REPUBLIC OF LEBANON
MINISTRY OF ENVIRONMENT

gef

UNDP

Empowered lives.
Resilient nations.

ECONOMIC COSTS TO LEBANON FROM CLIMATE CHANGE: A FIRST LOOK

2015

An element of
Lebanon's Third National Communication
To the United Nations Framework Convention on Climate Change

Economic Costs to Lebanon from Climate Change: A First Look

2015

An element of
Lebanon's Third National Communication
To the United Nations Framework Convention on Climate Change

This document should be referenced as:

MoE/UNDP/GEF (2015). Economic Costs to Lebanon from Climate Change: A First Look. Beirut, Lebanon.

The United Nations Development Programme (UNDP) is the UN's global development network, advocating for change and connecting countries to knowledge, experience and resources to help people build a better life. We are on the ground in 166 countries, working with them on their own solutions to global and national development challenges. As they develop local capacity, they draw on the people of UNDP and our wide range of partners.

For more information

http://climatechange.moe.gov.lb/
climatechange@moe.gov.lb

The climate change project management team

Vahakn Kabakian, Project Manager

Lea Kai Aboujaoudé, Project Officer

Yara Daou, Project Research Assistant

Leila El Sayyed, Economist

Mary Awad, Project Assistant

Sara El Rayes, Administrative Assistant

UNFCCC focal point

Samar Malek, Acting Head of Service of Environmental Technology

Disclaimer

Economic Costs to Lebanon from Climate Change: A First Look

Reference project

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

Executed by

Ministry of Environment

Funded by

Global Environment Facility

Implemented by

United Nations Development Programme, Lebanon

Report preparation

Ernie Niemi, of Natural Resource Economics, a consultancy in Eugene, Oregon USA, prepared this report on behalf of the Ministry of Environment and the United Nations Development Programme Lebanon.

Lead reviewers

Lea Kai Aboujaoudé

Yara Daou

Lama Bashour

Designer

Nathalie Hamadeh

Printing

Haber Printing

Foreword

Ministry of Environment

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

In the present report, an element of Lebanon's Third National Communication, the Ministry of Environment is digging deeper into the analysis to better understand some of the economic costs of negative climate change impacts in Lebanon.

The technical findings presented in this report will support policy makers in visualizing Lebanon's economy under a changing climate and therefore making informed decisions. The findings will also help academics in orienting their research towards bridging research gaps. Finally, they will increase public awareness on climate change and its relation to each sector. In addition, the present technical work complements the strategic work of the National Climate Change Coordination Committee. This Committee has been bringing together representatives from public, private and non-governmental institutions to merge efforts and promote comprehensive planning approach to optimize climate action.

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

Mohamad Al Mashnouk

Minister of Environment

Foreword

United Nations Development Programme

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

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

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

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

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

Ross Mountain

UNDP Resident Representative

Prologue

The Intergovernmental Panel on Climate Change (IPCC) and other scientific bodies have documented the effects of human-caused emissions of carbon dioxide and other greenhouse gases (GHGs). These effects include changes in climate: increasing average temperature, more extreme weather events, rising sea level, and ocean acidification, as well as resultant changes in ecosystems, species, human systems, and other aspects of life on Earth. They also have forecasted future emissions and their impacts under different scenarios that reflect different assumptions about the extent to which humans rein-in the behaviors underlying the emissions. This report describes the potential economic costs that the households, businesses, communities, and government of Lebanon might incur over the next several decades if they and their counterparts around the world continue to behave in a business-as-usual manner, so that the emissions of carbon dioxide and other greenhouse gases would continue to grow at rates similar to those seen in recent years. It also recommends general steps the Lebanese people, businesses, communities, and government might take to prepare for changes in climate and reduce their vulnerability to the negative effects of GHG emissions.

This report is made available as a stand-alone document and as the chapter on "Vulnerability and Adaptation" in Lebanon's Third National Communication (TNC) to the United Nations Framework Convention on Climate Change (UNFCCC).

For more information, please contact:

Climate Change Office
United Nations Development Programme
Ministry of Environment
climatechange@moe.gov.lb

Ernie Niemi, President
Natural Resource Economics
ernie.niemi@nreconomics.com

Acknowledgements

The project management team gratefully acknowledges and appreciates the valuable work undertaken by Mr. Ernie Niemi to conceptualize and produce this report. Thanks to him, Lebanon is able and for the first time to concretely examine the magnitude of negative impacts of climate change on the country's economy and households. The present report is an important tool to explain the complex issue of climate change in a simplified manner, and to deepen knowledge and experience on the subject in the country. Mr. Niemi's dedication allowed the production of widely endorsed results despite the many challenges, especially those related to the lack of national data.

We extend our deep appreciation to Mrs. Lama Bashour who nationally backstopped Mr. Niemi and provided precious input in terms of review, data collection and validation of assumptions.

We also thank all experts who participated in the meetings we held to ensure this report reflects national context as neatly as possible. Their dedicated involvement in this project and others is the key to successful outcomes. Specifically, we would like to thank the following individuals who provided written feedback on the final draft of the report:

Mr. Georges Akl

Dr. Georges Mitri

Dr. Hassan Harajli

Dr. Ihab Jomaa

Dr. Jean Stephan

Mr. Karim Osseiran

Ms. Lara Samaha

Mr. Nizar Hani

Ms. Petra Obeid

Mr. Samir Salameh

Acronyms

DALY	Disability-Adjusted Life-Years
GHG	Greenhouse Gas
GDP	Gross Domestic Product
IPCC	Intergovernmental Panel on Climate Change
MENA	Middle East North Africa
RCP	Representative Concentration Pathway
SNC	Second National Communication

Summary for policymakers

I. Climate change will impose costs on Lebanon directly, via heat waves, droughts, storms, etc., and indirectly, via slower economic growth

Changes in climate stem from global emissions of carbon dioxide (CO_2) and other greenhouse gases (GHGs) (IPCC 2013b). Figure i shows the trajectory of global GHG emissions expected through 2100 under the highest-emissions scenario (called RCP8.5) and the lowest-emissions scenario (RCP2.6) projected by the Intergovernmental Panel on Climate Change (IPCC). Figure ii shows the accompanying expected changes in the global average surface temperature. Under the highest-emissions scenario, which represents a continuation of current trends, temperatures would increase on a near-linear trajectory throughout the century. With the lowest-emissions scenario, they would increase through the middle of the century and then level off. Average surface temperatures in 2081-2100 would exceed those that prevailed in 1986-2006 by about 4–6°C under RCP8.5, and 2°C under RCP2.6 (IPCC 2014; p. 10). These temperature increases would add to an increase of 0.61°C observed between 1850–1900 and 1986–2005 (IPCC, 2013b; p. 5).

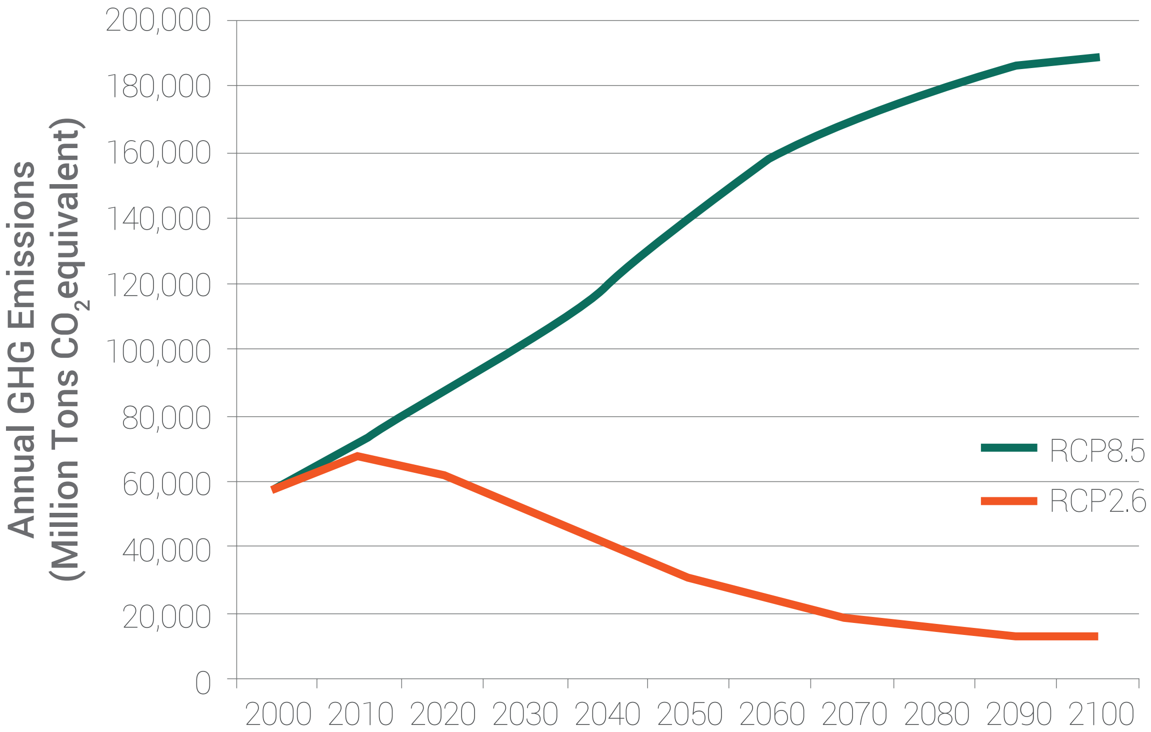


Figure i. Actual GHG emissions, 2000 and 2010, and projected emissions under RCP8.5 and RCP2.6, 2020-2100

Source | RCP Database (2015) and Myrhe et al. (2013; p. 714)

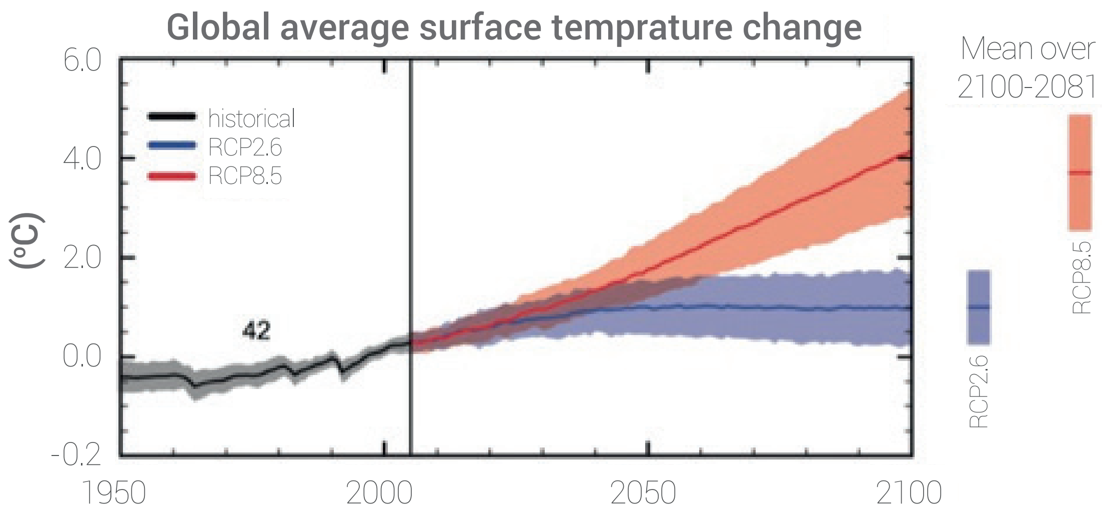


Figure ii. Observed changes in annual average surface temperature, 1950–2010, and projections under RCP8.5 and RCP2.6, 2020-2100.

Source | IPCC (2013; p. 21)

If current trends in GHG emissions continue, anticipated changes in climate likely would impose economic costs on Lebanon both directly and indirectly, as shown in Figure iii. Direct costs would materialize as higher temperatures, changes in precipitation, and extreme weather events, such as storms, reduce agricultural productivity, adversely affect human health, cause flooding, and impose similar damage on different segments of Lebanon's economy and society. Indirect costs would materialize as the direct costs slow the country's economic growth. The slower growth would reduce Lebanon's Gross Domestic Product (GDP) and lower business activity. These effects, in turn, would lower incomes for workers and households and cause government to experience lower revenues and higher costs.

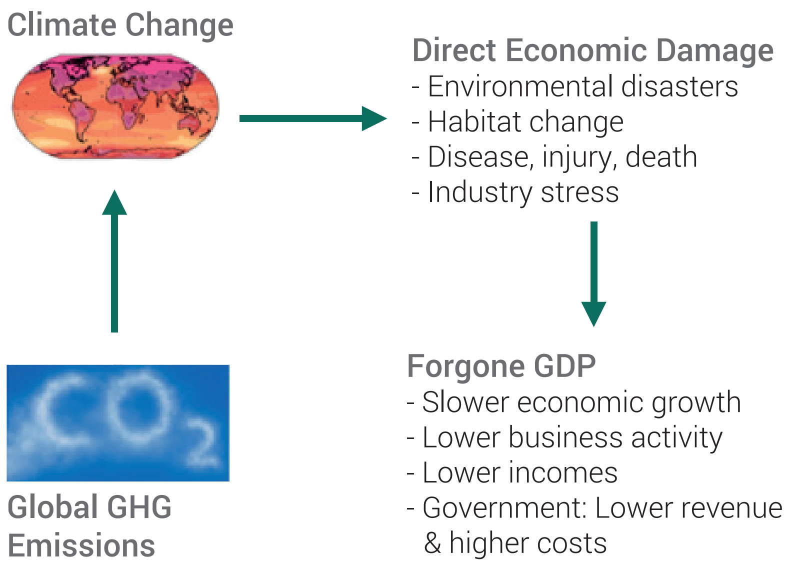


Figure iii. Climate change will impose costs on Lebanon by generating direct economic damage and slowing growth in GDP

This report describes the different ways in which future changes in climate might impose costs on Lebanon. It also calculates the general magnitude of some of these costs, drawing on currently available, relevant information.

