiative on Transparency (CBIT): As part of the CBIT project (2022-2025), a Measuring, Reporting and Verifying Coordinating Entity (MRVCE) is planned to be established with the responsibility to develop a long-term transparency strategy which will be a strong reference point for all stakeholders in planning their activities when it comes to reporting, capacity-building and institutional arrangements. Under the project, the MRVCE is expected to set up a cross-cutting system that tracks GHG emissions, mitigation and adaptation actions, support received and needed, and capacity building needs.

Capacity building is much needed at the national level to improve monitoring and reporting of sectoral mitigation and adaptation activities. Lebanon identifies the MRV for climate action actions as a priority area for capacity building, not only to set up a transparency baseline and an MRV system but also to support national institutions to develop indicators and track and report progress on mitigation and adaptation actions.

Lebanon is committed to improve data collection and management over time, and to formalize institutional arrangements that support the long-term collection, analysis and reporting of information on mitigation actions.

2.4 MRV OF FINANCE

Currently, no single entity is responsible for tracking and reporting on climate change projects and related expenditures in Lebanon. The MoE has attempted to identify and track climate change related activities across the years and their related financing, however limited information was available to estimate the overall support that Lebanon is receiving for climate action.

As part of the CBIT project, the MRV Coordination Entity is planned to set a mechanism to track climate change finance flows, through its network or partners or through a regular donor coordination process. In addition, the operationalization of an MRV platform will facilitate the exchange of data between Ministries, among which financial flows.

Technical support and capacity building is much needed in Lebanon in order to collect and report information on support received in a systematic and sustainable way. Nationally endorsed definitions on finance, capacity building and technology transfer are required to provide a common understanding of what should be considered when tracking support, both for the purposes of international reporting as well as for national decision-making processes. There is also a capacity building need to harmonise data from all sources (i.e., include all the actions implemented by private and public stakeholders), to estimate climate impacts of groups of actions and to avoid double counting of overlapping mitigation actions.

Support should target all involved stakeholders, as described in Table 5, to ensure an inclusive and complete reporting mechanism for climate finance flows. The establishment of an MRVCE is becoming essential to create a momentum and set the first bases of an MRV system.

Table 5 Key Stakeholders for tracking and reporting climate finance flows

Stakeholders	Potential role in climate finance reporting	Gaps and constraints
Cash Management Unit (CMU) at the Ministry of Finance	Reports information on related cash grants received by Lebanon public institutions	No reporting of Non-cash grants such as technical support, capacity building support or technology transfer
Public Debt Department at the Ministry of Finance	Reports related loans received by the Lebanese Government through the Debt Management and Financial Analysis System (DMFAS)	No details on the technical aspect and content of the loan to establish climate relevance or not. Only captures loans received by the Lebanese government
Expenditure Unit at the Ministry of Finance	Reports domestic finance flow based on the expenditure of governmental institutions	No details on the technical aspect of the expenditure to establish climate relevance or not
Ministerial budgets	Reports information on public expenditure on relevant project in a disaggregated form	Not publicly available for all ministries
Council for Development and Reconstruction	Reports technical and financial details on grants and loans managed by CDR through the JD Edwards data management system Reports cash and non-cash support received Reports information disaggregated per sector	Only reports on project implemented by CDR Different classification of information than MoF system
Ministry of Environment	Reports technical and financial details on support received through specific climate change and environmental funds (Adaptation Fund, Green Climate Fund, Global Environment Facility, etc.)	
Council of Ministers	Reports on loans and grants have been released in the official gazette	Information not easily searchable as it is scanned and included as pictures in the archiving system

UN agencies and international organizations	Report on technical and financial information related to grants received directly to international organizations	Information scattered across agencies Funds not accounted for in the Lebanese public sector
Municipalities	Report financial and technical information related to grants received directly to Municipalities	Grants are not registered by the cash CMU or the CDR.
Non-Governmental Organizations (NGOs)	Report financial and technical information related to grants received directly to NGOs	Grants not captured by any government agency.
Investment Development Authority of Lebanon	Reports Foreign Direct Investments	

CHAPTER 3

THE NATIONAL DIRECT AND INDIRECT GREENHOUSE GAS INVENTORY OF 2019

SUMMARY OF KEY POINTS

- In 2019, Lebanon emitted 30,089 Gg CO_2eq. (as total emissions), which is a 7% decrease from 2018 mainly due to a significant decrease in energy-related emissions.
- Due to the civil unrest of October 2019 followed by monetary devaluation, the annual consumption of fuel for electricity and energy generation dropped by around 10% compared to 2018. The decrease in fuel consumption was detected at both the EDL power plant levels, and the private generation levels.
- Import and consumption of petcoke, which has a high CO_2 emission factor, decreased by 40% in 2019, further decreasing energy-related emissions.
- Still, the main contributor to greenhouse gas emissions in Lebanon remains the energy sector (including transport) with 80% of GHG emissions, followed by industrial processes (11%).
- CO_2 removals from forestry and land use change amounted to -3,060 Gg CO_2, bringing Lebanon's NET emissions to 27,028 Gg CO_2eq.
- Total GHG emissions increased by approximately 3-fold since 1994, with an average yearly increase of 6%. The trend of increase in total GHG emissions closely follows the trend of emissions from the energy sector, reflecting the growing demand of fuel for electricity and transport, despite changing national circumstances.
- In terms of indirect emissions, results show that transport is still the main source of CO and NMVOC in 2019 and power generation the main source of SO_2, while emissions of NO_x are generated equally from both the energy and transport sector.
- During the period of 1994-2019, most of the indirect emissions increased, mainly due to the increase in energy and transport demand, the increase in reliance on private generators and the reduced efficiency and performance of EDL power plants.
- However, the year 2019 has witnessed a drop in emissions caused by the disruptions in fuel consumption post October 2019, especially in energy/electricity generation at the industrial and commercial levels.
- Transport related indirect emissions conserved their steady increase of 5 to 11% per year across the 1994-2019 period, with passenger cars contributing the most to emission generation (47% to 66% of emissions).

3.1 METHODOLOGY

The inventory of Greenhouse Gas (GHG) emissions in this report covers the year 2019, with a recalculated time series for 1994-2019 when needed. The inventory was prepared based on the 2006 IPCC Guidelines, and using the IPCC software version 2.54, including analysis of key categories, uncertainties and generation of trends. The inventory is in line with UNFCCC Decisions 17/CP.8 and 2/CP.17. To the extent possible, the inventory implemented the provisions of decision 18/CMA.1 on modalities, procedures and guidelines for the transparency framework. Emissions of Carbon Dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O) were estimated and reported in Gg CO_2eq. (1,000 tonnes) using the Global Warming Potential of the IPCC Fifth Assessment Report's. The following sectors are covered: 1. Energy (including transport), 2. Industrial Processes and Product Use (IPPU), 3. Agriculture Forestry and Other Land Use (AFOLU) and 4. Waste (including wastewater).

To estimate the GHG emissions, tier 1 methods were mostly applied using default emission factors, with activity data being derived from national sources, international organizations and other literature as identified in each sector. Proxy data, interpolations, extrapolations and estimations based on expert judgments were used in cases where data was unavailable.

Tier 2 methods were used to estimate emissions from cement manufacturing, product uses as substitutes for Ozone Depleting Substances (F-gases), road transport (for CH_4 and N_2O), solid waste disposal on land and wastewater treatment and discharge, while approach 3 was adopted for the representation of land use areas in some subcategories of AFOLU.

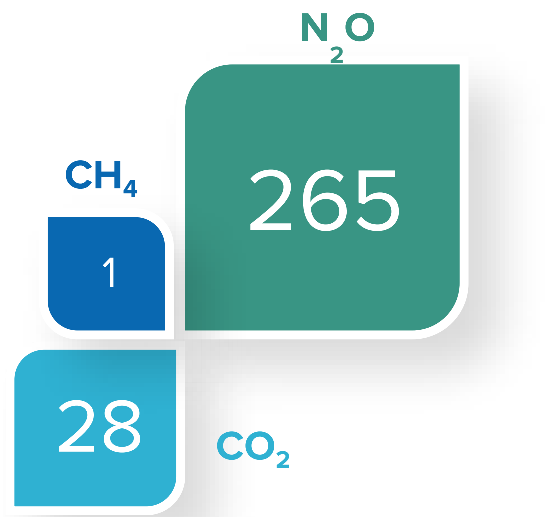


Figure 16: Global Warming Potential (IPCC, 2014)

For indirect greenhouse gases, CO, NO_x, NMVOC and SO_x have been calculated using the EMEP/EEA 2019 tier 1 methodology for all categories, except for transport where tier 2 technology-specific methodology was used. SO_2 emissions from transport were calculated based on the regulatory limit of sulfur content in fuels.

3.2 RESULTS AND TREND ANALYSIS

In 2019, Lebanon emitted 30,089 Gg CO_2eq. (as total emissions), which is a 7% decrease from 2018 (calculated as 32,472 Gg CO_2eq.), mainly due to a significant decrease in energy-related emissions. Indeed, due to the civil unrest of October 2019 followed by monetary devaluation, the annual consumption of fuel for electricity and energy generation dropped by around 10% compared to 2018. The decrease in fuel consumption was detected at both the EDL power plant levels, and the private generation levels. In addition, import and consumption of petcoke, which has a high CO_2 emission factor, decreased by 40% in 2019, further decreasing energy-related emissions. Still, the main contributor to greenhouse gas emissions in Lebanon remains the energy sector (including transport) with 80% of GHG emissions, followed by industrial processes (11%) (Figure 17 and Figure 18). CO_2 removals from forestry and land use change amounted to -3,060 Gg CO_2, bringing Lebanon's NET emissions to 27,028 Gg CO_2eq. (Table 6).

In general, total GHG emissions increased by approximately 3-fold since 1994, with an average yearly increase of 6%. The trend of increase in total GHG emissions closely follows the trend of emissions from the energy sector, reflecting the growing demand of fuel for electricity and transport, despite changing national circumstances (Figure 19).

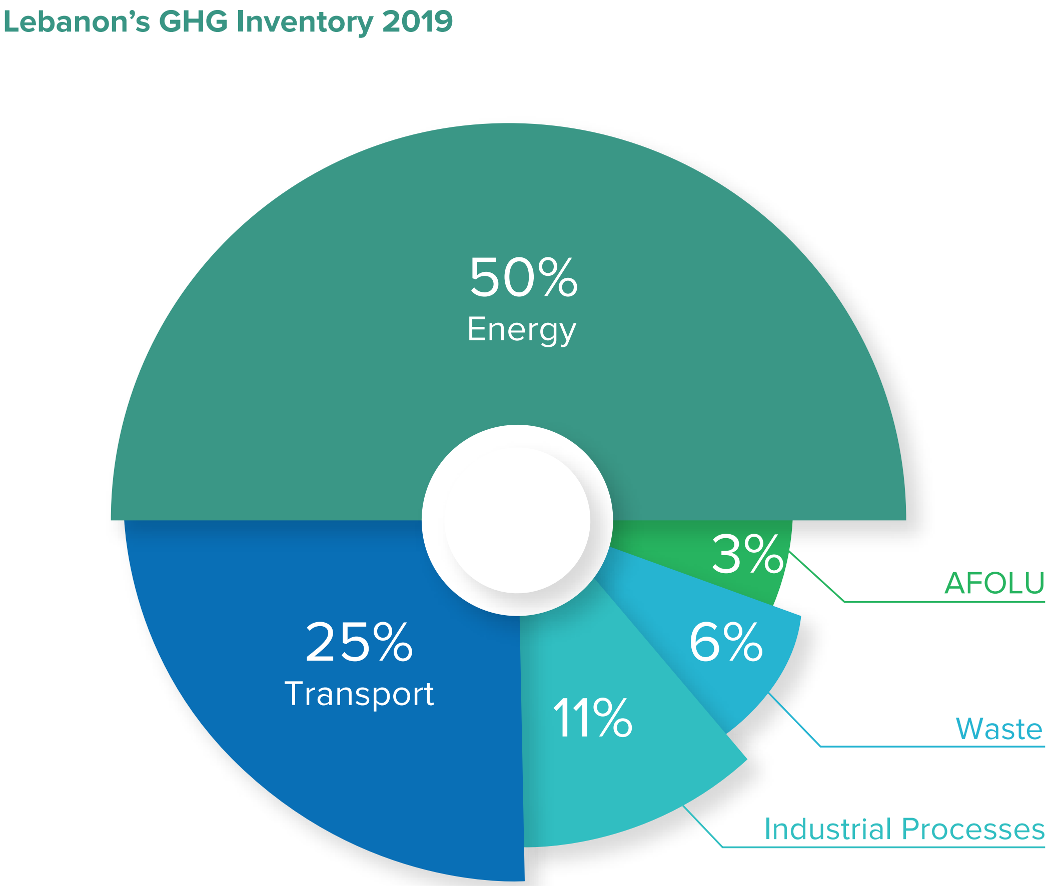


Figure 17: Lebanon's national greenhouse gas inventory by category in 2019

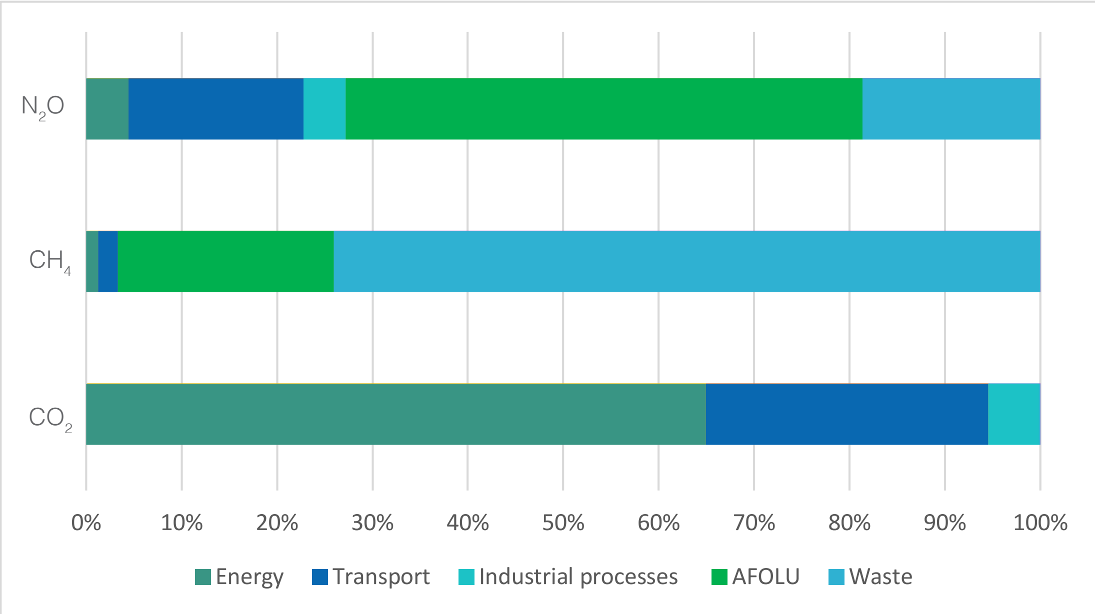


Figure 18: Lebanon's national greenhouse gas inventory by gas in 2019

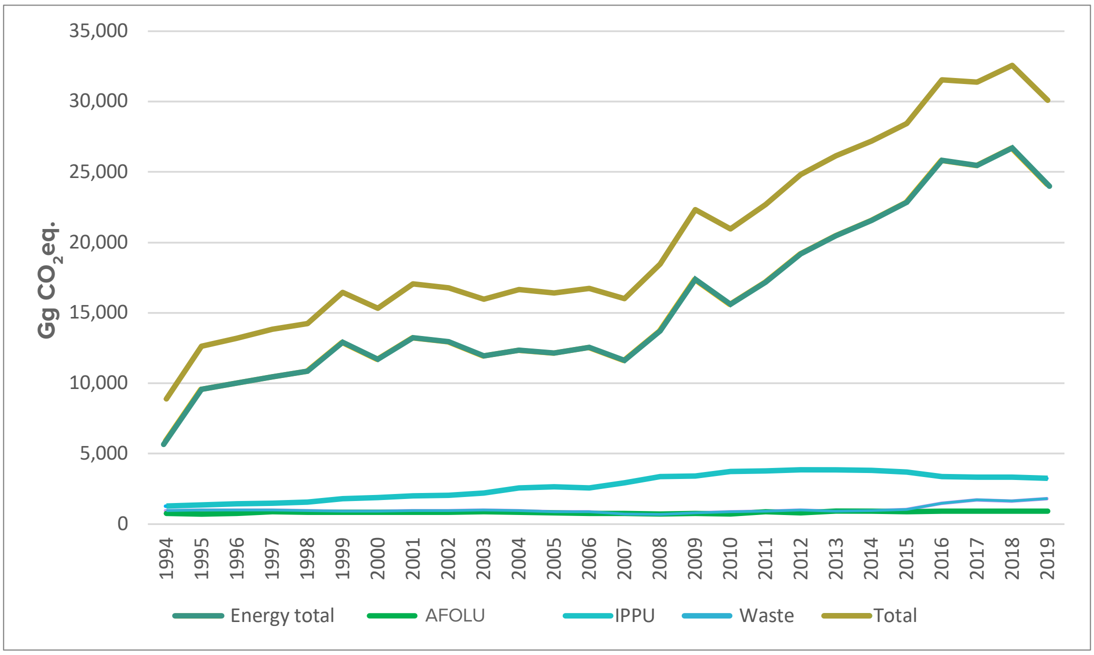


Figure 19: Trend in total and sectoral GHG emissions 1994-2019

Table 6 Lebanon's GHG emissions and removals for 2019 per gas and category

Greenhouse gas source and sink categories	CO_2 emissions/ removals	CH_4	N_2O	CH_4	N_2O	F-gases	Total emissions	Net emissions
	Gg	Gg	Gg	Gg CO_2eq.	Gg CO_2eq.	Gg CO_2eq.	Gg CO_2eq.	Gg CO_2eq.
Total National Emissions and Removals	22,191.73	78.85	2.84	2,207.78	751.46	1,877.75	30,089.63	27,028.72
1 - Energy	23,872.32	2.63	0.65	73.70	171.20		24,117.22	
1.A - Fuel Combustion Activities	23,872.32	2.63	0.65	73.70	171.20		24,117.22	
1.A.1 - Energy Industries	9,362.41	0.37	0.07	10.35	19.59		9,392.34	
1.A.2 - Manufacturing Industries and Construction	3,514.68	0.13	0.03	3.69	6.97		3,525.34	
1.A.3 - Transport	7,480.96	1.64	0.52	46.02	137.98		7,664.96	
1.A.4 - Other Sectors	3,514.27	0.49	0.03	13.64	6.67		3,534.58	
2 - Industrial Processes and Product Use	1,339.03		0.13	-	33.39	1,877.75	3,250.17	
2.A - Mineral Industry	1,338.52	NA	NA	NA	NA	NA	1,338.52	
2.A.1 - Cement production	1,336.56	NA	NA	NA	NA	NA	1,336.56	
2.A.2 - Lime production	0.75	NA	NA	NA	NA	NA	0.75	
2.A.3 - Glass Production	IE	IE	IE	NO	NO	NA		
2.A.4 - Other Process Uses of Carbonates	1.21	NA	NA	NA	NA		1.21	
2.B- Chemical Industry	NO	NO	NO	NO	NO	NA		
2.C - Metal Industry	NO	NO	NO	NO	NO	NA		
2.D - Non-Energy Products from Fuels and Solvent Use	0.51	NA	NA	NA	NA		0.51	
2.D.1 - Lubricant Use	IE	NA	NA	NA	NA			
2.D.2 - Paraffin Wax Use	0.51	NA	NA	NA	NA		0.51	
2.D.3 - Solvent Use	NE	NA	NA	NA	NA			
2.E- Electronics Industry	NO	NO	NO	NO	NO	NA		
2.F - Product Uses as Substitutes for ODS						1,877.75	1,877.75	
2.F.1 – Refrigeration/ Air Conditioning	NA	NA	NA	NA	NA	1,877.75	1,877.75	
2.F.2 - Foam Blowing	NO	NO	NO	NO	NO	NO		
2.F.3 - Fire Protection	NE	NE	NE	NE	NE	NE		
2.F.4 - Aerosols	NO	NO	NO	NO	NO	NO		
2.F.5 - Solvents	NO	NO	NO	NO	NO	NO		
2.G - Other Product Manufacture and Use			0.13		33.39		33.39	
2.G.1 - Electrical Equipment	NE	NE	NE	NE	NE	NE		
2.G.2 - SF_6 and PFCs from Other Product Uses	NE	NE	NE	NO	NO	NO		
2.G.3 - N_2O from Product Uses	NA	NA	0.13	NA	33.39	NA	33.39	
2.G.4 - Other	NE	NE	NE	NE	NE	NE		
3 - Agriculture, Forestry, and Other Land Use	(3,052.25)	17.82	1.54	498.91	406.92		914.49	
3.A - Livestock	-	17.75	0.41	497.08	107.95	-	605.03	

Greenhouse gas source and sink categories	CO_2 emissions/ removals	CH_4	N_2O	CH_4	N_2O	F-gases	Total emissions	Net emissions
	Gg	Gg	Gg	Gg CO_2eq.	Gg CO_2eq.	Gg CO_2eq.	Gg CO_2eq.	Gg CO_2eq.
3.A.1 - Enteric Fermentation	NA	14.39	NA	402.90	NA		402.90	
3.A.2 - Manure Management	NA	3.36	0.41	94.18	107.95		202.13	
3.B - Land	(3,060.91)	NA	NA	NA	NA		(3,060.91)	
3.B.1 - Forest land	(1,897.80)	NA	NA	NA	NA		(1,897.80)	
3.B.2 - Cropland	(1,219.94)	NA	NA	NA	NA		(1,219.94)	
3.B.3 - Grassland	NE	NE	NE	NE	NE		NE	
3.B.4 - Wetlands	NE	NE	NE	NE	NE		NE	
3.B.5 - Settlements	56.82	NA	NA	NA	NA		56.82	
3.B.6 - Other Land	NO	NO	NO	NO	NO		NO	
3.C - Aggregate sources and non-CO_2 emissions sources on land	8.66	0.07	1.13	1.82	298.98		309.46	
3.C.1 - Emissions from biomass burning		0.07	0.00	1.82	0.98		2.81	
3.C.2 - Liming	NO	NA	NA	NA	NA			
3.C.3 - Urea application	8.66	NA	NA	NA	NA		8.66	
3.C.4 - Direct N_2O Emissions from managed soils	NA	NA	0.75	NA	199.94		199.94	
3.C.5 - Indirect N_2O Emissions from managed soils	NA	NA	0.28	NA	73.15		73.15	
3.C.6 - Indirect N_2O Emissions from manure management	NA	NA	0.09	NA	24.90		24.90	
3.D Other								
3.D.1 - Harvested Wood Products	NE	NA	NA	NA	NA		NE	
4 - Waste	32.63	58.40	0.53	1,635.18	139.95		1,807.75	
4.A - Solid Waste Disposal	-	30.40	-	851.32	-		851.32	
4.B - Biological Treatment of Solid Waste	-	2.17	0.12	60.65	31.64		92.29	
4.C - Incineration and Open Burning of Waste	32.63	4.71	0.09	131.96	23.51		188.10	
4.D - Wastewater Treatment and Discharge	-	21.12	0.32	591.25	84.80		676.05	
Memo Items								
International Bunkers	948.61	0.02	0.03	0.46	6.89		955.95	
1.A.3.a.i - International Aviation	827.72	0.01	0.02	0.16	6.10		833.97	
1.A.3.d.i - International water-borne navigation	120.88	0.01	0.01	0.30	0.79		121.98	
Information Items								
CO_2 from Biomass Combustion for Energy Production	17.20							

Uncertainty estimates have been done at different inventory levels (from inputs data, to the national annual estimates of emissions or removals, and emissions or removals trends) using appropriate methods based on the IPCC Good Practice Guidances (IPCC, 2000; 2003), and the IPCC 2006 Guidelines (IPCC, 2006). Sectoral experts investigated the uncertainty parameters coming under their field of work, and uncertainties have been calculated for CO_2, CH_4 and N_2O (The analyse does not include the emissions of HFCs, PFCs, and SF_6). The estimated overall uncertainty of the total inventory reached 13% in 2019, with the corresponding uncertainty in trend 1994-2019 estimated to 156%. Details of uncertainty calculation are presented in Annex I.

3.3 KEY CATEGORY ANALYSIS

According to the IPCC definition, a key category is one that is prioritized within the national inventory system because its estimate has a significant influence on a country's total inventory of direct GHGs in terms of the absolute level of emissions, the trend in emissions, or both. Total emissions from the key categories amount to 95% of the total emissions included in the inventory. Key categories for Lebanon are determined under both the trend and level assessments as presented in the below tables.

Table 7 Key categories by level assessment (LA) for 2019

	IPCC Category	GHG gas	Emissions (Gg CO_2eq.)	Cumulative share LA (%)
1.A.1	Energy Industries - Liquid Fuels	CO_2	9,362.41	28.15%
1.A.3.b	Road Transportation	CO_2	7,469.36	50.60%
1.A.2	Manufacturing Industries and Construction - Liquid Fuels	CO_2	3,514.68	61.17%
1.A.4	Other Sectors - Liquid Fuels	CO_2	3,514.27	71.74%
2.F.1	Refrigeration/Air conditioning	F-Gas	1,877.75	77.38%
3.B.1.a	Forest land Remaining Forest land	CO_2	1,896.15	83.08%
2.A.1	Cement production	CO_2	1,336.56	87.10%
3.B.2.a	Cropland Remaining Cropland	CO_2	1,219.94	90.77%
4.A	Solid Waste Disposal	CH_4	851.32	93.33%
4.D	Wastewater Treatment and Discharge	CH_4	588.75	95.10%

Table 8 **Key categories by trend assessment (TA) for 2019**

	IPCC Category	GHG gas	Cumulative share TA (%)
1.A.2	Manufacturing Industries and Construction - Liquid Fuels	CO_2	19.2%
3.B.1.a	Forest land Remaining Forest land	CO_2	36.3%
1.A.1	Energy Industries - Liquid Fuels	CO_2	53.4%
3.B.2.a	Cropland Remaining Cropland	CO_2	63.8%
2.A.1	Cement production	CO_2	73.4%
1.A.4	Other Sectors - Liquid Fuels	CO_2	81.9%
1.A.3.b	Road Transportation	CO_2	86.3%
4.A	Solid Waste Disposal	CH_4	89.7%
3.A.1	Enteric Fermentation	CH_4	92.8%
4.D	Wastewater Treatment and Discharge	CH_4	94.2%
3.A.2	Manure Management	CH_4	95.1%

3.4 RECALCULATIONS

According to the IPCC 2006 guidelines, it is good practice to recalculate historic emissions with the availability of new activity data or emission factors so that the entire time series of emissions is consistent. In the 4NC, slight recalculations were made, specifically in the waste sector with an update of activity data for the industrial waste and open dumping/burning. The recalculation had no significant impact on the total emissions of Lebanon, with an average change of 0.18% over the time series.

3.4 COMPARISON BETWEEN THE SECTORAL AND THE REFERENCE APPROACH

According to the IPCC 2006 guidelines, carbon dioxide emissions from the energy sector should be calculated using both the reference (data on primary energy consumption based on fuel imports) and the sectoral approach (detailed disaggregation of energy consumption by sector and fuel).

The Reference Approach and the Sectoral Approach often have different results, with a typical allowable gap between of 5%. In Lebanon, the difference between the 2 approaches in the GHG inventory of 2019 is 1.46% (Table 9).

Table 9 Difference between reference and sectoral approach

	CO_2 emissions (Gg)	% Difference
Reference approach	23,906.85	1.46%
Sectoral approach	23,872.32	

3.5 INDIRECT GHG EMISSIONS

Emissions of carbon monoxide (CO), nitrogen oxides (NO_x) non-methane organic volatile compounds (NMVOC) and sulfur oxides (SO_x), which are gases that contribute to ozone formation and alter the atmospheric lifetimes of other greenhouse gases, have been calculated for the year 2019, based on the EMEP 2019 database. Recalculation has been made for CO emissions with new emission factors fuel combustion in electricity production.

Results show that transport is still the main source of CO and NMVOC in 2019 and power generation the main source of SO_2, while emissions of NO_x are generated equally from both the energy and transport sector (Figure 20 and Figure 21).

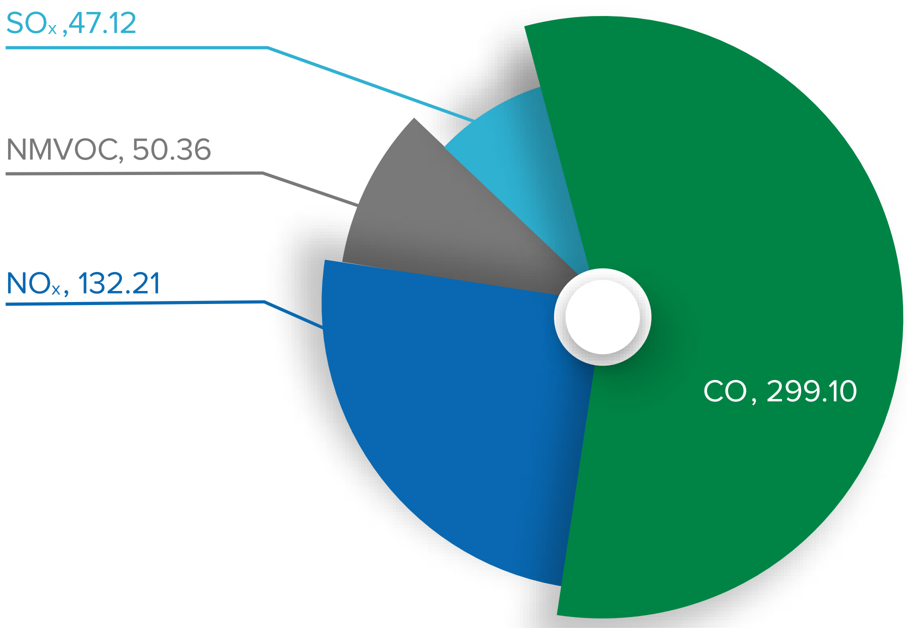


Figure 20: Indirect Emissions for Lebanon in 2019 (in Gg)

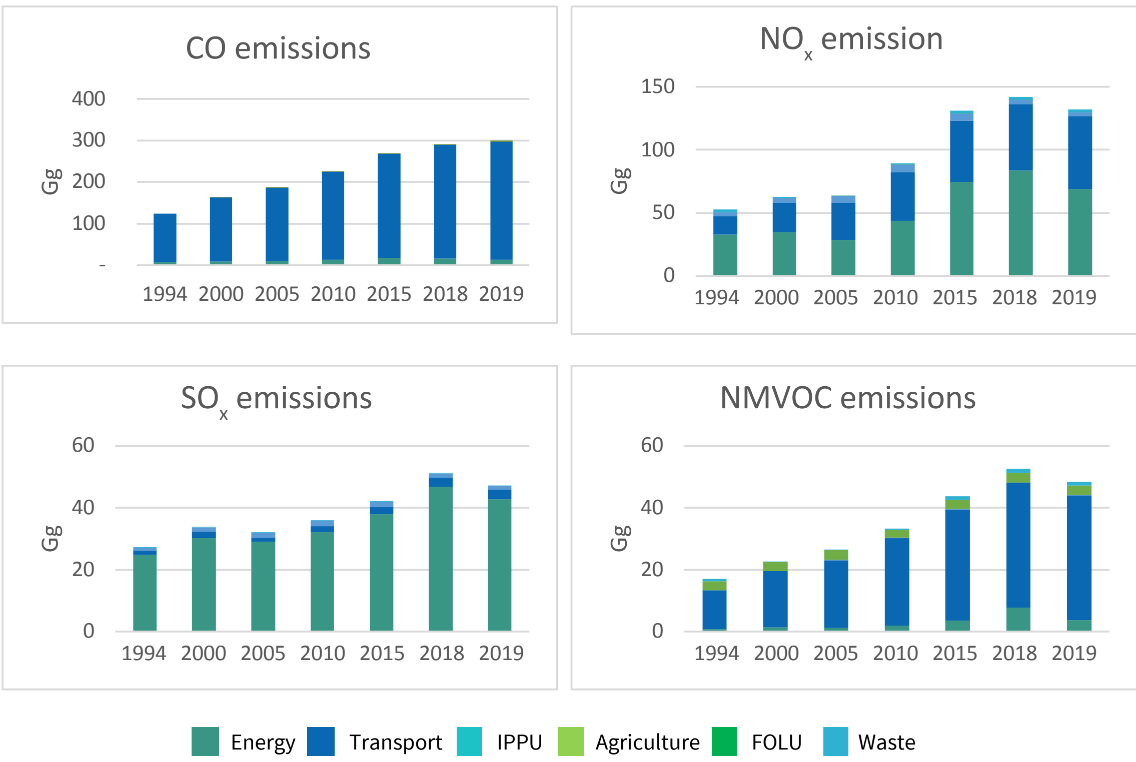


Figure 21: Emissions of indirect GHGs per category

During the period of 1994-2019, most of the indirect emissions increased, mainly due to the increase in energy and transport demand, the increase in reliance on private generators and the reduced efficiency and performance of EDL power plants. However, 2019 has witnessed a drop in emissions caused by the disruptions in fuel consumption post October 2019, especially in energy/electricity generation at the industrial and commercial levels (Figure 22 and Figure 23). Transport related emissions conserved their steady increase of 5 to 11% per year across the 1994-2019 period, with passenger cars contributing the most to emission generation (47% to 66% of emissions) (Figure 24). Details on the parameters used for the calculation of indirect GHG emissions are presented in Annex II.

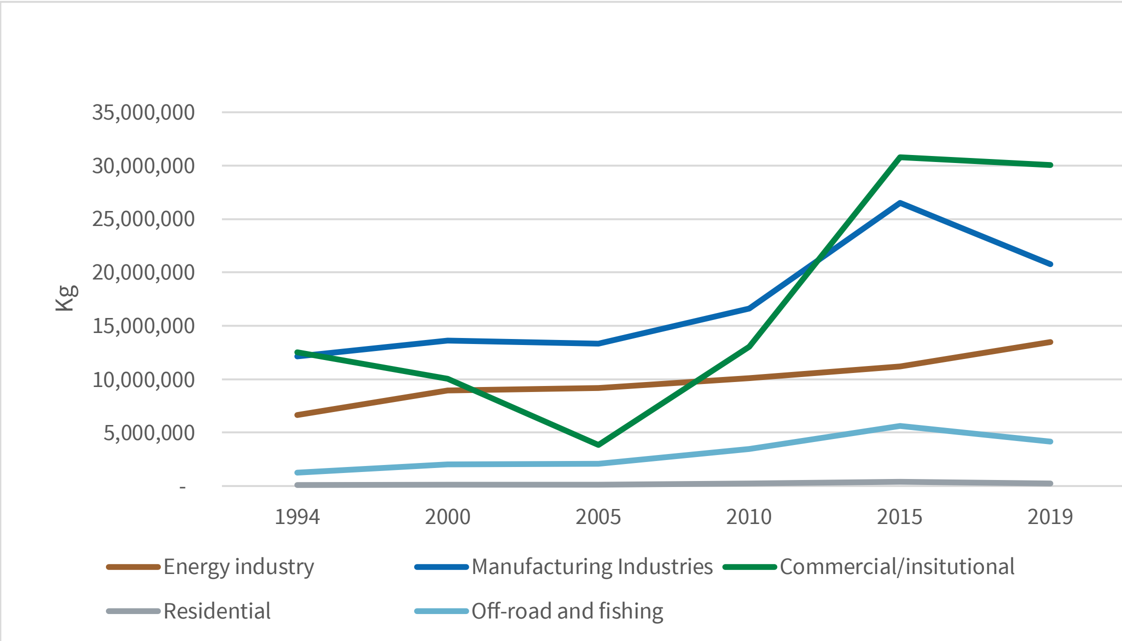


Figure 22: NO_x Emissions per Energy sub-categories

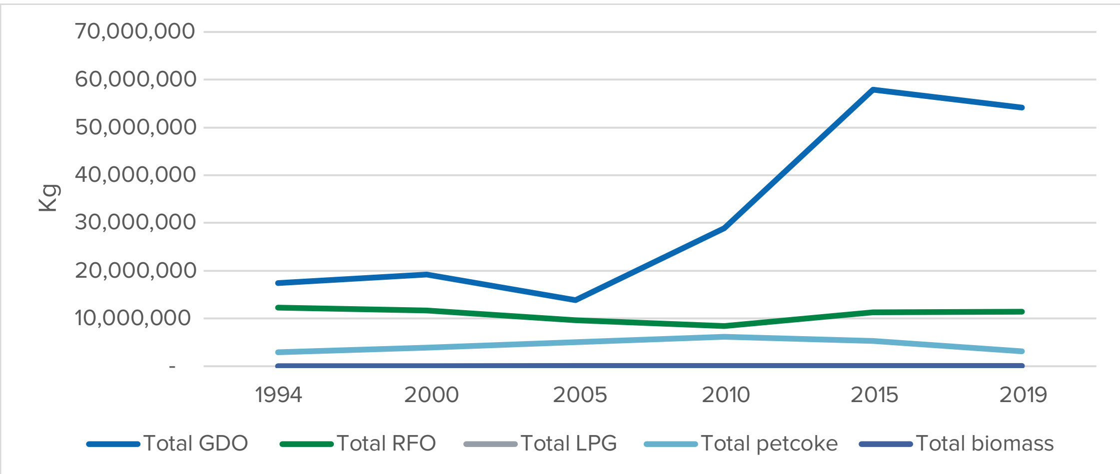


Figure 23: NO_x Emissions per energy fuel types

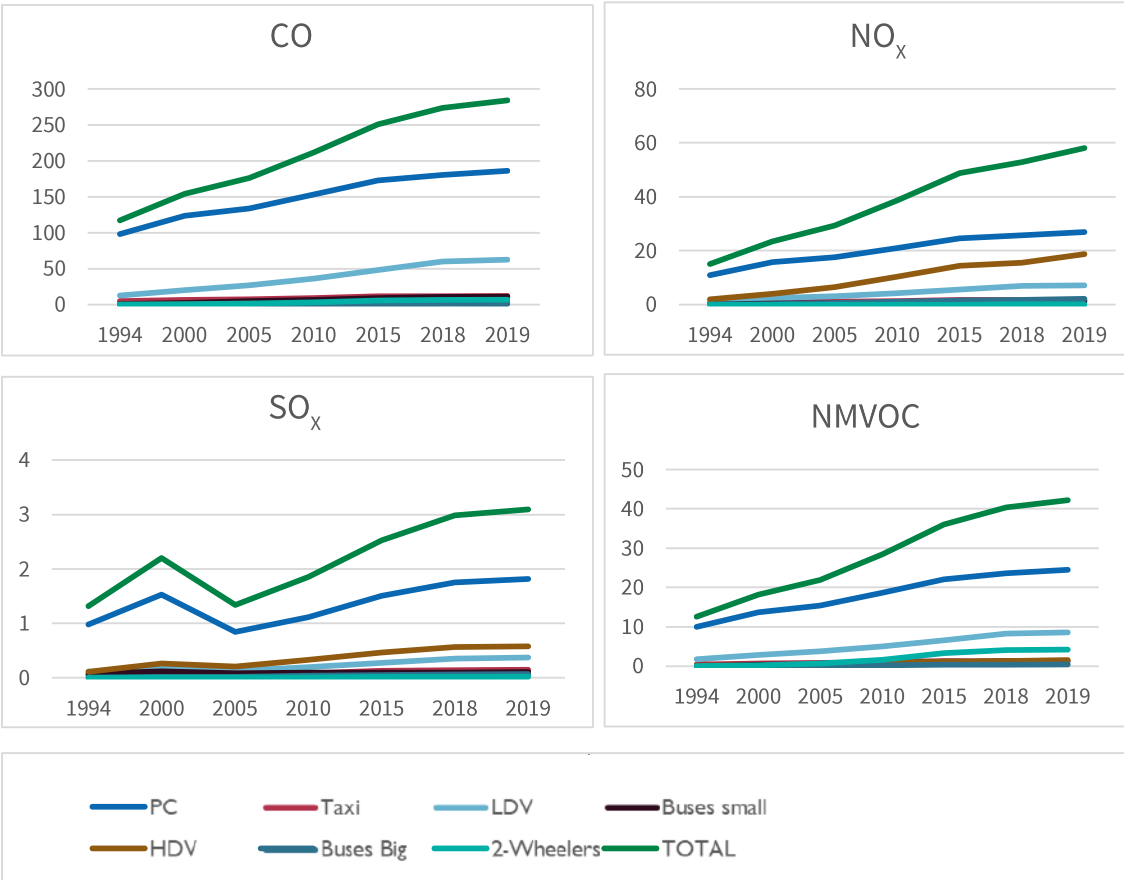


Figure 24: Emissions of indirect GHGs from transport per vehicle category

3.6 BREAKDOWN OF EMISSIONS BY IPCC SECTOR FOR 2019

1. Energy

According to the IPCC 2006 guidelines, the source category "Energy" covers all combustion sources of CO_2, CH_4 and N_2O emissions (1.A), fugitive emissions associated with the production, transport and distribution of fossil fuels (1.B) and Carbon Dioxide transport, injection and geological storage (1.C). Since no oil production activities, refineries or gas pipelines exist in the country, and Carbon Capture and Storage activities are undertaken, therefore emissions from (1.B) and (1.C) are reported as Not Occurring (NO) in the inventory reporting tables.

Fuel combustion activities (1.A) are 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 (residential and commercial/institutional sectors and agriculture/forestry/fisheries). Emission calculation is based on the yearly consumption of gas/diesel oil, heavy fuel oil and lubricants in thermal power plants and private generation, in addition to petroleum coke (in cement plants), LPG (in industrial, residential and commercial sectors) and biomass. Emissions from landfill gas are also estimated and included in totals.

Mobile combustion, including domestic civil aviation, road transport, and domestic navigation (Table 10).

Due to the absence of an energy balance for Lebanon, and the absence of information on specific carbon content of the imported fuel, the tier 1 methodology was mainly used for the calculation of energy related emissions. The Tier 2 methodology was however used for the calculation of emissions of CH_4 and N_2O from road transport where respective emissions factors are disaggregated by vehicle technology, fuel and operating conditions.

The energy activity data was collected from the Ministry of Energy and Water, Directorate General of Petroleum (fuel imports), Electricity Du Liban (fuel consumption per power plant), Lebanese Customs (Lubricant and petroleum coke) and IPTEC (distribution of fuel per end use). Data related to the transport sector was mainly based on the fleet categorization supplied by the Vehicle Registration Authority. Activity data used for the calculation of GHG emissions from the energy sector for the year 2019 is presented in Table 10 and Table 11. Details on methodology and other parameters used are available in Lebanon's Fourth Biennial Update Report.

Table 10 Activity Data used in the energy sector for the year 2019

Category	Type of fuel	Estimated consumption in 2019 (1,000 tonnes)
Energy Industries	Gas/Diesel oil consumed by EDL	1,251.74
	Residual Fuel oil	1,741.59
Manufacturing industries	Gas diesel oil	766.40
	Residual Fuel oil	62.25
	LPG	18.10
	Petroleum coke	261.92
Commercial/institutional	Gas diesel oil used	766.40
	LPG	20.99
Residential	Gas diesel oil	107.69
	LPG	179.54
	Biomass	9.85
Agriculture/forestry Stationary	Gas diesel oil	16.36
Fisheries Stationary	Gas diesel oil	16.36

Table 11 **Activity Data used in the transport sector for the year 2019**

Category	Number of vehicles in 2019	Type of fuel	Estimated consumption in 2019 (1,000 tonnes)
Passenger Car with three-way catalyst	876,522	Gasoline	697.88
Passenger Car without three-way catalyst	877,157	Gasoline	707.08
Light-Duty Vehicle with three-way catalyst	49,720	Gasoline	262.05
Light-Duty Vehicle without three-way catalyst	96,673	Gasoline	137.88
Heavy-duty Vehicle	51,851	Diesel	643.39
Motorcycles	159,954	Gasoline	14.97
Total Fleet	**2,111,877**		
Total Gasoline			**697.88**
Total Diesel			**707.08**

In 2019, the energy sector's GHG emissions were estimated at 24,117 Gg CO_2eq. (24.1 million tonnes CO_2eq.), representing 80% of the total greenhouse gas emissions in Lebanon. Emissions have decreased by 10 % from 2018, mainly due to the decrease in the consumption of heavy fuel oil in the Zouk and Jiyeh Power plants, the power barges and the industrial sector, in addition to a decrease in the import and consumption of petroleum coke used in cement industries. (Figure 25 and Figure 26).

Emissions from the transport sector conserved a steady increase concurrent with the increase in the vehicle fleet and demand for gasoline. It is assumed that the 2019 civil unrest had insignificant impact on the annual fuel consumed by Lebanese drivers.

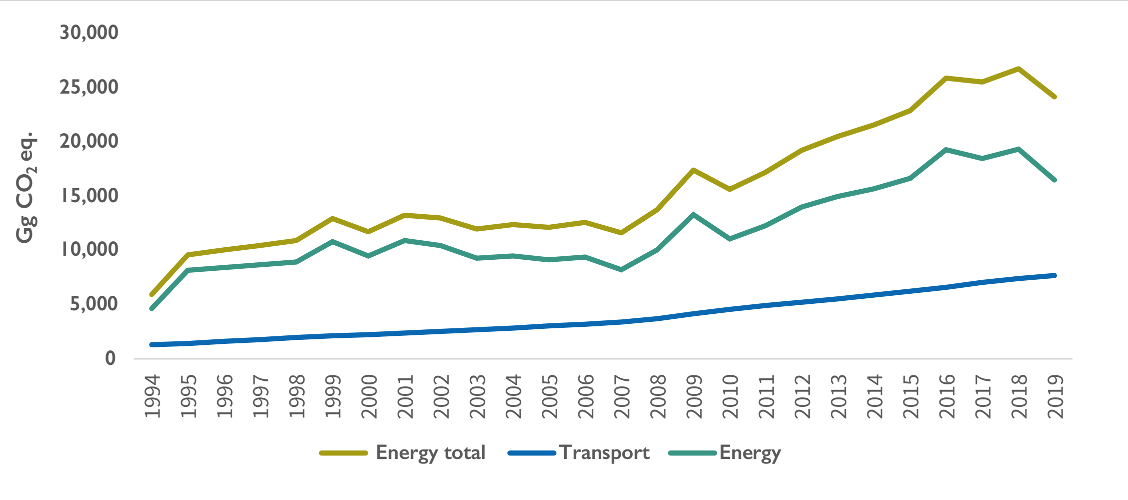


Figure 25: GHG emissions from 1.A Energy for the time series 1994-2019

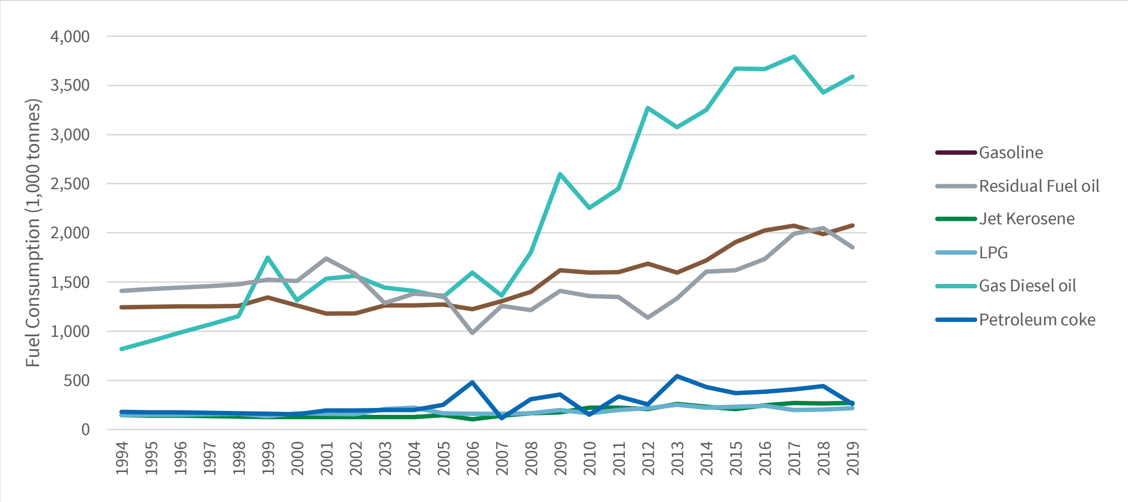


Figure 26: Fuel import per type for 1.A Energy for the time series 1994-2019

Energy industries or the generation of electricity from public thermal power plants remains the main contributor to emissions, (38.9%), as they are responsible for the consumption of 95% of the total imported heavy fuel oil and 35% of the total gas diesel oil. Zahrani, Deir Aamar and Zouk plants in addition to the rented barges are the highest emitters of greenhouse gases, given that they are the largest in terms of capacity, electricity generation and fuel consumption, although they are the "cleanest" in terms of CO_2 emission per MWh generation (Figure 27). Zahrani and Deir Aamar power plants generate about half of Lebanon's supply, and their switch to natural gas is expected to significantly reduce their emissions.

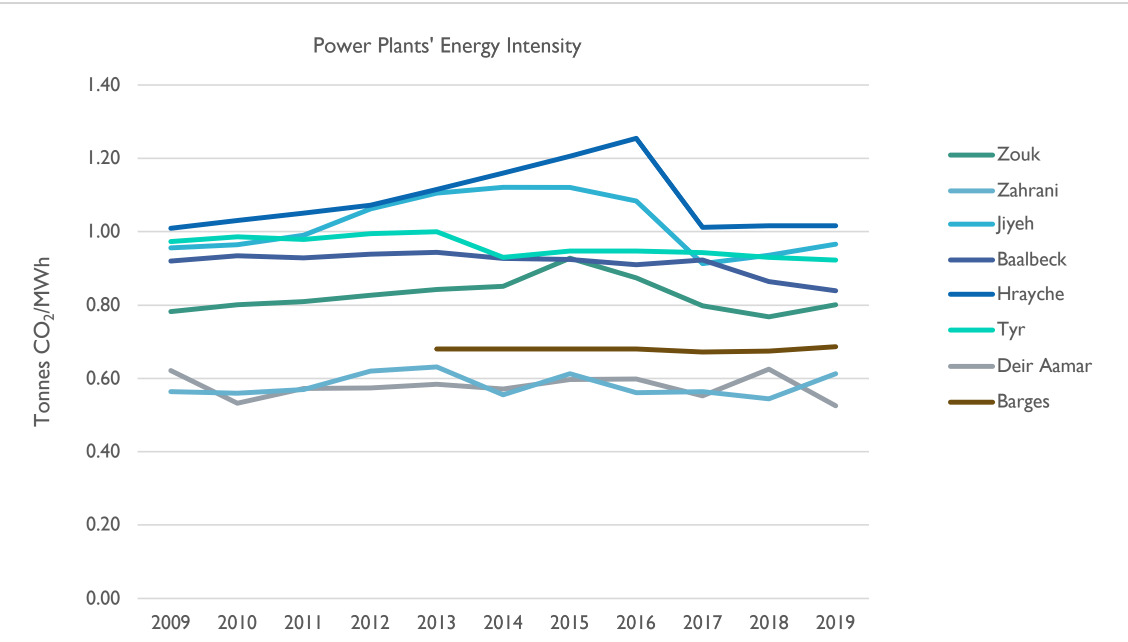


Figure 27: Greenhouse gas emissions per MWh generated

Manufacturing industries and construction, which include the consumption of petroleum coke, heavy fuel oil and diesel oil, represent 14.6% of energy emissions, while the commercial and residential sectors account for 10.11% and 3.62% respectively, with emissions generated from the consumption of diesel oil for private generation and heating, as well as LPG for cooking, as presented in Figure 28 .

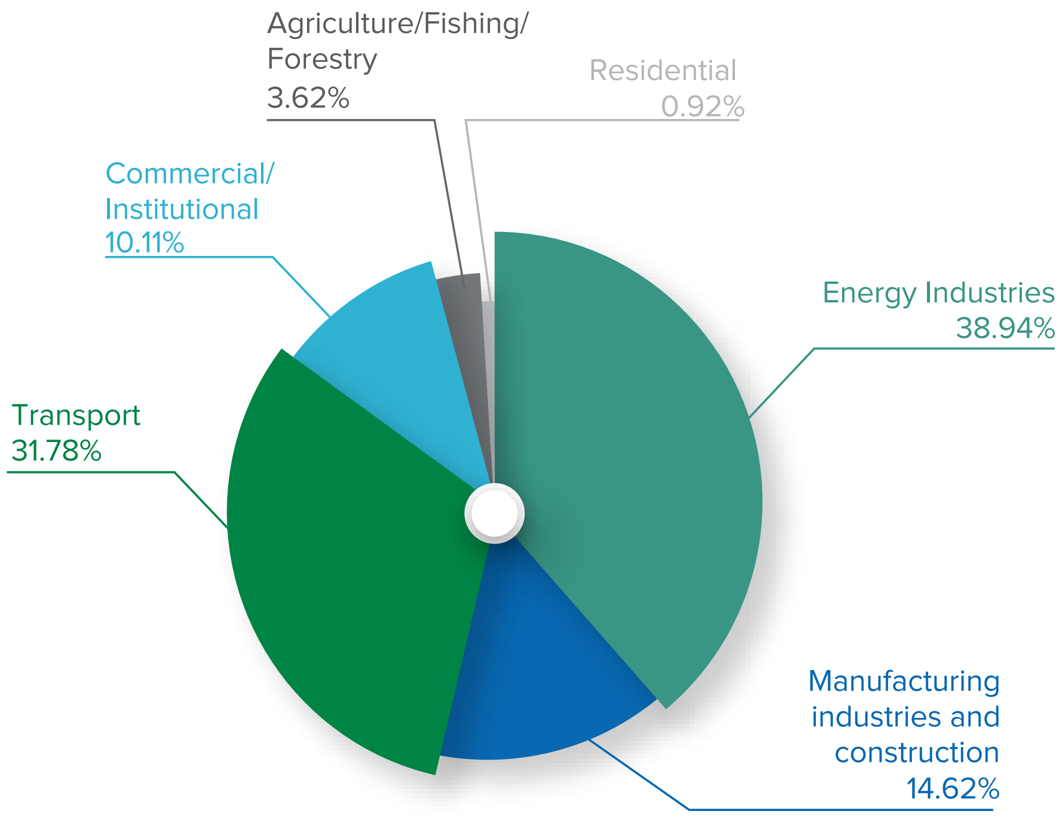


Figure 28: Contribution of energy emission sources to the sector's total for 2019

The decrease in emissions from 2018 is reflected in the national grid emission factor, which is estimated at 0.663 tonnes CO_2 per MWh in 2019 (compared to 0.684 tonnes CO_2 per MWh in 2018). This is mainly due to the decrease in thermal production (from 14,709 to 13, 888 GWh), increase of power purchase from Syria (from 11.63 to 90.78 GWh) and decrease in technical losses from 17% to 13.30%, all of which have lead to lower carbon emissions per unit of electricity produced in 2019.

Transport is also an important contributor to emissions with 7,664Gg CO_2eq. in 2019, constituting 25% of total emissions, mainly due to the consumption of gasoline in passenger cars (Table 12 and Figure 29). Emissions remain relatively constant over time with an average yearly increase of 7%, concurrent with the increase in the number of registered vehicles in Lebanon. In 2019, the overall fleet emission factor is estimated at 258g CO_2eq./km (including passenger cars, motorcycles, light duty and heavy duty vehicles) while the passenger cars only emission factor is estimated at 194g CO_2eq./km).

Table 12 **Transport sector GHG emissions for 2019**

Category	CO_2 (Gg)	CH_4 (Gg CO_2eq.)	N_2O (Gg CO_2eq.)	Total (Gg CO_2eq.)
1.A.3 - Transport	7,480.96	46.02	137.98	7,664.96
1.A.3.a - Civil Aviation	11.60	0.00	0.09	11.69
1.A.3.b - Road Transportation	7,469.36	46.02	137.89	7,653.27
1.A.3.b.i - Cars	4,235.33	31.32	90.95	4,357.61
1.A.3.b.ii - Light-duty trucks and vans	1,205.61	11.17	18.73	1,235.51
1.A.3.b.iii - Heavy-duty trucks and buses	1,983.30	2.92	27.66	2,013.88
1.A.3.b.iv - Motorcycles	45.11	0.60	0.55	46.27

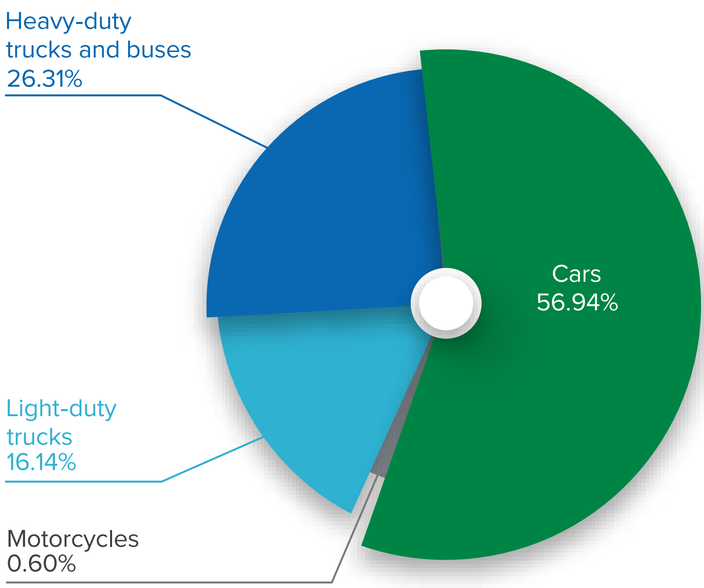


Figure 29: Emissions distribution per type of vehicle in 2019

International bunkers

For international bunkers, the total direct GHG emissions from aviation and marine amounted to 955.95 Gg CO_2eq. in 2019 as per the Table 13.

Table 13 Emissions from international bunkers

	GHG emissions (Gg CO_2eq.)
International aviation	833.97
International water-borne navigation	121.98
Total	955.95

2. Industrial Processes and Products Use (IPPU)

The IPPU category includes the following 2 sources of the emissions:

- Industrial processes that chemically or physically transform products, thus releasing greenhouse gases.
- Product use that releases gradually greenhouse gases that are contained in the products such as refrigerators, foams and aerosol cans.

Industrial activities are limited Lebanon, and the GHG emissions from the sector are mainly generated from mineral production (cement and lime production), HFC uses for refrigeration and air conditioning and some processes that use CO_2 carbonates.

The development of the complete inventory limits reporting of GHG emissions from some industrial categories as data collection remains a challenging task in Lebanon. The absence of an updated national industrial survey limits the identification of industrial processes taking place in Lebanon, which consequently hinders the complete calculation of some GHG emissions such as PFCs and SF_6 and some indirect emissions such as NMVOC. Extensive efforts have been deployed during previous inventories to collect data to estimate emissions from a number of industries such as food and beverages, but the data quality remains highly uncertain. Therefore, due to limited capacity, emissions from such industries are not estimated and are reported as NE in the reporting tables from NE categories is included into the planned improvements for later submissions.

The present section covers the following IPPU subcategories:

2.A.1 Cement production

2.A.2 Lime production

2.A.4.b Other Process Uses of CO_2 carbonates- soda ash use

2.D.1 Lubricant use

2.D.2 Paraffin wax use

2.F.1 Refrigeration and air conditioning

2.G.3 N_2O from product uses

The GHG inventory of industrial processes in Lebanon is carried out based on calculation methodologies of the 2006 IPCC Guidelines for national greenhouse gas inventories, using tier 1 methodologies with national and default emission factors for the other categories. Only cement production and emissions of F-gases adopted a tier 2 methodology. Emissions from fuel combustion in the industrial sector for energy purpose is not included under the IPPU sector, but rather in the energy sector (1.A.2).

Table 14 GHG emissions categories and activity data for 2019 for industrial processes and product use

Reporting categories	Methodology, description and remarks	Activity data
2.A Mineral industries		
2.A.1 Cement production	All 3 cement industries in Lebanon are covered in this calculation. Cement manufacturing is a key category in Lebanon, therefore tier 2 is adopted to calculate emissions from this category as per equations 2.4 and 2.5 of the IPCC 2006 guidelines.	2,519,903 tonnes clinker production
2.A.2 Lime production	The only lime production plant in Lebanon is covered in this calculation. Lime is also produced in cement manufacturing; however, it is already accounted for in clinker production in cement industries. CO_2 resulting from lime production is not a key category in Lebanon. The tier 1 method, an output-based	1,004 tonnes Lime
2.A.3 Glass production	The 2 glass producing factories in Lebanon shut down in the early 2000s. Glass is imported and manufactured into different shapes (containers, windows, etc.) using carbonates. Since there is no survey of the exact amount of carbonates used in glass production, related emissions are not reported under this category, but embedded within the emissions of category 2.A.4 (other carbonates). The notation key Included Elsewhere is therefore used.	NA
2.A.4 Other process Uses of Carbonates	Subcategories from which emissions occur in Lebanon include ceramics (2.A.4.a) and other uses of soda ash (2.A.4.b). Other subcategories do not occur and are reported as such. Data on ceramics is considered incomplete as it only includes the main ceramics production facilities in the country (sanitary and tile) and does not cover the entire time series considered in this inventory. Therefore, emissions from ceramics is Not Estimated in the current inventory. Note that category 2.A.4.a is not expected to be a key category. There is no soda ash production in Lebanon. National consumption is based on imported soda ash, and it is assumed that all imported soda ash is used during the year of import in the industrial sector. Percentages of soda ash used per type of industry (glass manufacturing, soap and detergents, water treatment etc.) are not available. Therefore, total national consumption is used as activity data.	2,908 tonnes of soda ash used

2.D Non-Energy Products from Fuels and Solvent Use		
2.D.1 Lubricant Use	There is no disaggregated data on the use of lubricants in Lebanon. Therefore, it is assumed that all imported lubricants are used in the power generation plants. Emissions from this subcategory are therefore reported as Included Elsewhere (reported under 1.A.1 Energy Industries).	NA
2.D.2 Paraffin Wax Use	Consumption of paraffin wax is based on the quantities imported as per the customs database. It is assumed that all imported quantities are consumed within one calendar year.	863 tonnes of Paraffin wax consumed (eq. to 35 TJ)
2.F Product uses as substitutes for ODS		
2.F.1 Refrigeration and A/C	HFC are mainly used in Lebanon under the Refrigeration and Air Conditioning (RAC) sector. The main HFC refrigerants are HFC-134a and the mixtures R404A, R407C, R410A resulting in emissions of HFC-125 (38% in 2018), HFC-32 and HFC-143a.	566.36 tonnes of HFC-134a 268.77 tonnes of HFC-125 175.75 tonnes of HFC-32 35.52 tonnes of HFC-143a
2.F.2 Foam blowing Agents	There is no HFC applications in the foam manufacturing sector. The notation key Not Occurring is therefore used.	
2.F.3 Fire protection	There are limited applications of HFCs in fire suppression systems. Due to lack of activity data, emissions from this category have not been estimated. The notation key NE is therefore used.	
2.G. Other product manufacture and use		
2.G.3 N_2O use for medical purposes	N_2O is used for medical applications in anesthetic use, analgesic use and veterinary use. Data is collected from the customs database.	100 tonnes of N_2O consumed

The Industrial Processes and Product Use (IPPU) category in Lebanon contributed around 11% of the total national emissions in 2019, with a total of 3,250.17 Gg CO_2eq. GHG emissions have decreased by 2% from 2018, mainly due to decrease in production of cement in 2019 following environmental restrictions. The main contributors to GHG emissions are consumption of F-gases (58%) followed by cement production (41%) (Figure 31).

Starting 2010, the share of F-gases from refrigeration and air conditioning increased rapidly due to high bank emissions resulting in almost 56% of the total IPPU emissions in 2019. In Lebanon, the leading HFC refrigerants is HFC-134a, however it is the mixtures of R404A, R407C, R410A that result in most of the emissions in terms of CO_2eq., due to high Global Warming Potential of HFC-125. It is estimated that 83% of emissions of F-gases are generated from stationary sources (residential and commercial refrigerators, air conditioning, condensing units and process chillers) and 17% from mobile sources (car air conditioning and refrigerated trucks). All other sources have minimal contribution to emissions in the sector (1-2% aggregated throughout the entire time-series).

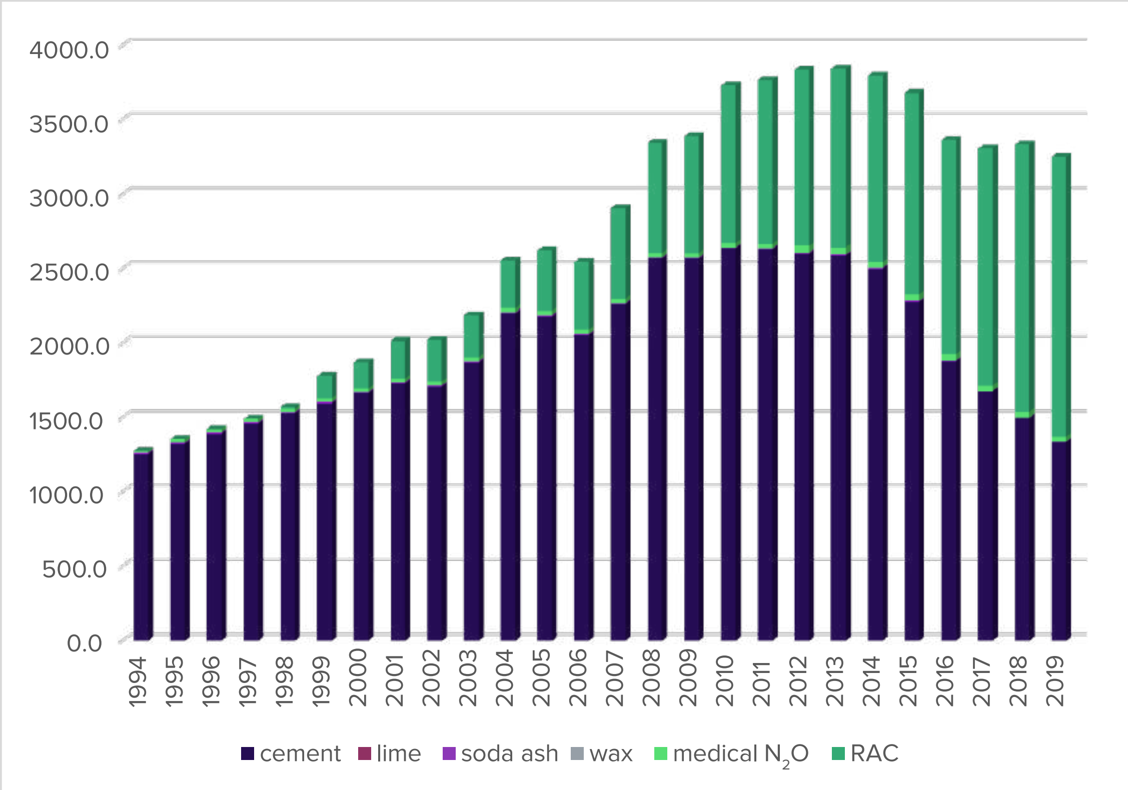


Figure 30: GHG Emissions trend in IPPU sector for 1994-2019

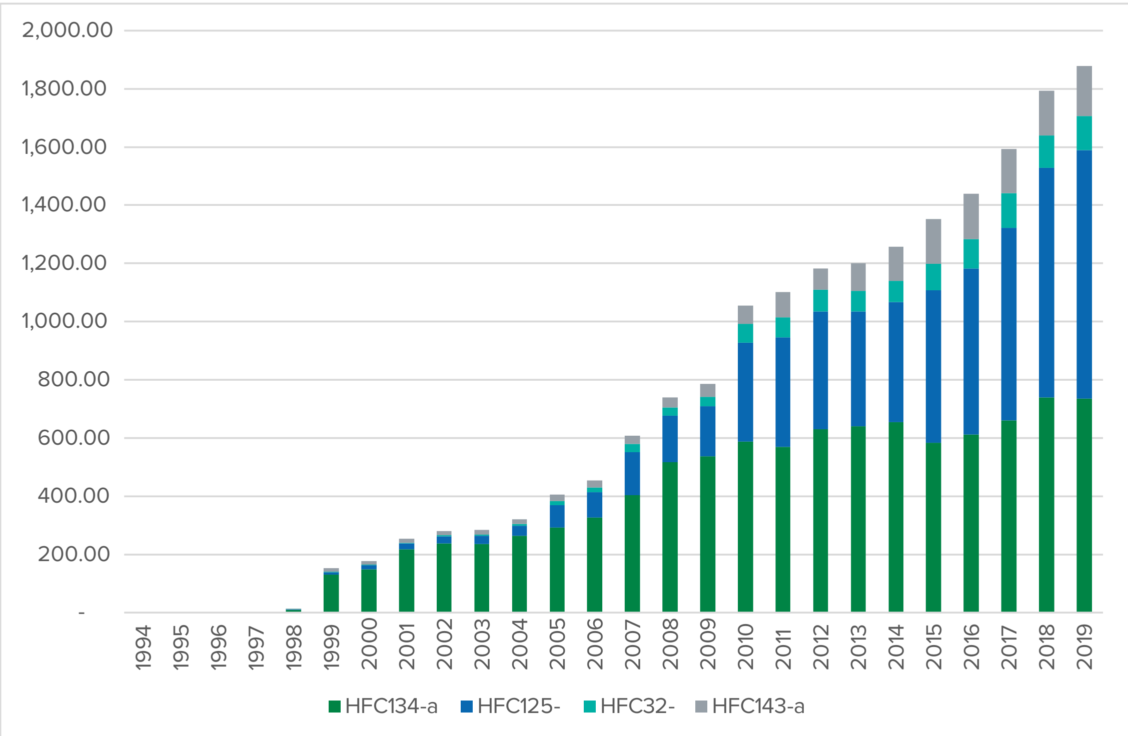


Figure 31: Total HFC emissions for 1994-2019

3. Agriculture, Forestry and Other Land Use (AFOLU)

Greenhouse gas emissions from the agricultural sector include Methane (CH_4) emissions from enteric fermentation of domestic livestock, manure management and biomass burning, as well as Nitrous Oxide (N_2O) emissions from manure management and direct and indirect emissions from managed soils following additions of urea-containing fertilizers, synthetic fertilizers and crop residues. The tier 1 methodology was adopted for the calculation of GHG emissions from enteric fermentation and manure management and aggregate sources

Emissions and removals from the Forestry and Other Land Use are estimated by calculating the absorption of CO_2 from the atmosphere by carbon sinks, such as plant biomass and the changes in carbon stocks in land-use categories such as forestland, cropland, grassland, wetland, settlements and others. For the representation of most land-use areas and land conversions, the Approach 3 of the IPCC guidelines and the national land-use classification system of the Land Cover / Land Use map of 1998 were adopted.

Activity data was collected directly from the Ministry of Agriculture (livestock, crop production, afforestation, etc.), Ministry of Environment (forest fires, afforestation, etc.), NGOs (afforestation) the Lebanese Customs (fertilizers used) and FAOSTAT when data was not available in national institutions. Academic institutions were also involved in the collection and validation of information. For the identification of changes in carbon stocks in the Land category, data was extracted from multi-temporal satellite images, including Landsat TM, ETM+ (1994-2012) and Landsat 8 imagery (2013-2018). The analysis of acquired data comprised of mapping and comparing changes in land cover and land use using comparable satellite data of the same spatial resolution and spectral bands in addition to validation through surveys and expert consultations.

Activity data used for the calculation of GHG emissions from AFOLU for the year 2019 is presented in Table 15. Details on methodology and other parameters used are available in Lebanon's Fourth Biennial Update Report.

Table 15 Activity Data for used in the AFOLU category for the year 2019

Sub-categories		Estimated values in 2019
3.A Livestock		
Livestock (heads)	Dairy Cows	53,000
	Other Cattle	32,862
	Imported beef*	20,548
	Sheep	455,840
	Goats	521,222
	Camels	129
	Horses	3,267
	Mules	4,662
	Asses	14,109
	Pigs (Swine)	6,251
	Poultry*	14,945,218

3.B Land		
Forests (ha)	Broadleaf forests	192,606
	Coniferous forests	34,784
	Mixed forests	26,264
	Reforested areas	146
Croplands (ha)	Annual crops	168,057
	Perennial woody crops	158,406
Grasslands (ha)	Grasslands	314,906
Wetlands (ha)	Flooded land	545
Land converted to settlements (ha)	Forests to settlements	89
	Cropland to settlements	220.51
	Grassland to settlements	70.94
Other lands (ha)	Other lands	4,4562
3.C Aggregate sources and non-CO_2 emissions sources on Land		
Biomass burning (ha)	Biomass burning in forest lands	1,352
	Biomass burning in croplands	172
	Biomass burning in grasslands	299
Fertilizers use (tonnes)	Urea	11,810
	Total Nitrogen fertilizers	83,626
**Adjusted to days alive*		

In 2019, GHG emissions from AFOLU were estimated at 914.49 Gg CO_2eq. (3% of total national emissions), of which 44% are generated from enteric fermentation (402.9 Gg CO_2eq.), 30% from managed soils (273.09 Gg CO_2eq.), and 22% from manure management (202 Gg CO_2eq.). The remaining negligible share is due to other aggregate sources. The prevailing part of CH_4 emissions from enteric fermentation and manure management is generated by cattle (67%), and most of the N_2O emissions (67%) is directly generated by managed soils, through the use of organic and synthetic fertilizers.

Forestry and Other Land Use registered removals of -3,060.91 Gg CO_2 in 2019, mainly attributed to the increase in vegetation cover within forest lands, croplands, and grasslands. Although the FOLU category is still a major sink, emissions from changes in land use were still high and could not be compensated by the afforestation activities. Compared to 2018, the analysis of the changes in CO_2 emissions/removals of the FOLU activities shows a net decrease in CO_2 removals (from -3,205 to -3,060 Gg CO_2) mainly due to losses in the vegetation cover from the 2019 wildfires.

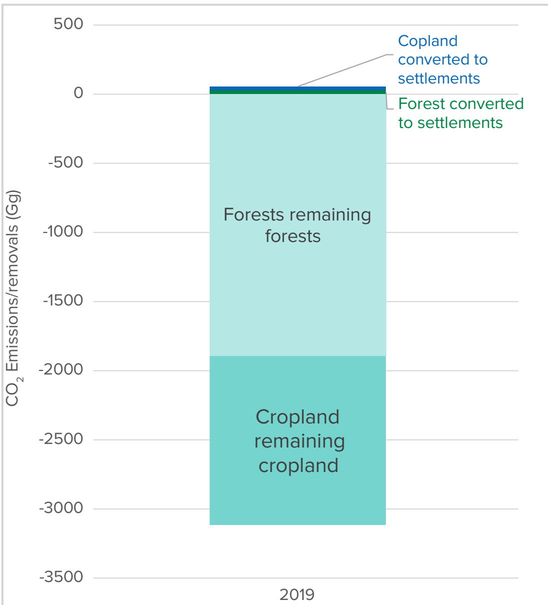


Figure 32: Total CO_2 emissions/removals from AFOLU

Total GHG emissions from the AFOLU category slightly increased from 2018 (1%) (Figure 33) primarily due to the increase in the imported quantities and the use of urea (main source of CO_2) and to the 2019 forest fires that ravaged 1,823 ha (compared to only 173 ha in 2018) causing significant increases in CH_4 and N_2O emissions (Figure 34 and Figure 35). Despite this increase, the share of emissions of the AFOLU category is still insignificant relatively to Lebanon's total GHG emissions, maintaining a share of 3% during the last decade.

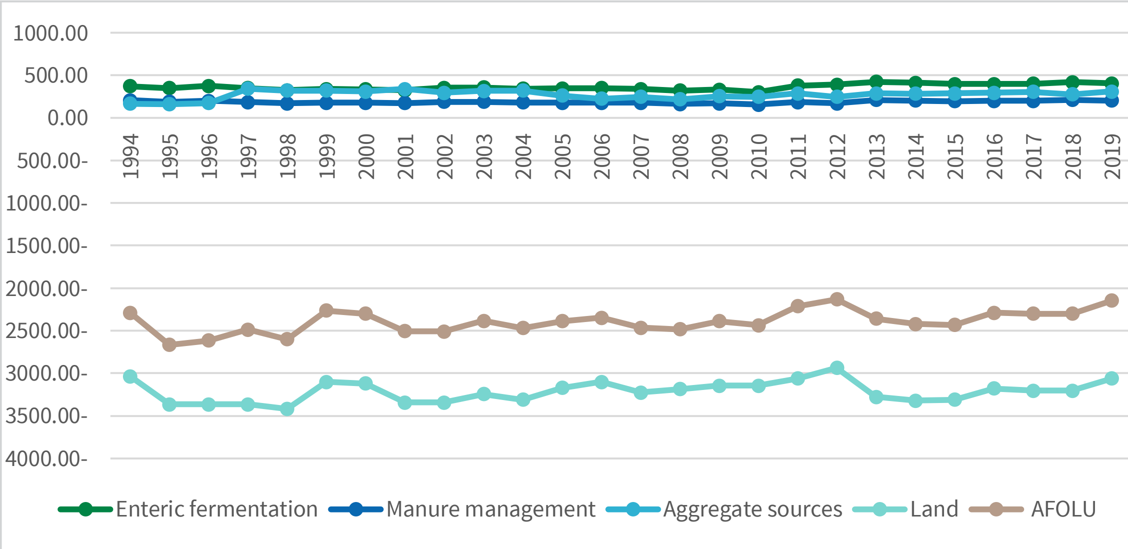


Figure 33: Trend analysis for net CO_2 emissions/removals from the AFOLU sector

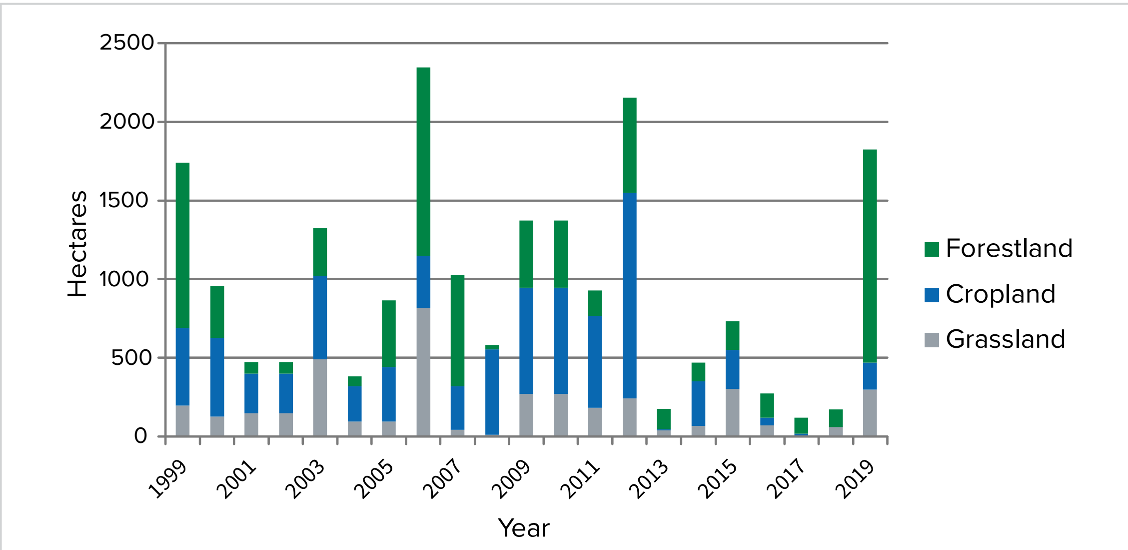


Figure 34: Annual spatial changes in burned areas

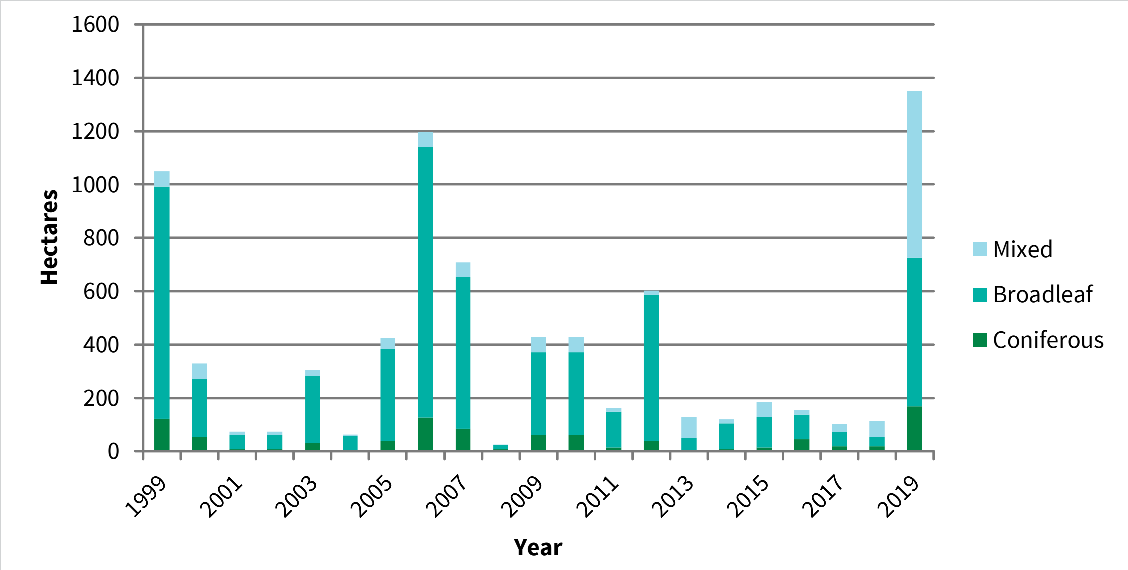


Figure 35: Annual change in areas of forest fires by subcategory

4. Waste and wastewater

According to the IPCC 2006 guidelines, the source category "waste" covers emission from disposal and discharge of both solid waste and wastewater, while differentiating between the various management options.

The present section covers the following waste subcategories:

4.A. Solid waste disposal - CH_4, CO_2

4.B Biological treatment of solid waste- CH_4, N_2O, CO_2

4.C Incineration and open burning of waste - CH_4, N_2O, CO_2

4.D. Wastewater treatment and discharge - CH_4, N_2O, CO_2

Since Solid Waste Disposal Sites on land (SWDS) category has been identified as a key category (CH_4 emissions) in previous inventories, and following the guidance of the IPCC 2006 guidelines, the tier 2 methodology has been used to calculate emissions from this category. Accordingly, the IPCC First Order Decay (FOD) method has been used with country specific activity data and defaults parameters and emission factors. Table 16 and Figure 36 present an overview of the main activity data and assumptions made for the calculation of GHG emissions from the solid waste sector.

Table 16 Activity data and main assumptions for solid waste

	Methodology, description and remarks	Activity data 2019
Population	The population of 2019 was taken from 1) the recent Household Survey prepared by the Central Administration of Statistics (CAS, 2020), 2) UNRWA reports on the Palestinians refugees (UNRWA, 2020) and 3) the UNHCR database on Syrian displaced (UNHCR, 2020).	6,041,289 (5,108,670 Lebanese+ refugees) (932,619 Syrian displaced)

Per capita waste generation rate	The waste generation rate for the Lebanese population, including foreign workers and Palestinian refugees is based on Lebanon's draft solid waste strategy (MoE, 2019). The generation rate used for Syrian displaced was adapted from Lebanon Environmental Assessment of the Syrian Conflict.	kg/cap/day 0.5 kg/displaced/day
Municipal solid waste generation	Waste generation is calculated based on the "per capita waste generation rate" (tonnes/capita/year) and the population (capita and displaced). It includes both urban and rural populations, without the differentiation between both categories.	2,333,340 tonnes
Industrial waste	The exact amounts of industrial waste generated in Lebanon is not available. Therefore, according to the 2006 IPCC guidelines industrial waste generation is estimated based on the Gross Domestic Product (GDP) of 2019 (USD 51.61 billion) and the industrial waste generation per GDP per year, (0.04 Gg of industrial waste/million USD in GDP). Industrial waste is considered to be disposed with the regular waste stream. Emissions from industrial waste quantities have been recalculated based on the availability of more accurate activity data.	203,760 tonnes
Municipal solid waste disposed in Solid Waste Disposal Sites (SWDS)	Based on the information made available by operators of the main landfills/dumping sites, it is assumed that in 2019 around 44% of generated municipal waste is disposed in landfills (SOER, 2020). The Tripoli, Jeb Jennine and Bar Elias sites are considered as managed anaerobic sites. The Naameh, Zahleh, Costa brava and Bourj Hammoud sites are considered as managed aerobic sites. All the other disposal sites, receiving around 41% of Lebanon's municipal and industrial waste in 2019, are considered unmanaged (open dumping), with 69% of them categorized as shallow sites, and 31% as deep sites.	1,022,054 tonnes of MSW in landfills 1,048,082 tonnes of MSW and industrial waste open in dumpsites

Open burning of waste	It is estimated that 69% of waste being deposited in open dumps are burned intentionally or unintentionally (MoE/UNDP/ELARD, 2017)	723,075 tonnes of MSW and industrial waste are open burned
Percentage of recycle/reuse and composting	Despite the waste crisis in 2015 and the closure of the main landfill and its waste sorting plants, the informal collection of valuable recyclables from waste streams increased, which preserved a recycling rate of 6 % in 2019 and a composting /anaerobic digestion rate of 12% from total waste generated.	147,940 tonnes of MSW recycled 286,469 tonnes of MSW composted
Quantity of recovered gas	The information of recovered gas in the operational landfills was provided from the supervising consultants' reports for each of the landfills through MoE. After the closure of the Naameh landfill, the amount of the recovered gas decreased significantly due to irregularities of contractual arrangements.	5.76 Gg
Exported quantities	Quantities of waste exported are minimal and are mainly composed of hazardous material. These amounts have not been taken into account in the calculation of CH_4 emissions from waste disposal mainly due to their composition.	N/A
Waste to energy	Since 2013, Saida anaerobic digestion is generating 730 MWh/yr of electricity, 839 MWh/yr of heat and 32,000 m^3/day of biogas from CH_4 recovered. However, after the waste crisis of 2015, anaerobic digestion activities were seized. In addition, since 2017, the CH_4 received from the Naameh landfill is being used to generate electricity, which is reported to be 64,350 MWh in 2018, and down to 34,610 MWh in 2019.	34,610 MWh
Incineration of waste	Incineration used in Lebanon for small amounts of clinical waste at various medical establishments, although without permits or monitoring. Starting 2012, incineration of plastic waste was initiated at the SICOMO industrial facility.	60 tonnes of clinical waste 41,313 tonnes of plastic waste

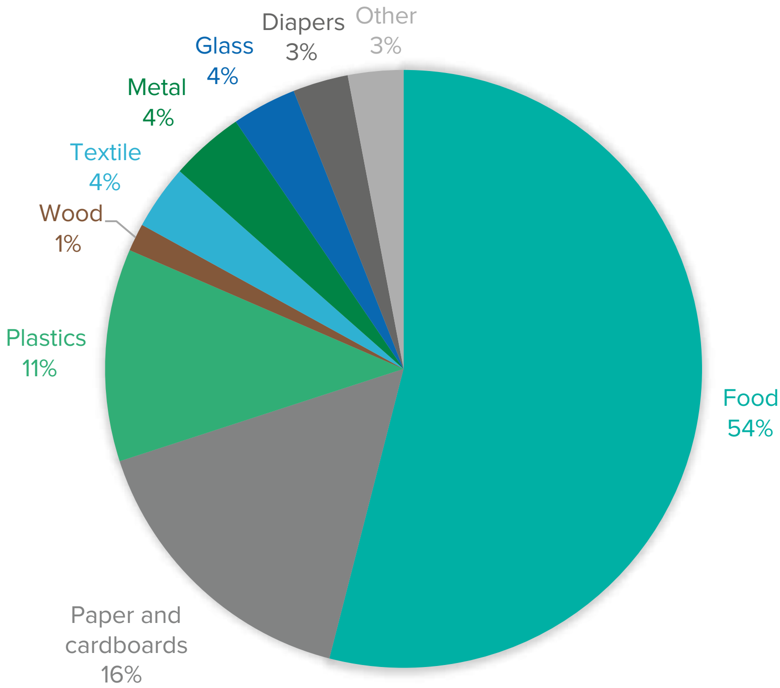


Figure 36: Waste composition in Lebanon (MoE, 2019; SOER, 2020)

In terms of GHG emissions from wastewater originating from domestic, commercial and industrial sources, estimation at the national level have been undertaken to estimate the amounts of wastewater generation, the distribution per discharge channel and the level of treatment, as presented in Table 17and Figure 37. Tier 2 methodology is used with national activity data and default emission factors.