II. Total costs might equal USD 1,900 million in 2020, rising to USD 138,900 million in 2080

Table i and Figure iv summarize the expected costs Lebanon would experience in 2020, 2040, and 2080 from the cumulative effects of global GHG emissions between 2015 and each of those years under the IPCC's highest-emissions scenario. The top line shows the expected damage in each year from the direct impacts of higher temperatures and other changes in climate on agricultural productivity, human health, flooding, ecosystem productivity, etc. This damage would impose costs on Lebanon of about USD 320 million in 2020, USD 2,800 million in 2040, and USD 23,200 million in 2080.

The analysis underlying the second line recognizes that, over time, these direct impacts would slow the growth of Lebanon's economy, measured as Gross Domestic Product (GDP). If current trends continue, global GHG emissions between 2015 and 2020 would reduce Lebanon's GDP by about USD 1,600 million, or 3%. This forgone GDP would constitute a real cost, or reduction in economic wellbeing for Lebanon's households, businesses, and government. If current trends continue to 2040 and 2080, Lebanon would experience reductions in GDP of USD 14,100 million (14%) in 2040, and USD 115,700 million (32%) in 2080.

The sum of the direct-damage costs and the forgone GDP equals the expected total estimated costs that global emissions in 2015 and beyond would impose on Lebanon, if current trends continue. The analysis indicates total costs of about USD 1,900 million in 2020, USD 16,900 million in 2040, and USD 138,900 million in 2080. These total amounts, divided by the expected number of households indicates an average cost per household of: USD 1,500 in 2020, USD 13,100 in 2040, and USD 107,200 in 2080. If the government's current role in the economy remains unchanged, it would bear about USD 610 million of the total cost in 2020, USD 5,400 million in 2040, and USD 44,300 million in 2080.

Table i: Potential costs in 2020, 2040, and 2080 from the cumulative effects of global GHG emissions in 2015 and subsequent years (2015 USD)

Potential costs	2020	2040	2080
Direct annual damage from drought, etc. in Lebanon (millions)	USD 320	USD 2,800	USD 23,200
Forgone GDP in Lebanon (millions)	USD 1,600	USD 14,100	USD 115,700
Percentage reduction in GDP	3%	14%	32%
Total cost to Lebanon (millions)	USD 1,900[a]	USD 16,900	USD 138,900
Average cost per household in Lebanon	USD 1,500	USD 13,100	USD 107,200
Government's share (millions)	USD 610	USD 5,400	USD 44,300

Numbers reflect the rounding rules described in the Introduction.

[a] Because of rounding, the total, USD 1,900 million differs slightly from the sum of USD 320 million and USD 1,600 million.

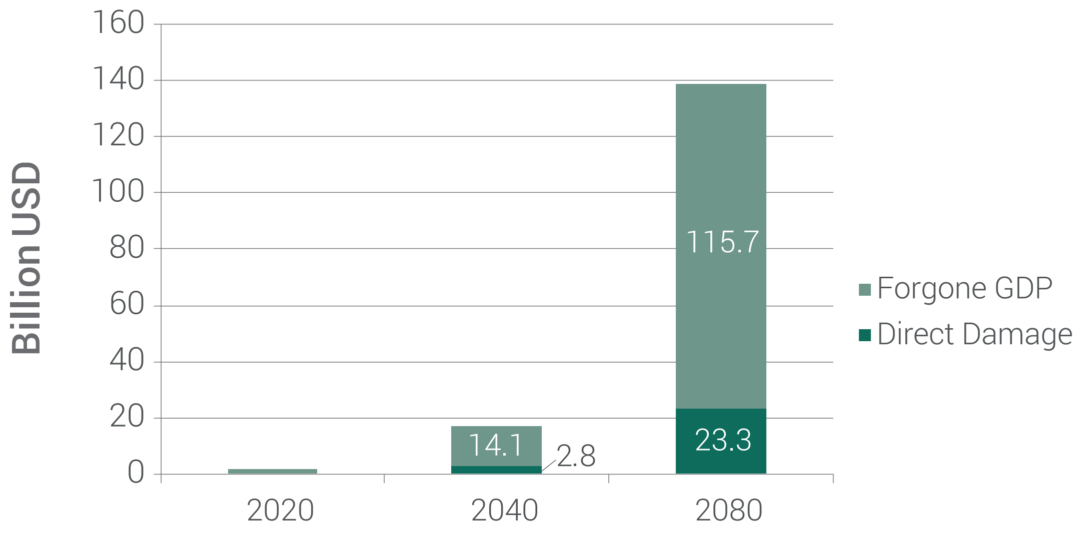


Figure iv. Potential costs to Lebanon from the cumulative effects of global GHG emissions in 2015 and subsequent years

The direct-damage costs and reduced GDP would reduce annual income for households throughout Lebanon. Rural households generally would experience larger percentage reductions than urban households. Farm households, though, would experience somewhat smaller reductions than their rural nonfarm counterparts, especially those receiving higher prices for their crops or livestock. For both rural and urban households, those with higher levels of income generally would experience smaller reductions.

III. Lebanon would experience smaller costs if global GHG emissions grow more slowly

Table ii and Figure v compare the costs to Lebanon that would result from global GHG emissions in 2020, 2040, and 2080 under the IPCC's highest- and lowest-emissions scenarios. In each case, the costs would materialize as a stream of annual costs in the decades following each of these years. To facilitate measurement of the costs from each year's emissions, the analysis converts the stream of expected costs to an equivalent single number. This number, which economists call the present value of the stream of costs, is measured in the year in which the emissions would occur: 2020, 2040, and 2080.

The top section of Table ii shows the costs under the highest-emissions scenario. The stream of annual costs resulting from global GHG emissions in 2020 would have a present value of USD 3,600 million. The resulting reductions in GDP would have a present value of USD 17,600 million. The sum of these two values, USD 21,200 million, represents an average per household of USD 16,400. If the government's current role in the economy remains unchanged, the present value of its stream of costs would be about USD 6,800 million.

The bottom section of Table ii shows what the costs would be if meaningful actions were taken to reduce global emissions to those in the IPCC's lowest-emissions scenario. Under this scenario, the present value of the stream of annual costs resulting from emissions in 2020 would total about USD 15,200 million. Relative to the highest-emissions scenario, this scenario would reduce total costs by about USD 6,000 million, or 28%. By 2080, this scenario would reduce total costs by USD 918,400 million, or 91%.

Table ii: Present value of economic costs that global GHG emissions in 2020, 2040, and 2080 would impose on Lebanon, under the highest- and lowest-emissions scenarios (2015 USD)

	2020	2040	2080
A. Potential costs if global emissions follow the IPCC's highest-emissions scenario (current trends)			
Total cost (millions)	USD 21,200	USD 80,700	USD 1,009,700
Average per household	USD 16,400	USD 57,300	USD 721,900
Government's share (millions)	USD 6,800	USD 25,800	USD 322,000
B. Potential costs if global emissions follow the IPCC's lowest-emissions scenario			
Total cost (millions)	USD 15,200	USD 30,800	USD 91,300
Average per household	USD 11,700	USD 21,900	USD 65,200
Government's share (millions)	USD 4,800	USD 9,800	USD 29,100
C. Potential savings from reducing global emissions to the lowest-emissions scenario			
Potential savings (millions)	USD 6,000	USD 49,900	USD 918,400
Potential savings (percentage)	28	62	91

Numbers reflect the rounding rules described in the Introduction.

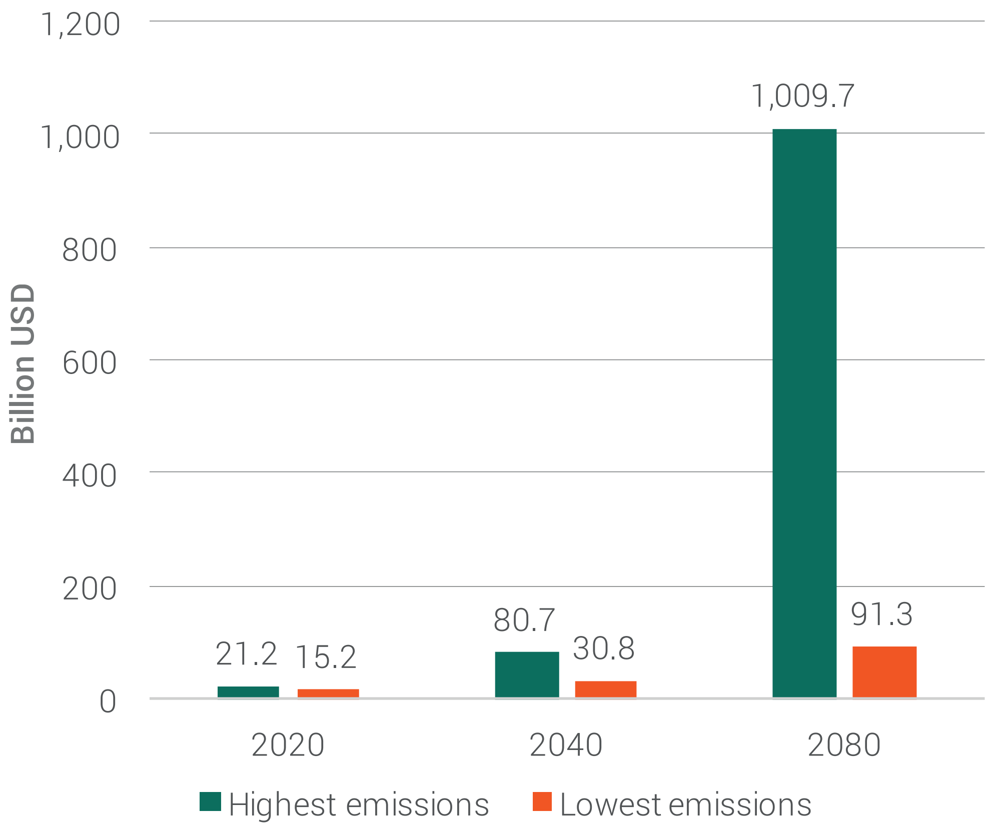


Figure v. Comparison of potential costs to Lebanon from global GHG emissions in 2020, 2040, and 2080 under the IPCC's highest- and lowest-emissions scenarios

IV. Climate change will impose costs across all segments of Lebanon's economy and society

Climate change will impose costs on every person, family, farm, business, community and region of Lebanon. Table iii and Figure vi summarize the costs for segments of the economy and society for which relevant data exist. In general, the estimate of costs for each segment has a distinct foundation assembled from an appropriate data set or past study. Some overlap may exist between the studies and data underlying different analyses, however. To avoid potential double-counting, readers are cautioned not to add different categories of costs without reviewing the calculations and checking to see if overlap exists.

Figure vi presents a graphic representation of the potential costs in 2020. The graph makes clear that potential impacts on human health pose the greatest risks. Costs associated with potential increases in the risk of death—from heat stress, malnutrition, diarrhea, malaria, floods, and cardiovascular disease—total USD 47,200 million (equivalent to USD 47.2 billion). Costs associated with potential increases in illness and disability—from the same climate-related factors—total USD 177,900 million.

Other major costs might materialize through the impacts of climate change on Lebanon's agricultural production and the prices Lebanese consumers pay for food. Reductions in Lebanon's overall agricultural production—resulting from higher temperatures, changes in precipitation, increases on soil aridity, etc.—would reduce Lebanon's overall GDP by about USD 300 million in 2020. If current trends continue, potential increases in global food prices might impose costs of USD 470 million on Lebanese consumers by raising the prices they pay for food and, because of the higher prices, inducing them to consume less food.

Table iii: Costs that climate change might impose on different segments of Lebanon's economy and society (million 2015 USD)

Potential cost	2020	2040	2080
A. Costs from impacts of climate change on agriculture and food supplies			
1. Reductions in Lebanon's agricultural production	USD 300	USD 860	USD 2,300
2. Reductions in production of wheat and maize	USD 10	USD 17	USD 28
3. Reductions in fish harvest	USD 13	USD 32	USD 32
4. Increases in global food prices	USD 470	USD 1,700	USD 5,000
B. Costs from impacts of climate change on water			
1. Reductions in agricultural and domestic / industrial water supply	USD 21	USD 320	USD 1,200
2. Reductions in water supply for generation of hydroelectricity	USD 3	USD 31	USD 110
C. Costs from climate-related natural disasters			
1. Increases in droughts, floods/landslides, and storms	USD 7	USD 36	USD 1,600
D. Costs from impacts of climate change on tourism			
1. Reductions in attractiveness of Lebanon's coastal resources	USD 22	USD 160	USD 1,800
E. Costs from impacts of climate change on electricity consumption			
1. Increases in demand for cooling	USD 110	USD 900	USD 34,800
F. Costs from impacts of climate change on human health			
1. Increases in risk of death	USD 47,200	USD 54,700	USD 61,400
2. Increases in risk of illness and disability	USD 177,900	USD 194,300	USD 191,500
G. Costs from impacts of climate change on ecosystems			
1. Reductions in biodiversity	USD 62	USD 150	USD 330
2. Increases in land degradation	USD 29	USD 78	USD 170
3. Increases in sea level	USD 59	USD 140	USD 320
H. Costs from impacts of climate change on society			
1. Increases in violence from higher temperatures	USD 38	USD 840	USD 8,600
2. Reductions in workers' productivity from heat stress	USD 43	USD 160	USD 1,400
3. Reductions in workers' productivity from childhood undernourishment	USD 22	USD 51	USD 280
4. Increases in internal migration	USD 57	USD 130	USD 320

Numbers reflect the rounding rules described in the Introduction.

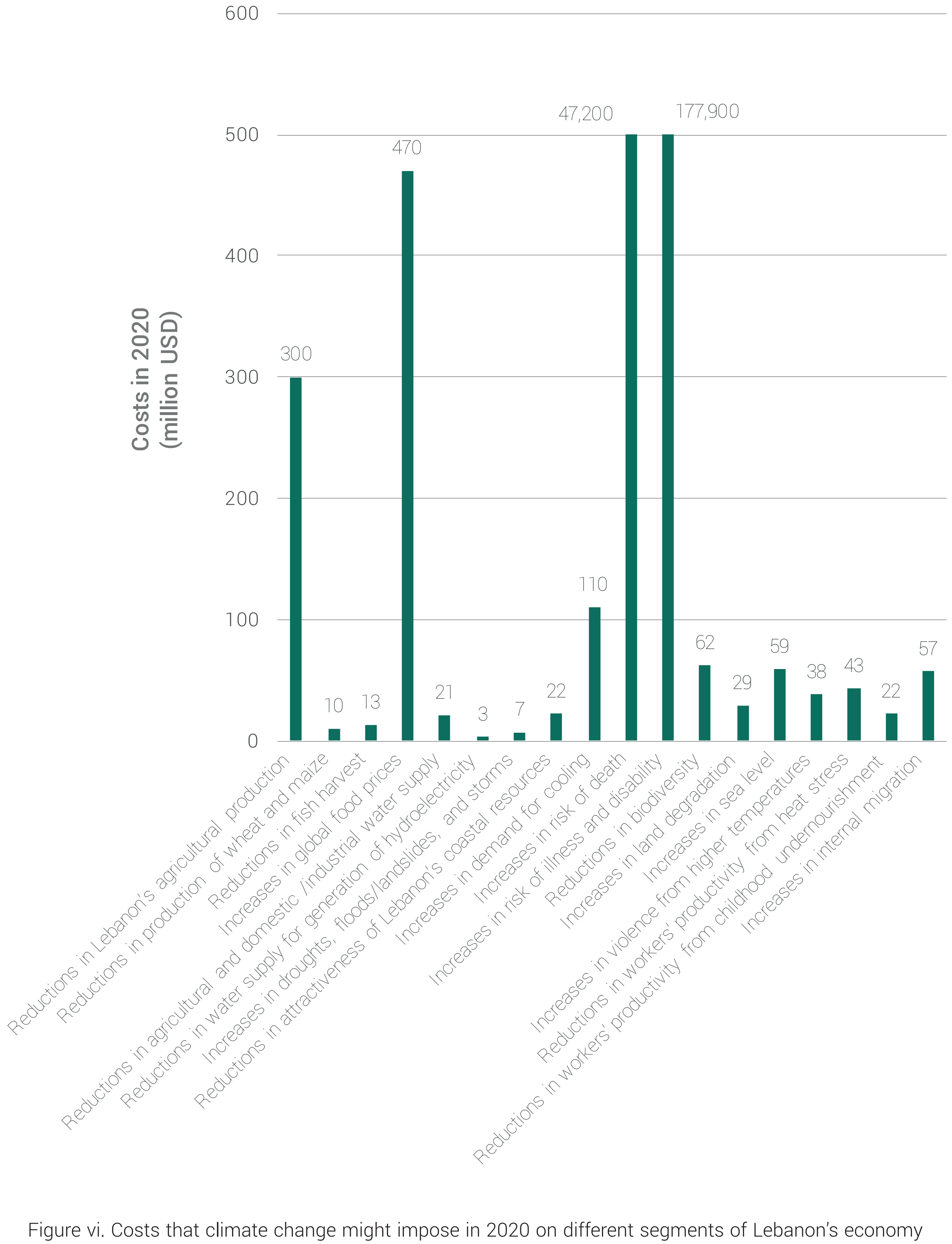


Figure vi. Costs that climate change might impose in 2020 on different segments of Lebanon's economy and society

V. Climate change will impose costs across all segments of Lebanon's economy and society

It is important to note that the findings reported in this report do not provide a comprehensive picture of the economic costs that changes in climate resulting from global GHG emissions might impose on Lebanon. In particular, limitations in the currently available data, models, and other information prevent the report from quantifying all types of potential costs. It does not, for example, quantify costs associated with increases in poverty and the marginalization of some women and minority groups that might result from changes in climate. The absence of monetized estimates for some types of costs does not mean they are necessarily inconsequential, or even less important than those that can be measured in monetary terms. Instead, this absence means only that there currently exists insufficient information to support reliable monetary estimates. On-going climate-related research likely will yield enough information to support monetized estimates in the foreseeable future for at least some of the omitted costs. Thus, all else equal, one should expect that, under the highest-emissions scenario, the actual costs that climate change imposes on Lebanon will exceed the amounts shown, and that future efforts to replicate this analysis will yield a more complete set of estimates than those shown herein.

In addition, the report does not consider the costs that would materialize if, relative to the assumptions embedded in the analyses included in this report:

- Global GHG emissions increase more rapidly.
- GHG emissions have a greater impact on climate.
- Changes in climate have a greater impact on ecological, economic, and social systems.
- Society places higher value on changes in these systems.

The analytical findings presented clarify Lebanon's vulnerability to climate change. They show the overall scale of the vulnerability if current trends in global GHG emissions continue, and the potential savings from curtailing emissions. They also show, in economic terms, the potential magnitude of the risks facing different segments of the economy and society.

VI. Lebanon might avoid some climate change costs by decreasing vulnerability and increasing resilience

This report does not investigate alternatives for reducing the costs climate change will impose on Lebanon, but it sets the stage for such an effort. The analyses of economic costs can provide a useful basis for a better understanding of the risks to different types of capital: human, natural, built, social, and cultural. Reducing costs will require reducing the vulnerability of each type of capital to climate-related risks.

Table iv illustrates actions that might be appropriate for lowering the potential impacts of global GHG emissions on Lebanon's capital stock. Some of these actions would involve developing a better and broader understanding of potential changes in climate and how they might affect the different types of capital. Some would entail taking steps to diminish or even block a particular type of risk to a specific asset. For example, a household, business, community, or the government might reinforce an existing or planned building against potential storms or increase its capacity to store water for emergency use should a storm occur. Education and training programs might be altered to include sections on risk-management. Providing information about potentially appropriate individual and collective actions for reducing the risk might reduce the vulnerability of households, businesses, and communities.

Table iv: Adaptive approaches for reducing the costs climate change will impose on Lebanon

Approach	Illustrative actions
1. Strengthen human capital	- Improve individual awareness of climate-related risks. - Improve education, nutrition, health, etc. - Reduce marginalization of women and others. - Reduce number of people in poverty. - Diversify economic skills and activities. - Strengthen resilience skills for responding to climate-related stresses that will occur.
2. Conserve natural capital	- Reduce non-climate stressors on ecosystems. - Conserve wetlands, soils, aquifers, and other core resources. - Implement ecosystem- and community-based management of natural resources. - Reduce risks of species extinction and loss of habitat. - Strengthen ecosystems' resilience to climate-related stresses that will occur.
3. Reduce vulnerability of physical capital	- Improve community understanding and awareness of climate risks, in general and to specific types of built capital. - Withdraw development from high-risk areas, such as floodplains. - Reinforce housing and work places against climate risks, such as storms. - Reduce risk of impairment of essential infrastructure: communication, transportation, water, wastewater, healthcare, electricity, etc. - Strengthen resilience of essential infrastructure to climate-related stresses that will occur.
4. Strengthen social capital	- Improve community understanding and awareness of climate risks, in general and to specific institutions and human relationships. - Improve adaptation plans and disaster-risk management systems. - Reduce risk of impairment of essential services. - Encourage development of and participation in insurance programs. - Improve access to information, finance, and technology. - Strengthen resilience of social systems to climate-related stresses that will occur.
5. Strengthen cultural capital	- Improve community understanding and awareness of climate risks to culturally important resources and activities. - Reduce risk to heritage sites and other cultural resources important to different cultural groups and communities (rural and urban). - Strengthen resilience of cultural capital to climate-related stresses that will occur.

Source | Adapted from IPCC (2014; p. 27)

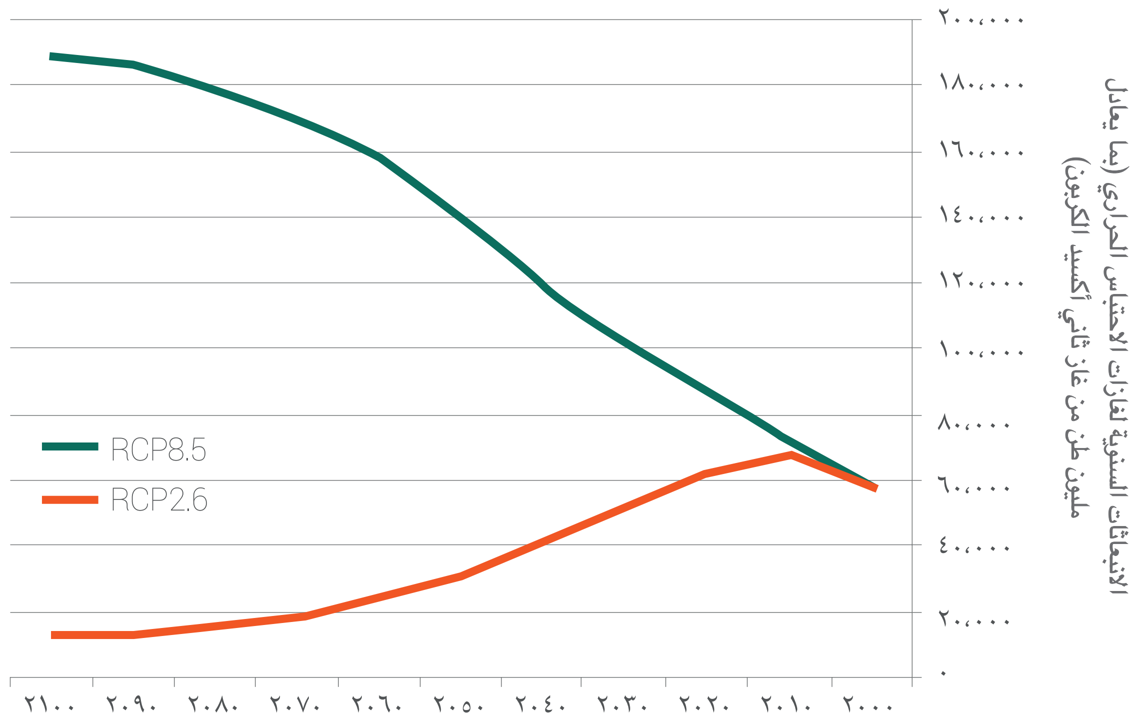
It is important to recognize that, although Lebanon might be able to reduce its vulnerability to climate-related risks, it cannot avoid them entirely. Global GHG emissions will, inevitably, have adverse effects on Lebanon's households, businesses, communities, and government. Hence, efforts to reduce the costs that these emissions impose on Lebanon should include elements that increase the ability of households, businesses, communities, and the government to respond to and recover from changes in climate. In other words, adaptive actions should focus not just on reducing vulnerability to climate-related risks but also on strengthening resilience to adverse events when they occur.

Effective planning and implementation of risk-management strategies to reduce vulnerability and increase resilience will require:

- Involvement by all stakeholders and institutions, with respectful recognition of their diverse circumstances, interests, resources, adaptability, and decision-making processes.
- Cooperative efforts at all spatial, institutional, communal, and governmental levels.
- Response to concerns about both the efficiency and the equity of risk-management actions.
- Recognition that, although some climate-related risks involve abrupt, severe events, such as extreme weather, others do not. Gradual increases in average annual temperature, for example, might, over time, affect the wellbeing of workers and families as much or more than extreme storms and heat waves.
- Application of the principles of risk-assessment and-management. These include assessing and taking actions to reduce risks in the context of clear objectives, considering the full range of probabilities and undesirable outcomes, using the best available information, considering both systemic and direct risks, and making transparent decisions.
- Use of both incentives and requirements to encourage risk-reducing behaviors. Incentives might involve market-based structures and tools, when appropriate, and recognize that alternatives may be required when significant market failures are present.
- Utilization of risk-oriented financial tools, such as appropriately scaled insurance, risk pooling, and access to financial resources during and after climate emergencies.

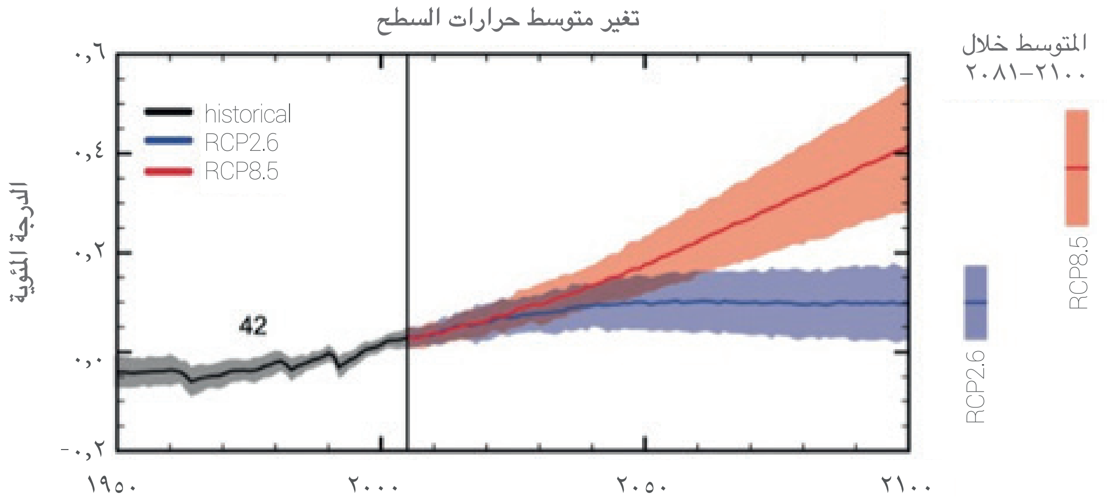
ا. سيفرض تغير المناخ تكاليف مباشرة على لبنان عبر موجات الحر الشديد وحالات الجفاف والعواصف، الخ... وأخرى غير مباشرة عبر نمو اقتصادي أبطأ.