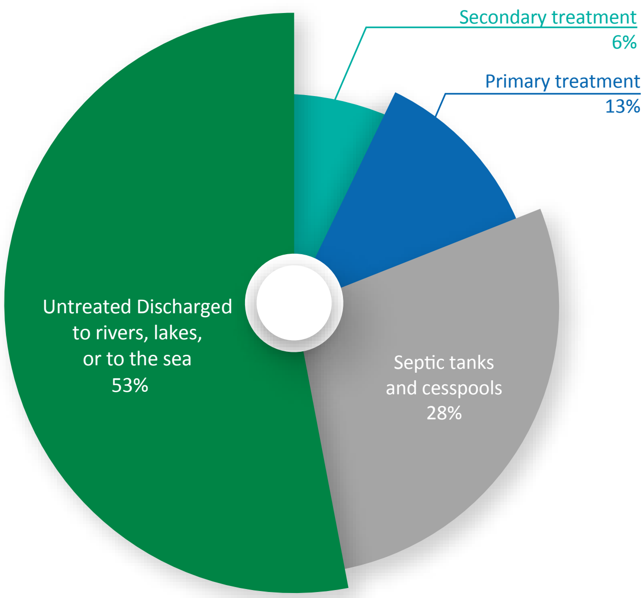


Figure 37: Percentages of the wastewater treatment systems and discharge pathways

Table 17 **Activity data and main assumptions for wastewater**

	Methodology, description and remarks	Activity data 2019
Wastewater generation (kg BOD/year)	Wastewater generation is based on the 2019 population of Lebanon with an average BOD generation rate of 25.4 kg BOD/year/capita – taking into consideration 23.7 kg for Lebanese/Palestinians residents (MoE/UNDP/GEF, 2019; World Bank, 2011) and 34.5 kg for Syrian displaced (MoE/UNDP/EU, 2014). The same generation rate is used for urban, peri-urban and rural areas.	6,041,289 Population 25.4 kg BOD/year/capita
Domestic wastewater discharge	Domestic wastewater in Lebanon is partly collected and treated in centralized plants or disposed of in waterways, lakes or the sea, via closed sewers. Estimation of the share of wastewater discharged/treated per type of system is based on data made available by MoEW (2010), CDR (2020), UNICEF (2016), USAID (2013), WHO/UNICEF (2020), as well as expert judgements.	52% discharged in sea/rivers 28% discharged in septic tanks 13% treated at primary level 6% treated at secondary level
Sludge removal **(kg BOD/cap/year)**	Following wastewater treatment, a fraction of the organic component is removed from wastewater, in the form of sludge. In Lebanon, based on default parameters, an average of 12.43 kg BOD/cap of organic sludge is being removed per year .	12.43 kg/cap/year
Per capita protein consumption (kg/cap)	Based on the FAO database and expert judgement, a default factor has been used for Lebanon.	30.66 kg/person
Industrial wastewater	The amount of industrial wastewater generated is estimated based on a rate of 19.58 m^3/tonnes of industrial products and a Chemical oxygen Demand of 2.055 kg COD/m^3. The estimation of production quantities of industrial products is limited to the manufacturing of food and beverage, which generate significant amount of wastewater (CAS, 2018; BLOMinvest bank, 2016) It is assumed that all industrial wastewater is discharged in sea or rivers.	2,359,575 tonnes of industrial products 19.58 m^3/tonnes of industrial products 2.055 kg COD/m^3

Results of waste and wastewater category

In 2019, activities related to the generation and treatment of solid waste and wastewater emitted 1,805 Gg CO_2eq., thus contributing to 6% of Lebanon's total GHG emissions. As expected, CH_4 emissions are the most common greenhouse gas emitted from waste and wastewater discharge and treatment, constituting 90% of the sector's emissions. As for N_2O emissions, they represent 7.75% of the waste category's emissions, mainly from wastewater discharge and treatment.

Solid waste disposal (SWDS) on land is the main source a CH_4 emissions due to the anaerobic and semi-anaerobic decomposition of the organic portion of the waste in landfills or open dumpsites.

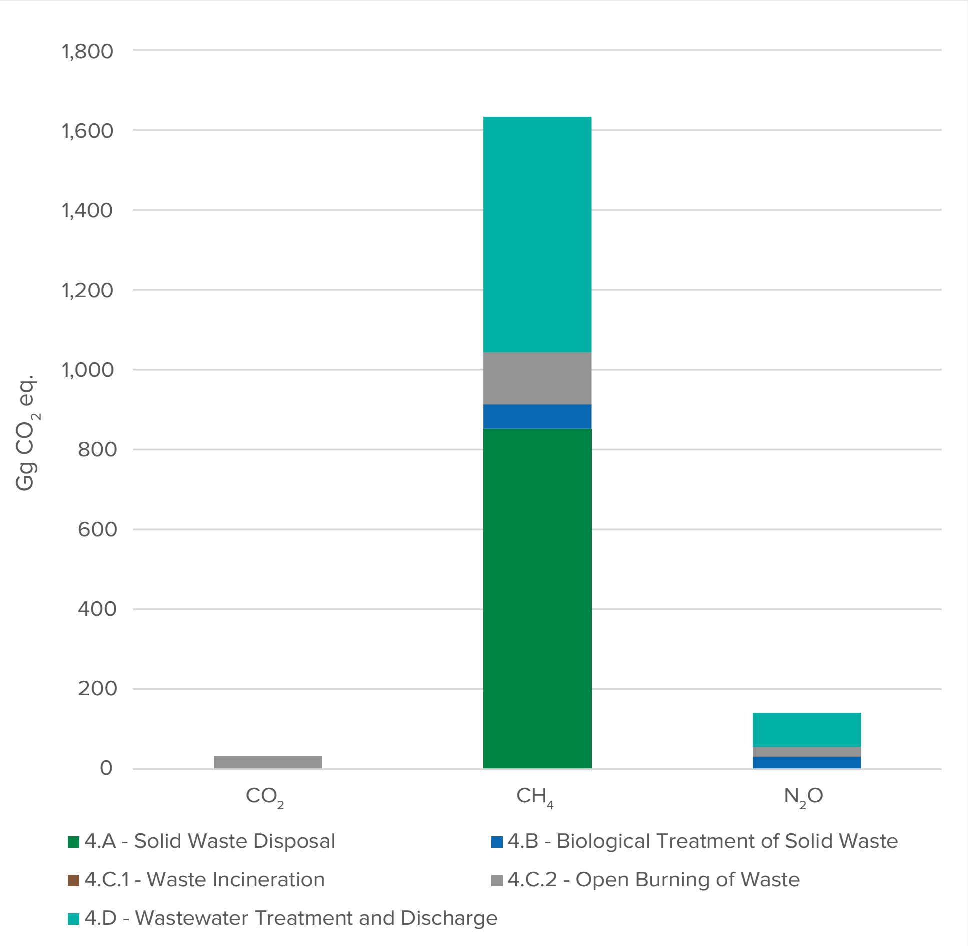


Figure 38: GHG emission from the waste sector in 2019 per subcategory

The trend of GHG emissions from the waste sector is highly fluctuating, as presented in Figure 39. the 2015 waste crisis has a significant impact on GHG emissions, mainly due to the increase rate of open dumping and open burning of unsegregated waste, thus reducing proper treatment of organic waste. Emission decreased with the start of operation of the Bourj Hammoud and Costa Brava landfills, where sorted waste is disposed in technically managed cells.

With respect to N_2O, the main source of emissions is domestic wastewater, where emissions reached 84.80 Gg CO_2 eq. in 2019. Nitrous oxide emissions from wastewater treatment processes gradually increased across the time series as a result of increasing Lebanon population and protein consumption.

Nitrous oxide emissions are not estimated from industrial wastewater treatment because there is no IPCC methodology provided or industrial wastewater emission factors available.

In 2019, wastewater treatment and discharge from both domestic and industrial sources amounted to 673.54 Gg CO_2eq. Figure 40 shows CH_4 and N_2O domestic wastewater emissions from three main sources for the year 2019.

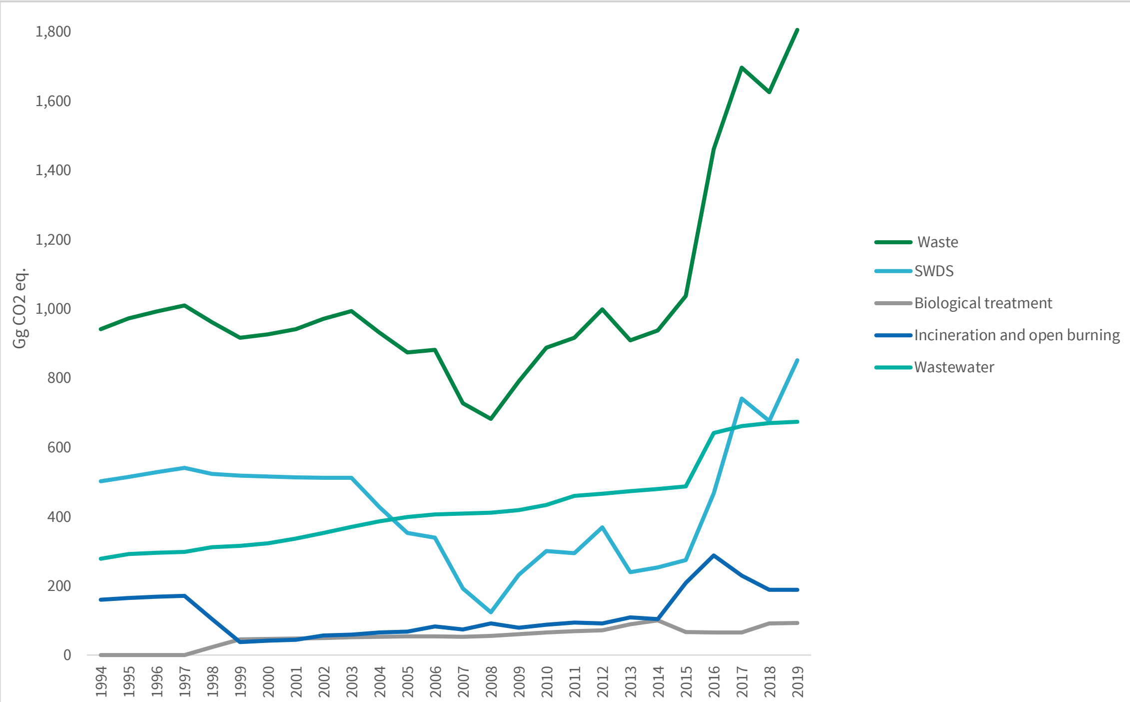


Figure 39: Trend in GHG emissions from the waste category for 2019

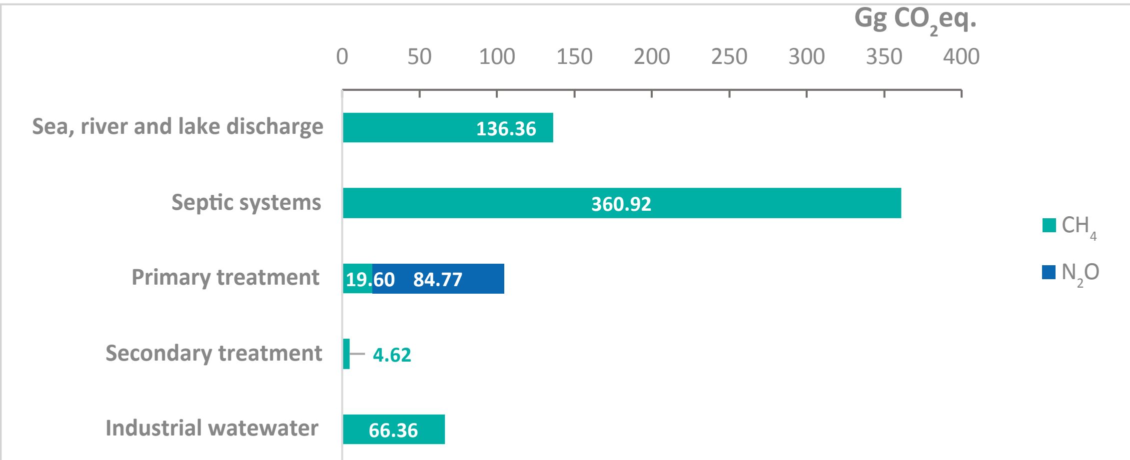


Figure 40: Domestic wastewater GHG emission for 2019

CHAPTER 4

CLIMATE RISKS, VULNERABILITY, AND ADAPTATION ASSESSMENT

SUMMARY OF KEY POINTS

Present state 1950-2020:

- An increase of 1.6°C of the annual mean temperature is recognized in Lebanon for the period 1950-2020, with the trend of increase being steeper for the period 1991-2020.
- Annual mean temperatures have risen across all regions of Lebanon from 14.22°C in 1901 to 15.83°C in 2020, with a slower rate of warming in the coastal region due to the cooling effect of the sea breeze.
- Precipitation shows a decreasing trend for the period 1950-2020 (0.53 mm per decade), although less pronounced for the period 1990-2020 (0.35 mm per decade).
- Precipitation exhibits, in the period of 1950-2020, strong fluctuations from year to year, less than 500 mm for years 1960-61, 2001, 2010 and 2019 and around 900 mm for years 1968-1970, 1994 and 2004.
- The amount of Consecutive Dry Days (CDD) when daily precipitation is less than 1mm shows a south to north gradient of the annual mean of CDD (in days) with considerably higher values for CDD in the southern part of Lebanon.
- Extreme events: There has been an increase in natural disaster frequency since 2010, with three times the number of flood incidents in 2015 and increase in heatwave intensity in 2020.

Projected Changes for 2050-2100:

- Temperature: An increase in the average temperature of 1.6°C to 2.2°C when compared to the reference period 1986-2005, depending the RCP scenario (4.5 or 8.5), is expected by mid-century according to most recent projections (2022), compared to a more modest increase of 1.2°C to 1.7°C previously projected under the IPCC AR5 (2014).The recent end-century projections expect an increase of 2.2°C to 4.9°C depending the RCP scenario; in the 2014 analysis, the respective increase was estimated from 1.5°C to 3.2°C, again depending the RCP scenario. Climate projections for the region for the SSP5-8.5 scenario show an increase in the annual mean temperature by 2.2°C by mid-century and 4.4°C by end-century, which is more or less aligned with the RCP scenario analysis. The increase is seasonally dependent, being more pronounced in summer and autumn. These results show that temperature in Lebanon is projected to increase intensely over a shorter timeframe. The Bekaa Valley and most coastal areas across Lebanon will suffer the most from such increases.

- Precipitation: Precipitation is expected to decrease by 6.5% to 9% by mid-century and by 9% to 22% by end-century based on RCP scenarios' most recent projections (4.5 and 8.5 respectively). It is important to note that previous scenarios from 2014 projected a 4% decrease in precipitation per each degree of global warming, which further highlights the fact that recent projections are showing almost 1.5 times the previously projected impacts for both mid- and end-century scenarios since temperatures are increasing more intensely and within a shorter timeframe. Climate projections for annual precipitation for the SSP5-8.5 scenario show a more severe reduction of 10% to 16% by mid-century and by end-century respectively as compared to the reference period of 1995-2014.
- Consecutive Dry Days: increase in all regions for the periods 2021-2040 and 2041-2060 for SSP5-8.5 is expected, although more pronounced at the southern regions and along the coast.
- On the basis of several precipitation indicators, drought risk is expected to increase towards 2050 under all scenarios (RCP4.5 and RCP8.5 as well as for SSP5-8.5).
- Heat waves: Increase in duration and intensity is expected, with considerable health impacts to people living in urban areas as well as enhanced needs for energy consumption for cooling needs. In terms of the days with temperature above 35°C (SU35) and 40°C (SU40), they are expected to almost double for the period 2041-2060 compared to the reference period 1995-2014 with the increase being more pronounced in the case of summer, at both the coastal and inland regions of Lebanon.
- Extreme events: Compound events of heatwaves and droughts are expected to increase almost fivefold for the period 2041-2060 as compared to the reference period 1986-2005. The increase will reflect up to 15 more incidents for inland Lebanon, and 20+ incidents for the northeast and southeast regions. Increase will be overall less pronounced in coastal regions.

SECTION A. **RISK ASSESSMENT**

4.1 LEBANON'S CHANGING CLIMATE

Lebanon has faced enormous challenges in recent years, which have affected every aspect of its society. Economic crisis, the COVID-19 epidemic, the Port of Beirut explosion, natural calamities, and extended political gridlock, have all posed challenges to the country. Lebanon has been hobbled by these obstacles, which have hindered its progress and reduced its ability to adapt. On top of the above, Lebanon faces a new challenge in the form of climate change: a threat multiplier that will exacerbate current problems and necessitates immediate and long-term response by the government and the people. Climate change impacts are projected to increase temperatures and increase water scarcity, which will affect people's lives, and will have a negative impact on agricultural outputs and communities' lives. Higher temperatures will also boost energy demand, placing a burden on businesses and utility services as they try to satisfy their power requirements.

Lebanon is characterized by hot dry summers (June to September) and cool rainy winters (December to mid-March) with an average annual temperature of 15°C and highs of 30-40°C in July and August (World Bank, 2022b). Most of the rainfall and snow takes place from November to March, with 75-80% of precipitation peaking in January and reaching up to 160-180 mm/month. The remaining 20 to 25% of rainfall is during the autumn thunderstorms and spring showers.

The mean climatology of Lebanon from 1991-2020 shows large variation of temperature and precipitation between summer and winter months (Figure 41). The increasing trend of the annual mean temperature during the period 1950-2020 can be seen in Figure 42 (left image); with the trend being enhanced in the sub-period 1991-2020, in comparison to periods before. The same holds for the mean monthly temperature (in Figure 42, right image), with increasing trends for the decades 2001-2010 and 2011-2020 (World Bank, 2022b).

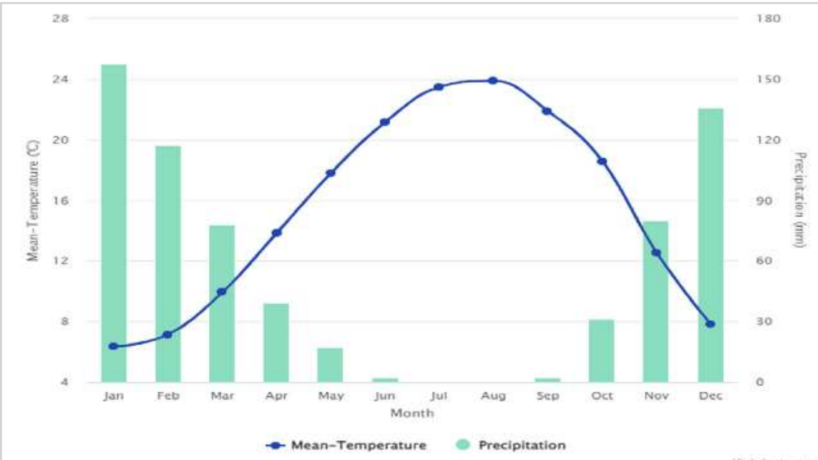


Figure 41: Mean climatology of mean temperature and precipitation in Lebanon from 1991-2020 (World Bank, 2022b).

Mean temperature - annual trends with significance of trend per decade – Lebanon

Mean temperature monthly trends- Lebanon

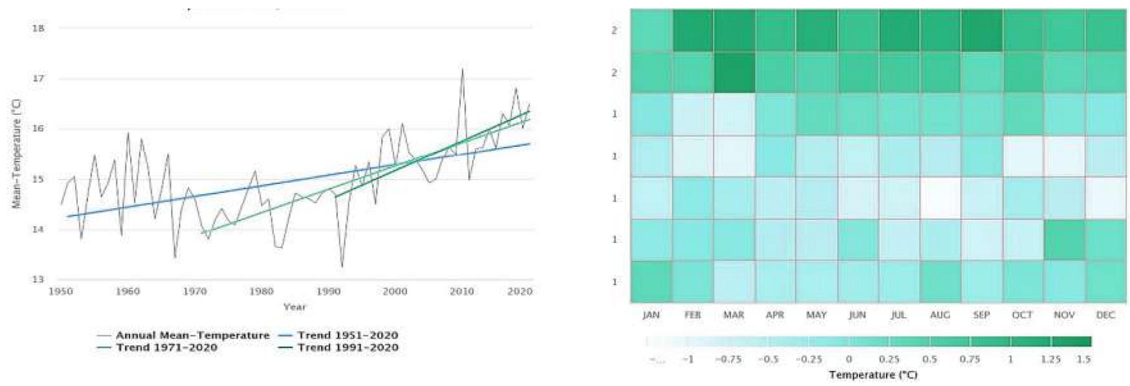


Figure 42: Mean temperature annual and monthly trends for Lebanon (World Bank, 2022b).

As presented in Figure 43, a decreasing annual trend in precipitation is observed for the period 1951-1990 (-0.53 mm per decade) with a less pronounced decrease (-0.35 mm per decade) in the period 1991-2020 for Lebanon (Figure 43, left image). The precipitation monthly trends for the period 1950-2020 show considerable fluctuations among the months of the year and the decade under consideration; overall for the period 1991-2020, limited decrease has occurred during the spring and summer months, while increase in precipitation is observed irregularly in some of the examined periods, for the months December to February. In most climate analyses, in contrast with temperature, regional or country level precipitation trends are less statistically significant.

Precipitation - annual trends with significance of trend per decade – Lebanon (in mm)

Precipitation monthly trends- Lebanon (in mm)

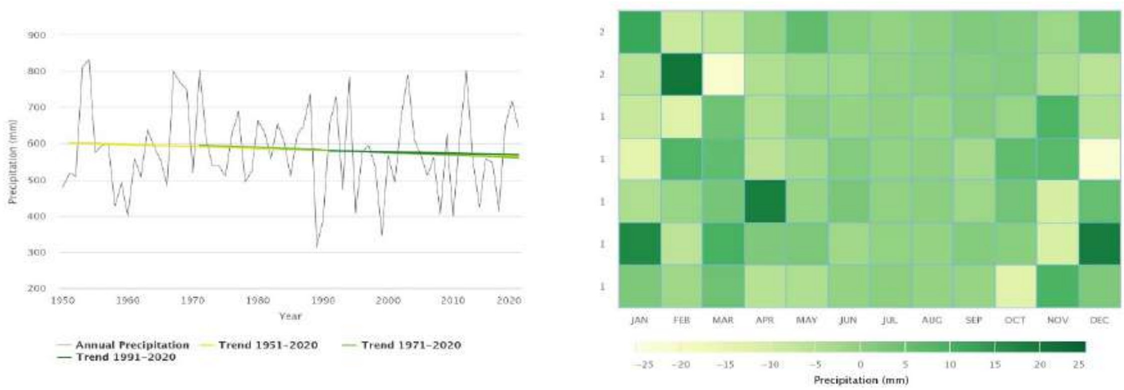


Figure 43: Precipitation annual and monthly trends for Lebanon (World Bank, 2022b)

Historical data precipitation analysis based on ERA5-Land Monthly Averaged - ECMWF Climate Reanalysis (at spatial resolution 0.1 degrees) for the period January 1981 – December 2020 is shown in Figure 44. In both periods, the trend is declining although less pronounced in the period 1991-2020; the application of Pettitt's test for change detection[1] detects a change in the trend in 1989 (Philippopoulos and Cartalis, 2022).

a) period 1981-1900

b) the period 1991-2020

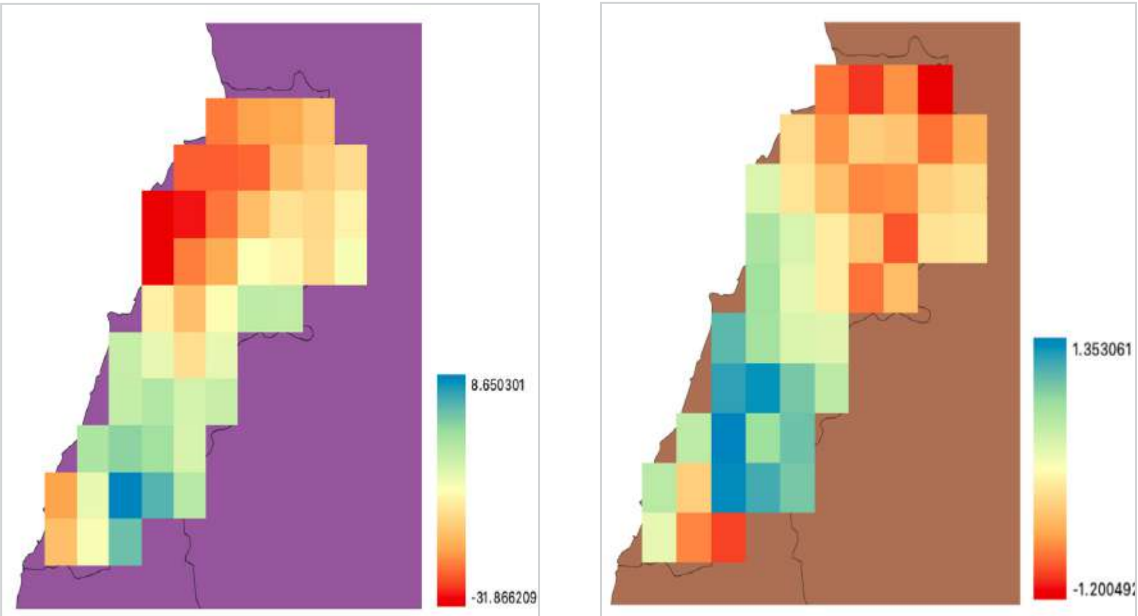


Figure 44: Sen Slope for precipitation for Lebanon

Precipitation is irregular spatially wise; it varies considerably from the narrow (only 6.5 km at its widest point) and relatively moist coastal plain, to the almost desert-like conditions in the Lebanon mountain chain. The rainfall distribution reflects a South-to-North gradient, leading to the northern, mountainous parts of the country receiving the most precipitation (Figure 45). The number of rainy days usually varies between 60 and 80, while the number of snowy days can exceed 30 at high altitudes. Dryness takes over from April to October and snowmelt occurs progressively from April to May (Abdallah et al., 2018).

From a wider perspective (Figure 46) for the period 1901-2020, Lebanon's climate is characterized by an increase in annual mean temperature of 1.6°C and strong fluctuations per year in precipitation. In terms of climate events in Lebanon, they show considerable variation in their type and intensity (Table 18).

[1] A non-parametric test for evaluating the occurrence of abrupt changes in climatic records.

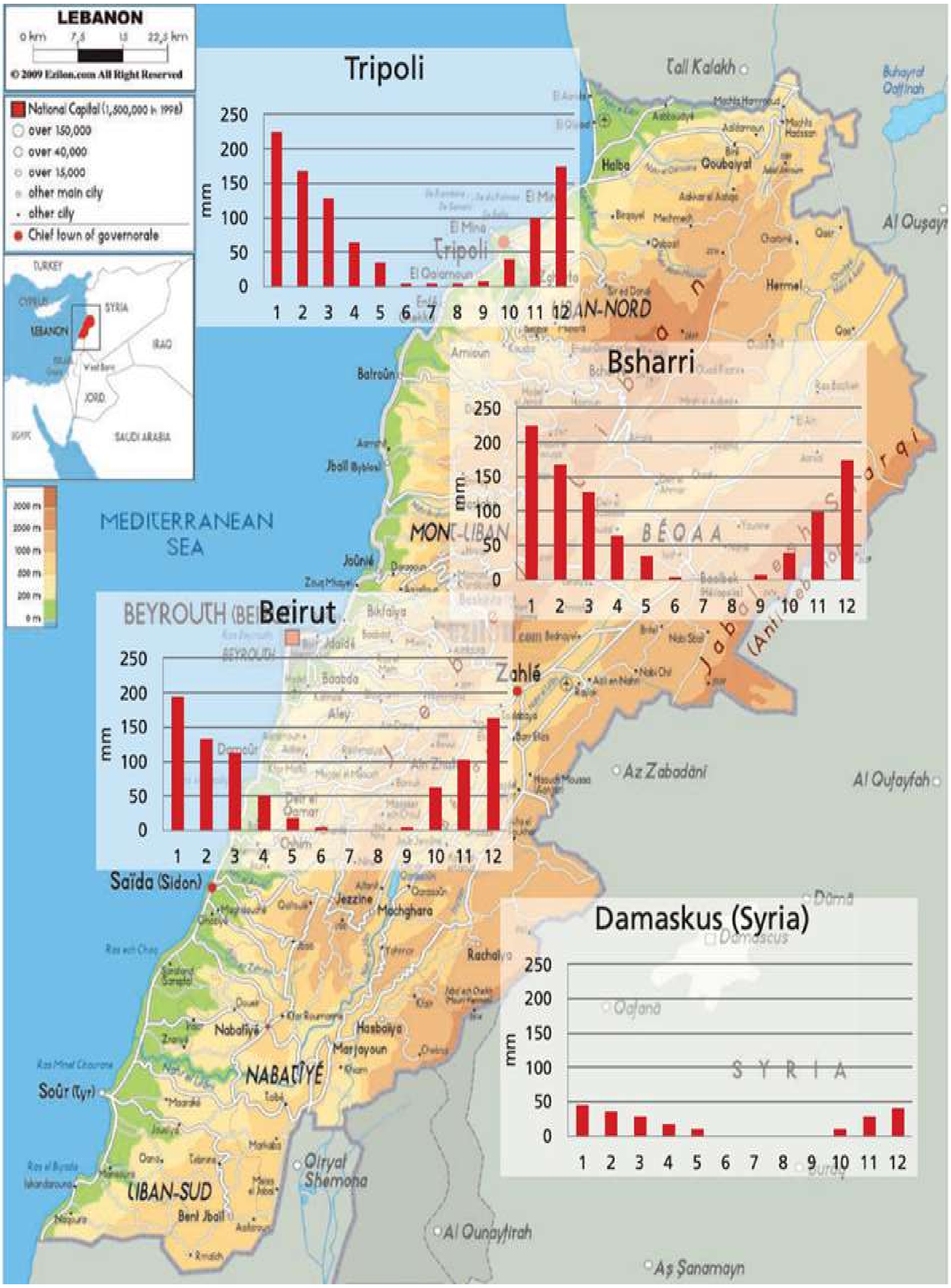


Figure 45: Mean monthly precipitation in mm from 1961 to 1990 for three Lebanese Climate Data Series (KNMI Climate Explorer from Verner et al., 2018).

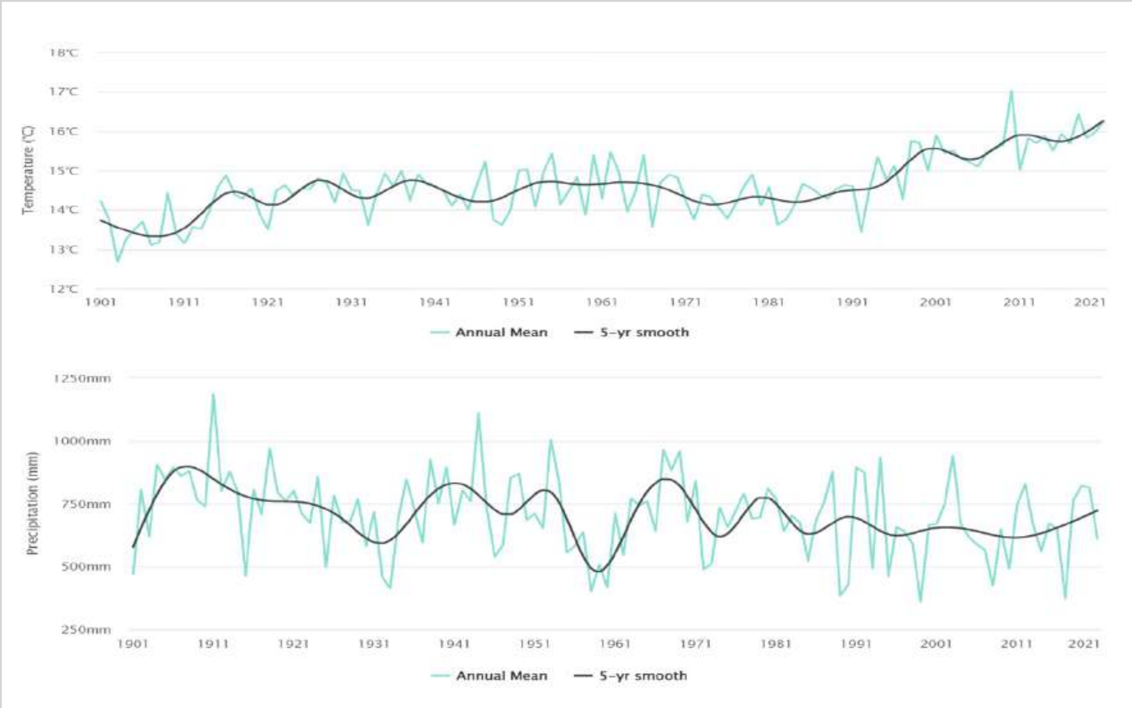


Figure 46: Annual mean temperature and precipitation in Lebanon from 1901 to 2020 (ten-year intervals) (World Bank, 2022b).

Table 18 Climatic events in Lebanon (Adapted from Verner et al., 2018)

Date	Climatic events
2007	Severe heat waves, where temperatures exceeded the 90th percentile during the summer months. Heat waves reached temperatures above 40°C for five days in June and seven days in July. This led to large local forest fires. Rainfall was also 50 % lower that summer.
2008	Well-below-average temperatures and drier-than-average conditions.
2009	Warmer-than-average temperatures prevailed throughout the country, followed by severe rainfall causing flooding.
2010	The average air temperature ranged from 2°C to 4°C higher than normal, with November being very dry. Lebanon received less than 40% of normal precipitation levels. Heatwaves were recorded over the Bekaa Valley (September 2010). In December, an extratropical cyclone brought heavy rainfall and strong winds to the eastern Mediterranean. Along the coast of Lebanon, waves reached ten meters tall.
2011	Temperatures and rainfall levels were normal. Flood damage in the Akkar, Danieh and Hasbni area.
2012	Summer was significantly warmer than normal with anomalies between +1°C and +3°C, reaching +4°C. Despite some extreme precipitation events, 2012 was slightly drier than normal, especially during the warm season. Precipitation surplus resulted in a wetter-than-normal winter with rainfall reaching 125% to 140% of long-term mean precipitation, especially in January. Spring was dominated by mostly dry conditions. Lebanon received 50 mm less precipitation than normal or 40% of the long-term mean.

2013	The Middle East was +1°C to +2°C warmer than normal, including winter and summer months. In the first days of January, snow, frost, and thunderstorms affected parts of Lebanon and surrounding areas. In March, a heatwave hit with maximum temperatures reaching nearly 40°C. Flash floods were recorded in North Bekaa and East Lebanon (November 2013).
2014	Middle East temperatures were 1°C to 2°C above the long-term mean and annual precipitation below normal. Lebanon had a dry year with high temperatures and low rainfall. Main frost events in Central and Northern Valley and North Lebanon (in March 2014) and heat and water shortages (September 2014).
2015	In the Middle East, temperatures were +1°C to +2°C warmer than the long-term mean. Windstorms and frost were recorded on the coastal areas in South Lebanon (January 2015), snow, wind and frost in Mount Lebanon (March 2015) and floods of Nahr El Kabir in Akkar area (February 2015).
2016	Heavy rain and snow caused a landslide in Chouf, Mount Lebanon
2017	Heatwaves and strong winds caused forest fires in several areas in North Lebanon (Akkar)
2018	Snow, heavy rain and some flooding have been observed in Tripoli in February 2018 where it recorded 81 mm of rain in 24 hours. In December 2018, storm "Norma" caused torrential rain, freezing winds and snow, causing damages to infrastructure, roads, and homes across the country.
2019	Heavy rain caused flooding (December 2019). Heat wave with temperatures in coastal and inland areas exceeding 36.5°C (July 2019)
2020	Heat wave for 2 weeks in July and August; temperatures reached more than 40°C.

4.2 PROJECTING FUTURE CLIMATE CHANGES: MAIN PATHWAYS AND RESULTS

The IPCC Sixth Assessment Report (AR6) on Impact, Adaptation and Vulnerability (2022) is the most recent and comprehensive assessment of climate change impacts and future risks at global and regional levels. The report generated for the first-time new scenarios based on a three-dimensional matrix comprised of the Representative Concentration Pathways (RCPs), Socioeconomic Pathways (SSPs), and Climate Shared Policy Assumptions (SPAs).

The IPCC AR6 builds on the four pathways previously developed under the AR5 (2018) (RCP2.6, RCP4.5, RCP6.0, and RCP8.5), which were limited to different levels of greenhouse gases (emissions and other radioactive forcings, and adds five new narratives (SSPs) that take into consideration socioeconomic factors such as global population growth, access to education, urbanisation, economic growth, resources availability, technology developments and lifestyle changes (Meinshausen et al., 2020).

The results of this more inclusive framework produced the Integrated Assessment Pathways (IAMs), which support the coordination across climate change research communities and provide a basis for systematic analysis of key questions of mitigation and adaptation, under different climate and socioeconomic futures.

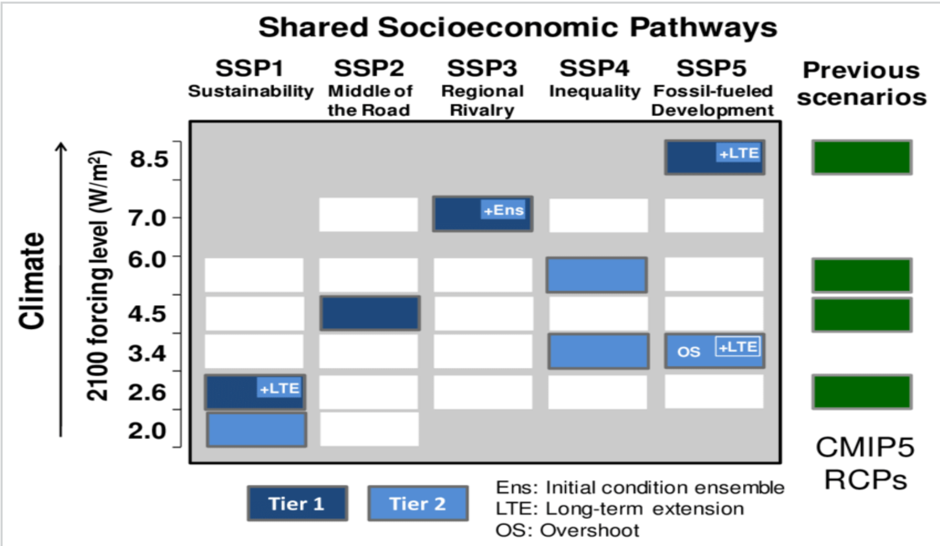
Socioeconomic Pathways (SSPs) adopted in IPCC AR6

The five Socioeconomic Pathways (SSPs) scenarios, adopted for the first time in the IPCC AR6 report, describe alternative evolutions of a future society in the absence of climate change or climate policy. SSPs 1 and 5 foresee relatively optimistic trends for human development, with substantial investments in education and health, rapid economic growth, and well-functioning institutions. However, SSP5 assumes an energy-intensive, fossil-based economy, while SSP1 promotes a shift toward sustainable practices. SSP2 envisions a central pathway in which trends continue their historical patterns without substantial deviations. SSPs 3 and 4 envision more pessimistic development trends, with little investment in education or health, fast-growing population, and increasing inequalities. In SSP3 countries prioritize regional security, whereas in SSP4 large inequalities within and across countries dominate leading to societies that are highly vulnerable to climate change.

SSP1	Sustainability – Taking the Green Road (Low challenges to mitigation and adaptation) The world shifts gradually towards a more sustainable path emphasizing more inclusive development that respects environmental boundaries. Consumption is oriented toward low material growth and lower resource and energy intensity.
SSP2	Middle of the Road (Medium challenges to mitigation and adaptation) The world follows a path in which social, economic, and technological trends do not shift distinctly from historical patterns. Global and national institutions made positive strides working towards, but making slow progress, in achieving sustainable development goals. Environmental systems experience continuous degradation.
SSP3	Regional Rivalry – A Rocky Road (High challenges to mitigation and adaptation) A resurgent nationalism, concerns about competitiveness and security, and regional conflicts push countries to increasingly focus on domestic issues. A low international priority for addressing environmental concerns leads to strong environmental degradation in some regions.
SSP4	Inequality – A Road Divided (Low challenges to mitigation, high challenges to adaptation) Highly unequal investments in human capital led to increasing inequalities and stratification both across and within countries. Social cohesion degrades and conflict and unrest become increasingly common. The globally connected energy sector diversifies, with investments in both carbon-intensive fuels like coal and unconventional oil, but also low-carbon energy sources. Environmental policies focus on local issues around middle- and high-income areas.
SSP5	Fossil-fuelled Development – Taking the Highway (High challenges to mitigation, low challenges to adaptation)

Six different Integrated Assessment Models (IAMs) were used to quantify the socioeconomic conditions of the SSPs and add a societal aspect (SSPs) to the previously established energy-based systems model (RCPs), to produce scenarios highlighting how GHG emissions can vary taking into consideration underlying socioeconomic factors.

SSP & RCP Projection Scenario Matrix=RCPs+SSPs+SPAs



Each cell in the matrix indicates a combination of socio-economic development pathway (SSP) and climate outcome based on a particular forcing pathway (RCP). Dark blue cells indicate scenarios that will serve as the basis for climate model projections in Tier 1, while light blue cells indicate scenarios in Tier 2. The SSP-RCP scenario matrix illustrates five scenario simulations covering the near-term (2021–2040), mid-term (2041–2060,) and long-term (2081–2100) time periods.

Table 19 provides the estimated warming at the planetary scale in degrees Celsius for the periods 2041-2060 and 2081-2100 compared to 1995-2014, for selected SSPs (IPCC, 2022). Estimated warming for SSP5-8.5 at the planetary scale may be compared to the respective estimated warming for the same scenarios for Lebanon.

Table 19 **Estimated warming for Shared Socioeconomic Pathways in the IPCC Sixth Assessment Report**

SSP	Scenario	Estimated warming (2041–2060)	Estimated warming (2081–2100)	Very likely range (2081–2100)
SSP1-1.9	Very low GHG emissions: CO_2 emissions cut to net zero around 2050	1.6°C	1.4°C	1.0 – 1.8°C
SSP1-2.6	Low GHG emissions: CO_2 emissions cut to net zero around 2075	1.7°C	1.8°C	1.3 – 2.4°C

SSP2-4.5	Intermediate GHG emissions: CO_2 emissions around current levels until 2050, then falling but not reaching net zero by 2100	2.0°C	2.7°C	2.1 – 3.5°C
SSP3-7.0	High GHG emissions: CO_2 emissions double by 2100	2.1°C	3.6°C	2.8 – 4.6°C
SSP5-8.5	Very high GHG emissions: CO_2 emissions triple by 2075	2.4°C	4.4°C	3.3 – 5.7°C

4.3 FUTURE CLIMATE PROJECTIONS FOR LEBANON

Several projects (Verner et.al, 2017 and World Bank, 2022b) and research studies (Almazroui, 2019; Bucchignani et al., 2018; Driouech et al., 2020; Ntoumos et al., 2020; Spinoni et al., 2020; Zittis et al. 2021; Varela, et al., 2020; Zittis, et al., 2019; Zittis and Hadjinicolaou, 2017) have examined the climatic profile of Lebanon and/or the Eastern Mediterranean and the Middle East over the years, intending to project probable changes in the near and far future.

In particular, and due to the complex topography and various microclimates in Lebanon and the lack of spatially and temporally complete meteorological records, various external data sources, tools, and models, such as the EURO CORDEX dataset, the CMIP5/CMIP6 datasets, the ARAB Domain dataset generated by RICCAR, the World Bank's Climate Change Knowledge platform, and others, have been used to conduct climatological studies in Lebanon, yielding a wide range of results.

This sub-section intends to summarize the main findings and projections of selected climate models regarding climate change in Lebanon. Main information on the climate models is presented in Table 20.

Table 20 Main information on the climate models used by international, regional, and national institutions to project climatic changes for Lebanon and the wider geographic area

Institution	Dataset/Model	Description	Type	Projection period	Reference
Intergovernmental Panel on Climate Change (IPCC)	Coupled Model Intercomparison Project Phase 5 CMIP5	CMIP5 is the model ensemble used for the Fifth Assessment Report of IPCC (AR5). CMIP5 uses Representative Concentration Pathways (RCPs) to build greenhouse gas concentration trajectories. Resolution: 70 to 250 km	Ensemble model and dataset	Reference period: 1986-2005 Projected periods: 2020–2049 (2030s), 2040–2069 (2050s), 2060–2089 (2070s) 2070–2099 (2080s)	IPCC 2014

Intergovernmental Panel for Climate Change (IPCC)	Coupled Model Intercomparison Project Phase 6 CMIP6	CMIP6 is the model ensemble used for the Sixth Assessment Report of IPCC AR6. CMIP6 uses Shared Socioeconomic Pathways (SSPs) and an ensemble of climate models. Resolution: 0.11º x 0.11º (12.5km x 12.5km)	Ensemble model and dataset	Reference period: 1995-2014 Projected periods: 2020–2049 (2030s), 2040–2069 (2050s), 2060–2089 (2070s) 2070–2099 (2080')	IPCC 2022
National Centre for Atmospheric Research, The National Oceanic and Atmospheric Administration	Weather Research and Forecasting (WRF)	WRF is a numerical weather prediction model. Resolution: 9 km spatial over a parent domain covering the Mediterranean and 3 km in an inner nested domain.	Model	Reference period: 2008 Projected period: 2029, 2040 and 2050 for RCP4.5 2023, 2035 and 2050 for RCP8.5	El Samra et al., 2016
Geophysical Fluid Dynamics Laboratory	High-Resolution Atmospheric General Circulation Model (HiRAM)	HiRAM model was developed by the Geophysical Fluid Dynamics Laboratory as a global model. 32 vertical levels and a horizontal resolution of roughly 50 km (varying between 43.5 and 61.6 km)	GCM model	Reference period: 2008 Projected period: 2007-2050	El Samra et al 2016; El Samra et al, 2018
World Climate Research Program and its Task Force for Regional Climate Downscaling	European Coordinated Regional Climate Downscaling Experiment (Euro-CORDEX)	A high-resolution regional climate change ensemble of models. Resolution: 0.11º x 0.11º (12.5km x 12.5km)	Ensemble model	Reference period: 1986-2005 Projected period: 2100	Zittis et al., 2019

RICCAR-ESCWA	Arab Domain based on the datasets generated by the Swedish Meteorological and Hydrological Institute (SMHI)	Regional climate modelling outputs were generated by SMHI using the Rossby Centre Regional Atmospheric Model (RC4), forced by three GCMs. RCP4.5 and RCP8.5 up by mid-century and end-century Horizontal resolution of 50km x 50 km	Ensemble model	Reference period: 1986–2005 Projected Period Mid-century period 2046–2065 End-century period 2081–2100	ESCWA 2017a, ESCWA, 2017b
MedECC First Mediterranean Assessment Report	European Coordinated Regional Climate Downscaling Experiment (Euro-CORDEX)	A high-resolution regional climate change ensemble of models Resolution: 0.11° x 0.11° (12.5km x 12.5km) RCP2.6 and RCP8.5	Ensemble model	Reference period: 1980-1999. Projected period 2020-2039, 2040-2059 and 2080-2099	MedECC, 2020
Cyprus Initiative	WRF driven by re-analyses for evaluation or CMIP5	1. Few-year MENA domain 16 km, nested EMME domain 4 km) 2. Multi-year/ decadal MENA at 24 km 3. WRF MENA 50 km projections produced for the MENA-CORDEX for RCP4.5 and 8.5	Ensemble	Reference period: 1986-2005 Projected period: 2006-2100	Ntoumos et al., 2021
Climate analytics – GCF technical support	Half a degree additional warming, Prognosis and Projected Impacts (HAPPI)	HAPPI experiment as based on a set of four HAPPI GCMs (ECHAM6, MIROC5, CAM4-2degree and NorESM1).	Global temperature constraint leading to regional response and extreme weather	Reference period: 2006-2015 Projected period: World with +1.5 °C and +2.0 °C above pre-industrial	MoE/GCF, 2021

4.3.1 Future change in temperature

There is robust evidence that the Mediterranean region has significantly warmed. Annual mean temperatures on land and sea across the Mediterranean Basin are 1.5°C higher than during pre-industrial times and they are projected to rise until 2100 by an additional 3.8 to 6.5°C for a high greenhouse gas concentration scenario (RCP8.5) and 0.5 to 2.0°C for a scenario compatible with the long-term goal of the UNFCCC Paris Agreement to keep the global temperature well below +2°C above the pre-industrial level (MedECC, 2020).

As far as estimates for any future change in temperature, modest increases in temperature averaging 1.2°C (for RCP4.5) to 1.7°C (for RCP8.5) at mid-century and 1.5°C (for RCP4.5) to 3.2°C (for RCP8.5) by end-century were estimated in a vulnerability assessment conducted by ASCSAD and ESCWA (2019). However, the coarse spatial resolution failed to capture localized climatic effects, including the increases displayed in the Lebanon Mountains or the lower increase of temperature at the coastal zones, the latter presumably due to the effect of sea breeze.

According to IPCC AR5 data for the region[2], the annual mean temperature is projected to increase by 4.3°C for the RCP8.5 scenario by end-century, whereas increases are also projected for all seasons, although at different degrees. The CMIP5 models indicate that for the RCP8.5 scenario by the end of the 21st century, country-scale temperatures could increase by 4.1–4.6°C during winter, 4.4–4.9°C during spring, 5.1–5.9°C during summer, and 5.1–5.8°C during fall (World Bank, 2022b).

All predictions above are simulated and provided in coarse resolution. This does not diminish the usefulness of climate predictions, yet it demonstrates the need for predictions at improved spatial resolution.

Bias adjusted[3] climate projections from EURO-Cordex[4] show that the annual mean temperature increase ranges from 1.6°C (RCP4.5) to 2.2°C (RCP8.5) by mid-century and from 2.2°C (RCP4.5) to 4.9°C (RCP8.5) by end-century when compared to the reference period 1986-2005. Projections were deduced with the use of an ensemble of three climate models. In particular, in Table 21, the mean temperature differences (°C) as well as the minimum and maximum values of the mean temperature differences are provided for Lebanon for the mid-term 2041-2060 and long-term 2081-2100 periods, compared to the reference period 1986-2005 (Philippopoulos and Cartalis, 2022).

The annual mean temperature for the period 1986-2005 and the changes to the annual mean temperatures for the periods 2041-2060 and 2081-2100 for RCP4.5 (Figure 47 a-c) and RCP8.5 (Figure 48 a-c) respectively, are spatially depicted for Lebanon. Significant deviations are observed moving from the coastal regions to the Bekaa valley. In terms of the coastal areas, the increase of annual mean temperature ranges from +1.4°C (RCP4.5) to +2.2°C (RCP8.5) by mid-century, and as much as +1.9°C (RCP4.5) to +4.4°C (RCP8.5) by end-century.

[2] Based on an ensemble of CMIP5 models at 1.0°x1.0° or 100 kmx100 km resolution

[3] SMHI- Distribution-Based Scaling

[4] CMIP5, at resolution of 0.11° x 0.11°, 12.5 km x 12.5 km

Table 21 Temperature differences for the mid-term (2041-2060) and long-term (2081-2100) periods compared to the reference period (1986-2005).

Mean temperature differences for Lebanon for mid-term (2041-2060) and long-term (2081-2100) compared to the reference period (1986-2005) in°C.

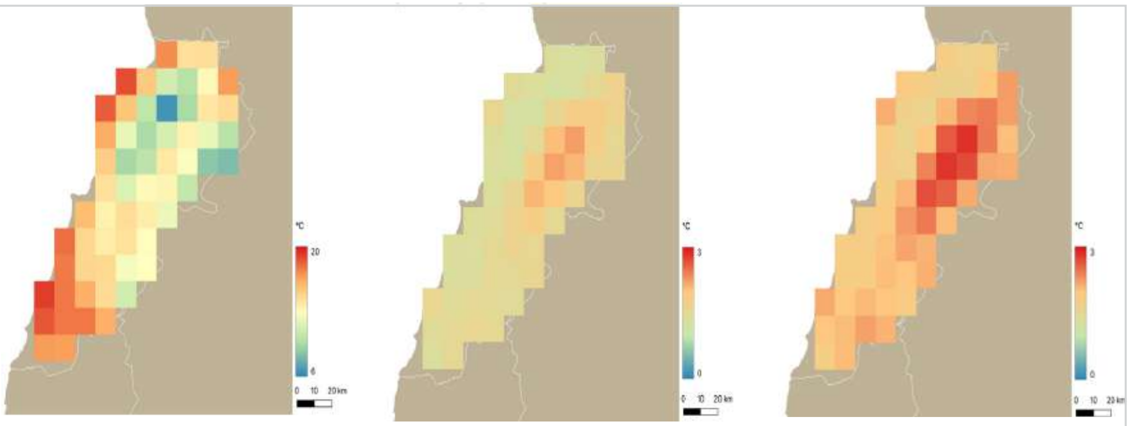
	2041-2060	2081-2100
RCP4.5	1.6	2.2
RCP8.5	2.2	4.9

Minimum values of the mean temperature differences for Lebanon for mid-term (2041-2060) and long-term (2081-2100) compared to the reference period (1986-2005) in°C.

	2041-2060	2081-2100
RCP4.5	1.2	1.7
RCP8.5	1.7	3.8

Maximum values of the mean temperature differences for Lebanon for mid-term (2041-2060) and long-term (2081-2100) compared to the reference period (1986-2005) in°C.

	2041-2060	2081-2100
RCP4.5	2.2	2.9
RCP8.5	3.0	6.6

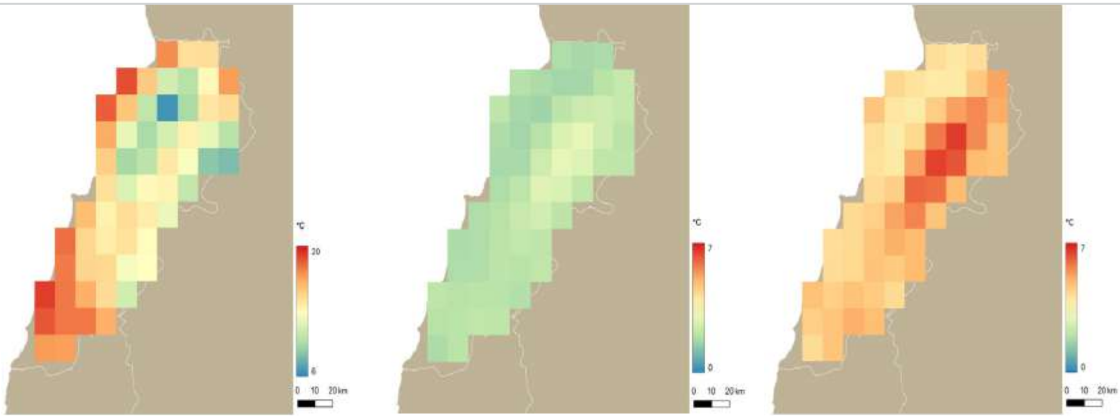


a) Mean temperature – annual 1986-2005 RCP4.5

b) Change of mean temperature – Annual (2041-2060) (1986-2005) RCP4.5

c) Change of mean temperature – Annual (2081-2100) (1986-2005) RCP4.5

Figure 47: Changes of mean temperature for RCP 4.5 for mid-century and end-century compared to the reference period



a) Mean temperature – annual 1986-2005 RCP8.5

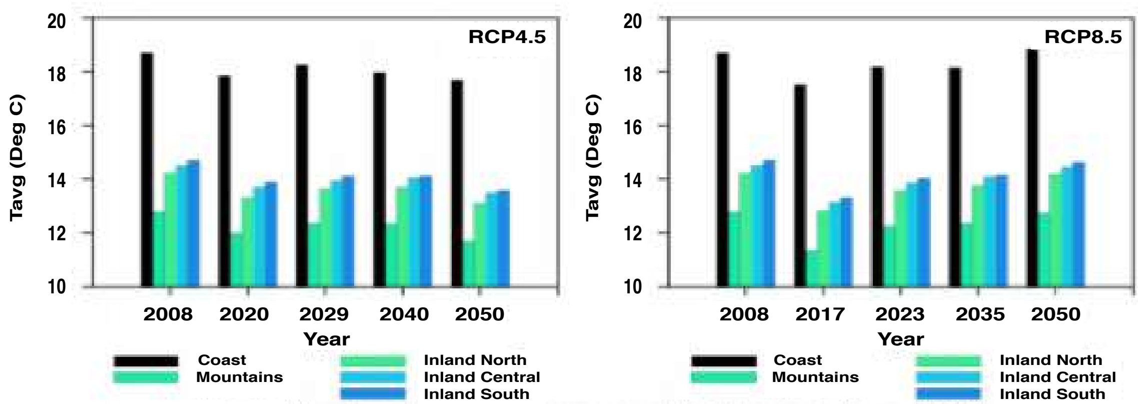
b) Change of mean temperature – Annual (2041-2060) (1986-2005) RCP8.5

c) Change of mean temperature – Annual (2081-2100) (1986-2005) RCP8.5

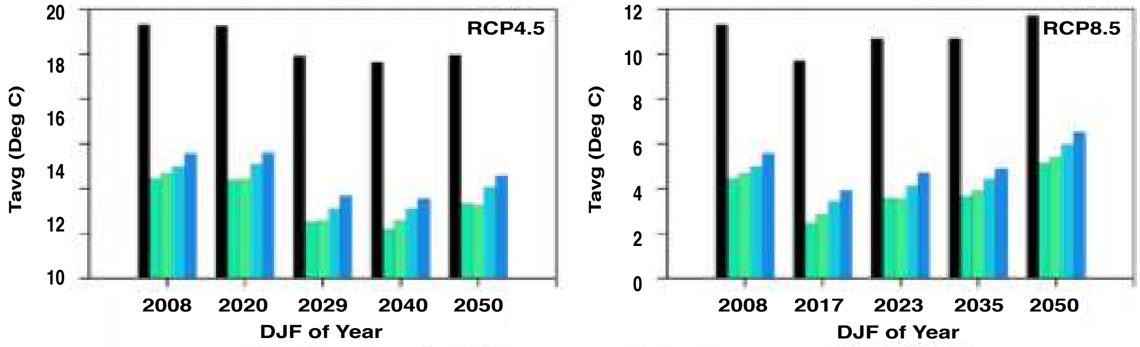
Figure 48: Changes of mean temperature for RCP 8.5 for mid-century and end-century compared to the reference period

Seasonal differences are observed (El Samra et.al, 2018) in all regions of Lebanon under RCP4.5 and RCP8.5, with unexpected decreases in the winter and spring temperatures (December-May) and increases in summer and autumn (June-November) temperatures.

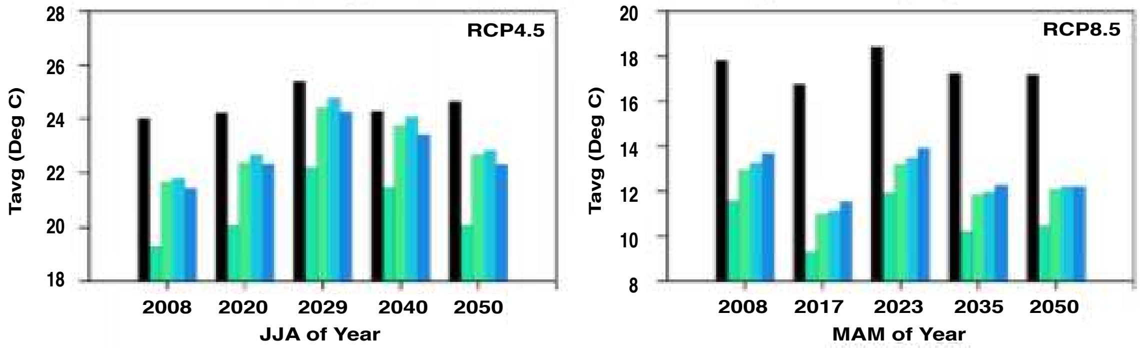
The unexpected decreases in the winter (December-January-February; Figure 49-a) and spring (March-April-May; Figure 49-b) temperatures almost offset the increases in summer (June-July-August; Figure 49-c) and autumn (September-October-November; Figure 49-d) temperatures resulting in an annual mean temperature increase by about 0.3°C under RCP4.5 (Figure 49-e).



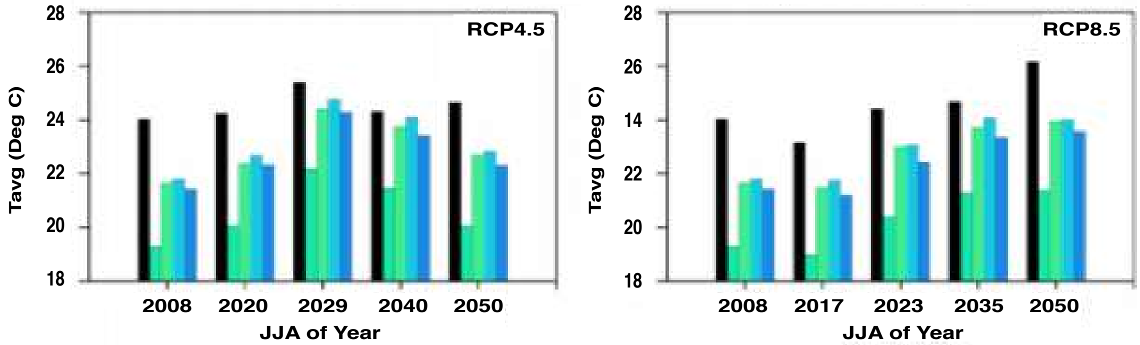
a. Regional annual average 2m temperature (°C)



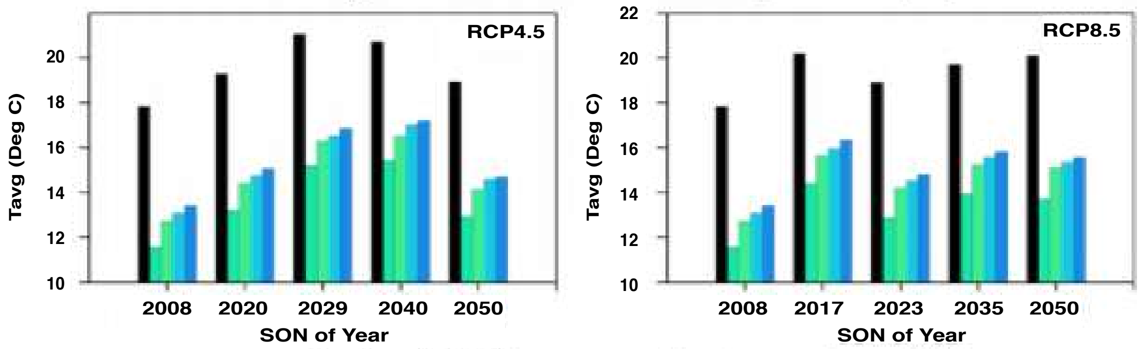
b. Regional DJF average 2m temperature (°C)



c. Regional MAM average 2m temperature (°C)



d. Regional JJA average 2m temperature (°C)



e. Regional SON average 2m temperature (°C)

Figure 49: Regional annual and seasonal average 2m temperature (°C) for the study area during the simulated years under RCP4.5 and 8.5 (El Samra et al., 2018).

Special consideration is given to climate projections for the SSP5-8.5 scenario. IPCC AR6 climate projections[5, 6] for the region, show that the annual mean temperature is projected to increase by 2.2°C by mid-century and 4.4°C by end-century for the SSP5-8.5 scenario (Figure 50) (World bank, 2022b).

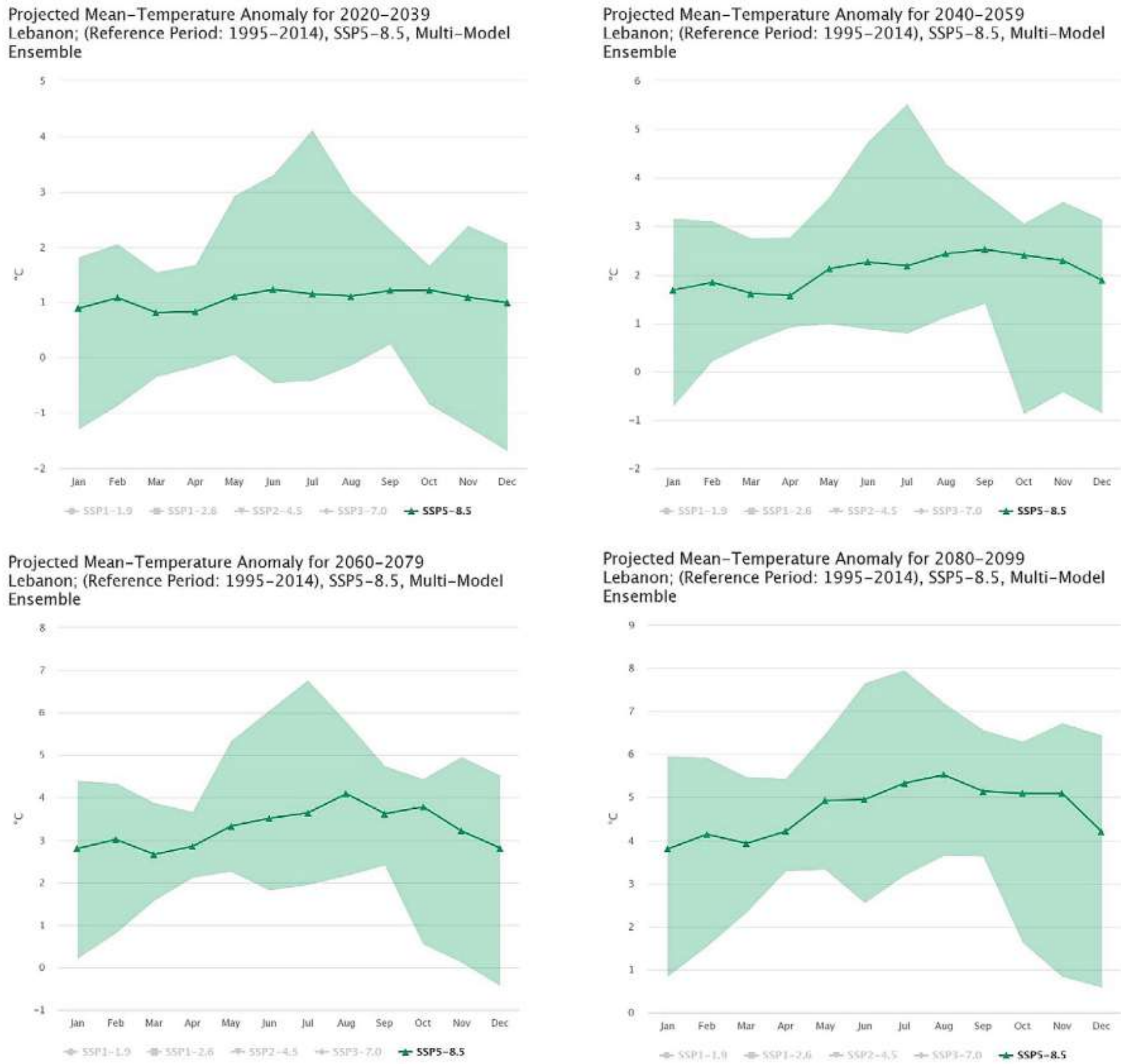


Figure 50: Projected mean temperature anomaly for Lebanon for four simulation periods and for SSP5-8.5 (World Bank, 2022b)

In the analysis done under RICCAR (ESCWA, 2021), downscaling at 10 km was performed for annual and seasonal air temperatures for an ensemble of six SSP5—8.5 models for the near-term (2021-2040) and midterm (2041-2060) periods (Figure 51). The increase of annual temperature for the period 2021-2040 as compared to the reference period

[5] The vital difference between CMIP5 and CMIP6 is the future scenario. CMIP5 projections are available based on 2100 radiative forcing values for four GHG concentration pathways. In contrast, CMIP6 uses socioeconomic pathways (SSPs) with the CMIP5 scenarios premises.

[6] at 1.0° x 1.0° or 100km x 100km resolution

(1995-2014) is on the average around 1.2°C, with limited deviations between coastal and mountainous areas (although the increase is most pronounced in the latter ones). The respective increase of annual temperature for the period 2041-2060 is on the average around 2°C, while it ranges from 1.8°C to 3°C depending on the area (coastal/inland south to mountainous respectively) within Lebanon.

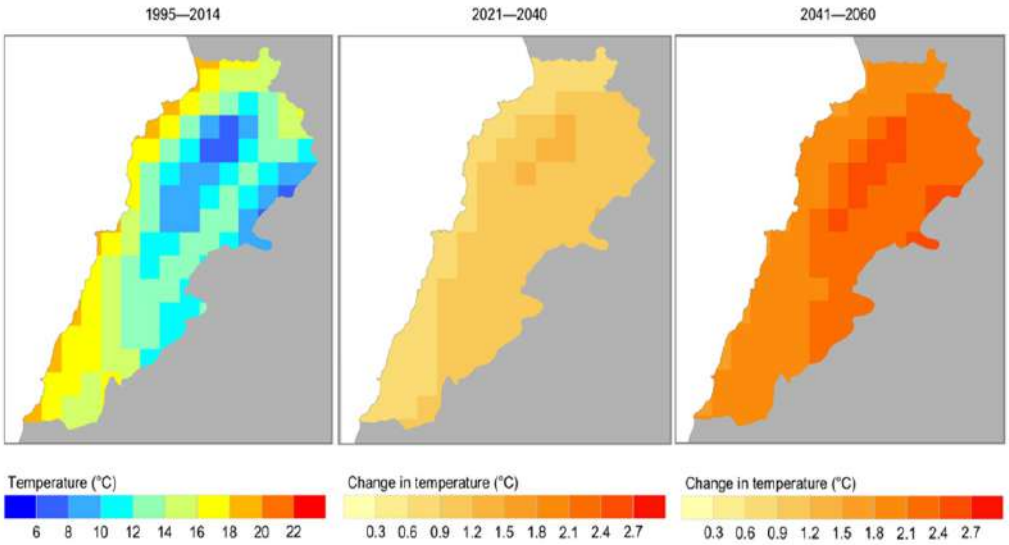
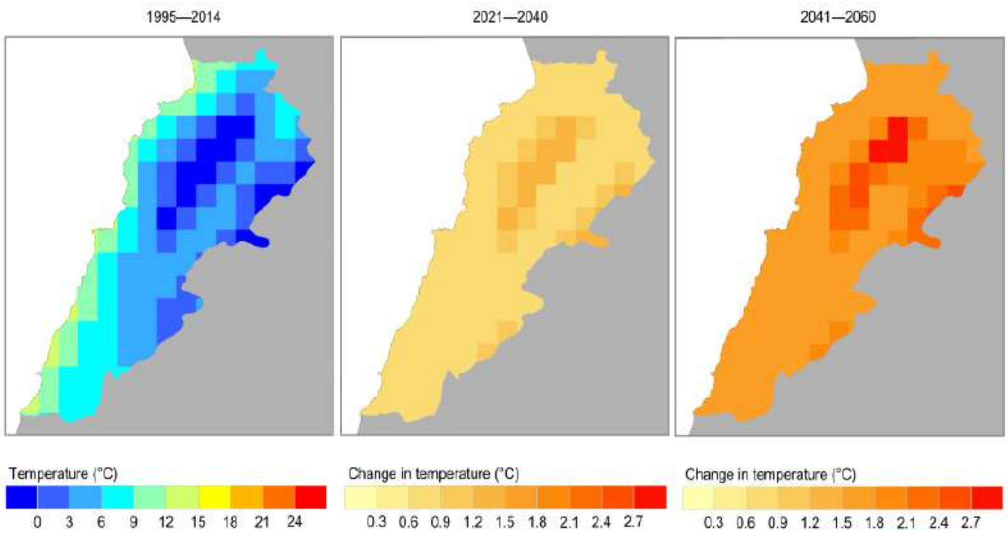
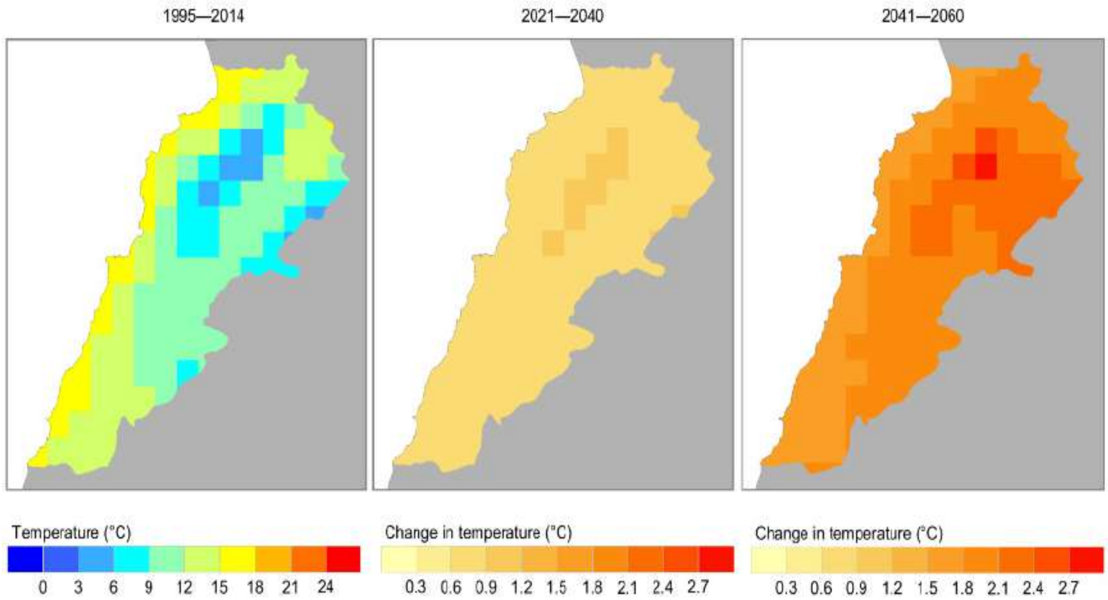


Figure 51: Downscaled climate projections for SSP5-8.5: temperature for the reference period 1995-2014 as well as changes in temperature between the periods 2021-2040 and 2041-2060 to the reference period (RICCAR, 2021).

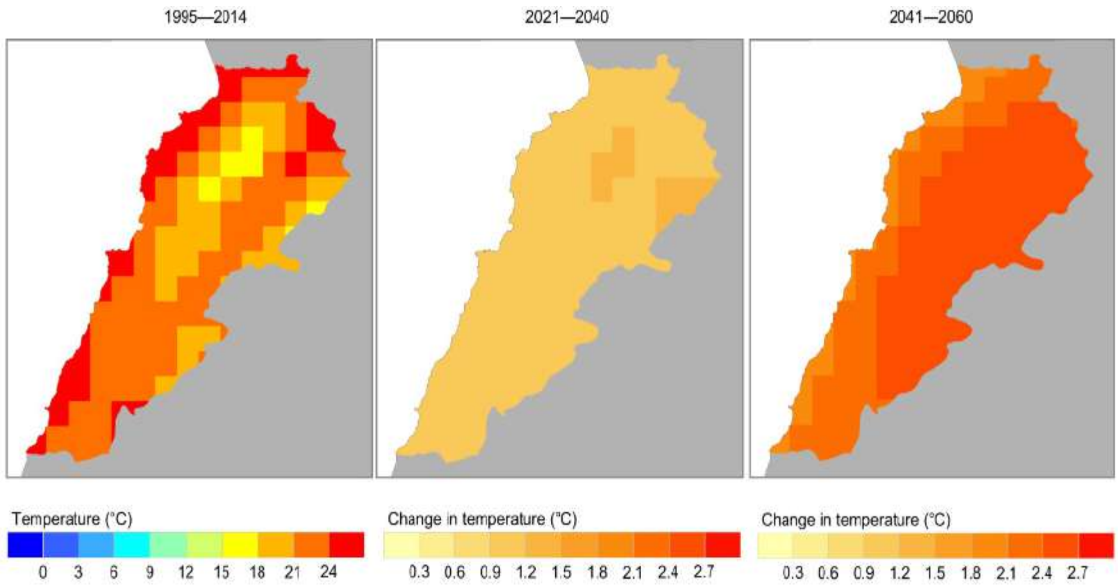
In Figure 52 (a-d), the mean change in seasonal temperature for near-term (2021-2040) and mid-term (2041-2060) for ensemble of six SSP5-8.5 projections compared to the reference period 1995-2014 is given for different periods. As expected, increase of temperature is higher for the 2041-2060 period, especially for the summer and autumn when the increase ranges from 2.4 to 3.0°C.



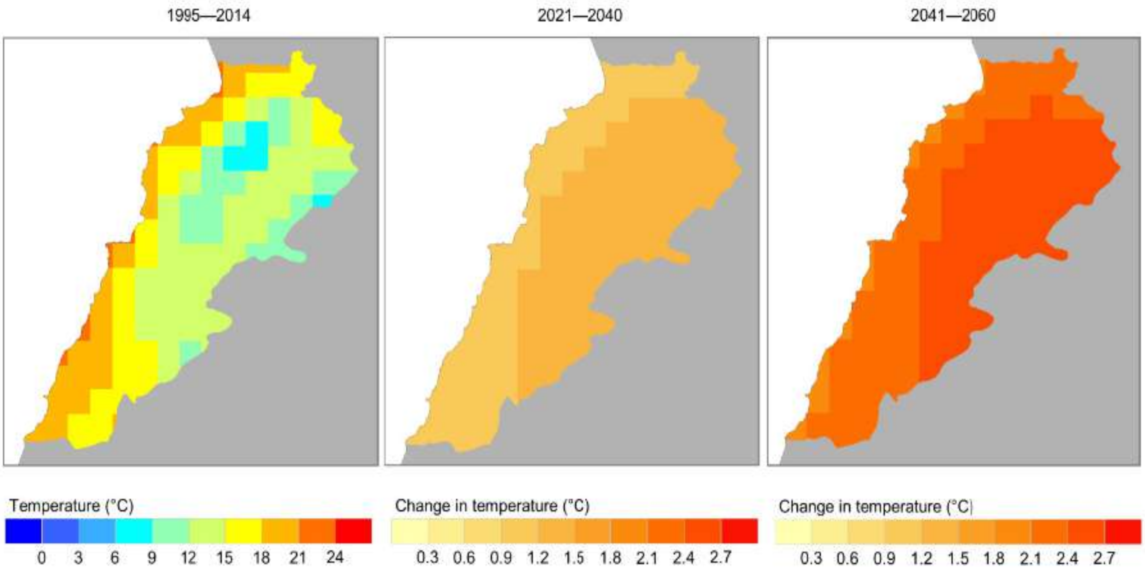
a) Mean changes in seasonal temperature for near terms (2021-2040) and mid-term (2041-2060) for ensemble of six SSP5-8.5 projections compared to the reference period for December-January-February (DJF)



b) Mean change in seasonal temperature for near terms (2021-2040) and mid-term (2041-2060) for ensemble of six SSP5-8.5 projections compared to the reference period for March-April-May (MAM)



c) Mean change in seasonal temperature for near terms (2021-2040) and mid-term (2041-2060) for ensemble of six SSP5-8.5 projections compared to the reference period for June-July-August (JJA)



d) Mean change in seasonal temperature for near terms (2021-2040) and mid-term (2041-2060) for ensemble of six SSP5-8.5 projections compared to the reference period September-October-November (SON).

Figure 52: Mean change in seasonal temperature for near-term (2021-2040) and mid-term (2041-2060)

It is interesting to note that the comparative examination of Figure 48 and Figure 52 shows that the annual mean temperature change for the 2041-2060 period as compared to the 1986-2005 one for RCP8.5 is similar to the respective one as estimated, also for the 2041-2060 period, with the use of the SSP5-8.5 (although for the reference period 1995-2014). These findings comply well with the analysis of Parding et al. (2020) as presented in Figure 53.

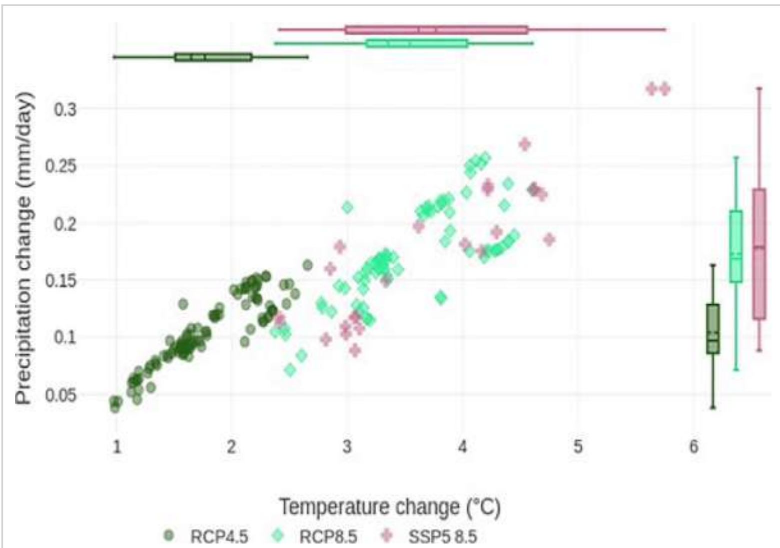


Figure 53: Scatterplots showing the global annual mean temperature and precipitation change from the present day (1981–2010) to the far future (2071–2100). The figure includes GCM runs for emission scenarios RCP4.5 (green) and RCP8.5 (turquoise) from the CMIP5 ensemble, and SSP5-8.5 (pink) for the CMIP6 ensemble (from Parding et al., 2020).

An indicator used to assess impacts of higher air temperature is the daily wet bulb temperature (Tw) as it captures more accurately the relationship between increased heat and humidity. Tw is defined as the temperature that an air parcel would attain if cooled at a constant pressure by evaporating water within it until saturation; high values of Tw imply hot and humid conditions. The Tw threshold of 35°C is often considered as a physiological limit of human tolerance to heat stress, as a human body is unable to cool itself beyond this point (MoE/GCF, 2021).

Changes in daily wet-bulb temperature (Tw) in Lebanon were calculated using the HAPPI experiment. Results (Figure 54) show that the probability of exceeding the dangerous threshold of 24.6°C once a year in Lebanon is virtually certain for both the 1.5°C and 2°C warmer worlds. Similarly the probability of exceeding the “extremely dangerous” threshold of 29.1°C once in a year, increases from the current value of 16% to the values 33% and 44%. The largest exceedance possibilities are expected to occur during the month of August, with the month of July also showing considerable exceedance possibilities. The higher probability of crossing the “extremely dangerous” threshold once in a year in Lebanon, demonstrates the importance of drafting adaptation plans to improve resilience to future heat stress over the country.

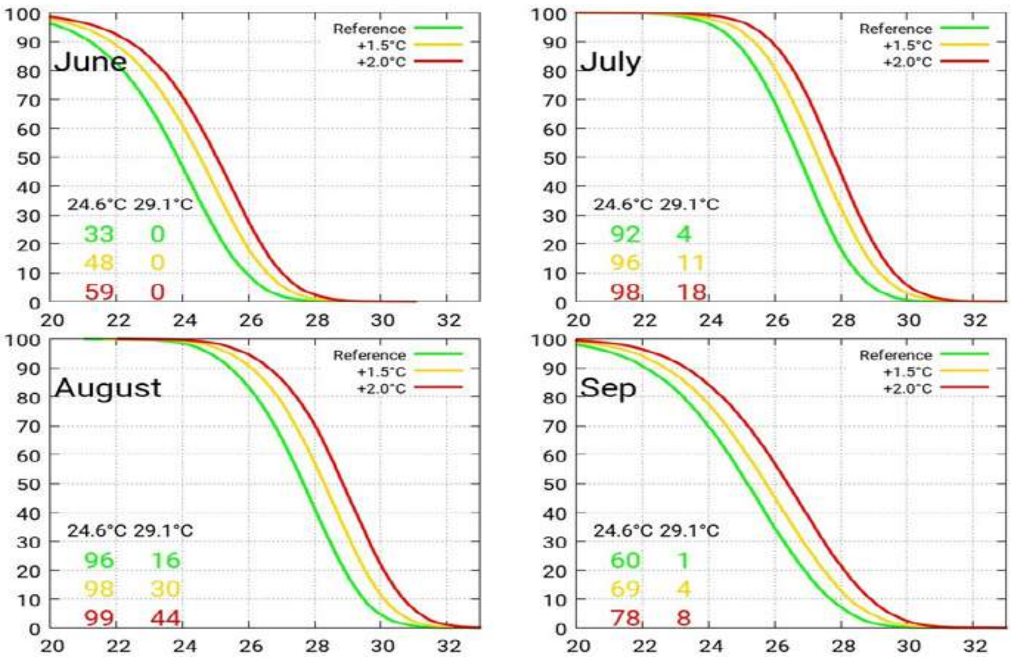


Figure 54: Exceedance Probability (vertical axis) versus Wet-bulb temperature (horizontal axis) The values inside each panel represent the exceedance probabilities at dangerous (24.6°C) and extremely dangerous (29.1°C) thresholds for Reference (green), +1.5°C (gold) and +2.0°C (red) periods (from Mitchell et al., 2017).

Table 22 summarizes the findings regarding future changes of temperature in Lebanon due to climate change.

Table 22 Summary of findings for changes in temperature in Lebanon

Reference	Changes in annual temperature	Reference period
MedECC	+3.8°C for RCP4.5 to 6.5°C for RCP8.5 by 2100	1980-1999
EURO-Cordex	+1.6°C (RCP4.5) to 2.2°C (RCP8.5) by mid-century and from 2.2°C (RCP4.5) to 4.9°C (RCP8.5) by end-century	1986-2005
RICCAR/3NC	1.2°C (for RCP4.5) to 1.7°C (for RCP8.5) by mid-century and 1.5°C (for RCP4.5) to 3.2°C (for RCP8.5) by end-century	1986-2005
IPCC (CMIP5)	4.3°C by 2100 for RCP8.5	1986-2005
IPCC (CMIP6)	Up to 2.2°C by mid-century and 4.4°C by end-century for the SSP5-8.5 scenario	1995-2014
WRF	Increase of average temperature of about 4°C by 2050	2008

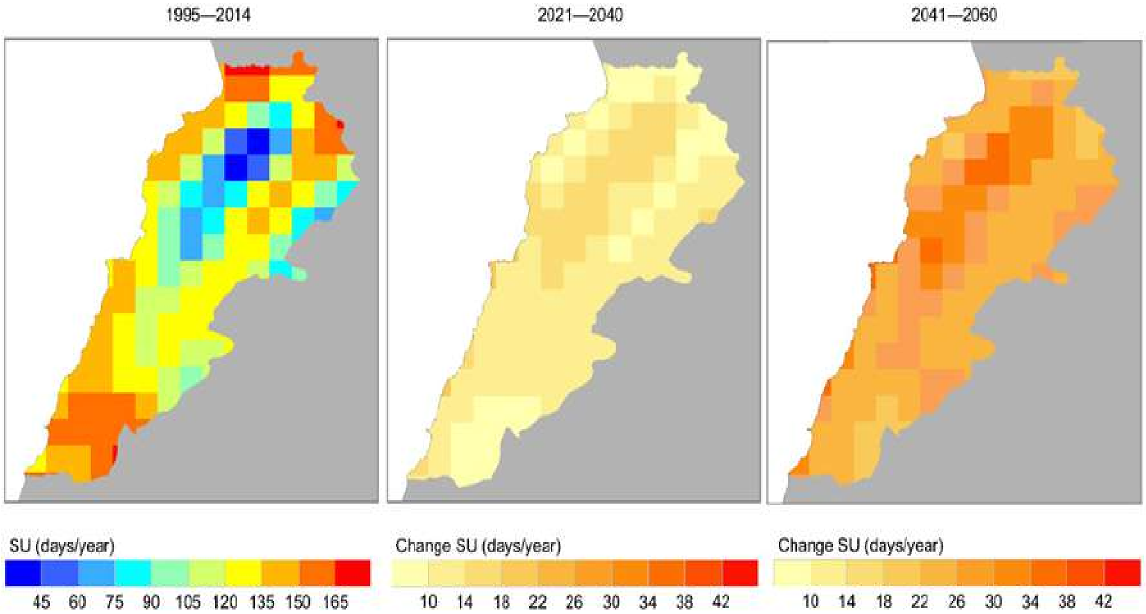
Change in temperature indicators

Summer Days (SU) refers to the total number of days in a year that exceed the fixed threshold of 25°C for the daily maximum temperature; similarly, SU35 and SU40 refer to the total number of days in a year that exceed the fixed threshold of 35°C and 40°C for the daily maximum temperature respectively.

More specifically, climate projections of SU, SU35 and SU40 for SSP5-8.5 (RICCAR, 2021) were used to assess changes for the period 2041-2060 as compared to the reference period 1995-2014. In terms of the annual mean change of SU for near-term and mid-term, 14 to 30 days more in Lebanon will exceed the fixed threshold of 25°C by 2040 and 2060 respectively, with the mountains being more vulnerable to the increase of SU for both RCP4.5 and RCP8.5 scenarios (Figure 55a). The increase is rather small (7-8%) along the coast for the period 2021-2040 and considerably higher (20-22%) for the period 2041-2060, while inland areas will face the highest increases (roughly 30% for the period 2041-2060). Seasonal changes of SU are more pronounced in summer (June-July-August) and thus contribute more to the annual changes, for both the near-term and the mid-term periods (Figure 55b).

SU35 (Figure 56 a,b) and SU40 (Figure 57 a,b) are expected to increase in the periods 2021-2040 and 2041-2060 compared to the period 1995-2014, with the increase (almost doubling of SU35 and SU40 for the period 2041-2060) being more pronounced in the case of summer, at both the coastal and inland regions of Lebanon.

a) Mean changes in number of summer days (Tmax>25°C) for near terms (2021-2040) and mid-term (2041-2060) for ensemble of six SSP5-8.5 projections compared to the reference period



b) Mean changes in number of summer days (Tmax>25°C) for near terms (2021-2040) and mid-term (2041-2060) for ensemble of six SSP5-8.5 projections compared to the reference period (JJA)

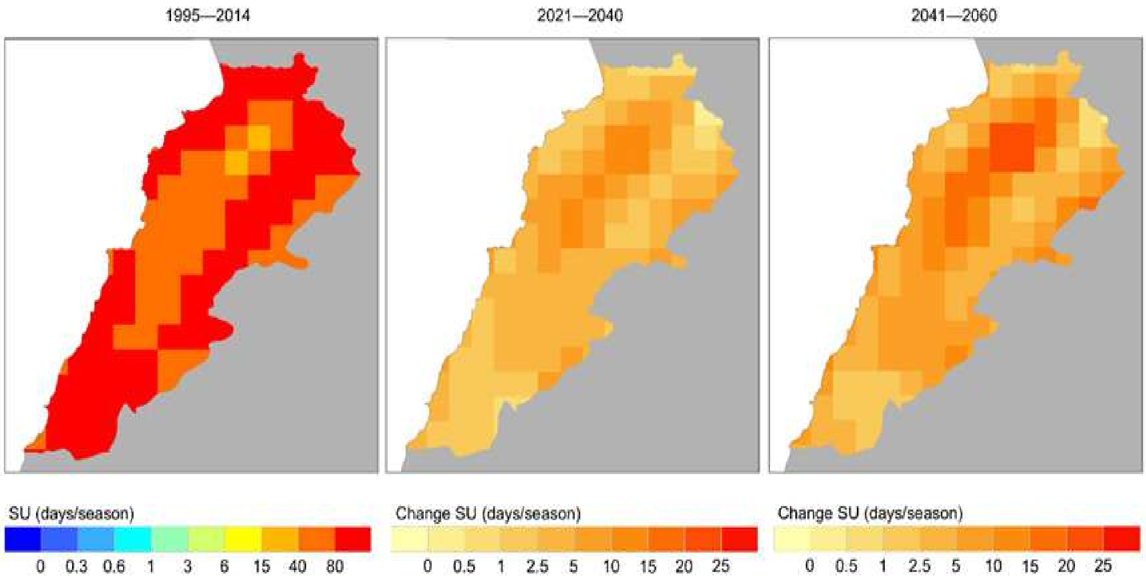
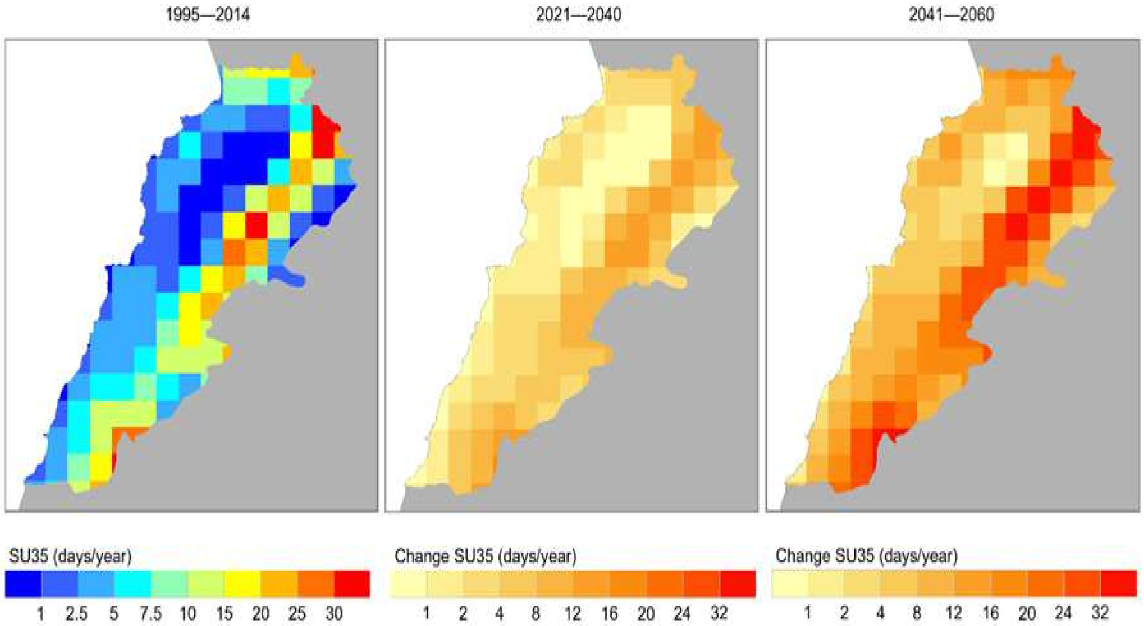


Figure 55: Mean change in the number of Summer Days (SU) at (a) an annual basis and (b) for June-July-August

a) Mean change in number of hot days (Tmax>35°C) for near term (2021-2040) and mid-term (2041-2060) for ensemble of six SSP5-8.5 projections compared to the reference period



b) Mean change in number of hot days (Tmax>35°C) for near term (2021-2040) and mid-term (2041-2060) for ensemble of six SSP5-8.5 projections compared to the reference period (JJA)

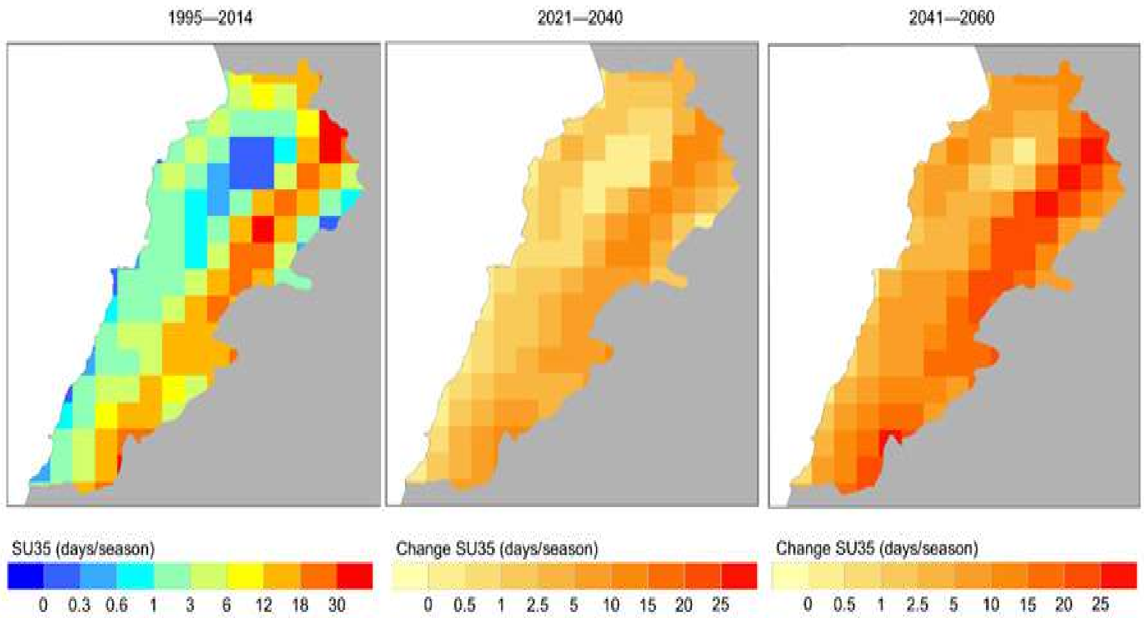
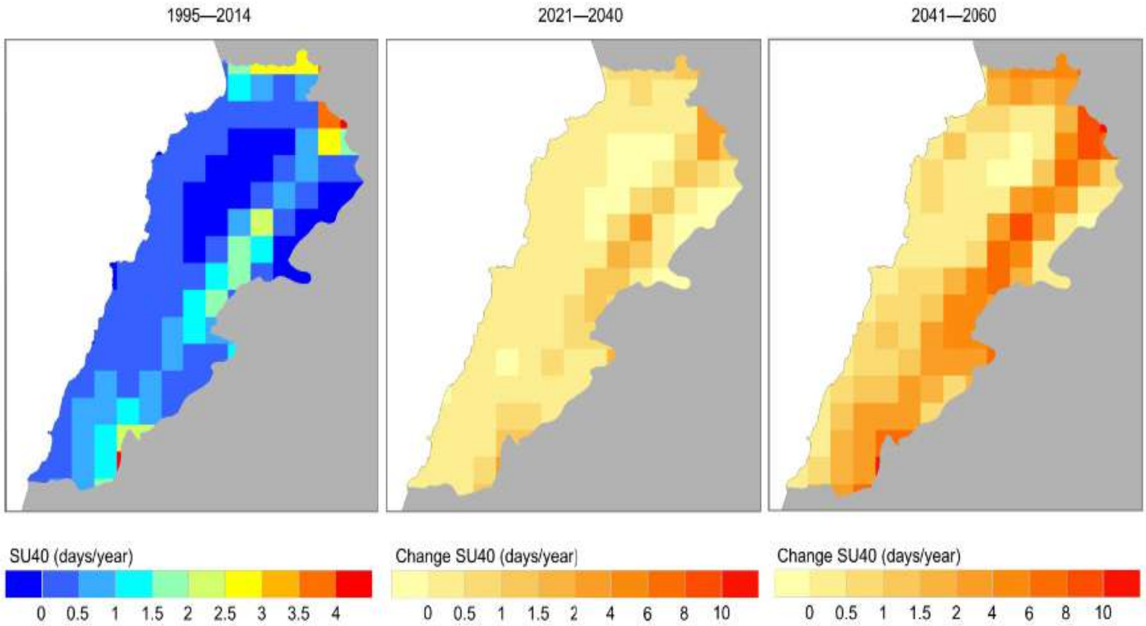


Figure 56: Mean change in the number of Summer Days above 35°C (SU35) at (a) annual basis and (b) for June-July-August

a) Mean change in number of very hot days (Tmax>40°C) for near term (2021-2040) and mid-term (2041-2060) for ensemble of six SSP5-8.5 projections compared to the reference period



b) Mean change in number of very hot days (Tmax>40°C) for near term (2021-2040) and mid-term (2041-2060) for ensemble of six SSP5-8.5 projections compared to the reference period (JJA)

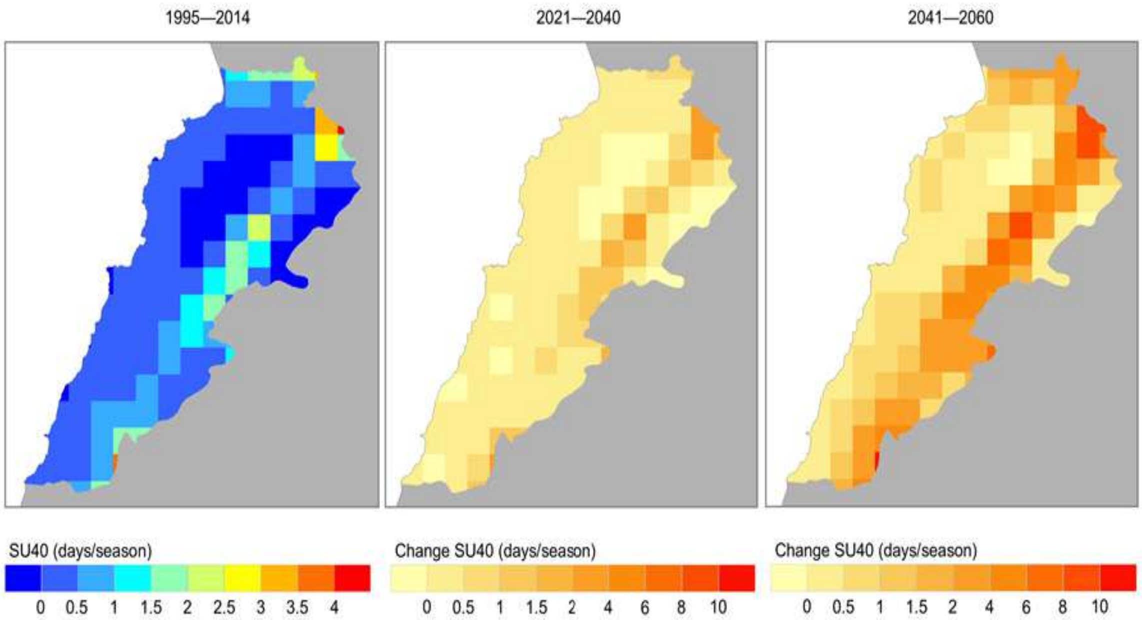


Figure 57: Mean change in the number of Summer Days above 40°C (SU40) at (a) annual basis and (b) for June-July-August

The overall increase in the number of Summer Days (SU, SU35 and SU40) leads to significant thermal burden for people living mostly in urban areas, whereas it enhances climate impacts in the event of concurrent droughts. Furthermore, the impacts to sectors as tourism and agriculture as well as to the energy sector (additional energy will be needed for cooling) are considered significant and need to be taken into consideration for improving resilience to climate extremes and safeguarding the development of Lebanon.

Trend analysis

Trend analysis of the summer days (SU, SU35 and SU40) on the basis of downscaled at 10 km climate simulations for SSP5-8.5 (RICCAR, 2021) shows an upward monotonic trend (Philippopoulos and Cartalis, 2022). For SU (annual) for both the historic period 1961-2010 (Figure 58a) and the one from 2011-2070 (Figure 58b), with the slope for the latter period being higher especially in the inland regions, meaning that the number of SU days will further increase over time. Upward monotonic trends are also observed for the periods September-October-November (SON) and December-January-February (DJF), with higher trends for the SON period in the northern part of Lebanon (Figure 59).

In terms of SU35 and SU40, all trends are upward monotonic for the reference period 1961-2010, while trends increase considerably (mostly to the south and to the inland) for SU35 and limitedly for SU40, for the period 2011-2070 for the whole are of Lebanon (Figure 59 and Figure 60).

a) Summer Days index (SU)- Annual 1961-2010- sen slope (days/year)

b) Summer Days index (SU)- Annual 2011-2070- sen slope (days/year)

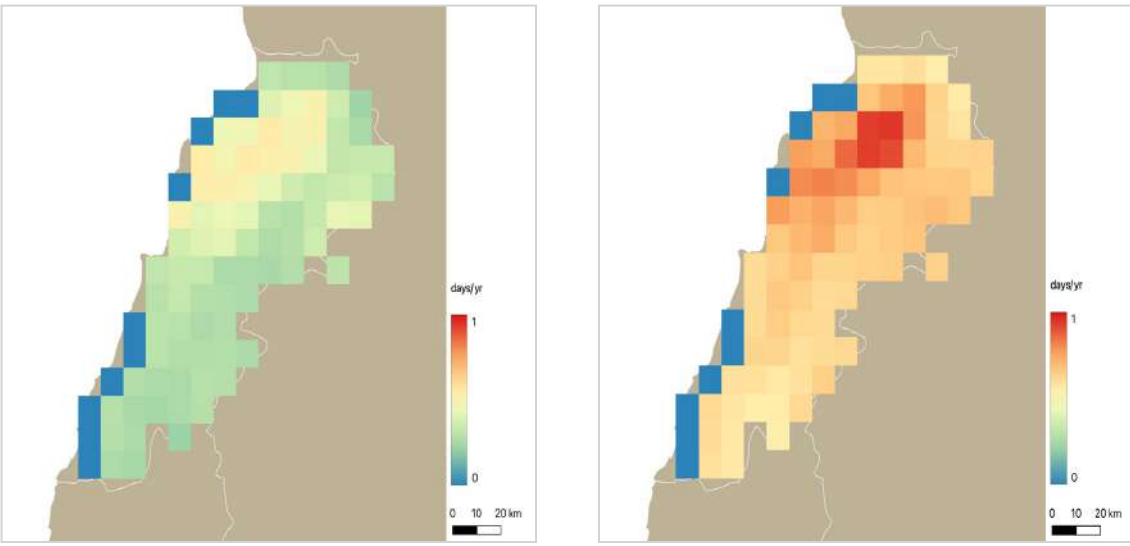


Figure 58: Trend analysis for the Summer Days Index (SU)

a) Hot days index (SU35)- Annual 1961-2010- sen slope (days/year)

b) Hot days index (SU35)- Annual 2011-2070 sen slope (days/year)

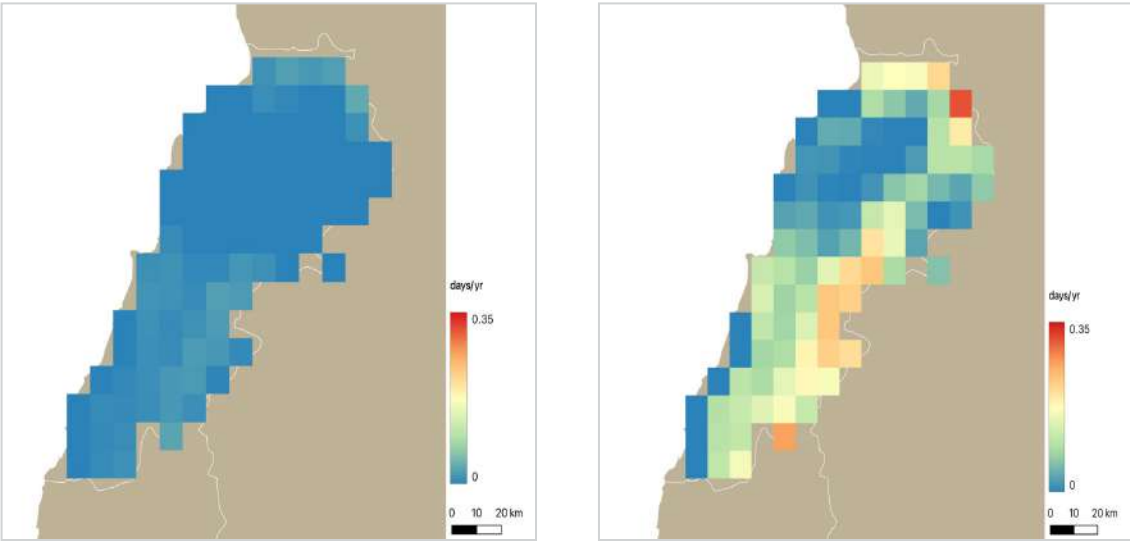


Figure 59: Trend analysis for the annual Summer Days above 35°C (SU35)

(a) Very hot days (SU40)- Annual 1961-2010- sen slope (days/year)

(b) Very hot days (SU40)- Annual 2011-2070- sen slope (days/year)

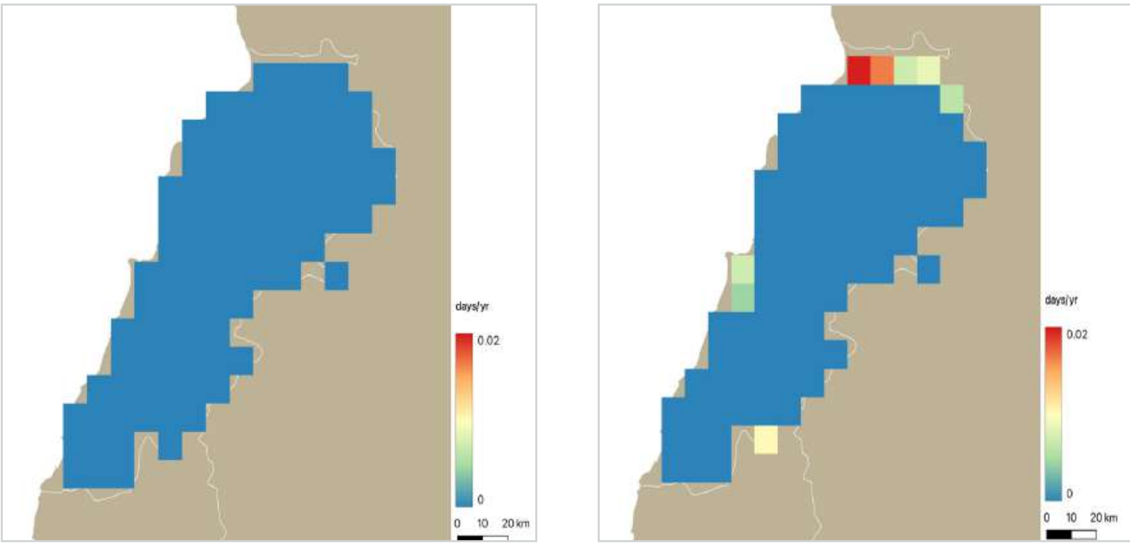


Figure 60: Trend analysis for the annual Summer Days above 40°C (SU40)

4.3.2 Future change in precipitation

According to the Lebanese Agricultural Research Institute (LARI), rainfall was reduced by 40 to 50% in 2016 compared to an ordinary year. Furthermore, the winter of 2013–14 was the driest on record with only 431 mm of rain, that is far below the yearly normal of 812 mm and less than half of the rainfall (905 mm) in the winter of 2012-13. Furthermore, the sign and magnitude of the observed land precipitation trends show pronounced spatial variability, depending on the time-period and season considered (MedECC, 2020).

A consistent decrease in precipitation during the 21st century is projected for the entire Mediterranean Basin during the warm season (April through September, with the highest magnitude in summer) and in winter for most of the Mediterranean (except for the northernmost regions). The mean rate of annual precipitation decrease among models is 4% per each degree of global warming, which implies a reduction in the range of -6.5 to -9% by mid-century for scenarios RCP4.5 and RCP8.5 respectively and of -9 to -22% by end-century. In addition, future climate projections indicate a predominant shift towards higher inter-annual variability, higher intensity of rainfall, stronger extremes (especially in winter, spring, and fall), decreased precipitation frequency, and longer dry spells especially in summer (MedECC, 2020).

IPCC AR5 projections indicate that Lebanon will experience substantially drier conditions with enhanced drought risk; in particular, precipitation may be reduced by 10 to 30% in the wet season (October–April) and from 10 to 40 % in the dry season (May–September). CMIP5 models for the RCP8.5 scenario show an annual decrease of -10% in precipitation during 2081-2100 versus 1986-2005. Precipitation will decline by about 0.5mm per day, and if evaporation is considered, the water flux will decline by 0.5 to 1mm. In addition, results indicate a reduction in soil moisture and relative humidity. According to the same projections, a change in the spatial distribution of precipitation is expected for the RCP4.5 and RCP8.5 scenarios, with a -20% decline in rainfall in the Bekaa valley and southern Lebanon, which are important agricultural areas that already feel water stress due to urbanization and limited infrastructure.

IPCC AR6 projections for precipitation for the SSP5-8.5 scenario show a reduction only in December for the period 2020-2039, whereas reductions expand to more months (mostly in the fall and winter) for all other simulation periods towards end-of-century. Reductions in annual precipitation for the SSP5-8.5 scenario may reach 60mm (-10%) to 100mm (-16%) by mid-century and by end-century respectively as compared to the reference period of 1995-2014.

In terms of the winter months (which from a climatological point of view refer to 70% of the annual precipitation in Lebanon), reductions for the SSP5-8.5 scenario may reach 25-30% per month. Figure 61 presents the projected mean precipitation anomaly for Lebanon for four simulation periods, for SSP5-8.5 (World Bank, 2022b).

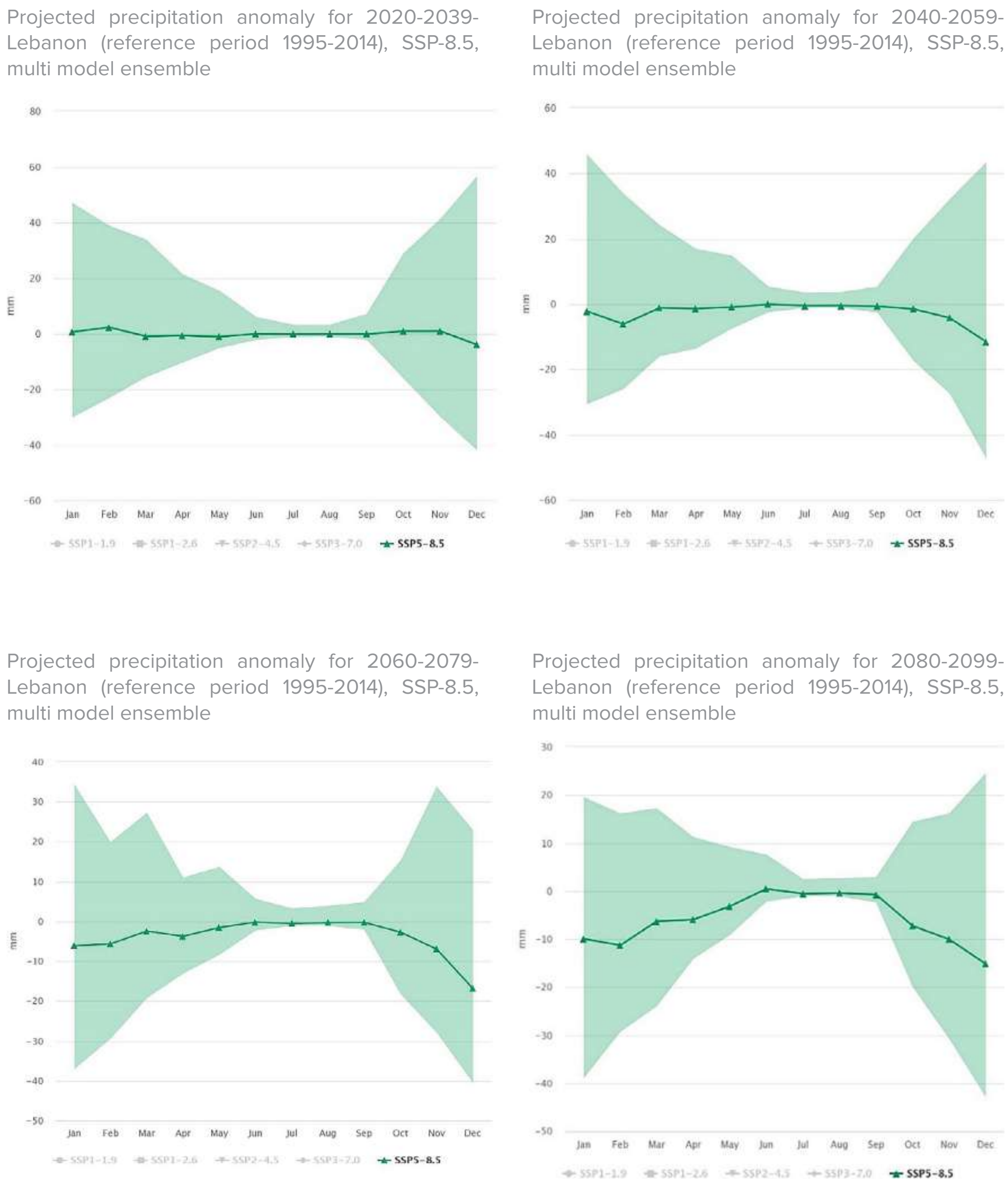


Figure 61: Projected mean precipitation anomaly for Lebanon for four simulation periods and for SSP5-8.5

In another study (ICBA, 2017), the annual rainfall anomaly in Lebanon compared to the mean annual total rainfall for the period 1976-2005 shows increasing values for the mid-century and end-century (Figure 62).

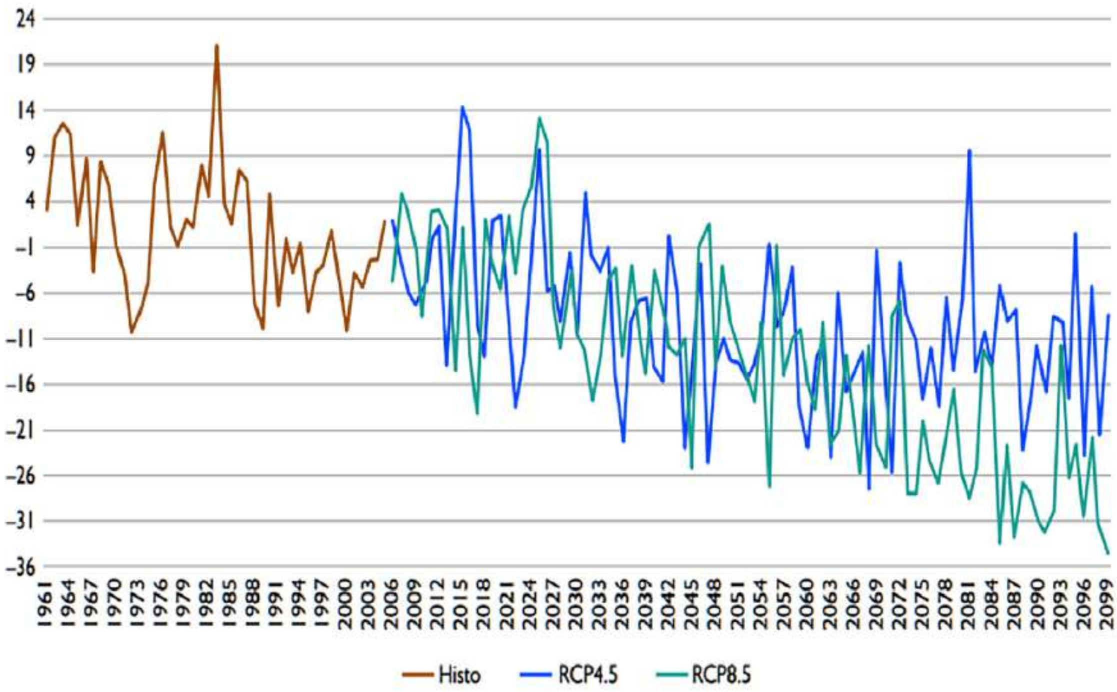


Figure 62: Annual rainfall anomaly in Lebanon compared to the mean annual total rainfall for the period 1976-2005 (ICBA, 2017). The brown line is the model's average for the historic period, the dark blue line is the model's average for RCP4.5 and the light green line is the model's average for RCP8.5.

A reduction in precipitation for Lebanon by -5% for RCP4.5 to -9% for RCP8.5 (-26 mm/year to -43 mm/year) by mid-century, and -6% for RCP4.5 to -11% for RCP8.5 (-48 mm/year to -96 mm/year) by the end of the 21st century is also reported on the basis of EURO-Cordex projections at improved grid analysis[7] (ACSAD/ESCWA, 2019). Reductions are rather modest in the north, northeast and the south, but intensify inland. The largest reductions are estimated at areas adjacent to the Lebanon Mountains, which can adversely impact groundwater aquifers dependent on snowfall. Very slight increases (up to +4 mm/year) are detected in specific areas located in the Bekaa Valley and along the southern coast; their overall impact is considered negligible.

Figure 63 provides a spatial analysis of precipitation change on the basis of EURO-Cordex simulations as compared to the reference period 1986-2005, at mid-century (top image) and at end-century (bottom image) for (a) RCP4.5 and (b) RCP8.5 at 0.11° grid resolution (ESCWA, 2017a).

[7] at 0.11° x 0.11° grid resolution or 12.5km x 12.5 km

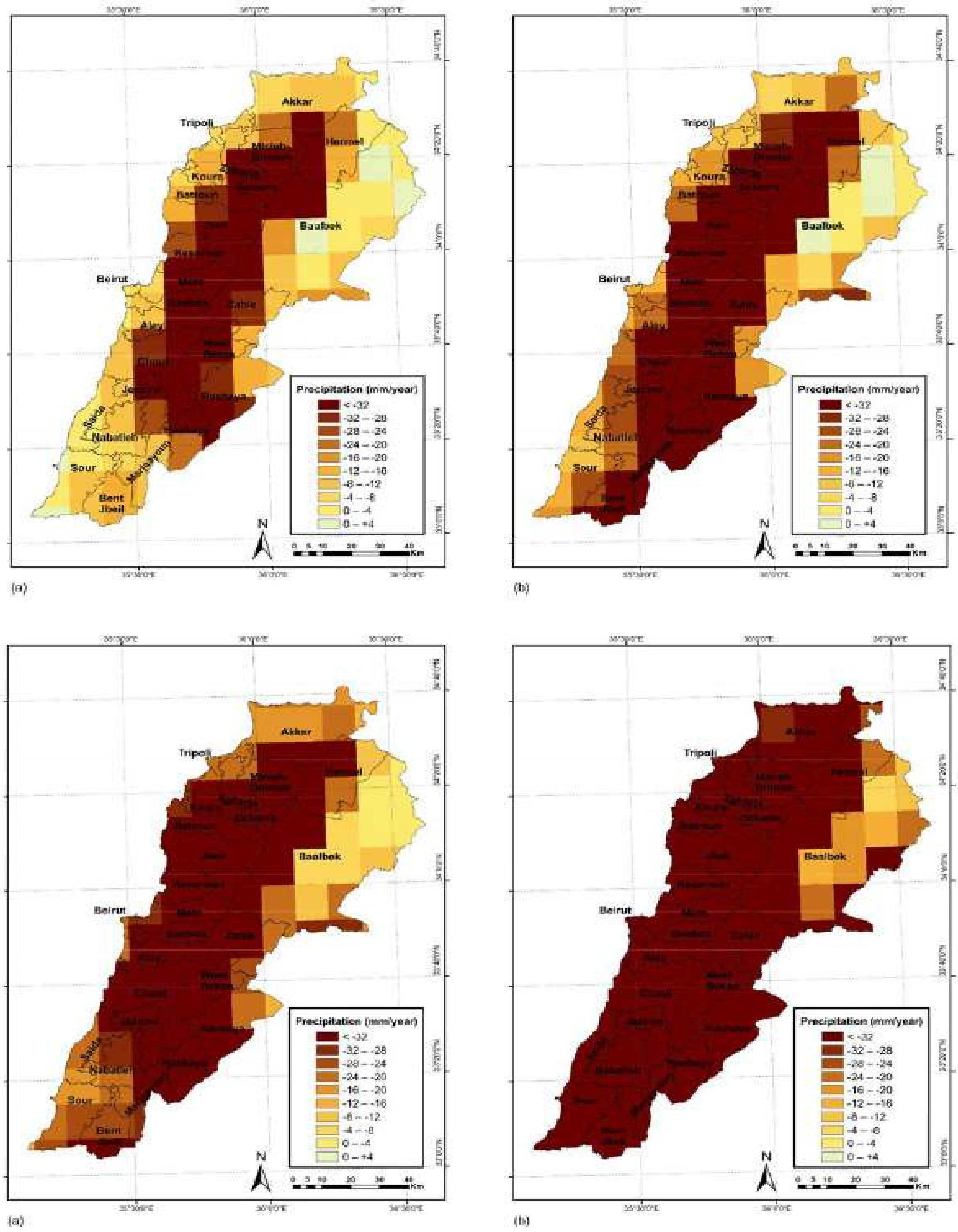


Figure 63: Change in precipitation from EURO-Cordex simulations and compared to the reference period 1986-2005, at mid-century (top image) and at the end of the century (bottom image) for (a) RCP4.5 and (b) RCP8.5 at 0.11° grid resolution (ESCWA, 2017a).

In the analysis by RICCAR (2021)[8], for the near-term (2021-2040) and mid-term (2041-2060) periods (Figure 64), reduction in precipitation is seen, whereas considerable variations are observed between different areas. Reductions are higher in the areas where precipitation had its higher values in the period 1995-2014 (blue areas). Furthermore, reductions are of the order of -3 mm/month to -6 mm/month for the near-term period (with the exception of the northern area where no reduction is predicted) and of – 3mm/month to -15mm/month for the midterm period.

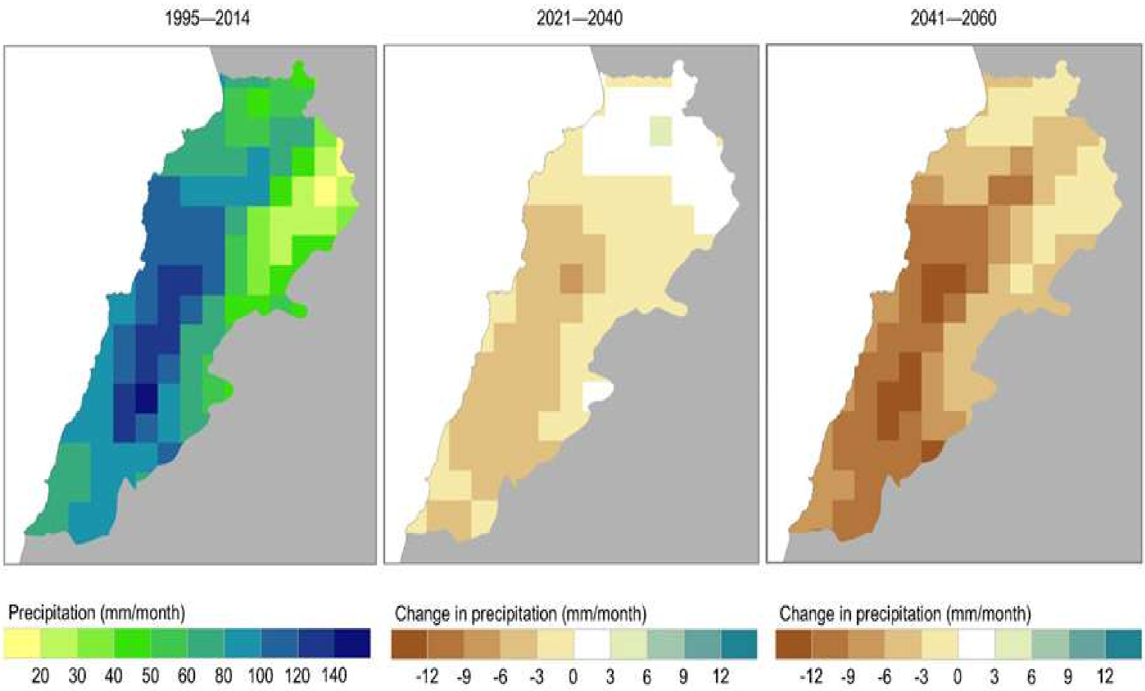
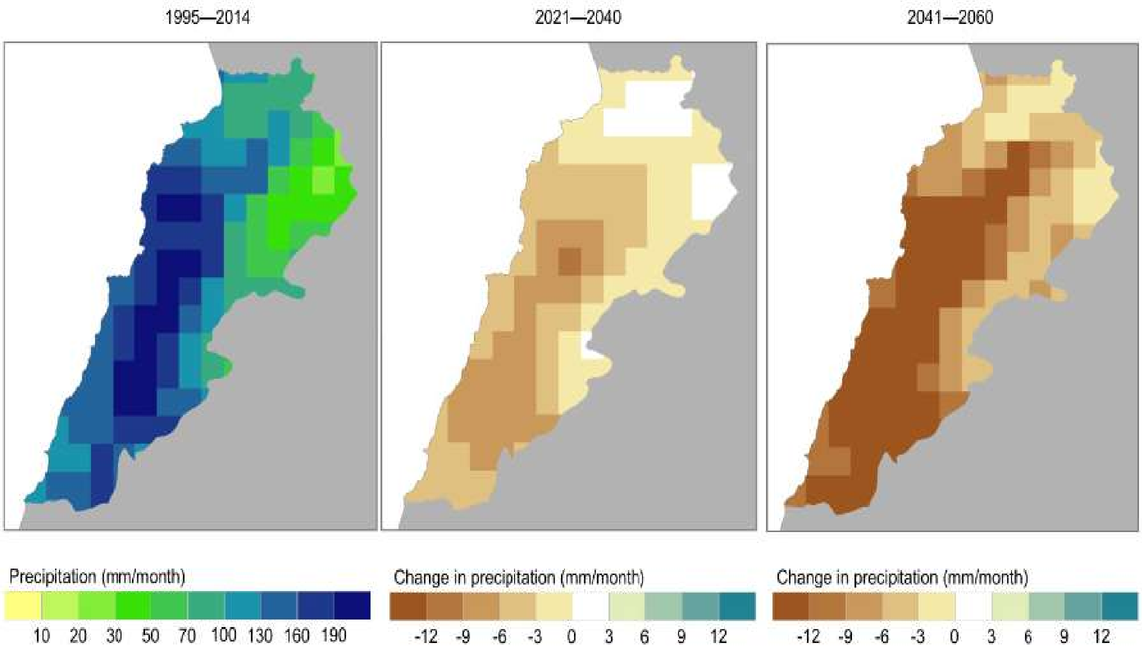


Figure 64: Mean change in precipitation (mm/month) for near-term (2021-2040) and mid-term (2041-2060) for an ensemble of six SSP-8.5 projections compared to the reference period (1995-2014).

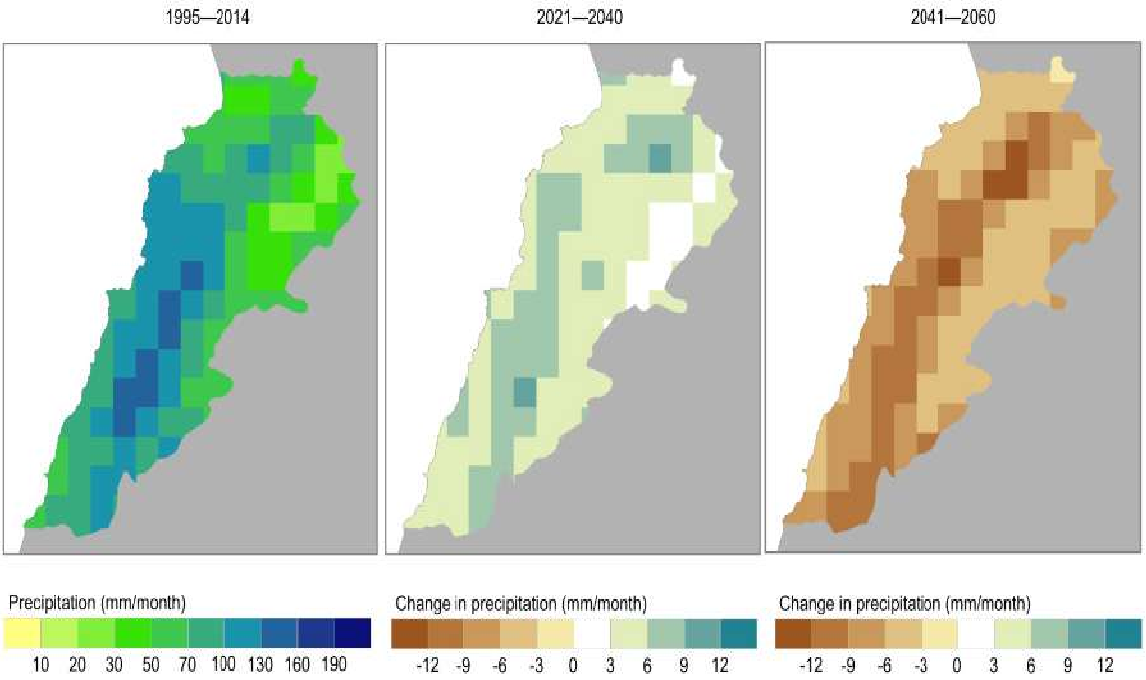
In Figure 65(a-d), the mean change in seasonal precipitation is presented (a) December-January-February (b) March-April-May (c) June-July-August and (d) September-October-November. For the near-term period (2021-2040), increase in seasonal precipitation is expected at all regions for the season March-April-May and at the northern parts of Lebanon for the season September-October-November. On the contrary, seasonal precipitation will decrease at all regions for the mid-term period (2041-2060), with the highest reductions in winter.

[8] downscaling at 10 km for an ensemble of six climate models for SSP5—8.5

a) Mean change in seasonal precipitation for near term (2021-2040) and mid-term (2041-2060) for ensemble of six SSP5-8.5 projections compared to the reference period for December-January-February (DJF)



b) Mean change in seasonal precipitation for near term (2021-2040) and mid-term (2041-2060) for ensemble of six SSP5-8.5 projections compared to the reference period for March-April-May MMA



c) Mean change in seasonal precipitation for near term (2021-2040) and mid-term (2041-2060) for ensemble of six SSP5-8.5 projections compared to the reference period for June-July-August (JJA)

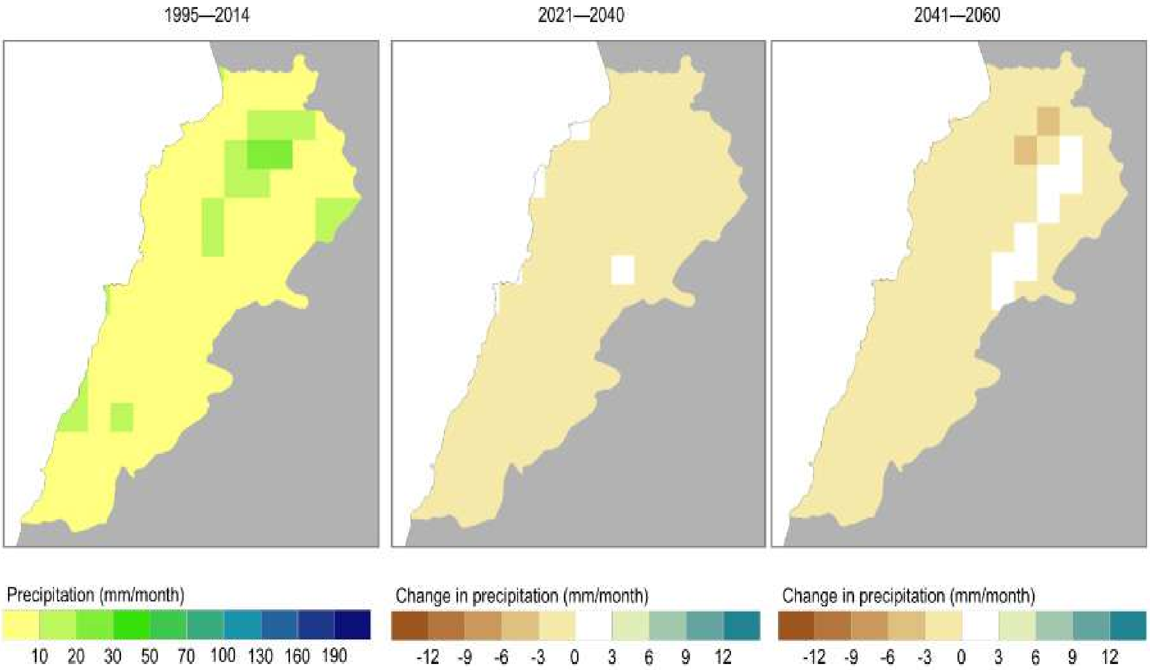


Figure 65: Mean change in seasonal precipitation (a) December-January-February (b (c) and (d)

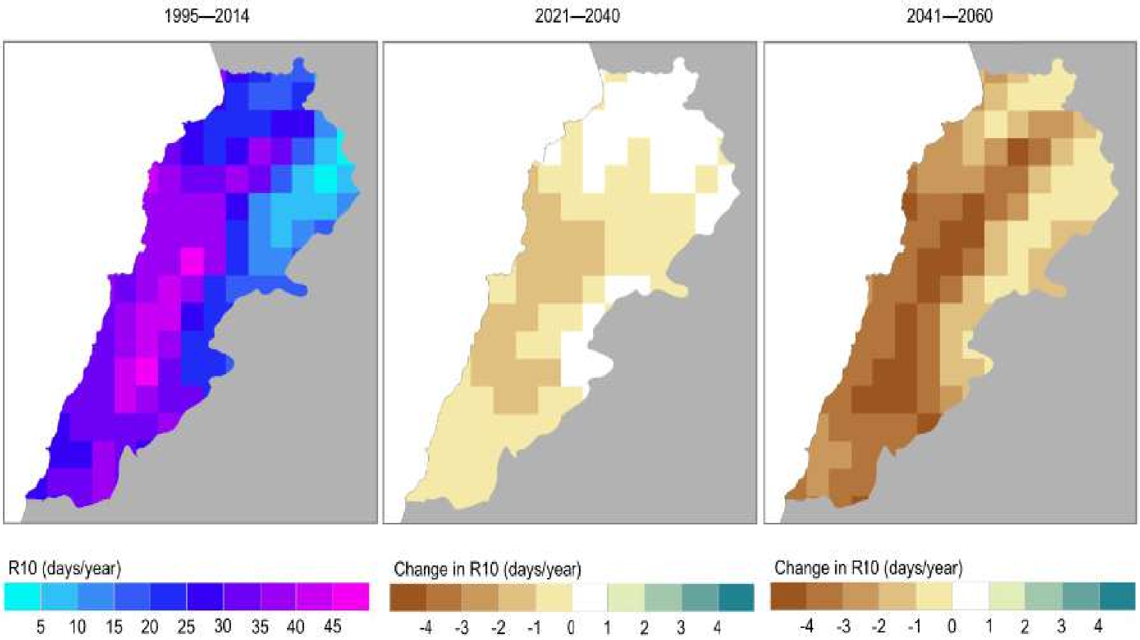
WRF simulations at 9km spatial resolution for future years show a significant decrease in annual precipitation by mid-century compared to the reference year (2008); in particular the reduction varies from -16% to -33% at mountainous areas and to -54% at inland north for the period 2020-2030 (El Samra et al., 2016). Considering that precipitation in mountains feeds the most productive agricultural regions of Lebanon, foreseen reductions will undoubtedly impact future production due to water shortage. Table 23 summarizes findings regarding future changes in precipitation in Lebanon due to climate change.

Changes in precipitation indicators

Climate projections (RICCAR, 2021) for the annual number of days when daily precipitation exceeds 10mm (R10) and 20mm (R20) as well as for the Simple Daily Intensity Index (SDII)[9] for SSP5-8.5 were used to estimate changes for the period 2041-2060 as compared to the reference period 1995-2014 (Figure 66).

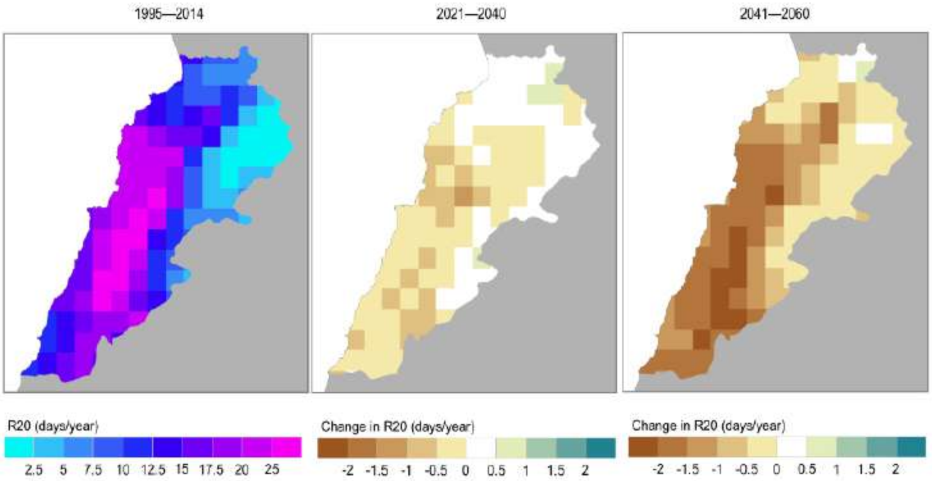
Table 23 Summary of findings: changes in precipitation in Lebanon

Reference	Changes in annual precipitation	Reference period
MedECC	-6.5 to -9% by mid-century and -9 to -22% by end-century for scenarios RCP4.5 and RCP8.5 respectively	1980-1999
EURO CORDEX	-5% to -9% by mid-century and -6% to -11% by end-century for scenarios RCP4.5 and RCP8.5 respectively	1970 - 2005
RICCAR/3NC	+1% to -7% at mid-century and -4% to -11% by end century	1986-2005
IPCC (CMIP5)	-10% by 2100	1986-2005
IPCC (CMIP6)	-10% and -16% by mid-century and by end-century respectively	1995-2014
WRF	-16% to -33% at mountainous areas -54% inland north by 2050	2008



Mean Change in number of 10 mm precipitation days (R10) for near term (2021-2040) and mid-term (2041-2060) for ensemble of six SSP5-8.5 projections compared to the reference period

[9] Ratio of the annual total precipitation in wet days (days with >1mm of precipitation) to the number of wet days (practically the mean precipitation in wet days).



Mean Change in number of 20 mm precipitation days (R20) for near term (2021-2040) and mid-term (2041-2060) for ensemble of six SSP5-8.5 projections compared to the reference period

Figure 66: Mean change of R10 and R20 for 2021-2040 and 2041-2060 compared to the reference period 1995-2014.

Annual R10 and R20 values are expected to decrease for 2021-2040 and 2041-2060 as compared to the reference period 1995-2014. In the case of R10, the decrease ranges from 2 to 4 days/year for the periods 2021-2040 and 2041-2060 respectively. In terms of R20, the decrease is smaller, from 0.5 days/year to 2 days/year for the periods 2021-2040 and 2041-2060 respectively.

Annual R10 values reflect similar spatial depiction for the reference period (1995-2014) and the period 2041-2060; higher values can be seen in the north and middle parts of Lebanon, while a decrease of the order of two days between the two periods is recognized. The same conclusion holds also for the annual values of R20 in days, although the decrease is smaller (of the order of 1 day). Finally, the Simple Daily Intensity Index (SDII) shows very limited differentiation between the periods 1995-2014 and 2041-2060 (Figure 67). As in the cases of R10 and R20, higher values of SDII are seen in the north and central parts of Lebanon.

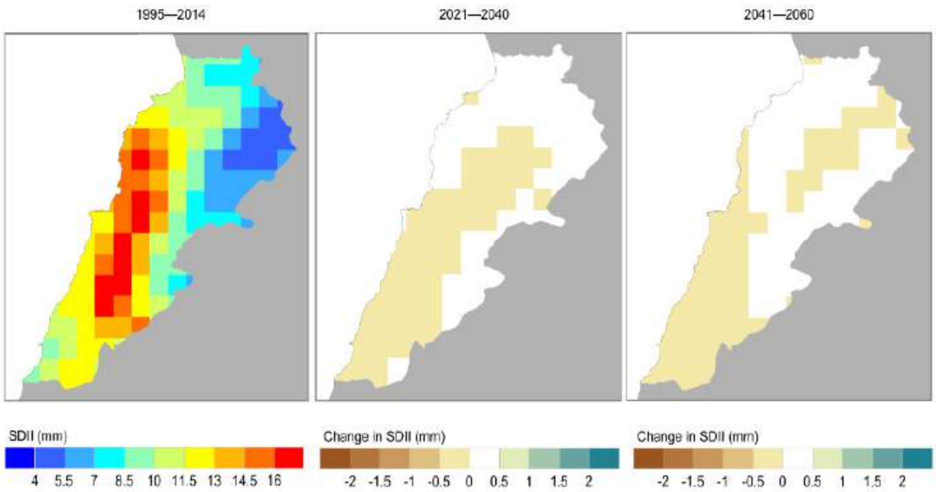


Figure 67: Mean change in annual of the Simple Daily Intensity Index (SDII) for 2021-2040 and 2041-2060 for six SSP5-8.5 projections compared to the reference period 1995-2014.

4.3.3 Future change in total runoff

The RICCAR data which used the Hydrological Predictions for the Environment (HYPE) and the Variable Infiltration Capacity (VIC) hydrological modes, showed high level of uncertainty due to data unavailability. According to EURO-Cordex simulations[10] an average decline in runoff of -29 mm/year to -45 mm/year is expected at mid-century and from -49 mm/year to -70 mm/year by end-century, as compared to the 1970-2005 reference period (ACSAD/ESCWA, 2019). Figure 68 presents the spatial change in runoff compared to the reference period for the mid-century and end-century for RCP4.5 and RCP8.5 (ACSAD/ESCWA, 2019).

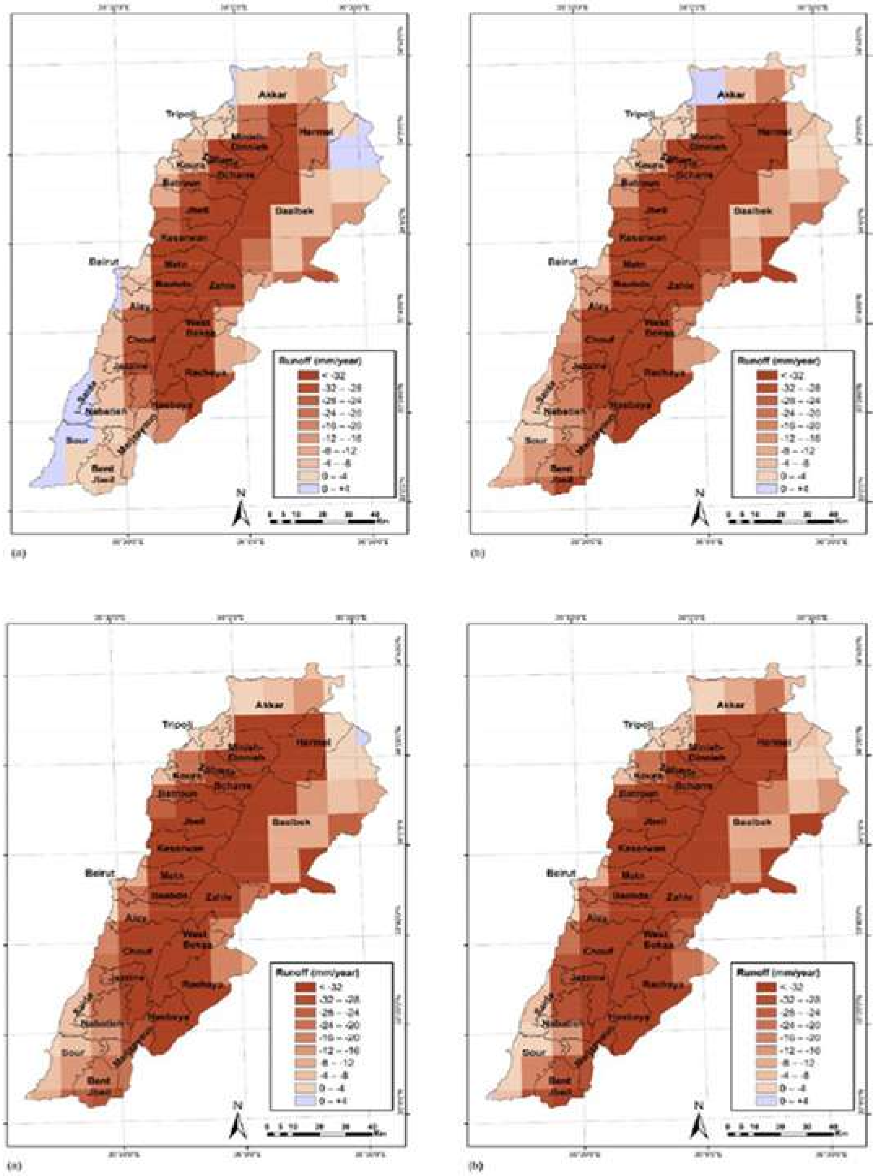


Figure 68: Change in runoff compared to the reference period for the mid-century (top image) and the end of the century (bottom image) for (a) RCP4.5 to the left and (b) RCP8.5 to the right (ACSAD/ESCWA, 2019).

[10] downscaling at 0.11o grid resolution

4.3.5 Future changes in sea temperature and levels

Since the beginning of the 1980s, average Mediterranean Sea surface temperatures have increased throughout the basin, but with large sub-regional differences ranging between +0.29 and +0.44°C per decade; furthermore, marine heat waves have become longer and more intense (MedECC, 2020).

Sea surface warming will continue in the 21st century by 1 to 4°C depending on the scenario (low or high greenhouse gas emissions), and deep waters in the Mediterranean will likely warm more than in other oceans around the world. In particular and in comparison, to the end of the 20th century, the annual-mean sea surface temperature is expected to increase by 0.6-1.3°C before the mid-21st century and by 1.1 to 2.1°C and 2.7-3.8°C under the RCP4.5 and the RCP8.5 scenarios respectively (Darmaraki, 2019). Larger increase is estimated with the use of WRF and HiRAM, namely 1.1°C and 1.7°C for RCP4.5 and RCP8.5 respectively for the year 2050 as compared to the reference year 2008 (El Samra, 2018).

Marine heat waves will very likely increase in spatial extent, become longer, more intense, and more severe than today (medium confidence). Under the high emission scenario, the 2003 marine heat wave may become (medium confidence) a regular event for the period 2021-2050 and a weak event at the end of the 21st century (MedECC, 2020).

Averaged across the Mediterranean Basin, mean sea level has risen by 1.4 mm/year during the 20th century and has accelerated to 2.8 mm/year recently (1993–2018) (high confidence) mostly due to global ocean and icesheet dynamics. There is high confidence that Mediterranean mean sea level rise will accelerate further throughout the 21st century. In particular, around 2100 and depending on the scenario, the basin mean sea level will likely be 37-90 cm higher than at the end of the 20th century, with a small probability of being over 110 cm (MedECC, 2020).

4.3.6 Future changes in extreme events

Extreme events are defined as a time and place in which environmental conditions, such as temperature, precipitation, drought, or flooding, rank above a threshold value near the upper or lower ends of the range of historical measurements or what is perceived to be "normal" climatic changes. Though the threshold is subjective, some scientists define extreme events as those that occur in the highest or lowest 5% or 10% of historical measurements (IPCC, 2022).

According to IPCC AR6 (2022), increased global temperatures directly impact climate extremes, droughts, and the overall climate system. Based on the projected changes in global temperature, it is estimated that for 0.5°C increase in global temperature, there will be an increase in heatwaves as well as in agricultural and ecological droughts.

Table 24 provides a summary of findings for selected climate indices based on high-resolution dynamical temperature downscaling for the year 2008 and the near future (2050) during eight extreme hot and dry years and with the use of RCPs 4.5 and 8.5[11] (El Samra et al., 2018).

[11] Downscaling was performed with the use of the WRF model with two nested grid resolutions of 9km and 3km, forced by the HiRAM at a resolution of 25 km.

Table 24 **Summary of findings for selected climate indices (El Samra et al., 2018).**

Variable	Simulated years under RCP4.5	Simulated years under RCP8.5
Average temperature (Tavg)	• Decreases in the winter and spring • Increases in the summer and autumn • Warmer June-July-August and September-October-November T_{avg} affect mostly mountains and inland regions	• Decreases in the winter and spring (except 2050) • Increases in the summer and autumn (except 2050) • Warmer June-July-August and September-October-November T_{avg} affect mostly mountains and inland regions
Maximum temperature (Tmax)	• Increases in all regions • Central inland severely affected by 13% increase on average	• Increases in all regions • Central inland severely affected by 15% increase on average
Minimum temperature (Tmin)	• Decrease across all regions with freezing temperatures along the coast, except in one year (2020)	• Decreases (except in 2050) less than RCP4.5 in all regions with subzero temperatures along the coast only in one year (2017)
Percent occurrence of warm nights (TN90P)	• Increases (except in 2050) over the mountains and inland regions, coast impacted	• Opposite to RCP4.5, with 2050 presenting the worst warming in all regions
Percent occurrence of warm days (TX90P)	• Increases in the mountain and inland regions with highest values of 25% in 2029	• Increases in the mountain and inland regions with highest value of 21% in 2050 when coast is affected too
Heat wave duration index (HWDI)	Increases over all regions in 2029 and 2040, milder results in 2020 and 2050	Increases over all regions in 2017 and 2035, milder results in 2023 and 2050, with no impact on the coast
Heat wave frequency index (HWFI)	• Increases over the mountains and inland regions, coast minimally affected	• Increases over the mountains and inland regions, coast minimally affected except in 2050 where coast is severely affected as well
Summer days (SU)	• Increases in all regions, signal stronger than under RCP8.5 • Mountains severely affected by 98% increase on average	• Increases in all regions • Mountains severely affected by 82% increase on average
Consecutive summer days (CSU)	• Increases in all regions, especially double in the mountains and triple inland	• Increases mildly at first in all regions to peak in 2050 (coast and inland: double; mountains: triple)
Consecutive frost days (CFD)	• Increases in all regions except in 2020, stronger signal than under RCP8.5 • Central inland severely affected	• Increases in all regions in 2017 and 2035 • Decreases in all regions in 2023 and 2050 • Central inland severely affected
Heating degree days (HD)	• Increases in all regions • Coast severely affected by 11% increase on average	• Increases in 2017 and 2035 in all regions • Decreases in 2023 and 2050 in all regions • Coast severely affected by 8% increase on average

Change in drought risk

Lebanon, like the rest of the Middle East and Mediterranean regions, are at risk of drought. Droughts will likely become more intense and common as the number of consecutive dry days rises (El Samra et al., 2018; IPCC, 2023, Tomaszkiewicz, 2021). This is notably the case for the Bekaa Valley and the country's northern and southernmost regions. Water reserves and runoff from the mountains will be influenced by a weakened hydrological cycle, making the dry season even more difficult to manage. When year-to-year fluctuation is taken into consideration, drought conditions are likely to recur on a regular basis. As a result, in the next 20 years more people will be exposed to drought conditions, whereas the amount of water available for irrigation will be reduced with considerable impact to agriculture (ACSAD/ESCWA, 2019).

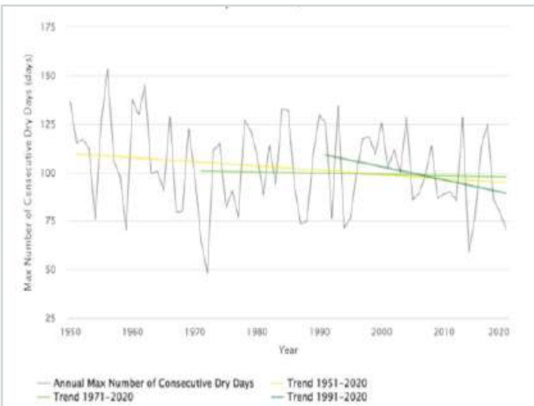
Definition and types of droughts

Drought is an extended period of deficient precipitation compared to the statistical average for a particular region which results in water shortages for some activity, group, or environmental sector. There are four types of droughts. These include:

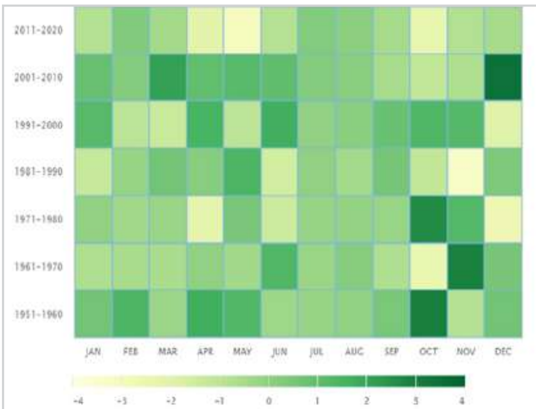
- Meteorological—when precipitation departs from the long-term normal.
- Agricultural—when there is insufficient soil moisture to meet the needs of a particular crop at a particular time, typically after a meteorological drought but before a hydrological one.
- Hydrological—when deficiencies occur in surface and subsurface water supplies.
- Socio-economic—when human activities are affected by reduced precipitation and related water availability. This definitionassociates human activities with elements of agricultural, hydrological, and meteorological drought.

Source: FAO and NDMC, 2008

An important parameter for assessing drought risk is the number of Consecutive Dry Days (CDD) when daily precipitation is less than 1mm. Figure 69 shows the climatology of Lebanon for CDD, while Figure 70 depicts spatially the annual mean of CDD (in days) for the period 1961-2010. A south to north gradient is clearly depicted, with considerably higher values for CDD in the middle and southern part of Lebanon.



Max number of Consecutive Dry Days, annual trends with significance of trend per decade – Lebanon



Max number of Consecutive Dry Days monthly trends, Lebanon

Figure 69: Annual (left) and monthly (right) trends of the maximum number of consecutive dry days.

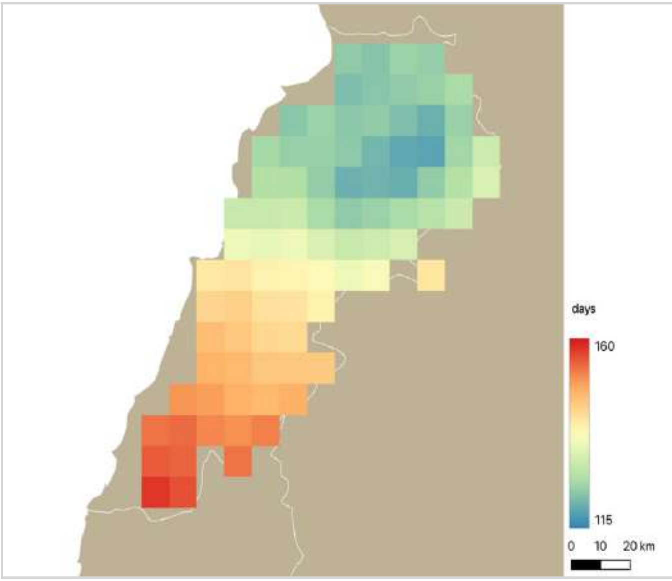


Figure 70: Spatial depiction of the annual mean of consecutive dry days for Lebanon (1961-2010) Mean (days)

Figure 71 provides the spatial distribution for Lebanon on the basis of climate projections (RICCAR, 2021) for the periods 2021-2040 and 2041-2060, for SSP5-8.5. CCD increase in all regions, although more to southern regions and along the coast.

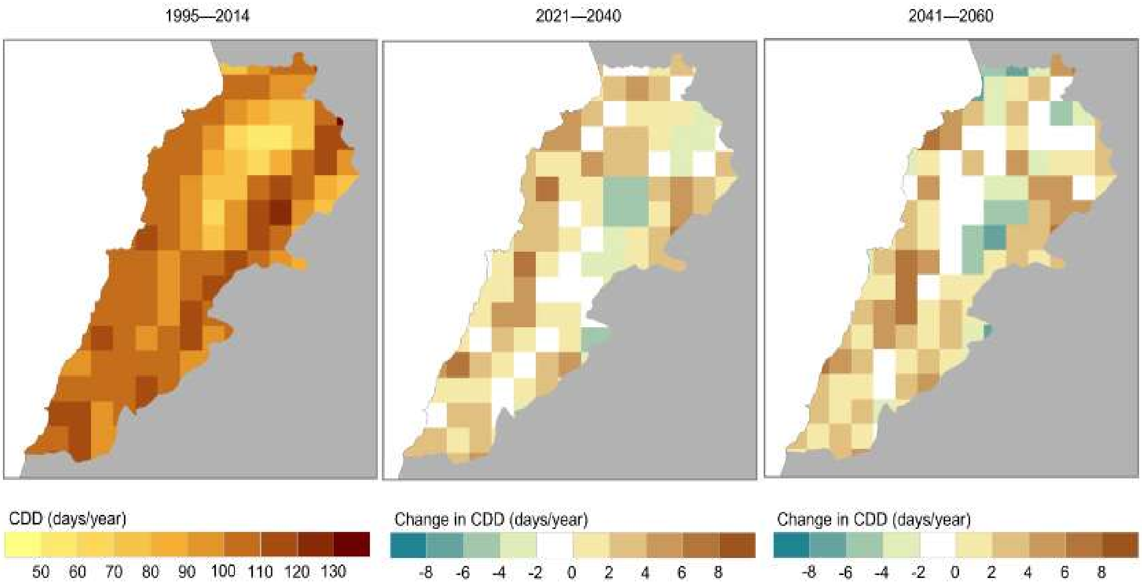


Figure 71: Mean change in maximum length of the consecutive dry days for the periods 2021-2040 and 2041-2060 compared to the reference period 1995-2014

The analysis is complemented with the use of climate projections (RICCAR, 2021) of the Consecutive Wet Days (CWD) for the mean change in the periods 2021-2040 and 2041-2060 compared to the reference period 1995-2014, for SSP5-8.5 (Figure 72). The majority of regions experience a decrease in CWD, especially for the period 2041-2060 and for the northern, central and southern parts of Lebanon.

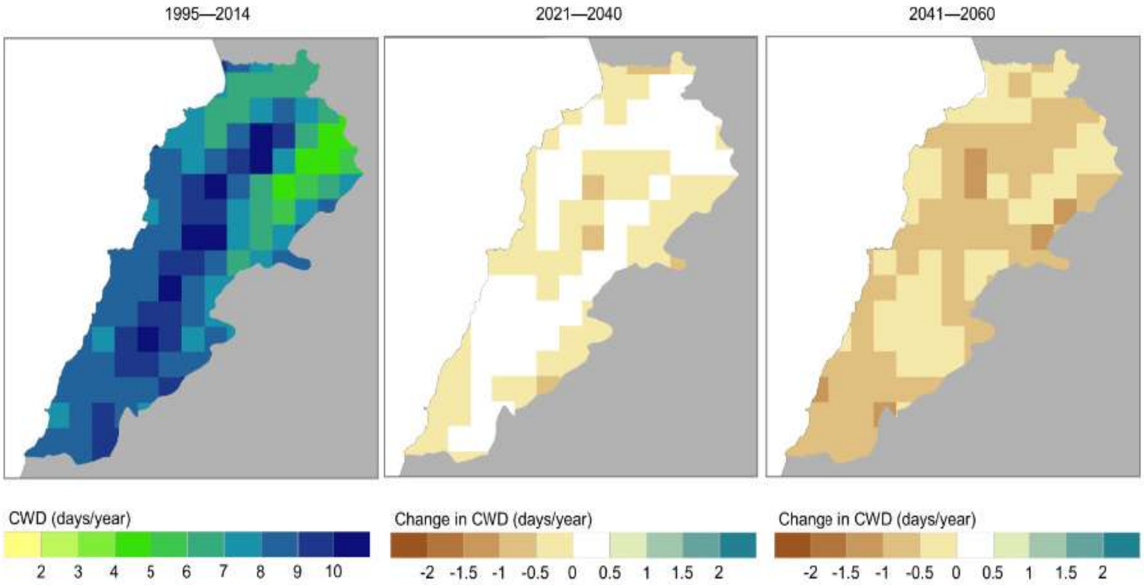
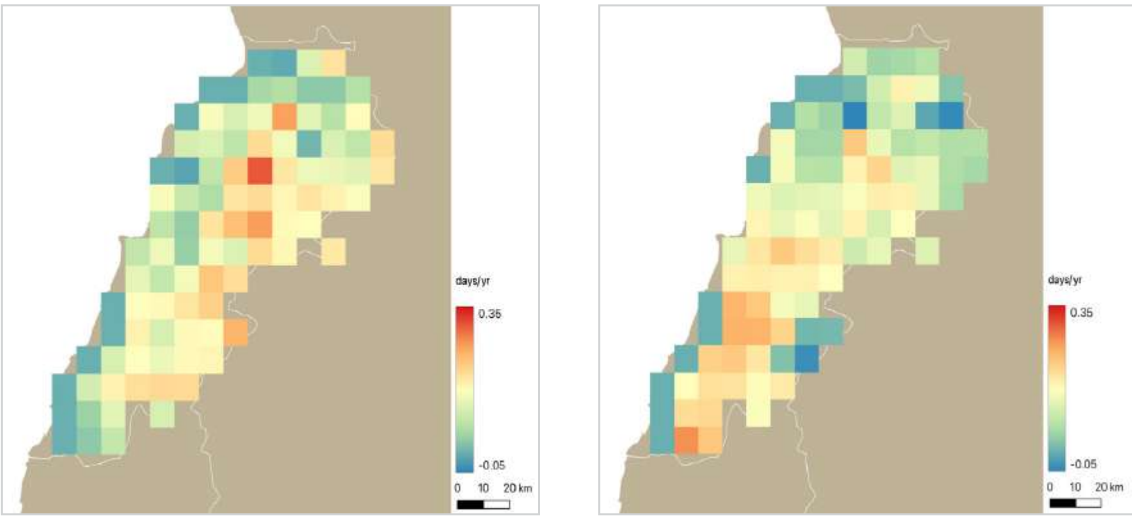


Figure 72: Mean change in the maximum length of wet spell (CWD) for the periods 2021-2040 and 2041-2060 compared to the reference period 1995-2014.

Trend analysis for extreme events

Trend analysis[12] of the annual amount of CDDs with the use of ESCWA simulations downscaled at 10km for SSP5-8.5, showed a monotonic upward trend in days/year for Lebanon for the period 1961-2010 as well as for the period 2011-2070 (Figure 73).



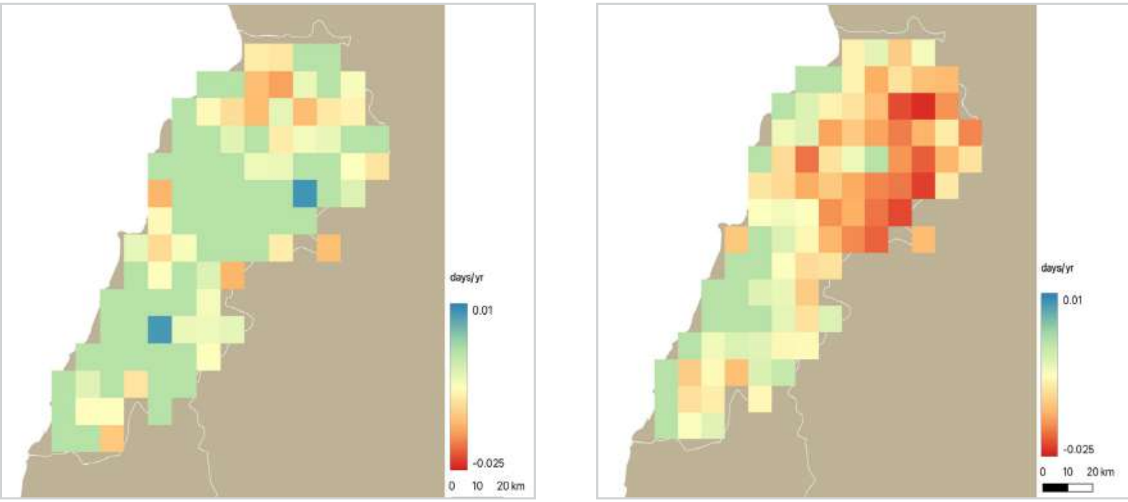
a) Consecutive Dry Days (CDD)- Annual (1961-2010) sen slope (days/year)

b) Consecutive Dry Days (CDD)- Annual (2011-2070) sen slope (days/year)

Figure 73: Trend analysis of Consecutive Dry Days (CDD) for Lebanon for the periods (a) 1961-2010 and (b) 2011-2070.

[12] Performed by Cartalis and Philippopoulos (2022) for the purposes of the National Communication

In terms of the Consecutive Wet Days (CWD), the trend is reversed, as observed for practically all areas of Lebanon, although more pronounced for the northern and central parts (Figure 74) (Philippopoulos and Cartalis, 2022).



a) Consecutive Wet Days (CWD)- Annual (1961-2010) sen slope (days/year)

b) Consecutive Wet Days (CWD)- Annual (2011-2070) sen slope (days/year)

Figure 74: Trend analysis of Consecutive Wet Days (CWD) for Lebanon for the periods 1961-2010 and 2011-2070.

Heat waves

Heat waves are defined as the number of days where, in intervals of at least six consecutive days, temperatures are above the 90^{th} percentile of mean daily temperatures. MedECC MAR1 (2020) assessment confirms the intensification of heat waves on land and in the sea, in duration and in peak temperatures.

Heat waves are a major cause of weather-related mortality (Paravantis et al., 2017; Pantavou et al., 2020) and it is further exacerbated by urbanization trends in the region and the potential synergistic interactions between heat waves and urban heat islands (El Samra et al., 2018, Agathangelidis et al., 2022).

Indices that characterize heat wave severity will strongly increase compared with the control period of 1961–1990 in the Eastern Mediterranean Middle East (EMME) region. Heat wave peak temperatures will be higher due to the overall mean warming as well as stronger summer anticyclonic conditions. As for the number of heat wave episodes, an increase from 2-3 events per year for the period 2017-2023 to 4 to 5 events in 2050 is predicted, with a strong increase in their intensity (Zittis et al., 2016).

Figure 75 presents the Heat Waves Duration Index (HWDI)[13] for Lebanon for simulated extreme years under RCP4.5 and RCP8.5 and with respect to the

[13] Heat wave duration index (HWDI) Using the time series of daily maximum temperatures (Tmax) for the year bein analyzed, and the mean (TXnorm) of the daily maximum temperature series of a five-day window centered on each calendar day from the year used as a reference, HWDI is the number of days where in intervals of at least six consecutive days, Tmax > TXnorm + 5°C. A further output is the number of heat wave periods longer than or equal to six days.

reference year 2008 (El Sarma, 2018). Increase for the years 2029 and 2040 is observed for RCP4.5, with a decline for the year 2050; in terms of RCP8.5, the increase is more pronounced for the year 2035. Increase in heat wave duration in the region is also reported in several other studies (Lelieveld et al, 2016; Almazroui. (2019); Driouech, 2020; Varela et al., 2020; Zittis et al., 2021).

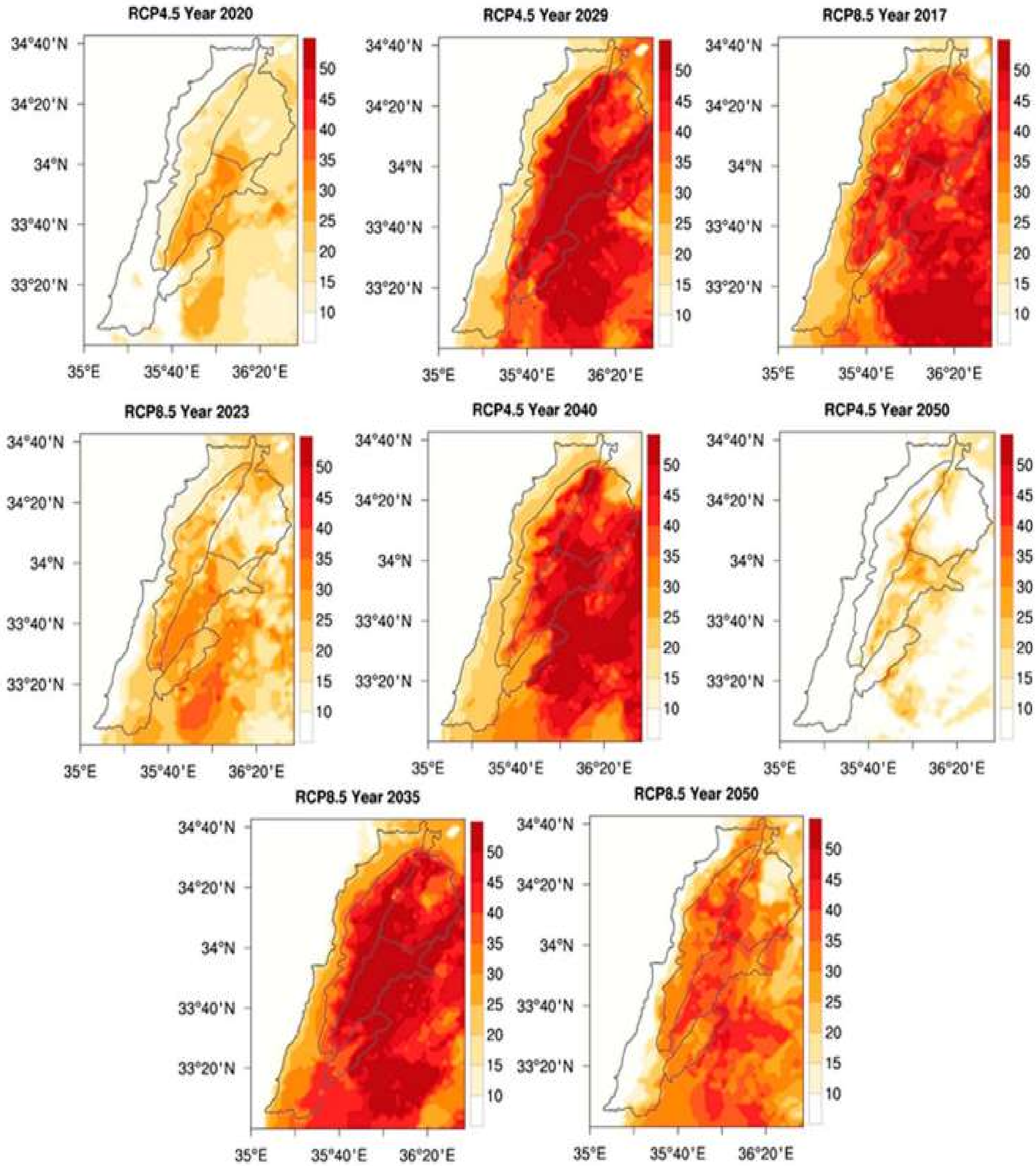


Figure 75: Heat wave duration index (days) for the simulated extreme years under RCP4.5 and 8.5, with reference to year 2008 (El Samra, 2018).

Another indicator is the Heat Stress Duration Index (HSDI), defined as exceedance of daily maximum wet bulb temperature (Tw) continuously for three days or more above 24.6°C ("dangerous" threshold) or above 29.1°C ("extremely dangerous" threshold). Lebanon will experience (Figure 76) an increase from 70 days per year in the current period (2006-2015) where temperatures are above 24.6°C for three consecutive days to almost 80 to 90 days in a 1.5°C and 2°C warmer worlds. Similarly, days where temperatures are above 29.1°C will increase from 5 days on average to more than 10 and 15 in the 1.5°C and 2°C warmer climates respectively (Saeed, 2021).

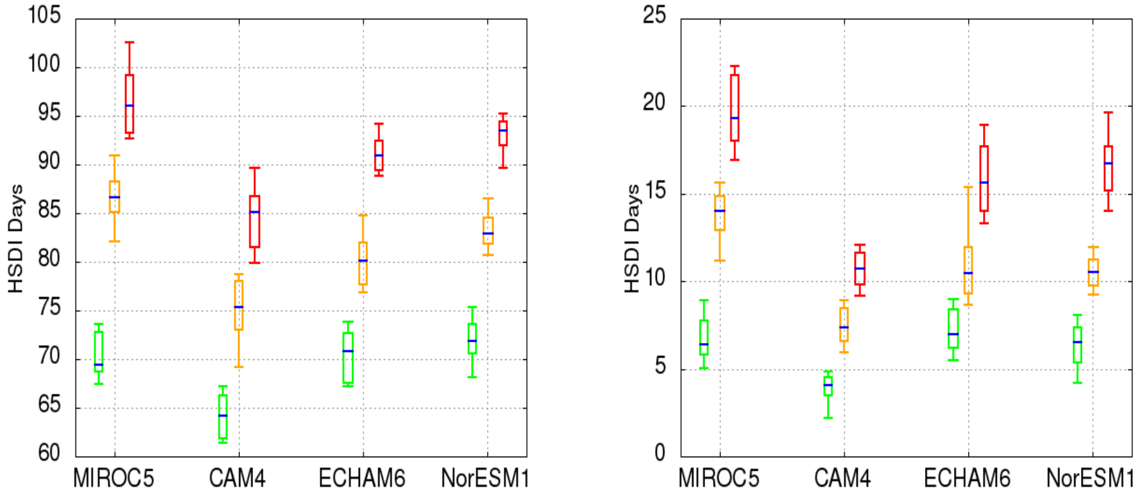


Figure 76: Heat Stress Duration Index (HSDI) for Reference (green), 1.5°C (orange) and 2°C (red) worlds for 4 GCMs with 20 members of 10-year simulations each over Lebanon. Left and right panels represent the HSDI at the "dangerous" (24.6°C) and "extremely dangerous" (29.1°C) thresholds respectively. The blue horizontal lines represent the ensemble median for each GCM.

Heat indicators

The **yearly maximum temperature (Tmax)** in Lebanon is also projected to increase between +1% to +5% (coast) and +13% +15% (central inland) in the decades leading to 2050 and with respect to the reference year 2008, with the central inland region experiencing the strongest warming on average with +5.9°C to +6.9°C by 2035. The number of **very warm days** (TX90P) will increase by +21% to +25% in the central inland zone when the daily Tmax value exceeds the reference period's (2008) 90th percentile (El Samra et al., 2018).