تنجم التغيرات المناخية عن الانبعاثات العالمية لغاز ثاني أكسيد الكربون (CO_2) وغيرها من غازات الاحتباس الحراري (GHGs) (الهيئة الحكومية الدولية المعنية بتغير المناخ ٢٠١٣ب). يظهر الشكل أ مسار الانبعاثات العالمية لغازات الاحتباس الحراري المتوقعة حتى ٢١٠٠ وفي ظل سيناريو أعلى نسبة انبعاثات (المعروف بمسارات التركيز النموذجية ٨٫٥ - RCP8.5) وسيناريو أدنى نسبة انبعاثات (مسارات التركيز النموذجية ٢٫٦ - RCP2.6) والمتوقع من الهيئة الحكومية الدولية المعنية بتغير المناخ. ويظهر الشكل ب التغيرات المتوقعة المرافقة في متوسط حرارة السطح العالمي. وفي ظل سيناريو أعلى نسبة انبعاثات، والذي يمثّل استمرارًا للاتجاهات الراهنة، ترتفع الحرارات في مسار شبه طولي عبر القرن. أما في سيناريو أدنى نسبة انبعاثات، فترتفع اعتبارًا من منتصف القرن لتنحسر بعد ذلك. أما متوسط حرارات السطح فترة ٢٠٨١ - ٢١٠٠ فستتخطى تلك التي كانت سائدة في الفترة ١٩٨٦ - ٢٠٠٦ بحوالي ٤ - ٦ درجات مئوية في سيناريو أعلى نسبة انبعاثات، ودرجتين (٢) مئويتين في سيناريو أدنى نسبة انبعاثات (الهيئة الحكومية الدولية المعنية بتغير المناخ ٢٠١٤؛ ص. ١٠). ومن شأن هذه الزيادات في الحرارة أن تضيف إلى زيادة بمعدل ٠٫٦١ درجة مئوية تم رصدها ما بين ١٨٥٠ - ١٩٠٠ و١٩٨٦ - ٢٠٠٥ (الهيئة الحكومية الدولية المعنية بتغير المناخ ٢٠١٣ب؛ ص. ٥).



الشكل أ: انبعاثات غازات الاحتباس الحراري الراهنة، ٢٠٠٠ و ٢٠١٠، والانبعاثات المتوقعة في ظل مسارات التركيز النموذجية ٨٫٥ ومسارات التركيز النموذجية ٢٫٦ ، ٢٠٢٠ - ٢١٠٠

المصدر | قاعدة بيانات مسارات التركيز النموذجية (٢٠١٥) و Myhre et al. (٢٠١٣؛ ص. ٧١٤)

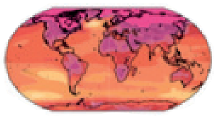


الشكل ب: التغيرات المرصودة في متوسط حرارات السطح السنوي، ١٩٥٠ – ٢٠١٠ ، والتوقعات في ظل مسارات التركيز النموذجية ٨,٥ ومسارات التركيز النموذجية ٢,٦ ، ٢٠٢٠ – ٢١٠٠

المصدر | قاعدة بيانات مسارات التركيز النموذجية (٢٠١٣؛ ص. ٢١)

في حال استمرار الاتجاهات الحالية لانبعاثات غازات الاحتباس الحراري، من شأن التغيرات المتوَّقعة في المناخ أن تفرض تكاليف اقتصادية على لبنان، مباشرة وغير مباشرة، كما يظهر الشكل ج. وتتمثّل التكاليف المباشرة بدرجات حرارة أعلى وتتمث وتغيّرات في المتساقطات وظاهرات جوية بالغة الشدة مثال العواصف، وانخفاض في الإنتاج الزراعي والتأثير سلبًا على صحة الإنسان والتسبّب بالفيضانات وفرض أضرار مماثلة على فئات مختلفة من الاقتصاد اللبناني ومجتمعه. أما التكاليف غير المباشرة، فتتمثل فيما تؤدي التكاليف المباشرة إلى إبطاء النموّ الاقتصادي للبلاد. ومن شأن حركة النمو الأبطأ أن تخفض من إجمالي الناتج المحلي اللبناني وأن تخفض أيضًا حركة نشاط قطاع الأعمال. وهذه التأثيرات من شأنها أن تخفف من مداخيل العمّال والأسر المعيشية وأن تتسبّب في اختبار الحكومة انخفاضًا في الإيرادات وارتفاعًا في التكاليف.

الأضرار الاقتصادية المباشرة
- الكوارث البيئية
- تغير الموائل
- الأمراض، حالات الإصابة، حالات الوفاة
- إجهاد الصناعات



ناتج محلي إجمالي ضائع
- نمو اقتصادي أبطأ
- انخفاض النشاط التجاري
- انخفاض الدخل
- الحكومة: انخفاض الإيرادات وارتفاع التكاليف

الشكل ج: ستفرض التغيرات المناخية تكاليف على لبنان من خلال توليد أضرار اقتصادية مباشرة وإبطاء النمو في الناتج المحلي الإجمالي

يعمل هذا التقرير على تفسير الطرائق المختلفة التي قد تفرض من خلالها التغيرات المستقبلية في المناخ التكاليف على لبنان. كما يقوم باحتساب الحجم العام لبعض هذه التكاليف، وذلك استنادًا إلى المعلومات ذات الصلة المتوفرة حاليًا.

II. مجموع التكاليف قد يساوي مليون و٩٠٠ ألف د.أ. في عام ٢٠٢٠، مرتفعًا إلى ١٣٨ مليون و٩٠٠ ألف د.أ. في عام ٢٠٨٠

يلخص الجدول أ والشكل د التكاليف المتوقعة التي سيواجهها لبنان في عام ٢٠٢٠ وعام ٢٠٤٠ وعام ٢٠٨٠ جراء الآثار التراكمية للانبعاثات العالمية لغازات الاحتباس الحراري بين عام ٢٠١٥ وكل من هذه السنوات، في ظل سيناريو أعلى نسبة انبعاثات الصادر عن الهيئة الحكومية الدولية المعنية بتغير المناخ. يظهر السطر العلوي الضرر المتوقع في كل عام والناجم عن الآثار المباشرة لارتفاع درجات الحرارة والتغيرات الأخرى في المناخ على الإنتاجي الزراعي وصحة الإنسان والفيضانات وإنتاجية النظام الإيكولوجي، الخ... ومن شأن هذا الضرر أن يفرض تكاليف على لبنان تبلغ حوالي ٣٢٠ مليون د.أ. في عام ٢٠٢٠ و٢،٨٠٠ مليون د.أ. في عام ٢٠٤٠ و٢٣،٢٠٠ مليون د.أ. في ٢٠٨٠.

ويقرّ التحليل الكامن وراء السطر الثاني أنه مع مرور الوقت، ستؤدي هذه الآثار المباشرة إلى إبطاء نمو الاقتصاد اللبناني، والذي يقاس حاليًا بالناتج المحلي الإجمالي. وإذا ما استمرت الاتجاهات الحالية، فإن الانبعاثات العالمية لغازات الاحتباس الحراري بين عامي ٢٠١٥ و ٢٠٢٠ ستخفض الناتج المحلي الإجمالي في لبنان بحوالي ١،٦٠٠ مليون د.أ.، أو ٣٪. ومن شأن الناتج المحلي الإجمالي الضائع هذا أن يشكل التكلفة الحقيقية، أو انخفاض في الرفاه الاقتصادي للأسر المعيشية والشركات التجارية والحكومة في لبنان. وفي حال استمرار الاتجاهات الحالية حتى عام ٢٠٤٠ وعام ٢٠٨٠، فإن لبنان سيواجه انخفاضات في الناتج المحلي الإجمالي بقيمة ١٤،١٠٠ مليون د.أ. (١٤٪) في عام ٢٠٤٠، و١١٥،٧٠٠ مليون د.أ. (٣٢٪) في عام ٢٠٨٠.

أما مجموع تكاليف الأضرار المباشرة والناتج المحلي الإجمالي الضائع فيساوي مجموع التكاليف المتوقعة التي ستفرضها الانبعاثات العالمية في عام ٢٠١٥ وما بعده على لبنان، وذلك في حال استمرار الاتجاهات الحالية. ويشير التحليل إلى تكاليف إجمالية بحوالي ١،٩٠٠ مليون د.أ. في عام ٢٠٢٠، و١٦،٩٠٠ مليون د.أ. في عام ٢٠٤٠، و١٣٨،٩٠٠ مليون د.أ. في ٢٠٨٠. وتشير هذه الكميات الإجمالية، مقسومة على العدد المتوقع من الأسر المعيشية، إلى متوسط تكلفة لكل أسرة هو: ١،٥٠٠ د.أ. في عام ٢٠٢٠، ١٣،١٠٠ د.أ. في عام ٢٠٤٠، و١٠٧،٢٠٠ د.أ. في ٢٠٨٠. أما في حال بقاء دور الحكومة الحالية في الاقتصاد على حاله، فإنها ستتحمل حوالي ٦١٠ ملايين د.أ. من التكلفة الإجمالية في عام ٢٠٢٠، ٥،٤٠٠ مليون د.أ. في عام ٢٠٤٠، و٤٤،٣٠٠ مليون د.أ. في ٢٠٨٠.

الجدول أ: التكاليف المحتملة في ٢٠٢٠، ٢٠٤٠ و٢٠٨٠ من الآثار التراكمية للانبعاثات العالمية لغازات الاحتباس الحراري في عام ٢٠١٥ والسنوات اللاحقة (٢٠١٥ د.أ.)

التكاليف المحتملة	٢٠٢٠	٢٠٤٠	٢٠٨٠
الأضرار السنوية المباشرة من حالات الجفاف، إلخ، في لبنان (مليون)	٣٢٠ د.أ.	٢،٨٠٠ د.أ.	٢٣،٢٠٠ د.أ.
الناتج المحلي الإجمالي الضائع في لبنان (مليون)	١،٦٠٠ د.أ.	١٤،١٠٠ د.أ.	١١٥،٧٠٠ د.أ.
نسبة التخفيض في الناتج المحلي الإجمالي	٣٪	١٤٪	٣٢٪
إجمالي التكلفة للبنان (مليون)	١،٩٠٠ د.أ.[a]	١٦،٩٠٠ د.أ.	١٣٨،٩٠٠ د.أ.
معدل التكلفة للأسرة المعيشية الواحدة في لبنان	١،٥٠٠ د.أ.	١٣،١٠٠ د.أ.	١٠٧،٢٠٠ د.أ.
حصة الحكومة (مليون)	٦١٠ د.أ.	٥،٤٠٠ د.أ.	٤٤،٣٠٠ د.أ.

تعكس الأرقام قواعد التدوير كما ورد وصفها في المقدمة

[a] نتيجة لعملية التدوير ، يختلف الإجمالي، ١،٩٠٠ مليون د.أ. قليلًا عن مجموع ٣٢٠ مليون د.أ. و١،٦٠٠ مليون د.أ.

الشكل د: التكاليف المحتملة على لبنان من الآثار التراكمية للانبعاثات العالمية لغازات الاحتباس الحراري في عام ٢٠١٥ والسنوات اللاحقة (٢٠١٥ د.أ.)

من شأن تكاليف الأضرار المباشرة والناتج المحلي الإجمالي المخفّض أن يؤديا إلى خفض الدخل السنوي للأسر المعيشية في كافة أنحاء لبنان. وسوف تشهد الأسر المعيشية الريفية بشكل عام نسب أكبر من التخفيضات من تلك التي ستشهدها الأسر المعيشية في المناطق الحضرية. إلا أن الأسر الزراعية فستختبر تخفيضات أقل نوعًا ما من نظرائها الريفيين غير الزراعيين، وبخاصة الأسر التي تتلقى أسعارًا أكثر ارتفاعًا مقابل محاصيلها أو ماشيتها. ولكلّ من الأسر الريفية والحضرية، تلك التي تتمتّع بشكل عام بمستويات أعلى من المدخول فستشهد نسبة أدنى من التخفيضات.

III. لبنان سيشهد تكاليف أقلّ في حال نمو الانبعاثات العالمية لغازات الاحتباس الحراري بشكل أبطأ

يقارن الجدول ب والشكل ه التكاليف التي سيتكبدها لبنان والتي ستنجم عن الانبعاثات العالمية لغازات الاحتباس الحراري في عام ٢٠٢٠، ٢٠٤٠، و٢٠٨٠ وفقًا لسيناريوهي أعلى وأدنى نسبة انبعاثات التابعين للهيئة الحكومية الدولية المعنية بتغير المناخ. في كل من هاتين الحالتين، تتجسد التكاليف على نحو سيلٍ من التكاليف السنوية في العقود التي تلي كل من هذه السنوات. لتسهيل عملية قياس التكاليف من انبعاثات كل سنة، يحول التحليل تيار التكاليف المتوقعة إلى ما يعادلها في عدد واحد. وهذا العدد، الذي يطلق عليه الاقتصاديون اسم القيمة الحالية لتيار التكاليف، يقاس في السنة التي تصدر فيها الإنبعاثات: ٢٠٢٠، ٢٠٤٠، و٢٠٨٠.

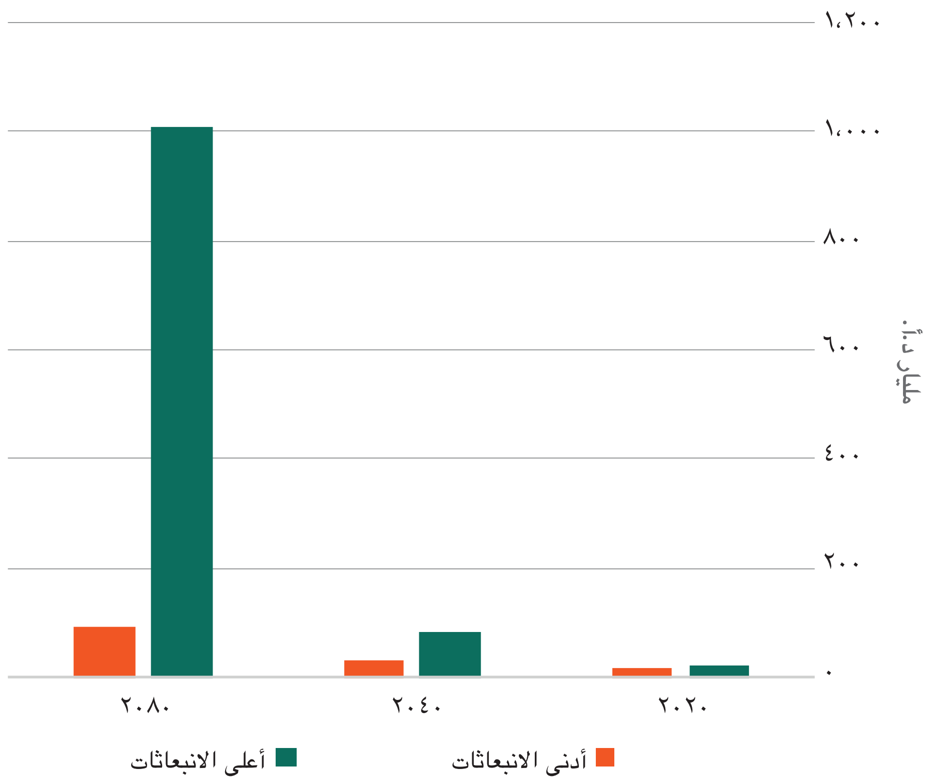
ويظهر القسم الأعلى في الجدول ب التكاليف في ظل سيناريو أعلى نسبة انبعاثات. وسيكون لتيار التكاليف السنوية الناجمة عن الانبعاثات العالمية لغازات الاحتباس الحراري في عام ٢٠٢٠ قيمة حالية هي ٣،٦٠٠ مليون د.أ. ويكون للتخفيضات الناتجة في الناتج المحلي الإجمالي قيمة حالية هي ١٧،٦٠٠ مليون د.أ. أما مجموعة هاتين القيمتين، أي ٢١،٢٠٠ مليون د.أ.، فيشكّل متوسطًا للأسرة المعيشية الواحدة يبلغ ١٦،٤٠٠ د.أ. وفي حال بقاء دور الحكومة في الاقتصاد على حاله، فتكون القيمة الحالية لتيار تكاليفها ٦،٨٠٠ مليون د.أ.