As for the nights, the **Warm Nights** indicator (TN90P) which detects change of more than +10% in night temperature, will increase by around 25% under RCP4.5 and 28% under RCP8.5 in 2050 as compared to the reference year 2008 (El Samra et.al, 2018). Such an increase will affect mostly coastal areas due to high humidity.

Climate change also affects temperature during wintertime, more pronouncedly under RCP4.5 than RCP8.5. Indeed, winter minimum temperatures are projected to decrease across all regions, and freezing temperatures are projected for the coastal zone. The extreme minimum temperatures are projected to decrease on average by -4.8°C in the northern part, -1.6°C along the coastal zone and -3.9°C in mountainous areas by 2050 under RCP4.5 (El Samra et.al, 2018). As a result, Heating Degree Days (HD) are expected (in reference to 2008) to increase, with the most affected area being the coastal zone where the increase in HD reaches 11% on the average compared to an increase of 5% over Lebanon.

Overall, Lebanon is likely to see an increase in extreme temperatures causing **heat waves and cold spells** to occur more frequently and for longer because of seasonal mean temperature increases.

Compound events of heat waves and drought

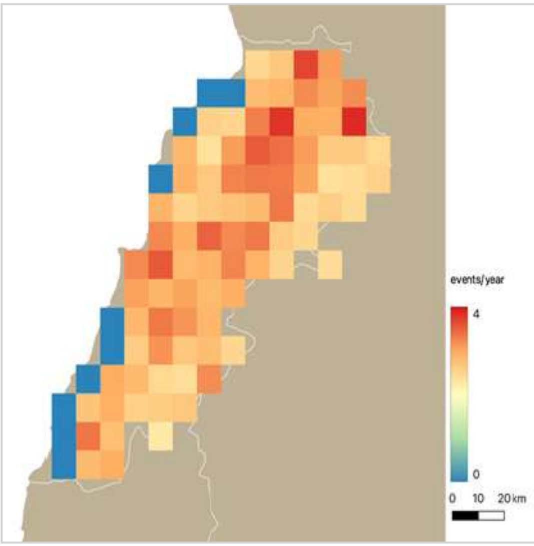
Compound events of heat waves and drought are expected to result in enhanced climate change impacts, especially on the hydrological cycle and the thermal stress (thus affecting considerably the agricultural sector and urban areas).

A tailored analysis was performed for the compound events of heat waves and droughts (Philippopoulos and Cartalis, 2022). The analysis took note of the hot and dry conditions as extracted from the 6-member ensemble projections downscaled at 10km and using the high (SSP5-8.5) emission scenario (RICCAR, 2021).

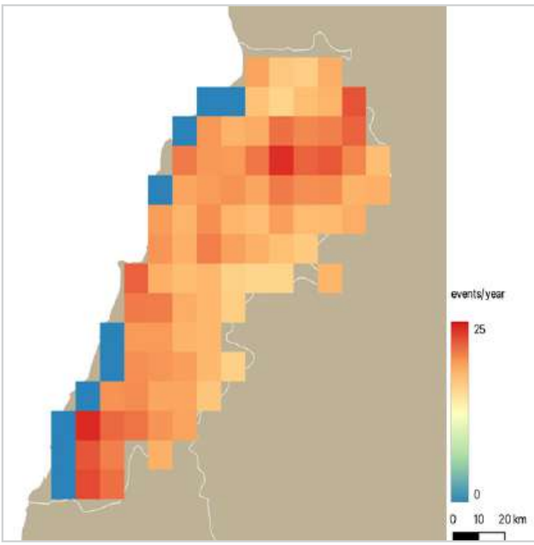
A specific methodology was applied (Ridder et al., 2022) and heatwaves and droughts were identified with the use of extreme indices, namely Excess Heat Factor (EHF) for heatwaves and the 3-months Standardized Precipitation Index (SPI) for meteorological drought, both determined using the historical period (1986–2005) as the baseline. Their thresholds were set to EHF>0°C and SPI≤−1.3 (moderate drought conditions).

EHF is an intensity measure that categorizes heatwaves by their severity. The calculation of EHF is based on a three-day averaged mean daily temperature, in relation to the 95th percentile of long-term average temperatures, and the recent (prior 30-days) temperatures, for a particular location. SPI is a widely used index to characterize meteorological drought on a range of timescales. On short timescales, the SPI as calculated using precipitation data is closely related to soil moisture, while at longer timescales, the SPI can be related to groundwater and reservoir storage (NCAR, 2022)

Results show a dramatic increase of the number of days in Lebanon (especially at the north part and the inland region) when both threshold criteria are satisfied in terms of heat waves and drought conditions. To this end, they are of considerable importance for the assessment of the vulnerability of areas as well as for the definition of the most appropriate adaptation measures.



a) Reference period (1986-2005) - in events per year.



b) Mid-term period (2041-2060) - in events per year

Figure 77: Hot and dry conditions for the mid-term period (2041-2060) in events per year, compared to the reference period

SECTION B. VULNERABILITY AND IMPACT ASSESSMENT

In this section, the sectors of (a) Agriculture, (b) Water Resources, (c) Terrestrial and Marine Biodiversity, (d) Cities and coastal societies and (e) Health, are examined in terms of vulnerability and impact assessment to climate change. Firstly, a synopsis of climate change impacts on the sectors above is provided, along with the associated climate stressors and projected risks (Table 25), followed by sectoral analysis in terms of vulnerability and impacts.

Table 25 Impacts, climate stressors and projected risks

Type of Impact	Climate stressors	Projected Risks
Reduced water Availability	• Increased temperatures • Reduced rainfall and snow cover • Increased drought incidences • Rise in sea level	• Altered seasonal water regimes; and increase up to 30% in winter floods • Reduced river flows leading to increased strain on limited groundwater sources in the dry season • Increased evaporation of surface water • Increased saltwater intrusion/salinization of coastal aquifers
Less snow	• Increased temperature • Reduced snowfall	• Reduced snow cover by 40% to 70% • Shift in snow fall from 1,500 m to 1,700 m by 2050, and to 1,900 m by 2090 • Decreased snow residence time from 110 to 45 days
Less agriculture productivity	• Increased temperature • Reduced rainfall and snow cover • More frequent droughts • More frequent heat waves and fewer frost days • Sea level rise	• Reduced land productivity (especially for wheat, cherries, tomatoes, apples, and olives; and may affect the quality of grapes) • Reduced fruit tree yields (up to 50% through blossom pollination and fecundation of mountainous fruit trees) • Declined soil moisture (high temperatures/ reduced precipitation/ higher evapotranspiration) impacting agricultural yields • Migration of mountain fruit production to higher elevations • Decreased crop quality (particularly wine grapes) • Increased infestation (fungi and bacterial diseases) • Shift in grazing areas and periods for livestock • Increased pumping for irrigation needs

High energy demand	• Increased temperatures	• Increased demand on cooling (1.8% increase in electricity consumption for a 1°C increase, and 5.8% for a 3°C increase)
Sea level rise	• Increased rise (30-60 cm in 30 years-2mm/ year)	• Increased seawater intrusion into aquifers • Increased risk of coastal flooding and inundation • Increased coastal erosion altering coastal ecosystems in natural reserves and elsewhere
Forests at risk	• Increased temperatures	• Increased adverse effects on forests suffering from fragmentation, pest outbreaks, forest fires and harmful practices
Increase in morbidity and mortality	• Increased temperatures • More intense and frequent heatwaves • Increased extreme weather events	• Increased outbreaks of infectious diseases • Increased morbidity and mortality from heat and other extreme weather events • Increased malnutrition from droughts and floods • Increased rates of water-borne, rodent-borne, and vector-borne diseases
Impacts to Tourism	• Increased temperatures • More intense and frequent heatwaves • Sea level rise • Reduced precipitation	• Impact on winter outdoor tourism • Shortened skiing season • Increased losses of natural attractions (e.g., sandy public beaches) • Increased structural damage to the country's archaeological heritage

Abdallah et al., 2018; ACSAD/ESCWA, 2019; Alameddine et al., 2018; Fragaszy, S. et al., 2022; MedECC (2020); Verner et al., 2021; WHO and UNFCCC, 2021; World Bank, 2017; WFP, 2020; Zittis et al.

According to the Notre Dame Global Adaptation Initiative (ND-GAIN) index, Lebanon ranked 112th (out of 182 countries) in 2019, and was considered to have a relatively medium vulnerability, and at the same time low readiness to tackle climate change (86th least vulnerable country and the 155th least ready country out of 182 countries). This index measures vulnerability by the exposure, sensitivity, and ability to cope with climate related hazards by accounting for the overall status of food, water, environment, health, and infrastructure within a country Additionally, it measures readiness by the "country's ability to leverage investments and convert them to adaptation actions by looking at the country's economic, governance and social readiness" (Notre Dame University, 2020). Still, it is important to note that since 2019 (the most recent index score), the quality of governance, climate readiness and adaptive capacity have further deteriorated in Lebanon, due to the compounded crisis the country is facing. Therefore, it is likely that the ND-Gain index considerably changed for the years 2020-2021, a period during which multidimensional poverty in Lebanon rose from 42% to 82% of the total population (RICCAR, 2021).

Detailed risks and impacts are highlighted in the different sectors below.

4.4 AGRICULTURE SECTOR

Lebanon's agricultural sector is highly vulnerable to climate change due to climate risks such as increases in temperature, reduction in precipitation levels, as well as changes in precipitation patterns and higher occurrence of extreme weather events. This results in damages to agricultural yields and affects the livelihood of a significant proportion of the Lebanese population that works in the agricultural sector (Figure 78). The agricultural sector's vulnerability is further enhanced due to high dependence on irrigation water, with its supply being further threatened by population growth, migration, environmental degradation, and competing sectors such as tourism, energy, housing.

Lebanon faces challenges unique to the rest of the Mediterranean region due to its land mass that is much smaller than other countries in the area, and its population which is smaller and more urbanized that other countries. This growing urbanization presents pressure on urban water supplies and relatively less pressure on agricultural water supplies (Verner et al., 2018).

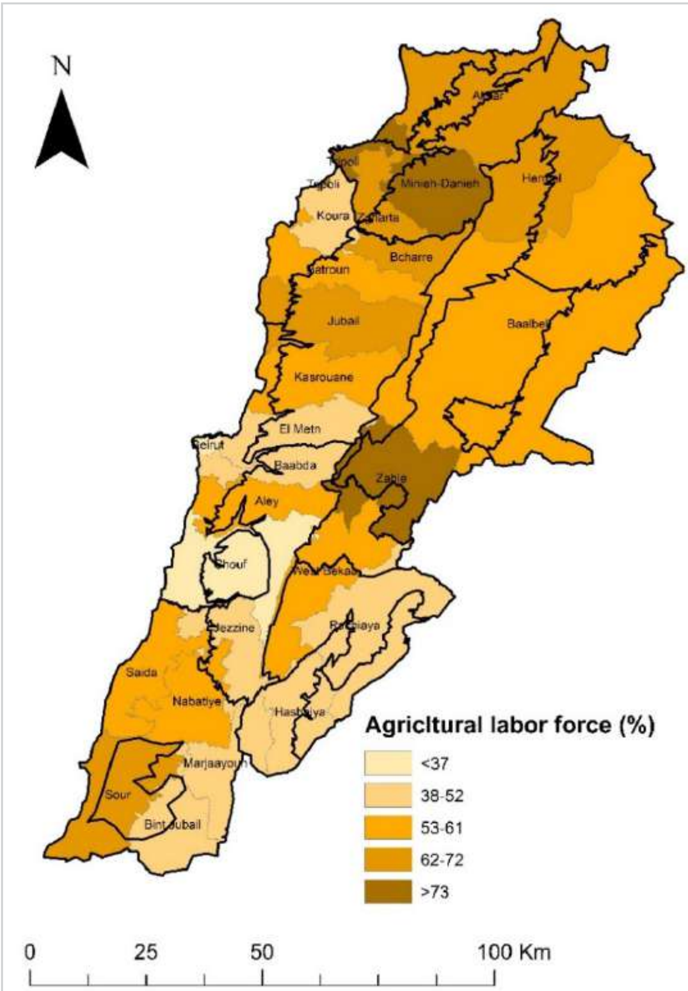


Figure 78: Spatial depiction of the agricultural labor force (%) in Lebanon (CAS, 2020)

Over the last decade, population growth has increased water pressures and these population changes—both natural migration and the forced migration of refugees from conflicted neighbouring countries—created water demand challenges associated with urbanization, agricultural expansion, and energy and industrial activities. Challenges are compounded by the contamination of urban water supplies and limited investment in water infrastructure. In addition, its natural water availability is constantly affected by aridity and droughts in humid and semi-arid areas, where agriculture relies on rainfall, not irrigation, for its water needs.

The main impacts of climate change on the agricultural sector are described in the following sections, as based on regional and national climate projection and considering key vulnerability parameters such as exposure, sensitivity, potential impact, adaptive capacity (Table 26) (ACSAD/ESCWA, 2019; World Bank, 2020b; RICCAR, 2021).

Table 26 Definition of parameters (ACSAD/ESCWA, 2019)

Exposure describes the nature and extent to which a system is subjected to climatic phenomena. It can consider single climatic variables (i.e., local temperature), specific storm events, or most commonly, climate change impacts.	**Sensitivity** depicts the weaknesses of a system, considering both the physical and natural environment. Typical indicators include land use, population density, and demographics	**Potential** impact portrays the prospective consequences of climate change on a system. It is based upon the combination of exposure and sensitivity.

Adaptive capacity reflects the ability of a system to adjust to adverse impacts stemming from climate change. It can consider factors such as damage control, opportunities, or coping mechanisms. Indicators include crop diversity, livelihood diversity, degree of machination, irrigation, expenditure, and level of education.	**Vulnerability** is the degree to which a system is susceptible to the adverse impacts of climate change. It considers exposure, sensitivity, and the resultant potential impact, as well as adaptive capacity.

Exposure

Lebanon's composite exposure to changes in temperature, precipitation, and runoff (aggregated together with equal weights) due to climate change is expected to be low to moderate by mid-century and increase by end-century to reach moderate exposure range from 14% for RCP 4.5 to 37% for RCP8.5 (ACSAD/ESCWA, 2019). This is further validated by climate projections at high spatial resolution (RICCAR, 2021) produced specifically for SSP5-8.5 for the purpose of developing the Fourth National Communication. The enhanced exposure, due to compound effects of droughts and heatwaves, also needs to be considered for both mid-century and end-century, although considerably more for the latter period (see section A on Climate Risks in Lebanon).

Sensitivity

Sensitivity represents the aggregated result of fifteen indicators[14] which describe social, environmental, ecological, and anthropogenic factors contributing toward agricultural susceptibility to climate change in Lebanon. The sensitivity composite indicator reveals areas of low, moderate, and high sensitivity (12%, 53%, and 35% of the study area, respectively).

Potential impact

Based on the exposure and sensitivity analysis, the potential impact of climate change on agriculture in Lebanon is projected to increase, in the absence of adaptation measures, from mid-century to end-century. Most areas in Lebanon will witness moderate potential impact, affecting 70% to 85% of agricultural areas, with 1% to 3% of areas signalling high potential impact by end-century.

Vulnerability

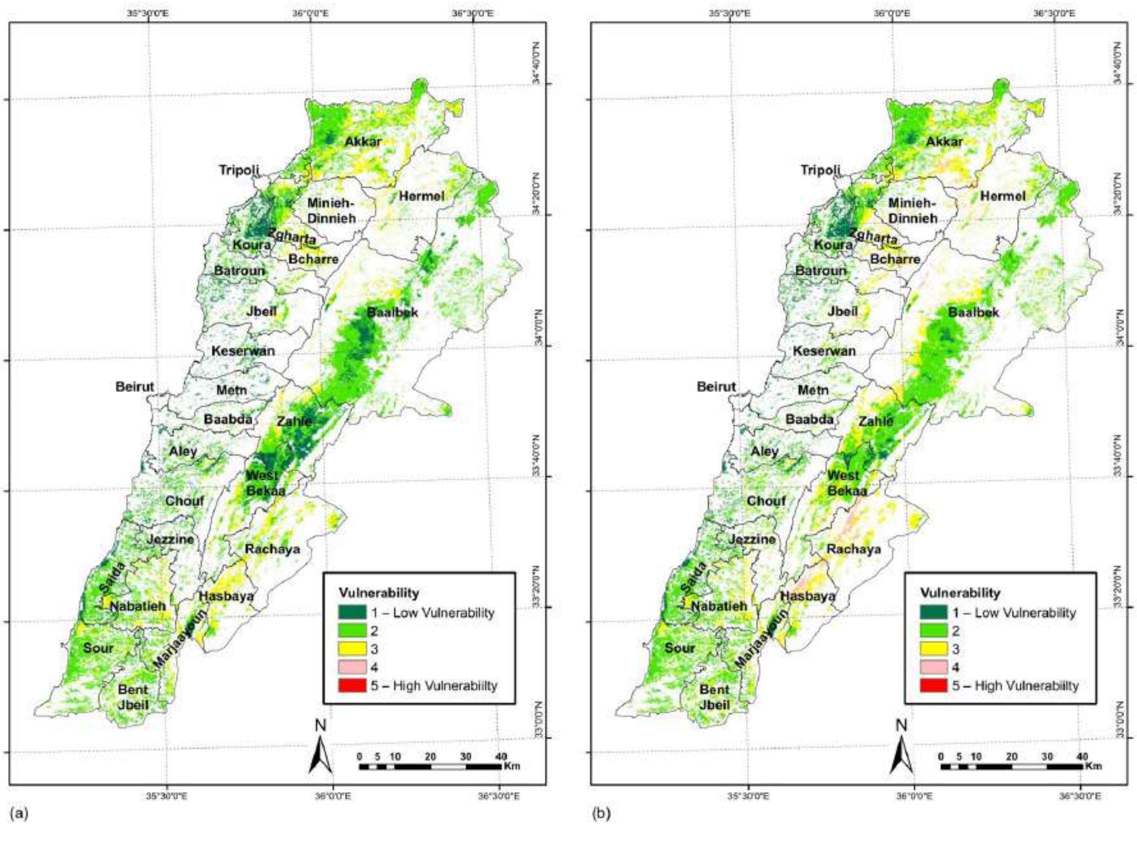
In general, Lebanon is projected to exhibit moderate vulnerability at mid-century with 82% (RCP4.5) to 87% (RCP8.5) of areas categorized as moderately vulnerable, while 3% of the area signals high vulnerability (RCP8.5) (Figure 79.a). Vulnerability is also moderate for the end of the century both for RCP4.5 and RCP8.5 (Figure 79.b). As for the agricultural sector in specific, ACSAD and ESCWA (2019) revealed that its vulnerability is mostly considered as moderate (with a maximum of 87% of land areas), with some areas such as Hasbaya, Rachaya and Becharreh categorized as highly vulnerable by the end of the century (up to 14% of land areas).

Weaknesses and Vulnerability of the agriculture sector in Lebanon (adapted) from Abdallah et al, 2018

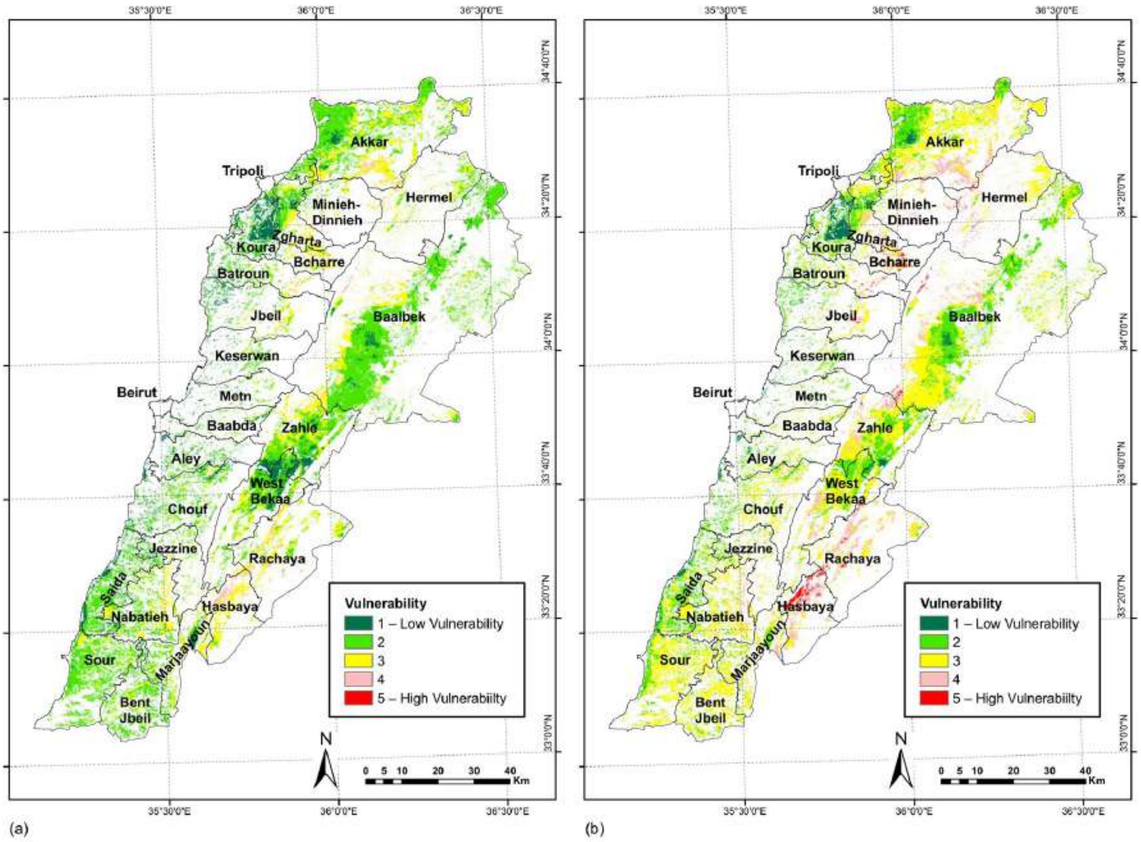
Plant production
Absence of long-term plans for managed irrigation, development and needed investment in a balanced manner in irrigation infrastructure
Limited number of policies and local/national programs for water management mechanisms
Absence of legislations for the establishment of a water users' associations
Poor information sharing systems at the local level
Absence of linkages between research and practical dissemination of research results onto best practices to increase water use efficiency
Weak agricultural extension in the rationalization of water used for irrigation
High cost of irrigation due to small sized and fragmentated holdings (economies of scale)
Old and inefficient irrigation systems
Lack of awareness of farmers of both water value and its balanced use
Poor wastewater management and treatment; high operation and management cost of treatment plants
Excessive water pumping in coastal areas leading to seawater intrusion, which is detrimental to coastal agriculture

[14] Indicators used: Population density, Land use/land cover, Agriculture Labor Force, Desertification risk, Livestock density, Irrigated croplands, Vegetation cover degradation, Soil storage capacity, Potential soil erosion hazard, Soil depth, Soil organic matter content, Flood hazard, Urban sprawl, Aspect/Topography, Elevation slope (ASCAD and ESCWA, 2019).

Livestock
Unchecked and monitored animal health
Insufficient animal health and production research and monitoring laboratories
Small and fragmented farms and production units
Irrational use of antibiotics and chemicals
Decrease in rangeland and pastures
Disparity in education levels of animal farmers
Discrepancies in post-production management
Poor conditions of slaughterhouses
Reduced capacity to come-up with new processes products
Weak export promotion of products with animal origin
Absence of traceability and implementation of international standards
Weak control of animal diseases and hygiene of dairy products
Weak management of pastureland



(a)



(b)

Figure 79: Spatial analysis of vulnerability to climate change for RCP4.5 (left) and RCP8.5 (right) at (a) mid-century and (b) end-century.

Impact of climate change: hot spot areas

In terms of exposure, areas of moderate exposure include Bcharre, Inland Baalbek, Zahle, northern West Bekaa, Chouf, and Jezzine while areas of high exposure are solely apparent for RCP8.5 (7% of study area) and include areas above 900 m, including areas within Hermel, western Baalbek, northern Zahle, southern West Bekaa, eastern Bcharre, eastern Jbeil, and eastern Keserwan.

In terms of sensitivity, areas with the highest sensitivity are Baalbek (~27,000 ha) and Akkar (~17,000 ha). The former (including the villages of Hermel, Baalbek, Brital, and Taraya) embody areas with high livestock density and include citrus and almond croplands. The latter (including the villages of Qabbair, Michmiche, Fneidek, Akkar El-Atika, and Akroum) primarily includes olives, apples, and vegetables.

In terms of highest potential impact, the Litani River valley in eastern Lebanon (Baalbek, Zahle, West Bekaa, Rachaya, and Hasbaya) and southeastern Akkar exhibit increased potential impact. Areas located in northern Lebanon near the coast until 600 m in elevation (Zgharta and Koura) will have lower potential impact by end of century, and happen to have relatively higher adaptive capacity than the rest of the country (ACSAD/ESCWA, 2019).

Finally, with regards to vulnerability, the cazas with the largest percentage of croplands (>50%) are classified as highly vulnerable by end-century (RCP8.5), and include Hasbaya, Bcharre, and Rachaya (Figure 79).

Vulnerability exhibits a strong correlation with adaptive capacity and a modest correlation with sensitivity. Thus, enhancing adaptive capacity measures will have the greatest potential to reduce projected vulnerability. Correlation with exposure is relatively weak, although differences between scenarios are due to exposure indicators. Examples of adaptive capacity measures include agricultural education centers, improved technology, and increased financial resources which will be delved into in more depth in the adaptation section.

Hotspots – Highly vulnerable areas for agriculture

Special attention needs to be given to hotspots, namely areas which have the highest vulnerability for the agriculture sector due to climate change. Hotspots are primarily located in five areas as follows:

South-eastern Akkar: Hotspot areas are estimated at ~2,600 ha and include fruit trees and field crops. This area is dominated by high sensitivity stemming from steep slope, occurrence of flooding, and soil erosion. Secondly, this area signals low adaptive capacity due to poverty, low irrigation capacity, and limited groundwater resources.

Hasbaya: Hotspots are estimated at ~3,800 ha and include olives, field crops, and fruit trees. Limited irrigation capacity, high unemployment and illiteracy, and lack of crop diversification contribute toward low adaptive capacity. Moreover, sensitivity is elevated due to poor soil characteristics, including shallow depth, low storage capacity, and low organic content. Lastly, exposure is moderate due to decreasing precipitation coupled with increasing temperature.

Rachaya: Hotspots are estimated at ~2,600 ha and include field crops, olives, fruit trees, and vineyards. Very high sensitivity is revealed, combined with low adaptive capacity. The area signals limited irrigation capacity, high percentage of unemployment, and shortage of groundwater resources.

Baalbek and Zahle: Hotspots are estimated at ~2,000 ha and include fruit trees, field crops, and vineyards.

Zgharta and Bcharre: Hotspots are estimated at ~2,100 ha and include field crops, fruit trees, and olives.

More recent assessments under RICCAR (SMHI/ESCWA, 2021), and livelihood mapping (IFI/WFP, 2021) resulted in similar outputs regarding vulnerable areas. When overlaying livelihood zone maps with climate resilience ranking and climate change impacts, the hotspots areas have been identified as East-Baalbeck, and Akkar as well as parts of West-Bekaa, especially related to food insecurity.

Figure 80 highlights the climate sensitivity of crops, taking into consideration IPCC AR5 (CMIP5) and ESCWA's EURO-CORDEX projections for the region and Lebanon, the availability of irrigation schemes, and the different types of crops and land uses. Adapted from WFP's 2020 livelihood mapping, the map shows that areas without irrigation schemes are significantly more climate sensitive than areas with irrigated crops, especially taking into consideration the changes in precipitation trends over the past ten years (IFI/WFP, 2021), as well as the projected ones towards mid-century and end-of-century (see Section A on Climate Risks).

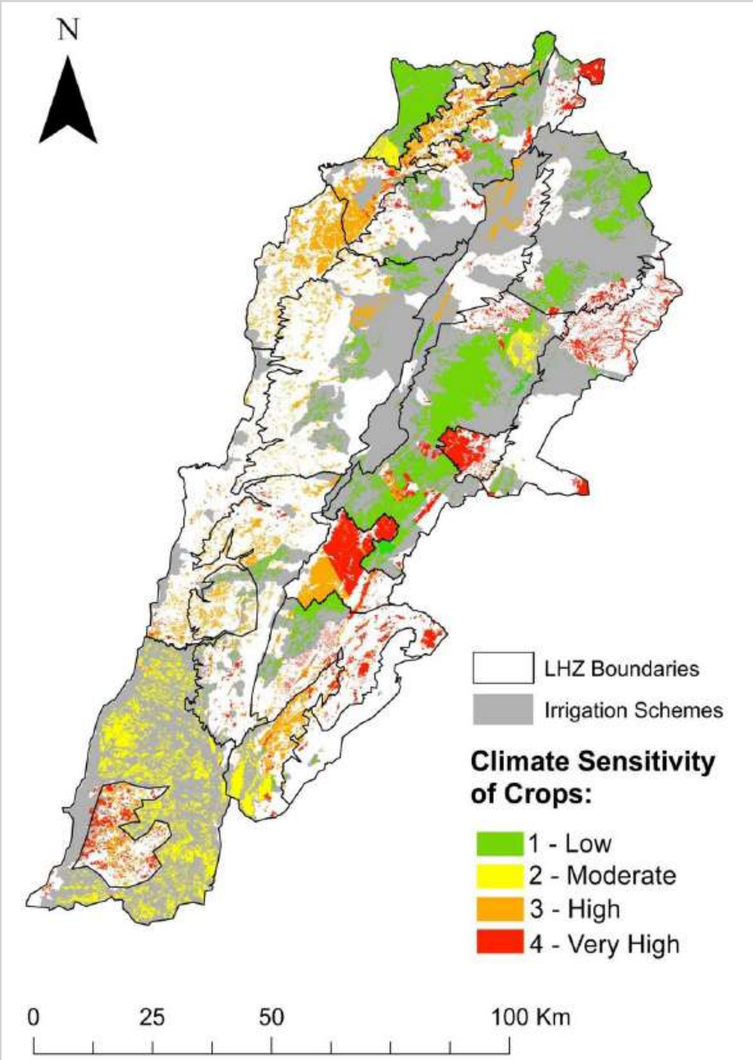


Figure 80: Climate sensitivity of crops (IFI/WFP, 2020)

Impact of climate change on crop production

Several severe drought periods (SPI[15] < − 1.5) have been historically recorded in Lebanon (such as the 1985–1986, 1988–1989, and 1998–1999 droughts), with the 2015 drought being the worst on record and identified as an extreme drought (SPI < − 2) (Kobrossi et al., 2021).

[15] The Standardized Precipitation Index (SPI) is the most commonly used indicator worldwide for detecting and characterizing meteorological droughts. The SPI indicator measures precipitation anomalies at a given location, based on a comparison of observed total precipitation amounts for an accumulation period of interest (e.g. 1, 3, 12, 48 months), with the long-term historic rainfall record for that period (source: https://edo.jrc.ec.europa.eu/

Analysis of monthly precipitation data for Lebanon for the period 1926-2015, shows that SPI-3 fall (October through December) has neither an increase nor a decrease, while SPI-6 fall–winter (October through March) has a sharp decrease. At seasonal levels (SPI-3 and SPI-6), the projections of SPI values indicate a possible increase in the degree of dryness (i.e., worse water availability) during the fall and winter months and a decrease in the spring period (better water availability). The results for longer time scales show a decrease of the SPI-9 and the SPI-12, corresponding to drier conditions (Kobrossi et al., 2021). These results are in line with other regional findings (World Bank, 2022b; IPCC, 2021; RICCAR, 2021) as well as the trend analysis for Consecutive Dry Days (CDD) and Consecutive Wet Days (CWD) presented in Section A.

Drought will disproportionately impact the poorest communities in areas such as Akkar and Baalbek-Hermel, where agriculture is a primary source of income and employment, further exacerbating an already sensitive balance. The limited capacity of these communities to manage drought risk, in addition to the pressure caused by Syrian displacement on local water availability and natural resources, contributes to making the impact more significant (World Bank, 2017).

On the compound effect of droughts and heatwaves, impacts will be considerably intensified, especially since heatwave are expected to increase in terms of frequency, duration and intensity by mid-century and end-of-century (see Section A on Climate Risks), a fact which in turn will further increase the vulnerability of the agricultural sector in the said communities.

Particularly, increased heat and more frequent droughts will detrimentally impact fruit trees, cereals, and food legumes, which constitute the majority of Lebanon's agricultural production, export commodities, and are major components of Lebanese cultural and culinary traditions. projected temperature increases over the next 60 years will expose plants at every growth stage. Heat sensitive cultivars may be rendered sterile if exposed to high temperatures above 35°C during flowering (Verner et al., 2018).

For temperature, a 1°C rise leads to a 13% loss in wheat yields, whereas the combined effect of drought and heat can cause 18% and 28% yield losses for grain legumes (Verner et al. 2018). Heatwaves can also result in the burning of crops and fruits, including grapes, olive, melon, apples and apricot and heat blisters can affect the summer vegetable season of watermelon, tomato and cucumber (Abdallah et al. 2018).

According to MedECC (2020), one of the crops that are most affected by climate change is maize, with yields projected to decline by 17% in some countries by around 2050 under the RCP8.5 scenario. Wheat yield losses of 5% to 22% are also projected due to decreased resilience of production and higher inter-annual variability in 2021-2050 under the RCP8.5 scenario, with no adaptation. Other water demanding crops, such as tomatoes, are also at risk, and the production of some currently rainfed crops such as olives, could become unfeasible without irrigation.

Sea level rise in the Mediterranean Basin will also impact the agricultural sector by 1) directly impacting (or causing the loss of) agricultural areas in coastal zones; 2) increasing by three-fold in the salinity of irrigation water and soil and 3) hindering the retention of sediments from reaching the coast (MedECC, 2020).

In terms of hazards, heavy wind, floods, and heatwaves can cause significant damages to agriculture, with heavy winds being the most recurrent hazard, based on past records. For every 100 heavy wind events occurring during a year, 89 can cause damage to agriculture, while only 56 wildfires out of 100 could be harmful to agriculture. Floods mainly affect temporary crops, heatwaves affect mainly permanent crops, heatwaves affect fruit trees and landslide, and heavy winds cause the most damage to greenhouses (Abdallah et al., 2018).

Overall, several climate risks will impact agricultural production in Lebanon, although at varying levels and with differentiations among crops (Table 27 and Figure 81; adapted from Abdallah et al., 2018).

Table 27 Vulnerability of crops to climate risks; adapted from Abdallah et al., 2018

● low ● moderate ● high

Sectors \ Risk	Temporarycrops	Fruit trees	Other permanent crops	Greenhouses
Floods	high	moderate	high	moderate
Cold Waves	high	moderate	moderate	moderate
Storms	high	high	moderate	moderate
Heat waves	high	high	moderate	low
Heavy rainfall	high	moderate	low	moderate
Wildfires	low	moderate	moderate	low
Heavy winds	moderate	moderate	moderate	moderate
Land erosion / Landslides	moderate	low	low	high

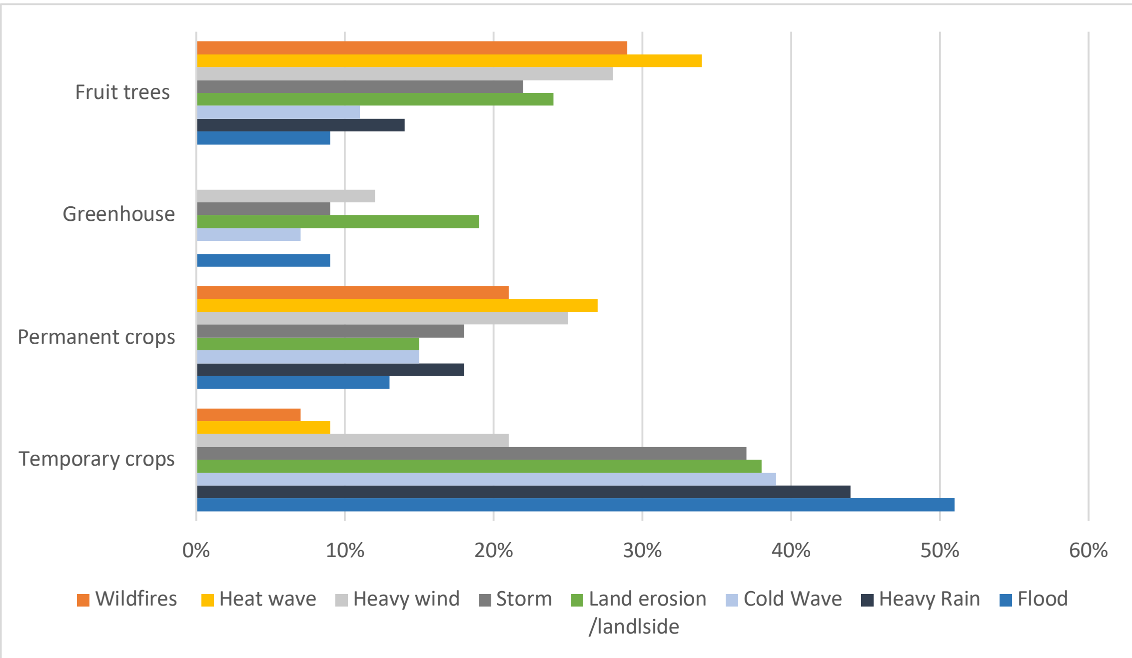


Figure 81: Disasters ranked by their damage to the agricultural sector (Adapted from Abdallah et al., 2018)

The combined examination of Table 27 and Figure 81, shows that temporary crops are overall the most vulnerable to climate change impacts. Temporary crops are more vulnerable to heavy rain and floods, while fruit trees and permanent crops are more vulnerable to heatwaves and forest fires, and greenhouses to land erosions.

Finally, Table 28 represents a synopsis that details the impacts of climate change on key crops in Lebanon (adapted from World Bank, 2017 and Abdallah et al., 2018).

Table 28 Impacts of climate change to key crops in Lebanon (adapted from Verner et al., 2018 and Abdallah et al., 2018)

Wheat	**Reduced rainfall and increased temperature damage wheat production** Increases in temperature (a 1°C rise could lead to a 13% loss in wheat yields) and decline in spring rainfall impact wheat yield, especially in the Bekaa valley where reduced spring precipitation is common.
Potato	**Potato production is affected by temperature extremes and water unavailability** Production is affected when temperatures rise or drop in a range of 10–30°C Higher winter temperatures make potatoes vulnerable, with higher humidity and milder temperatures leading to a higher frequency of disease. In the spring and autumn, potatoes are mostly affected by water unavailability and temperature extremes. In the summer, potatoes are vulnerable to drought if there is insufficient irrigation water.
Tomato	**Tomato is a warm weather crop, with extreme temperatures affecting production** Tomato production is affected by temperature extremes, frost, high humidity, water stress, and long dry periods. Growing periods will be shorter thus producing less yield, especially in Bekaa Valley, Marjayoun plains, and coastal areas (from water shortages and soil salinization).
Apples	**Apple blossoms are sensitive to high temperatures (>40°C)** Apples production potential is reduced in lower altitude due to the decrease in chilling hours (less than 400 to 900 hours of chilling temperatures per season). Apple harvest is damaged by drought, reduced cloud cover, insufficient water resources and sunburn associated with increasingly high temperatures.
Cherries	**Cherries are sensitive to high temperatures (> 21°C)** Cherries production declines from decrease in chilling hours (less than 700 chilling hours, or 70 days) caused by high temperatures. Production is also impacted by higher winter temperatures that limit frost days and increase the risk of wood insects.
Grapes	**Both temperature and precipitation changes will affect grape production as well as the wine quality** Grape yields and wine quality is mainly reduced in the Bekaa valley and in Akkar, to a limited extent. Sunburn and early ripening of grapes are expected due to early budding from high temperatures and eventual risk of spring frost. Water demand rises due to excessive evapotranspiration.

Citrus	**Increased water scarcity will have negative effects on citrus production** Citrus production is reduced due to shortage of water for irrigation and increased salinity from over-exploitation of groundwater on coastal areas. Fruits will develop in an accelerated way, leading to earlier maturity, lower acidity levels and less sugar content.
Almonds	**Almond cultivation is at risk from spring frosts** Almond production is reduced due to higher temperatures, which leads to early bud bursts, and increased vulnerability to spring frosts (especially traditional almond varieties like Awja)
Apricots	**Increased temperatures will have negative effects on the fruit.** Apricot fruits are smaller due to warm conditions that will accelerate anthesis, impact pistil development, and lead to reduced pistils, shorter styles, unswelled ovaries and female sterility.
Peaches	**Increased temperatures during flowering reduces peach flower size and germination** Peach production is significantly reduced due to high temperature.
Plums	**Heat can damage plums** Plum trees have a shorter lifespan and lower production with a 1°C rise in average air temperature between February and April leading to early blossoming. Plums fruits are discoloured from heavy direct sunlight.
Pears	**Pears are sensitive to rainfall and temperature extremes** Pear yield and fruit quality (poor colour) are impacts by drought stress, reduced chilling hours, disrupted reproductive processes, and increased incidence of sunburn from rising temperatures.
Banana	**Increased water scarcity and sea intrusion hinders banana growth** Banana production is reduced due to water unavailability for irrigation, especially on the coastal plains and during the arid season.
Olive trees	**Olive trees are vulnerable to changes** Although olive trees can withstand long droughts and temperatures above 40°C, still, prolonged warmer or colder weather and wetter or drier conditions can have negative impacts on production. Spring frosts and warm winters adversely impact production as well as olive oil quality. Decreased rainfall also led to slight yield reductions especially when combined with reduced chilling.

Table 29 summarizes the impacts of climate change (as presented in Section A on Climate Risks) with their respective damages to the agricultural sector (from Abdallah et al., 2018). Impacts are expected to be intensified towards mid-century and end-of-century, as a result of increasing temperature, declining precipitation, and soil humidity, as well as more frequent, lasting, and intense heatwaves combined with droughts.

Table 29 **Summary of climate change induced damages in Lebanon.**

Change	Impact	Damages
Temperature	Bias adjusted climate projections show that annual mean temperature is expected to increase from 1.6°C to 2.2°C by mid-century and from 2.2°C) to 4.9°C by end-century when compared to the reference period 1986-2005. The increase is seasonally dependent, meaning it's more pronounced in summer and autumn.	• Decreased productivity of lands used to produce most crops and fruit trees • Increased evaporation of surface water sources • Reduced snow cover and earlier snowmelt altering seasonal water regimes
Precipitation	Climate projections at improved grid analysis show an annual reduction in precipitation for Lebanon of 5% to 9% by mid-century and 6% to -11% by the end of the 21st century. Climate projections for the SSP5-8.5 scenario show that reductions in annual precipitation may reach 6.5% to 9% by mid-century and by 9% to 22% by end-century respectively as compared to the reference period of 1995-2014.	• Increased damage to crops and fruit trees damage • Earlier flowering of fruit trees • Increased vulnerability of agricultural plains of Akkar, Damour, Saida and Tyre to coastal flooding and inundation
Droughts	The number of Consecutive Dry Days will increase in all regions for the periods 2021-2040 and 2041-2060 for SSP5-8.5, while Consecutive Wet Days will decrease, more to southern regions and along the coast. Based on several precipitation indicators, drought risk is expected to increase towards 2050 for all scenarios	• Increased erosion risk • Decreased in rain fed agriculture • Decreased replenishment of groundwater source • Drying of surface water
Floods	Increase in the intensity of floods occurring in the Baalbek-Hermel governorate	• Damage to most crops • Increased erosion risk
Heatwaves	Increase in the frequency of occurrence, intensity and the duration of heatwaves	• Damage to most crops especially in the event of concurrent droughts

Impact of climate change on irrigation

Agriculture is the largest user of water in the Mediterranean region as irrigated agriculture is at least twice as productive as non-irrigated agriculture. Demand for irrigation is expected to increase by 4% to 18% by 2100 in the Mediterranean basin which can increase to 22% to 74% with demographic change and growth of large urban centres (MedECC, 2020).

In Lebanon, the total area of cultivated land in Lebanon is approximately 223,000 ha, of which half is irrigated (ESWCA, 2020, Verner et al., 2018). Climate change will exacerbate existing challenging conditions of water resources in combination with demographic and socio-economic drivers, reduced runoff and groundwater recharge, water pollution, increasing conflicts among users, ecosystem degradation and groundwater salinization in coastal aquifers. This reflects a considerable burden to agricultural production in Lebanon due to climate projections indicating that the country will experience substantially drier conditions with enhanced drought risk (see Section A on Climate Risks). In practical terms, droughts increase irrigation demand, which is met almost entirely by groundwater extraction, while also used for the water provisioning refugee communities and settlements.

For example, long and short-term environmental challenges in the Bekaa Valley are related to water shortages, water quality problems, groundwater table depletion, and the impacts of climate change by means of decrease in precipitation and increase of droughts. All these factors severely threaten the sustainability of irrigated crops in the Bekaa Valley as water demand is often greater than water supply (Sabbagh et al., 2022).

Crop water availability during drought periods is further reduced by the predominance of inefficient irrigation practices. Sprinkler and farrow systems dominate the landscape (over 75% of the area), while drip systems cover 22% of the area, almost entirely with non-pressure compensating emitters. Drip irrigation is most common for stone fruits and vegetables, while sprinkler irrigation is largely used to produce potatoes, wheat, tobacco, lettuce, and onions.

Deficit irrigation strategies, compared to those currently used, guarantee better production and lower water consumption. This relationship of improvement in the irrigation water management strategy is consistently projected under near-future climate change scenarios, demonstrating that irrigation management has a greater impact than the future agro-climatic conditions of the site. This can be explained as the irrigation treatment defines when and how much water enters the system, allowing or preventing the plant from transpiring satisfactorily (Fragaszy, et al., 2022).

Therefore, climate change will lead to a reduction in irrigation supply and an increase in irrigation demand, which will further lead to a reduction in potential irrigable areas in future irrigation systems. Thus, rural communities that rely the most on rainfed agriculture will be most impacted by climate change (Govind, 2022).

Damage and direct economic loss on agriculture

The direct economic loss[16] from damage caused by climate change and/or related disaster to the agricultural sector is estimated at USD 605 million in 2018. Floods (USD 330 million) are considered the most damaging disaster on the sector, with high annual financial losses, casualties, loss of animal and destruction to agricultural lands, damage to fisheries, boats, and forests in addition to triggering landslides. Flash floods harm freshwater raceway usually built along rivers including transported coarse and dine earth material, water turbidity and contamination. Other damages are caused by cold waves (USD 241 million), winter storms (USD 212 million), heavy

[16] calculated based on the: 1) estimated damaged area by crop, the lost yield, and the price per unit (prevailing market price as of 2018); 2) by the replacement cost (greenhouses or fishing boats) of the estimated destroyed units; 3) the number of dead animals and the market price

rainfall (USD 177 million), heatwaves (USD 149 million), wildfires (USD 125 million), strong wind (USD 93 million) and landslides/land erosion (USD 74 million) (Abdallah et al., 2018).

As for livestock (including cows, sheep, goats, and poultry), damage caused by climate change hazards include increases in animal mortality and damage to infrastructure such as animal shelters, beehives, and feedstock, which will reduce productive physical assets and have an impact on the food, nutrition and economic security of the population affected. Cold waves have been identified as the most recurrent hazards that cause damage to animals (estimated at around USD 11 million) followed by floods and storms (Abdallah et al, 2018).

In terms of areas being economically affected the most by climate change, the highest damage is expected to occur at the governorate of Baalbek- Hermel (USD 130 million), followed by Akkar (USD 113 million), and the Bekaa (USD 99 million) governorates (Abdallah et al. 2018).

Table 30 provides estimates of the damages (per year) in USD on crops due to climate hazards, while Table 31 shows the recurrence[17] percentage per climate hazard and provides the total economic cost per climate hazard.

Table 30 Damage in USD on crops and livestock from climate hazards (adapted Abdallah et al, 2018)

	Hazard	Cost per year (USD)
Temporary crops Cereals (wheat and barley), field crops (potato, tomato, cucumber) and leaf vegetables	Winter related hazards such as Frost and cold	415 million
	Wildfires and heatwaves	55 million
Fruit trees Pome fruits (apple and pear), stone fruits (cherry, plum, peach, etc.)	Heatwaves	70 million
	Cold waves	30 million
	Wildfires	45 million
	Heavy rainfall	8 million
Other Permanent crops (citrus, orchards)	Heatwaves	35 million
	Winter and autumn hazards	37 million
Greenhouses	Winter heavy wind	25 million
	Cold waves	12 million
	Flood	10 million
Animal sector (Cows, sheep, goats, and poultry)	Cold waves	11 million
Fisheries and aquaculture	Storms	NA

[17] A recurrence of 89% means that from 100 events with heavy winds in a year, 89 events resulted in damages in agriculture.

Table 31 **Hazards in terms of their percentage recurrence per year and the associated total economic cost (adapted Abdallah et al. 2018)**

Hazard					Total economic cost (USD million)
	Agriculture	Animal	Fishery	Forestry	
Heavy wind	89%	1%	5%	5%	93
Cold wave	84%	11%	1%	0%	241
Flood	83%	9%	5%	0%	330
Landslide	82%	0%	1%	9%	74
Storm	81%	8%	9%	5%	212
Heavy rain	79%	8%	2%	5%	177
Heat wave	71%	6%	0%	0%	149
Wildfire	56%	0%	0%	44%	125

Adaptation Guidelines for agriculture

The impacts of climate change described throughout section A will have a detrimental impact on the agricultural sector, which in turn will have socio-economic ramifications for households and businesses, reduce revenues, and increase costs to the government. Therefore, adaptation is vital not only to support the livelihood of rural populations and to sustain the viability of the agriculture sector, but also to maintain an acceptable level of food security.

The key adaptation measure for climate change is setting and implementing a sustainable agriculture policy, which has been reflected through the Ministry of Agriculture's strategy for 2015-2020 and 2020-2025 and in Lebanon's Nationally Determined Contribution (NDC). The updated NDC of 2021 prioritizes adaptation measures and actions that can enhance resilience in the agricultural sector by highlighting the importance of synchronization of adaptation action with the implementation of the Sendai Framework for disaster risk reduction. The listed adaptation priorities focus on achieving food security through sustainable resource management and enhancing infrastructure to mitigate climate risks by:

- Building the capacities of farmers and develop their skills towards sustainable farming
- Enhancing agri-food value chains efficiency and competitiveness
- Encouraging private investment in the agri-food value chain
- Enhancing efficient use of irrigation water
- Encouraging the use of renewable energy in agricultural irrigation
- In addition to the adaptation priorities presented in the NDC, there is an urgent need to further develop and implement adaptation plans and actions to cope with climate change. To this end, additional adaptation guidelines for agriculture include:
- Review the legislative framework related to agriculture and natural resources management and harmonize it with the conventions that are ratified by the Government in relation to climate change, combating desertification, and biodiversity.
- Implement the National Agriculture Strategy 2020-2025 and develop national action plans on the basis of a participatory

approach with local actors.

- Address inter-linkages and conflicting mandates between different institutions and define roles and responsibilities
- Review the human resources and organizational structure of the Ministry of Agriculture according to law amendments in order to provide the desired services related to adaptation measures
- Explore funding mechanisms and economic tools to implement and monitor adaptation measures. For instance, subsidies and credit facilitation policies should be in line with the proposed adaptation measures, i.e., promoting drought tolerant crops, drip irrigation, IPM, GAP, conservation agriculture.
- Rehabilitate infrastructure to address operational inefficiencies (quarantines, laboratories, frontier posts) and water losses (water harvesting and distribution systems, including dams, reservoirs and channels)
- Adapt crop management techniques resilient to climate risks especially drought tolerant crop types and varieties
- Adopt Integrated Pest Management (IPM) or organic farming
- Renovate orchards with low chilling requiring cultivars grafted on drought tolerant rootstocks
- Explore shifting in planting dates and shifting to adapted cultivars to increase tolerance to droughts
- Improve current irrigation schemes to reduce non-revenue water and ensure that water allocation is based on actual crop demand
- Expand irrigation schemes to cover all agricultural lands in Lebanon, especially in coastal areas and majorly agricultural livelihood zones
- Enhance water storage capacity to ensure water availability during the dry season
- Develop and apply improved rainwater harvesting techniques
- Train and educate farmers and agricultural communities on more efficient and climate resilient farming techniques
- Support research on the potential genetic resources and potential agriculture production systems (crop rotations, no-tillage agriculture, organic farming, mixed farming) that could adapt to climate change impacts
- Undertake studies on water consumption and water needs of various crops and cultivars, and their variability with climate change, agriculture production systems and regions

4.5 WATER RESOURCES

Water resources in the Mediterranean region are scarce, unevenly distributed, and often do not match human and environmental needs (Fader et al., 2020). Surface and groundwater resources in most of the region are projected to be further constrained under climate change conditions, particularly when considering pathways of strong radiative forcing such as business-as-usual scenarios (Zittis et al., 2022).

Impacts of even moderate (1.5 to 2°C) global warming and associated socio-economic pathways are expected to stem from reduced precipitation associated with increased evaporation, leading to a decline in runoff water (MedECC, 2020). In many regions of the Mediterranean basin, this will likely increase low-flow periods in summer and the frequency of no-flow events, as well as higher drought risks. Aquifer recharge will be strongly impacted by warming and reduced rainfall, particularly in semi-arid areas. And at current extraction rates, groundwater overexploitation is likely to continue having an even greater impact on decreasing groundwater levels than climate change. Important challenges to groundwater quality in coastal areas are likely to arise from salt-water intrusion driven by enhanced extraction of coastal groundwater aquifers and sea level rise.

Climate projections for parts of the region suggest an increase in the average seasonality, affecting hydrologic regimes due to shorter wet seasons and earlier snowmelts. Across the Mediterranean Sea, net freshwater loss (evaporation minus precipitation and river runoff) has increased since the last decades of the 20th century, due to the strong evaporation increase caused by local warming. The limited water resources in the region will likely be further reduced, while demand is expected to increase, driven by the population growth and heavy tourist flow, as well as increase of food production to meet the increasing demand, temperature increases, and precipitation changes (MedECC, 2020).

Lebanon particularly, faces major water challenges related to the sustainable management of water resources, and delivery of water services for domestic, agricultural, and industrial use. Like several Mediterranean countries, Lebanon is influenced by climate change, which is viewed not only from a fluctuation in climatic parameters standpoint, but also from its influence on the availability of water resources, which could lead to hydrologic drought. Indeed, climate change and climate variability can increase water challenges impacting the quantity and quality of available water resources and generate secondary effects that influence environmental sustainability.

Impact of climate change on saltwater intrusion and adaptation options

Significant impacts of climate change on water availability are predicted along coastal zones, with groundwater systems being most susceptible. In Lebanon, projected changes in temperature and precipitation will exacerbate the conditions of coastal aquifers which are already strained through high water demands in densely populated coastal regions, over-extraction of groundwater, and increased aquifer salinity. The vulnerability of these systems increases with population growth as well as with the projected expansion of industrial and agricultural activities on coastal zones.

However, studies have shown that sea level rise is not the main threat for coastal aquifers in Lebanon, as that the groundwater system in the coast seems to be more impacted by the high level of groundwater abstraction (due to population growth and increased water consumption rates) than by projected sea level rise induced by climate change (1 to 3.2 cm/year for the Eastern Mediterranean, with a total rise of 20 cm to 65 cm by 2032). More specifically, it was observed that the impact on saltwater intrusion of a 65 cm rise of sea level (by 2032) is comparable to only a 2% increase in abstraction rates under the baseline scenario (Safi et al., 2018).

Accordingly, any adaptation strategy or

management measure to alleviate saltwater intrusion must focus on controlling abstraction as a priority, which remains the main driver of saltwater intrusion. According to Fadel et al. (2018), adaptation options for domestic and agriculture water-use in coastal areas to reduce saltwater intrusion and sustainably manage coastal aquifers include:

Supply management options: storm water collection along coastal areas, dams (in or out of basin), desalination, water harvesting at building level, and greywater and wastewater reuse

Demand management options: install conservation appliances at households' level, smart metering, tariff restructuring, supply network efficiency (leaks / non-revenue water)

Technological adaptation options: installation of building-level reverse osmosis units, installation of city-level reverse osmosis supported by public-private partnerships, using fertigation via drip irrigation systems in agricultural lands and conjunctive use of groundwater and surface water (via canals) to control and reduce root-zone soil salinity and drainage

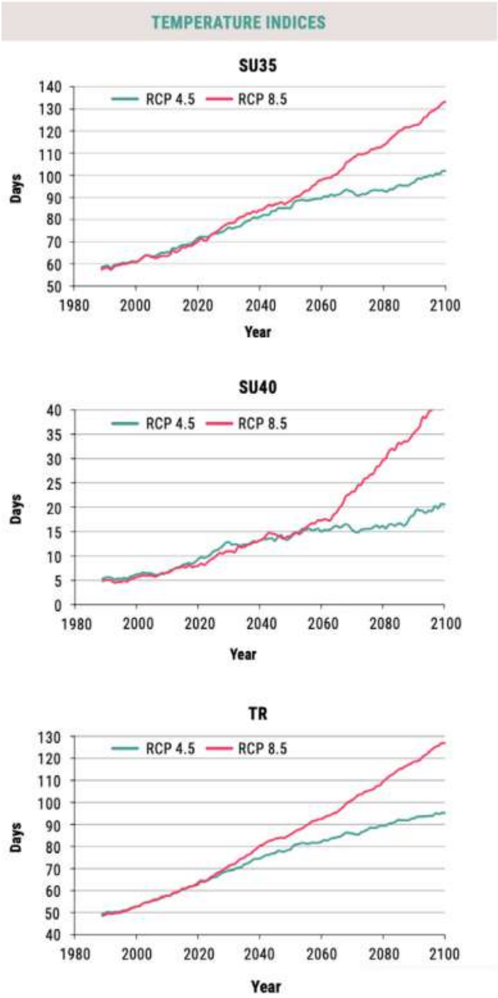
Institutional adaptation options: improvement and enforcement of regulations related to operation of building level desalination units, relocation of wells inland, change of land use patterns by switching to more salt-tolerant crops, reduction of extraction rates from the irrigation wells, tariff restructuring, and strengthening well permitting processes (Fadel et al., 2018).

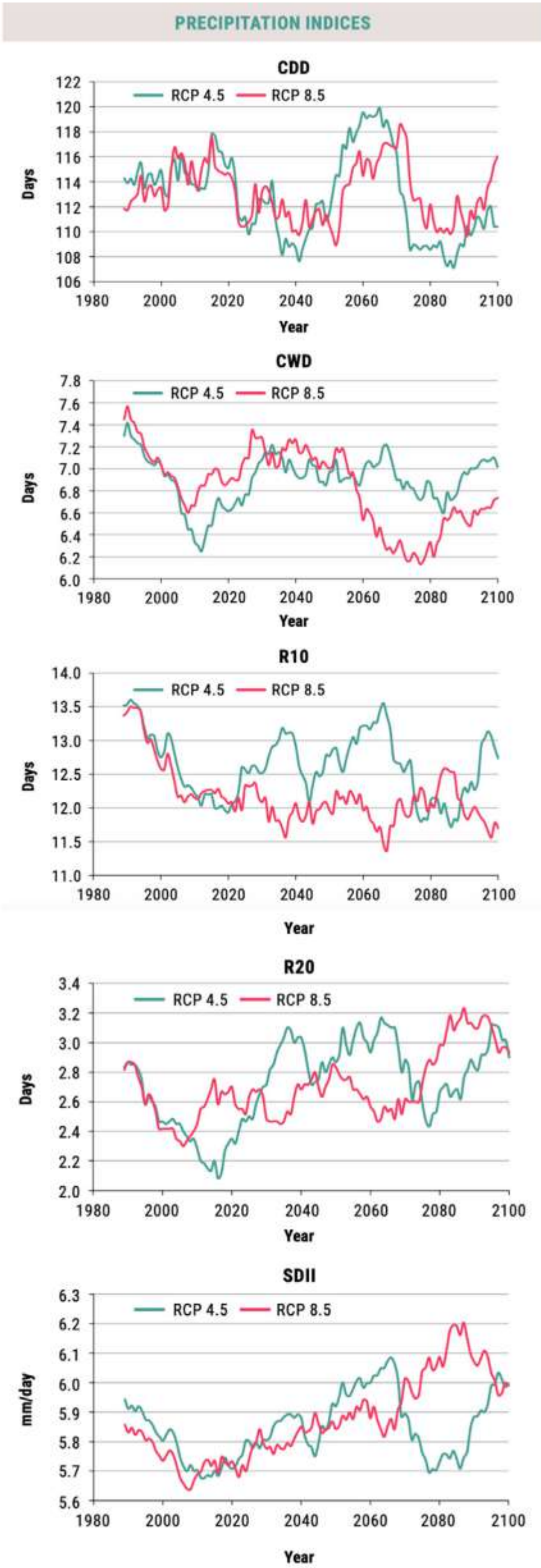
Impact of climate change on river basins and adaptation options

In Lebanon, analysis of impacts of climate change and extreme events such as extreme drought and floods have been conducted on Nahr El Kabir River Basin, Nahr El Kaleb, the upper-Litani Basin and Nahr Ibrahim (ACSAD/ESCWA, 2017; Hreiche et al.,2007).

In Nahr El Kabir watershed, drier conditions are projected due to increases in warm temperature and decreases in cold spells. For instance, SU35 is projected to increase from 60 days to 88 and 98 days at mid- and end-century, respectively, for RCP4.5 and up to 93 and 124 days for RCP8.5, which will in turn increase the occurrence of moderate droughts, for RCP8.5, but with no severe or extreme droughts events. A rise in Consecutive Dry Days (CDD) trends is expected during the mid-century period. Projections for precipitation extremes are more variable: days with heavy rain (R10) are projected to fluctuate over time under the RCP4.5 scenario, but follows a steady decline under scenario RCP8.5. Days with very heavy rain (R20) are projected to increase over time, especially by end-century (Figure 82) (ACSAD/ESCWA, 2017).

In addition, the Nahr El Kabir basin is likely to experience an increase in the magnitude of peak flow and flood frequencies over the 21st century, with a significant rise in the trends for the 100-year flood values (Figure 82) (ACSAD/ESCWA, 2017).





SU35 and SU40: the number of days with average temperatures above 35 and 40 degrees Celsius; TR: number of Tropical Nights; CDD and CWD: for Consecutive Dry and Wet Days respectively; R10 and R20: number of days with precipitation equal or higher of 10 and 20 mm respectively; SDII: Simple Daily Intensity Indicator

Figure 82: Mean changes in selected extreme events associated with temperature and precipitation for RCP4.5 and RCP8.5 projections for the Nahr el Kabir River basin (ACSAD/ESSCWA, 2017).

In Nahr Ibrahim watershed, changes in precipitation and increase in temperature are expected to amplify the runoff coefficient by 2, and change the mean daily discharge and discharge distribution. In Nahr Ibrahim watershed, changes in precipitation and increase in temperature are expected to amplify the runoff coefficient by 2 and change the mean daily discharge and discharge distribution. Accordingly, droughts are predicted to occur 15 days to one month earlier, snowmelt floods are often replaced by rainfall floods and the peak flow occurs two months earlier (Hreiche et al., 2007).

Analysis of the effects of climate change on the Upper Litani River Basin's hydrology and water resources also revealed significant impacts on the basin. A deficit of 120 Million Cubic Meters (MCM)/year is already projected by 2050 under a BAU scenario due to increased demand. The impact of climate change and increased demand will become more apparent after 2050, whereby the deficit is expected to consistently exceed 200 MCM/year (Alameddine et al., 2018).

The average yearly water demand in the Upper Litani Basin is expected to reach 500 MCM/year to 740 MCM/year by 2100, exceeding by far the annual renewable water resources, estimated at 320 MCM/year (average 2011–2100) under a worst-case future climate change scenario (ECHAM4-A1FI fossil intensive) and 370 MCM/year under the most optimistic scenario (CSIRO2-B2 ecologically friendly). Model simulations showed that the Upper Litani River Basin is highly vulnerable to projected future climate changes, putting at risk the current government plans aiming at increasing agricultural areas in the basin up to 900 km^2, of which 520 km^2 would be intensively irrigated (Alameddine et al., 2018).

Accordingly, a more integrated and strategic adaptation planning to the river basins is needed to tackle their high vulnerability. Various adaptation options show that only a fully integrated watershed development plan, integrating both supply- and demand-side measures, can lead to a more sustainable system. Such a system should include limited expansion in agricultural practices, changed cropping patterns, improved irrigation, enhanced connectivity, and network rehabilitation, in addition to improved water reuse and wastewater treatment.

Table 32 presents different adaptation alternatives studied for the upper Litani River Basin, which can be implemented in other river basins across Lebanon to increase the reliability of such systems, strengthen their resilience to climate change, and ensure sustainable environmental flows and water quality.

Table 32 **Possible management adaptation options for Litani River Basin (adapted from Alameddine et.al, 2018)**

Alternatives	Description of scenario	Simulation results of each management scenario
Reference ('Do Nothing')	Scenario with the same current water resources practices: • Economic development stable: water demand ~10% of urban demand by 2100 • Water consumption per capita 160 l/capita/day • Agricultural area stable (290 km² irrigated, 800 km² total agricultural lands • System losses 52.5%; irrigation efficiency 63% • Crop type distribution (55% mixed vegetables, 25% fruits, and 20% wheat) receives up to 15 MCM of water from Qaraoun Lake	• Water demand expected 500 MCM/year by 2100 • System reliability reduced to as low as 66% • Duration of system failure increased to around 4.2 months
Non-Conservative Agriculture	Scenario representing the current governmental plan for the basin. No specific adaptation measures implemented. • Moderate economic development: water demand ~ 30% of urban demand by 2100 • Water consumption per capita 180 l/capita/day by 2100 • Increasing agricultural area (520 km² irrigated by 2040 and stabilizing; 900 km²) • System losses 52.5%; irrigation efficiency 63% • Crop type distribution: (56% mixed vegetables, 19% fruits, and 25% wheat) • Receives up to 15 MCM of water from Qaraoun Lake	• Water demand expected 740 MCM/year by 2100 • The Upper Litany River Basin supply the total water demand only 50% of the times
Conservative Agricultural	Scenario assumes limited expansion in agricultural practices, while considering different demand side adaptation measures, focusing primarily on reducing agricultural water consumption by changing cropping patterns. • Economic development stable: water demand ~10% of total urban demand by 2100 • Water consumption per 160 l/capita/day • Increasing agricultural area (390 km² irrigated by 2040 and stabilizing, 800 km² total agricultural lands) • System losses 42.5%; irrigation efficiency 73.25% • Crop type distribution (40% vegetables, 15% fruits, and 45% wheat) • Receives up to 85 MCM of water from Qaraoun Lake	• Water demand expected 400 MCM/year by 2100 • System's reliability drops to between 73% and 88% • Duration of failure is expected to increase up to 4 months. • Reduced water deficits to levels slightly higher than 250 MCM • Reduced agricultural water consumption (Improved Irrigation) • Change in type of crops • Enhanced connectivity Improvement in agricultural technology & research

Management-Based Adaptation	Scenario assumes limited expansion in agricultural practices, while considering different demand side adaptation measures, focusing mainly on reducing losses from the supply system • Moderate economic development: water demand 20% of total urban demand by 2100 • Water consumption per capita 140 l/capita/day • Increasing agricultural area (390 km² irrigated by 2040 and stabilizing, 800 km²) • System losses 37.5%; irrigation efficiency 70% • Crop type distribution (45% vegetables, 20% fruits, and 35% wheat) • Receives up to 45 MCM of water from Qaraoun Lake	• Water demand expected 500 MCM/year by 2100 • High water deficit, due to limited ability of supply-side measures to reduce deficits • Water reliability varying between 65 and 74% • Enhanced connectivity • Network rehabilitation • Reduced agricultural water consumption (Improved irrigation) • Change in crop types Water conservation/ Sustainable water use (domestic water consumption)
Structural Focused	• Scenario accounts for increases in agricultural practices, with emphasis on supply-side adaptation measures • Water demand 500 MCM/year • Moderate economic development: water demand 30% of total urban demand in 2100 • Water consumption per capita 180 l/capita/day by 2100 • Increasing agricultural area (390 km² irrigated by 2040 and stabilizing, 800 km²) • System losses 20%; irrigation efficiency 69% • Crop type distribution (45% vegetables, 20% fruits, and 35% wheat) • Wastewater treatment and increased water-use efficiency • Receives up to 45 MCM of water from Qaraoun Lake	• High water deficit, due to the limited ability of supply-side measures to reduce deficits • Water reliability varying between 65 and 74%. • Enhanced connectivity • Network rehabilitation & expansion (infrastructure/ distribution) • Wastewater treatment • Increased water-use efficiency (water reuse, water recycling)
Full Development	Scenario assumes the implementation of a full suite of potential demand and supply-side adaptation measures at the basin level • Water demand 740 MCM/year • Moderate economic development: water demand 30% of urban demand in 2100 • Water consumption per capita 58.4 m³/capita/year (160 l/capita/day) • Increasing agricultural area (390 km² irrigated by 2045 and stabilizing, 800 km²) • System losses 20%; irrigation efficiency 73.25% • Crop type distribution: (40% vegetables, 15% fruits, and 45% wheat) • Wastewater treatment and increased water-use efficiency • Receives up to 85 MCM of water from Qaraoun Lake	• Minimal water shortages, ~20 MCM to ~50 MCM/year under the worst climate scenario • overall system reliability ranged between 78 and 92%. • The river basin would be able to supply between 86 to 94% of its water demands • Projected that the annual water deficit would not exceed the 150 MCM/year threshold even under the driest year modeled under the worst-case climate change scenario. • Enhanced connectivity • Network rehabilitation & expansion (infrastructure/ distribution) • Wastewater treatment • Reduce agricultural water consumption (Improved Irrigation)

All six alternatives assume of population growth (+1.45 million by 2100)

Impact of climate change on snow

Snow cover area and snow cover days' analysis between 1967 and 2019, and its correlation with temperature, demonstrates a decreasing trend of snow presence with the increasing average temperatures over the Lebanese mountains.

Studies have specifically shown a general downward trend of snow amounts for 1967-2009 and 2012- 2018, and a decrease in time residence of snow from 110 to 85 days due to higher melting rates and an interannual decrease in snow cover (70% difference between 2013 and 2018) (Figure 83) (Shaban, 2011; Halwani and Halwani, 2022). The coverage of snow fields was 10 times smaller in 2018 than in 2017, 12 to 50 times smaller in March and April in Akfka and Mzaar areas, indicating that snow melts are being expected earlier with time (Halwani and Halwani, 2022); Studies have also shown that an increase of 2°C in the Nahr Ibrahim Catchment area can reduce snow width by approximately 50% and replace the snowmelt floods of April–May by rainfall floods in February–March, leading to drought periods occurring 15 days to one month earlier (Hreiche et al., 2007).

Considering that snowfall is a significant fraction of the total precipitation and water availability, it bears notice that climate change will significantly decrease groundwater recharge and surface water availability during the dry months of the year (El Beyrouthy, 2022). As a result of the reduced snow cover in mountainous areas and changes in the snow-albedo positive climate feedback, temperature increases are overall projected to be strongest in mountainous areas (Zittis et al., 2022).

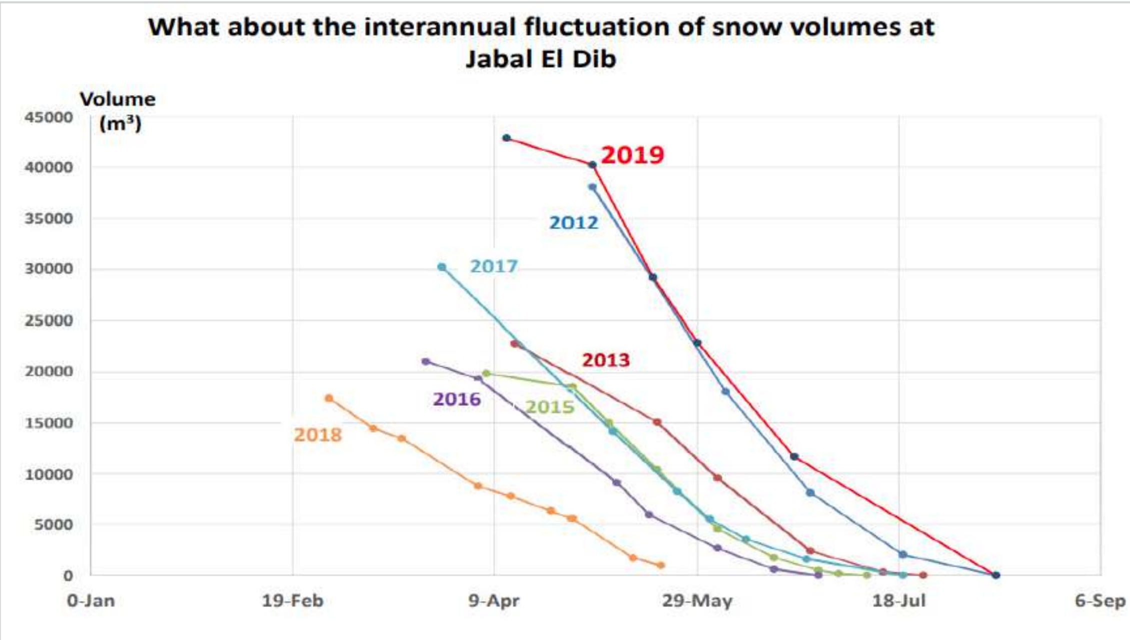


Figure 83: Interannual fluctuation of snow volumes at Jabal el Dib (Najem, 2020)

Impact of climate change on groundwater

Groundwater volume in major aquifers in Lebanon has already declined by 35-40% during the last four decades according to recent studies, resulting in the lowering of the water table (by 30-35m) and the increased contamination of the shallow groundwater due to insufficient water for irrigation and excessive use of fertilizers and chemicals (Shaban, 2019).

Groundwater resources in most of the Eastern Mediterranean region are projected to be further limited under projected climate change conditions, particularly when considering pathways of strong radiative forcing such as business-as-usual scenarios (Zittis et al., 2022).

In general, drought caused by climate change will have considerable impacts on groundwater usage and water quality. Groundwater quantity and subtraction frequency will significantly be impacted by increased temperature and evapotranspiration as well as less snowfall or a changing period of snow cover, which feeds springs and streams that meet agricultural water demand in summer. In addition, droughts will increase the concentration of chemical and biological pollutants in groundwater and surface-water, especially in the Bekaa and South Lebanon areas of the Litani river (Verner et al., 2018).

Adaptation guidelines for water resources

Based on the climate risks recognized for Lebanon and the climate projections for the future, there is an urgent need to develop and implement adaptation plans and actions to cope with climate change. In addition to the adaptation measures proposed for river basins and saltwater intrusion, general adaptation guidelines for the water sector include:

- Adoption and implementation of the National Water Strategy of Lebanon (2019) and the Beirut Water Declaration (2015)
- Building of an operational and sustainable legal and institutional framework to ensure a proper management of the water sector allowing the development of sustainable and efficient services
- Improvement of infrastructure to support water conservation, through the rehabilitation of the existing water infrastructure and supply network (reservoirs, canals, network, meters, etc) and the control of leaks from canals and conduits through the use of modern network management and tracking systems
- Development of watershed management plans with priority given to areas susceptible to droughts and decline in precipitation
- Implementation of economic water policies (e.g., tariffs, water metering, etc.) and development of financing tools for the sector to set-up financial mechanisms allowing the sustainability and the financial balance of the services
- Improvement of coordination between different institutions and government bodies related to water sector
- Involvement of all actors in the service chain and establishing sustainable mechanisms for collaboration and coordination to improve the sector monitoring and transparency

- Implementation of water demand side management strategies to reduce water consumption in the domestic, industrial and agriculture sectors
- Promotion of water reuse at all levels, including reuse of treated wastewater and greywater, rainwater harvesting and stormwater runoff management
- Promotion of efficient use of irrigation water and expansion of the supply of surface water sources for irrigation
- Implementation of the planned wastewater treatment plants throughout the country in order to preserve surface and groundwater quality
- Drafting of a penal code for polluting water bodies based on the polluter-pays principle and developing and implementing an emergency response plan to counter pollution events
- Protection of groundwater from salinization in coastal areas though an assessment of the sea-water intrusion in the major coastal aquifers, enhancing the artificial recharge of selected aquifers and control of drillings and over-pumping
- Improvement of land use planning to account for water management plans
- Improvement of storage capacities, including though the promotion of non-conventional water resources.

4.6 TERRESTRIAL AND MARINE BIODIVERSITY

Impact of climate change on marine resources

Climate change is projected to heavily affect marine resources in the Mediterranean Basin for the coming decades. Warming, acidification, and water pollution are likely to reduce marine productivity, affect species distribution and trigger local extinction of more than 20% of exploited fish and marine invertebrates by 2050 (MedECC, 2020).

Mediterranean marine ecosystems are unique due to their high number of endemic species, but they are also highly vulnerable to local and global pressures of environmental change. The Mediterranean Sea represents the highest proportion of threatened marine habitats in Europe (32%, 15 habitats) with 21% being listed as vulnerable and 11% as endangered.

Climate change and direct human activities are impacting the integrity of marine ecosystems by disturbing plankton ecology, reducing fish stocks, and more generally causing changes in physiology, growth, reproduction, recruitment, and behavior in marine organisms. Alterations of coastal ecosystem regimes (lagoons, deltas, salt marshes, dune systems, etc.) due to human activities and climate change are affecting the flow of nutrients to the sea, the magnitude, timing, and composition of plankton blooms; as a result, they are significantly increasing the number and frequency of jellyfish outbreaks and could have negative impacts on fisheries and coastal zones (MEDECC, 2020).

Under projected climatic changes, alterations of natural habitats for commercially valuable species are likely to occur, resulting in many repercussions on marine ecosystem services such as tourism, fisheries, climate regulation, coastal protection, and ultimately on human health. Although small pelagic species, thermophilic and/or exotic species of smaller size and of low trophic levels could benefit from environmental change, large-sized species, often with commercial interest, may find conditions for survival reduced (MEDECC, 2020).

In addition, the rapid spread of non-indigenous fish species represents a serious problem for trophic networks and fisheries in coastal areas, due to the local extinction of species that are preys of these generalist fish. In the future, environmental change, particularly warming, decreasing nutrient replenishment, and ocean acidification, are expected to cause changes in plankton communities at different levels, from phenology and biomass to community structure.

Impact of climate change on forests and terrestrial biodiversity

Eastern Mediterranean countries with relatively temperate climates that favor forest and shrubland biomes such as Lebanon, are the most affected by forest fires, which can be exacerbated by climate change. Severe drought events, which are expected to be more frequent in the future, can pre-condition the area for forest fires, predominantly during the warm and dry part of the year, as a positive correlation has been identified between the number of fires and area burned and annual drought episodes (Dimitrakopoulos et al., 2011). Recently in October 2019, extreme heat conditions in Lebanon coincided with massive wildfires, indicating that the fire season is prolonging to autumn months.

By the end of the century, changes in temperature, relative humidity, and surface wind speed can more than double the risk of extreme fire-weather conditions in the Eastern Mediterranean and Middle East region. This is mainly caused by the combined warming and drying of the region, associated with more frequent and extreme heatwaves and drought events (Zittis et al., 2022).

The Lebanese forestry sector is vulnerable and already threatened by forest fragmentation, quarries, grazing practices, overexploitation of forests, poorly enforced legislation, and pests and disease. Yet, the biggest threat in the past few years has been climate change, especially since the main causes of forest degradation are forest fires, land erosions, storms, and heavy winds (Abdallah et al, 2018). Figure 84 highlights financial damages caused by such extreme events in Lebanon.

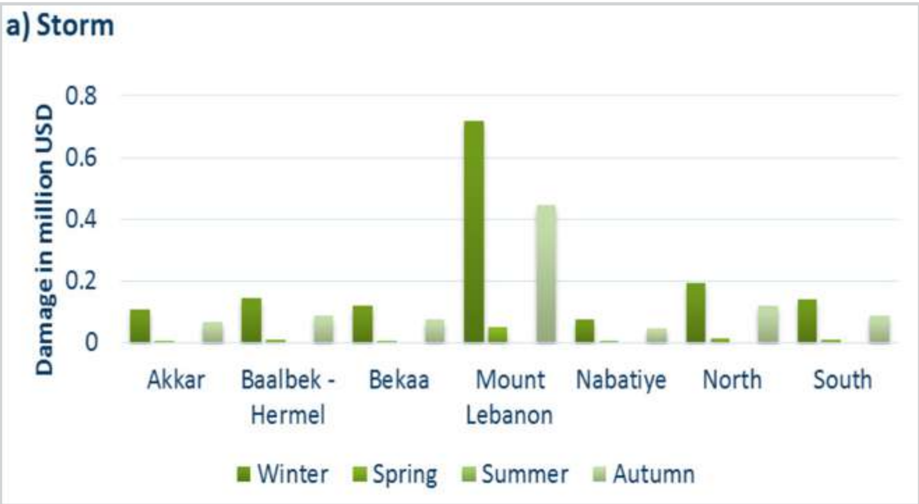


Figure 84: Damage (in $US millions) on forestry sector from a) Storm, b) Heavy Wind, c) Wildfires, and d) Land erosions/Landslides in governorates according to seasons (Adapted from Abdallah et al., 2018)

Terrestrial biodiversity is also highly threatened by climate change as drier climate and increased human pressure are expected to cause significant impacts forest productivity, burnt area, freshwater ecosystems, and agro-systems during the 21st century (MedECC, 2020).

Since the 1980's, biodiversity changes have occurred more quickly and extensively in different Mediterranean species groups and habitats than before. Species loss is marked by a general trend of homogenization (loss of vulnerable and rare species) recorded in several species' groups, and by a general simplification of biotic interactions (loss of specialized relationships).

In addition, over the last five decades, agricultural production has increasingly been impacted by loss of pollinators, with an increase three-fold in the number of crops requiring the intervention of pollinators. Mediterranean drylands have a significant and specific biodiversity value, with most plants and animals highly adapted to water-limited conditions (MedECC, 2020).

In addition, a general reduction of forest productivity in the medium- and long-term is likely associated with higher mortality and dieback, particularly for species or populations growing in water-limited environments, which constitute most Mediterranean forests (MedECC, 2020).

Adaptation guidelines for Biodiversity and Forests

Based on the climate risks projections for the future for the Mediterranean region in general and Lebanon in specific, it is important to develop and implement adaptation plans to increase the resilience and adaptive capacity of forests and terrestrial biodiversity. To this end, adaptation guidelines for Lebanon include:

1- Strengthen the legal and institutional framework to integrate climate change needs

- Revise protected areas legislation, construction law, urban development code and forest code to account for and orient existing land use practices related to natural resources use, grazing, wood cutting and ensure protection of sensitive ecosystems.
- Expand protected areas (in number and areas) to include more sensitive habitats and more vegetation / bioclimatic zones.
- Mainstream biodiversity conservation and ecosystem management in policy making and legislation development related to quarrying, construction, water use, education, etc.
- Encourage private initiatives promoting forest protection and sustainable use of forest resources.
- Reduce habitat fragmentation through controlled monitoring of urban expansion and through planning of natural corridors
- Ensure appropriate priorities for forests and biodiversity in the National Adaptation Plan (NAP)
- Implement the National Biodiversity Strategy (2015)

2- Integration of climate change and landscape levels planning in local/ regional development plans in Lebanon

- Endorse urban planning guidelines
- Enhance the ability of species to move

and migrate within their climatic envelops through planning the extension of existing protected areas and promoting landscape connectivity in terms of natural corridors between forests and other wooded lands

- Emulate long distance dispersal through habitat restoration.
- Diversify habitat type, forest types and land use at landscape level.

3- Improve data and support research

- Take stock of existing forest sector knowledge and policies and identifying gaps
- Analyze current and future climate scenarios in relation to forests and forests-dependent people and ecosystems
- Identifying and assessing forest and biodiversity's vulnerabilities to climate change
- Developing and update the forests and biodiversity's vulnerability map to climate change
- Identifying where forests and trees can contribute to strengthen climate change adaptation in identified vulnerable sectors, such as crops and livestock, water, cities and human settlements, energy, and health
- Identifying adaptation options for forests, tree systems and forests' dependent people, with emphasis given to areas which may face more heatwaves and droughts (either separately or as a compound event) and lower precipitation rates
- Increase awareness on ecosystem services and climate change to key target groups such as government agencies, order of engineers and architects, universities (introduction of related courses), schools (revision of curriculum).
- Collect, conserve and disseminate traditional and local knowledge, innovations and practices related to biodiversity conservation.
- Promote research and implementation of soil conservation, as soil carbon not only constitutes a carbon sink, but also improves site productivity.
- Promote and inform on forest ecosystems services.

4- Develop Forest management plans

- Prepare management plans for the most vulnerable ecosystems to climate change,
- Implement effective fire management strategies through forest management.
- Adopt an ecosystem/ community approach for reforestation activities
- Increase genetic, species and landscape diversity within the limits of ecological composition (vegetation series)
- Establish collections of seeds for the main forest tree species and understory species (seed/gene banks).
- Establish natural and ecological corridors to promote protected areas networks.
- Adopt effective land management practices, such as sustainable grazing, to prevent large reductions in ground cover.
- Conserve and/or restore biotic dispersal vectors: birds, insects, and migratory species
- Plan reforestation activities including future migration anticipation

4.7 COASTAL CITIES, SOCIETIES, AND TOURISM

Mediterranean cities are growing due to increasing population and socio-economic change, notably on the coasts of southern countries. Impacts of climate change on urban areas and cities are expected to be disproportionally high due to a concentration of population and assets – especially in high-risk prone areas – in combination with hazard-amplifying conditions (e.g., increased run-off resulting from soil sealing, or urban heat island effects).

The Mediterranean has a rich history as well as exceptional natural and cultural landscapes, which attracted more than 360 million tourists in 2017. In the past 20 years, the gross domestic product contribution from the tourism sector has steadily increased by 60% in Mediterranean countries. As a significant part of Mediterranean tourism is oriented towards coastal outdoor activities, tourism will likely be affected by climate change through reduced thermal comfort, degradation of natural resources, including freshwater availability, and coastal erosion due to sea level rise and urban development (MEDECC, 2020).

Impact of climate change on coastal cities

With an area of 10,452 km^2, Lebanon is considered a highly urbanized country. In fact, more than 87% of its population is living in urban areas, 64% of which live in large urban agglomerations (Beirut and its suburbs, Tripoli, Saida, Zahle and Tyre) . Rates of urbanization[18] have increased significantly over the last 60 years. In 1963, urbanized areas amounted to 221 km^2, which then increased to 465 km^2 in 1994 and further to 741 km^2 in 2005. This growth is expected to reach 884 km^2 in 2030 (UN-Habitat/ESCWA, 2021, GRUMP,2022).

The coast covers 225 km, with 50 km covered by urban areas, 49 km by beaches and dunes, 11 km by bare rocky outcrops, 34 km by fruit trees, 24 km by large industrial or commercial units, 18 km by tourism resorts and 23 km by ports. It is the wealthiest zone, but also the most vulnerable area of the country given that most industrial, commercial, and financial activities are concentrated in this corridor. The 500 m wide coastline corridor holds in fact 40% of the urbanization, 41% of agricultural areas, and 19% of the remaining natural areas (CDR, 2005, UN-Habitat, 2021).

The projected increases in temperature (up to 4.9°C by 2100) and decrease in precipitation (up to 22% by 2100) (see climate risks section A) in addition to sea level rise (an increase of 37-90 cm) stipulate a hotter and drier climate projected in Lebanon, including on the coast, in addition to seawater intrusion into aquifers, higher risk of coastal flooding and inundation and increased erosion of the coast, cover sand beaches, and will impact coastal eco-systems.