ويظهر القسم السفلي في الجدول ب ما ستكون التكاليف في حال اتخاذ إجراءات معقولة للحدّ من الانبعاثات العالمية حتى تلك الواردة في سيناريو أدنى نسبة انبعاثات التابع للهيئة الحكومية الدولية المعنية بتغير المناخ. وبموجب هذا السيناريو الأخير، فإن مجموع القيمة الحالية لتيار التكاليف السنوية الناجمة عن الانبعاثات في عام ٢٠٢٠ يكون ١٥،٢٠٠ مليون د.أ. ومقارنة بسيناريو أعلى نسبة انبعاثات، من شأن هذا السيناريو أن يحدّ إجمالي التكاليف بحوالي ٦،٠٠٠ مليون د.أ.، أو بحوالي ٢٨٪. وبحلول العام ٢٠٨٠، من شأن هذا السيناريو أن يحدّ إجمالي التكاليف بـ ٩١٨،٤٠٠ مليون د.أ.، أو ٩١٪.

الجدول ب: القيمة الحالية للتكاليف الاقتصادية التي ستفرضها الانبعاثات العالمية لغازات الاحتباس الحراري على لبنان في عام ٢٠٢٠ و٢٠٤٠ و٢٠٨٠، في ظل سيناريوهي أعلى وأدنى نسبة انبعاثات (٢٠١٥ د.أ.)

	٢٠٢٠	٢٠٤٠	٢٠٨٠
أ. التكاليف المحتملة في حال وقوع الانبعاثات تحت سيناريو أعلى نسبة انبعاثات التابع للهيئة الحكومية الدولية المعنية بتغير المناخ (الاتجاهات الحالية)			
إجمالي التكلفة (مليون)	٢١،٢٠٠ د.أ.	٨٠،٧٠٠ د.أ.	١،٠٠٩،٧٠٠ د.أ.
متوسط التكلفة للأسرة الواحدة	١٦،٤٠٠ د.أ.	٥٧،٣٠٠ د.أ.	٧٢١،٩٠٠ د.أ.
حصة الحكومة (مليون)	٦،٨٠٠ د.أ.	٢٥،٨٠٠ د.أ.	٣٢٢،٠٠٠ د.أ.
ب. التكاليف المحتملة في حال وقوع الانبعاثات تحت سيناريو أدنى نسبة انبعاثات التابع للهيئة الحكومية الدولية المعنية بتغير المناخ			
إجمالي التكلفة (مليون)	١٥،٢٠٠ د.أ.	٣٠،٨٠٠ د.أ.	٩١،٣٠٠ د.أ.
متوسط التكلفة للأسرة الواحدة	١١،٧٠٠ د.أ.	٢١،٩٠٠ د.أ.	٦٥،٢٠٠ د.أ.
حصة الحكومة (مليون)	٤،٨٠٠ د.أ.	٩،٨٠٠ د.أ.	٢٩،١٠٠ د.أ.
ج. الوفورات المحتملة في التكلفة جراء الحدّ من الانبعاثات العالمية حتى سيناريو أدنى نسبة انبعاثات			
الوفورات المحتملة (مليون)	٦،٠٠٠ د.أ.	٤٩،٩٠٠ د.أ.	٩١٨،٤٠٠ د.أ.
الوفورات المحتملة (النسبة المئوية)	٢٨	٦٢	٩١

تعكس الأرقام قواعد التدوير كما ورد وصفها في المقدمة



الشكل ه. مقارنة التكاليف المحتملة على لبنان والناجمة عن الانبعاثات العالمية لغازات الاحتباس الحراري في عام ٢٠٢٠ و٢٠٤٠ و٢٠٨٠ وفقًا لسيناريوهي أعلى وأدنى نسبة انبعاثات التابعين للهيئة الحكومية الدولية المعنية بتغير المناخ

١٧. تغير المناخ سيفرض تكاليف على كافة فئات المجتمع والاقتصاد اللبناني

سيفرض تغير المناخ التكاليف على كل شخص وعائلة ومزرعة وشركة تجارية ومجتمع محلي ومنطقة في لبنان. ويلخص الجدول ج والشكل و التكاليف لفئات من الاقتصاد والمجتمع التي تتوفر البيانات ذات الصلة لها. بشكل عام، يتمتع تقييم التكاليف لكل فئة بقاعدة متميّزة يتم تجميعها من مجموعة بيانات ملائمة أو دراسة سابقة. إلا أنه قد تتواجد حالات تداخل بين الدراسات والبيانات الكامنة وراء التحاليل المختلفة. ولتفادي ازدواجية الحساب المحتملة، يتم تحذير القراء من عدم جمع الفئات المختلفة للتكاليف من دون مراجعة العمليات الحسابية والتأكد من وجود حالات تداخل.

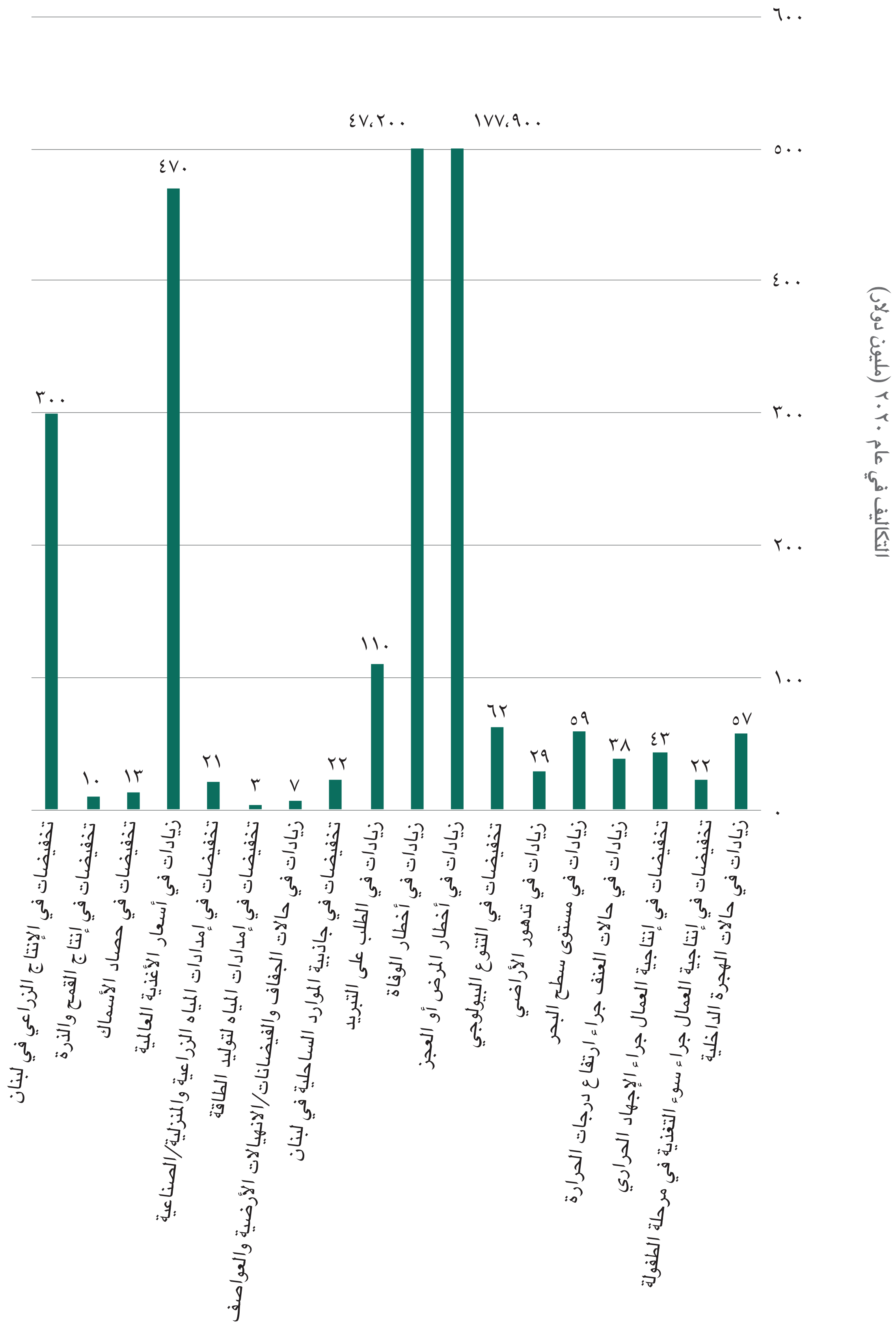
ويمثّل الشكل و تصويرًا بيانيًا للتكاليف المحتملة في عام ٢٠٢٠. ويوضح الرسم البياني أن الآثار المحتملة على صحة الإنسان إنما تشكّل أكبر المخاطر. فالتكاليف المرتبطة بالزيادات المحتملة لأخطار الوفاة – نتيجة الإجهاد الحراري وسوء التغذية والإسهال والملاريا والفيضانات والأمراض القلبية الوعائية ، تصل إلى ٤٧،٢٠٠ مليون د.أ. (أي ٤٧,٢ مليار د.أ.). أما التكاليف المرتبطة بالزيادات المحتملة للأمراض وحالات العجز – نتيجة العوامل ذاتها المتعلقة بالمناخ – فتصل إلى ١٧٧،٩٠٠ مليون.

وقد تتجسد التكاليف الرئيسية الأخرى من خلال آثار تغير المناخ على الإنتاج الزراعي في لبنان وعلى الأسعار التي يدفعها المستهلكون اللبنانيون مقابل الغذاء. وأما الانخفاضات في الإنتاج الزراعي العام للبنان – الناجمة عن ارتفاع درجات الحرارة والتغيرات في هطول الأمطار وحالات زيادة جفاف التربة، إلخ... – فقد تخفض الناتج المحلي الإجمالي في لبنان بحوالي ٣٠٠ مليون د.أ. في عام ٢٠٢٠. وفي حال استمرار التوجهات الحالية، قد تفرض الزيادات المحتملة في أسعار الغذاء العالمية تكاليف بقيمة ٤٧٠ مليون د.أ. على المستهلكين اللبنانيين وذلك بزيادة الأسعار التي يدفعونها مقابل المواد الغذائية، مما سيحثّهم، نتيجة ارتفاع الأسعار، إلى استهلاك كمية أقل من المواد الغذائية.

الجدول ج: التكاليف التي قد يفرضها تغير المناخ على الفئات المختلفة في الاقتصاد والمجتمع اللبناني (٢٠١٥ – مليون د.أ.)

الكلفة المحتملة	٢٠٢٠	٢٠٤٠	٢٠٨٠
أ. التكاليف الناجمة عن آثار تغير المناخ على الزراعة والإمدادات الغذائية			
١. تخفيضات في الإنتاج الزراعي في لبنان	٣٠٠ د.أ.	٨٦٠ د.أ.	٢،٣٠٠ د.أ.
٢. تخفيضات في إنتاج القمح والذرة	١٠ د.أ.	١٧ د.أ.	٢٨ د.أ.
٣. تخفيضات في حصاد الأسماك	١٣ د.أ.	٣٢ د.أ.	٣٢ د.أ.
٤. زيادات في أسعار الأغذية العالمية	٤٧٠ د.أ.	١،٧٠٠ د.أ.	٥،٠٠٠ د.أ.
ب. التكاليف الناجمة عن آثار تغير المناخ على المياه			
١. تخفيضات في إمدادات المياه الزراعية والمنزلية/ الصناعية	٢١ د.أ.	٣٢٠ د.أ.	١،٢٠٠ د.أ.
٢. تخفيضات في إمدادات المياه لتوليد الطاقة الكهرومائية	٣ د.أ.	٣١ د.أ.	١١٠ د.أ.
ج. التكاليف الناجمة عن الكوارث الطبيعية المتعلقة بالمناخ			
١. زيادات في حالات الجفاف والفيضانات/الانهيالات الأرضية والعواصف	٧ د.أ.	٣٦ د.أ.	١،٦٠٠ د.أ.
د. التكاليف الناجمة عن آثار تغير المناخ على السياحة			
١. تخفيضات في جاذبية الموارد الساحلية في لبنان	٢٢ د.أ.	١٦٠ د.أ.	١،٨٠٠ د.أ.
ه. التكاليف الناجمة عن آثار تغير المناخ على استهلاك الكهرباء			
١. زيادات في الطلب على التبريد	١١٠ د.أ.	٩٠٠ د.أ.	٣٤،٨٠٠ د.أ.
و. التكاليف الناجمة عن آثار تغير المناخ على الصحة البشرية			
١. زيادات في أخطار الوفاة	٤٧،٢٠٠ د.أ.	٥٤،٧٠٠ د.أ.	٦١،٤٠٠ د.أ.
٢. زيادات في أخطار المرض أو العجز	١٧٧،٩٠٠ د.أ.	١٩٤،٣٠٠ د.أ.	١٩١،٥٠٠ د.أ.
ز. التكاليف الناجمة عن آثار تغير المناخ على النظم الإيكولوجية			
١. تخفيضات في التنوع البيولوجي	٦٢ د.أ.	١٥٠ د.أ.	٣٣٠ د.أ.
٢. زيادات في تدهور الأراضي	٢٩ د.أ.	٧٨ د.أ.	١٧٠ د.أ.
٣. زيادات في مستوى سطح البحر	٥٩ د.أ.	١٤٠ د.أ.	٣٢٠ د.أ.
ح. التكاليف الناجمة عن آثار تغير المناخ على المجتمع			
١. زيادات في حالات العنف جراء ارتفاع درجات الحرارة	٣٨ د.أ.	٨٤٠ د.أ.	٨،٦٠٠ د.أ.
٢. تخفيضات في إنتاجية العمال جراء الإجهاد الحراري	٤٣ د.أ.	١٦٠ د.أ.	١،٤٠٠ د.أ.
٣. تخفيضات في إنتاجية العمال جراء سوء التغذية في مرحلة الطفولة	٢٢ د.أ.	٥١ د.أ.	٢٨٠ د.أ.
٤. زيادات في حالات الهجرة الداخلية	٥٧ د.أ.	١٣٠ د.أ.	٣٢٠ د.أ.