An assessment of Lebanon's coastal zones, conducted under the Second National

[18] Based on Socioeconomic Data and Applications Center (SEDAC), areas are considered urbanized when encompassing a population greater than 5,000

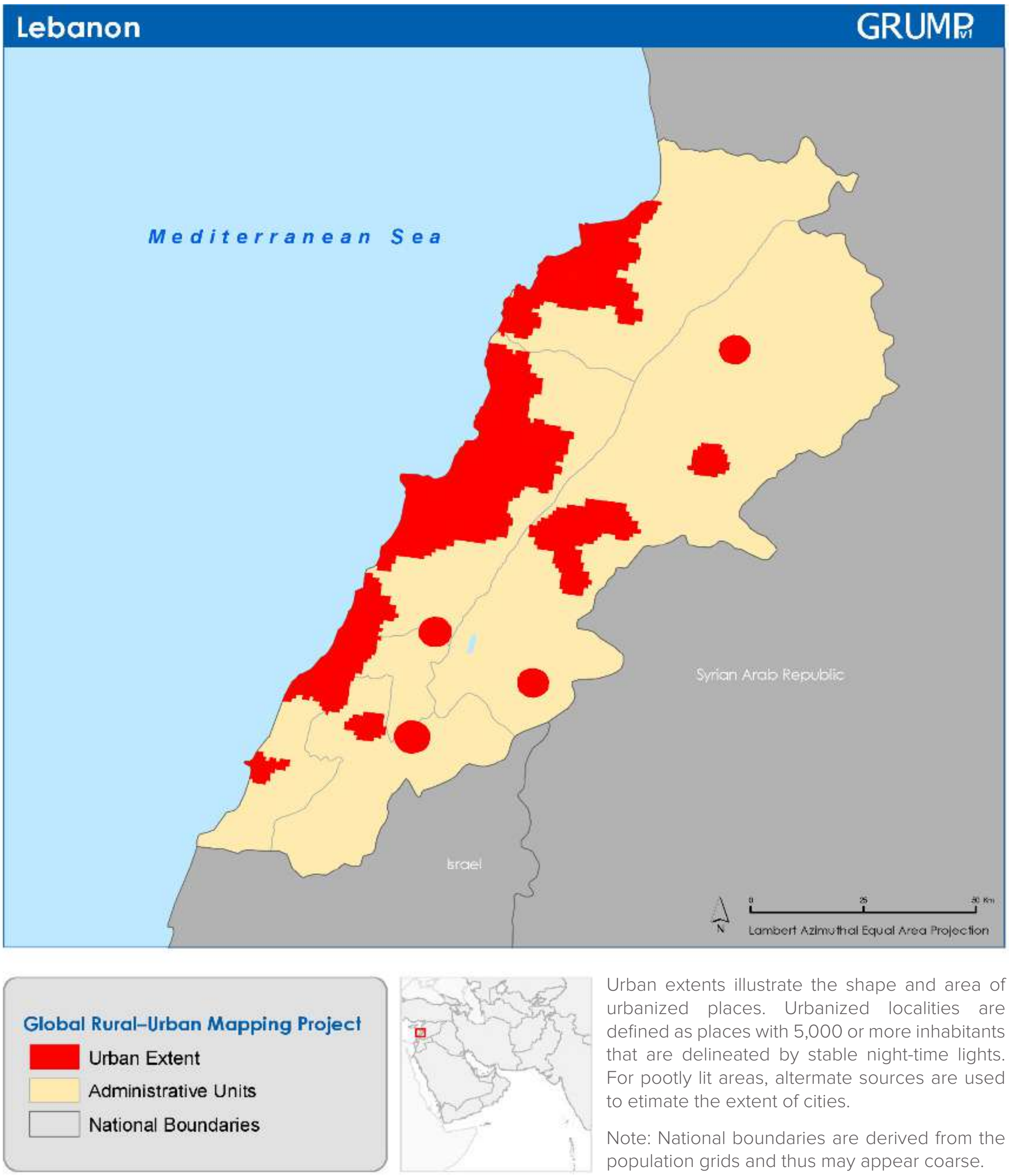


Figure 85: Urban extent according to SEDAC mapping

Communication (MoE/UNDP/GEF, 2011) showed that their vulnerability to climate change varied between 'moderate' to 'very high', rendering these units as areas of concern (MoE/UNDP/GEF, 2011). This is aligned with global analysis that showed that in general urban agglomerations have a high sensitivity to climate change due to urban heat from increased temperatures, presence of construction and buildings in flood-prone areas near the coastline, and the existence of poor communities in those areas (IPCC, 2013).

Impact of climate change on coastal tourism and local economic development

Climate change imposes a burden to tourism due to the increase of temperature and other interrelated climate risks such as extreme weather events, heatwaves, sea level rise, floods, etc. As tourism is relatively labor-intensive, a reduction in tourism demand will result in job losses and in lower wage incomes potentially increasing regional or rural–urban inequality and imposing further costs on society. To this end assessing vulnerability of tourism to climate change and designing adaptation plans to ameliorate impacts has become a major priority in the tourism sector.

In a study conducted by the Issam Fares Institute (IFI) and Friedrich Ebert Stiftung (FES) in 2022 (IFI/FES, 2022), the coastal cities of Batroun and Tyre were selected for a vulnerability assessment based on a set of indicators (Table 33 and Table 34). The assessment focused on infrastructure, tourism and fisheries, the vulnerability of these sectors to climate change impacts and the overall impact on the resilience of coastal cities.

Table 33 Indicators for the tourism sector

Potential Impact	Vulnerability Components	Components	Indicators
Destination impact	Exposure	Temperature	Change in annual temperature
			Mean monthly temperature
			Number of hot days
		Extreme precipitation	Number of urban floods during summer (rainfall above 20mm)
			Extreme precipitation events
	Sensitivity	Land Use Land Cover	Green cover extent
			Touristic sites located in flood prone area on the coast
			Shore erosion level
			Area constructed in coastal zone
		Environmental Criteria	Air quality (index, relative to standards...)
			Generators in the city
			Acidification of marine water
			Water quality (safe for swimming)
	Adaptive capacity	Funding	Budget of the municipality for sustainable development of touristic sites
			Budget of the ministry of culture for sustainable development of touristic sites
		Governance	Guidelines for sustainable practices in tourism

Potential Impact	Vulnerability Components	Components	Indicators
Operational impact	Exposure	Temperature	Change in annual temperature
			Mean monthly temperature
			Number of hot days
		Extreme precipitation	Number of urban floods during summer (rainfall above 20mm)
			Extreme precipitation events
	Sensitivity	Structures	Elevation above sea level
			Protection (Extent of break waters)
		Risk to sites due to location	Proximity to shore
	Adaptive capacity	Funding	Financial projects for climate change activities
		Maintenance	Frequency of maintaining and rehabilitating touristic/ archeological sites
		Governance	Integrated coastal zone management plan
			Mainstreaming of Climate Change impacts in urban/ master/local plans
			Emergency management plan (DRM, insurance etc.)
			Syndicates for touristic areas

Table 34 **Indicators for the infrastructure sector**

Potential Impact	Vulnerability Components	Components	Indicators
Performance	Exposure	Temperature	Change in annual temperature
			Mean monthly temperature
			Number of hot days
		Precipitation	Change in annual precipitation
			Mean monthly precipitation
		Storms	Extreme precipitation events

Potential Impact	Vulnerability Components	Components	Indicators
Performance	Sensitivity	Stormwater drainage/ wastewater	Proportion of wastewater network at flood risk
			Age of wastewater network
			Sewage network coverage by population
			Combined sewage outflow
		Water supply	% Non-revenue water
			Age of water network
			Water Supply Coverage by Population
			Hours of public water supply
		Electricity	Location of electricity poles/lines
			Age of the electrical network
			Type of cables used for electricity
			Weather-related disruption of electricity supply
			Percentage of electricity demand being met by existing power supply
		Transportation	Percentage of roads at risk from flooding
			Age of road network
			Percentage of roads that are near the coast
			Percentage of underpasses
		Telecommunication	Location of telecommunication network
			Proximity of telecommunication network to the sea (% located in coastal plain)
			Material used in telecommunication network
			Telecommunication structures (such as cellphone towers) in flood prone areas
			Disruption of telecommunication services due to weather-related events.
Performance	Adaptive capacity	Storm Water Drainage	Frequency of maintaining and rehabilitating Storm infrastructure (pipelines, cables)
		Water	Frequency of maintaining and rehabilitating water infrastructure (pipelines, cables)
			Water network storage capacity
		Electricity	Frequency of maintaining and rehabilitating electricity infrastructure (pipelines, cables)
			%Renewable energy
		Transportation	Frequency of maintaining and rehabilitating transport infrastructure
		Telecommunication	Frequency of maintaining and rehabilitating telecom infrastructure (pipelines, cables)
		Governance	Emergency management plan (DRM, insurance etc.)
			Funding for construction and maintenance of infrastructure
			Mainstreaming of Climate Change impacts in urban/ master/local plans

The tourism sector was identified as the most vulnerable sector in both coastal cities, which are popular destinations for both foreign and Lebanese tourists. Both potential impacts (destination and operational) are mainly affected by daily and monthly (mean, max and min) temperatures, heat waves and extreme precipitation events. Furthermore, warmer temperatures will increase heat stress for tourists as well as the cooling costs (MoE/UNDP/ GEF, 2015; IFI/WFP, 2021).

Extreme precipitation events will contribute to the destruction of the tourism infrastructure, blocking roads and changing the hydrologic cycle (Grimm, Alcântara, & Sampaio, 2018). Extreme precipitation events will also contribute to beach erosion, lost sand, destruction of reef and sediment plumes (Becken, 2020).

The increase in acidification of marine water will have the strongest effect on the tourism destination. In fact, the acidification can change the marine ecosystem, decrease natural shoreline protection and increase the risk of inundation and erosion of the low-lying coastal areas (Nader et al., 2021).

Adaptation guidelines to climate change for cities and tourism

Considering urbanization trends, sustainable spatial planning and the design of climate resilient cities are important for ameliorating the adverse effects of climate change. The synergistic impacts of global and regional warming plus the urban heat island effect makes such measures even more urgent. Adaptation guidelines to climate changes for Lebanese coastal cities include:

- Implement the Integrated Coastal Zone Management strategy presented in 2015, which was further emphasized in 2021 through the NDC.
- Implement the National Biodiversity Strategy (2015) and conduct economic valuation studies
- Enforce laws and regulations related to coastal zone management including illegal construction, illegal sand extraction
- Address administrative overlapping of authorities and defined roles and responsibilities of national and sub-regional institutional
- Focus adaptation measures on the fisheries sector, as well as on the local community that lives in the coastal area and depend directly on marine resources for their wellbeing.
- Integrate climate change and its effects in urban planning and introducing protective sustainable and eco-friendly measures through soft engineering techniques
- Modify urban and spatial planning to take note of climate change risks and impacts
- Enhance urban greening and integrate nature-based solutions to spatial planning
- Promote green roofs in public and private buildings
- Use cool materials in buildings and artificial surfaces
- Remove sources of anthropogenic heat (for instance by restricting motor traffic in favor of mass transit systems, converting streets to pedestrian pathways, etc.)
- Improve the energy and water efficiency of the built environment
- Design and implementing coastal erosion protection measures
- Secure the capacity of the energy system in the event of heat waves

Climate-proofing infrastructure is necessary to withstand present and future climate change impacts in the coming decades. Investments in research and development will greatly reduce the costs of adaptation. Table 35 presents the risks associated to climate change as well as the specific impacts on cities and potential adaptation solutions.

Table 35 Risks associated to climate change along with the impacts on cities and adaptation solutions

Climate change	Associated risks	Impacts of cities	Adaptation solutions
Higher temperatures	Enhanced urban heat islands	• Health risks • Increased consumption of energy for cooling • Increased photochemical air pollution	• Plant trees and develop parks in the urban areas for cooling effect • Use cool materials at constructions, pavements, and road surfaces • Mitigate anthropogenic heat sources
Heat waves of increased frequency, duration, and intensity	Thermal discomfort	• Health risks • Increased consumption of energy for cooling • Increased photochemical air pollution	• Plant trees and develop parks in the urban areas for cooling effect • Use cool materials at constructions, pavements, and road surfaces • Mitigate anthropogenic heat sources
Extreme precipitation	Floods	• Losses of lives and property • Reduced water quality	• Maintain trees coverage and use semi-permeable materials to facilitate infiltration in the soil and reduce runoff
Sea level rise	Inundations	• Loss of properties • Degradation of the natural environment at the coastal zone	• Conserve and restore mangroves Plant trees along the coastal zone
Increased frequency of forest fires in the vicinity of the city	Increase of suspended particles Loss of forestry	• Health risks associated with respiratory functions • Higher risk for floods • Deterioration of urban microclimate	• Prevent forest fires • Promote reforestation plans • Manage the forest-urban interface

In addition to the proposed adaptation measures for coastal cities, specific measures have to be designed and implemented to minimize the impact of climate change on the tourism sector. To this end, adaptation guidelines for tourism at the coastal level include:

- Assess and update national tourism plans to take note of climate change and include climate change adaptation measures in its goals
- Create financial incentives to encourage investment in more sustainable touristic activities such as ecotourism
- Improve local microclimate with urban greenery and nature-based solutions
- Promote shading in open air tourist attractions

- Monitor coastal erosion and promote protection measures for sea level rise
- Design and implement energy retrofit programs for hotels to account for climate change
- Secure energy for cooling especially in the event of heatwaves
- Improve health facilities in touristic areas to cope with excessive heat
- Develop emergency plans for extreme weather events in touristic areas.

4.8 PUBLIC HEALTH AND HEALTHCARE FACILITIES

Impact of climate change on public health

Extreme climatic changes will have direct and indirect impacts on public health (IPCC 2021; WHO, 2021). Heat related risks are one of the biggest challenges associated with rising temperature, for instance there will be increased incidences of infectious diseases and changes in the geographical distribution of disease vectors, such as mosquitoes, waterborne pathogens, in addition to poor water quality, and air pollution, that would further challenge weak health systems. Additionally, higher levels of ambient CO_2 would increase allergic reactions and pulmonary diseases. Therefore, climate change can impact health directly, undermining its social determinants, and threaten various environmental services provided by existing natural systems, presenting multiple hazards that interact with and exacerbate vulnerability factors through several exposure pathways (Figure 86).

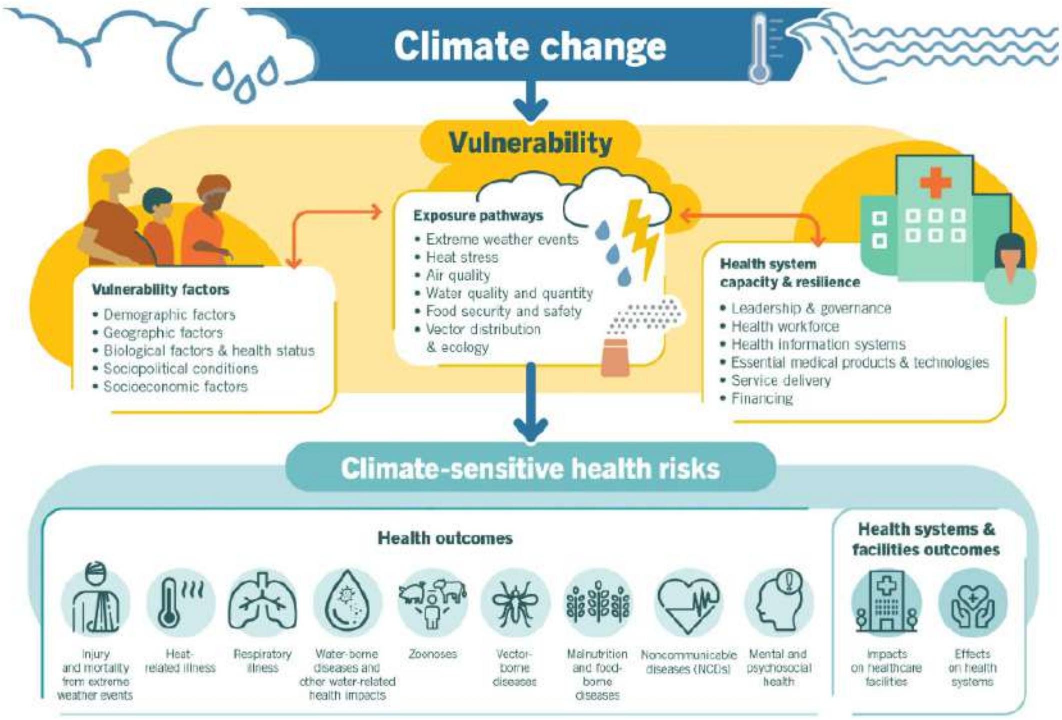


Figure 86: An overview of climate-sensitive health risks, their exposure pathways and vulnerability factors, **Source:** Climate change and health (WHO, 2021)

In addition to physical health risks, climate change-induced phenomenon and disasters would have mental health consequences, while they could increase post-traumatic stress disorders among the population (Woodward and Porter, 2016). Table 36 summarizes WHO's climate change induced disasters on public health.

Table 36 Summary of health impacts for several climate change impacts (adapted from WHO, 2021)

Extreme Weather Events	Heat Stress and Extreme Heat	Slow-onset climate events	Decrease in water quality and quantify	Food security	Changes in vector-borne diseases
Landslides, wildfires, floods, storms	• Increase in min-mean-max air temperatures, extreme hot days, heat waves and the urban heat island effect	• Drought, • Desertification • Sea level rise	• Contamination of water sources through flooding • Changes in rainfall patterns	• Changes in seasonality and rainfall that have negative agricultural effects • Increase in temperature	• Shifts in the range of pathogens • Appearance of pathogens in new areas
	• Worsens respiratory and cardiovascular conditions • Exacerbates allergies • Heat induced illnesses • Decreased productivity especially for outdoor workers	• Increase in food and water insecurity • Forced migration • Poverty	• Increase threats to water-borne diseases • Harmful algae blooms • Dehydration	• Foodborne illnesses • Undernutrition	• More diseases • Pandemics • Greater burden on health systems

Population vulnerability to the impacts of environmental and climate change is strongly influenced by population density, level of economic development, food availability, income level and distribution, local environmental conditions, pre-existing health status, and the quality and availability of public health care. Vulnerable populations include the elderly, the poor, and people with pre-existing or chronic medical conditions, displaced people, pregnant women, and babies. People who are disadvantaged due to a lack of shelter, clean water, energy, or food are more at risk from extreme events. Heatwaves are responsible for high mortality rates causing tens of thousands of premature deaths, especially in large cities and among the elderly. Heat-related morbidity and mortality has been partially reduced in recent years by more efficient protection of people (MedECC, 2020).

In Lebanon, summer months are known for high levels of humidity which coincides with hot temperatures. Previous research indicated the relationship between climate change-induced temperature rise and premature mortality in Lebanon (El-Fadel and Ghanimeh, 2013). Moreover, years of civil war in Lebanon (1975–1990) and the recent economic crisis and Beirut port explosion resulted in considerable destruction in its towns and cities, with significant impacts on buildings and infrastructure. Most notably, the electricity sector continues to suffer from power outages, which adds to the vulnerability of the people in exposing them further to the heat related illnesses during summer months. According to the RICCAR report, the expected increase in the warming trend in Lebanon, reaching up to 43 additional days with maximum temperatures higher than 35°C, will affect public health. (ESCWA, 2015; MoE/UNDP/GEF, 2016).

Increases in temperature and concurrent heat stress are associated with increased mortality risks from hyperthermia, and respiratory and cardiovascular diseases (MoE/UNDP/GEF, 2015). Exposure to extreme heat can also exacerbate pre-existing conditions such as cerebral, respiratory, and cardiovascular conditions (Portier et al., 2010). Furthermore, intense short-term fluctuations in temperatures cause heat stress (hyperthermia)/ extreme cold (hypothermia) conditions that would result in increased death rates from heart and respiratory diseases and heat–related illnesses (dehydration, rash, cramps, heatstroke, heat exhaustion) (Honda et. al 2014; WHO and UNFCCC, 2021).

As such, projections reflect heat stress related deaths in Lebanon among elderly (>65 years) would increase from 2 deaths per 100,000 to 48 per 100,000 in 2080 under a high emission scenario RCP8.5, and as such stresses the importance of rapidly reducing emissions that would significantly decrease the rate to 10 deaths per 1,000,000 (Honda et.al, 2014; WHO and UNFCCC, 2021). When using the Wet Bulb Temperature as an indicator, studies in Lebanon showed that the increase in the probability of crossing the “dangerous” (24.6°C) and “extremely dangerous” (29.1°C) thresholds of Wet Bulb Temperature during summer months and the increase in Heat Stress Duration Index (HSDI) days under a 1.5°C and 2°C warmer climates will translate into an increased population exposure to HSDI events by 0.1 to 0.3 million person-days compared to the reference period in 1.5°C and 2°C warmer periods (Figure 87) (MoE/GCF, 2021).

In the absence of (artificial) cooling, a prolonged exposure to extreme heat stress may lead to different types of illnesses (such as heat stroke, heat exhaustion, heat cramps etc.). Therefore, extremely poor population with very limited resources to afford (artificial) cooling such as air conditioning is considered most vulnerable under these situations. It is estimated that the risk ratio[19] for “extremely dangerous” thresholds (29.1°C), range between 1.8[20] and 3.8 are for June, July, August at 1.5°C of global warming level which increases to 2.6 and 7.6 for 2°C (Figure 88) (MoE/GCF, 2021).

[19] A risk ratio (RR), also called relative risk, compares the risk of a health event (disease, injury, risk factor, or death) among one group with the risk among another group. It does so by dividing the risk (incidence proportion, attack rate) in group 1 by the risk (incidence proportion, attack rate) in group 2.

[20] A risk ratio of 1.8 indicates that the exposed group to climate change impacts has 1.8 times the risk of having the outcome as compared to the unexposed group.

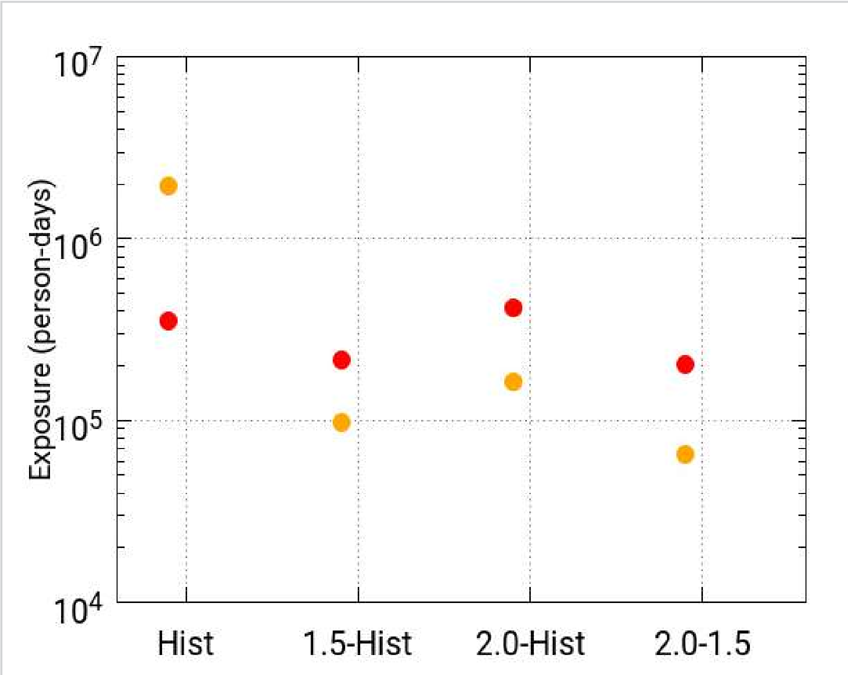


Figure 87: Risk ratios between the reference and the future warmer climate for each month at the poverty levels of 22% (left) and 11% (right).

Figure 87 Population exposure to HSDI events in mean number of person-days per year which considers population values at levels of 2010 for HSDI of "dangerous" (24.6°C) and "extremely dangerous" (29.1°C) thresholds represented by orange and red dots respectively.

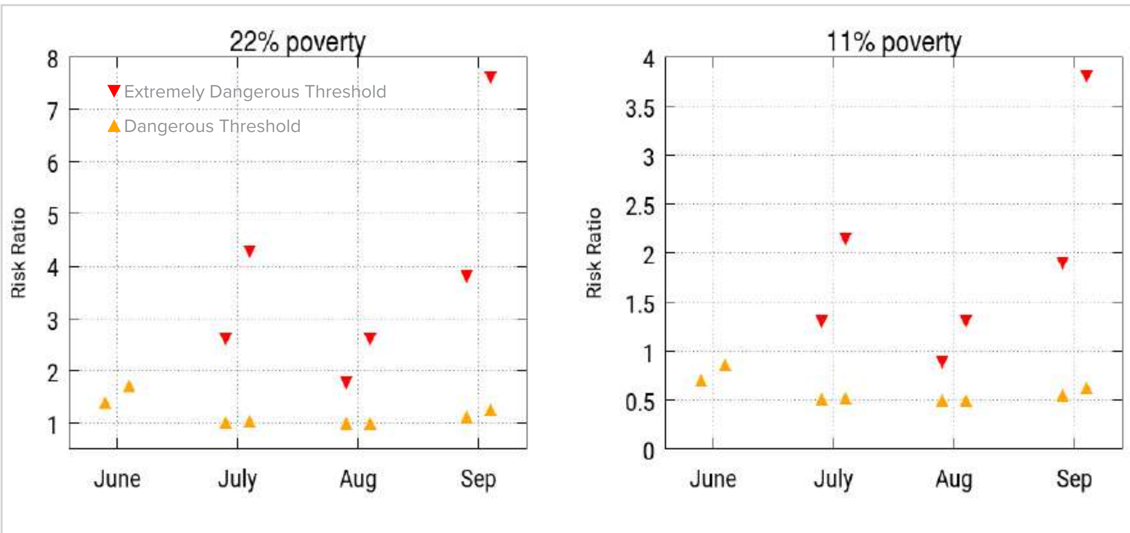


Figure 88: Risk ratios between the reference and the future warmer climate for each month at the poverty levels of 22% (left) and 11% (right).

Additionally, respiratory diseases could be exacerbated by warming-induced increases in the frequency of smog (ground-level ozone) events and particulate air pollution (D'Amato et al., 2015). Sunlight and high temperatures, combined with other pollutants such as nitrogen oxides and volatile organic compounds, can cause ground-level ozone to increase (Nuwayhid et al., 2016; ACSAD/ESCWA, 2017; Jurdi, 2021). In Lebanon, the proportion of the urban population with existing respiratory problems would be at a higher risk of damage to lung tissue as rising air temperatures would cause higher build-up of ground-level ozone concentrations (Nuwayhid et al., 2016; MoE/GEF/UNDP, 2016).

Lastly, increases in wildfires in Lebanon over the past few years, in addition to generator-based point source air pollution increases within and around most neighborhoods across the country will have a direct impact on the increase of vector and water borne diseases (Table 37).

Table 37 Climate Sensitive Infectious Diseases (Adapted from Confalonieri et al., 2007, Jurdi, 2021; WHO and UNFCCC, 2021)

	Type of Disease	Disease	Relevance to Lebanon
1	Vector-Borne diseases transmitted by arthropods such as mosquitoes, ticks, sandflies, blackflies and rodents	Malaria Dengue Fever	Malaria cases reported by MoPH all originate in Africa. Still, with the expected increase in temperature in Lebanon might widen the area of distribution of the vectors, favoring their growth and development over time. In this case, population groups with lower socio-economic status, no insurance coverage, and lower access to health care, as well as children and the elderly will be more vulnerable. Lebanon does not appear among the countries at risk of dengue transmission (Jurdi, 2021), However, with the expected increase in temperature and drought periods, dengue transmission might emerge in Lebanon.
2	Rodent-borne diseases transmitted directly to humans by contact with rodent urine, feces, or other body fluids		Environmental factors that affect rodent population dynamics include unusually high rainfall, drought, introduction of exotic plant species and food sources (Confalonieri et al., 2007). Diseases associated with rodents and ticks include leptospirosis, tularemia, viral hemorrhagic diseases plague, Lyme disease, tick borne encephalitis and Hantavirus pulmonary syndrome. Cutaneous Leishmaniosis may emerge in Lebanon through flies nesting on rodents in open fields, which manifests on the skin and is particularly sensitive for women engaged in agriculture. These diseases might flourish in Lebanon in case of increased floods (Jurdi 2021; WHO and UNFCCC, 2021).

3	Waterborne and foodborne diseases	Cholera Typhoid Hepatitis A Diarrhea	The potential contamination of drinking water supplies and disruption of sewer systems and/or wastewater treatment plants and flooding that could result from climate change could lead to an increased incidence of cholera, typhoid, and Hepatitis A cases in Lebanon (WHO, 2021). Regions with lower access to sanitation will be more exposed to water-borne diseases, and those with lower access to health care and insurance coverage, in addition to children and the elderly will be more affected (WHO and UNFCCC, 2021).

Impact of climate change on healthcare facilities

In addition to its impacts on health in Lebanon, climate change would exacerbate the challenges faced by Lebanon's healthcare system, a healthcare system burdened by various socio-economic and political factors.

Impacts on healthcare facilities due to climate change would result from: (a) direct effects, (b) effects mediated through natural systems, and (c) effects mediated by human systems. Health care facilities are expected to face increased challenges coping with climate-related risks, such as droughts, extreme temperatures, fires, and changed patterns of climate-sensitive diseases which will affect their physical and operational capacity. The increased intensity and frequency of natural hazards can affect the functioning of healthcare facilities, and result in increased demand for services. As such, climate change can affect the delivery of healthcare services in large hospitals and small facilities, and in high- and low-income settings alike. In addition, healthcare facilities' concerns can be exacerbated by climate change hazards by impacting their infrastructure, support systems, supply chains and workforce (MoE/UNDP/GEF, 2022)

A vulnerability assessment of the health care facilities to climate change conducted by the MoE/UNDP in 2022 showed a high risk, based on in the following key vulnerability areas (MoE/UNDP/GEF, 2022):

- Health Workforce (human resources, capacity development and communication and awareness raising)
- WASH and Health Care Management (monitoring and assessment, risk management and health safety regulations)
- Energy Management (monitoring and assessment, risk management and health safety regulations)
- Infrastructure, technologies, Products and Processes (adaptation of current systems and infrastructures, promotion of new systems and technologies, and sustainability of health care facility operation).

According to this study, the level of preparedness of Lebanese healthcare facilities is low and what has been achieved, to date, to improve the preparedness is relatively minimal. The analysis, which is based on the type of accreditation or certification programme that a healthcare facility has, and the degree of compliance it meets, shows that the compliance in addressing the four key vulnerability areas is minimal, even for facilities accredited by one or more accreditation programs. In addition, the accreditation coverage in Lebanon is still low with only 8% of primary healthcare centers being currently accredited and centers are not evenly distributed throughout the country with a low coverage in the most vulnerable spots such as Baalbeck and Akkar Cazas, (8.5% and 10.4%, respectively). Moreover, major deficiencies in fulfilling health workforce and infrastructure requirements, among non-accredited centers has been documented, especially in centers not supported by International NGOs.

For hospitals, the setting is also complex considering the current socio-economic and financial situation of Lebanon that is hindering accredited hospitals from following up on the Revised National Hospital Accreditation Standard 2019, especially in governmental hospitals that lack the accreditation infrastructure.

The financial crisis that Lebanon has been facing since 2019 further exacerbated these challenges with a hoarding of unpaid bills for hospitals, rejection of coverage from some insurance companies, high cost of pharmaceuticals and medical supplies, unsafe working conditions, low salary wages, and layoffs of healthcare workers and the continued fluctuation of the Lebanese Lira leading the migration of skilled personnel. Moreover, the oil and fossil fuel shortages were some of the major challenges for providing electricity through generators, especially to patients surviving on ventilators, kidney dialysis units, and other medical devices.

Adaptation guidelines to climate change for health and healthcare facilities:

Based on the climate risks recognized for Lebanon and future climate projections, it is important to develop and implement adaptation plans to cope with climate change. To this end, adaptation guidelines to climate change for health include (Jurdi, 2021):

- Develop and implement a climate and health adaptation plan, based on the National Health and Environment Strategy National Framework of Action 2021-26.
- Assess the vulnerability of public health sector to climate change, identify the current and future health effects and establish early warning systems
- Identify associated potential health impacts, and populations and locations vulnerable to these health impacts.
- Estimate or quantify the additional burden of health outcomes associated with climate change
- Identify the most suitable health interventions for the identified health impacts of greatest concern
- Develop health system response strategies, plans and projects and integrate them into national health strategies
- Evaluate periodically the impact of the plan and improve quality and effectivity of activities and measures

In addition to protecting public health from climate change impacts, increasing resilience at the health care facility level is of equal importance to effectively adapt to climate change. This necessitates an integrated approach to building climate resilience, which can be achieved through two types of interventions:

1- Direct interventions, at the micro level, that aims to develop set procedures for healthcare facilities to continuously implement and evaluate risk management programs to stay responsive to the facilities' needs under climate change related emergency events.

The most direct approach is to increase the accreditation rate of healthcare centers in Lebanon and integrating the basic requirements for: (a) health workforce (human resources, capacity development and communication and awareness raising); (b) WASH and HCW management (monitoring and assessment, risk management and health safety regulations); (c) energy management (monitoring and assessment, risk management and health safety regulations); and (d) infrastructure, technologies, products and processes (adaptation of current systems and infrastructures, promotion of new systems and technologies, and sustainability of health care facility operation).

Table 38 Summary recommendations for increasing climate change preparedness of health care facilities (MoE/UNDP/GEF, 2022)

- Determining the baseline of climate change resilience through assessing the facilities' vulnerability to climate change hazards
- Integrating WHO's checklist for climate change vulnerability in the accreditation standards and certification systems
- Increasing the geographical coverage of PHCCs to respond to impacts of climate-induced events in vulnerable areas
- Acquiring accreditation integrating basic requirements for health workforce, WASH, waste/energy management and infrastructure technologies
- Securing support by international NGOs to improve the provision of a better health workforce and infrastructure
- Annexing a complementary modified checklist to the Joint Commission International (JCI) Accreditation and the Hospital Accreditation 2019 Standards to enhance the preparedness of hospitals
- Develop a plan of action for governmental hospitals based on a modified climate change vulnerability checklist, to address direct, intermediate, and long-term interventions

2- Indirect, at the macro level, that aims to support healthcare facilities through strengthening health sector's preparedness and response to emergencies.

Complementary national policies and strategies that provide an enabling environment for the health system should be in place and building resilience and preparedness should be a cross-government priority that involves all stakeholders and actors to be able to work in a coordinated manner. WHO recommends the adoption of the 5 building blocks of: (a) health governance and policy, (b) human resources for health, (c) information systems, (d) service delivery, and

(e) financing. It is crucial to direct health governance and policy towards protecting human health from climate risks and strengthening partnership with health-determining sectors to benefit mitigation and adaption measures. This can be achieved through:

- Ensuring coordination and communication between stakeholders to raise awareness and ensure policy coherence
- Building technical, organizational, and institutional capacity
- Mobilizing resources to support effective implementation
- Directing Management Systems towards climate change research, translation of research findings to policy-making, and structured risk communication.
- Directing service delivery towards determining health risks related to disasters, water, waste, food, and air pollution and strengthen community-based risk reduction.
- Mobilizing international climate change financing for projects and programs focused on building the health systems' resilience (e.g., the GEF, Adaptation Fund, bilateral donors).

CHAPTER 5

MITIGATION ASSESSMENT

SUMMARY OF KEY POINTS

- Despite the economic, financial and social crisis that Lebanon has been witnessing since 2019, and despite its insignificant global share of GHG emissions (estimated at less than 0.07% in 2019), Lebanon is pursuing its mitigation efforts to reduce its national emissions.
- Under the NDC update, Lebanon aims at reducing its national emissions by 20% unconditionally and 31% conditionally by 2030. The NDC also sets a target of generating 18% to 30% of the electricity demand and 11% to 16.5% of the heat demand (in the building sector) from renewable energy sources (unconditionally and conditionally respectively).
- Further reductions can be achieved in transport, wastewater treatment and afforestation, as analyzed in this report.
- In the transport sector, increasing the share of hybrid vehicles to 75% of newly registered vehicles can reduce emissions up to 17% in 2050. If electric vehicles are targeted instead, a penetration rate of 50% newly registered electric vehicles (with only 25% of hybrid) can reduce emissions by 34% by 2030 and by 51% by 2050. However, with the implementation of such measures, the transport system remains characterized by being highly personal vehicle oriented. Consequently, adding a shift to public transportation can further reduce emissions by 21% by 2030 and by 48% by 2050 compared to a business-as-usual scenario.
- Potential for emission reduction can also come from the electrification. Switching 50% of new truck registrations and 75% of LCVs in 2050 to electric powertrains can reduce emissions by 40% compared to a business-as-usual scenario; while moving to electric rail (50% of heavy freight transport in 2030) can only reduce 13% of emissions, even with the elimination of tank-to-wheel emissions of trucks and using zero emission electric rail. Combining all freight mitigation options together can yield a total potential emission reduction of 49.4% by 2050 compared to a business-as-usual scenario.
- In terms of wastewater collection and treatment, treating 50% of the domestic wastewater by 90% by 2050 can reduce related emissions by 65% by 2050 compared to a business as usual scenario, while the potential of treating 100% of both domestic and industrial wastewater can reduce emissions to 55% by 2030 and 76% by 2050.

Over the last decade, Lebanon has gone through a succession of crisis that have impacted its readiness and capacity to implement mitigation actions: the Syrian refugee crisis (2011-current), the October 2019 revolution, the economic crisis, the COVID-19 pandemic (2020-2022), the Beirut port explosion (2020), the fuel crisis (2021), and several other environmental stressors. These challenges have crippled the country, adversely impacted its environment, and halted its coping capacity.

Despite the crisis and despite its insignificant global share of GHG emissions (estimated at less than 0.07% in 2019), Lebanon is pursuing its mitigation efforts to reduce its national emissions and contribute to the international community's goal to hold global average temperature increase to "well below 2°C above preindustrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels", as stated by the Paris Agreement.

Lebanon's mitigation plans have been clearly reflected in its Nationally Determined Contribution (NDC) presented in 2015, and updated in 2021 in accordance with Article 4.9 of the Paris Agreement. The NDC update, which has been synchronized with the government economic plans and reforms, aims at driving sustainable, low emission growth as well as increasing the resilience of the economy, communities and ecosystems to sustain any future shocks, including climate events.

Under the NDC update, Lebanon aims at reducing its national emissions by 20% unconditionally and 31% conditionally by 2030. The NDC also sets a target of generating 18% to 30% of the electricity demand and 11% to 16.5% of the heat demand (in the building sector) from renewable energy sources (unconditionally and conditionally respectively).

In addition, Lebanon is currently in the process of finalizing its Low-Emission Development Strategy, which will enable the move to a green and blue economy by removing barriers to clean investments, enhancing research and development and decoupling economic growth and GHG emissions, in line with the concept of sustainable development, just transition and leave no one behind.

In order to accelerate the implementation of its NDC, Lebanon has joined the NDC partnership in 2019 and accordingly has prepared NDC partnership plans for key mitigation and adaptation sectors. In addition, Lebanon is constantly exploring new mitigation opportunities to attract climate finance to reduce GHG emissions while enhancing key economic, social and environmental parameters.

This chapter presents an overview of the mitigation efforts undertaken by Lebanon to reduce its national emissions, and recommends steps to be taken to accelerate emission reduction (Section A). Furthermore, the chapter provides an analysis of possible additional mitigation scenarios for the transport and wastewater sectors through the elaboration of a 1) baseline scenario to project GHG emissions the medium-term (2030) and long-term (2050) under business-as-usual conditions, and 2) mitigation scenarios with an estimation of their emission reduction potential in 2030 and 2050 (Section B.)

SECTION A. **OVERVIEW OF MITIGATION MEASURES**

5.1 MITIGATION MEASURES FOR THE ENERGY SECTOR

Energy is a major contributor to greenhouse gas emissions in Lebanon, with 16,452 Gg CO_2eq. in 2019, representing 55% of the total greenhouse gas emissions in Lebanon (transport emissions not included). However, due to the recent national circumstances, emissions have decreased by 10 % from 2018, mainly due to the decrease in the consumption of heavy fuel oil in EDL power plants, the power barges and the industrial sector, in addition to a decrease in the import and consumption of petroleum coke used in cement industries. Although such a decrease cannot be evidently linked to increased mitigation efforts, it has however positively contributed in reducing GHG emissions in 2019.

Concurrently, efforts have been sustained through the 2018-2019 period to reduce emissions, in terms of planning and implementing activities related to fuel switch, increasing the share of renewable energy, improving energy efficiency at plant and consumer levels, while strengthening the institutional and legal framework and creating financing mechanisms. An overview of such activities is presented in Table 39. After 2019, and amidst the economic crisis, activities have been re-prioritized and mitigation efforts have slowed down to cater for new realities. The impacts of the crisis on emissions and on the progress of mitigation projects have not yet been assessed, and therefore, are not reported under this section.

It is important however to note that due to the absence of institutional arrangements for reporting mitigation actions in a systematic and sustainable way, the list of activities is not exhaustive, which underestimates emission reduction efforts undertaken in Lebanon. In addition, due to the lack of data and progress indicators, emission reductions from the implementation of all activities could not be estimated for this report.

Table 39 Mitigation measures planned and/or implemented for the energy sector

Mitigation measures	Description
Fuel switch	According to the updated electricity policy paper (2019), the conversion of some power plants from gas/diesel oil to natural gas was planned. Discussions have been initiated at the political level to transport Egyptian gas to Lebanon through the Arab Gas Pipeline which passes through Jordan and Syria. To date, no concrete plans and timeline were agreed upon to start the import and proceed with the fuel switch.

Renewable energy	In 2019, 21.16 MWp of solar PV capacity were installed, bringing Lebanon's total installed capacity to 78.65 MWp. 111.71 GWh were generated from solar PVs in 2019, with the industrial sector being the biggest investor and beneficiary. Accordingly, emission reductions were estimated at 21,697 tonnes CO_2eq. in 2019, with a cumulative emission reduction estimated at 225,124 tonnes CO_2eq. for the period 2010-2019. In addition, 111 GWh were generated from hydropower and 34 GWh from the Naameh landill in 2019, amounting to a reduction of 96 tonnes of CO_2 eq.) In 2022, the Lebanese government has approved 11 licenses for 165 MW of PV capacity. The licenses are part of a 180 MW solar tender that the country initiated in January 2017. The 11 projects are spread across four main regions: Bekaa, Mount Lebanon, South and North, and generation is expected by 2025. As for wind power generation, the first bid to develop three wind farms in the region of Akkar with a capacity between 200 and 220 MW was launched in 2013, and 3 companies were selected for the implementation. The wind PPA contract was concluded, but implementation is still pending. In 2018, a second round was launched for a capacity of 200 to 400 MW. Contracting modalities has been put on hold following the 2019 crisis.
Energy efficiency	Based on the assessment and evaluation of the NEEAP 2016-2020, new measures have been recommended for the NEEAP 2021-2025, to set a clear path for reducing annual growth of energy consumption, in line with the NDC. Recommendations put forward through the Build-ME project include the enforcement of mandatory energy performance standards for heating and cooling equipment, improvement of regulations to offer incentives for municipalities and the private sector for energy-efficient projects, update of Lebanese building code, strengthen enforcement systems in the construction and maintenance phase, in addition to capacity building activities for different stakeholders. In terms of energy efficiency at the consumer level, 711,778 m^2 of solar water heaters were installed in 2019, which is an increase of 15% from 2018. The draft NREAP 2021-2025 suggests that the solar water heater market will witness a yearly increase of approximately 54,000 m^2, and projects with a total installed solar water heaters surface area of 1,028,486 $m^2$by 2025 and 1,296,854 $m^2$by 2030. As for energy efficiency at the transmission level, EDL has undertaken a series of rehabilitation and upgrade activities in 2019 to increase the efficiency of the existing power plants of Jiyeh, Zouk, Deir Aamar, Zahrani, and some hydropower plants, in line with the transmission master plan of 2017, which aims at lowering the technical losses on the transmission grid.
Financing mechanisms	A number of financing mechanisms were established in Lebanon to facilitate access of the private sector to loans with low interest rates for renewable energy and energy efficiency projects (NEEREA, LEEREF, GEFF). However due to the financial and economic crisis, such mechanism have either been cancelled or put on hold. However in 2022, and in order to support low-income households to ensure affordable and sustainable energy, a new financial mechanism has been established with Banque de l'Habitat and LCEC to provide subsidized loans for renewable energy installations in the residential sector.

Institutional and legal framework	To date, the draft decentralized renewable energy law and the energy conservation law have not been approved by Lebanese Parliament, The draft update of the of the electricity sector law 462 is still no approved by CoM. Law 288 was issued in 2014 allowing the CoM and upon the recommendations of the MoEW and MoF to license Independent Power Producers for a period extending from 2014 to 2016. Law 54 issued in 2016 prolonged the period until 2018.

In order to reach the NDC targets of 2030, specifically those related to the energy sector, a series of technical, institutional and financial measures should be implemented to scale up current mitigation efforts. Table 40 presents a general overview of such recommendations.

Table 40 Implementation gaps and needs for the energy sector

<table>
<tr><th></th><th>Gap/challenge</th><th>Corresponding need and request</th></tr>
<tr><td rowspan="6">Technical</td><td>Energy insecurity: Lebanon heavily depends on imported petroleum products to meet its energy demand</td><td rowspan="2">• Facilitate the import and use of natural gas in power plants
• Import electricity from neighboring countries
• Increase energy production from public utilities and increase clean energy production
• Establish a modality to connect renewable energy to the grid
• Establish a mechanism for renewable energy IPP licensing</td></tr>
<tr><td>Low renewable energy integration: high-risk investments, lack of needed infrastructure</td></tr>
<tr><td>Limited access to risk coverage instruments</td><td>Consider derisking measures to facilitate development and access to financing and risk mitigation schemes</td></tr>
<tr><td>Limited interest from local banks to fund small-scale distributed RE projects</td><td>Bundle smaller-size renewable energy projects to achieve the required scale</td></tr>
<tr><td>Land acquisition limitations and complex administrative processes for RE expansion</td><td>• Consider conducting land-specific auctions taking into account the inherent trade-offs between potentially the most cost-effective outcomes
• Standardize requirements in the bidding process</td></tr>
<tr><td>Inadequate governing framework for hydropower concessions</td><td>• Develop new administrative framework and a re-evaluation of the agreements of existing hydropower concessions to include higher tariffs
• Consider the broader benefits of sustainable hydro development as contributions to irrigation as well as flood and drought control</td></tr>
</table>

Technical	High technical losses and non-technical losses	• Implement EDL transmission plan (2017) • Complete the installation of several transmission lines • Improve distribution through removing infringements and imposing fines • Complete the electric distribution projects and the smart grid to limit losses and control billing and collection
	High energy demand: lack of standards, high-consumption lifestyle	Decrease energy demand through: • Finalizing and implementing NEEAP 2021-2025 • Adopting the energy conservation Law, standards for green buildings, green public procurement, standards for retrofitting • Disseminating the use of energy efficient technology through proper incentives • Improving the existing building thermal standards including an analysis of the Thermal Standards for Buildings in Lebanon • Setting the double wall ordinance to improve building's envelope performance • Establishing a reporting mechanism for energy conservation and renewable energy and developing ESCO operations • Respecting and complying with international standards in the areas of consumption guidance, environment and public safety
	Grid instability and capacity constraints	• Conduct a complete grid impact assessment • Reinforce the transmission grid through the implementation of the existing transmission master plan • Deploy smart meters at the distribution level to ease the connections of distributed RE projects
	Lack of certification and standardization of distributed and off-grid solar systems in the local Lebanese market	Complete the set of standards and adopt a national certification scheme for the design and installation of renewable energies
Policy, legal, regulatory and Institutional	Lack of a stable regulatory framework, including for renewable energy deployment, and incomplete implementation of Law 462	• Update and implement Law 462/2002 • Establish an independent electricity regulatory authority • Approve the draft decentralized renewable energy and energy efficiency laws.
	Coupling heating and cooling technologies in a national scheme	• Enforce mandatory energy performance standards for heating and cooling equipment being imported in the country • Reinstate incentives for the installation of small-scale heating and cooling applications

5.2 MITIGATION MEASURES FOR THE INDUSTRIAL SECTOR

The industrial sector has witnessed a decrease in its emissions in 2019 due to the decrease of cement production, which is the main source of GHG emissions from this sector. Since 2015, local production of clinker has decreased by 40% in Lebanon, following a set of reforms imposed by consecutive governments to enforce stringent regulations on quarries, which has halted the activities of the 3 cement plants for months between 2017 and 2022. Although such measures have not been implemented intentionally to mitigate climate change, they have however contributed in decreasing CO_2 emissions by 1,303 Gg since 2015 (a decrease in 37%), from both clinker production (-940 Gg) and petcoke consumption (-363 Gg).

On the other hand, the industrial sector is investing significant resources in diversifying its electricity and energy sources amidst the economic crisis, the rise of oil prices and the inability of EDL to ensure a continuous and reliable supply of electricity. Therefore, several industries opted for the installation of renewable energy systems, with a capacity estimated at 24.35 MWp in 2019 and 28.43 MWp in 2020 (MoEW/LCEC, 2022). However, the emission reductions of such mitigation measures are not accounted under the industrial sector, but are rather reported under the energy sector.

5.3 MITIGATION MEASURES FOR THE AGRICULTURAL SECTOR

Limited activities with an emission reduction potential have been implemented in Lebanon with regards to the agricultural sector. Pilot projects related to water pumping and irrigation using renewable energy have recently been initiated across the country, with no quantifiable emission reductions yet. Other activities are being explored through research and knowledge generation, capacity building and policy and regulatory framework support related to manure management and the type of fertilizers used. Most climate change related projects and programmes in the agriculture sector are adaptation oriented with the aim to decrease climate change impacts, improve resilience and adaptive capacity of infrastructure and protect the livelihoods of rural communities.

5.4 MITIGATION MEASURES FOR FOREST AND OTHER LAND USE

The Forest and Other Land Use category (FOLU) is a major GHG sink in Lebanon with net removals of -3,052 Gg CO_2eq. in 2019, mainly attributed to the conservation and increase in vegetation cover within forest lands, croplands, and grasslands. However, due to the rapid conversion of land to settlements, the urban sprawl, lack of law enforcement and increase in wildfires, the CO_2 sink has been decreasing since 1994, with a total reduction of 5.58% by 2019.

In order to conserve the removal potential of Lebanon's forests and lands, mitigation measures such as reforestation and afforestation activities, have been designed and implemented in Lebanon as part of the Ministry of Agriculture and Ministry of Environment mandates with the participation of NGOs, communities, and local authorities. A total cumulative area of 2,556 ha was planted between 2005 and 2019 with an average of 182 ha of land planted per year. Assuming an average of 700 planted trees/ha, a total number of 1,788,927 planted trees was achieved by 2019. Other mitigation actions have been implemented under FOLU including forest and fire risk management activities. However, it has not been possible to constantly quantify the impact of such measures including the assessment of burned areas avoided.

If the 2005-2019 historical trend of reforestation / afforestation activities continues under a business as usual scenario, it is expected to reach 3,375,000 of planted trees by 2030, which constitutes only 17% of the NDC unconditional target of 20 million trees or 13% of the NDC conditional target of 26 million tree (Figure 89). Therefore, radical measures in re-afforestation are needed to be taken to ensure meeting the NDC targets in relation to number of trees successfully planted by 2030 (MoE, 2015).

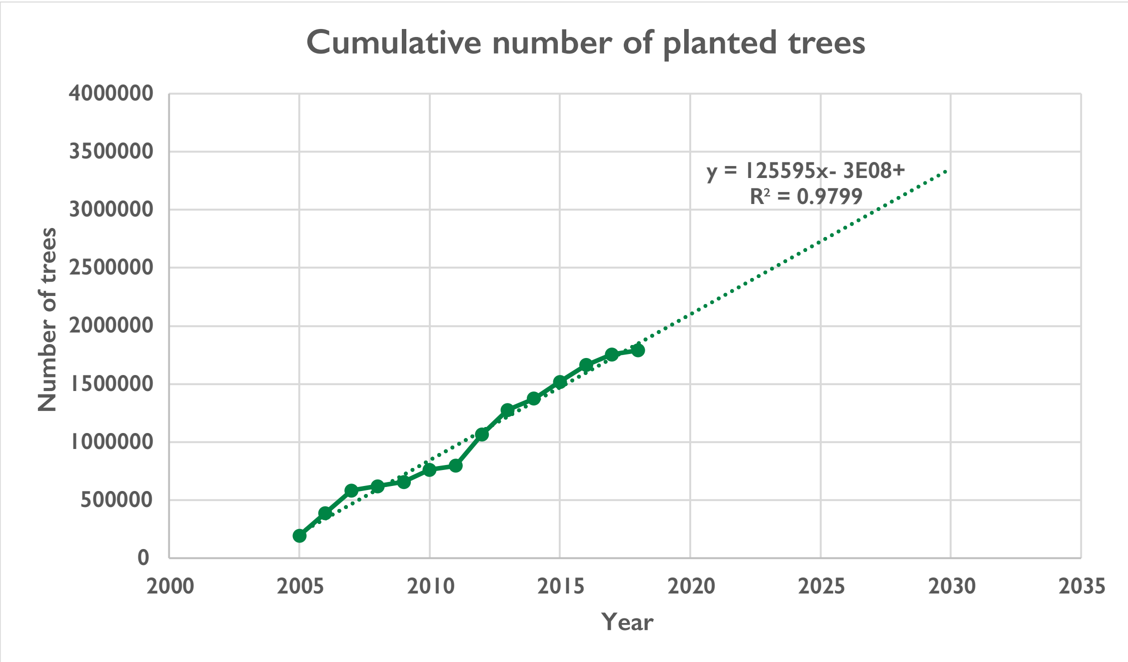


Figure 89: Cumulative and forecasted number of planted trees

An important step towards achieving the NDC 2030 targets includes the implementation of Lebanon's NDC Partnership Plans for FOLU, which were developed for prioritized projects and initiatives under the NDC partnership in 2019 and updated in 2021. Main recommendations include the following:

1- Reach Land Degradation Neutrality (LDN) in line with Lebanon's voluntary targets under the UNCCD (MoA, 2018) through:

- Restoring forest landscapes through reforestation and afforestation on at least 10,000 hectares
- Implementing Sustainable Forest

Management (SFM) practices on all public forests, and promoting the sustainable management of private forests.

- Restoring and managing grasslands in high mountain areas on at least 1,000 hectares
- Promoting sustainable agricultural practices on at least 80,000 hectares.
- Enhancing the sustainability of cities and towns through the development of urban and peri-urban forestry and the implementation of agro-sylvo-pastoral practices.
- Mainstreaming LDN into land-use planning and in sectoral policies and strategies.
- Developing financial incentives for the implementation of sustainable land management practices, in line with mitigation and adaptation strategies on climate change and conservation of biological diversity.
- Developing partnerships with local, national and international organizations for the promotion of sustainable land management practices and land degradation neutrality.

2- Improve fire risk management in line with the objectives of Lebanon's national strategy for forest fire management (Decision No. 52/2009 and its draft update 2022) through:

- Supporting and promoting the improvement, know-how sharing, monitoring and dissemination of knowledge on fire ecology, fire management and post-fire vegetation dynamics among all relevant actors (science/research, policy makers, land managers, grassroots" groups), bridging science and traditional knowledge.
- Developing effective measures intending to reduce fire vulnerability, to increase ecological and social resilience to fire, and prevent the occurrence of harmful fires and unsustainable fire regimes.
- Undertaking all possible provisions by individuals, communities and fire and land management agencies to be prepared before a fire event occurs, and improving interventions and safety in monitoring the probability of fire and detecting the event of fire.
- Suppressing the fires within the first 20 minutes after they start and limiting the extension of fires through the development of methods and techniques coupled with appropriate material and very well trained personnel
- Providing support for individuals and communities in the immediate aftermath of the fire and in the medium and longer term efforts of community and economic renewal, and restoring healthy ecological conditions of burned forest land to facilitate the natural recovery of vegetation and increase forest resilience against future fires.

3- Improve forest and nature conservation as highlighted the state of Lebanon's forests 2018 (Mitri et al., 2019) through:

- Improving forestry sector practices, accountability, and transparency in management of forests.
- Promoting fundamental and strategic research in national universities, especially research geared towards developing improved socio-economic and environmental management practices within the forestry sector.
- Ensuring adequate, more comprehensive and thorough monitoring and control system of Lebanon's forests, other

wooded lands, trees and rangelands embracing the biophysical, social and economic properties of the resources, their management, uses and users including the drivers of change and degradation.

- Addressing in future assessments the forest ecosystem status (i.e., advance the use of Red List of Ecosystems by evaluating further criteria and indicators). This approach combined with species Red List is a more powerful assessment of biodiversity status.
- Addressing conflicting responsibilities between institutions involved in the forestry sector in order to eradicate the current overlaps.
- Mobilizing stronger financial support to the forestry and rangelands sector from the national public funds and where needed through international collaborations and partnerships
- Adopting and ensuring the implementation of national guidelines for forest management and rangeland management such as those developed by UNDP and MoE's Sustainable Land Management in the Qaraoun (SLMQ) project.
- Increasing in forest protected and sustainably managed areas (including new biosphere reserves, himas and geoparks among others) and terrestrial nature reserves.

A summary of the main challenges related to the implementation of mitigation measures in the forestry and land use category are presented in Table 41.

Table 41 Implementation gaps and needs for the forestry and land use category

	Gap/challenge	Corresponding need and request
Technical and financial	Absence of a monetary valuation of forestry services.	Perform valuation of forest goods and services and develop studies on economics of land degradation
	Absence of promotion for sustainable use of natural resources	• Promote sustainable forest management allowing timber and wood production, valorisation of non-timber forest products such as aromatic and medicinal plants • Develop sustainable rangeland management • Encourage related opportunities for agro- and eco-tourism
	Limited financial resources for reforestation activities to restore forest cover	Mobilize funding for reforestation on public lands and increase urban forests
Legal and Institutional	Outdated Forest Law and lack of its enforcement	• Update Forest Law • Strengthen the role of the judiciary system in the follow-up on illegal activities impacting forest areas (including fires and wood cutting) and impose sanctions on perpetrators • Activate the role of environmental policing with MoE to protect terrestrial natural resources

Legal and Institutional	Lack of adequate forest management causing intense and large forest fires	• Adopt and ensure the implementation of the national guidelines for forest management, developed under the SLMQ project • Update and implement the national fire strategy • Provide infrastructure and equipment for forest fire fighting
	Poor land management due to the lack of enforcement of zoning Decrees.	Update zoning Decrees, complete zoning, and complete land cadastral survey map
	Inconsistencies in land classification	Develop guidelines for restoration of landscapes and promote agro-sylvo-pastoral practices in legal documents
	Lack of enforcement on privately owned buffer zones around reserves	Allocate fund for expropriation in buffer zones around reserves
	Lack of implementation of the National Land Use Master Plan: "Schéma d'Aménagement du Territoire Libanais"	Develop regional master plans and allocate fund for endorsement and implementation of national and regional parks and undertake capacity building and update the master plan
	Absence of a monitoring system for forests and other wooded lands	Ensure adequate, more comprehensive and thorough monitoring and control system of Lebanon's Forests , other wooded lands, trees and rangelands
	Overlapping responsibilities and mandates in forest management and conservation	Revise and streamline conflicting responsibilities to overcome current overlaps
Research	Lack of linkages between research and informed decision making	Promote fundamental and strategic research in national universities towards improved socio-economic and environmental management practices

5.5 MITIGATION MEASURES FOR THE SOLID WASTE SECTOR

Improving solid waste collection, treatment and management has been a priority for Lebanon since 2015, not for climate change reasons, but for urgent environmental, social and health issues that have been accumulating since decades. Therefore in 2018, the Integrated Solid Waste Management (ISWM) policy was adopted by the COM (Decision No. 45 on 11/01/2018) and consequently, Law No. 80/2018 on ISWM was issued by the government, setting the backbone of future legislative, technical and communication improvements.

Although some of the requirements for the enforcement of Law 80 have been achieved such as the establishment of the National Solid Waste Coordination Committee and the development of the strategy and the 2019-

2030 roadmap, the economic crisis and Beirut Port Blast not only halted all processes but exacerbated the already challenging circumstances. The explosion caused severe environmental impacts from resulting quantities of waste streams, including hazardous and electronic waste and debris, and caused significant damage to municipal solid waste management infrastructure.

Therefore, planning and implementing measures related to solid waste management will have an indirect impact on reducing GHG emissions from solid waste, notably from closing open dumpsites, increasing composting rates and re-activating methane recovery and waste-to-energy operations. Table 42 presents the current gaps that are hindering the implementation of the ISWM.

Table 42 Implementation gaps and needs for the waste sector

	Gap/challenge	Corresponding need and request
Policy, legal regulatory	Absence of legislation specifying the procedures, conditions, standards and specifications regarding waste management	Adopt provisions for the development of a national waste management and prevention plan, and regional waste management. These provisions will define responsibilities, timeframe, content and specifications for the plans
	Weak environmental monitoring of waste management activities	Establish recycling, treatment and disposal monitoring and reporting system (self-monitoring, compliance control and field inspections). On the medium term, establish permits for waste collectors
	Frequent political interference not in line with the view, priorities and arrangements of integrated waste management	Enforce the implementation of Law 80/2018 and issue operational decrees
	No decentralized / regional planning	Establish conditions, regulations, specifications and requirements for the regionalization of waste management
	Secondary products (compost, Compost Like Output, Refuse Derived Fuel, etc.) lack standardization and qualities applicable to end users	Set standards and specifications for reusable, recycled and secondary products, and run a study for the marketing of secondary products
	Absence of a grid feed-in-tariff and proper regulatory text related to the operation of waste-to-energy applications	Issue proper regulation to allow selling electricity to the grid from waste-to-energy facilities
Institutional	Weak capacities of authorities in relation to the scale, complexity and demands of integrated waste management	Increase staffing of MoE and strengthen administrative capacities in relation to waste planning
	Lack of financial and human resources of waste management operators for proper design, construction and operation of facilities	Strengthen capacities of all institutions involved in waste management by additional re-organization and financial resources, additional employment and adequate training of staff at national, regional and local levels
	Lack of organized effort for implementation of source-specific separation systems that will facilitate materials utilization from waste	Enforce cooperation between industrial sectors so as industrial side streams and waste of one sector to be channeled as raw materials or to be exploited by other industrial sectors

Financial	Absence of economic instruments (taxes, pay as you throw, etc.) and other incentives	• Introduce a landfill tax on the medium ru • Promote the polluter pays principle and develop a methodology for the development of waste tariffs connected to the real cost of waste management.
	High cost of collection due to lack of economies of scale since each municipality organizes its own collection system	Connect inhabitants to organized waste collection services
	Inability to finance in a sustainable manner and to cover the current waste management cost.	• Develop a financing plan for recycling activities (including a cost recovery system and the introduction of economic instruments for waste reduction) • Ensure full cost recovery and self-sustainability of the waste management system while minimizing the need for governmental subsidies
	Lack of provisions and methodology for full cost accounting and cost recovery of waste management services	Establish Extended Producer Responsibility on the medium term, and design a cost recovery system
Technical	Most infrastructure is developed as a response to waste crisis and not on adequate planning.	Improve waste management infrastructure and support sustainable operation and maintenance
	Local technologies are deficient. Specifically, waste collection equipment is inappropriate, insufficient and not properly maintained	Set standards and specifications for waste collection equipment
Environmental	Non-existent initiatives for waste prevention and reduction	Acquire equipment for home-composting, promote reuse and repair centers, set training programs for waste prevention
	High risk of pollution for ground and underground water and atmosphere from dumpsites	• Rehabilitate priority dumpsites and develop technical specifications for that purpose • Develop guidelines for the improvement of the operation of existing and new sanitary landfills • Ensure adequate leachate management • Introduce a penalty system for uncontrolled disposal
Awareness	Poor public awareness around waste prevention and segregation	Improve public awareness on waste segregation at the source, and organize awareness campaigns for waste prevention
	Insufficient promotion of the concept of integrated solid waste management and waste management principles (e.g. circular economy, resource efficiency, waste hierarchy)	Organize education and public awareness sessions around uncontrolled disposal, special waste streams management, and training programmes for waste prevention
	Inadequacy of some locations for new landfills especially in the coastal areas	Follow the set of criteria (including social) introduced in the National Solid Waste Strategy when selecting a location for waste management facilities

SECTION B. **ADDITIONAL MITIGATION ANALYSIS**

5.6 MITIGATION ANALYSIS AND OPTIONS FOR THE TRANSPORT SECTOR

The transport sector contributed to 23% of Lebanon's emissions in 2019, with most of GHG emissions emanating from passenger cars that run on gasoline. With the absence of efficient and organized public transport, Lebanon's transport patterns are still dominated by the use of private cars, with one of the highest car ownership rates in developing countries (865 out of every 1,000 residents in Lebanon own a car) and a low vehicle occupancy (1.2 compared to average standards for computing travel time reliability of 1.7) (Mckinsey, 2019; Saroufim and Otayek, 2019).

Solving the problems of the Lebanese transport sector requires both a holistic and integrated strategy that goes beyond the visible incidence of the sector's problems and extends to setting a national transport strategy managing all transport services as a whole. This section explores a series of measures targeting both passenger cars and freight transport that can be included in such a strategy, with an analysis of the impact of such mitigation measures on transport activity, energy use, and CO_2 emissions by the years 2030 and 2050. Mitigation measures include:

For passenger transport:

1- Replacement of old and inefficient vehicles gradually with Hybrid technologies (75% of newly registered vehicles) by 2050

2- Replacement of old and inefficient vehicles gradually with Hybrid (25%) and Battery electric vehicles (50% of newly registered vehicles) by 2050

3- Increase share of mass transport

For freight transport[1]:

1- Switch 50% of new truck registrations and 75% of LCVs in 2050 to electric powertrains

2- Switching 50% of heavy freight transport in 2030 to electric rail

3- Combination of both options

The results of the analysis of the potential CO_2 emissions and energy use reductions using the ForFITS model showed that renewing the fleet with hybrid and electric vehicles (up to 75% of newly registered vehicles) can lead to significant reductions of 34% by 2050 compared to the business-as-usual mobility patterns. However, since the vehicle stock and vehicle-kilometer activity will both double in 2050 compared to 2010, problems pertaining to chronic congestion and all related complications of time and productivity losses will persist.

Increasing the share of mass transport activities can also induce significant CO_2 and energy use savings of 48% by 2050 compared to the business-as-usual patterns, and reverse the growth trend by reducing the energy use and emissions 32% compared to the base year 2010. These are due to maintaining vehicle-kilometer activities close to the 2010 levels. Consequently, the lessons

[1] Freight transport in Lebanon consists of conventional engine light-duty commercial vehicles (76% of total freight vehicles in 2010) and medium and heavy duty trucks (24% of total in 2010), with no rail service currently operational for passengers or freight

learned from this mitigation analysis concludes that the transport national strategy for Lebanon should necessarily be based on the integration of a carefully designed portfolio of policies and incentives, deploying mass transit systems first and then promoting the shift to environmentally-friendly vehicles.

As for freight transport, results show that increasing the share of electric LCV and trucks can lead to a reduction of 4.2% in energy use and corresponding CO_2 emissions by 2030 and 40% by 2050 compared to the business-as-usual, but is not enough to reverse current growth trends. Increasing the share of rail transport for heavy freight starting in 2030 can lead to 13% reduction of energy use and corresponding emissions by 2050, indicating good potential to help overturn adverse growth trends. Combining both mitigation options naturally led to the highest savings, with 49.4% reductions achieved by 2050. This comes at a cost of providing the necessary electric charging infrastructure and clean energy mix to operate these vehicles effectively.

5.6.1 Methodology

The mitigation options analysis builds on the For Future Inland Transport Systems model (ForFITS), a modeling tool that converts information on transport activity into fuel consumption and CO_2 emission estimates considering the influence of the demographic and socio-economic context, including policy inputs (UNDA, 2013). The analysis covers passenger and freight mobility services on inland transport modes, taking into consideration the different vehicle classes, powertrains, and fuel blends consistent with the technology requirements. Table 43 characterizes the modal and sub-modal levels considered in the modeling framework and presents the types and classes of vehicles that currently operating in Lebanon in addition to potential future technologies that are applicable based on available refueling infrastructure. Note that non-motorized transport (walking and cycling), aviation, and maritime transport are excluded from the analysis.

Table 43 Transport modal characteristics considered in the ForFITs model.

<table>
<tr><td colspan="15">Urban and non-urban</td></tr>
<tr><td colspan="9">Passenger</td><td colspan="6">Freight</td></tr>
<tr><td colspan="3">Motorcycles</td><td colspan="3">Light Duty Vehicles</td><td colspan="3">Large Roads</td><td colspan="3">Light Duty Vehicles (2t ≤ mass < 3.5t)</td><td colspan="3">Trucks (mass > 3.5t)</td></tr>
<tr><td>Small motorcycles and scooters (engine not exceeding 50 cm³)</td><td rowspan="3">Internal Combustion Engine (ICE) Taxi</td><td rowspan="3">Gasoline</td><td>Small light vehicles (unladen kerb mass < 1t)</td><td rowspan="3">ICE, Hybrid Electric (HEV) and Battery Electric (BEV)</td><td rowspan="3">Gasoline</td><td rowspan="3">Buses (carry more than 8 seated passengers)</td><td rowspan="3">ICE</td><td rowspan="3">Gasoline/Diesel</td><td rowspan="3">Light commercial vehicles</td><td rowspan="3">ICE and BEV</td><td rowspan="3">Gasoline</td><td rowspan="3">Trucks (Medium and heavy-duty vehicles)</td><td rowspan="3">ICE and BEV</td><td rowspan="3">Diesel</td></tr>
<tr><td>Motorcycles (engine exceeding 50 cm³)</td><td>Midsize light vehicles (unladen kerb mass ≥ 1t and < 1.5 t)</td></tr>
<tr><td>Three-wheelers</td><td>Large light vehicles (unladen kerb mass ≥ 1.5 t)</td></tr>
</table>

Transport zones | Transport services | Transport modes | Vehicle classes | Powertrain technologies | Fuel blends

The model provides yearly projection figures on vehicle stock, transport activity, energy use, and CO_2 emissions as presented in Table 44, to help understand and assess trends in the evolution of the transport sector in 2030 and 2050. The evaluation of energy use and CO_2 emissions is performed using the ASIF framework of equations, based on the decomposition of fuel use into transport activity, energy intensity, and Structural components, such as the type of transport service (passenger vs. freight), mode, vehicle class, and powertrain group.

Table 44 Output parameters of the ForFITS model.

Output parameter	Unit	Description
Vehicle stock	vehicles	The annual number of vehicles in the fleet stock, provided by transport mode (motorcycles, LDV, buses, LCV, and trucks)
Transport activity	vehicle-km	The annual vehicles' overall distance travel activity
Energy use	toe	The annual overall fuel consumed by vehicles For consistency, gasoline and diesel consumption units are converted to tonne-oil-equivalent (toe)
CO_2 emissions	Gg	The annual overall tank-to-wheel CO_2 emissions from vehicles

Projection Scenarios

Baseline scenarios for both passenger cars and freight have been carried out first to estimate CO_2 emissions projection under Business-As-Usual (BAU) conditions, basing the projections calculations on available transport system data in the base year (2010), and on data 5 and 10 years prior to the base year (2005 and 2000 respectively). Then mitigation scenarios of increasing the share of electrified vehicles and mass transport for passenger cars, and gradually increasing electrification of freight have been developed and compared to the baseline. They are run based on a set of hypotheses, intended to evaluate policy impacts of shifting and BAU. The mobility demand (1) from high consuming vehicles to efficient passenger vehicles and (2) from private vehicles to mass transit systems in addition to 3) shifting to freight electric power trains and 4) shifting to electric rail. Table 45 and Table 46 provide details on the set of hypotheses that defines each of the scenarios and summarize the parameters that are subject to variation across the different scenarios.

Table 45 Set of hypotheses adopted in the baseline and mitigation scenarios for passenger cars by 2050

	Gasoline and Diesel price	Passenger transport system index	Passenger LDV powertrain shares	
			Hybrid	Electric
Baseline: Business As Usual scenario		0.1[1]	0%	0%
Mitigation option 1: Increase share of Hybrid Vehicles (HEV)	50% up by 2050	constant over time	75% of newly registered vehicles by 2050	
Mitigation option 2: Increase share of HEV and Battery Electric Vehicles (BEV)			25% of newly registered vehicles by 2050	50% of newly registered vehicles by 2050
Mitigation option 3: Increase share of mass transport		0.17 pkm 30% increase in share on collective passenger vehicles[2]	0%	0%

(Shaded cells highlight the key changes from a scenario to another)

[1] The "passenger transport system index" aims to allow the understanding of the modal shift in passenger transport (changes associated with shifts to/from private vehicles from/to mass transport). It is related to the shares of pkm on personal and mass passenger transport. An index of 1 reflects a full reliant transport system on collective passenger vehicles, and an index of 0 reflects a totally dependent system on personal vehicles. According to the transport activity data, the passenger transport index is below 0.1 for Lebanon in 2010, reflecting high dependence on private passenger vehicles.

[2] Increase the passenger transport system index to 0.17 to increase the share of pkm to 30% in mass transit.

Table 46 Set of hypotheses adopted in the baseline and mitigation scenarios for freight transport

Mitigation option	Share of electric rail freight transport in 2050	Share of electrified truck powertrains in 2050	
		Electric LCV	Electric Trucks
Mitigation Option 1: Partial switch to electrified truck technologies	0%	75% of new LCV registrations	50% of new Trucks registrations
Mitigation Option 2: Partial switch of heavy freight to electric rail	50%	0%	0%
Mitigation Option 3: option 1 + option 2 combined	50%	75% of new LCV registrations	50% of new Trucks registrations

5.6.2 Baseline and BAU Scenario

Assumptions

The baseline scenario emulates the evolution of the transport activity based on the current business-as-usual conditions; therefore, the scenario maintains all identified transport characteristics for the base year 2010 constant across time:

- Constant passenger transport system index reflecting the preferential use of personal motorized passenger vehicles despite collective transportation systems. The passenger transport system index is related to the shares of passenger-kilometer on personal and mass passenger transport. An index of 1 reflects a full reliant transport system on mass transport, and an index of 0 reflects a totally dependent system on personal vehicles. A value below 0.1 has been reported from the passenger activity data of 2010.

- Constant low environmental culture index reflecting the poor behavioral changes associated with environmental consciousness. A value of 0.2 is estimated, knowing that a value of 1 represents a strongly focused culture on protecting the environment, while a value of 0 represents the absence of environmental consciousness in decision making.
- Constant CO_2 emission factors, reflecting no changes in fuel blends with respect to tank-to-wheel emission characteristics, and therefore excluding switches towards lower carbon-intensive fuel options on conventional vehicles.

In addition, the business-as-usual scenario considers the following parameters:

- Growth in gasoline and diesel fuel price by 50% in 2050 compared to 2010 (hypothesis adopted for all considered mitigation scenarios).
- The GDP expected to recover by 2035 to levels similar to those prior to the economic crisis in 2019 and to double by 2050 compared to 2035 (GDP projection values between 2020-2025 are estimated by Lazard and values between 2025-2050 were considered based on the average target growth of 5 % from the McKinsey Report for Lebanon's economy and its future potential).

In addition to the socio-economic data that define the context in which the transport system should evolve, information on the characteristics of the transport system in the base year (2010) is provided, as summarized in Table 47 (MoIM vehicle fleet database, 2019). These information are compiled and used in the ASIF equations 1 and 2 to determine the total energy and emissions use. Table 48 and Table 49 show the values of the main outputs for passenger and freight transport in the reference scenario at the base year 2010, 2030, and 2050.

Table 47 Characteristics of the road transport sector in 2010.

	Vehicle Stock	New registered vehicles	Annual traveled distance (km)	Vehicle load (pass/veh)	Vehicle fuel consumption (lge/100 km)
Passenger					
2-3 Wheelers	60,588	13,416	5,000	1	3-6.5
Passenger LDV					
Private cars	1,182,229	95,489	12,000	1.2	8-16
taxis	50,000	1,785	25,000	1.2	15
Buses	12,388	1,188	50,000	11.2	25
Freight					
LCV	96,235	7715	25,000	0.5	15
Trucks	29,968	3225	50,000	6	25

Table 48 Main modeling assumptions for freight under the BAU scenario in 2010

Factor	Value in 2010	BAU Projection
Freight types and transport shares by [LDV, HDV] modes (shares assumed)	Bulk goods: [20%, 55%] Food: [20%, 20%] Manufactured: [20%, 25%] Other goods: [35%, 0%]	Maintained constant
Load factor (ForFITS default)	100% (empty trips are excluded)	Maintained constant
Vehicle capacity (ForFITS default)	average value per class	Maintained constant
Powertrain shares	100% Gasoline ICE for LCV 100% Diesel ICE for Trucks	Maintained constant but with improving powertrain efficiencies
Trip distances, trip shares and transport shares by [LDV, HDV] modes	Short < 60km: 90% [70%, 30%] Medium < 400km: 10% [0%, 100%]	Maintained constant
Fuel prices including tax (USD/lge) (lge = liter gasoline equivalent)	Gasoline: 1.09 Diesel: 0.62	Growth to 150% by 2050 assumed compared to 2010
CO_2 emission factors (tank-to-wheel) (kg CO_2/lge)	Gasoline: 2.32 Diesel: 2.48	Maintained constant, reflecting no changes in fuel blends due to continued use of conventional engine vehicle technologies

Table 49 Baseline and BAU scenario projections for passenger and freight transport.

	unit	2010 (Base Year)	2030	2050
Passenger cars				
Total passenger vehicle stock	vehicles	1,292,433	1,693,136	2,663,349
2-3 wheelers	vehicles	60,587	66,900	122,500
LDV	vehicles	1,219,460	1,496,724	2,523,986
Buses	vehicles	12,387	16,002	12,180
Total vehicle-km	billion vkm/yr	16.04	19.79	34.17
Total energy use	toe/year	1,679,287	1,760,661	2,182,636
Total CO_2 emissions	Gg CO_2/yr	4,852	5,092	6,300
Freight				
Total freight vehicle stock	vehicles	126,202	206,694	855,175
LCV	vehicles	96,235	176,651	777,740
Trucks	vehicles	29,968	30,043	77,435
Total vehicle-km	billion vkm/yr	3.90	5.86	23.81
Total energy use	toe/year	540,547	706,230	2,261,115
Total CO_2 emissions	Gg CO_2/yr	1,618	2,097	6,675

In terms of projections under a BAU scenario, passenger cars maintain a quasi-steady activity between 2020 and 2035, given the sharp decrease in the GDP after 2019 - resulting from the economic meltdown - and the ensuing slow recovery. The economic downturn in 2019 triggers a stabilization in the number of personal passenger cars (Figure 90) and their annual distance travel (Figure 91), especially for passenger LDV where the vehicle-kilometer activity decreases by 4% compared to 2020. Consequently, energy use (Figure 92) and CO_2 emissions (Figure 93) are maintained close to the levels observed in 2020. Similar conclusions are observed for the freight where the vehicle-kilometer, energy use, and CO_2 emissions slightly decrease compared to the 2020 figures.

However, passenger and freight activity substantially increase after 2040, as the GDP reaches levels similar to those prior to the economic crisis in 2019. This surge in activity lead, consequently, to a significant increase in transport activity and energy use by 2050. The energy use for passengers increases by 30% in 2050 compared to the base year, whereas it triples for freight. This increase is caused by (1) the surge in freight activity, and (2) the reliance on light commercial vehicles (with 76% of the total freight vehicles at the base year, and estimated to reach 91% in 2050) (Table 49). Light commercial vehicles are known to be less energy efficient per tonne-kilometer than large freight modes.

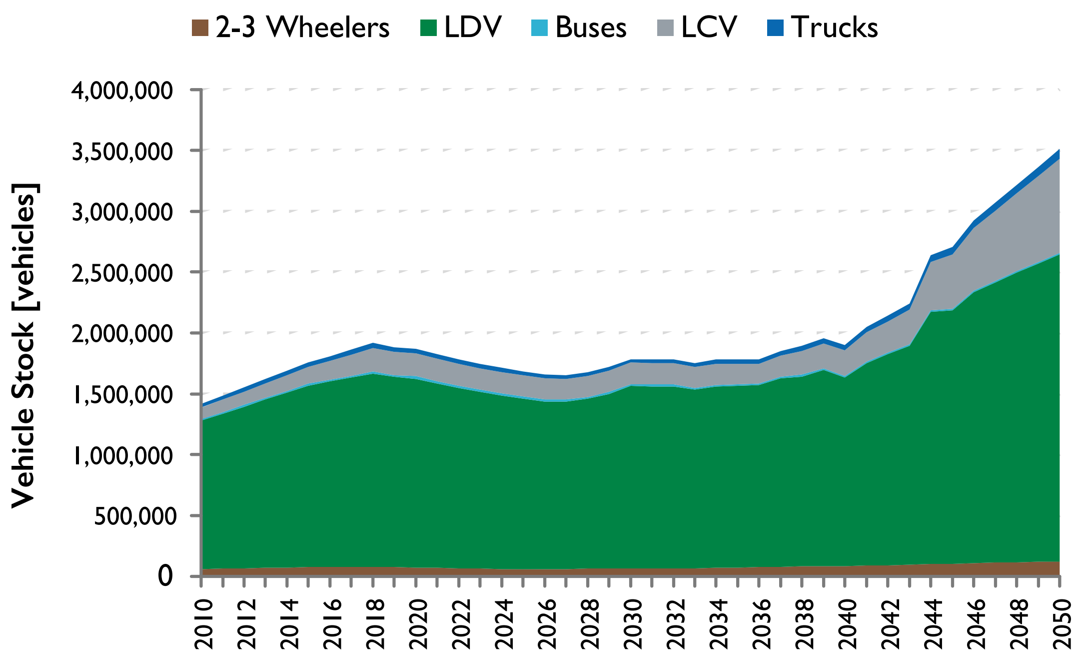


Figure 90: Business-as-usual projection of passenger and freight vehicle stock.

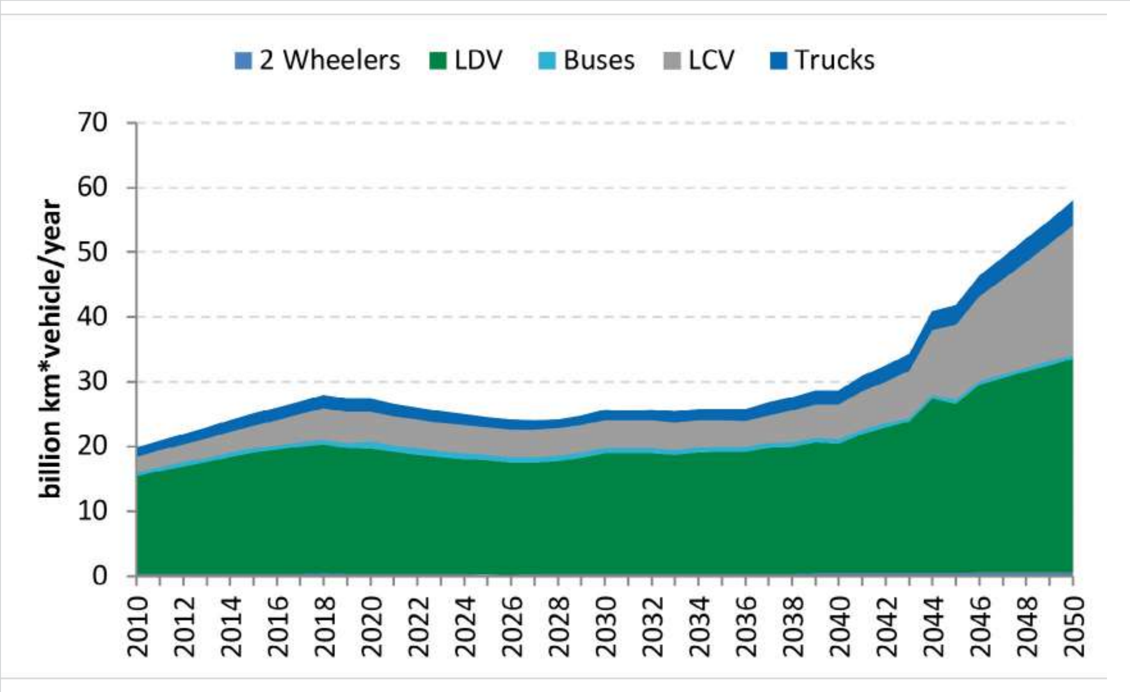


Figure 91: BAU annual estimated passenger and freight activity.

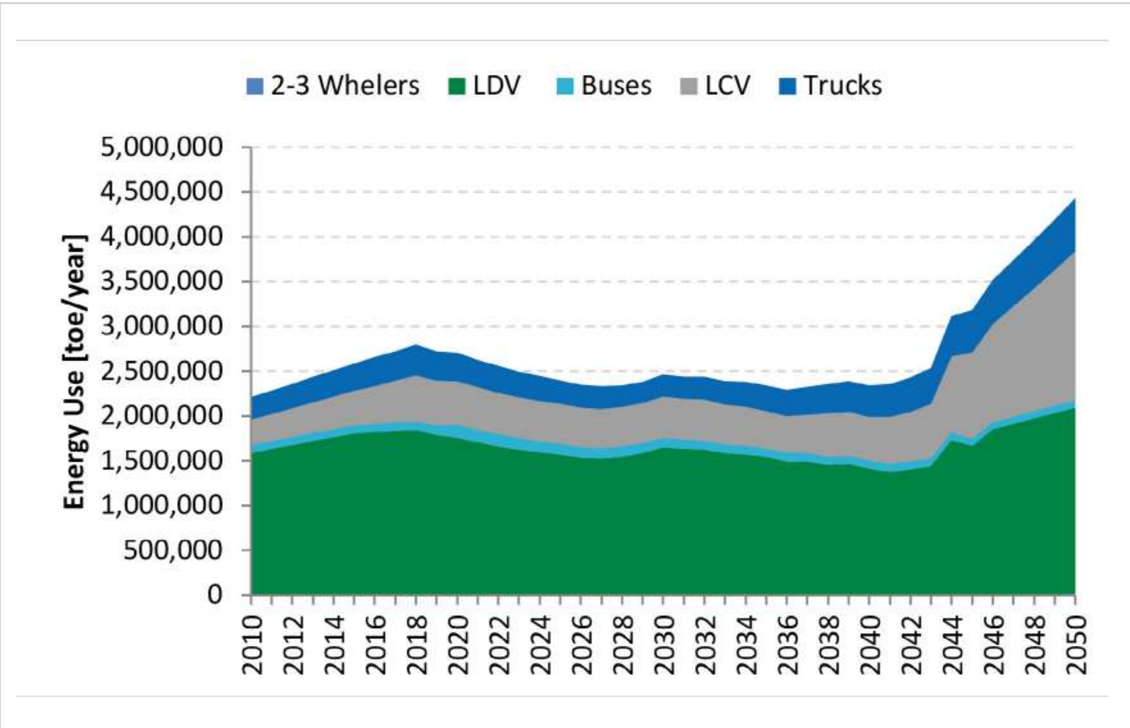


Figure 92: BAU projection of passenger and freight energy use.

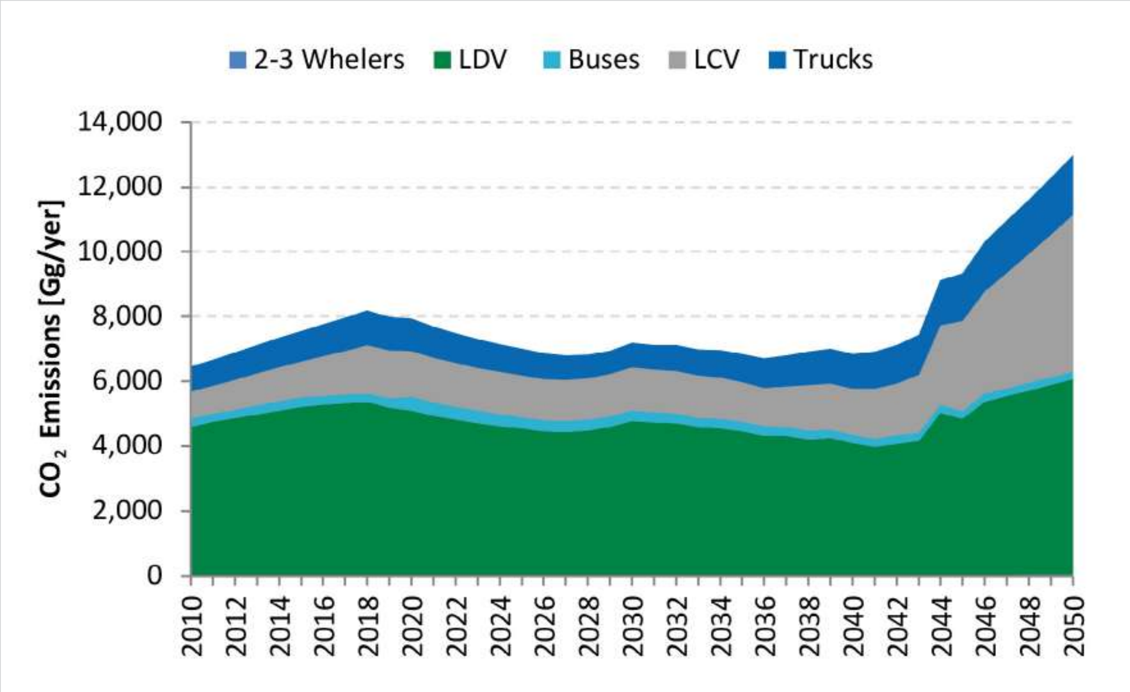


Figure 93: Baseline projection of passenger and freight CO_2 emissions

5.6.3 Mitigation scenarios and emission reduction potential for passenger cars

Mitigation Option 1: Increase the share of Hybrid Electric Vehicles (HEV)

Hybrid Electric Vehicles (HEV) combine an electric motor and battery pack to the internal combustion engine in conventional vehicles. They are classified as micro-hybrid, mild-hybrid, full-hybrid, plug-in hybrid, and range-extender electric vehicles; and they differentiate by the level of electric energy stored onboard. Note that the more electric energy is available, the additional fuel reduction will result, at the expense of an increase in the vehicle purchase cost.