تعكس الأرقام قواعد التدوير كما ورد وصفها في المقدمة



الشكل و. التكاليف التي قد يفرضها تغير المناخ في عام ٢٠٢٠ على الفئات المختلفة للاقتصاد والمجتمع اللبناني

٧. التكاليف الفعلية على الأرجح أن تكون أعلى من تلك المقدّرة هنا

من المهم الإشارة إلى أن النتائج الواردة في هذا التقرير لا تقدم صورة شاملة للتكاليف الاقتصادية التي قد تفرضها التغيرات المناخية الناجمة عن الانبعاثات العالمية لغازات الاحتباس الحراري على لبنان. وبشكل خاص، تحول القيود في البيانات والنماذج وغيرها من المعلومات المتاحة حاليًا دون تمكّن التقرير من قياس كافة أنواع التكاليف المحتملة. فعلى سبيل المثال، لا يقوم التقرير بقياس التكاليف المرتبطة بالزيادات في الفقر وتهميش بعض النساء ومجموعات الأقليات التي قد تنجم عن التغيرات في المناخ. وغياب التقديرات النقدية لبعض أنواع التكاليف لا يعني بالضرورة أنها غير ذات أهمية، أو أنها ذات أهمية أقل من تلك التي يمكن قياسها من حيث القيمة النقدية. عوضًا عن ذلك، هذا الغياب لا يعني سوى أنه حاليًا ثمة معلومات غير كافية لدعم التقديرات النقدية الموثوقة. وعلى الأرجح أن تعطي الأبحاث المتواصلة المتعلقة بالمناخ معلومات كافية لدعم التقديرات النقدية في المستقبل المنظور بالنسبة لبعض التكاليف المحذوفة على الأقل. لذلك، ومع افتراض بقاء العوامل الأخرى على حالها، على المرء أن يتوقع، وفي ظل سيناريو أعلى نسبة انبعاثات، أن تتخطى الكلفة الفعلية التي يفرضها تغير المناخ على لبنان المبالغ المبيّنة، وأن الجهود المستقبلية التي ستبذَل لتكرار هذا التحليل ستعطى مجموعة تقديرات أكثر كمالًا من تلك المبيّنة في هذا التقرير.

إضافة إلى ذلك، فإن التقرير لا يأخذ بعين الاعتبار التكاليف التي قد تتجسد في حال، نسبة إلى الافتراضات المضمنة في التحليل الواردة في هذا التقرير:

– زيادة الانبعاثات العالمية غازات الاحتباس الحراري بشكل أكثر سرعة.
– كان لانبعاثات غازات الاحتباس الحراري آثار أكبر على المناخ.
– كان للتغيرات المناخية أثرٌ أكبر على النظم الإيكولوجية والاقتصادية والاجتماعية.
– وضع المجتمع قيمة أعلى على التغيرات في هذه النظم.

توضح النتائج التحليلية المقدمة قابلية تأثر لبنان بتغير المناخ؛ كما أنها تظهر النطاق العام لقابلية التأثر في حال استمرار الاتجاهات الحالية للانبعاثات العالمية لغازات الاحتباس الحراري، والوفورات المحتملة الناتجة عن الحد من الانبعاثات. كما أنها تبين، من الناحية الاقتصادية، الحجم المحتمل للمخاطر التي تواجه القطاعات المختلفة من الاقتصاد والمجتمع.

٧I. قد يتفادى لبنان بعض التكاليف الناجمة عن تغير المناخ من خلال الحدّ من قابلية التأثر وزيادة القدرة على التأقلم

لا يحقق هذا التقرير في الطرق البديلة للحدّ من التكاليف التي سيفرضها تغير المناخ على لبنان، إلا أنه يحضر الأرضية لمثل هذه الجهود. ويمكن لتحاليل التكاليف الإقتصادية أن تقدم قاعدة مفيدة لفهم أفضل لمخاطر مختلف أنواع رؤوس الأموال: البشري والطبيعي والمبني والإجتماعي والثقافي. وسيتطلب الحدّ من التكاليف تخفيفًا لقابليّة التأثر لكل نوع من رؤوس الأموال بالمخاطر المتعلقة بالمناخ.

يشير الجدول د إلى الإجراءات التي يمكن أن تكون ملائمة للحدّ من الآثار المحتملة للانبعاثات العالمية لغازات الاحتباس الحراري على مخزون لبنان الرأسمالي. وتشمل بعض هذه الإجراءات تطوير فهم أفضل وأوسع للتغييرات المحتملة في المناخ وكيفية احتمال تأثيرها في مختلف أنواع رؤوس الأموال. وقد يشمل بعضها اتخاذ خطوات للحد من نوع معين من المخاطر على أصل محدد، أو حتى الإحالة دونه. على سبيل المثال، يمكن لأسرة معيشية أو شركة تجارية أو مجتمع أو الحكومة أن تدعم مبنى قائمًا أو مخططًا له ضد العواصف المحتملة، أو زيادة قدرته على تخزين المياه لاستعمالها في الحالات الطارئة عند حدوث العواصف. ويمكن تعديل برامج التعليم والتدريب لإدراج أقسام تتناول إدارة المخاطر. ويمكن لعملية توفير المعلومات عن الإجراءات الفردية والجماعية الملائمة للحد من المخاطر أن تخفف من قابلية تأثر الأسر المعيشية والأعمال التجارية والمجتمعات.

الجدول د: النهوج التكيفية للحد من التكاليف التي سيفرضها تغير المناخ على لبنان

النهج	الإجراءات التوضيحية
١. تعزيز رأس المال البشري	– تحسين الوعي الفردي على المخاطر المتعلقة بالمناخ. – تحسين التعليم والتغذية والصحة، إلخ. – الحد من تهميش المرأة وغيرها. – الحد من عدد الأشخاص المحرومين. – تنويع المهارات والنشاطات الإقتصادية. – تعزيز قدرات التكيّف للإستجابة للضغوط المتعلقة بالمناخ التي ستطرأ.
٢. المحافظة على رأس المال الطبيعي	– الحد من الضغوطات غير المناخية على النظم الإيكولوجية. – حفظ الأراضي الرطبة والأتربة وخزانات المياه الجوفية وموارد أساسية أخرى. – إنشاء إدارة للموارد الطبيعية تستند إلى النظام الإيكولوجي والمجتمع. – الحد من مخاطر انقراض الأنواع وخسارة الموئل. – تعزيز قدرة النظم الإيكولوجية على التكيف للضغوط المتعلقة بالمناخ التي ستطرأ.
٣. الحد من قابلية رأس المال المادي للتأثر	– تحسين فهم المجتمع ووعيه على مخاطر المناخ بشكل عام وعلى أنواع محددة من رأس المال المبني. – عزل التنمية من المناطق العالية المخاطر، مثال السهول الفيضية. – تعزيز أماكن السكن والعمل لمقاومة مخاطر المناخ مثال العواصف. – الحد من مخاطر ضعف البنية التحتية الأساسية: الإتصالات والنقل والمياه ومياه الصرف الصحي والرعاية الصحية والكهرباء، إلخ. – تعزيز قدرة البنية التحتية الأساسية على التكيف للضغوط المتعلقة بالمناخ التي ستطرأ.
٤. تعزيز رأس المال الإجتماعي	– تحسين فهم المجتمع ووعيه على مخاطر المناخ بشكل عام وعلى مؤسسات محددة والعلاقات الإنسانية. – تحسين مخططات التأقلم وأنظمة إدارة مخاطر الكوارث. – الحد من مخاطر تعطيل الخدمات الأساسية. – تشجيع تنمية برامج التأمين والمشاركة فيها. – تحسين إمكانية الوصول إلى المعلومات والموارد المالية والتكنولوجيا. – تعزيز قدرة الأنظمة الإجتماعية على التكيف للضغوط المتعلقة بالمناخ التي ستطرأ.
٥. تعزيز رأس المال الثقافي	– تحسين فهم المجتمع ووعيه حول مخاطر المناخ على الموارد والنشاطات المهمة ثقافيًا. – الحد من المخاطر على مواقع التراث والموارد الثقافية الأخرى التي تهم مختلف المجموعات والمجتمعات الثقافية (الريفية والحضرية). – تعزيز قدرة رأس المال الثقافي على التكيف للضغوط المتعلقة بالمناخ التي ستطرأ.

المصدر | مقتبسة عن الهيئة الحكومية الدولية المعنية بتغير المناخ (٢٠١٤؛ ص. ٢٧)

من المهم الإقرار بأنه، على الرغم من أن لبنان قد يتمكّن من الحد من قابليته للتأثر بالمخاطر المتعلقة بالمناخ، إلا أنه لا يمكنه تفاديها بالكامل. وسيكون للانبعاثات العالمية لغازات الاحتباس الحراري، لا محالة، آثارًا سلبية على الأسر المعيشية والأعمال التجارية والمجتمعات والحكومة في لبنان. لذا، على الجهود الرامية إلى الحد من التكاليف التي تفرضها هذه الإنبعاثات على لبنان أن تشمل عوامل تزيد من قدرة الأسر المعيشية والأعمال التجارية والمجتمعات والحكومة على الاستجابة للتغيرات المناخية والتعافي منها. بتعبير آخر، على الإجراءات التكيفية أن تركز لا على الحد من قابلية التأثر بالمخاطر المتعلقة بالمناخ فحسب بل على تعزيز قابلية التكيف للحوادث السلبية أيضًا، عند وقوعها.

وستتطلب عملية التخطيط والتنفيذ الفعالية لاستراتيجيات إدارة المخاطر للحد من قابلية التأثر وزيادة المرونة:

- التـزام كافـة أصحـاب المصلحـة والمؤسسـات، مـع الإقـرار بظروفهـم المتنوعـة ومصالحهـم ومواردهـم وقدرتهـم علـى التكيـف وعمليـات اتخـاذ القـرارات.
- جهود التعاون على كافة المستويات المكانية والمؤسسية والمجتمعية والحكومية.
- الاستجابة للمخاوف حول كل من فعالية إجراءات إدارة المخاطر وإنصافها.
- الإقـرار بأنـه علـى الرغـم مـن أن بعـض المخاطـر المتعلقـة بالمنـاخ تشـمل الأحـداث المفاجئـة والشـديدة مثـال سـوء الأحـوال الجويـة، فبعضهـا الآخـر لا يشـملها. ويمكـن للزيـادات التدريجيـة فـي متوسـط درجـات الحـرارة السـنوية، علـى سـبيل المثـال، ومـع مـرور الوقـت، أن تؤثـر علـى رفاهيـة العمـال والعائـلات بقـدر أو أكثـر مـن العواصـف وموجـات الحـرارة الشـديدة.
- تطبيـق مبـادئ تقييـم المخاطـر وإدارة المخاطـر. وهـذه تشـمل عمليـة التقييـم واتخـاذ الإجـراءات المناسـبة للحـد مـن المخاطـر فـي سـياق الأهـداف الواضحـة، وذلك بمراعـاة المجموعـة الكاملـة مـن الاحتمـالات والنتائـج غيـر المرغـوب بهـا، باسـتخدام أفضـل المعلومـات المتوفـرة وبالنظـر إلـى كل مـن المخاطـر المنهجيـة والمباشـرة، وباتخـاذ قـرارات شـفافة.
- اسـتخدام كل مـن الحوافـز والمتطلبـات للتشـجيع علـى سـلوكيات الحدّ مـن المخاطـر. وقـد تشـكل الحوافـز الأدوات والهيـاكل القائمـة علـى السـوق، عنـد الاقتضـاء، والإقـرار بإمكانيـة طلـب البدائـل فـي حـالات الإخفاقـات الكبيـرة فـي السـوق.
- اسـتخدام الأدوات الماليـة الموجهـة نحـو المخاطـر مثـال التأمـين المحـدد بشـكل ملائـم وتجميـع المخاطـر وإمكانيـة الوصـول إلـى المـوارد الماليـة خـلال حـالات الطـوارئ المناخيـة وبعدهـا.

Table of contents

List of tables

List of figures

1. Introduction

Extensive evidence shows that changes in climate stemming from emissions of carbon dioxide (CO_2) and other Greenhouse Gases (GHGs) already impose economic costs on Lebanon's households, businesses, communities, and government (DARA and Climate Vulnerable Forum, 2012). For example, higher temperatures erode the health of children and the elderly, reduce the productivity of workers exposed to the heat, and reduce the productivity of crops. Reductions in water supplies diminish the wellbeing of water users throughout Lebanon. Changes in ecosystems impair their ability to provide valuable goods and services. Research also predicts more severe changes in climate—and costs for Lebanon—will occur in the future (IPCC, 2013b and IPCC, 2014).

This report quantifies many of these potential costs. To do so, it knits together information from the best available sources of data and most recent research. The results offer general calculations of the costs Lebanon's households, businesses, communities, and government might expect in 2020, 2040, and 2080. It also includes a summary discussion of approaches and principles that might be appropriate for reducing Lebanon's vulnerability to changes in climate and for strengthening its ability to respond to changes in a resilient, positive manner. Thus, it provides a foundation for better understanding the importance of making decisions—globally, nationally, and locally—to reduce GHG emissions and to prepare for changes in climate that cannot be avoided.