This scenario targets an increase in the share of hybrid vehicles to levels where 75% of newly registered vehicles by 2050 are hybrids, all classes combined. The market for these vehicles will develop gradually with new vehicle registrations over time as OEMs are expected to gradually increase the offering of electrified vehicles to abide by emissions regulation.

Mitigation Option 2: Increase the share of Hybrid and Battery Electric Vehicles (HEV/BEV)

Battery Electric Vehicles (BEV) have no internal combustion engines and derive all their power using an electric motor exclusively from rechargeable battery packs. These vehicles do not produce tailpipe GHG emissions, but emissions result from the power plants while generating the electricity needed to power these vehicles.

This scenario adopts the same assumptions as Mitigation Option 1, i.e. 75% of newly registered vehicles by 2050 are clean and efficient vehicles, with 50% to be BEV and 25% HEV. It relies on the implementation of policies to improve the environmental culture of drivers and direct their purchases to environmentally friendly vehicles.

Mitigation Option 3: Increase the share of mass transport

The shift to the mass transport scenario is illustrated by the increase in the passenger transport system index, for which the share of passenger-kilometer activity is assumed to increase to 30%. The rationale is to reduce the gap between the passenger transport system index of Lebanon and mass-transport-oriented European cities by 15% in 2050.

This assumption is represented by the deployment of a well-designed mass transit system covering the Greater Beirut Area, in addition to a wide number of policies favoring mass transport over personal vehicles, such as parking and access restrictions for personal vehicles, land-use policies that encourage lane dedication for buses, and support for the provision of appealing, widely available and high-quality public transport services.

Results of mitigation analysis for passenger cars

Figure 94 to Figure 96 illustrate the evolution of the passenger activity (vkm), energy use (toe), and CO_2 emissions (Gg) under the 3 considered scenarios, allowing a comparative assessment of the impacts caused by the changes in each scenario compared to the baseline. The graphs clearly show a gradual decrease in emission reductions with the gradual increase in the share of cleaner technologies, and a significant reduction with the addition of mass transport.

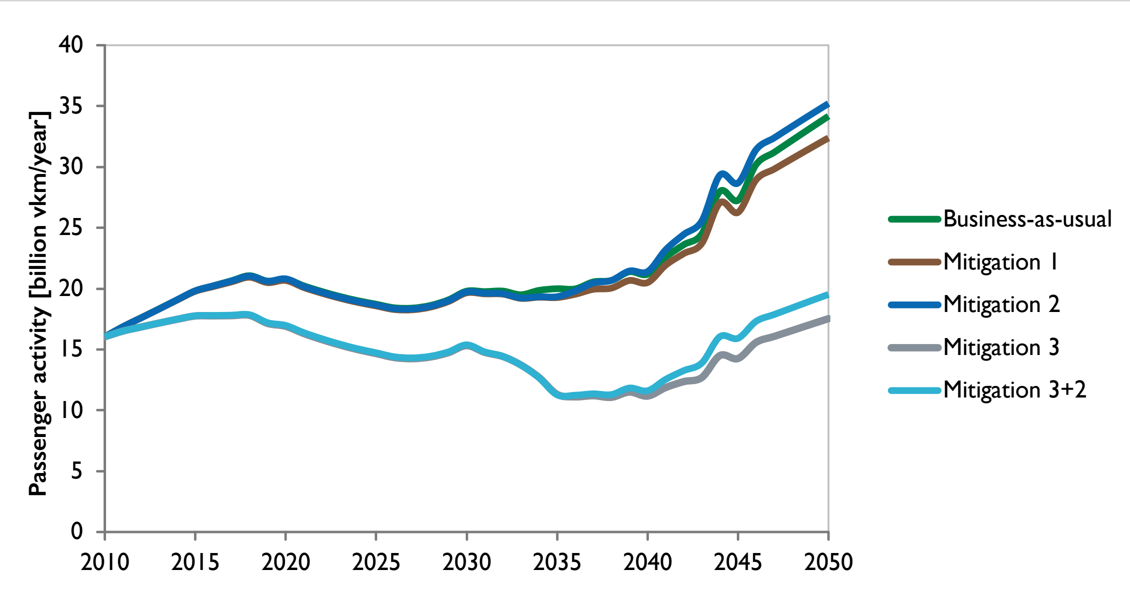


Figure 94: Change in transport activity.

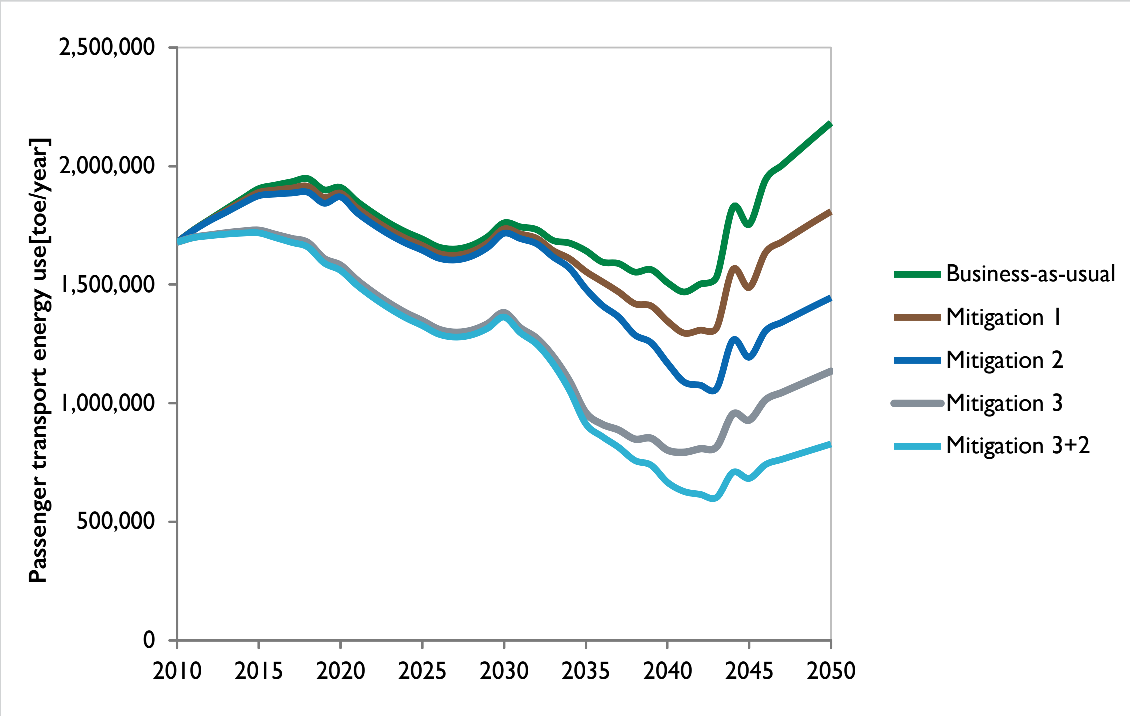


Figure 95: Change in energy use.

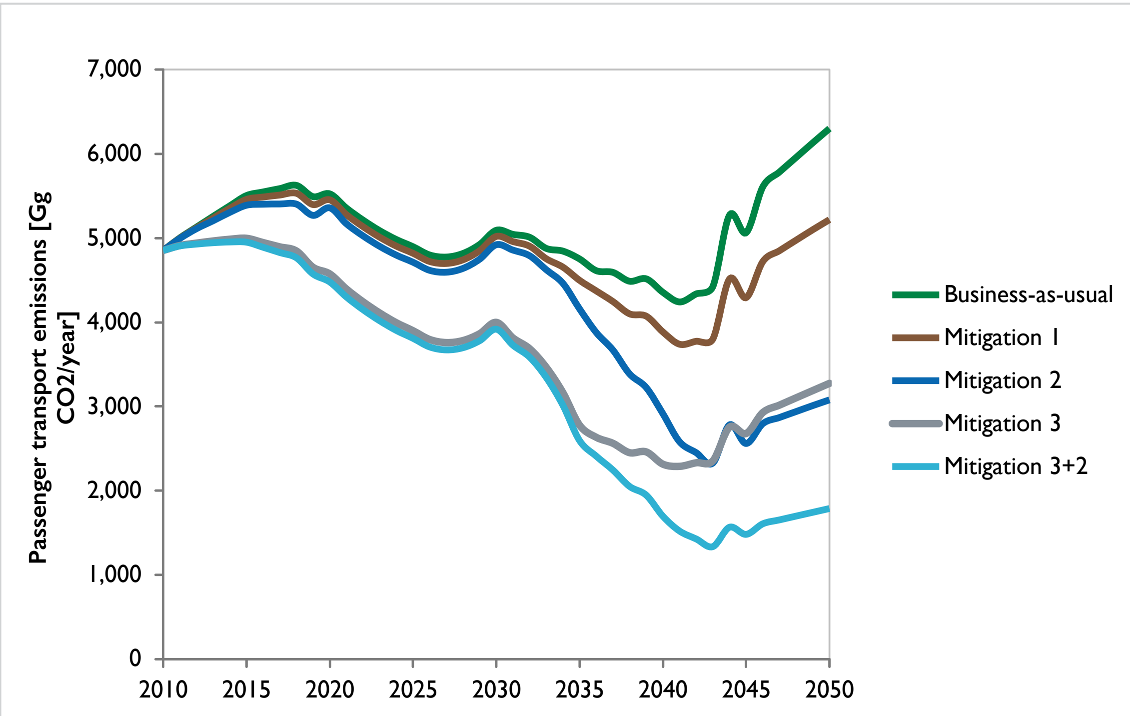


Figure 96: Change in CO_2 emissions.

Emission reduction from Mitigation Option 1: Increase the share of Hybrid Electric Vehicles

Although this scenario reduces the passenger transport energy use and CO_2 emissions in 2050 by 17% compared to the business-as-usual scenario, the transport system remains characterized by being highly personal vehicle oriented, as the use of mass transport still represents less than 15% of the total passenger-kilometer transport activity.

Reduction in energy use and CO_2 emissions are the consequence of (1) the improvement of the fuel consumption per kilometer of vehicle technologies over time and (2) the fuel price increase by 50% in 2050 compared to 2010. Both factors lead to a reduced transport activity compared to the business-as-usual as shown in Figure 94. Note that a no-growth fuel price scenario in 2050 would increase the transport vehicle-kilometer activity; consequently, CO_2 emission savings will be counterweighed. Therefore, the fuel price (or from a wider perspective: the mobility cost per mode) is a key parameter to ensure the successful implementation of this scenario, through controlling the transport activity.

Table 50 presents the values of the main outputs of this scenario by 2030 and 2050. Note that the energy use over time is stabilized: only an increase of 3.3% and 7.2% in 2030 and 2050 compared to 2010. CO_2 emissions follow the same trend. This steadiness in energy use and emissions is due to the stabilization in the number of personal passenger cars and their annual distance travel until 2035 and then followed by an increase in the share of HEV (Figure 97), which present up to 28% fuel savings compared to conventional vehicles.

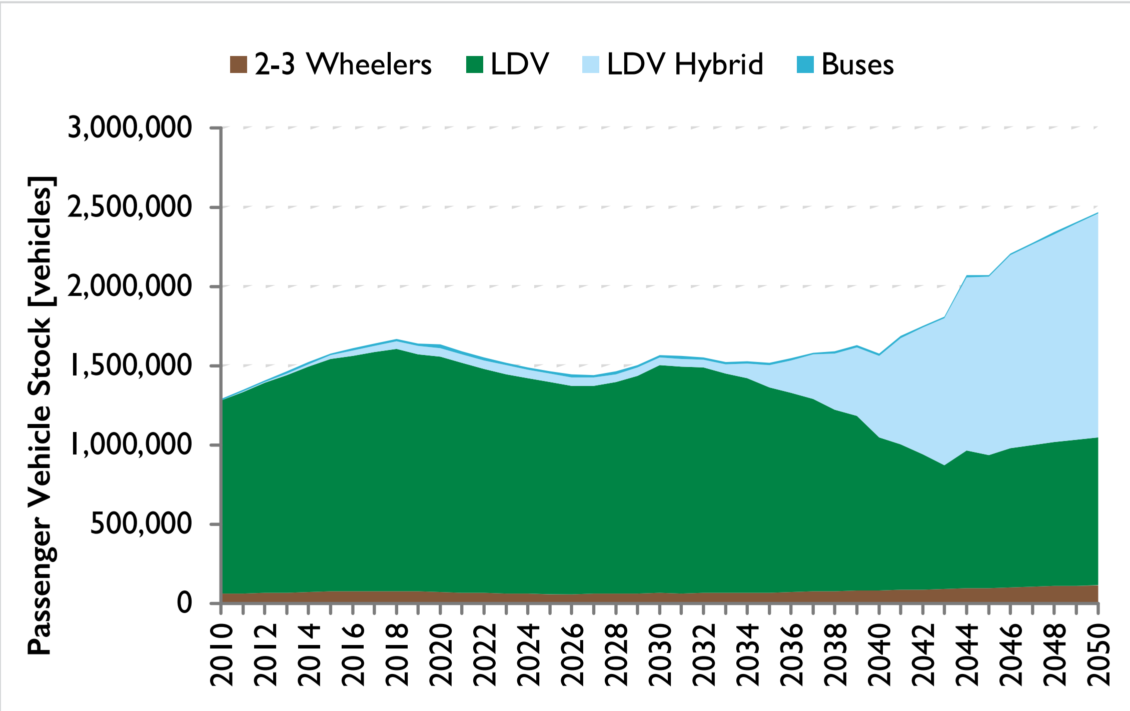


Figure 97: Mitigation option 1 projection of passenger vehicle stock.

Table 50 Passenger transport projections of the mitigation option 1 scenario.

		Baseline	BAU scenario		Mitigation 1 scenario	
	unit	2010	2030	2050	2030	2050
Total passenger vehicle stock	vehicles	1,292,433	1,693,136	2,663,349	1,566,527	2,468,597
2-3 wheelers	vehicles	60,587	66,900	122,500	65,807	114,240
LDV Conventional	vehicles	1,219,460	1,496,724	2,523,986	1,435,989	933,891
LDV Hybrid	vehicles				49,020	1,409,245
Buses	vehicles	12,387	16,002	12,180	15,712	11,220
Total vehicle-km	billion vkm/yr	16.04	19.79	34.17	19.66	32.39
Total energy use	toe/yr	1,679,287	1,760,661	2,182,636	1,735,372	1,808,926
Total CO_2 emissions	Gg CO_2/yr	4,852	5,092	6,300	5,019	5,218

Emission reduction from Mitigation Option 2: Increase the share of Hybrid and Battery Electric Vehicles

The same trend in transport vehicle-kilometer activity is observed or HV and BEV compared to the business-as-usual scenario (Figure 94); therefore, the transport system still evolves in a highly personal vehicle oriented scheme. Nevertheless, the deployment of HEV and BEV leads to reductions in energy use and CO_2 emissions as presented in Table 51 and Figure 95, and Figure 96:

- Compared to energy use and CO_2 emissions of passenger transport in the base year 2010, 14% and 36% reductions are observed in 2050, respectively.
- Compared to the business-as-usual scenario, the energy and CO_2 emissions savings from mitigation option 2 are 34% in 2030 and 51% in 2050, respectively. This is due to the increase in the share of BEV and HEV as of 2035 which will constitute 75% of total passenger LDV in 2050, as illustrated in Figure 98.
- Compared to the results of mitigation scenario 1, mitigation scenario 2 stimulates 20% of additional savings in energy use and 41% in CO_2 emissions.

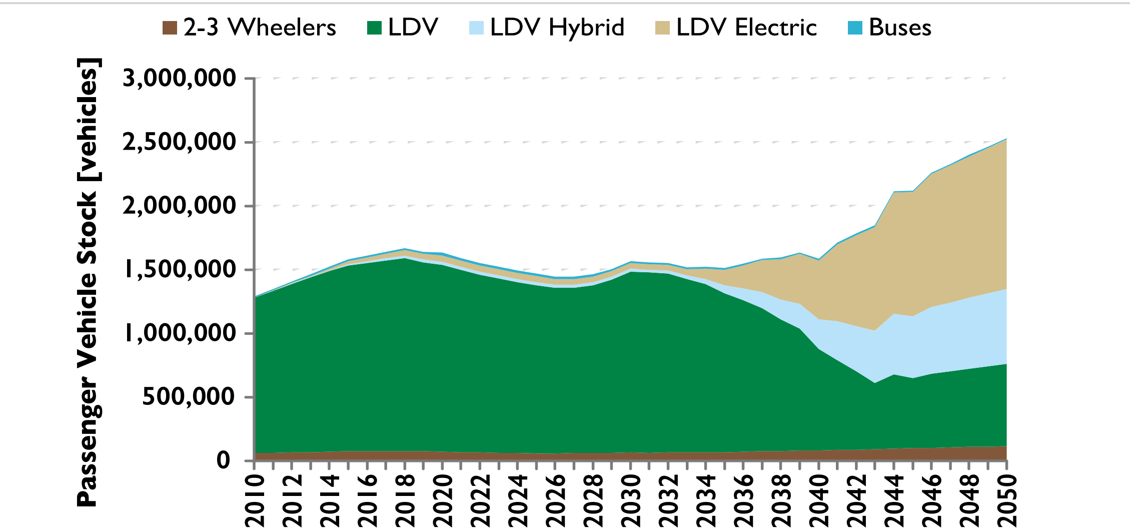


Figure 98: Mitigation option 2 projection of passenger vehicle stock.

Table 51 Passenger transport projections of the mitigation option 2 scenario.

		Baseline	BAU scenario		Mitigation 2 scenario	
	unit	2010	2030	2050	2030	2050
Total passenger vehicle stock	vehicles	1,292,433	1,693,136	2,663,349	1,567,162	2,531,634
2-3 wheelers	vehicles	60,587	66,900	122,500	65,815	115,928
LDV Conventional	vehicles	1,219,460	1,496,724	2,523,986	1,420,213	644,150
LDV Hybrid	vehicles				21,816	586,842
LDV Electric	vehicles				43,633	1,173,684
Buses	vehicles	12,387	16,002	12,180	13,961	14,339
Total vehicle-km	billion vkm/yr	16.04	19.79	34.17	19.73	35.21
Total energy use	toe/yr	1,679,287	1,760,661	2,182,636	1,716,816	1,445,214
Total CO_2 emissions	Gg CO_2/yr	4,852	5,092	6,300	4,920	3,079

Emission reduction from Mitigation Option 3: Increase the share of mass transport

Shifting to mass transport can result in a 49% reduction of vehicle-kilometer activity in 2050 compared to the business-as-usual scenario, which could reflect a net improvement in traffic congestion. As a result, energy use and CO_2 emissions are reduced by 21% in 2030 and 48% in 2050 compared to the business-as-usual scenario (Table 52, Figure 95 and Figure 96).

From the 3 mitigation scenarios, the combination of increasing HEV and BEV share in the fleet coupled with increasing the share of mass transport would bring the most emission reduction in 2030 and 2050.

Table 52 Passenger transport projections of the mitigation option 3 scenario.

		Baseline	BAU scenario		Mitigation 3 scenario	
	Unit	2010	2030	2050	2030	2050
Total passenger vehicle stock	vehicles	1,292,433	1,693,136	2,663,349	1,382,524	1,752,457
2-3 wheelers	vehicles	60,587	66,900	122,500	47,895	87,330
LDV	vehicles	1,219,460	1,496,724	2,523,986	1,323,052	1,653,504
Buses	vehicles	12,387	16,002	12,180	11,577	11,623
Total vehicle-km	billion vkm/yr	16.04	19.79	34.17	15.32	17.53
Total energy use	toe/yr	1,679,287	1,760,661	2,182,636	1,382,036	1,135,437
Total CO_2 emissions	Gg CO_2/yr	4,852	5,092	6,300	3,999	3,275

5.6.3 Mitigation scenarios and emission reduction potential for freight

The proposed mitigation options for freight are:

Mitigation option 1: switching 50% of new truck registrations in 2050 to electric powertrains, since this technology is cleaner and more fuel-efficient than diesel, without compromising the ability for long-haul heavy freight operation where electric charging is not always available; and 75% of LCVs to electric powertrain since this technology has zero tailpipe emissions as needed for clean operation inside cities.

Mitigation Option 2: switching 50% of heavy freight transport in 2030 to electric rail (which has zero tank-to-wheel emissions) based on medium-term government plans for upgrading the electricity supply infrastructure and reactivating rail services on a portion of the disabled railway network in the country

Mitigation Option 3: Combining both options 1 and 2 at the same time.

Results of mitigation analysis for freight

To allow for a comparison of the benefits of each mitigation option relative to the other scenarios, Figure 99 presents the modeling results of the energy use (in tons of oil equivalent or toe) and CO_2 emissions (in Gg), respectively, for all the considered mitigation scenarios. The figure also includes the results of the BAU scenario for the purpose of comparing against the Business-as-usual conditions.

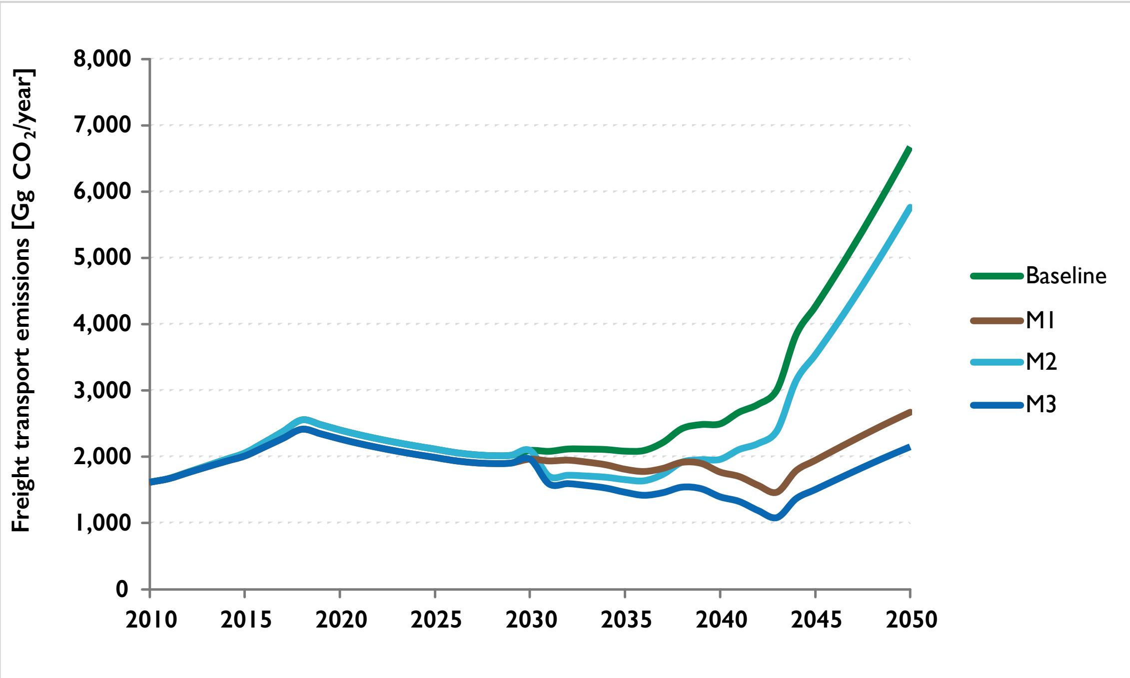


Figure 99: Change in CO_2 emissions from freight transport under the different mitigation scenarios

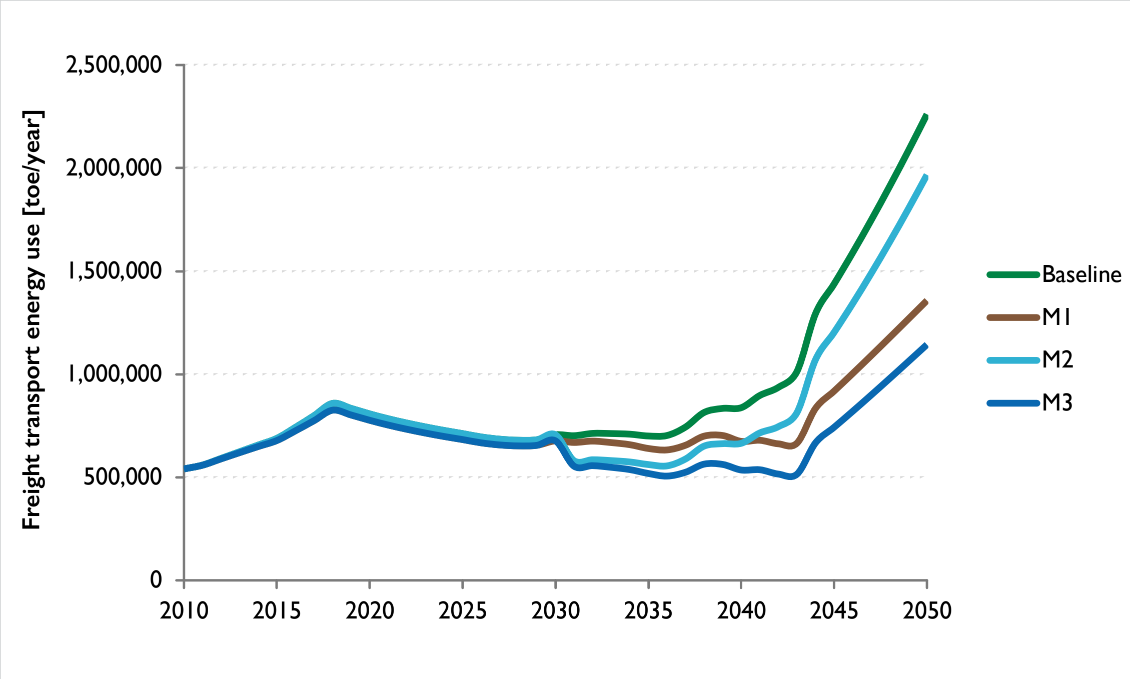


Figure 100: Change in energy use from freight transport under the different mitigation scenarios

The first mitigation option of renewing a part of the truck fleet can reduce freight transport energy use and CO_2 emissions in 2030 by 4.2%, and in 2050 by 40% compared to the BAU scenario as a result of the improved fuel economy and the lower tailpipe emissions of the cleaner electrified vehicle technologies.

The second mitigation option of shifting a portion of heavy freight to rail transport starting in 2030 can result in 13% reduction in 2050 compared to the BAU, due to the elimination of tank-to-wheel emissions of truck transport for 50% of heavy freight from using zero emission electric rail.

Combining both mitigation options together results in 4.2% reduction compared to the BAU in 2030 and 49.4% in 2050. It can be concluded from the above that combining mitigation options is essential for achieving needed reductions in freight transport.

It's important to note that all of the proposed mitigation options would require an extensive electric charging infrastructure to ensure these vehicles are able to operate effectively without range anxiety. This also requires a clean energy mix to ensure that well-to-tank emissions at the power plant do not offset the tank-to-wheel benefits achieved from the elimination of on-road emissions. Therefore, to quantify the overall contribution of electrified vehicle technology to the reduction of GHG emissions, a comprehensive well-to-wheel assessment is needed to account for the additional emissions on the electricity supply side. In any case, electric vehicle technology would become much more beneficial under Lebanon's 2030 plans for a clean energy resource mix in the electricity sector where the current polluting mix relying on heavy fuel oil and diesel oil would be completely replaced by natural gas and more renewable sources.

In developing countries where such infrastructure is lacking and financial resources are severely limited, this can be a challenging target. This is why it's essential to start the transition to electric vehicles and freight rail transport early on, and to increase the share of these cleaner freight transport modes over the medium to long-term. Consequently, the adoption of an integrated strategy for the entire road transportation sector, which must include the re-establishment of rail service for freight transport, is necessary to transition the sector to a sustainable future.

A summary of the challenges related to the implementation of mitigation measures for the transport sector are included in Table 53.

Table 53 Implementation gaps and needs for the transport sector

	Gap/challenge	Corresponding need and request
Policy, legal and regulatory	Insufficient regulations to specify the operations maneuvers of private bus operators and taxi owners	Set clear regulations for operation maneuvers, preceded by setting up a national policy for public transport
	Lack of implementation of legislation governing buses emissions	Update and implement Decree 6603/1995 related to standards for operating diesel trucks and buses, monitoring and permissible levels of exhaust fumes and quality
	Lack of regulations on the informal sector	• Collect/update data on informal sector in transport • Design a plan to integrate informal sector into transport strategy
	Possible decrease in some government revenues due to deployment of transit bus systems	• Enforce legislative reforms in urban planning Laws, expropriation Laws and traffic Laws • Restructure, empower and enhance the role of the traffic management organization
	Missing/insufficient executive and regulatory bodies relevant to mass transit systems	Create/enhance executive and regulatory bodies in charge of ensuring the design, deployment and follow-up of the regulatory framework.
	Lack of regulation or legislation on fuel efficiency and emission standards of imported pre-owned cars	• Update and implement Decree 6603/1995 related to standards on permissible levels of exhaust fumes and quality. • Enforce/update the vehicle inspection program requirements, taking into account the requirements for hybrid cars inspection, and mandate the presence of catalytic converts on conventional gasoline cars.
Institutional	Fragmentation and/or overlapping of responsibility among government agencies	Clarify and centralize responsibility among concerned government agencies to tackle the gap in the transport system management function
	Insufficient coordination between relevant ministries and car suppliers. No	Enforce cooperation and communication on transport studies between relevant authorities.
	Lack of/inefficient regulatory body in the transport sector, and lack of institutions to support technical standards for transportation	Set up a mechanical inspection unit in charge of checking the emissions and safety standards of imported pre-owned cars before entering the country.
	Lack of R&D in transportation	Promote R&D in transportation to adopt knowledge-intensive, high-tech management approaches: • Encourage local industry to develop and manufacture spare parts • Provide incentives to R&D institutions playing a key role in mitigating transport technologies • Encourage universities to create engineering mobility programmes • Create Mobility Monitoring Indicators to support transport studies aiming at the development of sustainable transportation strategies.

Market failures	Poor market infrastructure for mass bus systems: • Poor passenger demand • Under-developed supply channels of transit bus system • Mismanaged public sector with irregularities in bus operation and poor information on bus tracking	• Stimulate passenger demand through the design of a complete bus network covering all boroughs within the high density areas • Deploy effective infrastructure measures such as an optimized land use planning. • Deploy effective operation measures such as optimizing the operation management of the system through real-time information and tracking, intelligent transport technologies, cleanliness programs, etc. • Develop the supply channels of the transit system (purchase enough buses, construct bus stations)
	Few Hybrid and Electric Vehicles reference projects in Lebanon	Require all government vehicles to switch to HEV when buying new cars to take the lead as a reference project.
	Well-established alternatives to public transit systems	Manage the transport demand by deploying a combination of access, personal travel planning, and parking spots to lock the benefits from the operational and infrastructural measures
Financial	High purchase cost of clean bus technologies; High implementation cost of mass transit bus system, and lanes reservation	• Exempt mass transit buses from custom and excise fees, registration fees, and other fees. • Plan for BRT/Feeder Buses in high traffic areas
	Favorable treatment for conventional pre-owned gasoline vehicles rather than the mass transit bus system, including the lack of consideration of negative externalities in pricing transportation	• Provide incentives to taxi drivers to get involved in the bus system • Allocate concessionary fares to the elderly, students and disabled. • Use smart card ticketing schemes with subscription choices
	Favorable treatment for conventional pre-owned gasoline vehicles rather than hybrid vehicles, including the lack of consideration of negative externalities in pricing transportation	• Enforce tax policies that disadvantage the demand for high fuel consuming pre-owned vehicles • Set up stringent fuel-efficiency and emission standards on pre-owned imported vehicles to help set adequate tax policies.
	High tax on maintenance and repair of imported spare parts in mass transit bus systems	Exempt spare parts from custom and excise fees
Awareness	Consumer preference: using their own private passenger cars rather than public transportation	Incentivize the use of mass transit buses: use smart card ticketing schemes with appropriate reduced tariffs and possibilities for long term subscriptions that reduce cost.
	No dissemination of information on ecological and economic benefits of transit bus systems	Provide information on CO_2 and fuel savings comparing to passenger cars, through the proper info display tools: mobile applications, dedicated website, media campaigns, etc.

5.7 MITIGATION ANALYSIS AND OPTIONS FOR WASTEWATER MANAGEMENT

Wastewater treatment and discharge is not a major contributor to Lebanon's GHG emissions, with only 673.54 Gg CO_2eq. in 2019 or 2% of national emissions, but it is one of the main environmental problems, from which the country has been suffering since the early 90's. Although wastewater treatment plants have always been prioritized in several environmental strategies, reconstruction plans, sector's policy papers and investment plans, little improvement has been achieved in this regard. When efficiently applied, wastewater collection and treatment technologies can reduce GHG emissions while preventing pollution from untreated discharges, promoting water conservation and increasing water availability for irrigation, aquaculture, artificial recharge of aquifers, or industrial applications. Therefore, exploring mitigation options for wastewater treatment and discharge has been undertaken under this Fourth National Communication to estimate the potential of emission reduction in wastewater treatment and further mainstream climate change in such development and infrastructure projects.

5.7.1 Methodology

The mitigation options analysis for the wastewater sector builds on the 2006 IPCC Revised Guidelines -tier 2 - to estimate the emission reduction potential of 2 mitigation scenarios compared to a Business-as-Usual scenario (BAU) for the years 2030 and 2050. The GHG emissions estimation under the BAU scenario follows the same trend of GHG emissions from wastewater treatment and discharge for the period 2016-2019 while the GHG emission estimation under scenario 1 and scenario 2 (more optimistic) takes into consideration the current policies, strategies, or plans considered and approved at the national level (Table 54).

Table 54 BAU and mitigation scenarios

Category	BAU scenario	Mitigation scenario 1	Mitigation scenario 2
Domestic wastewater treatment	No successful treatment for municipal wastewater.	50% of wastewater is treated by 2030 and 90% by 2050.	85% of wastewater is treated by 2030 and 100% by 2050.
Industrial wastewater treatment	Industrial wastewater remains mixed with municipal wastewater or discharged to waterways, lakes or the sea.	50% of industrial wastewater is treated by 2030 and 90% by 2050.	75% of industrial wastewater is treated by 2030 and 100% by 2050.
Evaluation of scenario	This is a non-optimistic scenario where no action is taken.	This an optimistic realistic scenario where part of the national strategies is implemented.	This is a highly optimistic scenario which considers the strategies achieved.

5.7.2 BAU scenario

The Business-as-Usual scenario is a non-optimistic scenario where no or limited action is taken, and where the current wastewater management practices for domestic and industrial wastewater are maintained.

For domestic wastewater, the BAU scenario assumes that there is no effective treatment of effluents, therefore conserving the percentage of served population by the different wastewater treatment systems and discharge pathways as it is in 2019 (Table 55). As for population growth, which is an important parameter to estimate wastewater quantities, an annual population growth of 2.33% is estimated for the Lebanese population.

Table 55 Percentage of served population for domestic wastewater treatment systems and discharge pathways in Lebanon under the BAU scenario

Year	Population	Domestic wastewater			
		Primary treatment	Secondary treatment	Septic tank and cesspool	Untreated discharged to rivers, lakes, or to the sea
2019	6,041,289 (4,954,719 Lebanese + 1,086,570 refugees)	13%	6%	28%	53%
2030	6,383,395 Lebanese Only	13%	6%	28%	53%
2050	10,118,386 Lebanese Only	13%	6%	28%	53%

By taking into account the increase in wastewater quantities over the years due to population growth, GHG emissions are expected to increase by 8% by 2030 compared to 2019, and 71% by 2050 as shown in Table 56. It is worth noting that since Syrian displaced are not accounted as part of the projected population of 2030 and 2050, emissions are increasing at a slower rate than the last decade.

Table 56 Summary results of GHG emissions under the BAU scenario

Year	Domestic wastewater GHG emissions (Gg CO_2eq.)	Industrial wastewater GHG emissions (Gg CO_2eq.)
2019	567.22	69.91
2030	599.34	88.99
2050	950.02	141.78

5.7.3 Mitigation scenarios and emission reductions

Mitigation scenarios in wastewater management have been developed based on the National Water Sector Strategy (NWSS) prepared by the Ministry of Energy and Water (MoEW) in 2010 and endorsed by the Government of Lebanon in 2012 in addition to the 2019 updated water sector strategy. The NWSS presents the GoL plans for wastewater management, treatment and reused, and foresees the collection and treatment of wastewater to at least a preliminary level of 95% by 2020. Pretreatment of all industrial wastewater by 2020 and secondary treatment and reuse for all inland and for coastal systems where reuse is applicable by 2020 are also planned for. In addition, the strategy outlines a set of immediate and long-term initiatives that include studies and investments necessary to achieve the set targets. The 2019 update of the strategy sets as a target the "improvement of water quality by 2030 [...] and halving the proportion of untreated wastewater". Therefore, the elaboration of the mitigation scenarios 1 and 2 align with the 2019 strategy updates and proposes additional measures to further reduce emissions as per Table 57 below.

Table 57 Various treatments' scenarios for wastewater mitigation

Year	Population	Domestic wastewater				Industrial wastewater
		Primary treatment	Secondary treatment	Septic tank and cesspool	Discharge to water bodies	Treated
BAU		13%	6%	28%	53%	0%
Scenario 1-2030	6,383,395	0	50%	28%	22%	50%
Scenario 1-2050	10,118,386	0	90%	5%	5%	90%
Scenario 2-2030	6,383,395	0	85%	10%	5%	75%
Scenario 2-2050	10,118,386	0	100%	0	0	100%

Mitigation Scenario 1:

This scenario considers improved domestic and industrial wastewater treatment services reaching 50% in 2030 and 90% in 2050. This implicitly reduces discharges in surface water and in the sea, without any implication on household connections and use of septic tanks by 2030. By 2050, it is assumed that most of residential and commercial units are connected to a sewer system and discharges are treated at secondary level, whether at municipal or industrial level.

Mitigation Scenario 2:

This scenario assumes significant improvements of wastewater treatment services reaching 85% in 2030 and 100% in 2050; and industrial wastewater treatment services reaching 75% in 2030 and 100% in 2050. This scenario also implies gradual improved wastewater collection rates and therefore decreased discharges in septic tanks and in surface waters.

Results of mitigation analysis

It is estimated that treating 50% of wastewater by 2030 and 90% by 2050 (Mitigation scenario 1) can lead to reduction of 12% and 65% of GHG emissions respectively as presented in Figure 101, and an additional reduction of 3% if industrial wastewater treatment is added.

Under a more optimistic scenario and with the increase in the level of wastewater connection and treatment to 85% in 2030 and 100% in 2050, analysis under Mitigation scenario 2 shows a decrease of 55% to 77% from domestic wastewater emissions and a decrease of 52 % to 70% from industrial wastewater emissions, leading to a total potential reduction of 55% and 76% compared the BAU by 2030 and 2050 respectively (Figure 102).

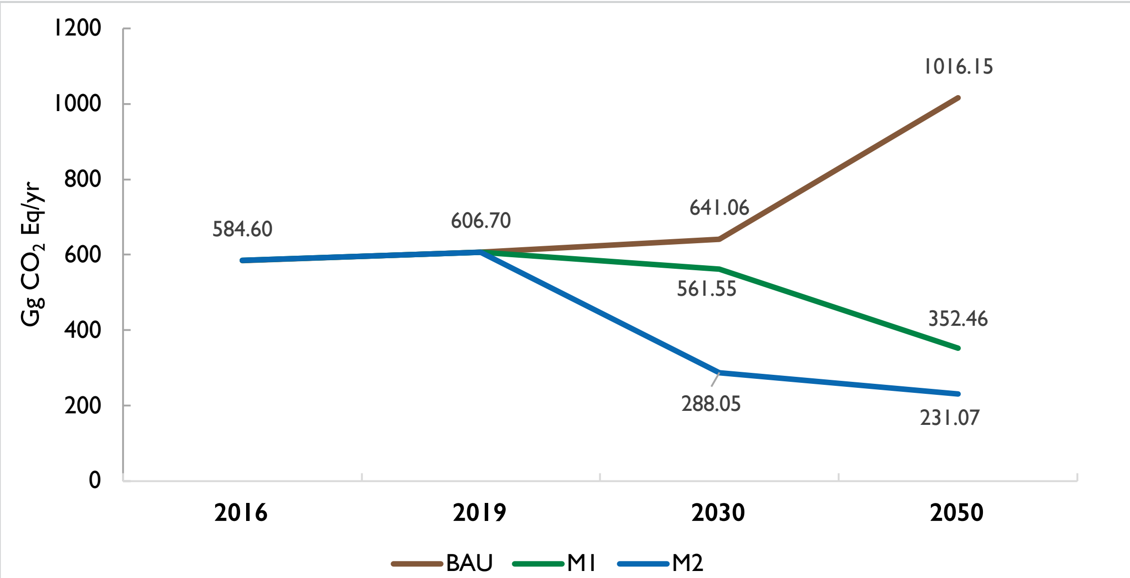


Figure 101: Potential reduction of CH_4 emissions only from domestic wastewater under different mitigation scenarios

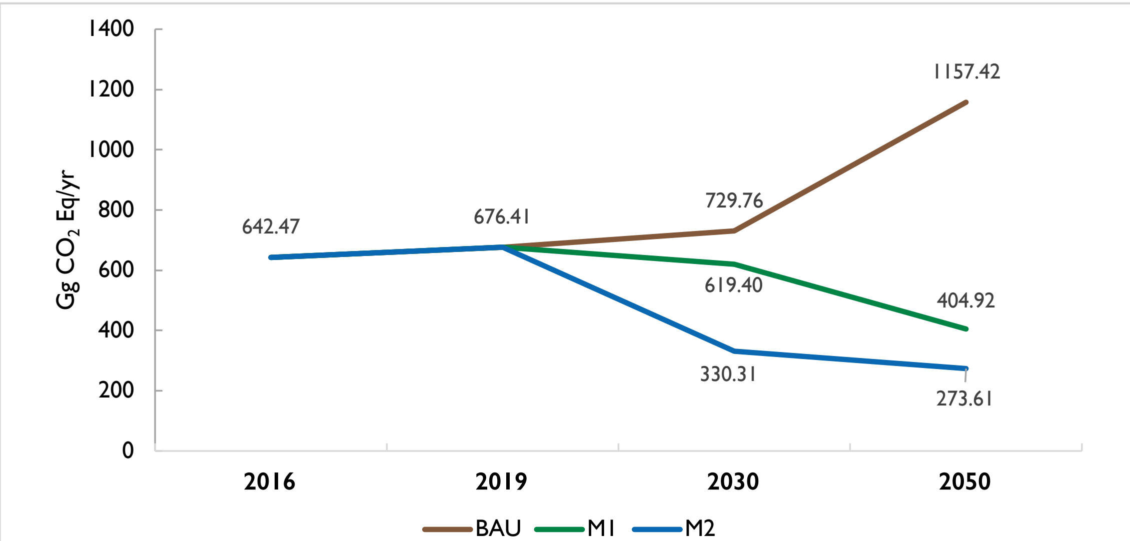


Figure 102: Total GHG emissions reduction from mitigation scenarios for both domestic and industrial wastewater under different mitigation scenarios

The main driver of emission reduction is the diversion of wastewater from septic tanks and water bodies to secondary treatment plants (Figure 103 to Figure 105). In fact, diverting 100 L of domestic wastewater from a septic tank to a treating facility can reduce up to 98% of methane emissions. Although CH_4 emissions are also emitted from treating wastewater, it still records levels that are much lower than those emitted from discharging untreated wastewater in nature.

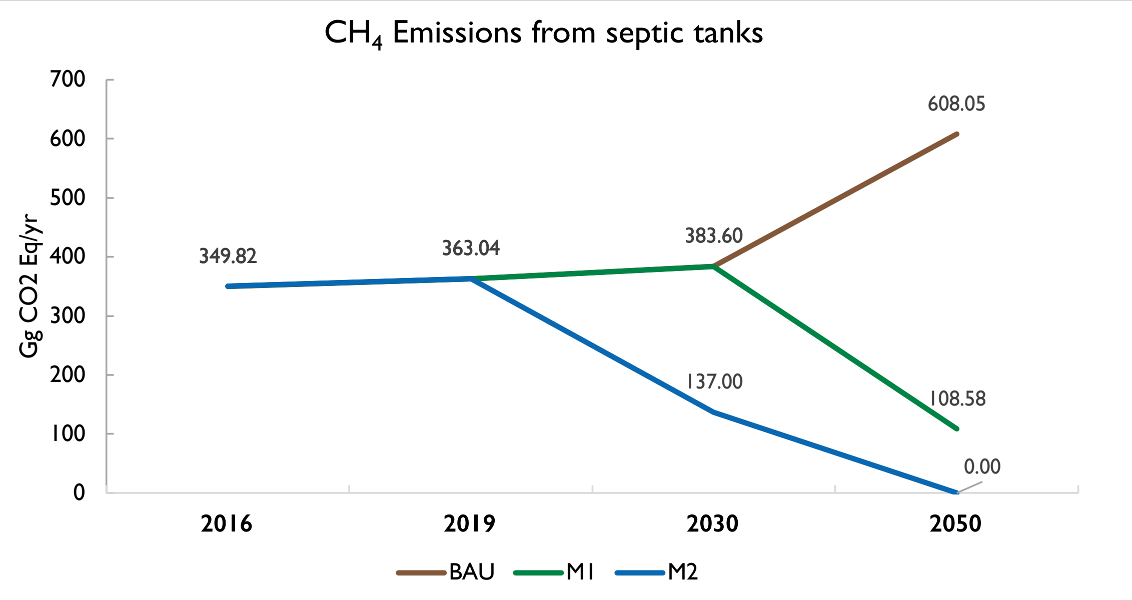


Figure 103: CH_4 emissions from septic tanks under different mitigation scenarios

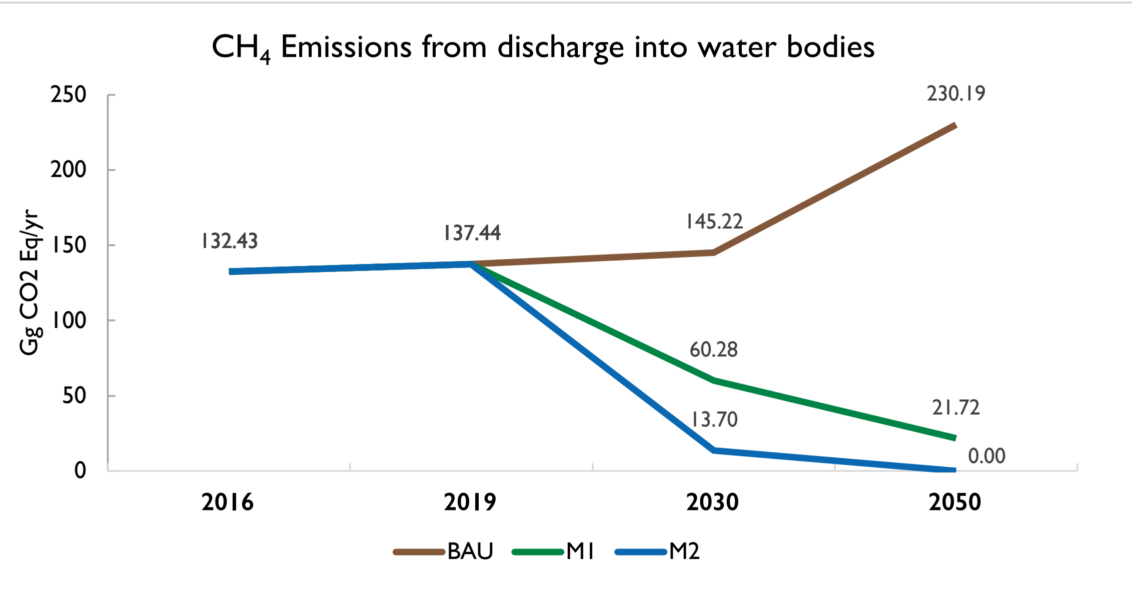


Figure 104: CH_4 emissions from discharge into water bodies under different mitigation scenarios

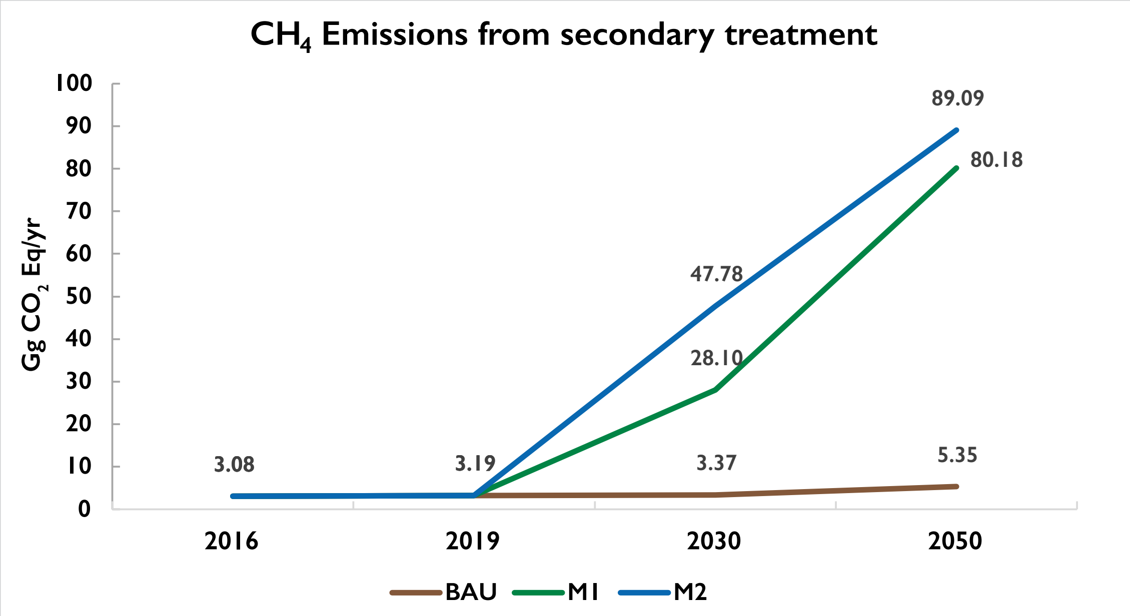


Figure 105: CH_4 emissions from secondary treatment under different mitigation scenarios

5.7.4 Mitigation measures recommendations

Apart from reducing GHG emissions, mitigation efforts for wastewater treatment can have positive side effects due to the intersection with other economic, environmental and societal goals. Many of the co-benefits relate to the improvement of water and soil quality, and the associated health benefits, as well as improved crop quality, protection of biodiversity, and enhanced infrastructure and system resilience. However, several regulatory, technical and institutional measures need to be put in place in order to reach the targets analyzed under the two mitigation scenarios, developed for 2030 and 2050 respectively.

According to the National Water Sector Strategy (2020), the overarching main priority of wastewater management is to protect the environment and the health of citizens by eradicating or at least minimizing the discharge of untreated wastewater into the environment or in waterbodies. Additional objectives include decreasing the cost of wastewater treatment and empowering the existing water establishments who will oversee the operationality and manpower of WWTP in Lebanon.

The latest updated strategy developed by the Ministry of Energy and Water as well as numerous studies conducted on the wastewater sector in Lebanon identify five main challenges regarding wastewater treatment (MoEW, 2020; IFI, 2021):

1- Human resources at both the Water Establishments (WE) and the Ministry of Energy and Water (MoEW) levels

There is a lack in human resources in all water establishments (temporary and permanent staff currently cover only 50% of the needed positions). Employees are assigned several tasks which do not correspond to their specific skill sets, consequently hindering their efficiency and performance. The organizational decrees of Law 221/2000 are no longer adapted for proper human resources management and development of technical expertise.

2- Absence of legal and regulatory framework for wastewater reuse

   Currently, there are no legal basis for reuse of wastewater in Lebanon, with no regulations, guidelines and standards for the reuse of treated wastewater for different purposes. Two propositions for Lebanese Guidelines on Sewage Sludge Use in Agriculture and for Lebanese Wastewater Reuse Guidelines have been prepared by FAO in 2010. However, these have not been officially adopted yet. According to the Water Code, a wastewater fee must be paid by non-connected houses to the sewage network as a sort of "pollution tax" for damaging the environment. Currently, the WE's are charging fees that are not sufficient to cover the O&M cost of wastewater systems (a maximum of 60, 000 LBP if connected and a maximum of 25,000 LBP if not connected, which does not take into consideration the recent devaluation of the Lebanese pound). The standards for wastewater discharge into receiving water bodies are presented in MoE Decision no. 8/1, and Decision 52/1.

3- Transparency, monitoring, evaluating, and verification of data

   Due to the issues in human resources, there has been limited capacity for monitoring actions across the water and wastewater sector with limited capacities to produce technical reviews, and no assigned body for those activities. At the financial level, international reporting standards are not applied, the current water and waste water sector data is incomplete and all the above have increased the lack of trust from users in the water institutions leading to low collection rate and dilution of responsibilities.

4- Inadequate financial framework and billing system

   On one hand, there is a lack of annual audits of the financial statements and ledgers by an international independent audit firm, and no transparency of financial statements and inability of MoEW to monitor the WE's and fairly compare their performance. On the other hand, the current pricing system does not ensure a financial balance to the WEs which leads to insufficient control of facilities operating costs, incomplete customers databases and discrepancy between the number of official customers and the actual population tapping from the network.

5- Difficulty in maintaining operations and facilities and services

   One of the main challenges is the fragmentation of management roles at the water establishments levels. There is a need for WEs need to outsource some of their tasks to private operators but lack an efficient and effective contracting framework and internal technical skills to properly supervise the proper implementation if such contracts.

In order to overcome the above challenges and move towards an integrated wastewater management system that would decrease environmental pollution and mitigate climate change, the following recommendations are proposed:

1- At the human resource levels, an in-depth analysis of the skills of MoEW and WE's permanent staff is needed to identify and prioritize new recruitment needs. Analysis of indicators such as staff categories, profiles, positions and tasks of permanent and temporary staff, and qualifications and position of engineers, will enable a general analysis of MoEW and the WE's' situation. The recruitment of engineers and staff with business management degrees is also crucial in order to develop a customer service-oriented strategy and to improve service management.

2- At the legal and regulatory levels, there is a need for an in-depth analysis of the current wastewater facilities management arrangements and financing tools (fee added to the water bill, municipal tax, etc.) and setting benchmarks from successful frameworks used in Lebanon and abroad. There is also strong coordination need between the water establishments, MoEW, CDR, donors and partners to conduct joint discussions and to propose scenarios and financial arrangements for wastewater facilities management.

3- In terms of data availability, the establishment and regular update of a unified database for data monitoring is essential to ensure. Such a database should include specific sector data on water resources, water quality, water uses, management of water, wastewater and irrigation services (as part of the WE KPI to collect and harmonize within this unified database managed by the Ministry), status of infrastructure projects and on financing tools of the sector. It can also include a users' databases for the wastewater management services, where wastewater services users can be identified and registered in specific databases as in some regions not all users of (households connected to sewage networks and ultimately to treatment plants) are subscribers to the water service of water establishments.

4- For the financial framework and billing system, there is a need to cross-reference the database of subscribers to the WE's with the database of users of wastewater services. A specific system of pricing and collection of the sanitation fee will have to be applied to those who are not yet WE's subscribers. But more importantly, it is crucial to develop a solid water metering system across the country.

5- Concurrently with the financial framework, it is essential to maintain operations and facilities and services through the introduction of a wastewater fee proportional to the water consumed and the setting of another specific wastewater fee for households that are not subscribing to the WE's.

CHAPTER 6

TECHNOLOGY NEEDS ASSESSMENT FOR CLIMATE CHANGE

In 2012, Lebanon prepared and submitted its Technology Needs Assessment (TNA) to the UNFCCC, which identified adaptation and mitigation technologies for 4 priority sectors: energy, transport, agriculture, and water. Table 58 presents the current status of the previously identified technologies.

In 2022, under this Fourth National Communication, Lebanon is updating its TNA for the same priority sectors which are still relevant today, as new technologies keep emerging to help mitigate and adapt to climate change. The objectives of the technology needs assessment are to examine the contribution that different technologies can make to national climate change mitigation and adaptation goals and recommend technology action plans to further expand climate-friendly technologies in Lebanon.

Table 58 Status of technologies prioritized in the 2012 Technology Needs Assessment

Prioritized Technologies	Technology Updates
Energy sector	
Combined Cycle Gas Turbines	CCGT plants are still not operating on natural gas in Lebanon since there is neither agreement on the establishment of Floating Storage Regasification Units (FSRU) nor on the purchase and transport of Natural Gas from Egypt through the Arab Gas Pipeline. Political discussions are underway.
Wind Power	Developers were selected in 2013 to develop three wind farms in the Akkar, totaling a capacity of between 200 and 220 MW. All contracting modalities are currently suspended. Request for Proposal launched in 2018 for the installation of 200-400 MW. All contracting modalities are currently suspended.
Photovoltaic Cells	Grid connected PV systems installed in 2013 and 2018 including the Beirut River snake project (1MWp) and the Zahrani oil installations (1MWp). Expression of interest launched in 2017 for 12 PV farms, each with a capacity of 10-15 MW. 11 companies granted permits to develop and operate PV farms in 2021. Expression of launched in 2018 to install 3 PV farms of 100 MWp capacity combined with a minimum storage capacity of 70 MW each. Request for proposals currently suspended. Draft Law on distributed solar PV finalized by MoEW- currently under review by Parliament Decentralized Solar PV installations increased from 0.79 MWp (1,250 MWh) in 2012 to 89.84 MWp (129,019 MWh) in 2020 (MoEW/LCEC, 2022).
Hydropower	Rehabilitation of existing power plants included in the NREAP 2016-2020, as a measure to increase annual generation by more than 1,000 GWh. Expression of interest launched in 2018 for the installation of 300 MW of hydroelectric power plants - Request for proposals currently suspended.
Transport sector	
Transit Bus Technologies	BRT project for greater Beirut launched in 2018 with World Bank at a cost of USD 345 million, mostly as a loan to the Lebanese government. After the 2019 crisis, the project was suspended. Study on Cost Benefit Analysis for the Use of Natural Gas and Other Low Carbon Fuels in the Transport prepared in 2018 by UNDP/MoEW highlighting the climate and environmental benefits of using electric buses in a BRT system.

Fuel Efficient and Hybrid Vehicles	Tax incentive scheme issued by the government under the budget law of 2018 and renewed in the budget laws of 2019-2020-2021-2022, providing cuts on customs and registration fees for the purchase of hybrid and electric vehicles in Lebanon. No specific measures undertaken for fuel efficient vehicles.
Agriculture sector	
Selection of Adapted Varieties and Rootstocks	Over 32 new high-yielding varieties, including bread wheat, durum wheat, barley, and chickpea, lentils, fava bean, and forage legumes disseminated in Lebanon by ICARDA. Certified plant propagation material (true-to-type and virus-free), assessment of the Genetic Diversity of the Lebanese Carob Germplasm and detection of viruses and new diseases using real-time PCR activities implemented by LARI. Higher yields wheat variety seeds (Miki, Lahen 2, Lahen 3, Saragolla, and Italian) provided by LARI at subsidized prices to farmers- around 50% of the producers in the West Bekaa use these seeds.
Conservation Agriculture (CA)	Conservation agriculture activities included in the Ministry of Agriculture strategies (2015-2019 and 2020-2025) Low rate of adoption of CA, mainly limited to field trials. 1,400 ha of cropland (less than 1% of total cropland) is currently under CA, while the remaining area is mainly under perennial systems (Devokta et al., 2022) Minimum till practiced at many olives and other fruit orchards but not as part of a nationwide strategy for the promotion of CA. Factors hindering the adoption of CA include farming experience, information sources, frequency of irrigation, and severity of weed infestation in the past, capacity building, and farmers' perception about the long-term impact of CA
Good Agricultural Practices	Terracing widely encouraged and subsidized by the government through the Green Plan activities, which has supported almost 68,000 farmers (37,000 ha) in reclaiming abandoned lands or rehabilitating low-productivity lands 150 ha of agriculture terraces restored in the Qadisha Valley and the Shouf Biosphere Reserve (period 2015-2018) under the FAO Forest Landscape Restoration Mechanism Crop rotation promoted by ICARDA/GIZ/LARI/ACSAD/AUB through extension services and field trials. Crop rotation trials were conducted including rain-fed wheat, irrigated corn, alfalfa, barley, and a barley-vetch mixture, within olive trees, vineyards, and apple orchards. Increase in no till-cultivation in Lebanon from 4 ha in 2007 to 1,200 ha in 2015 (ACSAD, 2014). Mixed farming systems (crop-livestock) practiced – around 8% of farmers adopted wheat production combined with animal production as a production system, mainly in the West Bekaa. Agro-biodiversity practiced including crop diversification, inter-planting (mixed cropping), varying crop planting dates, planting early maturing crop cultivars, and planting drought- or disease-resistant varieties.

Water sector	
Rainwater Harvesting from Greenhouses	National guidelines to promote greenhouse rainwater harvesting prepared and published by UNDP Pilot project to harvest rainwater from the tops of agricultural greenhouses conducted by UNDP and IFAD (under the AGRICAL project) in different areas in Lebanon, covering around 5ha of cultivated land and providing 25,000 cubic meters of stored water for supplementary irrigation.
Rainwater Harvesting from Roads	No initiative undertaken specifically to collect runoff rainwater from agricultural roads. Other initiatives included the installation of rainwater harvesting systems for vulnerable communities across Lebanon. 35 rainwater harvesting systems installed by ACTED, benefitting over 100 families in Akkar hence reducing water expenditure by as much as USD 100 per month per household (ACTED, 2020). 8 new hill lakes constructed or rehabilitated in Akkar, Baalbek-Hermel, and the Bekaa to harvest rainwater.
Water User's Association	Legal status of Water Users Association drafted/updated in several watersheds in Lebanon Awareness campaigns and training sessions organized to introduce farmers to WUAs concepts through conducting visits to other international WUAs (USAID)

Table 59 Main "climate-smart" varieties that are disseminated by LARI

Crop	Varieties
Wheat	Provided by LARI: Miki, Lahen 2, and Lahen 3, Saragolla and Italian Provided by commercial suppliers: Shem 1, Shem 2, and Shem 3, Ae. Ventricose, Ae. Caudata, Th. Intermedium, Ae. Mutica, Th. Bessarabicum, T. timopheevii, Triticum araraticum, Triticum dicoccoides: tested by LARI
Barley	ACSAD176, field trials conducted in Tal Amara and Lebanese farmers' fields showed a variety of barley "ACSAD176" has high productivity and good grains quality, tolerant to drought, and resistant to diseases Hordeum vulgare L.—drought-tolerant species Hordeum bulbosum: tested by LARI High yielding varieties of barley used in field trials by ICARDA: MSEL/LOGAN-BAR (Malt-9), BRS195/ND19098-1(Malt-10), Harmal-02/ Soufara (Reem) (Malt-11), Cristalia (origin: UK) (Chalak et al., 2015)
Chickpea	Kabuli Chickpea: ILC 202, ILC 482, ILC 1930 and ILC 3279 (ICARDA, 2022)
Faba bean	Vicia faba L., genotype: FLIP06-010FB field trials conducted at Terbol in Lebanon for one season (2011-12) with three irrigation treatments and at Kfardan in Lebanon for two seasons, 2008-09 (rainfed) and 2010-11 (rainfed and SI); results show that FLIP06-010FB is the highest yielding genotype (Maalouf et al., 2015)
Lentil	L. culinaris subsp odemensis wild lentil accessions grown at ICARDA field locations in Terbol, Lebanon, PI533690, and PI533693 showed an increase in biomass compared to the controls (Thavarajah et al., 2017). Lens orientalis tested by LARI
Potato	Three potato cultivars ('Vivaldi', 'Annabelle' or 'Colomba') a demo plot established in north Lebanon by the international labor organization (ILO) in collaboration with LARI to support new potato varieties plantations that are disease resistant and acceptable for EU export (Choueiri et al., 2017).

6.1 TECHNOLOGIES FOR THE ENERGY SECTOR

The energy sector is facing great structural transformations with the increased development in sustainable renewable energy and smart grid technology. At the same time, there is a need to meet continued demand growth on top of the need for refurbishment and replacement of aging assets while coping with climate change and maintaining a reliable and competitive energy service. While new breakthrough technologies are becoming more and more available and technically mature, competitiveness is still a major challenge as many countries which invested heavily in renewable energies have seen significant increases in the Levelized Cost of Energy (LCoE) of their energy mix.

The 2012 Technology Needs Assessment (TNA) covered the potential of the natural gas operated CCGT, wind, hydro, PV, biomass, reciprocating engines, and combined heat and power technologies. As many of these technologies are already under development in Lebanon by the existing policies, this TNA update covers new technologies that were not addressed before and that present new possibilities for climate change mitigation in the energy sector.

Some of the most promising low carbon technologies are reviewed under this section with their applicability to Lebanon and the specific challenges and needs for their deployment. The assessed technologies include:

1- Smart Grids

2- Concentrated Solar power

3- Pumped hydro

4- Carbon Capture and Storage /Use

5- Hydrogen fuel and cells

6- Geothermal and ground source heat pumps

7- Sea energy

6.1.1 Smart Grids

Smart grids emerged as a modern alternative to conventional grids, which are often large, inefficient grids that lose power in transmission, require an overcapacity of generating capability to cope with unexpected surges in energy use and allow one-way communication only – from provider to customer.

"A Smart Grid is an electricity network that can efficiently integrate the behavior and actions of all users connected to it – generators, consumers and those that do both – in order to ensure economically efficient, sustainable power system with low losses and high levels of quality and security of supply and safety" (EC, 2010). To do so, "smart grids coordinate the role of stakeholders involved in the electricity supply chain including generators, grid operators and end users taking into account their needs and capabilities." (IEA, 2011). Smart grids incorporate applications for grid optimization, monitoring, control, and consumer enabling to contribute to grid management and improvement of the physical capacity and flexibility of the network.

Smart grids can reduce emissions through enabling the integration of clean, renewable generation sources, reducing electrical losses, increasing penetration of distributed energy resources, and increasing the efficient use of energy through feedback to consumers. However, smart grids' emissions reduction potential is not a straightforward estimation as it depends on specific technologies, their inherent interactive relationships, the uncertainty in the individual technology emissions reduction estimates, and the resulting diversified emissions reduction effects that can increase significantly when combined. Thereby all technical smart grid mechanisms need to be considered in great analytical depth to rigorously address the quantification of the estimated reductions in electricity and CO_2 emissions and associated uncertainties.

A 2010 study from the US Department of Energy provided an assessment of the associated reductions in electricity and CO_2 emissions of nine mechanisms using smart grids. While several of them were estimated to have small or negligible impacts, five of the mechanisms could potentially provide reductions of over 1%. Moreover, the combined effect of the direct mechanisms was 12%, and the indirect mechanisms total 6% of energy and emissions for the U.S. electricity sector. These correspond to 5% and 2% of the U.S. total energy consumption and energy-related CO_2 emissions for all sectors (including electricity). The magnitude of these reductions suggests that, while a smart grid is not the primary mechanism for achieving aggressive national goals for energy and carbon savings, it can provide a very substantial contribution to the goals for the electricity sector. Further, a smart grid may help overcome barriers to deployment of distributed solar renewables at penetrations higher than 20% (USDoE, 2010).

The Smart Grid concept deployment is driven by three technologies:

Distributed Generation (DG)

Distributed Generation refers to a variety of technologies, renewable and conventional, that generate electricity close to where it will be used. Distributed generation may serve a single structure, or it may be part of a microgrid. When connected to the electric utility, distributed generation can help support delivery of clean, reliable power to additional customers, reduce electricity losses along transmission and distribution lines, reduce voltage fluctuations, improve power quality, reduce energy cost, and increase customer satisfaction. The integration of numerous distributed power sources of different characteristics into the electric system requires a smart grid that can manage dynamically the varying inputs to maintain the power system stability.

Energy Storage Systems (ESS)

Energy Storage Systems provide a wide array of technological approaches and services to managing the power supply such as frequency control, voltage regulation, spinning and stand reserves, black start service peak shaving, load leveling, islanding support, or other service mainly related to private uses of the ESS (e.g., residential use for increased self-consumption of distributed generation production, industrial applications, uninterruptable power supply etc.).

ESS are mainly differentiated in terms of storage time capability. The short-term ESS (<0.25 hours) can be used for primary and secondary frequency control, spinning reserve, black start, peak shaving, islanding, electro-mobility, and uninterruptable power supply. The medium-term ESS (1–10 hours) can provide services of tertiary frequency control, standing reserve, load leveling, islanding, electro-mobility, residential self-consumption increase, and UPS. Long-term ESS (from 50 hours to weeks) can be exploited for long duration services, during periods when there is no or scarce generation of electricity from renewable sources.

The following table summarizes the main characteristics of the well-established ESS technologies.

Table 60 Large-Scale Well-Established Energy Storage systems

Technology	Brief description of technology	Power	Energy density	Storage Time	Response Time	Efficiency
Pumped Hydro ESS	Stores gravitational potential energy of water, pumped from a lower reservoir to a higher one.	1 MW–4 GW	400 MWh–20 GWh	1h–Weeks	10-15 min	70–85%
Compressed Air ESS	Stores the elastic potential energy of compressed air in an airtight space	10 MW–300 MW	1.16 GWh–3 GWh	1h–Weeks	12 min	50-90%
Battery ESS	Stores the chemical energy in electrochemical cells	100 W–100 MW	1 kWh–200 MWh	1–10 h	Seconds	60–80%
Flywheels ESS	Stores rotational energy into an accelerated rotor	5 kW–90 MW	5 kWh–200 kWh	<0.25 h	Seconds	85–95%
Hydrogen ESS	Stores Hydrogen Gas produced by surplus electrical energy	10 MW-1 GW	1 MWh-10 TWh	50 h-1 Month	15 min	65-70%

ESS are an integral part of smart grids and complement distributed generation by providing a means to store the available energy at times of low load and make it dispatchable as needed. ESS development is thereby essential for allowing a greater deployment of low-carbon generation systems that lack the same level of load-following flexibility as compared with a conventional fossil fuel power generation. ESS can reduce emissions by shifting on-peak energy use to off-peak periods. As peak power is largely fossil fuel fired and renewables are steadily increasing as a percentage of the off-peak power mix, the emissions benefits of ESS will continue to grow as off-peak generation will increasingly have a cleaner emissions profile than peak generation.

Demand side management (DSM)

The Demand Side Management comprises of techniques and policies which aim at controlling the shape of daily energy consumption towards an equalized pattern that is close to that of the base-load generation capacity. The main challenge in the implementation of a DSM program is that of having real time information on the daily behavior of loads in the electrical system, which is generally not available from conventional systems. Smart Grid technology creates an environment which enables the exchange of information and control actions among the various segments of the power grid.

DSM allows generators and loads to interact in an automated fashion in real time, coordinating demand to flatten spikes. Eliminating the fraction of demand that occurs in these spikes eliminates the cost of adding reserve generators, cuts wear and tear, extends the life of equipment, and allows users to cut their energy bills by telling low priority devices to use energy only when it is cheapest.

Some practical examples of smart grid technologies applications in DSM are sensors for remote measuring, chips and controllers for monitoring, smart meters (advanced metering infrastructure or automatic meter reading), energy accounting software, smart billing software– IP-based billing or prepaid metering, grid management systems (e.g. supervisory control and data acquisition and output management system), asset inventory and network design systems (e.g. GIS tools), load analysis and automated dispatch software, workflow management systems for the grid, performance contracting applications, demand response software that allows automated load maintenance, protocols for grid-wide system interoperability, and advanced telecommunications to allow distributed energy producers to pool resources and handle spikes in supply and demand.

Other ICT platforms that help reduce technical losses include remote measurement and monitoring of energy use, remote grid element management and energy accounting, which together would help utilities monitor energy use across the grid better and allow them to trace the source of energy losses, whether they be theft or otherwise.

One important smart grid application that is essential for the operations of the smart grid infrastructure is smart metering. Smart meters provide instant and precise metering and are equipped with advanced ICT interfaces that ensure two-way communication between grid and smart meter making them quite sophisticated and detailed. In addition to instant data acquisition, data storage capability for blackouts, remote metering, monitoring and control capabilities, smart meters can also calculate power factor, record detailed consumption data, voltage and current values, predict power consumption at intervals, and accommodate remote billing requirements as well as Time of Use billing. Smart meters also allow users to remotely monitor and control their home energy management systems. An Advanced Metering Infrastructure (AMI) is used to define a smart meter-based infrastructure along smart grid applications since it provides measurement of consumed energy, power demand rates, and power quality of entire grid. Smart meters could also potentially help with power quality issues such as automatic voltage restore, frequency and voltage control, active and reactive power control, demand side management, decentralized generation in the context of microgrid and cyber-secure communication systems (Kabalci, E. and Kabalci, Y., 2019).

Applicability of Smart Grids in Lebanon

In the last two decades Lebanon started the transition towards smart grids by establishing a National Control Center (NCC) in 2006, contracting Distribution Service Providers (DSP) and planning for the procurement of renewable energy production facilities with energy storage features. Unfortunately, the Beirut Port explosion in 2020 incurred severe damage to the existing NCC, located in EDL central building, and it has not yet been reconstructed due to lack of resources. The repair and upgrade of the NCC is crucial to integrate any renewable energy project efficiently in the grid and apply other smart grid features.

Lebanon has also launched a series of DSP contracts to implement of the Advanced Metering Infrastructure program, which includes supply and installation of smart meters at several levels, as well as data concentrators (to gather and relay information collected by meters) and meter interface material (i.e., breakers, transformers, panels and wiring). However, despite significant achievements, the DSPs faced many issues and delays, and the results have been uneven between the various DSP areas. The main achievements of the DSPs include the implementation of planned distribution works and Operation and Maintenance programs including connection of new customers, incorporation and training of EDL temporary staff transferred to the DSPs, implementing Health and Safety procedures, survey and georeferencing of distribution assets, improvements in customer relationships, a reduction in distribution network faults and distribution losses, improvements in bill collection, a reduction of non-technical losses and the gradual replacement of the conventional meters with smart meters.

As for Energy Systems, the introduction of renewable energy facilities with energy storage has also started as the Ministry of Energy and Water provided permits in May 2022 to 11 companies to build solar power plants that can produce 15 megawatts each.

6.1.2 Concentrated Solar Power

Concentrated Solar Power (CSP) technologies use a mirror configuration to concentrate the sun's light energy onto a receiver and convert it into heat. The heat can then be used to create steam to drive a turbine to produce electrical power or industrial process heat.

CSP plants can integrate a thermal energy storage system that uses heat to drive a heat engine that drives in turn an electric generator to generate Alternative Current (AC) electricity during cloudy periods, or for hours after sunset or before sunrise. This ability to store solar energy makes CSP a flexible and dispatchable source of renewable energy in comparison with Photovoltaic (PV) systems which do not use the sun's heat to generate power but use sunlight instead. Table 61 provides a comparison of both technologies.

Table 61 **Summary table of the main features of both CSP and PV**

	Concentrated Solar Power	Photovoltaic
Energy Storage and efficiency	CSP systems can store energy by use of Thermal Energy Storage technologies (TES), which are far more efficient than EES technologies.	PV systems do not produce or store thermal energy as they directly generate electricity that cannot be easily stored (e.g., in batteries) especially at large power levels
Power Dispatch Ability on Demand	Dispatchable. TES is often integrated with CSP.	Needs costly EES Technology to become dispatchable
Off-Grid Capability	Not Mature - Under Development	Adapted Mature Technology
Scalability	Scalable	Extremely Scalable
Land Use	2-3.5 ha/MW	2-3.5 ha/MW
Capital Needs*	5,774 to 6,474 $/kW	995 $/kW
LCoE*	18 to 25 ¢/kWh	6 to 7 ¢/kWh
Capacity Factor*	Typically, 37 to 45% - may reach 70%	18 to 20 %

*Source - IRENA, 2020

CSP is often considered more expensive than PV. However, it's worth noting that PV is cheaper when the power produced is directly sent to the grid, but its cost increases when batteries are added. On the contrary, the intrinsic way of storing energy of CSP eases the integration of Thermal Energy Storage (TES) which are around 10 times cheaper than Electrical Energy Storage (EES). Thus, CSP systems integrated with TES are currently a cost-competitive technology to provide reliable and baseload power (Bravo and Friedrich, 2018).

CSP systems can be also combined with combined cycle power plants resulting in hybrid power plants which provide high value, dispatchable power. They can also be integrated into existing thermal-fired power plants that use a power block like CSP, such as natural gas, biofuel, or geothermal plants.

CSP can be used only in regions where the Sun's Direct Normal Irradiation (DNI) is significant. Typically, the benchmark is a DNI of 2,000 kWh/m²/yr which corresponds to the DNI of Southern Europe and some areas in Lebanon such as Akkar and the Bekaa. For DNI in the range of 2,300 or 2,700, as encountered in the MENA region or in some parts of the USA, the LCoE cost could be decreased by 20 to 30% (CEDRO, 2012).

The most advanced and commercially proven CSP technologies are Parabolic Trough (PT) and Solar Tower (ST). PT uses long curved mirrors arranged in a line to concentrate sunlight on pipes located at the mirrors' focal center. These pipes run down the length of the trough and contain heat transfer fluid which is heated to produce steam. ST use a large array of mirrors to track the sun and reflect its light onto a central receiver mounted on top of a tower at the center of the mirrors array. ST can achieve higher temperatures and higher efficiencies than parabolic trough.

Commercial PT plants in operation have capacities between 14-80 MWe. They reach a maximum operating temperature of 390°C, which is limited by a thermal degradation of the synthetic oil used as the heat transfer fluid. The efficiency (i.e., the ratio of electricity generated to the solar energy input) is about 14-16% and the capacity factor is on the order of 25-30%, depending on the location. Some PT and ST plants have molten salt thermal storage systems with storage capacities of 6-15 hours, which increase the plant capacity factors to over 40% and 70%, respectively, and thus make it more efficient than solar PV (IRENA, 2013).

The following table summarizes the value proposition and deployment optima of both CSP technologies:

Table 62 Summary table of the value proposition and deployment optima of CSP technologies

	Parabolic Trough	Solar Tower
Value Proposition	Commercially proven and bankable technology	Commercially proven and bankable technology
	Maturity level and operational experience	Efficiency
	Modularity	High operating temperatures
	Large number of EPC providers	
Application / Deployment Focus	Centralized grid access locations	Centralized grid access locations
	Locations with hybridization possibilities	Locations with hybridization possibilities

Source: ATKEARNEY, 2010

Applicability in Lebanon

Lebanon has significant CSP potential with an estimated potential of 1,210 MW and a subsequent power supply of 2,741 GWh (based on a 15% annual average solar-to-electric efficiency and 30% land use factor is that if only 15% of the total land area is used) (MoEW/LCEC, 2016). Already, a study has been commissioned by MoEW/LCEC in 2021 to assess the feasibility of installing and operating a Concentrated Solar Power Plant in Hermel, with a minimum capacity of 50 MW and 7.5 hours of storage. In addition, In the IRENA Remap 2030 projection for Lebanon adopted in the updated NDC 2020, a 100 MW CSP deployment is foreseen by 2030 (IRENA, 2020).

6.1.3 Pumped Hydro Energy Storage

The Pumped Hydro Energy Storage (PHES) is a well-established and commercially acceptable technology for utility-scale electricity storage with large volume, long storage period, high efficiency, and relatively low capital cost per unit of energy and has been used since as early as the 1890s.

PHES requires a hill, pump turbines and two reservoirs of waterm one at the top of the hill and another at the bottom. The water reservoirs serve for daily and seasonal energy storage, thus basically solving the energy storage problem. The electrical energy produced in excess by the renewable energy system is converted in potential energy by pumping water to a higher elevation where it can be stored indefinitely and then released as needed to pass through the pump turbines and generate electricity.

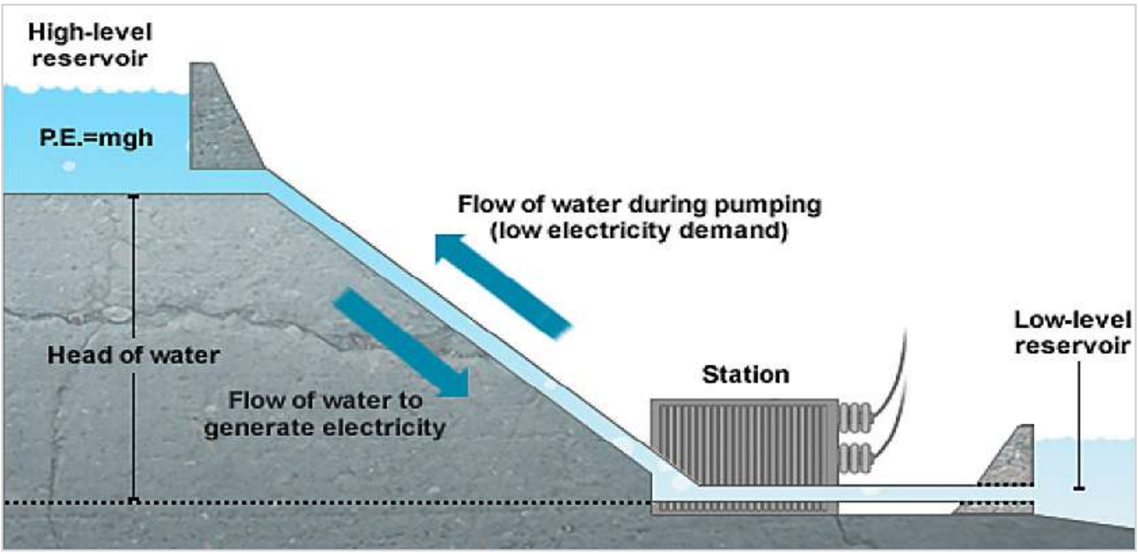


Figure 106: Schematic of a PHES system (Zohuri B., 2019)

In the early 2000's, this technology emerged again as an economically and technologically acceptable option for providing flexibility through system inertia, frequency control and voltage regulation for grid stability improvement, storage and reserve power with rapid mode changes, peak load shaving and black-start capability. Pumped storage excels at long discharge duration and its high-power capacity is crucial in reducing transmission congestion, overall costs, and emissions in the power sector. PHES is an economical addition to a system, which increases the load factor of other systems or energy mix and provides additional capacity to meet the peak loads.

PHES can complement renewable energy sources as it can accommodate for their inherent uncertainty, intermittent, variability, and seasonality making these a difficult source to dispatch. It can also provide a way to store energy on a large scale and make it available on demand, thereby increasing the integration level of the renewable sources on the electrical grid.

There is a vast potential for pumped storage sites worldwide and there is growing research on possibilities for retrofitting disused mines, underground caverns, non-powered dams, and conventional hydro plants. During peak demand periods, PHES reduces the need for additional generation by inefficient costly units so the total utility generation cost can be diminished. When integrated with a renewable energy facility PHES can also significantly increase the profitability of such facility by allowing the energy sale during high tariff periods (Simão and Ramos, 2020).

One variant of PHES is sea water pumped hydro energy storage, which, with a high flow rate and low head, is technically and economically feasible for increasing the ability of national grids to allow high penetration of intermittent renewable energy.

Applicability in Lebanon

The existing and projected dams in Lebanon can be used as lower basins and candidate locations can be identified for upper pumped storage basins in the vicinity of these dams without affecting their functionality. These upper basins can be semi-natural basins with the least amount of construction required. The positive effect on the behavior of the power system when the PHES is included will be an increase in the renewable energy source integration level and capability to dispatch on demand. A preliminary study on the PHES potential in Lebanon has identified 3 inland and 6 seashore potential PHES sites with total capacity of 1,173 MW (Geadah, 2009).

6.1.4 Carbon Capture and Storage (CCS) and Carbon Capture and Use (CCU)

Carbon Capture and Storage (CCS) is a process used to control CO_2 emissions from industrial and energy related sources. The process consists of the separation of CO_2 and its transportation to a storage location and long-term isolation from the atmosphere (IPCC, 2005). After capture, carbon dioxide is compressed and then transported to a site where it is injected underground for permanent storage (also known as "sequestration"). CO_2 is commonly transported by pipeline, but it can also be transported by train, truck, or ship. Geologic formations suitable for sequestration include depleted oil and gas fields, deep coal seams, and saline formations. These formations are often a kilometer beneath the surface and consist of porous rock that holds the CO_2. Overlying these formations are impermeable, non-porous layers of rock that trap CO_2 and prevent it from migrating upward.

Carbon capture and utilization (CCU) follows a similar process but aims to use CO_2 as an alternative feedstock in the production of goods instead of storing it. CCU includes the direct use of CO_2 or its conversion into chemicals or materials. One of the most acknowledged examples of direct use of CO_2 is enhanced oil recovery, which revolves around injecting CO_2 in an almost depleted oil reservoir to increase the amount of oil that can be extracted. CO_2 can also be used in the production of products such as carbonates, chemicals, fuels, and materials such as plastics. CCU main advantages are that it can generate revenues that (partially) offset the cost of carbon capture by introducing CO_2 in the fuel and chemical production chain and cover for the lack of geological storage potential for CCS in specific areas.

Bioenergy with Carbon Capture and storage (BECCS) is another CCS application that uses biomass energy applications to provide net removal of atmospheric CO_2. Under BECCS, biomass (organic material) is converted into heat, electricity, or liquid or gas fuels (the "bioenergy" step), and the carbon emissions from this bioenergy conversion are captured and stored in geological formations or embedded in long-lasting products (the "carbon capture and storage" step). Because biomass draws carbon from the atmosphere as it grows, BECCS can be a negative emissions technology when it is well implemented.

With further development, CCS may even become one of the few carbon abatement technologies that can be used in a 'carbon-negative' mode, removing carbon dioxide from the atmosphere. The International Energy Agency predicts that in 2040, 60% of primary energy generation will still come from fossil fuels, despite acceleration in renewable generation. In the face of the steep emission cuts that are needed to meet climate change targets, using CCS and CCU is a hedging strategy and a means of fending off climate change until the world has substantially reduced its reliance on fossil fuels.

Most modelling studies agree that a portfolio of CO_2 mitigation options including Carbon Capture is needed to reach the required CO_2 emission reduction. In a pathway from the IEA to limit global warming by 2°C the CCS accounts for 13% CO_2 emission reduction (IEA, 2015). In 2014, the Intergovernmental Panel on Climate Change (IPCC) concluded that without Carbon Capture and Use or Storage, the costs of climate change mitigation could increase by 138%, furthermore, that realizing a 2°C scenario may not even be possible without CCS and CCU technologies (IPCC, 2014). CCS provides one of the most mature and cost-effective options for reducing emissions from processes and high-temperature heat demand. Several reports, including from the Energy Transition Commission and the IEA, have concluded that achieving net-zero emissions in industry without CCS may be impossible and at best more expensive (IEA, 2019; ETC, 2021).

However, CCS, and potentially CCU, are also associated with adverse impacts that affect the environmental performance of the technologies. The large energy required by the CO_2 capture unit is one of the main drawbacks of the technology, because it lowers the efficiency (of a power plant) or increases the primary fuel consumption per unit of output (in an industrial process). Furthermore, the CO_2 capture process increases the cooling demand, electricity consumption (for CO_2 compression), and the use of chemicals and/or solvents. These drawbacks lead to an increase of direct non-CO_2

emissions at the power plant or industrial process, as well as a rise in indirect CO_2 and other emissions caused by, for example, the additional production of fuels and chemicals (IPCC, 2005).

The possibility of widespread deployment of carbon capture technologies depends largely upon their cost, and fluctuations in cost depend entirely upon developments in technology. So long as Carbon Capture technologies are necessary for the transition to a zero-carbon economy, their technologies and resulting products will move toward efficiency, and decrease the cost curve.

Applicability to Lebanon

In the case of Lebanon, the American University of Beirut, launched a study on "CO_2 Capturing and Sequestration in Lebanon – A Full Cycle Assessment and Optimization towards Minimizing the Country Emissions Footprint" in 2019, with the aim at mapping the current and expected future CO_2 emission sources in Lebanon and recommending feasible options towards minimizing the CO_2 emission footprints through sequestration or other utilization of CO_2.