Structure of this report

Presentation of the analysis occurs in these sections:

- **Section 2** presents the conceptual framework for the analysis. It gives an overview of anticipated changes in climate resulting from global GHG emissions, ways in which these changes in climate might impose costs on Lebanon, and a summary of the analytical approach used to calculate some of these costs.
- **Section 3** quantifies the overall climate-related economic costs in 2020, 2040, 2080 resulting from past GHG emissions and from the anticipated emissions in each of those years if recent trends in emissions continue.
- **Section 4** quantifies several distinct types of cost that anticipated changes in climate would impose on Lebanon in 2020, 2040, and 2080.
- **Section 5** discusses approaches Lebanon's households, businesses, communities or government might take to prepare for and reduce the costs of anticipated changes in climate.
- **Annexes:** Annex I identifies stakeholders who participated in a consultation workshop held in Beirut in March 2015. Annex II summarizes calculations associated with three variables that lie at the core of the analysis: Lebanon's potential population, number of households, and temperature in 2020, 2040, and 2080. Annex III quantifies some potential costs from activities within Lebanon that contribute to climate change. Finally Annex IV presents some frequently asked questions related to this report.

Presentation format

The presentation of each type of cost follows this format:

Description: A brief explanation of the cost and how it is expected to materialize.

Results: A short discussion of the analytical results plus a table presenting the expected costs to Lebanon in 2020, 2040, and 2080. To facilitate the presentation, all costs are measured in 2015 USD millions. Sometimes, however, the text describing the costs may refer to those larger than USD 1,000 in the equivalent, billion-USD terms. Thus, a cost of USD 1,200 million is the same as USD 1.2 billion.

Assumptions, data, and calculation: A stepwise explanation of the analytical steps that were taken to complete the calculation of the results. This section also explains all assumptions and data used in the calculation.

Discussion: A brief summary of the context for understanding the calculation and results. As appropriate, this section identifies key factors that will likely influence the actual costs and explains reasons for anticipating that they will turn out to be higher. This information is intended to indicate ways in which the economic risk to Lebanon from climate change might be greater than shown by the cost estimates.

Uncertainty and rounding: Readers are encouraged to bear in mind that the costs shown in this report are estimates of the costs that global GHG emissions might impose on Lebanon. Each cost estimate embodies uncertainty about multiple factors: how the emissions will affect the climate, how the changing climate will affect ecosystems and socio-economic systems, how these effects will reduce the value of goods and services available to Lebanon's households, businesses, and government. Because of this uncertainty, it is impossible to estimate each cost with absolute precision. Instead, costs are approximated through the use of rounding. The rounding rules are:

When an analysis indicates a cost is:	The report rounds it to:
USD 1,000 million or higher	The nearest USD 100 million
Smaller than USD 1,000 million but larger that USD 99 million	The nearest USD 10 million
Smaller than USD 100 million but larger than 1 million	The nearest USD 1 million
Smaller than USD 1 million but larger than 999	The nearest USD 1 hundred
Smaller than USD 1,000	The nearest USD 10

These rounding rules are intended to communicate to readers the existence of uncertainty in a systematic manner. They are not intended to indicate the magnitude of the uncertainty associated with each cost estimate.

2. Conceptual framework

This section offers a short overview of human-caused climate change, and describes the ways in which future changes in climate might impose economic costs on Lebanon. It also explains the general analytical assumptions and approach used in the subsequent sections to estimate the monetary value of some of these costs.

2.1. Overview of the effects of global GHG emissions on climate

The Intergovernmental Panel on Climate Change (IPCC) (2013b; p. 11) has concluded that human-caused emissions of carbon dioxide, methane (CH_4), and nitrous oxide (N_2O), which have "increased to levels unprecedented in at least the last 800,000 years," likely underlie observed changes in climate. These changes include: increases in average surface temperature, changes in precipitation levels and patterns, increases in extreme weather events, rising sea level, acidification of oceans and other surface waters, and changes in ecosystems.

Looking forward, climate scientists and others are focusing on a set of scenarios, called Representative Concentration Pathways (RCPs), that project a range of plausible future levels of GHG emissions and atmospheric concentrations. The highest-emissions scenario is called RCP8.5, the lowest-emissions scenario is called RCP2.6.[1]

Figure 1 shows the trajectory of global GHG emissions expected under RCP2.6 and RCP8.5 through 2100. Figure 2 shows the accompanying expected changes in the global average surface temperature. Under the highest-emissions scenario, temperatures would increase on a near-linear trajectory throughout the century. With the lowest-emissions scenario, they would increase through the middle of the century and then level off. Average surface temperatures in 2081-2100 would exceed those that prevailed in 1986-2006 by about 4–6°C under RCP8.5, and 2°C under RCP2.6 (IPCC 2014; p. 10). These temperature increases would add to an increase of 0.61°C observed between 1850–1900 and 1986–2005 (IPCC, 2013b; p. 5).

[1] Four RCP scenarios of future GHG emissions, including RCP8.5 (highest) and RCP2.6 (lowest), underlie the IPCC's most recent, Fifth Assessment Report, summarized in IPCC (2013b) and IPCC (2014). These scenarios evolved from the IPCC's Special Report on Emissions Scenarios (IPCC, 2000), which considered about 40 different scenarios, but focused primarily on four (descending order): A1FA, A2, A1B, and B1. Scenario A1F1 corresponded most closely to, and somewhat exceeded RCP8.5; scenario B1 projected that emissions would remain substantially higher than those projected in RCP2.6 (Climate Change in Australia, 2015).

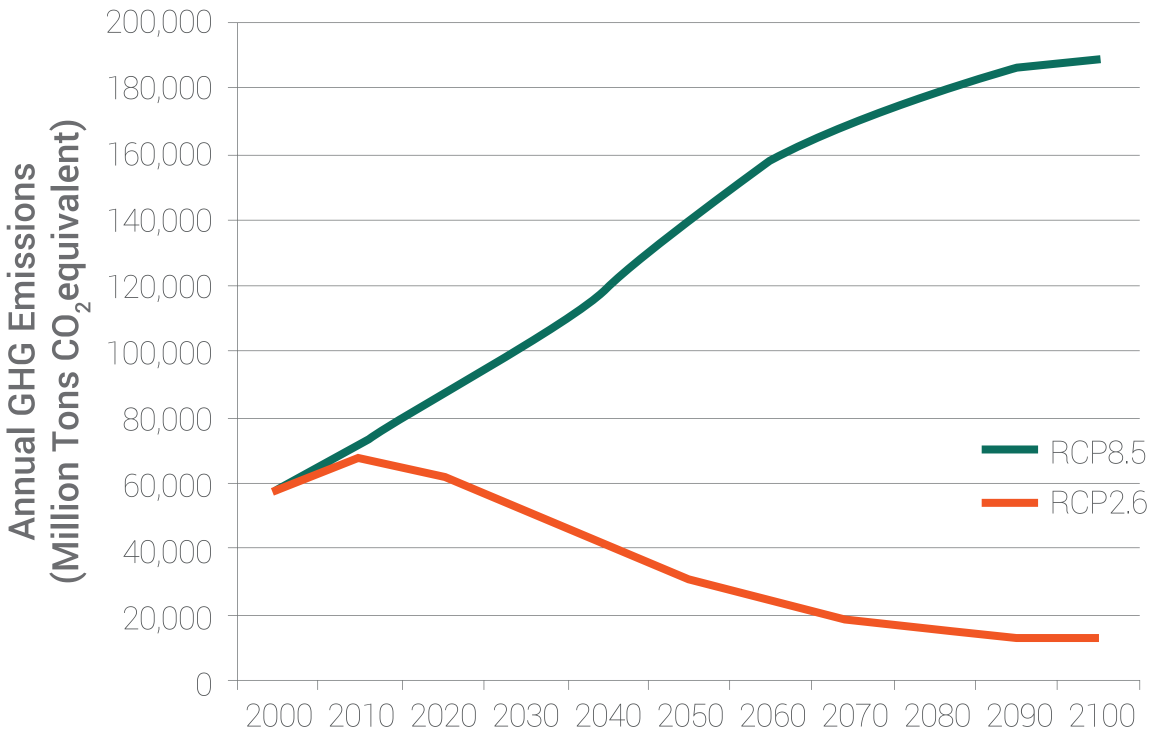


Figure 1. Actual GHG emissions, 2000 and 2010, and projected emissions under RCP8.5 and RCP2.6, 2020-2100

Source | RCP Database (2015) and Myrhe et al. (2013; p. 714)

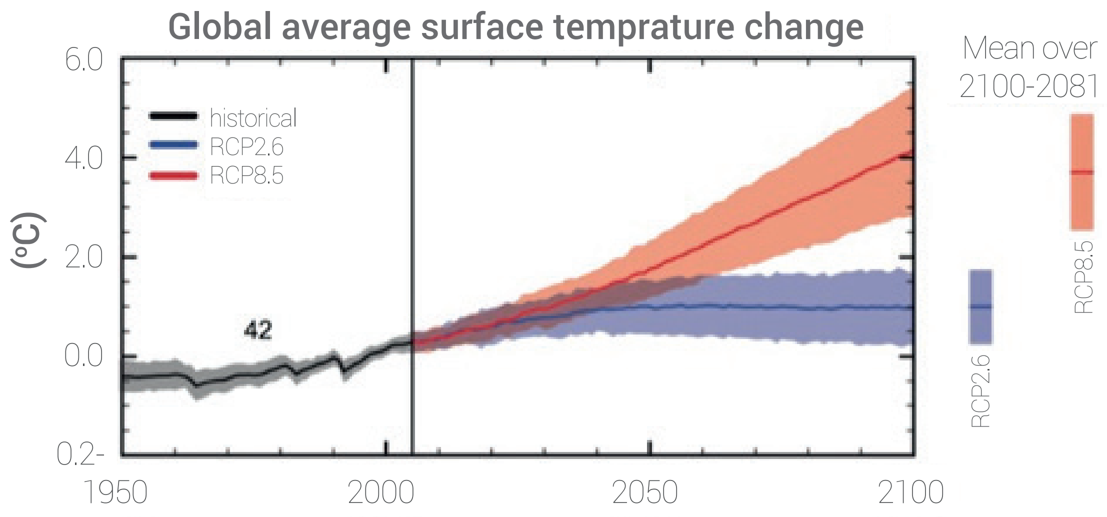


Figure 2. Observed changes in annual average surface temperature, 1950–2010, and projections under RCP8.5 and RCP2.6, 2020-2100

Source | IPCC (2013b; p. 21)

Figure 3 shows the spatial pattern of expected increases in average surface temperature under RCP2.6 and RCP8.5. Lebanon and other countries in the eastern Mediterranean region likely would experience some of the highest temperature increases.

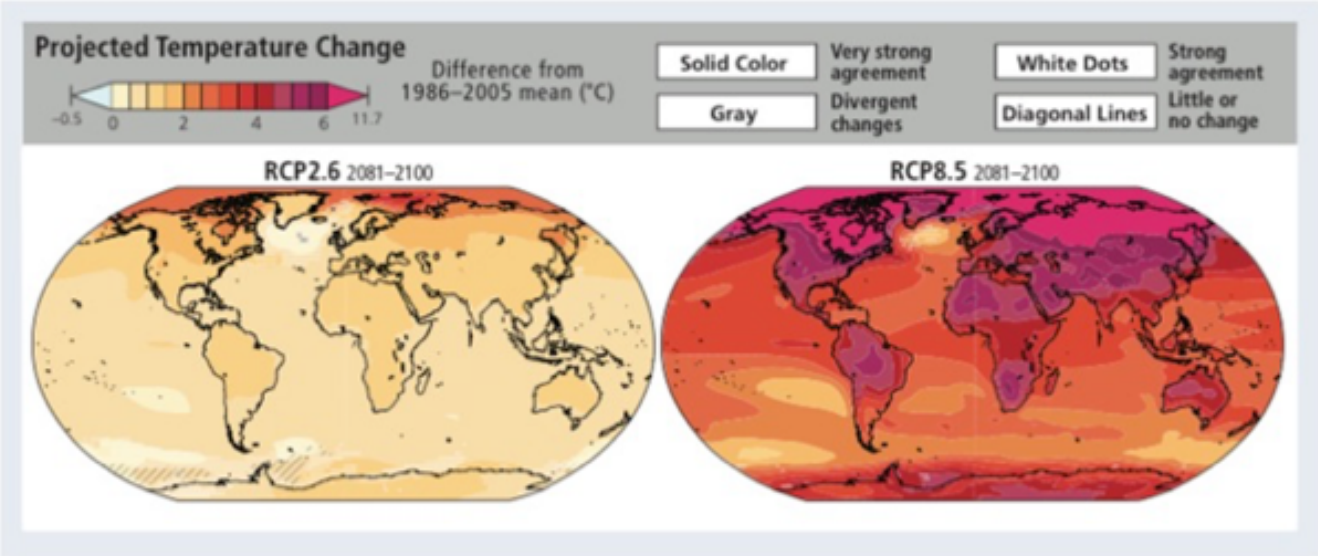


Figure 3: Projected increase in surface temperature, 2081–2100 vs. 1986–2005, resulting from global anthropogenic GHG emissions, RCP8.5 and RCP2.6

Source | IPCC (2013b; p. 20)

2.2. Overview of potential climate change impacts on Lebanon

The full effects on Lebanon of the anticipated increases in temperatures, changes in precipitation, rising sea levels, and other direct effects of continued global GHG emissions have not been quantified. MoE/UNDP/GEF (2011; pp. ix-xvii), however, has concluded that the effects likely will include the following:

- Relative to the present climate, temperatures will increase from around 1°C on the coast to 2°C in the mainland by 2040, and by 2090 they will increase 3.5°C to 5°C.
- Rainfall will decrease, relative to the present, by 10-20% by 2040, and by 25-45% by the year 2090. The total volume of water resources will decline 6 to 8% with an increase of 1°C and 12 to 16% with an increase of 2°C.
- By the end of the century, Beirut will see 50 more days with temperatures exceeding 35°C and 34 more nights with temperatures exceeding 25°C.
- Droughts will occur 15 days to 1 month earlier, and countrywide drought periods will extend 9 days longer by 2040 and 18 days longer by 2090. The already dry regions, such as the Bekaa, Hermel, and the South, will experience the sharpest effects. In addition, cost impacts will be added to irrigation needs, as more pumping hours will be required, therefore consuming more energy.
- Climate change will induce a reduction of 40% of the snow cover of Lebanon with an increase of 2°C in temperature and will reach 70% decrease in snow cover with an increase of 4°C.
- Less precipitation will fall as snow, with snow that currently falls at 1,500 m shifting to 1,700 m by 2050, and to 1,900 m by 2090. Snow will melt earlier in the spring. These changes will affect the recharge of most springs, reduce the supply of water available for irrigation during the summer, and increase winter floods by up to 30%.
- Soil moisture will decline in response to higher temperatures, reduced precipitation, and higher evapotranspiration.