6.1.5 Hydrogen and Fuel Cells

Hydrogen is a clean-burning fuel that produces only water and heat when burnt (i.e., no CO_2) and has potential as a clean fuel alternative for generating electricity. Hydrogen can be produced without carbon footprint using non-fossil energy sources or from a variety of processes that use fossil energy sources combined with CO_2 sequestration. Renewable or green hydrogen is produced by electrolysis with electric energy that can be provided by a renewable energy source, or from biomass by a variety of methods, such as gasification or fermentation.

Hydrogen can be burned in gas turbines and internal combustion engines or used in fuel cell systems, reacting with oxygen in an electrochemical process where electricity and water are produced. Most gas turbines manufacturers can accommodate the use of up to 15 % to 20% hydrogen fuel mix on their standard combustion system. There are still limitations on the percentage of Hydrogen that can be mixed with natural gas and the type of units that can be used for hydrogen combustion. Efforts by gas turbines manufacturers to develop 100% hydrogen-fueled gas turbines have recently shifted into high gear, as most manufacturers committed in January 2019 to provide gas turbines that can handle 100% hydrogen by 2030. It is estimated that by the time the gas turbines technology will mature for the large-scale use of hydrogen as a primary fuel, the hydrogen production costs will be competitive with that of conventional fuels.

Several technical and economic challenges remain, however, before hydrogen can be exploited in the same way as conventional fuels. Hydrogen is a substance that is very flammable and highly combustible (i.e., it only needs energy equivalent to static electricity to ignite and has a broad combustion range). It has unparalleled lightness that makes it burn violently and easily explode. These characteristics, in addition to its low volumetric energy density, make hydrogen difficult to handle at all stages of the supply chain during production, storage, distribution, and use.

Hydrogen can also be used in fuel cells to generate power using a chemical reaction rather than combustion, producing only water and heat as by-products. Hydrogen fuel cells produce electricity by combining hydrogen and oxygen atoms. The hydrogen reacts with oxygen across an electrochemical cell like that of a battery to produce electricity, water, and small amounts of heat.

The market for stationary fuel cells for CHP (Combined Heat and Power) and distributed generation applications can be divided into three different market segments: residential (micro-CHP, 1-5 kW), commercial (5 to 400 kWel), and industrial for applications for prime power or CHP beyond 400 kWel. For large applications, modular fuel cells can be stacked to increase the power output from a few Watts up to MW-size without appreciably affecting the electric efficiency. Stationary fuel cells are also currently used in uninterrupted power systems as a primary power or as a back-up, especially for remote off-grid telecom sites.

Although hydrogen fuel cells have many advantages their large-scale deployment is still slow for many reasons as summarized in Table 63.

Table 63 Advantages and disadvantages of Hydrogen Fuel Cells

Hydrogen Fuel Cells - HFC	
Pros	**Cons**
• Hydrogen is an abundant and renewable source of energy, and is considered a clean energy source • HFC's are a powerful source of energy with good energy efficiency. • HFC's have almost Zero Emissions • HFC's have Fast Charging Times (i.e., below 5 min) • HFC's do not produce noise pollution • HFC's are compact with low visual footprint • HFC's have long usage times, are not impacted by outside temperatures, and do not deteriorate in cold weather. • Because of availability of Hydrogen, HFC's are ideal for remote areas • HFC's have Low Maintenance Costs	• Hydrogen extraction requires a significant amount of energy and water • HFC's require investments to become more mature and viable • HFC's are costly as they require precious metals for their fabrication • Hydrogen storage is difficult and costly • The use of Hydrogen requires infrastructure • Hydrogen is highly flammable

Applicability in Lebanon

The use of Hydrogen Fuel Cells in Lebanon for stationary applications is still not a viable option as Lebanon lacks the necessary infrastructure and the technology itself requires more time to become mature and competitive in terms of cost.

6.1.6 Geothermal and Ground Source Heat Pumps

The slow decay of radioactive particles in the earth's core, a process that happens in all rocks, produces geothermal energy. Therefore, there is a constant heat flow to the Earth's surface and atmosphere from the immense heat coming from within the Earth that is transferred through groundwater from rocks to the surface and can be accessible through boreholes or naturally occurring cracks and faults.

Geothermal Energy is a renewable energy as, through proper reservoir management, the rate of energy extraction can be balanced with a reservoir's natural heat recharge rate. Geothermal resources are classified according to their reservoir fluid temperature at 1 km depth into low (< 100°C), medium (100 – 180°C) and high enthalpy (> 180°C).

Depending on the geothermal resource temperature, geothermal exploitation could be used for power generation, direct use or for of Ground Source Heat Pumps (GSHP) (SETIS, 2014).

Geothermal energy for power generation: Geothermal Power Plants (GPP) capacity factor is higher than 90%, which is the highest of all technologies including nuclear. GPP are baseload plants that produce electricity consistently, running 24 hours per day/7 days per week, regardless of weather conditions without any fuel consumption. GPP are thereby a renewable energy source which does not fluctuate and is not intermittent. GPPs are very compact with a small footprint using less land per GWh (404 m^2) than coal (3,642 m^2), wind (1,335 m^2), or solar PV with center station (3,237 m^2). GPPs are clean as modern closed-loop geothermal power plants emit no greenhouse gases; life cycle GHG emissions (50g CO_2eq./kWhe) are four times less than solar PV, and 6 to 20 times lower than natural gas. Geothermal power plants consume less water on average over the lifetime energy output than the most conventional generation technologies (EERE, 2022).

Geothermal energy for direst use: Direct use of geothermal heat is mostly applicable for agriculture and industrial processes like growing mushrooms, fish farming, greenhouses heating, and drying of agriculture or industrial products.

Geothermal energy for Ground Source Heat Pumps (GSHPs): Geothermal resources of very low temperature can be potentially used in any application that requires thermal power for central heating, cooling, or sanitary hot water, using a ground heat exchanger. A typical GSHP system consists of three main components (Figure 107) a ground heat exchanger circuit for extraction or injection of heat into the subsurface, a heat pump that extracts heat from the ground heat exchanger to the distribution grid or vice versa and a distribution network that transfers the heat from the heat pump to the building for heating and hot water, and from the building to the heat pump during cooling applications (CEDRO, 2017).

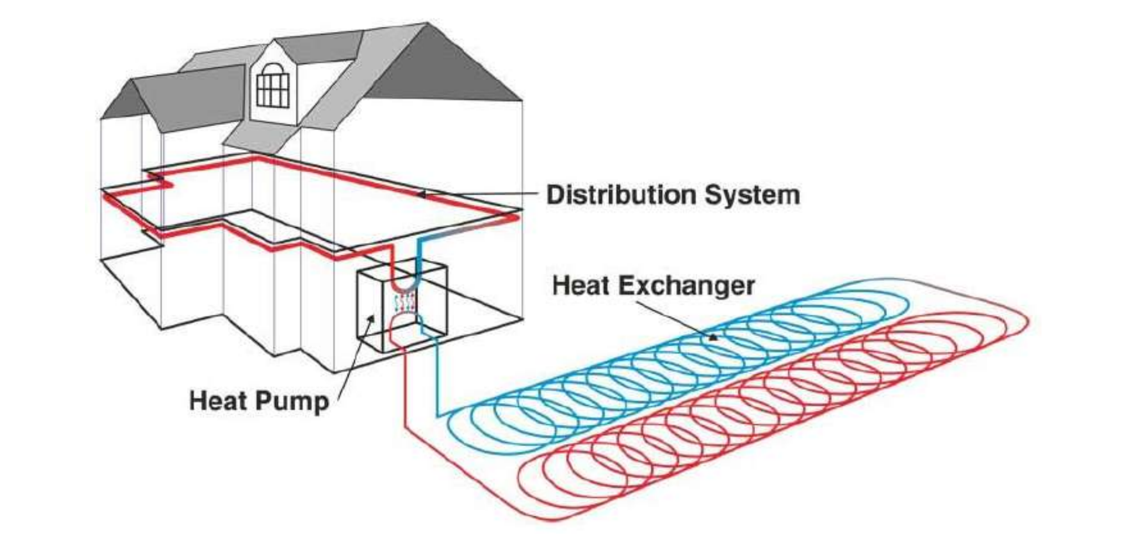


Figure 107: GSHP system (Lim, 2014)

There are many advantages of using Ground Source Heat Pumps for heating and cooling purposes, as they have very low running costs, do not suffer the problems of "intermittency" that effect other sources of renewable energy, can be used efficiently at all hours of day and night, are silent, reliable, invisible, free from polluting chemicals, and produce no carbon emissions on site.

GSHP systems, uniquely amongst renewable energy technologies, offer the opportunity to recycle heat energy. By using the power of a heat pump to provide cooling, heat energy is captured when it is freely available in the summer, stored in the ground over the autumn, and released to heat buildings in winter. GSHP systems contribute also to the energy security of the country by providing heating and cooling from energy which occurs naturally in the country, instead of relying on imported fossil fuels.

Although ground source energy requires upfront investment, the reduction in emissions of greenhouse gases is significant and an investment in ground source energy lasts much longer than other renewable energy investments. The infrastructure needed for ground source systems, a major part of the cost, can be expected to last for over 50 years (EERE, 2022)

The potential for reducing CO_2 emissions assuming a 30 % share of heat pumps in the building sector using technology presently available is about 6 % of the total worldwide CO_2 emissions. Taking into consideration advanced future technologies in power generation, in heat pumps, and in integrated control strategies; an increase up to 16 % seems to be possible. Therefore, heat pumps are one of the key technologies for energy conservation and reducing CO_2 emissions (IEA, 2011).

Applicability to Lebanon:

The National Geothermal Resource Assessment of Lebanon study estimated that geothermal energy has a high potential in Lebanon, with Akkar being the region with most convenient availability. The most suitable technologies to use taking into consideration Lebanon's conditions are low-enthalpy technologies using cycle power plants (Badoux and Mégel 2014).

The capital costs for the realization of a geothermal power plant in Lebanon were estimated in 2014 to be around USD 25 million in the Akkar District and approximately USD 70 million for an enhanced geothermal system project in Beirut. Depending on geothermal conditions in the reservoir (temperature and transmissivity), the energy costs are estimated to be comprised between 0.21 USD/kWh and 1.37 USD /kWh, with an average cost of 0.46 USD/kWh.

An asset of geothermal power is the possibility to co-generate heat in very large quantities. The proximity of energy users with high heat demand (industry, thermal spa, greenhouse agriculture) could be a major asset for selecting the site of the geothermal power plant, as the commercial use of co-generated heat could considerably increase its economic feasibility (Badoux and Mégel 2014).

As for groundwater source heat pumps, Lebanon does not have any assessment for shallow geothermal potential, however two pilot projects have been initiated in Bejjeh Municipality in Mount Lebanon and Medrar medical center in South Lebanon. The projects have not been completed amidst the 2019 economic crisis.

6.1.7 Sea Energy

Oceans and seas represent a significant resource for renewable energy that can be used to produce electricity. In Europe, wave and tidal energy could reach an installed capacity of 100 GW by 2050 and deliver 260 TWh of electricity which equals the consumption of about 65 million households (Magagna et al. 2014).

Tidal current energy

Tidal flows provide a consistent source of kinetic energy because of the interaction between the gravitational forces of the Earth-Moon-Sun system. As tidal energy production is not influenced by weather conditions but only by well-known cycles of the moon, sun, and earth, it is predictable hundreds of years in advance and could therefore provide a stable output to the grid, compared to other renewable energy sources. Kinetic energy can be harnessed usually near shore and particularly where there are constrictions, such as straits, islands and passes.

Tidal device operation is like a wind turbine, albeit operating in a different environment. Since water is 832 times denser than air, tidal devices capture more energy than their wind counterpart and can use smaller blades. Tidal turbines can be fixed to the seabed or floating nearer the surface with moorings attached to the seafloor.

Tidal technology has been taking off recently, with the first pre-commercial tidal current farms are currently hitting the water around Europe. In 2016 the world's first operational tidal farms were commissioned and in 2018 the world's most powerful tidal energy device broke previous records for power export to the grid. These developments are setting the scene for larger activity in the coming years which will allow tidal current to reach scale and drive down costs.

Wave energy

Wave energy is created as kinetic energy from the wind transmitted to the upper surface of the ocean and sea. At present there are several different waves energies technologies designs, and some are at the cutting edge of engineering design. Wave energy from the sea gives the possibility to avoid land use, which is widely discussed by public opinion. Installations could be in fact in areas close to the coast unused or of low tourist value, or at a distance enough to eliminate the visual impact for man. Another advantage is predictability: the wave resource is characterized by a high degree of predictive reliability with respect to solar and wind resources. This makes the integration of renewable energy in the power grid easier and constitutes a reliable generation node in smart grids. Wave devices are currently lagging tidal in terms of technological development. Many different wave energy devices and designs are currently being studied and/or developed but only about 20% of them are at a full-scale prototype stage.

Applicability to Lebanon

A preliminary appraisal study of wave power prospects in Lebanon done in 2013, attempted to methodologically assess the wave power prospects off the coast of Lebanon. Working around 1.5 years of buoy data, measurements for the significant wave height and wave period concluded that the wave resources are in the lower end of what is 'technically viable' and therefore, given the state of technology at the time of the study, it was concluded that wave power cannot contribute to the target of renewable energy in the Lebanese energy mix. A re-evaluation of the wave power prospects post-2020, based on an actual and more robust data collection system, was recommended (Aoun, et al., 2013).

6.1.8 Technology prioritization

Based on a series of criteria related to each technology's GHG reduction potential, maturity, scalability, cost and compatibility with the Lebanese context, a Multi-Criteria Analysis (MCA) was undertaken by key stakeholders to prioritize technologies for further assessment. Accordingly, 1) pumped hydro energy storage, 2) smart grid and 3) geothermal/ground source heat pumps have been prioritized for the energy sector. More details on the prioritization process are available in Annex III.

6.1.9 Barriers and needs for deployment of priority technologies in Lebanon

Analysis of Technology: Pumped Hydro Energy Storage

The following are intrinsic barriers identified for PHES technologies that have been identified in many countries that have already worked on the PHES implementation:

Table 64 Challenges and needs to deploy the PHES concept

Key Aspect	Challenges/Obstacles	Needs
Financial	High development costs of PHES projects are major deterrents to developers. Projects generally take more than 4 to 5 years from the point of conception to 'power on' or operationalization.	The use of existing reservoirs, underground caverns, or the sea as a lower reservoir, shall be explored to mitigate the high costs and long period associated with the conditioning of difficult sites and the absence of infrastructure.
Technical	The viability of a new PHES project is dependent on a sufficient price differential between the generation price and the pumping costs to pay for the pumping, repay the heavy capital investment, and account for the efficiency losses in transmission, pumping and generation.	Variable speed, reversible pump turbines will increase the operational flexibility of PHES facilities and better equip these to support the integration of variable renewable generation.
Regulatory	Lack of appropriate definition for storage. Most electrical systems are conceived under a traditional paradigm long ago and are based on obsolete regulation.	Power utility related policies and procedures should be framed to ensure compliance with legislative or regulatory requirements for PHES technologies implementation.
Legal	The stakeholders currently operating the existing hydro facilities and dams do not have Energy Storage in their scope.	A legal framework that is adapted to the PHES concept must be elaborated and put in place. The existing laws or decrees need to be amended accordingly.
Economic	Market uncertainty, lack of long-term stable policies and regulations for free market tariffs. Lack of Feed -in Tariff (FIT)	Energy Storage Markets must be regulated and the complex dynamics in which energy is traded must be well defined to make a business model that is attractive to banks and investors. The business model of PHES and Energy Storage Systems in general requires a variable tariff structure that is adapted.
Structural	National Control Center (NCC) is not operational – requires rehabilitation and upgrade	Energy Storage Systems and effective energy management require a fully operational modernized NCC.
Social	PHES projects can occupy many square kilometers that can be used for other purposes and require transmission lines to connect to the electricity market.	PHES projects need to attend to environmental and social issues associated with the project. Mitigation alternatives such as the potential use of wastewater in PHES applications to improve water quality through aeration and other processes can be explored. Social acceptance can be improved through campaigns of public information, by consultation and communication with local communities, and by referencing successfully completed and attractive projects.

Analysis of Technology: Smart Grids

The following are barriers that are intrinsic to the smart grid technology that have been identified in many countries that have worked on the smart grid implementation:

Table 65 Challenges and needs to deploy the Smart Grid concept.

Key Aspect	Challenges/Obstacles	Needs
Financial	Lack of financial resources. Investment payback period is relatively long compared to the high initial investment.	Despite benefits arising from the implementation of the smart grid concept, governments need to have sufficient proofs for justification for high investments and ensure guaranteed return to systematic payback schemes, supported by public incentives and subsides.
Economic	Market uncertainty. Lack of long-term stable policies and regulations for free market tariffs.	Standards and business models of smart grids must be defined in order to establish global standardized regulatory definitions to generate revenue. The business model of smart grids should not accommodate subsidies and requires having a tariff structure that reflects the real costs, accommodate marginal capacity costs, high cost of peak loads, time of day tariff etc..
Structural	National Control Center (NCC) is not operational – requires rehabilitation and upgrade Lack of 24 hours service of electricity EDL corporate structure is not adapted for effectively managing a smart grid system.	Distributed Generation and effective energy management require a fully operational modernized NCC. The success of the Demand Side Management concept relies on the ability to shift loads as needed to optimize the use of the electrical system. Having a 24-hour service is essential for enabling effective demand side management. Major investments are needed in EDL for upgrading its human resources, administrative structure, and communication structure in view of enabling an effective management of smart grid systems.
Legal	Lack of Feed-In Tariff (FIT)	Power utility related policies and procedures may be framed to assure compliance with legislative or regulatory requirements for smart grid technologies implementation.
Social	Lack of innovation in the industry. Reluctance of the industry for the introduction of new methods maintaining traditional for safe and guaranteed return for investment.	A combination of financial support, stable legal regulation and education in the industry may lead to transform traditional industrial operation into new innovative processes, solutions and finally products.

Technical	Lack of proper infrastructure	Additional infrastructure is required including amongst others a well-defined communication infrastructure, sensors, intelligent electronic devices, distributed energy resources, cyber security devices, advanced metering systems and other end-user devices.
	Technology immaturity	Standards are required to assess features of solutions brought into the market. These standards and further validation of solutions will allow the ancillary facility to cop up with market requirements.
	Integration of the grid with large scale renewable generation. Lack of coordination between electric energy and telecom agencies.	An integrated complex system is required to guarantee the appropriate interconnection amongst large number of dissimilar distribution networks, power generating sources and energy consumers.
	Potential weaknesses concerning worms, viruses, malware, etc. in the smart grid communication system.	Safe communication systems must be defined and implemented to ensure privacy of users across the supply chain.

Analysis of Technology: Ground Source Heat Pumps

The following are barriers that are intrinsic to the GSHP technology that have been identified in many countries that have worked on the Ground Source Heat Pumps implementation:

Table 66 Main Challenges and needs to deploy the Ground Source Heat Pump technology

Key Aspect	Challenges/Obstacles	Needs
Economic	High capital cost of GSHP systems The economic recession hinders the ability of builders to raise high capital	Adequate subsidies or tax exemptions for the installation of GSHP systems need to be implemented.
Market	Lack of policymaker and regulator knowledge of and/or trust or confidence in GSHP system benefits	Assemble independent, statistically valid, hard data on the costs and benefits of GSHPs. Organize Public awareness campaigns to make the decision makers aware of the GSHP game changing potential. Future policies should ensure that GSHP systems are not excluded from renewable portfolio standards and goals and related environmental initiatives.
Social	Lack of public awareness and confidence on the GSHP technology potential and benefits	Installation of demonstration systems in governmental buildings and public awareness activities on the technology and its benefits need to be organized.

Technical	Efficient reliable, environmentally compliant, and safe GSHP are the work of highly skilled system constructors; they do not sell heat pump units, they sell systems.	The GSHP market development requires the training of highly skilled system constructors to give confidence in the technology.
	Lack of marketing by installers and manufacturers of GSHPs	GSHP manufacturers and installers need to join their forces to advertise for the GSPH technology benefits to home owners, commercial institutions and real estate developers.
	Reluctance by builders to deviate from conventional HVAC	Builders bear the burden of raising the high capital costs of the GSPH systems while they will not benefit from the operational costs savings made by the home users. The Home users need to become aware of the advantages of the GSPH systems so that they request these when looking for a home. Builders will follow the market wants when they perceive that there is a demand for GSPH systems.
	Studies on the GSHP potential in Lebanon are lacking	Investing in studies and data collection will give confidence in the sector and lay the ground for developing the GSHP market.

6.2 TECHNOLOGIES FOR THE TRANSPORT SECTOR

Despite the global fall of CO_2 emissions of the transport sector by 10% in 2020 during the pandemic, it was demonstrated the scenario of reduced mobility activities of passengers and freight cannot be the solution to curb transportation emissions and meet emissions targets, especially since it hampers other sectors of the economy. This traditional supply-side approach can be regarded as only a short-term solution, that must be complemented by other mitigation measures on the demand side such as the Avoid-Shift-Improve (ASI) approach (Haddad, Mansour, & Stephan, 2015). The approach relies on the principle of maximizing efficiencies of systems, trips and vehicles by 1) avoiding or reducing travel by motorized modes through, for instance, the integration of telecommuting and e-commerce, 2) shifting to more environmentally friendly modes such as public transport and non-motorized transport and 3) Improving vehicle and fuel technology of all modes of transport to improve the environmental efficiency from each kilometer traveled.

A comprehensive guide for mainstreaming transport in Lebanon's national urban policy was released in 2021, structured under the Avoid-Shift- Improve (ASI) approach (Haddad, 2021). This guide proposes a set of tailored policy recommendations for the Lebanese case, aimed at improving the sustainable development of transport and mobility based on the ASI approach. The ASI approach was facing many challenges and obstacles for implementation at the global level, particularly in Lebanon given its car-centric transport system. However, the pandemic and the economic crisis helped indirectly implement and accelerate the adoption of some of the ASI measures both globally and in Lebanon, as presented in the following sections.

The transport technologies that were prioritized in the 2012's TNA (mass transit bus systems, hybrid and fuel-efficient vehicles) were based on two main criteria: minimizing GHG and pollutant emissions, and maximizing the environmental, social, and economic benefits. The current TNA update builds up on the previous assessment and explores new technologies that could be used in Lebanon as a result of the new normal (post-pandemic and post-economic crisis), considering new consumer mobility preferences, mature technologies available on the global market, and the regulatory measures needed in Lebanon to better rebuild a transport sector with sustainability goals. The technologies addressed cover on the one hand, the mobility needs of passengers in low, middle, and high-income classes; and on the other hand, clean technology options for the freight sector, namely:

1- Non-motorized Transport (NMT)

2- E-bicycles and scooters

3- Tuk-tuks or auto-rickshaws

4- Electrified freight transport

5- Hybrid and Electric Buses

The impact of the COVID-19 Pandemic on transport technologies

The pandemic has drastically affected all forms of transport, with global road transport activity dropping in 2020 to 50% below the 2019 average, and trips were reduced by over 90% in many major cities during the crisis. However, lockdown measures and shelter-at-home orders served as a catalyst to accelerate a partial adoption of the Avoid-Shift-Improve approach, namely limiting the need or desire to travel, and shifting travel preferences to new forms of mobility solutions.

After being an uncommon practice for a long time, telecommuting to work has become widely adopted and accepted in the work culture. Limiting home-to-work commutes did not only help contain the coronavirus, but it has also contributed to reducing congestion and consumption, and led to economic benefits at multiple levels, from reduced costs, higher employee satisfaction and retention, and increased productivity from the saved travel time.

The lockdown measures have also fostered the use of digital means to access services and goods, which has drastically limited the need to take physical trips. Electronic commerce has witnessed remarkable growth compared to the rates from the pre-pandemic era and studies showed that e-commerce lead to improved transport system efficiency particularly when the right means of transport technology and delivery schedules are considered (US International Trade Administration, 2020) (Argonne National Laboratory, 2020).

Travel preferences and priorities connecting people to goods, services, and employment have also changed when it comes to consumer travel decisions. In response to the imposed measures to control the pandemic, the shift towards non-motorized means like walking and cycling has re-emerged, and the traveled distance of micro mobility technologies like electric bikes and scooters has increased, despite the global decrease in total miles traveled by motorized vehicles. These mobility solutions were mainly replacing the reliance on public transport for short and medium trips, as the risk of infection has become the top concern and motivation in making travel choices, compared to pre-COVID when destination time demand and travel cost criteria used to be a priority.

The automotive industry has been hit hard by the pandemic, especially with the continuing supply chain shortages of semiconductor chips. However, investments in vehicle electrification and decarbonizing the vehicle production process have continued and contributed to the market take-up of electric vehicles during the pandemic, in addition to the efforts made to grow the charging infrastructure accordingly, and the regulatory actions around the globe that kept pushing ahead on sustainability goals such as banning internal combustion engines progressively after 2035 (ITF, 2021).

6.2.1 Non-motorized Transport (NMT)

Non-motorized transport (also known as active transportation and human powered transportation) includes walking and cycling, and variants such as small-wheeled transport (cycle rickshaws, skates, skateboards, push scooters and hand carts) and wheelchair travel. These modes provide both recreation and transportation and are especially important for short trips up to 7 kms, which take up the largest share of trips in urban areas (Witting et al., 2006). While categorized as soft technologies, they still do benefit from technological advancements that improve their mode sharing. In fact, a common trend that has emerged in previous years is bicycle sharing and renting, where a user can locate and rent a bicycle from a station through various phone applications. This has significantly increased the cycling mode sharing as it (1) removes the burden of carrying a bicycle on trips, (2) lets users rent bicycles without the need to own their own, (3) replaces the cost of ownership with a small rental cost, and (4) increases the availability of bicycles through the cycling stations.

The benefit of shifting to non-motorized modes of transportation is not only reducing GHG emissions and mobility costs but it's also improving the quality of life, health, and the impact that the latter has on reducing healthcare costs.

In terms of environmental benefits, the reduction in GHG emissions is a direct result of switching from GHG-emitting transport modes such as passenger cars to active zero-emission modes.

Regarding the cost of mobility, savings can be directly calculated by switching to other modes (car, bus, etc.) since walking is free while cycling has a minimal cost (cost of ownership of a road bike from USD 200, or bike rental for as low as 2 USD per hour in Beirut).

NMT can be stimulated by a policy package consisting of investments in facilities, awareness campaigns, smart urban planning, improved public transport and disincentives for the use of motorized private vehicles.

Applicability of NMT in Lebanon

Non-motorized modes of transportation, being the preferred mode choice for small trips in European cities, are not as popular in Lebanon due to the lack of regulations that protect the safety of pedestrians and cyclers on one hand, and due to the underdevelopment of the pedestrian and cycle route network infrastructure on the other. The main challenges to increasing the share of active modes in Lebanon are (1) the lack of suitable pavements and dedicated bike lanes, (2) the absence of a national non-mobilized transport strategy that establishes an overall vision for coordinating policies and targets for cycling and walking, and (3) lack of adequate traffic enforcement. The most critical among these challenges is the lack of bicycle lanes and pedestrian-only sidewalks and pavements. The development of an appropriate road network will not only reduce congestion, but also increase citizens' sense of safety by adopting active modes of transportation. For cycling, dedicated lanes can be either shared bus-bike lanes or a lane reserved for cyclists with a recommended width of 2 to 4 meters.

A few bike-sharing and rental projects have been launched in Lebanon, notably in Beirut and Byblos in 2017 such as the Bike-4-All initiative supported by local authorities and municipalities but have failed to gain traction for the reasons mentioned earlier.

6.2.2 E-Bikes and E-Scooters

Due to the physical limitations of human-powered bicycles, e-bikes and scooters are emerging as potential alternative means of transportation in cities as they are both powerful and affordable. An e-bike has a rechargeable battery powering an electric motor to help with propulsion. The motor can either assist the rider's pedal power, known as assisted e-bikes or add throttle power, known as motorized e-bikes. A similar technology that offers the same benefits as electric bicycles is electric scooters, which are in general slower than e-bikes, but more affordable.

Similarly, to non-motorized modes of transport, adopting e-bikes for daily trips has several benefits such as reducing GHG emissions, easing traffic congestion, reducing travel times, and reducing mobility cost. In addition to being more powerful than regular bicycles, e-bikes also provide the advantage of going on longer trips with less effort and at a faster pace.

For instance, using an e-bike (25 km/h) for a congested 5 km trip inside Beirut (with 12 stops per kilometer) reduces the trip duration by 24% compared to an average ICE vehicle (19 km/h), and 20% compared to a bicycle (20 km/h).

From an environmental point of view, electric bicycles have a very low electricity consumption (9.5 Wh/km), 10 to 20 times lower than the consumption of small electric vehicles. Therefore, the GHG emissions associated with charging e-bike batteries are minimal, even with a dirty electric mix as in the current case of Lebanon.

Applicability of E-bikes and E-scooters in Lebanon

E-bike and E-scooters are still new in Lebanon, with very few models available on the market. However, the recent economic crisis and drastic increase in fuel prices increased the demand for such technologies, which accelerated the growth of its share in the market. Start-ups like "Wave Beirut" and "Loop Beirut" have recently gained popularity as they offer sharing services and/or subscription packages for users to use e-bikes and scooters in the greater Beirut area.

Challenges to implementing these technologies in Lebanon are the same as non-motorized transport, notably (1) the lack of proper dedicated bike lanes, (2) the lack of a national cycling strategy, and (3) the absence of proper regulations. In fact, the lack of law enforcement to regulate the use of e-bikes and e-scooters is one of the major contributors to the reduced sense of safety among citizens willing to adopt these technologies. Several countries have already enforced laws to regulate their usage, as summarized in Table 67.

Table 67 e-Bikes and Pedalers Regulations

Country	Power Limit	E-PB Allowed	Maximum Speed	Additional Requirement
EU	250 W	No	25 km/h	Power assistance only when pedaling
USA	750 W	Yes	32 km/h	Operable pedals required
China	-	Yes	20 km/h	-
Canada	500 W	Yes	32 km/h	-
Australia	250 W	Yes	25 km/h	Operable pedals required

6.2.3 Tuk-Tuks and Auto Rickshaws

Tuk-tuks or rickshaws have long been a popular mode of transport in developing countries, especially as vehicle-for-hire to replace taxis, as they are inexpensive to own and operate. Auto-rickshaws are usually motorized three-wheeler vehicles, equipped with an ICE (previously popularized as a two-stroke engine rickshaw, and currently popularized with a four-stroke engine) running either on liquified petroleum gas, diesel, or more recent models on compressed natural gas and on electricity. These three-wheelers have on average a maximum speed of 70 km/h and can drive several hundreds of kilometers..

The main advantage of tuk-tuks and auto-rickshaws is the lower fuel consumption compared to the relatively old taxi fleet, and their ability to navigate through narrow streets, reducing congestion and trip duration.

From an environmental perspective, on average, autorickshaws can run 35 kms per liter of gasoline, which implies 3 to 5 times less fuel than a taxi vehicle, and therefore, 3 to 5 times fewer GHG emissions. With the recent national strategies in developing countries pushing toward electrifying rickshaws, the potential for emission reduction increases significantly.

Applicability of Tuk-Tuks and Auto Rickshaws in Lebanon

Rickshaws aren't as popular in Lebanon as they are in countries with tropical and subtropical climates, but it's not uncommon to see auto rickshaws in some parts of the country, especially city-centers of major cities known for tourism. Auto-rickshaws were first used in Lebanon for tourism, in areas like Byblos and Batroun in earlier years. With the economic crisis and fuel shortage, three-wheelers known as tuk-tuks are replacing taxis across the country. In fact, several business owners now own a fleet of multiple tuk-tuks that they rent out to drivers to provide taxi services, which has become common in the Bekaa region.

Challenges in increasing the share of rickshaws in Lebanon mainly lie in (1) poor roads and lanes infrastructure, as rickshaws are not as strong as regular passenger vehicles, and (2) protection of rickshaw drivers and passengers in the current absence of road enforcement and regulations. Also, unlike taxis, this technology is still unregulated for transporting passenger services as red plates do not exist for tuk-tuks in Lebanon.

6.2.4 Electrified vehicles for freight

Freight vehicles include light-commercial vehicles, vans, and trucks of different sizes categorized mainly as medium- and heavy-duty vehicles. Though the electrification of heavy-duty vehicles is underway, the focus in this section will be only on market-ready technologies of electrified light-duty vehicles, vans, and medium-duty trucks.

The electrification of these vehicles can be achieved through several powertrain architectures, either fully electric where the vehicles are solely powered by a battery, or a hybrid configuration where an engine and battery power the vehicles.

Electrified freight vehicles have the potential to significantly reduce GHG emissions if the electricity mix is cleaned up. In fact, all-electric powertrains have zero tank-to-wheel emissions, meaning that well-to-wheel GHG emissions are only associated with those from power generation and transmission (more details available in chapter 5 of this report).

Applicability of electrified vehicles for freight in Lebanon

Electrification of commercial light-duty vehicles (LDV) are particularly suitable in the case of Lebanon for last-mile and intercity deliveries, where the total daily mileage is limited. LDVs in Lebanon represent approximately 76% of the total Lebanese freight vehicle fleet, and they all run on an ICE.

The challenges related to the implementation of these technologies in Lebanon mainly reside in (1) the lack of an appropriate infrastructure of charging stations distributed throughout the country, (2) the additional cost induced by the ownership of electrified vehicles in general due to the additional cost of batteries, and (3) the current carbon-intensive electricity mix in Lebanon which reduces the benefits of these technologies in reducing GHG emissions.

6.2.5 Hybrid and Electric Buses

Several bus technologies are gaining popularity worldwide, relying on alternative fuels other than diesel, notably compressed natural gas, liquified natural gas, and liquified petroleum gas. Other lower-emitting technologies are emerging, notably battery electric buses (having a battery pack and an electric motor instead of a fuel tank and an engine), plug-in hybrid electric buses (having both an electric motor and an ICE), and fuel cell electric buses (having a fuel cell system powered by hydrogen that generates electricity to operate the vehicle).

On the other hand, the improvement of bus transport can be further enhanced if these technologies are operated on dedicated lanes such as a Bus Rapid Transit (BRT) system. The combination of an efficient BRT system and electrified bus technologies improves the overall efficiency of bus transport as it decreases energy consumption (per person-kilometer), due to higher speeds and bus occupancy.

The environmental and socio-economic benefits of improving bus technologies and implementing an efficient BRT system are numerous, including: (1) improved air quality in cities, (2) reduced GHG emissions, (3) reduction of congestion, and (4) social equality in providing affordable transportation.

Applicability of hybrid and electric buses in Lebanon

Mass transport in Lebanon includes both public and private buses, with a predominance of diesel bus technologies. While these buses constitute a very small part of the road vehicle fleet in Lebanon (1% in 2010), around 5.6% of the total road transport energy consumption is allocated to a relatively old fleet (Mansour, Haddad, & Afif, 2017). Moreover, very little data exists about buses in operation in Lebanon, the latest feedback on road transport is provided by the central administration of statistics, and dates to 2008 (Table 68).

Table 68 Public Collective Transport in Lebanon in 2008

Region	Average number of working buses	Total trips	Distance traveled (km)	Total passengers
Beirut and suburb	271	29001	1302201	1489596
Bekaa	29	2045	153976	107161
Tripoli and suburb	10	1125	53976	51662

Bus transportation contributes in general to lower GHG emissions and air pollution compared to passenger transportation due to the higher passenger-kilometer efficiency of buses. As indicated in the previous TNA report, with an estimated passenger car occupancy rate in Lebanon of less than 2, 80.3% of CO_2 savings are achieved with diesel buses with an occupancy rate of 30 passengers/vehicle compared to the Lebanese passenger car fleet. However, CO_2 emission savings can be further reduced by electrifying the powertrain, as fuel consumption is further reduced for hybrid and electric buses, as shown in Figure 108.

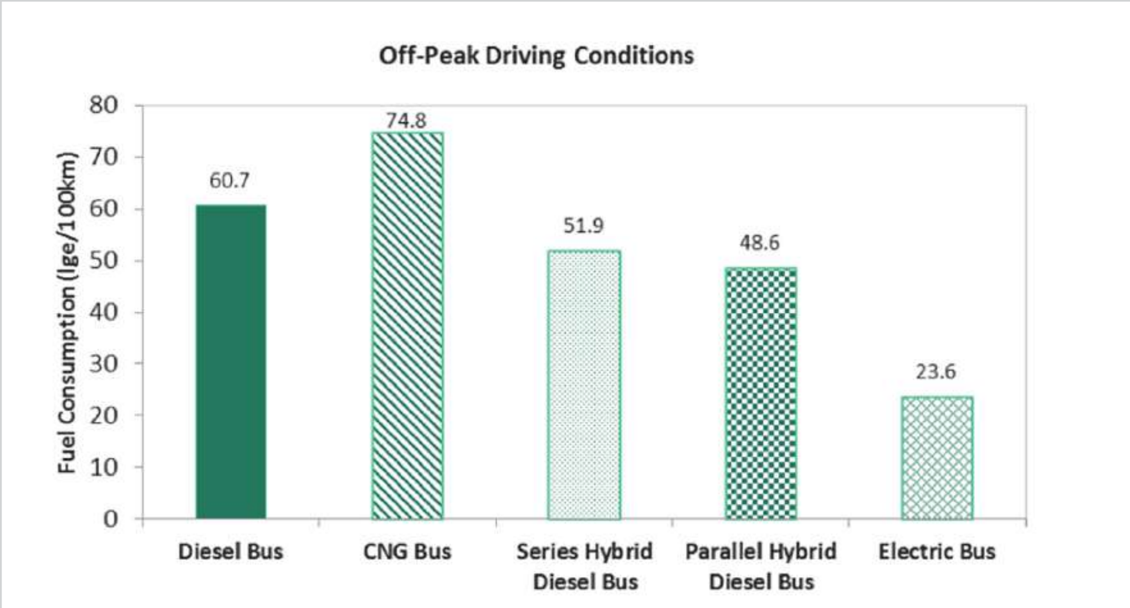


Figure 108: Energy use of different bus technologies

However, the main challenge in implementing electrified bus technologies and an efficient BRT system in Lebanon is investment costs, which can vary significantly depending on the bus technology and the BRT required capacity. Additionally, an optimized network requires dedicated lanes and road space, which further increases expenditure.

6.2.6 Technology prioritization

Among the list of technologies identified and based on consultation meetings conducted with transport experts (Annex III), the prioritized technologies were identified as the 1) deployment of e-bikes and 2) electrified freight vehicles, as both have the highest benefits in terms of emissions reduction and driving down mobility cost. Electric bicycles present an affordable and clean solution for short distance commuting in addition to multiple other health and productivity benefits, while freight is a major contributor to the environmental impacts of the road transport sector in Lebanon, so that, if no action is taken, freight movement can potentially offset the mitigation of emissions from passenger mobility.

Electric bicycles and electrified freight vehicles are complementary to the electrified passenger vehicles and mass transit technologies that were extensively evaluated and prioritized in the 2012 TNA report. This portfolio of technologies has a unique potential to drastically combat GHG and pollutant emissions in urban areas, reduce mobility costs and contribute to Lebanon's sustainable development goals if their deployment is properly orchestrated.

6.2.7 Barriers and needs for deployment of priority technologies in Lebanon

Analysis of Technology: E-Bikes

Impact of the technology

Considering the economic crisis that Lebanon is facing, e-bikes are of particular interest for the Greater Beirut Area (GBA) and other major cities, as they have the potential to (1) limit traffic congestion, (2) reduce trip duration, (3) reduce trip cost, (4) improve quality of health, (5) reduce GHG emissions, and (6) increase energy security by limiting the reliance on fossil fuels.

No study has been conducted on the impact of e-bikes in Lebanon so far, but considering the TNA report in 2012, 50% of Greater Beirut Area vehicle trips are 5 km or less, which can be partially substituted by e-bikes. Using simple calculations and assumptions presented in Table 69, e-bikes are shown in Figure 109 as having the potential to reduce CO_2 emissions by almost 99% compared to car trips. The low amount of CO_2 emitted by e-bikes is due to electricity consumption, with e-bikes consuming between 7 to 12 Wh/km and assuming they are charged using the local electric mix.

Another benefit of replacing passenger cars with e-bikes is the reduction in travel time. For a conventional ICE speed of 19 km/h and an e-bike speed of 25 km/h, the travel time is reduced by about 24% as shown in Figure 110. This means that a shift from passenger cars to electric bicycles not only reduces the cost of travel, but also increases overall household income by reducing wasted time that could otherwise have been better invested (Mansour & Haddad, 2019).

In addition to the environmental and economic benefit of electric bicycles, their impact on improving the quality of life and health is considerable. Although no studies have been conducted for Lebanon specifically on this topic, a study published in the journal Environmental Health Perspectives shows that increasing physical activity by adopting active modes of transportation can increase life expectancy up to 14 months (de Hartog, Boogaard, Nijland, & Hoek, 2010). This is in addition to the economic benefit which translates into reduced healthcare costs.

Table 69 **Assumptions for e-bike CO_2 emissions and trip duration assessment (Mansour & Haddad, 2019)**

Car	
Average ICE car fuel consumption in GBA (L/100km)	10.4
Average vehicle speed (km/h)	19.07
Stops/km	12.19
e-Bike	
Average e-bike speed (km/h)	25
Electricity consumption (Wh/km)	9.5
Bicycle	
Average Bicycle speed (km/h)	20

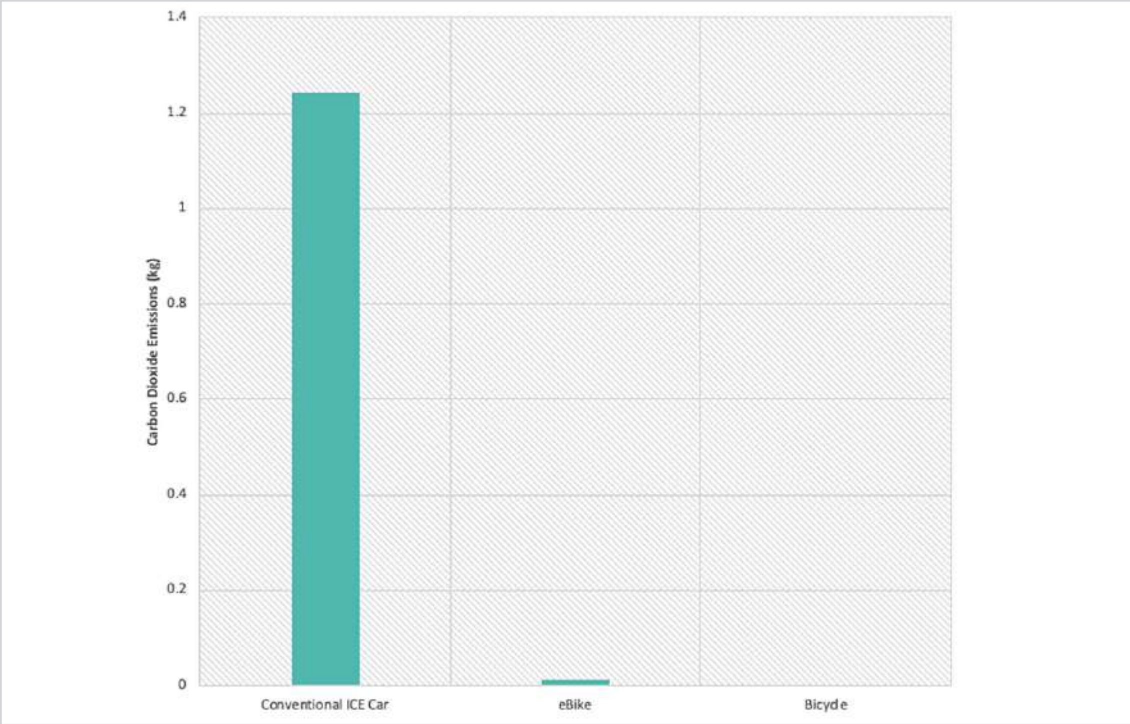


Figure 109: CO_2 emissions for a conventional ICE car, e-bike, and bicycle for a 5 km trip

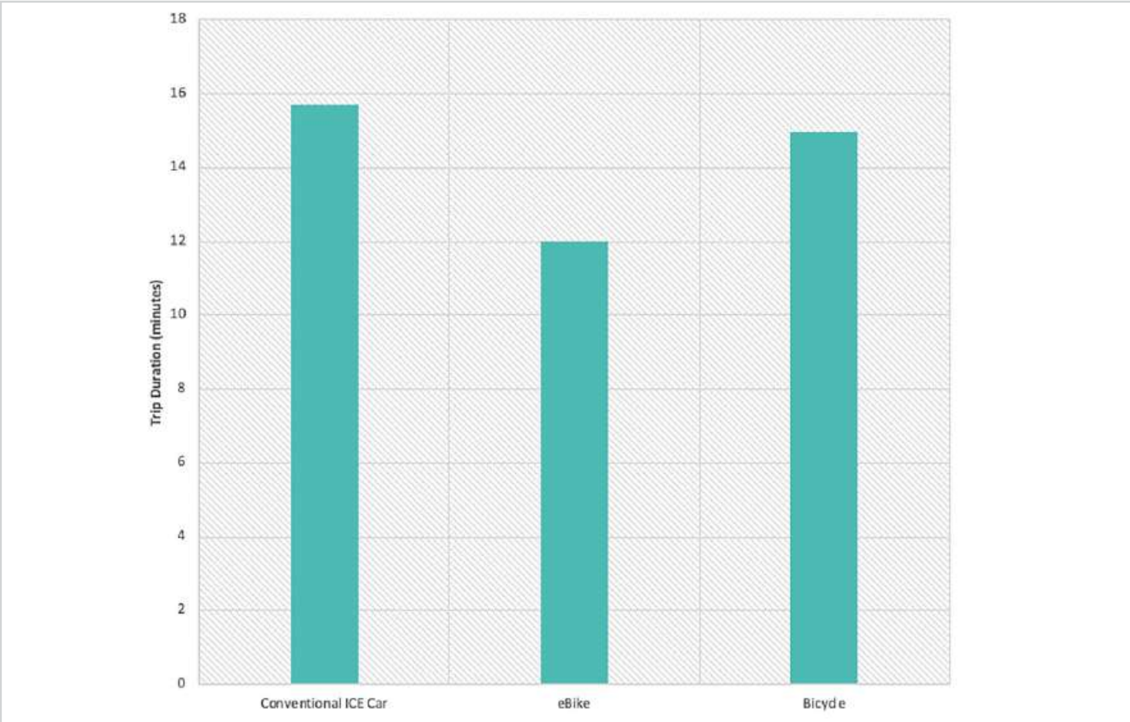


Figure 110: Trip duration for a conventional ICE car, e-bike, and bicycle for a 5 km trip

Identification of barriers and measures

The financial and non-financial barriers are presented in Table 70 and Table 71 , and the main conclusions are as follows:

The main barrier to the adoption of e-bikes or bicycles is the lack of a sense of safety when riding on local roads, due to the lack of dedicated cycle lanes and regulations to protect cyclists and reduce the risk of accidents

The lack of incentives and subsidies for the purchase of e-bikes is another major obstacle to the early deployment of e-bikes to replace private cars. Such incentives and subsidies cause a conflict of interest with the current tax scheme which reaps tax revenue from fuel imports and car purchases.

The implementation cost of an e-bike system with dedicated lanes is also a major financial barrier.

Table 70 Financial barriers to the deployment of e-bikes

Economic and financial barriers	
The higher purchase cost of e-bikes compared to bicycles	• Inadequate government policies on the purchase cost • No consideration of negative externalities in pricing transportation • Lack of incentives and subsidies
Implementation cost	• Absence of bike dedicated lanes • Increased cost of urban planning
Foregone Government revenue	Promoting active modes imposes a modal shift from passenger cars to e-bikes, and thus, might deprive the government of some revenues related to passenger car usage: • Tax revenues from customs on the car purchase • Revenues from VAT • Revenues from registration • Revenues from road-usage fees • Tax revenues levied on consumed gasoline

Table 71 Non-financial barriers to the deployment of e-bikes

Market imperfection	
Poor market infrastructure (cycling lanes) for e-bikes	Low passengers demand for active modes and lack of sense due to unestablished bike lanes
Policy, legal and regulatory	
Insufficient legal and regulatory framework	No regulation or legislation on e-bikes maximum allowed speed, maximum allowed power, etc. to increase safety and reduce risks
Weak alignment of interests	• Overlapping mandates and responsibilities between MoF and customs, MoE, MoPwT, MoIM, and local communities • Foregone government revenues

Institutional and organizational capacity	
Limited institutional capacity	• Weak capacity to promote and enhance the market of e-bikes • Absence of specialized bodies and experts in relevant ministries and institutions at the transportation planning level and operational level
Human skills	
Insufficient personnel	• Insufficient number of specialized experts in relevant ministries at planning and operational levels, to prepare projects and draft legislation for biking and cycling
Social, cultural, and behavioral	
Consumer preferences and social biases	• Dominance of a car-centric culture • Absence of dedicated cycling lanes and regulations that protect cyclers/bikers • Negative attitude and perception of drivers/commuters on use and efficiency of e-bikes

Measures for the deployment of e-bikes are divided in the same way as the barriers, by financial and non-financial measures, as presented in Table 72 and Table 73 . The main measures for the deployment of e-bikes are on the one hand the development of infrastructure via dedicated cycling lanes and the reduction of the speed limit of private cars in urban areas, and on the other hand, offering subsidies and incentives to purchase and use e-bikes.

Table 72 Financial measures for the deployment of e-bikes

Economic and financial measures		
Appropriate financial incentives	Favorable treatment for e-bikes in comparison with conventional pre-owned gasoline vehicles	Exempt e-Bikes from custom and fees
		Provide a yearly "sustainable transport monetary allowance" for citizens based on the number of kilometers traveled using e-bikes

Table 73 Non-financial measures for the deployment of e-bikes

Market development		
Develop market infrastructure	Deploy effective infrastructure measures	Reserve lanes within GBA and major cities for e-bikes and bicycles
	Develop the supply channels for e-bikes	Construct e-bike stations taking into consideration the physical access to the stations such as access ramps for people with limited accessibility, etc.
Policy, legal and regulatory		
Set up a regulatory framework for the mass transit sector	Legislation favoring cycling in general and e-Biking in particular	Set clear regulations for e-bikes operation to reduce risks and accidents
	Enforce legislative reforms in urban planning laws	Redefine the use of urban road infrastructure
	Reduce cars speed limit in urban areas	Reduce car speed limits in the city to reduce the risks associated with cyclers/riders

Institutional and organizational capacity		
Develop institutional capacity	Launch cycling and e-biking services	Recruit specialized maintenance technicians
		Recruit management staff in charge of managing and optimizing the operation of e-bikes
Social awareness		
Dissemination of information	Inform travelers of ecological and economic benefits of e-bike systems	Provide information on benefits through dedicated media campaigns

Technology action plan for the deployment of e-bikes

The deployment of e-bikes aims to highlight the benefits of switching from the private car to e-bikes, in terms of environmental benefits by reducing of CO_2 emissions, economic and social benefits by reducing travel times, and health benefits by improving the health quality. Therefore, the focus was on identifying the appropriate strategy for this deployment, with a total of six measures proposed in Table 74.

Table 74 Technology Action Plan for the deployment of e-bikes in the GBA

Measures	Objective	Priority	Who should do it	Time scale	M & E indicators
Deploy effective infrastructure measures	Shift short-distance travels to e-bikes by designing a complete cycling network with dedicated lanes	1	Municipalities CDR	Short term	e-bike and cycling network on reserved lanes in GBA
Develop the supply channels of e-bikes	Increase the availability of e-bikes by providing e-bike service stations and charging points	1	MoPWT	Short term	e-bike service stations
Exempt e-bikes from customs and fees	Decrease the cost of e-bike ownership	1	MoF	Short term	Law on fee exemption enacted by the government
Provide a yearly “sustainable transport monetary allowance” for citizens based on the kilometers travelled using e-bikes	Provide a financial motivation for shifting towards e-bike while reducing transport costs for citizens	2	MoF	Short term	Annual budget allocated for the allowances

Set clear regulations specifying the maximum power and maximum speed allowed for e-bikes	Reduce risks and accidents when riding e-bikes	1	MoPWT	Short term	Legislation on regulating the use of e-bikes
Provide information on CO_2, fuel and cost savings of e-bikes compared to passenger cars	Increase awareness of travelers on ecological and economic benefits of e-bikes	2	MoPWT	Short/Medium term	Mobile applications, dedicated websites, media campaigns, etc.

Analysis of Technology: Freight Electrified Vehicles

Impact of the technology

Freight transport is a major contributor to GHG emissions in Lebanon, such that if no action is made to mitigate freight emissions, freight movement can potentially offset the benefits that can be achieved in the passenger transport sector through improving vehicle technologies and public transport. This is due to the increase in freight activity as a result of economic growth, as well as the large share of light duty freight vehicles (estimated at 76% of the total fleet of freight vehicles in 2010) which are less energy efficient per ton-kilometer than larger heavy-duty trucks.

In Lebanon, electrification of commercial LDV can have significant benefits, as these technologies are particularly suitable in the case of Lebanon for last-mile and intercity deliveries, where most of the total daily mileage does not exceed 100 km.

A study conducted in 2019 showed that increasing the share of plug-in hybrid electric HDV and fully electric LDV trucks can result in a 19% reduction of energy use and corresponding CO_2 emissions by 2040. Moreover, switching up new LDV registrations to 100% electric in 2040 can reverse the current unsustainable trends in Lebanon's freight transport sector. This comes at a cost of providing the necessary electric charging infrastructure and clean electricity mix to operate these vehicles effectively (Haddad, Mansour, & Diab, 2019).

Identification of barriers and measures

The financial and non-financial barriers for the electrification of freight transport in Lebanon are presented in Table 75 and Table 76, with the main barriers including:

The main financial barrier is the inappropriate financial incentives and disincentives, which, in their current form, favour diesel and gasoline LDVs and MDVs.

The main non-financial barrier is the insufficient legal and regulatory support to deploy electrified freight vehicles and their charging systems, as the deployment of electrified freight vehicles goes against the interest perceived under the current tax system.

The root cause of all the barriers is the absence of a sustainable transport policy, along with the poor market demand for electrified vehicles in general, and for the freight transport sector in particular

Table 75 **Decomposition of financial barriers to the deployment of hybrid and electric LDVs and MDVs technologies**

Economic and financial barriers	
High maintenance cost particularly of hybrid and electric LDVs and MDVs	Inadequate government policies on the purchase cost including Inadequate road-usage fees and high taxes on imported spare parts
Inappropriate financial disincentives for ICE LDVs and MDVs and a fast-charging network	Dominance of pre-owned LDVs and MDVs import dating up to tens of years old Lack of consideration of negative externalities in pricing transportation including high urban pollution and GHG emissions and travel time wasted due to traffic conditions in GBA
Foregone government revenues	Potential deprivation of the government from tax revenues on consumed fuel and vehicle purchase cost

Table 76 **Decomposition of non-financial barriers to the deployment of hybrid and electric LDVs and MDVs technologies**

Market failure and imperfection	
Limited presence of hybrid and electric LDVs and MDVs in the market	Low demand for hybrid and electric powertrain technologies
Underdeveloped competition	Insufficient number of hybrid and electric LDVs and MDVs suppliers
Policy, legal and regulatory	
Insufficient legal and regulatory framework	Legislation favors conventional gasoline vehicles Lack of implementation of legislation governing vehicle emissions Absence of safety control measures on pre-owned imported vehicles when entering the country
Network failures	
Weak connectivity between actors	Insufficient coordination between relevant ministries and freight electrified vehicle suppliers
Institutional and organizational capacity	
Absence of professional institutions	Absence of specialized bodies in relevant ministries at the transportation planning level and operational level Weak engagement of institutions to support technical standards for transportation
Limited institutional capacity	No R&D culture in transportation or an appreciation of R&D role in mitigating transport technologies
Human skills	
Absence of service and maintenance specialists	Low availability of qualified technicians for hybrid and electric LDVs and MDVs maintenance and damage repair except at some car dealers
Social, cultural, and behavioral	
Tradition and habits	Resistance to change due to non-familiarization and wrong perception of hybrid and electric vehicle technologies

Information and awareness	
Inadequate information	Lack dissemination of information on ecological and economic benefits and performance of hybrid and electric powertrain technologies
Technical	
Inadequate standards, codes, and certification	Lack of initiatives to set standards on emissions and fuel efficiency
	Lack of facilities for testing vehicles and certification
Data and information	
Lack of transportation monitoring data	Limited data to support transport studies aiming at the development of sustainable transportation strategies
	Lack of Mobility Monitoring Indicators (MMI) framework, which serves as the basic step in setting a national sustainable mobility strategy
	Lack of transparency and sharing of information related to transport studies carried out by ministries and relevant authorities

The financial and non-financial measures aimed to stimulate the growth of electrified powertrain vehicles are presented in Table 77 and Table 78. However, this can only happen with appropriate financial disincentives for non-efficient, gasoline and diesel LDVs and MDVs, to create a shift in technologies. The main measures are on one hand exempting hybrid and electric LDVs and MDVs from custom and excise fees, registration fees, and road usage fees, and on the other hand, adopting a tax policy that relates taxes to the CO_2 emissions of the vehicle.

Table 77 Financial measures for the deployment of freight electrified vehicles

Economic and financial measures		
Issue government incentives to reduce hybrid and electric LDVs and MDVs purchase and ownership costs	Create consumer incentives	Exemption from registration fees Reduce loan interest for freight electrified vehicle technologies
	Create technicians' incentives	Help domestic maintenance and repair technicians to buy equipment through banking facilities
Issue government disincentives to reduce import of non-efficient pre-owned LDVs and MDVs	Set up coherent tax policies disadvantaging the demand for high fuel consuming pre-owned vehicles	Increase road usage and registration fees on imported pre-owned high consuming freight vehicles
		Reduce road usage and registration fees on new and pre-owned electrified freight vehicles
		Reduce gradually maximum age of imported pre-owned LDVs and MDVs

Table 78 **Non-financial measures for the deployment of hybrid and electric LDVs and MDVs technologies**

Market development		
Implement a truck and van scrappage program with incentives	Create a vehicle termination plant	Create a plant that deals with the vehicle termination process after the swap in a scrappage program
Policy, legal and regulatory		
Set up new coherent tax policies	Issuance of law modifying the current tax figure in favor of low-emission LDVs and MDVs technologies	Adopt a tax policy where polluters pay more annual road-usage fees
	Implement legislation governing vehicle emissions	Update the vehicle inspection program requirements taking into consideration the special requirements for hybrid and electric freight vehicles inspection
Institutional and organizational capacity		
Strengthen professional institutions	Strengthen existing institutions such as LIBNOR to support technical standards for transportation	
Promote technological development	Promote R&D culture in transportation	Encourage local industry to develop and manufacture spare parts
		Provide incentives to R&D institutions which play an essential role in mitigating transport technologies
		Encourage universities to create engineering mobility programs
Social awareness		
Design awareness campaigns to promote hybrid and fuel-efficient trucks and vans	Dissemination of information to consumers on hybrid and electric LDVs and MDVs' environmental and economic benefits	Encourage car dealers to post up factsheets on all vehicles, displaying information on vehicle average fuel consumption and average CO_2 emissions
		Encourage all government vehicles to switch to hybrid and electric vehicles when buying new vehicles, to take the lead as a pilot project
Data and information		
Set up a mobility monitoring organism	Create Mobility Monitoring Indicators (MMI) framework to support transport studies	

Technology action plan for the deployment of freight electrified vehicles

The main strategy in the deployment of hybrid and electric LDVs and MDVs is to replace non-efficient ICE LDVs and MDVs running on gasoline and diesel, with more efficient vehicles, through a scrappage program. This can only be achieved by implementing regulations and tax reforms that favor electrified powertrains over non-efficient vehicles, and by creating an effective vehicle retirement program. The technology action plan is presented in Table 79, highlighting the main proposed measures.

Table 79 Technology Action Plan for the deployment of hybrid and electric LDVs and MDVs

Measures	Objective	Priority	Who should do it	Time scale	M & E indicators
Reduce the maximum age of imported pre-owned LDVs and MDVs	Limit the import of pre-owned non-fuel efficient LDVs and MDVs	1	MoIM	Short/Medium-term	Law on import of pre-owned cars
Issue a tax policy that forces polluters to pay more taxes by reconsidering road usage fees according to emissions	Provide disincentives for non-efficient LDVs and MDVs	2	MoF	Short term	Tax scheme
Renew the freight vehicle fleet by creating a scrappage program based on swapping current LDVs and MDVs with hybrid and electric ones	Enhance the efficiency of the freight vehicle fleet	2	MoF MoIM Vehicle dealers	Short term	Car scrappages program
Implement a vehicle retirement program through a vehicle termination plant	Remove old vehicles from the fleet	3	MoPWT MoIM MoE	Short/Medium-term	Car termination plant
Update the vehicle inspection program requirements taking into consideration special requirements for hybrid and electric vehicles	Improve the vehicle inspection program	4	MoE MoIM	Short/Medium-term	Updated vehicle inspection program
Strengthen institutions to support technical standards for transportation	Limit the import of deficient and non-efficient pre-owned vehicles	5	MoPWT MoE	Short/Medium-term	Mechanical inspection unit
Encourage vehicle dealers to post factsheets displaying information on LDVs and MDVs fuel consumption and average CO_2 emissions	Promote hybrid and electric LDVs and MDVs	6	MoPWT MoE	Short/Medium-term	Awareness campaign
Create Mobility Monitoring Indicators (MMI) framework	Develop sustainable transportation strategies	7	MoPWT MoE	Short/Medium-term	Mobility monitoring indicator framework

6.3 TECHNOLOGIES FOR THE AGRICULTURE SECTOR

The agricultural sector in Lebanon, as well as in the region, is a resource-intensive one and is by nature sensitive to climate variability. Given the barriers to some of the technologies presented earlier in 2012 for climate change adaptation for agriculture that limited their expansion, new hard and soft technologies are being explored and suggested based on the existing challenges as defined for each adaptation response.

The selection of the newly proposed adaptation technologies herein shall be contextualized and take into consideration the existing and future climate challenges specific to the agro-climatic zones that distinguish Lebanese agriculture. The two major themes under which adaptation technologies are suggested herein are water scarcity for irrigation in agriculture and the unknown climate risks. To improve knowledge on climate risks in Lebanon, technologies for vulnerability assessment and hazard and risk assessment are sought. For climate vulnerability assessment, one technology is selected: climate change agricultural vulnerability assessment. Under Hazard and risk assessment, two technologies are selected: crop yield monitoring applications, and evaporative stress index mapping.

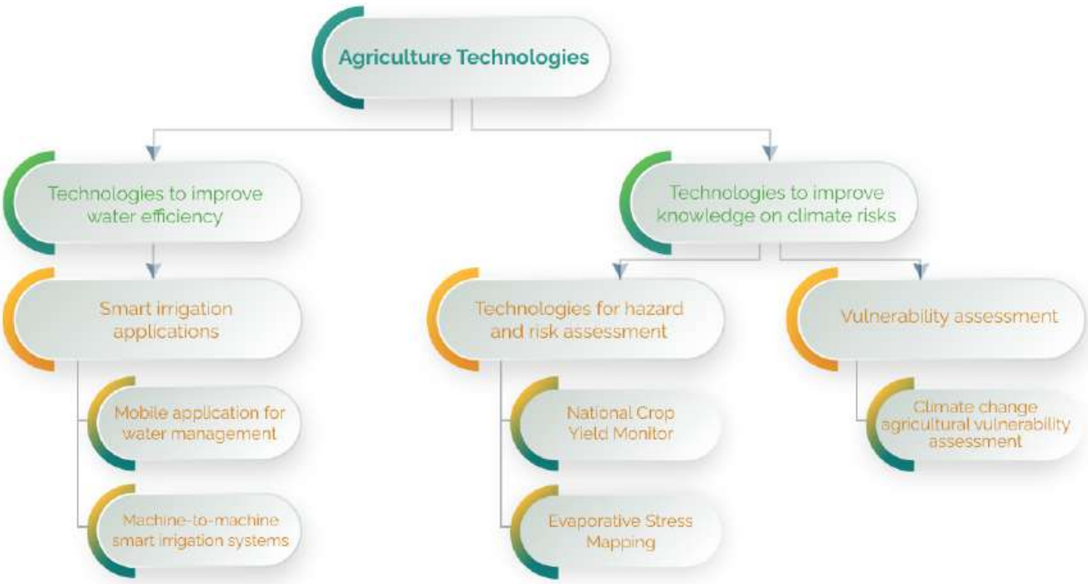


Figure 111: Rationale for selecting the agricultural technologies for climate change resilience

6.3.1 Smart Irrigation Applications

Smart irrigation systems are designed to offer the ability to increase water application efficiency at the farm level, thereby reducing the environmental footprint of agriculture (in terms of water and energy use) while also providing farmers with a financial benefit (by decreasing their operational expenses).

Applicability in Lebanon

A survey done in Lebanon with 678 farmers interviewed randomly shows little knowledge about crop irrigation requirements. Yet there is a high potential for farmers to adopt technologies such as smart irrigation applications. According to the findings of the study, 90% of the farmers think that better irrigation management can boost their farm's economic production, and a comparable percentage are willing to use free smart mobile apps to help them manage (schedule) irrigation for their crops (Jaafar and Kharroubi, 2021).

Irrigation scheduling is one of the most important practices that can help farmers get the most out of their water. Most farmers polled in Lebanon said they irrigate at a fixed frequency (60.7%), while 16.2% irrigate when sign of crop water stress appears and 9.9% only irrigate dry soil. Only 6.3% of participants said they used irrigation metering or timing devices. Almost two-thirds of research participants said they used fuel in private generators to irrigate their cultivated land, 12.6% said they used electricity, and 19.6% said they used both. There is therefore a high potential here for climate-smart irrigation interventions that will help farmers adapt to water stress while at the same time, saving energy and not risking yield reductions.

Regarding the use of a smart mobile application by farmers, the majority (89.3%) agreed or strongly agreed that they would be prepared to utilize a free smart mobile app to aid them in controlling (scheduling) irrigation systems for their crops. When asked if they are willing to pay for a smart smartphone app to help them manage (schedule) irrigation, 60.6% of farmers agreed or strongly agreed. While Lebanese farmers do not adequately measure or know their crop water requirements and the amount of water applied, they seem to be willing to adopt better irrigation management techniques when guided, especially in the form of a mobile smart irrigation application.

6.3.2 Machine-to-machine smart irrigation systems

Aside from smart mobile apps in irrigation, improved irrigation technology includes more efficient irrigation systems that operate via machine-to-machine systems. In such a system, irrigation run-times are derived based on reference evapotranspiration (using on-site temperature measurements and the latitude of the site), as well as user-input data to determine the irrigation run times based on the application rate of the irrigation system, the type of soil, the slope of the field, and the crop type/growth coefficient). Users can communicate with the controller when needed via a mobile application that connects to an air card that communicates with telecom towers. The system automatically turns on the irrigation pump and the solenoid valves and then shuts them off when the necessary irrigation amount has been applied, thereby reducing the uncertainty for the farmer/user.

The crop will receive water when the soil moisture in the root zone reaches a pre-set threshold based on evapotranspiration calculated on site or received from nearby stations. This technology can be extended to sprinkle irrigation and furrow irrigation that operates using surge flow techniques.

Applicability in Lebanon

A case study of such a system is showcased in Lebanon and a pilot testing was initiated in the Bekaa Valley, Lebanon in 2014-2015, where the system was successfully implemented for two seasons on cultivating an Origanum crop (Jaafar et al., 2017). The study aimed at testing the applicability and operability of smart and automated irrigation systems in agricultural settings. Rather than having the farmer decide on irrigation times and amount, the designed system depends on field measurements that allow the automated start and shutoff of the irrigation cycle to irrigate the crop when needed and as needed. Irrigation is made possible in an automated way remotely based on local measurements of evapotranspiration (Figure 112).

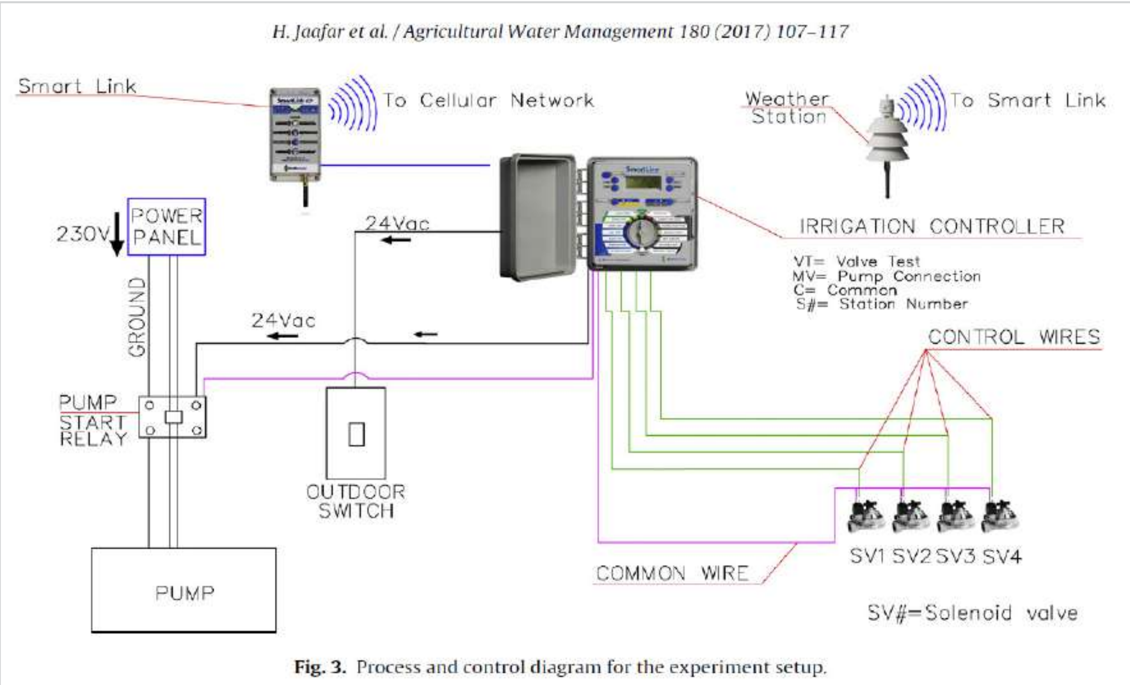


Figure 112: Process and control diagram for a machine-to-machine smart irrigation system implemented at AREC, Lebanon, for irrigation Origanum

6.3.3 National Crop Yield Monitor

Among the technologies that can improve the knowledge of climate risks and assess hazards and risks to agriculture is the national crop yield monitor, which aims at providing open, timely, and remote-sensing driven information and data on the major strategic crops (such as potatoes, wheat, and onions) and their conditions to support planning for food security risks. The crop monitor should bring together crop data, agro-meteorological variables such as rainfall and temperature along with biophysical variables (biomass, derived from remote sensing) to generate information about the crop conditions and yield forecasts that can help assess hazards in the agricultural sector.

Applicability in Lebanon

The complex topography characterizing the Lebanese territories creates different micro-climatic regimes within Lebanon: relatively humid Mediterranean conditions on the coast, the semi-arid climate within the central Bekaa Valley, and arid conditions in northern Bekaa. Such regimes dictate site-specific monitoring when it comes to climate change adaptation practices. Using satellite products, the National Crop Monitor can be utilized to generate crop yield forecasts spatially in each of the agro-climatic zones. Recently, Jaafar and Mourad (2021) developed a global mapper and given the advancement of supercomputers and platforms for imagery analysis, the crop monitor can be deployed at the national scale with high resolution (covering fields of around 0.5 ha with ease).

6.3.4 Evaporative Stress Mapping

Evaporative stress monitoring and mapping is a tool that helps governments, cooperatives, and various types of farmers understand the water stress status of the cropland. It allows farmers and irrigation managers to assess the current agricultural conditions in the country in terms of water availability for both irrigated and rain-fed agriculture. Evaporative stress Index (ESI) aims to quantify temporal anomalies in the ratio of actual water consumption of the crops to that of the potential water consumption over a spatial domain of interest. If the evaporative stress in an irrigation command area is high, that area would need irrigation to prevent yield losses. If the evaporative stress in a forested area is high, then that area is at risk of fires (if other conditions like wind and humidity are favorable). Also, pest infestations would be highly probable. This technology would therefore help reduce the risk of yield loss, fires, pests, and mitigate adverse climate effects. The ESI can be calculated spatially using satellite imagery and weather reanalysis products such as the Copernicus ECMWF product. Other indices such as the Normalized Difference Soil Moisture Index (NDMI), the Normalized Difference Water Index (NDWI), which is sensitive to the change in the water content of leaves. A well-known indicator is the Standardized Precipitation-Evapotranspiration Index (SPEI) (which compares water availability to evapotranspiration rates). To develop an ESI monitor and assess the risks, a platform can be developed that could be accessed by government employees, municipalities, ministries, and farmer's associations.

Applicability in Lebanon

Limited activities related to the design and use of an evaporative stress map in Lebanon have been initiated. One initiative has been launched for the for the Bekaa valley, which provided the historical water use and evaporative stress for three decades using the full Landsat archive, showing that the amount of water-use, and the extent of water stress can be quantifiable both at the field and at the watershed level (Jaafar and Ahmad, 2020). Other information on the Evaporative stress index is available for the region and Lebanon via global databases such as the Crop explorer (USDA, 2021).

6.3.5 Climate change agricultural vulnerability assessment

Agriculture vulnerability assessments look at the exposure, sensitivity, and adaptation capability to determine the degree to which changing climate will affect various agricultural systems in different geographical areas. The aim is to evaluate the true level of impacts and prioritize essential changes based on the sensitivity of the agricultural system's constituents Vulnerability assessments are developed to provide guidance and support for adaptation planning and justification for project implementation in order to create a more objective decision-making process and strategically design and implement adaptation interventions.

Applicability in Lebanon

The suggested technology aims at developing studies that aim at assessing the response of each agro-ecological zone in Lebanon to the different climate impacts be it increases in temperature, reductions in precipitation, changes in crop calendars, or extreme weather variability. Although several agricultural vulnerability assessments have been conducted in Lebanon, more accurate models are needed to assess for example how vulnerable is rain-fed agriculture in different areas in Lebanon to changes in rainfall patterns and how it varies with crops, or how susceptible is irrigated agriculture to reduced water and energy availability and water quality deterioration.

6.3.6 Prioritization of technologies

The suggested technologies have been assessed and prioritized by key stakeholders using a multi-criteria Analysis and based on criteria such as capital and operational cost, the importance of economic impact, improvement of resilience to climate, technology capability and suitability for the country, human and information requirement, and social suitability for Lebanon. Accordingly, the top three ranked technologies were 1) Free Mobile applications for smart irrigation, 2) National Crop Yield monitor and 3) Evaporative Stress Mapping. The implementation of these technologies will have a direct benefit and positive impact on agricultural productivity in the country as water remains one of the most widely limiting factors for crop production in Lebanon and have been selected as priority technologies for adaptation in the agricultural sector in Lebanon. More details on the prioritization process are available in Annex III.

6.3.7 Barriers and needs for deployment of priority technologies in Lebanon

Analysis of Technology: Mobile application for water management - AgSAT

A new app for smartphones to calculate crop evapotranspiration in real-time has been developed in Lebanon to support field-scale irrigation management. The app, AgSAT, uses meteorological data to calculate daily water requirements using the ASCE-Penman–Monteith method and vegetation indices such as the Normalized Difference Vegetation Index from satellite imagery to derive the basal crop growth coefficient, $K_{cb.}$

AgSAT can provide water requirements data to all types of users, from small-holder farmers to irrigation districts and regional water planners (Figure 113). It can also guide decision-makers in water allocation for agriculture and landscape and help farmers produce more crops with less water and energy, thereby reducing the environmental footprint of agriculture.

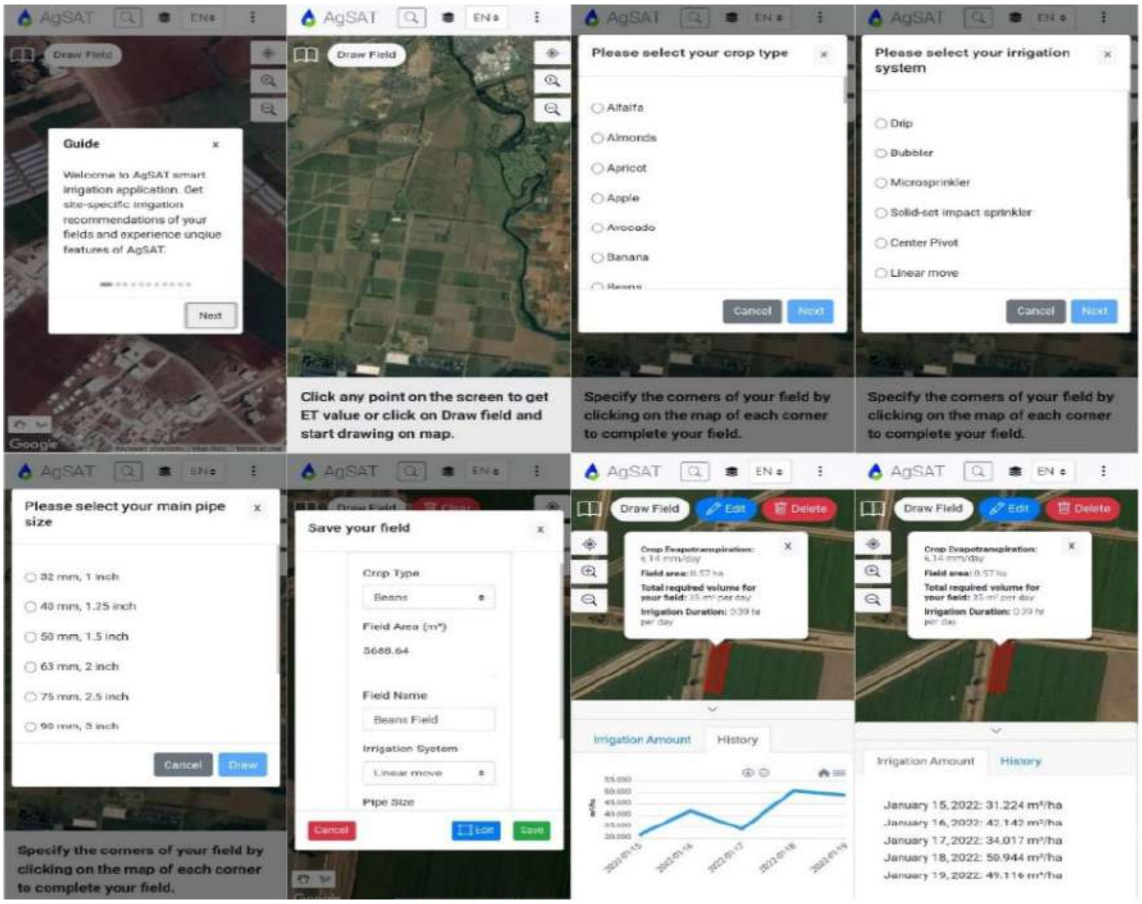


Figure 113: The interface of AgSAT and screenshots for the application detailing the procedure to obtain results

The adoption of such technology can be done by ministries and municipalities, farmers, irrigation engineers, water authorities, large and small farming enterprises, non-governmental organizations, agriculture companies, and international organizations. Currently, the application is accessible freely for non-commercial usage and training is available on use. The application can be used anywhere where irrigation is practiced and can be used where cellular network coverage is available and farmers have smartphones. Also, it is best used in places where sprinkle and trickle irrigation are applied. It can be used for surface irrigation at the district level or water authority level. It can inform farmers and farm operators on irrigation timing and volume required for their crops, thereby helping them save on energy use and water diversions.

Environmental benefits for this technology include the optimization of water applications in agriculture and landscape, thereby reducing groundwater pumping, conserving water and energy, thus reducing greenhouse gas emissions. By reducing irrigation applications, there will be lower nitrate leaching and less pesticide contamination into aquifers. The app will have many socio-economic benefits: It will save on pumping costs and improve yields due to better irrigation timing, hence increasing economic water productivity and cash flow to farmers. It will also allow more water for other sectors by reducing water diversions to agriculture.

Identification of barriers and measures

One of the barriers for adopting smart irrigation technologies is the low level of human capital in the agricultural sector, which is mostly elderly people and people lacking higher education. The size of the farm is also restrictive as many holders are small farmers with less than 2 ha, making this technology less appealing due to the lack of high-resolution data that can cover their lands with a higher number of pixels. Greenhouse farmers will be also excluded from the use of this technology as it requires satellites viewing open fields.

Another barrier could be the cost of mobile data and the requirement for high internet connectivity. The data transfer through mobile applications requires third generation (3G) and fourth generation (4G) networks. Based on the Worldwide Mobile Data Pricing Survey for the cost of mobile data in 2020, Lebanon ranks 132 among 228 countries, reflecting an expensive mobile data service. The average price of 1GB of mobile data in Lebanon is US$3.82 per month in 2020, which is higher than the global average (USD1.56 per month). In addition, the majority vulnerable populations in Lebanon face inequalities and impediments to digital access due to limited network coverage and lower smartphone ownership.

Other key barriers include low digital skills of farmers. Smallholder farmers in Lebanon have Lower literacy and education rates as opposed to larger commercial farmers. This may create or widen a digital divide between small and large farmers. Youth literacy rates in Lebanon exceed adult literacy rates, which may favor youth compared to adults in their ability to use smartphone applications. According to the Lebanese Ministry of Agriculture, 16% of farmers are illiterate; another 61% have only primary education, but control 60% of the total utilized agricultural area in the country (MoA, 2012).

Some farmers may have issues trusting technologies. They could have low confidence in these technologies and may not trust the application recommendations. It is necessary that demonstration plots and showcases be established to build trust and prove that the application is indeed worthwhile adopting.

In order to overcome the barriers and encourage the use of such applications, information sessions and training workshops for farmers and cooperatives in the major agricultural areas in the country should be conducted. The series of sessions and workshops may take place in North Lebanon, Akkar, Zahel, Baalbeck-Hermel, South Lebanon, Mount Lebanon, and Nabatiye. The MoA should organize and lead such workshops with support from the app developers. Capacity building sessions on application usage should also target MoA staff and extension engineers in the various administrative divisions.

Hero farmers should also be selected based on their willingness to dedicate a portion of their land for testing the application, as well as providing proof of concept if indeed they managed to save water and energy and improve their yields. Farmers' field days can be organized to showcase the advantages of using smart irrigation and increase adoption with other farmers. Since most farmers in Lebanon are not aware of alternative water-saving techniques that could be used instead of conventional irrigation practices, the recommended measure is to further deploy such technologies and help them irrigate according to crop water requirements. The deployment would facilitate the transition to a volumetric water application-based tariff. The transition would require special legislative efforts and parliament decrees.

Based on the above identified challenges, Table 80 presents an action plan for the proper deployment of smart irrigation applications in Lebanon.

Table 80 Technology Action plan for the AgSAT smart irrigation applications

Measures	Priority	Objective	Responsible parties	Beneficiaries	Time scale	Monitoring & Evaluation indicators	Estimated cost (USD)	Donors
Conducting training sessions and field work	1	To increase the experience of technicians to train farmers	Government, NGOs MoA, FAO, LRA, LARI	MoA, NGOs, LRA, farmers,	Short term	Number of training sessions Percent active technicians in disseminating the apps	USD 20,000 For 50 technicians	World Bank Adaptation Fund GEF IFAD FAO Islamic Bank EU USAID Kuwaiti Fund Italian, Spanish Cooperation CGIAR SWISS DEVELOPMENT AGENCY UNDP
Conducting experimental studies at the research institutes and farm level	1	To demonstrate to farmers the advantage of using Smart apps in saving energy and conserving water while improving yields	LARI, Academic institutions, MoA, FAO	MoA, LRA, NGOs, farmers, LARI	medium term;	Briefs on results Number of experimental plots Field results of smart app irrigation vs. traditional irrigation Water conserved and energy saved	USD 250,000 for experiments at AREC, AUB, LARI stations and 20 on-farm plots covering 5 crops, with flow meters and record-keeping of water and energy usage	
Conducting field days and visits to demonstration plots, seminars, and TV program	1	To change farmers' behavior concerning irrigation practices and show the comparative advantages of smart vs. traditional irrigation	MoA, LARI, Academic institutions, NGOs	Farmers Establishments, MoA, LRA	Medium term	Number of farmers converting to smart applications Number of attendees in seminars	USD 20,000 for 500 farmers participating in seminars and field days. USD 50,000 for TV program	

Lobbying to get ministerial support to shift from fixed irrigation tariff in LRA to volumetric tariff	2	To increase adoption among farmers and decrease water diversions for agriculture	MoA, LARI, Academic institutions, NGOs	Farmers, Establishments, MoA, LRA Private sector	Medium term	Parliament and government decisions and law amendment	USD 20,000 For meetings and feasibility study for LRA	World Bank Adaptation Fund GEF IFAD FAO Islamic Bank EU USAID Kuwaiti Fund Italian, Spanish Cooperation CGIAR SWISS DEVELOPMENT AGENCY UNDP
Create special packages for internet usage	1	To decrease the cost of internet usage	MoA, MoT, MoF	Farmers, Establishments, MoA, LRA Private sector	Medium to Long term	Number of packages created and sold	To be refined by Ministry of Telecom ~USD100,000 for 100,000 farmers	
Prioritize internet delivery systems in farmers areas	2	To increase internet coverage in remote locations	MoA, MoT	Farmers, Establishments, MoA, LRA Private sector	Medium to Long term	Spatial increase in coverage over agricultural areas	To be estimated by Ministry of Telecom	

Analysis of Technology: National Crop Yield Monitor

A crop yield monitor is one of the manifestations of precision agriculture. Yield mapping and monitoring is a technology that has continued to evolve since the 1980's and continues to be one of the approaches that help farmers improve agricultural and yield management. Current market research estimates that yield monitoring market will reach USD 3.8 billion by 2026. While the adoption of this technology globally is still not widespread, there are some companies that provide this service to farming enterprises and governments. One example is Eleaf, which provides this service to farmers in South Africa. Testimonies indicate that farmers were able to use 20% less water, and others were able to increase their yield by 30% (Eleaf, 2022)

The national crop yield monitor proposed for Lebanon is a platform that allows decision makers and other stakeholders in agriculture to assess crop yields both at the national and field level. This will allow practitioners and government decision makers to visualize the downloaded yield data analytics to enhance food security-related decisions through:

1) better preparedness for future climate conditions, particularly catastrophic events like floods and droughts, as well as identifying hot spots to reduce crop losses and damages caused by poor adaptation;

2) better understanding of the impact of climate on diseases, water stress, and management practices and their implications on crop yields; and

3) improved agricultural technology and management practices on a continuous basis by identifying areas with higher yield.

In addition to crop data, a typical crop monitor provides reliable weather forecast as well as historical data and easy-to-use satellite field monitoring. A crop monitor would gather data from optical imagery, synthetic aperture radar imagery, big data processing and crop modeling algorithms and possibly artificial intelligence all to provide solutions for farmers that will help them increase their revenues. Farmers would improve crop production management strategies by estimating how much yield they can get from any crop for an upcoming season based on historical data trends.

The crop monitor would be used to produce maps and information on crop conditions in Lebanon (whether the conditions are exceptional, favorable, poor, failure, out of season, or no data), as well as crop stages (vegetative, reproductive, ripening, and harvest) and crop yields. An example of a yield mapper is shown in Figure 114.

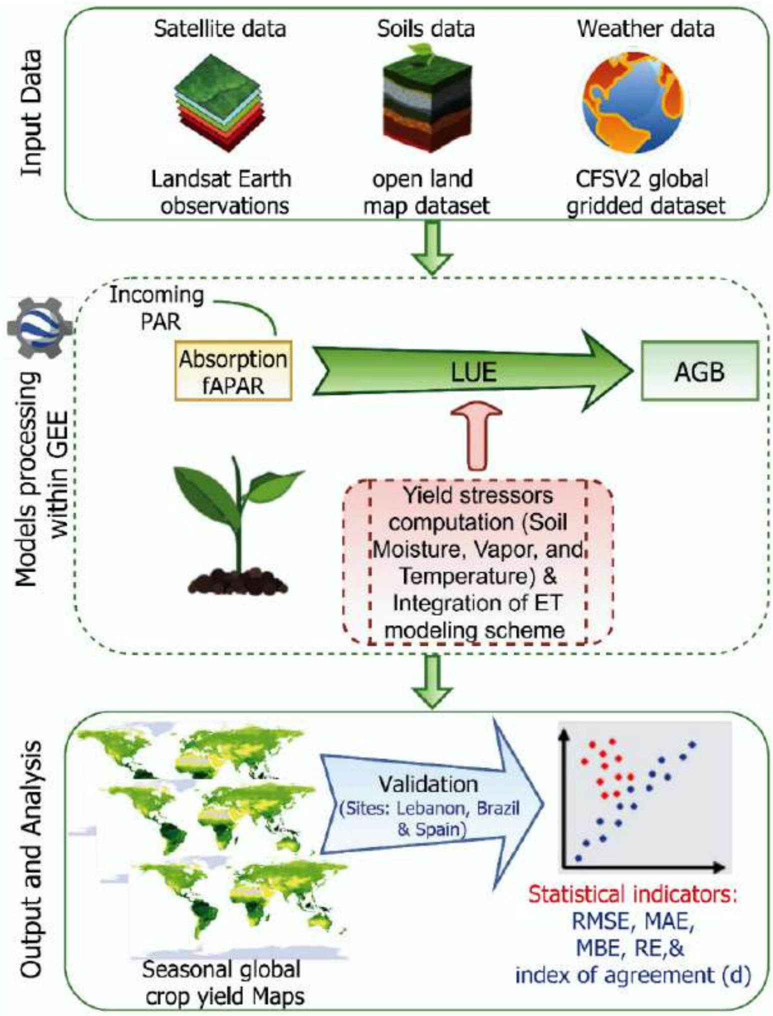


Figure 114: Methodology used to develop a global field scale crop yield mapper that could be used in the suggested technology

Identification of barriers and measures

The barriers to the success of use of a crop yield monitor require crop is mainly linked to the quality and quantity of survey data and, to some extent, local weather data to decrease the uncertainty associated with remote sensing technology. The latter is easier to collect than the former due to the availability of such data from LARI as well as from the Civil Aviation Authority.

There could be also low confidence in technology among the farmers and decision makers, hindering the adoption of resulting recommendations. Therefore, ground validation processes are required to assess the relationship between modeled yield and observed evaporative stress impacts on yields and showcase to the farmers success stories where the monitors provide more accurate data than their own assessment. This can be complemented by extension services, capacity building, and awareness plans.

As public expenditure on agriculture is quite low, external funding is required to support such activities. Additionally, crop yield monitors require input from the farmers on harvest dates, especially for fruit trees. In Lebanon, most farmers do not keep records of their farming practices, and applications in this context can be used to collect such data.

Some measures to overcome these barriers and further deploy such technologies include:

- Extensive validation of remote sensing data at field level
- Data quality improvements by correlating with local stations and applying bias correction
- Training on advanced remote sensing skills and data analytics for Ministry of Agriculture personnel
- Stakeholders' awareness on remote sensing systems monitoring and how it can be used to aid decisions
- Development of open-access databases and platforms for data sharing and access facilitation
- Capacity building to keep records and possibly develop an application to help farmers log their data online and track it and access it later
- Engagement of youth to advance precision farming and digital agriculture.

Table 81 presents the technology action plan for the deployment of national crop monitor.

Table 81 Technology Action plan for National Crop Monitor

Measures	Priority	Objective	Responsible parties	Beneficiaries	Time scale	Monitoring & Evaluation indicators	Estimated cost (USD)	Donors
Acquire the necessary funding from donors	1	To be able to design and implement the national crop monitor	Government, UNDP, FAO, LARI	MoA, LRA, farmers	Short term	Proposal write-up Acceptance of proposal	USD 50,000	World Bank Adaptation Fund GEF IFAD FAO Islamic Bank EU USAID Kuwaiti Fund Italian, Spanish Cooperation Japanese Embassy Swiss Development agency UNDP
Setup and develop the crop monitor	1	To set up the monitor and install it at the Ministry of Agriculture, LARI, and the Litani River Authority	Private firms, LARI, Academic institutions, MoA, FAO	MoA, NGOs, farmers, LRA, LARI, cooperatives	Short term	Establishment of the platform	USD 200,000 For platform setup in the ministry	
Crop survey initiation	1	To identify hero farmers, select pilot areas and establish methodology of survey	MoA, LARI, FAO, UNDP	MoA, NGOs, farmers, LRA, LARI, cooperatives	Medium term	Survey progress (ha surveyed, information collected)	USD 100,000 For conducting field surveys	

Conducting training sessions for Ministry Personnel on data analytics	2	To train the personnel on how to use the monitor, how to generate the data, and how to analyze it and report it to policy and decision makers	MoA, LARI, Experts from Academic Institutions FAO	Farmers Municipalities MoA MoT MoI MoEW MoE	Short term	Number of trainees Number of sessions Feedback surveys Interviews Reports generated	USD 100,000 for 50 personnel	World Bank Adaptation Fund GEF IFAD FAO Islamic Bank EU USAID Kuwaiti Fund Italian, Spanish Cooperation Japanese Embassy Swiss Development agency UNDP
Ongoing assessment and validation	2	To demonstrate to stakeholders, extension agents, farmers, and other stakeholders the results of the monitor against field results	MoA, Private sector, Academic sector, LARI, Farmers	Farmers, MoA, LARI, Cooperatives	Medium and Long term	Regular Modelled crop results, degree of alignment with census data	USD 200,000 Policy briefs, newsletters, notifications	

Analysis of technology: Evaporative stress mapping

Mapping evapotranspiration at the field scale is crucial for a better understanding of the factors that limit crop production under a warming climate and dryer weather conditions. Valuable spatio-temporal information about crop response and soil moisture can be derived from field-scale evapotranspiration. Knowledge of what the optimal conditions should be, in comparison to historical patterns, with distinction between rain-fed and irrigated conditions, would be very valuable for quantifying the evaporative stress and consequently advising the most appropriate action.

For irrigated areas, drought mapping may not provide enough insight on water stress levels. Existing global indices (e.g. MODIS data) are mainly characterized by course resolution thereby offering limited capability for small-scale farmers as most of the agricultural holdings are less than 2 ha (Qiaozhen et al., 2011; Dal et a., 2021). Thus, a different measure should be used and parameterized to advise farmers on irrigation run-times and to provide an assessment of the hazard impact on agricultural productivity. The alternative is to provide high resolution actual evapotranspiration (ET) data along with potential ET data at the 30-m field scale. Evaporative Stress mapping have been developed and used in many continents and countries such as Australia, Brazil, Korea, and USA, among others.

In Lebanon, ET mapping has been initiated for the Bekaa valley, providing a time series of daily evaporative fraction for the upper Litani river basin using two different models (Figure 115). The deployment of such a mapper in Lebanon would require a platform for calculating reference ET from local weather stations or from gauge-corrected remote sensing data along with the use of high-resolution satellite imagery (Jaafar and Ahmad, 2020).

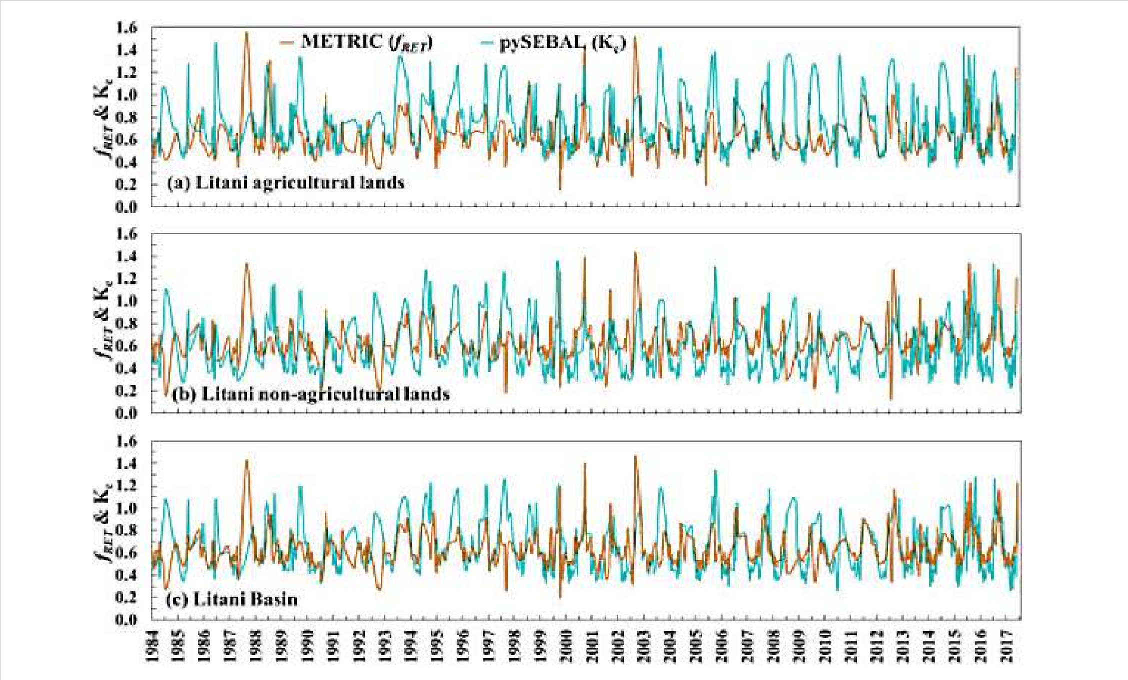


Figure 115: Time series of daily METRIC's f RET and pySEBAL's Kc over (a) agricultural lands, (b) non-agricultural lands, (c) the upper Litani Basin for the period 1984–2017.

Identification of barriers and measures

The barriers for the development and use of evaporative stress mappers are like the ones identified for the crop yield monitor, in the sense that they both require field data collection, ground validation processes, capacity building and awareness plans in addition to funding. The measures that can help in the deployment of such technology in Lebanon are presented in Table 82. A final summary of barriers for all prioritized technologies can be found in Table 83.

Table 82 Technology Action plan for Evaporative Stress Mapping

Measures	Priority	Objective	Responsible parties	Beneficiaries	Time scale	Monitoring & Evaluation indicators	Estimated cost (USD)	Donors
Acquire the necessary funding from donors	1	To be able to design and implement the evaporative stress mapping	Government, UNDP, FAO	MoA, LRA, farmers	Short term	Acceptance of proposal Proposal write-up	USD $50,000	World Bank Adaptation Fund GEF IFAD FAO Islamic Bank EU USAID Kuwaiti Fund Italian, Spanish Cooperation Japanese Embassy Swiss Development Agency UNDP
Setup and develop the ES mapper	1	To set up the mapper and install it at the Ministry of Agriculture, LARI, and the Litani River Authority	Private firms, LARI, Academic institutions, MoA, FAO	MoA, NGOs, farmers, LRA, LARI, cooperatives	Short term	Establishment of the platform Survey progress (ha surveyed, information collected)	USD $200,000 For conducting field surveys and for platform setup in the ministry	

Conduct training sessions for Ministry Personnel on data analytics	1	To train the personnel on how to use the Mapper, how to generate the data and how to analyze it and report it to policy and decision makers	MoA, LARI, Experts from Academic Institutions FAO	Farmers Establishments, authorities	Medium term	Number of trainees Number of sessions Feedback surveys Interviews	USD 50,000 for 25 personnel	World Bank Adaptation Fund GEF IFAD FAO Islamic Bank EU USAID Kuwaiti Fund Italian, Spanish Cooperation Japanese Embassy Swiss Development Agency UNDP
Conduct ongoing assessment and validation	2	To demonstrate to stakeholders, extension agents, farmers and other stakeholders the results of the mapping	MoA, Private sector, Academic sector, LARI, Farmers	Farmers, MoA, LARI, Cooperatives	Medium and Long term	Regular Modelled ES data degree of alignment with census data	USD 200,000 Policy briefs, newsletters, notifications	
Integrate advance precision farming and digital agriculture in curriculum of agricultural schools	2	To build youth capacities to advance precision farming and digital agriculture	Research institutes, academic sector	Youth, farmers	Long-term	Sections on digital agriculture and precision farming integrated in curriculum	USD 100,000 For developing new course material	

Table 83 **Summary table of the list of barriers to the suggested new technologies for the agriculture sector**

Category	Smart Irrigation Applications	National Crop Monitor	Evaporative Stress Mapping
Financial	High training and dissemination costs: • Cost of continuous field validation, surveys, and data monitoring • Cost of training for new personnel • Costs for training Difficulty in allocating the necessary budget for research and development and demonstration plots and extension	High cost for the development of the monitor and for field validation Difficulty in allocating the necessary budget for research and development and demonstration plots and extension	High cost for the development of the map and for field validation Difficulty in allocating the necessary budget for research and development and demonstration plots and extension

Technical	Lack of technical expertise at farmer level Lack of irrigation management scheme at MoA, extension services and farmers levels Low internet coverage/slow internet in some agricultural areas (Akkar, Bekaa) Lack of consistent power supply	Lack of technical expertise at the Ministry level Lack of crop modeling skills High uncertainties on data or/and model since crop yield monitors require input from the farmers on planting and harvest dates. Lack of bookkeeping: most farmers do not keep records of their farming practices	Lack of technical expertise at the Ministry level Difficulty of field validation (AI techniques, crop classification)
Social	Low confidence in technology amongst farmers	Low confidence in technology among farmers	Low confidence in technology among farmers
Human	Lack of farmers of know-how, Low literacy rate Lack of remote sensing and digital skills	Lack of remote sensing and GIS skills for data processing	Lack of digital skills
Information and Awareness	Lack of capacity building Lack of extension services, and awareness	Lack of capacity building Lack of extension services, and awareness	Lack of capacity building Lack of extension services, and awareness

6.4 TECHNOLOGIES FOR THE WATER SECTOR

Water resources in Lebanon have always been under pressure, from population growth, urbanization, pollution and weak management, a situation that is further exacerbated by climate change impacts.

Therefore, there is an urgent need to address current challenges, change and build adaptive capacity of systems through the identification of suitable water adaptation technologies.

There are many issues that have been identified and presented in consecutive strategies developed by the Ministry of Energy and Water, which have suggested, among other, building dams and increasing water storage to cater for the increasing water demand, in addition to increasing the capacity of wastewater treatment plants and connecting more households to sewage networks. Therefore, technologies related to increasing water storage, and treating and reusing wastewater have been extensively studied and analyzed in the country and will not be explored further in this TNA report.

The analysis of adaptation technologies in the water sector will focus on tools and equipment that have not been fully explored in Lebanon, and which will target the non-agricultural water sector. Reducing water stress in urban areas and improving efficiencies will be a key factor to addressing climate change adaptation in the water sector. Therefore, the proposed technologies feed into two major themes: 1) improving water use efficiency and 2) reducing water stress at the consumer level and include the following technologies:

1- Smart District Water Metering/SCADA system

2- Climate-sensitive basin-level dynamic water modelling

3- National water dashboard

4- Water-efficient household appliances

5- Green infrastructure: porous asphalt

6- Crowd sensing applications

Technologies that help improve agricultural water management, and address water use efficiency in agriculture (the largest water consuming sector in Lebanon), are addressed under the Agricultural section of the TNA.

6.4.1 Smart district water metering/SCADA system

In order to better adapt the country to a warming climate, tracking water consumption and controlling water allocation per capita is an essential management tool for any integrated system. Therefore, water accounting through smart water meters is highly needed for proper water supply measurement and management.

District level smart water metering is one of the measurement technologies that make it easier to keep track of water delivered, and water consumption in non-agricultural sectors (domestic, industrial, municipal, tourism, and health). Knowledge of delivered water and allocations in near real-time can help water utilities to have a clearer understanding of zones with high water usage, to implement water conservation measures, quantify non-revenue water and achieve climate-sensitive social equity in water distribution.

Applicability in Lebanon

In Lebanon, district water metering can be an efficient tool for water establishments to practice equitable water distribution while knowing exactly how much is being delivered to each zone and evaluate water use per capita. District-metering is a prerequisite for installing smart meters at the household level, where subscribers would pay their water fees for amount of water consumed.

Meters that are not linked to pricing charges, can be used to monitor extraction rates by cities, towns, and villages or other conglomerations. Meters can be installed at wells and pumping stations delivering water to the customers. Smart water metering should be a part of Supervisory Control and Data Acquisition (SCADA), which is essentially a distributed computer system that is used by operations and management for process monitoring and automation. Accordingly, establishments will know exactly how much water is being delivered to each district/village/zone, enabling them to assess leaks and detect pipe bursts, illegal tapping, and therefore improve transmission and distribution efficiencies. They will be able to evaluate system pressure and assess energy expenditures, and consequently reduce system losses.

6.4.2 Climate-sensitive basin-level dynamic water modeling

In order to complement hydrologic measurement techniques in assessing water resources at basin levels, hydrologic and water resources management modeling emerged as a key exercise to understand the availability and the reliability of water supply systems. By understanding the water dynamics in a basin of interest, a science-based water planning and allocation policies can be developed, whether in water resources planning, flood mitigation, or well licensing. Sectoral water allocations can be improved by understanding seasonal water availability and dynamics, regarding historic trends and future climate projections. With the increase in water demands for an expanding population and a warming climate, improved modeling within the context of climate change is now a must.

The Water accounting tool for example (WA+) can be very useful in this context. Modeled seasonal water availability (based on previous trends and future climate predictions, for example) can be combined with several other factors such as using various water use scenarios to examine the environmental and economic consequences of various basin allocation options.

Applicability in Lebanon

To date, Lebanon still lacks climate-sensitive river basin-level water allocation modeling. Modelling efforts have so far lacked studying climate change scenarios and their impact on water resources at the basin scale, mainly due to the absence of area-specific data. As such, results of basin modeling did not translate into concrete policy actions.

Also, current modeling lacks the integration of a climate change dimension, and many groundwater and surface water interactions are still not well understood. Salt-water intrusion in coastal basins and impact of snow melt scenarios on water future water availability is still not tackled in depth.

6.4.3 National Water Dashboard

A national water dashboard is a platform in which surface and ground water levels and flows, water quality, spring flows, precipitation, and temperature can be measured and displayed, monitored and made publicly accessible. Real-time data relayed by satellite or other telemetry is automatically broadcasted to a map viewer.

A water dashboard relies on a network of measurement stations (river/spring flow gauges, and groundwater well monitoring, agro-meteorological stations) that send data wirelessly to a centralized location (virtual hub) where it can be viewed, analyzed, and used to advise policy, support decision making, and improve water management at the national scale. It can also serve as a way for rationing water use at times of drought, warn against floods, heatwaves, or extended drought periods and providing transparency to the public via building trust and synergy with institutions.

Applicability in Lebanon

As unpredictable weather patterns and their repercussions are projected to have negative consequences for freshwater resource quantity and quality in Lebanon, such a national water dashboard can serve as an important adaptive response to climate change. Some initiatives have been undertaken to centralize and visualize data, however, to date, no national water dashboard has been operational.

6.4.4 Water-efficient fixtures and appliances

Water-efficient fixtures and appliances can reduce water demand at the domestic and municipal levels. Promoting such appliances can act as a step forward towards a water management practice that will help reduce stress on the aging water infrastructure found commonly in large cities. Using this technology in restaurants, hotels, hospitals, companies, and other community buildings can make a difference in water demand and help in water conservation. In addition, such technologies can change the mindset of the public through increasing awareness of water conservation practices.

Installing water-efficient appliances can save considerable amounts of water. For example, replacing inefficient toilets with water saving ones can help families save up to 50 m^3/year per family. Efficient showerheads can save 10 m^3/year and efficient faucets can save 4 m^3/year.

Applicability in Lebanon

In Lebanon, there is no regulation or standard to promote the use of water-efficient appliances or to increase their share in the market. Studies have shown that such technologies can save up to 64 m^3 of water/year per family, totaling 64 MCM per year assuming 1 million families implement this practice in the country. This could amount to more than 12% of the non-agriculture water demand. Authorities will need to advocate for new building codes and import regulations to limit the option for non-efficient appliances in the market on the one hand and to incentivize the purchase of water efficient equipment on the other hand. Market instruments can be developed via introducing tax incentives and preservation standards. Such technology can also be further expanded in the market with the adoption of per usage water tariffs, rather than the flat tariffs currently in place countrywide.

6.4.5 Green infrastructure - porous asphalt

Reducing storm water runoff and increasing infiltration in and upstream of urban areas can lead to better aquifer recharge and therefore reduce saltwater intrusion in groundwater in coastal areas. Therefore, climate proofing urban infrastructure is becoming an essential requirement to support cities adapt to rising sea levels, flooding and drought as climate change worsens. One of the practices currently being explored in the world is the use of permeable materials for roads and pavements such as porous asphalt, which facilitates the drainage of the water to the sides of the road, prevent aquaplaning and improves water infiltration into the soil.

Studies have shown that shifting towards using porous asphalt can increase storm water infiltration from 2% (for regular asphalt) to 16%. Such asphalt can be placed over highly permeable soils or in low-density parking areas. Typical installation should entail various courses such as porous asphalt, top filter course, filter fabric and subgrade material.

Applicability in Lebanon

Currently there has been no studies on the potential of using porous asphalt in Lebanon. All the roads are paved using regular asphalt/bitumen, with specifications set by LIBNOR. However, the technology is worth exploring further as urban flooding and saltwater intrusion is becoming a significant challenge in most of the coastal areas in Lebanon.

6.4.6 Crowd-sensing application for pipe bursts and leaks

Mobile crowd-sensing systems are applications that aim to collect and distribute data, using users' mobile devices in a way that will mobilize social interaction, hence reaching the common goal of having sustainable monitoring across communities.

Crowd-sensing applications for pipe bursts and leaks aim at detecting and reporting visible leaks/bursts from water systems to ensure their repair as soon as conveniently possible. The app can report the location of the leak, accompanied by a picture which can be analyzed to assess the leak or burst pipe diameter and it can be complemented by smart sensing of flows and pressures in the network. The sharing of such information can subsequently accelerate the repair process and reduce the volume of water loss. While there is no guarantee that a reported leak will be fixed, crowd sensing can help amplify the pressure on water utilities to tend to the situation.

Applicability in Lebanon

The updated Water Sector Strategy 2020 estimated technical losses in the transmission and distribution water networks to 20%, mainly caused by pipe leaks and bursts that are left unnoticed or that suffer from delays in repair, especially following the economic crisis that incurred significant financial and employment losses to water establishments. Currently, the water establishments have call centers that receive complaints and calls from customers during working hours. Although some have 24-hour hotlines, their response rate has been compromised due to low technical and human capacities. Therefore, the use of such crowd sensing applications can bring a new dimension by linking alerts to these hotlines and by sending SMS messages or app notifications to administrators who in turn will help mobilize the field teams for a quicker response.

6.4.7 Prioritization of technologies

The suggested technologies have been assessed and prioritized by key stakeholders using a multi-criteria Analysis and based on criteria such economic viability, social acceptability and ease of adoption of technologies in Lebanon. Accordingly, the prioritized technologies were identified as 1) smart water metering at district level, 2) water efficient household appliances, and 3) crowd-sensing application for pipe bursts. More details on the prioritization process are available in Annex III.

6.4.8 Barriers and needs for deployment of priority technologies in Lebanon

Analysis of Technology: Smart Water metering at the district level

This technology, which is still at its inception phase in some pilot areas in the country, comprises of the installation of smart water metering (digital with telemetry) at key locations or specific districts on the network, connecting them to a central (or decentralized by water establishment) monitoring and control system, where flows and pressures are measured, reported, and visualized. The meters are associated with data loggers (to log the sensed data), as well as a communication technology (usually GPRS or telemetry), for data transmittal to a server for information processing. Figure 116 provides a schematic overview of locations of district (sector) meters as an example in a water distribution network.

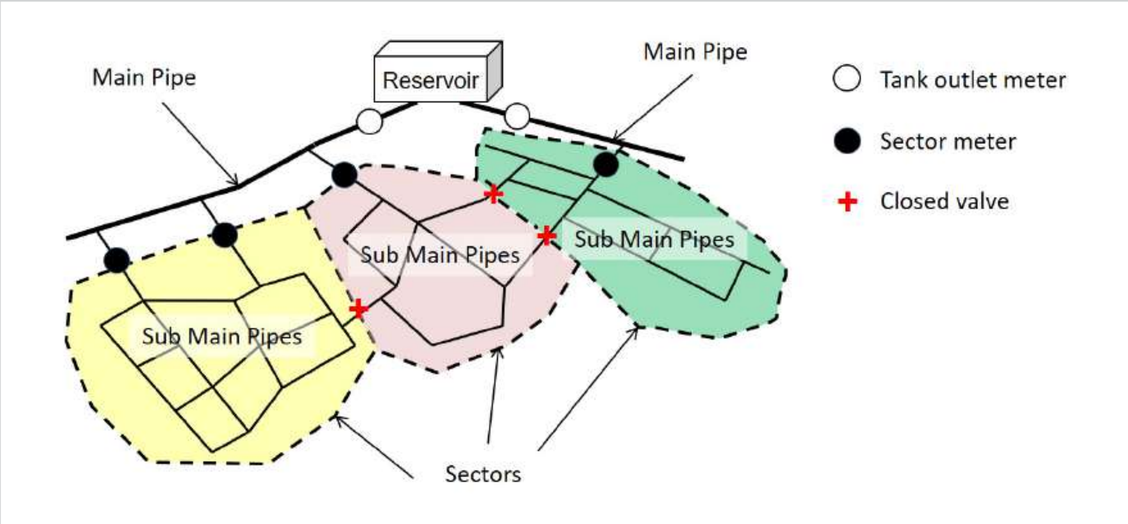


Figure 116: Schematic overview of locations of district (sector) meters

The system will give the establishment access to the water delivery data using online portals via desktops or via mobile field devices. Smart water metering improves operations at the water establishments by monitoring water consumption data and logging any unexpected increases from wastage, leakages, and pipe bursts, thereby improving operational and maintenance costs. Analyzing data from smart meters will allow for a real-time evaluation of water deliveries and system losses, which can improve fraud detection, increase data collection accuracy, and provide a better overview of water flow distribution in the various districts while allowing to estimate more precise estimate of consumption patterns in different neighborhoods.

Identification of barriers and measures

The main barriers for the deployment and use of smart meters at district levels in Lebanon include:

- High deployment and maintenance costs
- High infrastructure requirements to support smart metering

- Lack of human skills to analyse big data at the water establishments levels
- Lack of structured databases to support decision making
- Inter-operability, compatibility and standardization issues with existing systems, (for example the lack of compatible devices is a challenge if existing wireless infrastructure does not support the transmission technologies, expensive upgrades, lack of compatibility)
- Weak communication signals in some locations due to building and structures or interferences
- Resource intensive at high data collection and transmission frequency (battery life varies with frequency, solar power may be vandalized, etc.)
- Power cabling challenges in confined locations
- Difficulty of access of water establishment staff in some areas due to security issues

Based on the above identified challenges, Table 84 presents an action plan for the proper deployment of smart metering at district level in Lebanon.

Table 84 Technology Action plan for Smart Metering

Measures	Objective	Responsible parties	Beneficiaries	Time scale	Monitoring & Evaluation indicators	Estimated cost (USD)	Donors
Identify districts of interest and install the meters	To improve water measurement and service delivery of water establishments	MoEW, Water Establishments, Private Sector firms Suppliers	MoEW, Establishments, Water service subscribers Private Sector firms Suppliers	Short–medium term	Number of districts covered Number of meters installed and operating Number of subscribers covered by meters	USD 200,000 for meter costs for 100 districts (assuming USD 2,000 for smart meters cost and installation)	World Bank Adaptation Fund USAID, EU, Kuwaiti Fund Italian, Spanish Cooperation
Test logging, power and communication and establish platform at establishments	To set up a communication protocol and data center at the establishments for streamlining the data from the meters into the platform	MoEW, Water Establishments	MoEW, Establishments, Water service subscribers	Short term-medium term-Long term	Platform up and running Number of tests done	USD 240,000 for experiments at AREC, AUB, LARI stations and 20 on-farm plots covering 5 crops	
Develop a guiding manual for integrating data and analytics from smart meters into the operational regime of the establishments	To enable the effective utilization of smart meter data in the daily and strategic operations of the establishments	MoEW, Water Establishments Academic Institutions Consultants	MoEW, Establishments, Water service subscribers	Medium term	Progress reports Manual published	USD 9,000 for 450 farmers participating in seminars and field days. USD 6,000 for TV program	

Analysis of Technology: Water-efficient fixtures and appliances

Water saving appliances can save more than 12% of total water consumption at the domestic and municipal level. Various water saving devices can be used such as low flow faucet aerators, low flow shower fixtures and toilets, in addition to water efficient washing machines and dishwashers. Reducing the flow of water fixtures can not only save water, but it can also conserve energy used to heat the water.

To disseminate the use of such devices, several measures should be taken at different levels. First, new standards and certification programs need to be put in for water saving fixtures and appliances in the country. This could be standards for importing showerheads, faucets, washing machines, and toilettes or production standards for local manufacturing. Second, specific incentives such as reduction of taxes can be targeted to traders who prioritize the import and sale of water saving devices. In 2017, Decree 167 established the grounds for a Customs Duty Abatement Rate on Environmental goods in Lebanon, including water efficient equipment. The Decree still needs to be disseminated and explained to traders and importers to encourage its application. Other tax incentives can be targeted to retrofitting and replacing older fixtures.

Finally, marketing campaigns to the public, main distributors and retailers in Lebanon could be used to direct the purchasing choices of the public and stakeholders in the construction sector to more water-efficient fixtures and appliances.

Identification of barriers and measures

The main barriers hindering the widespread and use of water efficient fixtures in Lebanon include:

- Incremental cost of water efficient equipment compared to the available products in the market
- Unwillingness of consumers to invest in replacing the traditional fixtures by water-efficient ones.
- Prioritization of low-cost water fixtures for real estate developers and contractors over efficient ones with a higher cost
- Absence of consumption-based water tariff
- Difficulty in retrofitting old houses and replacing inefficient fixtures,

A technology action plan for the diffusion of water-efficient fixtures and is presented in Table 85 .

Table 85 Technology action plan for water saving devices

Measures	Objective	Responsible parties	Beneficiaries	Time scale	Monitoring & Evaluation indicators	Estimated cost
Market assessment of water-efficient devices in Lebanon status of standards and regulations governing water appliances in Lebanon	To assess the current share of water efficient devices in the market, assess the potential and requirements for their market expansion and evaluate status of standards and regulations	LIBNOR MoEW	MoEW Design and construction industry Private sector Water users	Short term	Market assessment study of	USD 500,000 for study preparation including sample survey and field visits

Measures	Objective	Responsible parties	Beneficiaries	Time scale	Monitoring & Evaluation indicators	Estimated cost
Dissemination of Decree 167 on customs duty abatement for environmental goods	To increase the application of Decree 167 on water saving appliances and to create a parallel competitive market to traditional ones and lower the cost on the consumer	MoEW, Ministry of Finance - customs Ministry of Economy Trade Private sector	MoEW Design, and construction industry Private sector	Short term	Awareness campaigns and capacity building sessions with importers and traders to take advantage of tax cuts proposed by Decree 167	USD 50,000 for meetings and workshops (6 workshops/ meetings over 2 years)
Development of / update of building codes for green certification for incorporating water conservation into designs	To ensure the adoption of water efficient fixtures in new buildings	Syndicate of engineers LIBNOR	MoEW, Establishments, Design and construction industry Private sector Water users	Long term	Number of codes generated Number of new buildings adopting the codes	USD 50,000 for meetings and workshops (6 workshops/ meetings over 2 years)
Organization of awareness campaign through seminars, radio, and TV programs, as well as social media campaigns	To educate users about water scarcity issues and the impact of water conservation practices	MoEW, Establishments, NGOs, academic institutions	Service providers technicians, general public	Short-Medium term	Number of campaigns Number of seminars Number of TV and Radio Programs Number of people interacting on social media	USD 200,000 for launching a series of campaigns and TV ads and programs
Building the capacity of plumbers and students in technical schools	To pave the way for a new generation of water saving fixtures and phase out the use of traditional ones	Establishments, NGOs, MoEW, MOE End-user	MoEW, Establishments, Design and construction industry Private sector Technical Schools Water users	Short-long term	Number of teaching classes related to water efficiency	USD 100,000 for module development

Analysis of Technology: Crowd-sensing application for pipe burst and leak detection

According to the National Water Sector Strategy, it is estimated that 20% of domestic water supply in Lebanon are not accounted for, especially that the water network in most urban areas is more than 50 years old, and the pipes are always subject to leaks. Leaks could be due to aging networks and corrosion; illegal connections; damage from other infrastructure operations; or other causes of pipe bursts.

Pipe bursts and leaks are frequent incidents in water distribution networks. Pipe burst reporting and repair is often delayed, causing water loss, exposing the network to contamination, and further damaging the infrastructure.

The proposed crowd-sensing application needs to be developed with geotagging ability and it needs to be connected to the hotline services of the water establishments. Alerts should be also set up to send alerts or notifications to those in the higher management and relevant ministries (in case of extremely delayed response and increased damage), and those in charge of the infrastructure repairs. The application can be installed by the establishment's administrator's team with special privileges to monitor the speed of the field team in responding to the burst.

Identification of barriers and measures

The specific barriers relevant to the dissemination and use of crowd sensing applications include:

- Lack of interest from the public in downloading the app due to lack of incentive and trust in the response
- Technical difficulties in using the application
- Uncertainty of response rate between reporting the leak and fixing it in due time, which might lead to decreased interest by the users
- High Maintenance and operation cost of the servers (including power supply) within the water establishments
- Lack of human resources at water establishment level to maximize the call centre response rate
- Lack of technical and human resources to intervene in due time and fix reported leaks

The technology action plan for this technology is presented in Table 86.

Table 86 Technology Action plan for Crowd Sensing Technology

Measures	Objective	Responsible parties	Beneficiaries	Time scale	Monitoring & Evaluation indicators	Estimated cost (USD)	Donors
Developing the application and linking it to the hotline service at the water establishments and at the Ministry	To enable the technology at the level of the establishment	MoEW water Establishments	MoEW, Establishments Water users	Short-term	Application developed Number of users Number of bursts reported Number of pipes fixed	USD 100,000 for the application USD 100,000 for the room and the setup	World Bank Adaptation Fund GEF IFAD FAO Islamic Bank EU USAID Kuwaiti Fund Italian, Spanish Cooperation

Developing and launching a marketing campaign through social media and TV/ radio programs	To introduce the crowd-sensing application concept within the public	MoEW Water Establishments NGOs	MoEW, Establishments municipalities, (all water users)	Medium to long term	Number of TV programs and their duration App download analytics Interaction and engagement via social media	USD 200,000 for launching a series of campaigns and TV ads and programs	World Bank Adaptation Fund GEF IFAD FAO Islamic Bank EU USAID Kuwaiti Fund Italian, Spanish Cooperation
Building capacities of the water establishment personnel	To be able to dedicate personnel for analyzing the data and coordinating repair effort	App and system developer Establishments MoEW	Establishments MOEW	Short to medium term	Responsiveness of staff to data	USD 10,000 for training personnel	

Table 87 **Summary of Barriers for the three technologies prioritized for the water sector**

Category	Smart Water Metering/SCADA at the sub-district level	Water-efficient household appliances	Crowd-sensing application to detect and report leakages
Financial	High deployment costs (consider upgrading traditional flow meters if existing rather than purchase new ones) High cost of telecommunication related to big data	Incremental cost of water efficient technologies	High cost of developing the application
Technical	High infrastructure requirements to support smart metering Lack of structured databases to support decision making Inter-operability, compatibility and standardization issues with existing systems Weak communication signals in some locations Power cabling challenges in confined locations	Maintenance and sustainability of the equipment Absence standards and labelling programs for import and local production Difficulty in retrofitting old houses and replacing inefficient fixtures,	Lack of monitoring system Lack of data management system GIS online will automatically be linked geolocation of the image Slow response time for intervention
Social	Difficulty of access of water establishment staff in some areas due to security issues	Unwillingness of consumers to invest in replacing the traditional fixtures by water-efficient ones. Prioritization of low-cost water fixtures for real estate developers and contractors	Lack of trust between the WE and people
Legal	Lack of analysis of existing data and link it to decision making Lack of implementation of existing laws	Lack of tax incentives for green equipment Absence of consumption-based water tariffs	
Human	Lack of staff for data management and sharing Weak technical skills for utility workers to manage management information systems		Lack of staff for replying to reporting alerts Lack of technical staff to repair leaks and bursts

CHAPTER 7

CONSTRAINTS AND GAPS AND RELATED FINANCIAL, TECHNICAL AND CAPACITY NEEDS, INCLUDING A DESCRIPTION OF SUPPORT RECEIVED

As per decision 17/CP.8 on the preparation of national communications, this section presents an assessment of challenges and related financial, technical and capacity needs associated with the preparation and improvement of national communications and with the implementation of activities, measures and programmes envisaged under the Convention. It also describes proposed and/or implemented activities for overcoming the gaps and constraints.

In addition, this section provides information on financial resources and technical support received by Lebanon for the implementation and reporting of climate activities and identifies barriers to further accessing financial support.

7.1 GAPS AND NEEDS TO IMPROVE CLIMATE REPORTING

Through the progressive preparation of the 4 BURs and 4 NCs, Lebanon's climate reporting has significantly improved, as described and commended by the different teams of technical experts of the International Consultation and Analysis (ICA) process.

However, given the iterative nature of submissions under the UNFCCC, improvements are always possible, especially in light of the Enhanced Transparency Framework and the new Modalities, Procedures and Guidelines (MPG). Based on the gaps and needs identified and compiled through the ICA process, capacity building needs have been proposed in order to improve Lebanon's climate reporting (Table 88).

Main results of the UNFCCC ICA 2022 for Lebanon's BUR4

"The current TTE noted improvements in the reporting in the Party's fourth BUR compared with that in its third BUR. The information reported demonstrates that the Party has taken into consideration the areas for enhancing the transparency of the information reported noted by the TTE in the summary report on the technical analysis of the third BUR. However, improvements are on-going, and the Party has taken note of outstanding areas for future improvement.

Regarding the areas for enhancing understanding of the extent of the information reported in the BUR noted by the previous TTE in the summary report on the technical analysis of the Party's previous BUR, Lebanon identified the areas that were not addressed in its current BUR owing to lack of data, including providing information on emissions from solvent use; steps envisaged for achieving the actions, progress of implementation and quantitative goals for a number of mitigation actions in the energy and agriculture sectors; and nationally determined technology needs, which are potentially areas for enhancing national capacity."

Table 88 **Capacity building needs identified by the UNFCCC Technical Team of Experts during the ICA 2022 of BUR4**

	Capacity building needs
GHG emissions and removals	Developing institutional arrangements at the national level in order to improve systematic collection of AD for the solvent use category in IPPU sector, including an industrial census;
	Strengthening national capacity to estimate F-gas emissions using higher-tier methodologies and associated uncertainties;
	Strengthening national capacity to design and implement a mechanism for continuous spatial monitoring and assessment for land subcategories combined with using satellite remote sensing, geographic information system data and data published in official reports
	Improving the quality and quantity of data collected on water waste and wastewater management;
Mitigation Actions	Enhancing national capacity to facilitate systematic collection of information from stakeholders to enable tracking the progress of implementation of mitigation actions in all sectors, complementing the planned work in this area supported by the GEF under CBIT;
	Enhancing technical capacity in the short term to further improve collection, analysis and reporting of data on mitigation actions in the transport sector (specifically for micro-projects implemented by the private sector and at the community level) and in the agriculture and waste sectors, building on best practices from the Greater Beirut Transport Project, the planned nationally appropriate mitigation action and the energy sector, as appropriate and in accordance with sector-specific needs;
	Harmonizing data from all sources to estimate climate impacts of groups of actions and to avoid double counting of overlapping mitigation actions (i.e. including all actions implemented by private and public stakeholders);
Support needed/ received	Building national capacity to develop technology action plans and mobilize finance for deploying technologies on the market;
	Enhancing the GHG inventory data collection platform and its operationalization to facilitate data exchange between ministries, including on financial flows;
	Strengthening national capacity to define, identify and report technology transfer and support received.
	Developing and implementing a well-defined and institutionalized methodology for systematically identifying and quantifying technical, financial, technological, capacity-building and other needs;
	Strengthening capacity of stakeholders to mainstream gender in climate change mitigation and adaptation.

In order to improve Lebanon's climate reporting quality and completeness, abide by Article 13 of the Paris Agreement, its corresponding MPGs and subsequent COP decisions, and enhance policy implementation through progress tracking, Lebanon has launched in November 2022 the Capacity Building Initiative on Transparency (CBIT) project. The aim of the project is to establish a national transparency framework and design and implement a robust MRV system that includes sustainable governance structures, enhanced mechanisms for data collection and improvement of institutional capacities.

Overview of the CBIT project

Capacity Building Initiative on Transparency (CBIT) project

Budget: USD 990,000

Timeframe: 2022-2025

Donor: Global Environment Facility

Executing Entity: Ministry of Environment

Implementing Entity: UNDP

Outcomes and outputs:

Component 1: Strengthening national institutions to implement the enhanced transparency framework

- Outcome 1.1 Established national transparency framework in line with national priorities
  - Output 1.1.1 Transparency baseline established, and priorities set
  - Output 1.1.2 National MRV system established through an MRV network of partners for information-sharing on mitigation, adaptation and support
- Outcome 1.2 Enabled national institutions to implement transparency-related activities
  - Output 1.2.1 National institutions' capacities built for the preparation of sectoral GHG inventories using the 2006 IPCC guidelines
  - Output 1.2.2 National institutions' capacities built to track and report progress of mitigation and adaptation actions, and support received
  - Output 1.2.3 Long-term transparency strategy developed

Component 2: Provision of parameters to improve the TACCC of national information

- Outcome 2.1 Improved capacities to monitor and track GHG inventory and mitigation and adaptation activities
  - Output 2.1.1 Parameters to enhance GHG inventories developed (AD, EF, etc.)
  - Output 2.1.2 Methodologies for QA/QC and uncertainty analysis developed and improved
  - Output 2.1.3 Indicators to track implementation progress of mitigation and adaptation activities and support received developed
  - Output 2.1.4 Web-based knowledge platform for sharing, storing, analyzing data, and indicators designed
- Outcome 2.2 Project results disseminated to increase global cooperation
  - Output 2.2.1 Information on the project implementation, best practices, and lessons learned shared with other Parties and initiatives through the Global Coordination Platform and other South-South cooperation networks

7.2 GAPS AND NEEDS TO IMPROVE IMPLEMENTATION OF CLIMATE ACTION

As part of the GCF country programming process, a gap assessment was conducted to assess the gaps and needs required for Lebanon to accelerate the planning and implementation of climate action. As a result of the assessment and based on the NDC Partnership Plans key intervention areas have been identified that would enable and support effective programming of climate actions in Lebanon. These include needs in relation to policies and strategies, and institutional and human capacity.

In terms of policies and strategies, Lebanon's updated NDC sets out clear mitigation targets, specifically related to energy efficiency and renewable energy, and seven adaptation priorities, which are intended to increase climate resilience alongside reducing the impact of economic shocks and other possible disasters. While mitigation co-benefits are identified for many of the adaptation priorities, additional elaboration is needed to formulate strategic investments in mitigation and to enhance synergies between mitigation and adaptation.

In terms of institutional and human capacity, although the Ministry of Environment is actively engaged in climate change activities, there is a need to strengthen its capacity and that of other implementers and stakeholders, including non-state actors. There is a need to coordinate the efforts of non-state actors to better capture and guide such activities and ensure a targeted implementation that would simultaneously serve national climate targets including the NDC and international reporting requirements. Table 89 summarizes the needs related to enhancing and targeting climate action by non-state actors.

Table 89 Support needed to coordinate climate action by non-state actors and align it with the NDC

Gap	Needed support	Description
Lack of strategy, vision and direction	Establish a strategy with objectives, targets and indicators that would form the framework of non-state actors initiatives.	Set a GHG reduction target and evaluate action of non-state actors against these targets. Include lines of work dedicated to sectoral action like academia, banks, syndicates, retails, etc.
Lack of awareness and common understanding of what qualifies as climate action	Communication and awareness campaign on how non-state actors can design and implement climate change projects.	Use existing platforms like the Lebanon Climate Act to communicate how climate action can bring transformational change. Develop further training material based on recent national developments and lessons learned from previous initiatives.

Lack of financing mechanisms to support private investments	Revise feasibility of existing funding mechanisms and establish new procedures to mobilize funds to non-state actors	Assess the feasibility nationally or regionally available financial mechanisms, in view of the current circumstances Accelerate the establishment of Lebanon's Green Investment Facility (LGIF)
Lack of technical information on available technologies	Improve communication on the availability and technical feasibility of RE and other technologies	Establish an interactive platform to guide business in making climate-friendly choices Connect non-state actors with the appropriate service and products providers
Scattered non-state actors initiatives	Define links among non-state actors related initiatives and platforms in Lebanon, with a focus on the Paris Agreement and the NDC.	Establish a platform to build a non-state actors network and facilitate connection and communication
Achievements not captured, information scattered, progress against targets of action plans unclear	Set institutional arrangements that anchor the linkages among the various non-state actors and systematically capture their achievements.	

The updated NDC also lays out a broad commitment to policy and fiscal reforms that would enable the improvement of the energy and transport sectors through energy efficiency, the sustainable use of Lebanon's land and water resources, the reduction of polluting practices in agriculture, waste, and industry, and enhancing the resilience of communities and infrastructure. Table 90 presents an overview of potential projects ideas and their estimated investment needs in order to accelerate the implementation of climate change activities in Lebanon.

Table 90 Preliminary estimates of investment needs (MoE/GCF, 2022b)

Sector	Context	Investment Priorities	Investment Need
Industry	Most industries in Lebanon use in-house generators, which consume considerable amounts of Gas/Diesel Oil, as a result of the intermittent electricity supply by EDL and constant power shortages. Emissions reductions in this sector are closely tied to improvements in green energy supply. The cement industry is also a major source of industrial emissions	• "Greening" industrial expansion plans by meeting additional energy demand through renewable sources.	N/A

Transport	Heavily dependent on high-polluting private vehicles and based on poorly maintained infrastructure. This deficit was acknowledged in the 2018 Capital Investment Plan, which allocated almost one-third of funding to improvements in the transportation sector.	• Infrastructure rehabilitation (including rail) • Expanding mass transit and alternative transport options (e.g. Bus Rapid Transit) • E-mobility or alternative fuels	USD 5.6 billion
Waste and wastewater	As set out in the 2017 Nationally Appropriate Mitigation Actions (NAMA) for the waste sector, there is an urgent need to find sustainable waste management solutions to reduce emissions from landfills. A lack of treatment facilities sees large volumes of wastewater discharged into the environment	• Landfill gas management (LFG), with priority sites identified in 2017 NAMA for the waste sector • Collection and utilization of gas from landfill sites and open dumps • Improvements to wastewater collection and treatment, including technical assistance as outlined in NDC Partnership Plan for the water sector	USD 830-1,400 million (MoE/UNDP, 2017).
Energy generation and access	Energy generation shows the largest mitigation potential. The NDC sets an unconditional target of generating 18% of Lebanon's power demand (i.e. electricity demand) and 11% of its heat demand (in the building sector) from renewable energy sources by 2030. Moreover, Lebanon conditionally commits to generate 30% of its power and 16.5% of its heat demand from renewable energy sources in 2030.	• Utility-scale RE programmes • Scaling up of distributed RE and EE (this requires policy and regulatory reforms, and capacity building)	USD 2.2 billion (IRENA, 2020)
Agriculture	The most pressing priorities are on the adaptation side, although these present considerable scope for cross-cutting mitigation benefits.	• Greater resource efficiency (water, fertilizers, seeds and fuel).	USD 105 million (MoA, 2020)
Forests and land use	Lebanon is one of the most forested countries in the Middle East as a percentage of its land area, with forests and woodlands covering 23.4% of the country's surface. There are mitigation opportunities in reducing deforestation (including reducing emissions from land use interventions and fires), reforestation and sustainable forest management. Lebanon's NDC implementation plans include a National Forest Plan.	• Implementation of National Forest Plan • Afforestation (target of 70,000 ha)	USD 540 million (MoA, 2015; MoA, 2012)

Energy efficiency	Lebanon has sought to address energy efficiency via its National Energy Efficiency Action Plan (NEEAP), which previously received financial support through the NEEREA initiative. However, new regulations and financial incentives are needed.	● End-use efficiency measures, which would target buildings, industry, SMEs, agriculture, public services and facilities ● Prioritization of EE in the reconstruction of buildings and infrastructure damaged by the Beirut port explosion	USD 1.3 billion (MoEW/LCEC, 2011)

Achieving the mitigation targets of Lebanon's NDC and increasing Lebanon's resilience to the negative impacts of climate change require significant coordinated work by line government, non-governmental institutions and the private sector in the main mitigation and adaptation related sectors. Many gaps still need to be bridged to optimize synchronized implementation of sectoral strategies .

With the support from the NDC partnership, a detailed list of gaps and needs to accelerate the implementation has been prepared in consultation with stakeholders and based on national strategies from the following sectors: energy, transport, waste, forestry, agriculture and water. The needs have also been update based on new published reports such as the NDC update 2020, IRENA outlook 2020, Electricity policy paper 2019, Agriculture strategy 2020, the Water sector policy 2019, and the SOER 2020. Details of the sectoral needs for climate change implementation are available in Lebanon's Fourth Biennial Update Report (MoE/UNDP/GEF, 2022).

Therefore, there is a need to coordinate the efforts of non-state actors to better capture and guide such investments and ensure a targeted implementation that would simultaneously serve national climate targets including the NDC and international reporting requirements.

7.3 INFORMATION ON FINANCIAL, TECHNICAL AND CAPACITY BUILDING SUPPORT RECEIVED

Climate finance from multilateral and bilateral sources plays an important role in advancing climate action in Lebanon. It has contributed to the implementation of sectoral policies and programmes and supported initiatives from governmental and non-governmental institutions. Therefore, having a clear understanding of these finance flows is crucial to assess outcomes of support received and optimize available and future climate resources. However, due to the absence of institutional arrangements for reporting support received in a systematic and sustainable way, the list of climate-related projects is not exhaustive as it might lack the inclusion of some funding directed to the private sector, local NGOs or subnational entities. In addition, due to the lack of a clear definition of climate finance, capturing accurately support received is a challenging exercise, due to the difficulty in differentiating between what is considered climate finance and what is simply an underlying investment in development. Since funding is not always principally targeting climate change, the association of a project's budget to climate finance is based on the OECD Rio Markers of principal (100% of the budget earmarked as climate finance) and non-principal (30% of the budget earmarked as climate finance) to categorize projects based on how directly they relate to climate change mitigation and adaptation (OECD, 2019).

Despite the significant adverse impacts of climate change on Lebanon's fragile economy and the livelihoods of its people, the flow of international climate finance does not correspond to the Lebanon's aspiration. Since 2015, around USD 22.15 million were provided to Lebanon as direct climate-finance through multilateral funds (Figure 117), and an additional USD 22.35 million as indirect finance through other development projects in different sectors (ex. Transport, land degradation and agriculture). Furthermore, Lebanon received support though regional projects (total USD 21.9 million) to implement additional mitigation and adaptation activities.

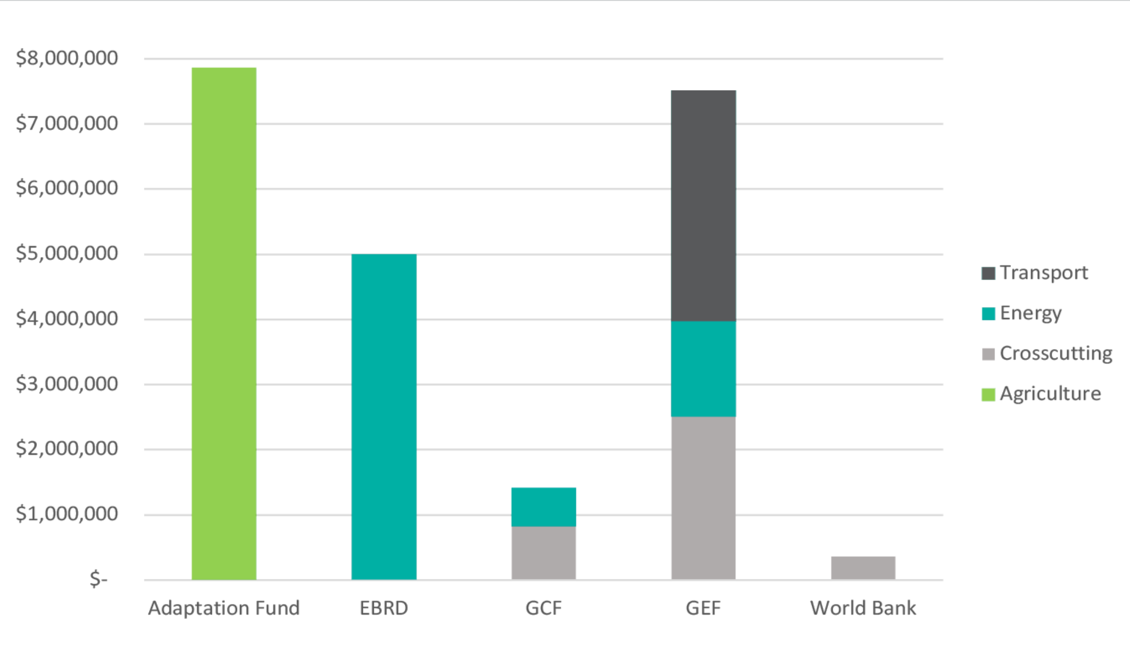


Figure 117 Climate Funding received by Lebanon from multilateral funds (excluding regional projects)

In parallel to the above, additional climate financing was channeled to Lebanon through bilateral flows, as presented in Figure 118 where climate related projects were funded and implemented by development agencies such as AFD (France), KFW, GIZ and BMZ (Germany), USAID (USA), SIDA (Sweden), etc. It is estimated that since 2015, Lebanon has received USD 89.7 million as principal funding for climate change projects (39% of total bilateral funding) and USD 142.4 million as non-principal projects (61% of total support). Support received has mainly focused on mitigation with 46% of total funding, whereas 17% of funding focused on adaptation, and 37% on crosscutting issues including both adaptation and mitigation measures.

The assessment further shows that the sectors that received the most financing (from both multilateral and bilateral sources) are energy, water, waste and wastewater, mainly due to high infrastructural needs and related costs essential to successfully implementation of such projects (Figure 119). For the energy sector, USD 80 million were received mainly for the installation of renewable energy systems and the implementation of energy efficiency measures. For water projects, USD 62 million were received for irrigation infrastructure to support agricultural livelihoods and increasing efficiency of water supply, while USD 58 million was received for waste and wastewater projects to upgrade current treatment facilities and reform the solid waste and wastewater sectors.

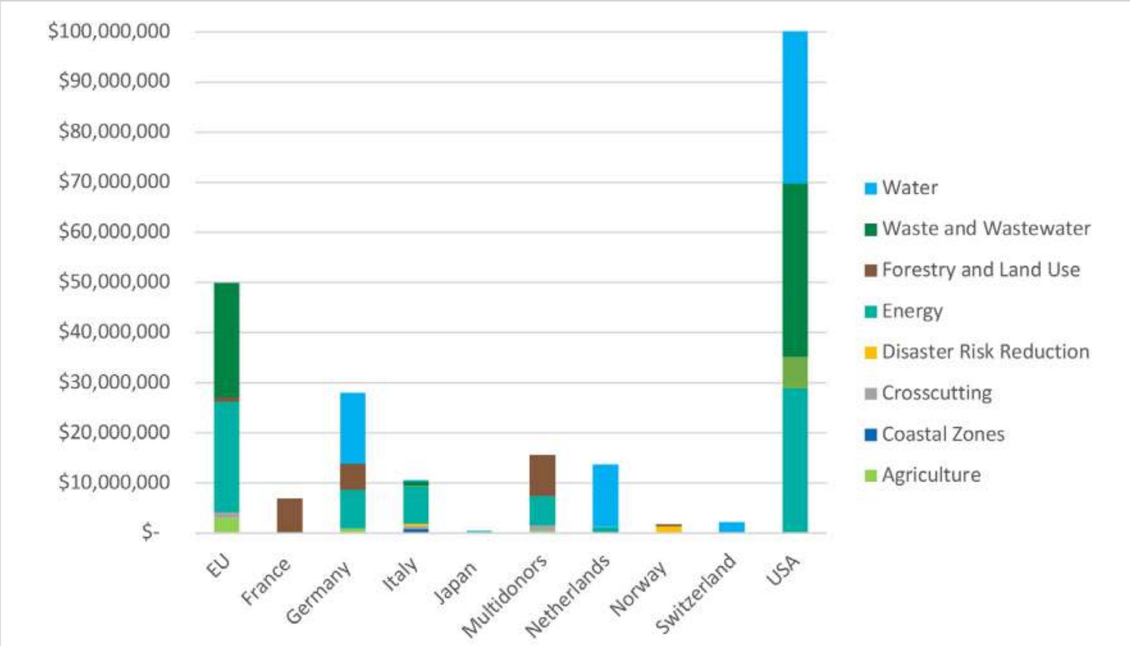


Figure 118 Distribution of bilateral climate finance per sector

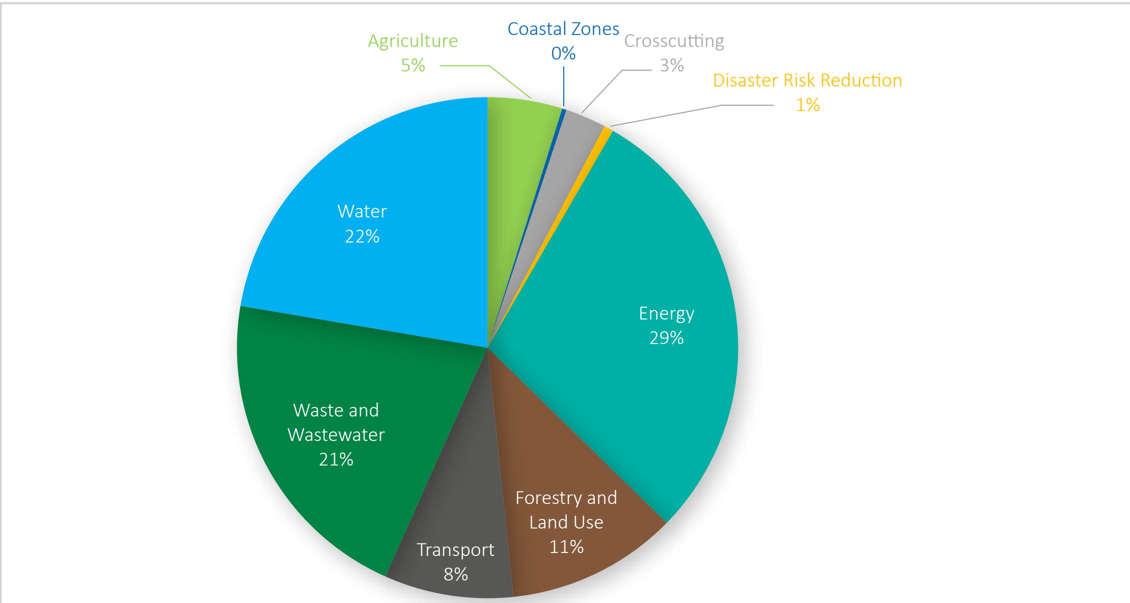


Figure 119 Share of support received per sector (percent of total funding received in million USD)

Lebanon currently faces considerable challenges in terms of accessing and disbursing climate finance. The pipeline of new climate finance projects and programmes is largely blocked, with no new initiatives worth over USD 5 million approved since 2018 (and up to the date of writing this report, i.e., end of 2022). There are significant financial and non-financial barriers to new financing, as shown in Table 91.

Table 91 Economic, financial and non-financial barriers to climate finance

Economic and financial barriers	
Access to climate finance	• Multilateral institutions (e.g. World Bank) have reduced/redirected or suspended funding in the absence of IMF reform agreement • Limited scope for new activities remains through the restructuring and reallocation of resources approved for existing projects
Market barriers	• Foreign exchange barriers. Lenders expect repayment in dollars due to lira currency risk but borrowers lack access to dollars. Repayment capacity is limited given rapid devaluation of lira. Hedging is not possible until lira is stabilized, and macroeconomic stabilisation is achieved • Liquidity constraints. Insolvency of the Lebanese banking sector has limited local lending. International capital perceives Lebanon as high risk environment • High cost of equity and debt
Non-financial barriers	
Governance	• Political instability and power vacuum • Lack of coordination on climate and development finance between different ministries
Policy and regulatory	• Lack of political consensus over effective policy initiatives • Uncertainty around renewable energy strategy implementation, absence of integrated electricity/energy strategy, , lack of streamlined Power Purchase Agreement process • Monetary policy not aligned with climate physical and transition risk inclusion
Technical	• Most financial intermediaries, particularly commercial banks, lack the technical capacity to assess and manage climate-related investments, inlcuding physical risk assessment
Information and awareness	• Data collection and distribution. • Limited capacity to monitor investments
Pipeline	• Lack of national direct access Accredited Entities • Underdeveloped project pipelines, due to lack of sectoral technical expertise, and perceived high risk in the current uncertain economic and political environment

Climate finance alone cannot overcome many of these barriers, which require political and economic reforms. However, new projects and programmes can address specific capacity building, technical assistance and information sharing needs, and build a platform for future investment. Two ongoing initiatives are particularly notable here.

- **NDC Partnership:** Lebanon became a member of the NDC Partnership in 2019. The Ministry of Environment, which serves as its focal point, has used this framework to coordinate with other ministries in developing Partnership Plans for the energy, transport, waste, water and wastewater, agriculture, and forestry sectors, which present priority climate change actions, identify technical and financial assistance needs, and facilitate results tracking.
- **Lebanon Green Investment Facility (LGIF):** The LGIF would help to accelerate implementation of Lebanon's NDC by providing technical assistance and accessible financial instruments to support measures that lower greenhouse gas emissions and increase resilience across various sectors, building on the NDC Partnership plans. The LGIF would particularly target private sector investment, including through efforts to develop financial markets and capacity in "green" sectors. UNDP Climate promise and the Islamic Development Bank (IsdB) are supporting the initiative as implementation partners.

In common with other activities in Lebanon's current climate finance pipeline, initial operations of the LGIF would have to be grant based or highly concessional, and as part of its remit may directly address capacity weaknesses in the financial sector. As the political and financial situation in Lebanon stabilizes, there would be more scope to incorporate other financing instruments.

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ANNEXES

ANNEX I. QA/QC PROCEDURES AND UNCERTAINTY ASSESSMENT

Quality control

The team uses standardized notations in the documentation sheets to document changes, data sources and necessary improvements.

Recalculation of the time series for the gases CO_2, CH_4 and N_2O for all sectors caused changes to the greenhouse gas calculations which were verified by sum checks and by using the previous data sets to compare the results. The sum checks were performed for the totals and for the sectors to ensure no data was lost. Also, the transfer of activity data from the documentation sheets to IPCC model was made more automatic decreasing a chance for inserting errors. Recalculations files, comparing the current and the previous submission, allow to check that no changes were made unless necessary and documented. General and sectoral QC activities include cross-checking of outputs, tables and calculation files at various stages of the inventory compilation process.

Table A.1.1 List of general QC procedures applied to BUR4

QC Activity	Procedures
Collection, input and computation of data	
Transcription errors between data input and reference	Cross-check descriptions of activity data and emission factors with information on categories and ensure that these are properly recorded and archived
	Confirm that bibliographical data references are properly cited in the internal documentation
	Cross-check a sample of input data from each category for transcription errors.
	Utilize electronic data where possible to minimize transcription errors
	Use automatization (e.g. calculation formulae and Lookup functions in Excel) to minimize user/entry error
	Do not include values like emission factors, net calorific values, assumptions into formulae, rather link them to documented cells
	Ensure spreadsheets contain clear instructions for updating and a description of how the spreadsheet works
	Ensure a record is kept in the spreadsheets of developments, how these have been implemented and checked
Calculations	Reproduce a representative sample of emissions/removals calculations
	Record the work done and the findings. Record any improvements identified

Units and conversion factors	Check that units are properly labelled in calculation sheets and the data and methodology documentation sheet Check that units are correctly carried through from beginning to end of calculations Check that conversion factors are correct Check that temporal and spatial adjustment factors are used correctly
Consistency	Identify parameters (e.g., activity data, constants) that are common to multiple categories and confirm that there is consistency in the values used for these parameters in the emissions/removals calculations
Documentation	
Check that there is detailed internal documentation to support the estimates and enable duplication of calculations Check that every primary data element has a reference for the source of the data Check that inventory data, supporting data, and inventory records are archived and stored to facilitate detailed review Check that the archive is closed and retained in secure place following completion of the inventory	
Calculation	
Completeness	Confirm that estimates are reported for all categories and for all years from the appropriate base year over the period of the current inventory For subcategories, confirm that the entire category is being covered Check that known data gaps that result in incomplete category emissions/removals estimates are documented, including qualitative evaluation of the importance of the estimate in relation to total net emissions (e.g. subcategories classified as 'not estimated')
Recalculations	Check for consistency in time series input data for each category Check for consistency in the method used for calculations throughout the time series Reproduce a representative sample of emission calculations to ensure mathematical correctness
Time series consistency	Check for consistency in time series input data for each category Check for consistency in the method used for calculations throughout the time series Check methodological and data changes resulting in recalculations
Trend	For each category, compare current inventory estimates to previous estimates, if available. Check if there any unusual or unexplained trends noticed for activity data or other parameters across the time series

Table A.1.2 List of specific QC procedures applied to BUR4

QC Activity	Procedures
Emission factors	
Evaluate whether national conditions are similar to those used to develop the IPCC default factors	
Compare country-specific factors to IPCC defaults; document any significant discrepancies	
Consider options for obtaining country-specific factors	
Document results of this assessment	

Time series consistency
Review changes in year-on-year estimates for categories and sub-categories
Where possible, use alternative methodologies to cross check results (i.e., reference and sectoral approach for energy sector)
Activity data
Determine the level of QC performed by the data collection agency and document it.
Ensure that qualifications of individuals providing expert judgement for estimates are appropriate and properly recorded

Quality assurance

Lebanon's GHG inventory reported under BUR3 has been subject to review by international sectoral experts for the Waste, Agriculture and Forestry and Other Land Uses (AFOLU) categories. Some of the recommended improvements were applied in the preparation this BUR4. Other improvements -requiring time and resources- will be applied in subsequent GHG inventories. The results of the reviews are prioritized in terms of their contribution to total GHG emissions and the magnitude of the flagged issue.

Results and recommendations from the reviews of previous BURs through the International Consultation and Analysis (ICA) were considered also in the BUR4.

Uncertainty Assessment

IPCC Category	Base year emissions (Gg CO_2 eq)	Current year emissions (Gg CO_2 eq)	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Contribution to Variance in current year	Type A sensitivity	Type B sensitivity	Uncertainty in the trend in national emissions introduced by EF	Uncertainty in the trend in national emissions introduced by AD	Uncertainty introduced into the trend in total national emissions
1A1 - Fuel Combustion Activities - Energy Industries (Liquid Fuel) - CO_2	508.00	9,362.41	1%	5%	0.051	0.000	1.297	1.729	0.065	0.024	0.005
1A1 - Fuel Combustion Activities - Energy Industries (Liquid Fuel) - N_2O	1.06	19.59	1%	60%	0.600	0.000	0.003	0.004	0.002	0.000	0.000
1A1 - Fuel Combustion Activities - Energy Industries (Liquid Fuel) - CH_4	0.56	10.35	1%	30%	0.300	0.000	0.001	0.002	0.000	0.000	0.000
1A2 - Fuel Combustion Activities - Manufacturing Industries and Construction - CO_2	2,534.00	3,514.00	5%	5%	0.071	0.000	1.490	0.649	0.075	0.046	0.008

1A2 - Fuel Combustion Activities - Manufacturing Industries and Construction - N_2O	4.90	6.97	5%	60%	0.602	0.000	0.003	0.001	0.002	0.000	0.000
1A2 - Fuel Combustion Activities - Manufacturing Industries and Construction - CH_4	2.60	3.69	5%	30%	0.304	0.000	0.002	0.001	0.000	0.000	0.000
1A3b - Fuel Combustion Activities - Transport - Road transportation - CO_2	1,265.00	7,469.00	30%	5%	0.304	0.006	0.307	1.379	0.015	0.585	0.343
1A3b - Fuel Combustion Activities - Transport - Road transportation - N_2O	16.24	137.89	30%	60%	0.671	0.000	0.012	0.025	0.007	0.011	0.000
1A3b - Fuel Combustion Activities - Transport - Road transportation - CH_4	14.39	46.02	30%	50%	0.583	0.000	0.004	0.008	0.002	0.004	0.000
1A4a b - Fuel Combustion Activities - Other Sectors - CO_2	1,562.00	3,514.27	15%	5%	0.158	0.001	0.672	0.649	0.034	0.138	0.020
1A4a b - Fuel Combustion Activities - Other Sectors - N_2O	2.86	6.67	15%	60%	0.618	0.000	0.001	0.001	0.001	0.000	0.000
1A4a b - Fuel Combustion Activities - Other Sectors - CH_4	6.50	13.64	15%	50%	0.522	0.000	0.003	0.003	0.001	0.001	0.000
2A1 - Mineral industry - Cement Production - CO_2	1,172.45	1,336.56	1%	2%	0.022	0.000	0.745	0.247	0.015	0.003	0.000
2A2 - Mineral Industry - Lime Production - CO_2	2.90	0.75	1%	2%	0.022	0.000	0.002	0.000	0.000	0.000	0.000
2A4 - Mineral Industry - Soda Ash Use - CO_2	6.90	1.21	5%	1%	0.051	0.000	0.006	0.000	0.000	0.000	0.000
4A - Enteric Fermentation - CH_4	373.00	402.90	20%	20%	0.283	0.000	0.241	0.074	0.048	0.021	0.003

4B - Manure Management - CH_4	108.00	94.18	20%	20%	0.283	0.000	0.074	0.017	0.015	0.005	0.000
4B - Manure Management - N_2O	100.30	107.95	62%	50%	0.796	0.000	0.065	0.020	0.033	0.017	0.001
5A1 - Forest Land Remaining Forest Land (Removals) - CO_2	-2,075.00	-1,897.80	10%	92%	0.925	0.005	1.412	0.350	1.299	0.050	1.691
5B1 - Cropland Remaining Cropland (Removals) - CO_2	-1,236.00	-1,219.00	10%	70%	0.707	0.001	0.824	0.225	0.577	0.032	0.333
5D2 - Land Converted to Settlements (Emissions) - CO_2	71.00	56.82	10%	60%	0.608	0.000	0.050	0.010	0.030	0.001	0.001
5A1 - Forest Land Remaining Forest Land - Biomass Burning - CH_4	0.00	1.82	14%	70%	0.714	0.000	0.000	0.000	0.000	0.000	0.000
5A1 - Forest Land Remaining Forest Land - Biomass Burning - N_2O	0.00	0.98	14%	70%	0.714	0.000	0.000	0.000	0.000	0.000	0.000
4D1 - Direct N_2O Emissions from Managed Soils - N_2O	102.30	199.94	20%	60%	0.632	0.000	0.050	0.037	0.030	0.010	0.001
4D3 - Indirect N_2O Emissions from Managed Soils - indirect N_2O	39.83	73.15	20%	80%	0.825	0.000	0.020	0.014	0.016	0.004	0.000
4D2 - N_2O Emissions from Grazing Animals - N_2O	22.97	24.90	20%	70%	0.728	0.000	0.015	0.005	0.010	0.001	0.000
6A - Solid Waste Disposal - CH_4	492.60	851.32	43%	30%	0.524	0.000	0.260	0.157	0.078	0.096	0.015
6C - Incineration of Waste - CO_2	26.90	32.63	10%	40%	0.412	0.000	0.017	0.006	0.007	0.001	0.000
6B2 - Wastewater Treatment and Discharge: Domestic - N_2O	33.70	84.80	13%	90%	0.909	0.000	0.013	0.016	0.012	0.003	0.000
6B2 - Wastewater Treatment and Discharge: Domestic - CH_4	256.30	588.74	59%	70%	0.915	0.000	0.108	0.109	0.076	0.091	0.014
	5,416.26	24,546.35				0.016					2.436
					Percentage uncertainty in total inventory	13%				**Trend uncertainty**	156%

ANNEX II. INDIRECT GHG EMISSIONS

Road transport for EMEP/EEA methodology

Table A.2.1 Parameters for road transport for EMEP/EEA methodology

	Average Travelled Distance (km)	Fuel Economy (L/100 km)	Fuel Density (kg/L)
Private Passenger cars – Gasoline fueled			
Pre ECE	12,000	10.41	0.74
ECE 15.00-01	12,000	10.41	0.74
ECE 15.02	12,000	10.41	0.74
ECE 15.03	12,000	10.41	0.74
ECE 15.04	12,000	10.41	0.74
Euro 1	12,000	8.91	0.74
Euro 2	12,000	8.91	0.74
Euro 3	12,000	8.91	0.74
Euro 4	12,000	8.91	0.74
Euro 5	12,000	8.91	0.74
Euro 6	12,000	8.91	0.74
Taxis – Gasoline fueled			
Pre ECE	50,000	10.41	0.74
ECE 15.00-01	50,000	10.41	0.74
ECE 15.02	50,000	10.41	0.74
ECE 15.03	50,000	10.41	0.74
ECE 15.04	50,000	10.41	0.74
Euro 1	50,000	8.91	0.74
Euro 2	50,000	8.91	0.74
Euro 3	50,000	8.91	0.74
Euro 4	50,000	8.91	0.74
Euro 5	50,000	8.91	0.74
Euro 6	50,000	8.91	0.74
Light Commercial vehicles - Gasoline fueled			
Conventional	25,000	11.49	0.74
Euro 1	25,000	9.46	0.74
Euro 2	25,000	9.46	0.74
Euro 3	25,000	9.46	0.74
Euro 4	25,000	9.46	0.74
Euro 5	25,000	9.46	0.74
Euro 6	25,000	9.46	0.74
Vans - Gasoline fueled			
Conventional	50,000	11.49	0.74

Euro 1	50,000	9.46	0.74
Euro 2	50,000	9.46	0.74
Euro 3	50,000	9.46	0.74
Euro 4	50,000	9.46	0.74
Euro 5	50,000	9.46	0.74
Euro 6	50,000	9.46	0.74
Heavy Trucks – Diesel fueled[1]			
Conventional	50,000	29.9	0.83
Euro I	50,000	29.9	0.83
Euro II	50,000	29.9	0.83
Euro III	50,000	29.9	0.83
Euro IV	50,000	29.9	0.83
Euro V	50,000	29.9	0.83
Euro VI	50,000	29.9	0.83
Buses – Diesel fueled			
Conventional	50,000	29.9	0.83
Euro I	50,000	29.9	0.83
Euro II	50,000	29.9	0.83
Euro III	50,000	29.9	0.83
Euro IV	50,000	29.9	0.83
Euro V	50,000	29.9	0.83
Euro VI	50,000	29.9	0.83
2- wheelers - Gasoline fueled			
2-strokes <50cc			
Conventional	5,000	3.38	0.74
Euro 1 and above	5,000	2.7	0.74
2-strokes >50cc			
Conventional	5,000	4.46	0.74
Euro 1	5,000	3.38	0.74
Euro 2	5,000	3.11	0.74
Euro 3 and above	5,000	2.30	0.74
4-strockes 250-750 cc			
Conventional	5,000	5.0	0.74
Euro 1 and above	5,000	4.86	0.74

[1] Average Travelled Distance for HDV and Buses for the year 2018 is 38,000 km

Source of fuel economy (except HDV diesel consumption): EMEP/EEA 2019 guidebook, chapter 1.A.3.b.i. ii.iii.iv, Table 3-27

Table A.2.2 Emission factors for CO, NO_x, and NMVOC for the EMEP road transport

	CO emission factor (g/km)	NO_x emission factor (g/km)	NMVOC exhaust emission factor (g/km)	NMVOC evaporation emission factor (g/day/veh)
Passenger cars – Gasoline fueled				
Pre ECE	37.3	2.53	2.8	7.8
ECE 15.00-01	29.6	2.53	2.19	7.8
ECE 15.02	21.7	2.4	2.06	7.8
ECE 15.03	21.1	2.51	2.06	7.8
ECE 15.04	13.4	2.66	1.68	7.8
Euro 1	3.92	0.485	0.53	7.8
Euro 2	2.04	0.255	0.251	7.8
Euro 3	1.82	0.097	0.119	7.8
Euro 4	0.62	0.061	0.065	7.8
Euro 5	0.62	0.061	0.065	7.8
Euro 6	0.62	0.061	0.065	7.8
Light Duty vehicles - Gasoline fueled				
Conventional	25.5	3.09	3.44	12.7
Euro 1	8.82	0.563	0.614	12.7
Euro 2	5.89	0.23	0.304	12.7
Euro 3	5.05	0.129	0.189	12.7
Euro 4	2.01	0.064	0.128	12.7
Euro 5	1.3	0.064	0.096	12.7
Euro 6	1.3	0.064	0.096	12.7
Heavy Duty Vehicles– Diesel fueled				
Conventional	2.13	8.92	0.776	-
Euro I	1.02	5.31	0.326	-
Euro II	0.902	5.5	0.207	-
Euro III	0.972	4.3	0.189	-
Euro IV	0.071	2.65	0.008	-
Euro V	0.071	1.51	0.008	-
Euro VI	0.071	0.291	0.008	-
Motorcycles - Gasoline fueled				
2-strokes <50cc				
Conventional	14.7	0.056	8.38	4.6
Euro 1	4.6	0.18	3.18	4.6
Euro 2	2.8	0.17	2.56	4.6
Euro 3	1.8	0.17	1.78	4.6
Euro 4	1.8	0.17	1.78	4.6
2-strokes >50cc				
Conventional	24.3	0.067	9.97	4.6

Euro 1	16.3	0.028	5.82	4.6
Euro 2	11.2	0.104	1.84	4.6
Euro 3	2.73	0.28	0.806	4.6
Euro 4	2.73	0.28	0.806	4.6
4-strockes 250-750 cc				
Conventional	25.7	13.8	7.17	3.03
Euro 1	0.233	0.477	0.317	0.194
Euro 2	1.68	1.19	0.918	0.541
Euro 3	4.6	4.6	4.6	4.6
Euro 4	25.7	13.8	7.17	3.03

Source:

Exhaust emissions EMEP/EEA 2019 guidebook, chapter 1.A.3.b.i. ii.iii.iv, Table 3-17/21/23/25

Evaporative emissions EMEP/EEA 2019 guidebook, chapter 1.A.3.b.v Table 3-2

Table A.2.3 International bunkers default direct GHG CH_4 and N_2O emission factors (kg/TJ)

Fuel type	CO emission factor	NO_x emission factor	SO_2 emission factor	NMVOC emission factor
Aviation gasoline (kg/TJ)	100	250	43.75	50
Jet kerosene (kg/TJ)	100	250	21.98	50
Heavy fuel oil (kg/tonne)	7.4	79.3	20	2.7

Source I table 3.6.5 page 3.64 chapter 3 volume 2, IPCC 2006 guidelines, EMEP/EEA 2019, table 3-1 Navigation chapter.

Table A.2.4 Sulfur content of automotive fuels

Period (years)	**Gasoline Sulfur content (ppm)**	**Diesel Sulfur content (ppm)**
1994-2001	1,000	3,000
2002-2016	500	350
2017-2019	500	10

Source:

Lebanon SNC to UNFCCC

Lebanese decree 3054/2016

Lebanese decree 8442/2002

Table A.2.5 SO_2 emission factors for the EMEP road transport

	SO_2 emission factor (g/km) 1994-2001	**SO_2 emission factor (g/km) 2002-2016**	**SO_2 emission factor (g/km) 2017-2019**
Passenger cars – Gasoline fueled			
Pre ECE	0.154	0.077	0.077
ECE 15.00-01	0.154	0.077	0.077
ECE 15.02	0.154	0.077	0.077

ECE 15.03	0.154	0.077	0.077
ECE 15.04	0.154	0.077	0.077
Euro 1	0.132	0.066	0.066
Euro 2	0.132	0.066	0.066
Euro 3	0.132	0.066	0.066
Euro 4	0.132	0.066	0.066
Euro 5	0.132	0.066	0.066
Euro 6	0.132	0.066	0.066
Light Duty vehicles - Gasoline fueled			
Conventional	0.17	0.085	0.085
Euro 1	0.14	0.07	0.07
Euro 2	0.14	0.07	0.07
Euro 3	0.14	0.07	0.07
Euro 4	0.14	0.07	0.07
Euro 5	0.14	0.07	0.07
Euro 6 up to 2016	0.14	0.07	0.07
Euro 6 2017-2019	0.14	0.07	0.07
Heavy Duty Vehicles – Diesel fueled			
Conventional	1.488	0.1736	0.00496
Euro I	1.488	0.1736	0.00496
Euro II	1.488	0.1736	0.00496
Euro III	1.488	0.1736	0.00496
Euro IV	1.488	0.1736	0.00496
Euro V	1.488	0.1736	0.00496
Euro VI	1.488	0.1736	0.00496
Motorcycles - Gasoline fueled			
2-strokes <50cc			
Conventional	0.05	0.025	0.025
Euro 1	0.04	0.02	0.02
Euro 2	0.04	0.02	0.02
Euro 3	0.04	0.02	0.02
Euro 4	0.04	0.02	0.02
2-strokes >50cc			
Conventional	0.066	0.033	0.033
Euro 1	0.05	0.025	0.025
Euro 2	0.046	0.023	0.023
Euro 3	0.034	0.017	0.017
Euro 4	0.034	0.017	0.017
4-strockes 250-750 cc			

Conventional	0.074	0.037	0.037
Euro 1	0.072	0.036	0.036
Euro 2	0.072	0.036	0.036
Euro 3	0.072	0.036	0.036
Euro 4	0.072	0.036	0.036

Source: SO_2 emission factor calculated based sulfur content values

ANNEX III. PRIORITIZATION OF TECHNOLOGIES UNDER TNA

Energy sector

Criteria and weight for prioritization:

1- GHG reduction potential to meet Climate Change Targets: The identification of the best technologies for the reduction of the GHG emissions and reaching Lebanon's national objectives are the main objectives of the TNA exercise, this criterion has been given the highest weight of 18%

2- Lebanese Context Readiness for Technology Deployment: The applicability of the technology to the Lebanese context being a necessary condition for its effective use for the GHG emissions reductions in Lebanon, this criterion has been given the weight of 17%

3- Technology Maturity, Scalability and Economics: These three criteria that are all important factors that affect the effectiveness of the technology use for the intended purpose have been given each the weight of 10%

4- Technology Capital Intensity: The technology economics having already covered the competitiveness in terms of LCoE, the technology capital requirements have only an effect on the ability to raise funds for implementing the technology. This criterion has been given the weight of 5%

5- Technology Safety: This criterion is important for a country like Lebanon where the safety culture is not very strong, thereby the safer the inherent characteristics of the technology are, the more attractive it is for being applied. This criterion has been given the weight of 5%

6- Resource Predictability: The more predictable the resource is, the more attractive is the technology. This criterion has been given the weight of 5%

7- Technology Deployment Time per Facility or Unit: This criterion relates to the promptness of deployment to meet the Climate Change targets. As it is already partially covered in the technology scalability criterion, it has been given the weight of 5%

8- Technology Footprint: The technology environmental footprint has been divided into effect on land use, water use, noise emissions, waste emissions, heat emissions and visual footprint. The overall weight for the environmental factors is 14% (i.e., land and water 3% each, 2% for the others)

Multi-Criteria Analysis (MCA) results

Technology	Criteria															Results	
										technology footprint							
	GHG reduction potential	Lebanese context readiness	Technology Maturity	Technology Scalability	Technology economics	Technology Capital Intensity	Technology safety	resource predicability	deployment time	Land use	water use	noise	waste	heat	visual landscape	Score	rank
criteria weight(%)	18%	17%	10%	10%	10%	5%	5%	5%	5%	3%	3%	3%	2%	2%	2%		
Pumped Hydro Energy Storage PHES	4	5	5	4	5	3	5	4	3	3	3	4	5	5	3	4.28	1
Smar Grid	2	5	4	5	4	4	5	3	5	5	5	5	5	5	5	4.11	2
Geothermal and Ground Source Heat Pumps	2	4	4	3	4	4	5	5	3	4	3	4	5	5	4	3.6	3
Concentrated Solar Power CSP	5	4	4	3	2	2	4	4	3	3	3	3	3	3	3	3.58	4
Small Modular Nuclear Reactors SMR	3	1	3	4	3	2	1	5	2	4	5	5	3	5	4	2.87	5
Hydrogen and Fuel Cells	1	1	3	2	1	1	2	4	4	4	5	5	5	5	4	2.2	6
Carbon Capture and Stoage or Use	2	2	3	2	3	1	1	3	2	3	3	3	3	3	2	2.28	7
Sea Energy	1	1	2	1	1	2	3	5	3	3	5	3	5	5	2	1.97	8

Agricultural sector

Criteria for technology prioritization and respective scales:

Criterion	Description	Scale
Capital and operational cost	The initial cost to establish the technology as well as the annual maintenance and operational costs. Some figures per surface or volume units are provided for some technologies. It highlights the easiness of access of farmers to the technology.	Very low (5) Low (4) Medium (3) High (2) Very High (1)
Importance of economic impact	It integrates the following indicators: Increase of income/profit at farm level Number of beneficiaries/covered area Economic importance of targeted crops It highlights the equity among regions and importance in food security and national policy	Very low (1) Low (2) Medium (3) High (4) Very High (5)
Improvement of resilience to climate	The technology's ability on improving crop resilience under current and future climate scenarios. If several types of impact due to different climate adverse (drought, frost, chilling requirement, insect outbreak, etc.) are minimized, the degree of improvement is higher.	Very low (1) Low (2) Medium (3) High (4) Very High (5)
Technology capability and suitability	It assesses how much the technology is widely applicable within the different bioclimatic zones. If it is applicable for different crops, or cropping systems, and suitable for different geographical contexts, it is higher scored. It highlights the degree of viability of the technology.	Very low (1) Low (2) Medium (3) High (4) Very High (5)
Social suitability for Lebanon (readiness)	Social acceptance at all levels: farmers and social suitability, organizational requirements and institutional arrangements at decision-makers level.	Very low (1) Low (2) Medium (3) High (4) Very High (5)
Human and information requirement (readiness)	Human requirements and their qualification, coupled with the capacity building and technology/information transfer needed to deploy the technology. It highlights the time requirement to establish and disseminate the technology.	Very low (5) Low (4) Medium (3) High (2) Very High (1)

Multi-Criteria Analysis (MCA) results:

Results of the technology prioritization in the agricultural sector

Stakeholders	AgsAT Mobile Application for farmers	Automated Controlled irrigation systems	National Crop Monitor	Evaporative Stress Mapping	Vulnerability Assessments
1	23	21	22	22	19
2	16	17	15	17	14
3	22	20	18	19	18
4	19	19	18	18	18
5	27	27	19	21	21
6	30	13	29	28	20
Average score	**22.8**	**19.5**	**20.2**	**20.8**	**18.3**

Water sector

Criteria for technology prioritization and respective scales:

Affordability - Capital investment	The initial cost to establish the technology;
Affordability – Low operational cost	The annual maintenance and operational costs;
Importance of economic impact	Increase of income/profit at utility or ministry or customer level; Number of beneficiaries/covered areas; Economic importance of targeted application; Economic importance of targeted application
Improvement of resilience to climate	The technology's ability on improving resilience under current and future climate scenarios;
Technology capability and suitability	It assesses how much the technology is widely applicable. If it is applicable for different regions, and suitable for different geographical contexts, it is higher scored. It highlights the degree of viability of the technology;
Social/Institutional suitability for Lebanon	Social acceptance at all levels: users and social suitability, organizational requirements, and institutional arrangements at decision-maker level;
Human resources readiness	Human requirements and their qualification, coupled with the capacity building and technology/information transfer needed to deploy the technology. It highlights the time requirement to establish and disseminate the technology;

Multi-Criteria Analysis (MCA) results:

Results of the technology prioritization in the water sector

Stakeholders	Smart Water Metering	Climate-sensitive basin-level modeling	Water-efficient household appliances	National Water Dashboard	Green infrastructure-porous asphalt	Crowd-sensing application to detect and report leakages
1	30	32	28	30	16	24
2	25	14	33	12	26	22
3	20	17	23	21	21	19
4	27	23	26	25	21	26
5	33	33	27	35	21	35
6	27	24	25	25	24	25
7	19	18	19	21	25	25
8	23	20	27	19	21	29
9	25	22	25	25	18	30
10	26	23	22	18	18	21
11	27	24	31	24	21	31
12	18	25	24	25	27	21
13	27	31	25	22	19	23
14	29	26	26	27	25	29
15	27	28	18	27	18	24
16	19	24	26	35	27	31
17	23	20	19	24	13	32
Average score	**25**	**24**	**25**	**24**	**21**	**26**

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