- Changes in temperature and rainfall will decrease productivity of lands currently used to produce most crops and fruit trees—especially wheat, cherries, tomatoes, apples, and olives—and may affect the quality of grapes.
- Most crops also will face increased infestation of fungi and bacterial diseases.
- Higher temperatures in summer will increase demand for cooling, with related consumption of electricity increasing 1.8% for a 1°C increase in temperature, and 5.8% for a 3°C increase in temperature.
- Sea levels will rise up to 30-60 cm in 30 years, if the recent rate of rise, approximately 20 mm/year, continues. The higher sea levels will lead to seawater intrusion into aquifers, increase the risk of coastal flooding and inundation, increase coastal erosion, cover sand beaches, and alter coastal ecosystems in natural reserves and elsewhere.
- Changes in temperature and rainfall will reduce the extent of sub-humid forests and increase semi-arid forests, especially in higher-elevation transition zones. All forests will experience greater fragmentation, pest outbreaks, and wildfires.
- Lebanon will experience increases in the incidence of infectious diseases, morbidity, and mortality resulting from higher temperatures, more frequent extreme weather events, increased malnutrition from droughts and floods that affect agriculture, and reduced availability of clean water. Increases in temperatures will cause 2,483 to 5,254 additional deaths per year between 2010 and 2030.
- Buildings and public infrastructure will suffer damage from changing patterns in precipitation, sea level rise, and increased frequency and intensity of storms. This damage will materialize from inundation of coastal settlements and buildings, floods, mudslides, and rockslides.
- Winter outdoor tourism will diminish as warmer temperatures and reduced precipitation shorten the skiing season. Other impacts on tourism will occur in response to changes in ecosystems, loss of natural attractions, such as sandy public beaches, and structural damage to the nation's archaeological heritage.
- Impacts will concentrate on vulnerable population groups, especially the elderly and people living in socio-economically deprived areas, in semi-arid areas and in areas with lower access to health and other public services.

These, and similar, potential impacts constitute climate-related risks to Lebanon's ecological, social, cultural, and economic systems (IPCC, 2014; 12-20). As such, they provide the basis for describing the costs climate change might impose directly on Lebanon. They also provide context for understanding that changes in climate elsewhere might indirectly impose costs on Lebanon, e.g., by altering global or regional markets for food and other items.

2.3. Analytical assumptions and approach

The calculation of climate-related costs in monetary terms is a straightforward, three-part process:

First, obtain a credible, quantitative estimate of the per-year change in some factor—public health, agricultural production, energy costs, etc.—expected to result from climate change that will worsen the future economic wellbeing of households, businesses, or communities in Lebanon.

Second, obtain a credible estimate, in monetary terms (2015 US dollars), of the per-unit value of the factor.

Third, multiply the two estimates to yield an estimate of the potential economic harm per year. For those costs where others have developed a credible estimate of the quantitative change, the per-unit value, or both, this analysis employs that information. Where this information does not exist, this analysis estimates these variables directly. In every case, the results are sensitive to the reliability of the assumptions and data employed, which are documented.

The analysis focuses on estimating the costs climate change might impose on Lebanon in three target years: 2020, 2040, and 2080. The 2020 estimates generally represent near-term costs that cannot be avoided, insofar as the climate impacts of past GHG emissions are still unfolding, and inertia in economic systems and behaviors suggest that the current trends in climate and its effects likely would continue with little change. The 2040 estimates generally represent costs that likely would materialize within the lifetimes of most Lebanese citizens alive today. The 2080 estimates generally represent costs that likely would materialize within the lifetimes of today's children.

In some cases, there exist credible estimates for one or more of the target years, and the analysis uses that information directly. In others, there exist credible estimates for other years, and the analysis interpolates to get a value for a target year when it falls between two values available from the literature, or extrapolates when it falls outside them. In general, the interpolation and extrapolation involves estimating the average percentage rate of growth per year and assuming it would extend from 2020 to 2080. In some cases, available information suggests it would be more appropriate to interpolate or extrapolate assuming linear growth.

Whenever possible, the monetary calculations reflect the IPCC's current scenario with the highest levels of potential GHG emissions, known as Representative Concentration Pathway 8.5 (RCP8.5). The top line of Figure 1, above, shows this scenario. In many cases, however, estimates of climate-related impacts on Lebanon come from research that employed other scenarios of future GHG emissions. Some research reports identify the underlying scenario only in general terms. Whenever possible, the analysis identifies the scenario being employed.

The bottom line in Figure 1 illustrates expected emissions under the IPCC's current lowest-emissions scenario, known as RCP2.6. It includes the most extreme, yet plausible, assumptions about changes in economic development, behaviors, etc., beginning in 2010, that would yield reductions in GHG emissions. Insofar as such changes have not fully materialized, RCP2.6 likely overstates the potential reductions, at least for the near future. This bias notwithstanding, the analysis sometimes uses data from RCP2.6 to describe the potential costs Lebanon would avoid if global society took the steps necessary to move emissions from the path represented by RCP8.5 to the path represented by RCP2.6.

Other important assumptions embedded in this analysis include:

- The percentage changes in economic and social characteristics of Lebanon presented throughout this report are relative to a business-as-usual scenario of population and GDP growth. The business-as-usual scenario does not take into account the effect that political instability, social unrest or regional turmoil might inflict on predicted population and GDP growth. The business-as-usual scenario also does not take into account the elaboration and implementation of any new development plan that might change the performance of the main sectors of the economy in Lebanon.
- Lebanon's population will total 5.5 million in 2020, 6.0 million in 2040, and 5.9 million in 2080. It also will have 1.3 million households in 2020, 1.4 million in 2040, and 1.4 million in 2080. Annex II explains the derivation of these numbers.

- Without the effects of global GHG emissions, Lebanon's Gross Domestic Product (GDP) would grow from about USD 47.3 billion in 2015 to USD 55.4 billion in 2020, USD 104.1 billion in 2040, and USD 366.9 billion in 2080. (GDP is an indicator of the value of the annual output of the commercial, industrial, and governmental sectors of the economy.)
- Past GHG emissions have not yet produced their full impact on climate. Hence, some climate-related costs will materialize regardless of efforts to rein-in future GHG emissions.
- Lebanon's households, businesses, communities, and government will continue to engage in behaviors and adopt technologies similar to those of today. This assumption acknowledges the inertia that exists insofar as these behaviors—as well as the existing residential, commercial-industrial, and public capital—generally reflect climate conditions of the past rather than those of the future.
- In 2010 global GHG emissions over the preceding decades had raised annual average temperatures in Lebanon by 0.85°C, relative to the 1880-1919 reference period. If current trends in global GHG emissions continue, average annual temperatures in Lebanon will be higher. Relative to the reference period of 1880-1919, the increase will be: 1°C in 2020, 2°C in 2040, and 5°C in 2080. Relative to 2010, the increase will be: 0.15°C in 2020, 1.15°C in 2040, and 4.15°C in 2080. Annex II also explains the derivation of these numbers.
- Some of the estimates of climate-related costs presented below derive from prior analyses that incorporate different assumptions about Lebanon's population, or the expected climate-related increases in temperature. The associated text explains the differences.

Both market costs and non-market costs are important. Market costs would quickly materialize as lower disposable incomes for households, higher costs and lower net revenues for businesses, and higher costs or lower financial resources for government. Higher temperatures, for example, could reduce workers' productivity, reducing their incomes and the output of business and government. Non-market costs might yield such outcomes more slowly. If future climate-related droughts were to displace farm families from their homes, or sea-level rise was to displace coastal families, for example, the resulting disruption might lower the ability of children to secure a good education and lower their earnings as adults. By their nature, non-market costs are not measured by market prices. Instead, measuring them requires targeted studies that look at how people express their desire for non-market goods and services or at how they respond to differences in these items. In general, such studies are lacking for non-market goods and services potentially susceptible to the impacts of climate change in Lebanon.

Hence, this report does not measure the value of the non-market costs resulting from climate change. This omission likely causes it to substantially understate the full costs climate change would impose on Lebanon if current trends in global GHG emissions continue.

Available information suggests the results reported herein generally understate the true, potential economic costs that climate change would impose on Lebanon if current trends in GHG emissions continue. Moreover, as global GHG emissions endure, the likelihood that they will accelerate changes in climate and initiate irreversible changes in ecosystems and social systems will increase. Hence, the degree of understatement will likely grow larger as GHG emissions continue over time.

Some of the potential costs, especially in the near term, may not actually materialize, as projected as households, businesses, and communities may take steps to mitigate or offset them. As higher temperatures reduce food production, for example, the prices of some foodstuffs would likely rise and stimulate actions to develop replacement, drought-tolerant crops. The analysis in Sections 3 and 4, however, describe the potential costs if such steps are not taken or are not effective.

3. The overall economic costs that future global GHG emissions might impose on Lebanon

This section illustrates the overall economic costs that climate change might impose on Lebanon's families, businesses, communities, and government over the next several decades if recent trends in global GHG emissions continue. It sets the stage for the analyses in Section 4, which illustrate the potential disaggregated costs associated with several, distinct ways in which climate change might affect Lebanon's workers, households, businesses, communities, and ecosystem (cost of impact on water resources, agriculture, tourism, etc.).

The section presents 4 analyses. They look from different perspectives at the total costs climate change might impose on Lebanon:

1. The total costs that Lebanon might experience in 2020, 2040, and 2080 from the cumulative effects of global GHG emissions between 2015 and each of those years.
2. The costs from single-year emissions in 2020, 2040, and 2080.
3. The extent to which costs could be avoided if nations around the world acted soon to rein-in global GHG emissions. It compares costs expected under the IPCC's lowest-emissions scenario, RCP2.6, against the highest-emissions scenario, RCP8.5.
4. The potential distribution of costs among different groups within Lebanon. It distinguishes among the costs to urban, rural farm, and rural nonfarm households. Within each group, it distinguishes among the costs to households with different levels of income.

3.1. Potential costs from cumulative global GHG emissions

Description

This analysis calculates the costs Lebanon might experience in 2020, 2040, and 2080 from the cumulative effects of GHG emissions between 2015 and each of those years. It recognizes that, once emitted into the atmosphere, CO_2 and other GHGs will change the climate and impose economic costs on Lebanon for decades, perhaps hundreds of years. The changes in climate—and accompanying costs—from each year's emissions will build atop the effects of emissions from previous years, including years prior to 2015.

The analysis considers two major categories of potential costs. One is the reduction in Gross Domestic Product (GDP) that would occur as changes in climate reduce the rate of Lebanon's economic growth. The other is the economic damage that would materialize each year through climate-related changes in net agricultural productivity, human health, the impacts of floods and storms on property, the value of services derived from Lebanon's ecosystems, etc.

Results

Table 1 shows the potential costs Lebanon might experience from the cumulative effects of global GHG emissions if recent trends continue through 2020, 2040, and 2080. Emissions between 2015 and 2020 would impose direct damage costs from drought, etc. of about USD 320 million and cause Lebanon's GDP to be about USD 1,600 million (equivalent to USD 1.6), or 3%, smaller in 2020 than it otherwise would be. The forgone GDP would be about USD 14,100 million (14%) in 2040, and USD 115,700 million (32%) in 2080.

The total cost, USD 1,900 million, in 2020 would be equivalent to about USD 1,500 per household, on average. The government would bear about USD 610 million of the total cost if it were to maintain its current general role in the economy. The overall cost resulting from global GHG emissions between 2015 and 2040, and between 2015 and 2080, would total USD 16,900 million in 2040 and USD 138,900 million in 2080.

These numbers suggest that the average cost per household would likely exceed average household annual earnings soon, which currently are about USD 12,000[2], with many households becoming impoverished. If the government were to maintain its current general role in the economy, its share of the overall costs would total about USD 610 million in 2020, USD 5,400 million in 2040, and USD 44,300 million in 2080. These costs could represent sizeable portions of government's budgets, insofar as its 2012 expenditures were about USD 72,000 million (Ministry of Finance, 2013; p. 3). The actual budgetary impact of climate change on government could be higher, especially if it accepts new responsibilities for addressing needs associated with the anticipated increases in household poverty.

Table 1: Potential costs for Lebanon from the cumulative effects of global GHG emissions, 2015–2020, –2040, and –2080 (2015 USD)

	2020	2040	2080
Direct annual damage from drought, etc. in Lebanon (millions)	USD 320	USD 2,800	USD 23,200
Forgone GDP in Lebanon (millions)	USD 1,600	USD 14,100	USD 115,700
Percentage reduction in GDP	3%	14%	32%
Total cost to Lebanon (millions)	USD 1,900[a]	USD 16,900	USD 138,900
Average cost per household in Lebanon	USD 1,500	USD 13,100	USD 107,200
Government's share (millions)	USD 610	USD 5,400	USD 44,300

Numbers reflect the rounding rules described in the Introduction.

[a] Because of rounding, the total, USD 1,900 million differs slightly from the sum of USD 320 million and USD 1,600 million.

Assumptions, data, and calculation

This analysis first calculates the forgone GDP in 2020, 2040, and 2080 that would result from the cumulative effects of future global GHG emissions, if recent trends in emissions continue. The calculation draws on Moore and Diaz (2015), which finds that, if unchecked, global GHG emissions would reduce the growth of GDP from 3.2% to 2.6% through the remainder of this century in countries unable to respond to major extreme events with no discernible negative effect on GDP.

The analysis then calculates the direct damage that would materialize in each of the three years, building on a comparison of Interagency Working Group on Social Cost of Carbon (2015) with

[2] Average earnings per household calculated by dividing workers' total earnings by the number of households. Total 2010 earnings = annual earnings per worker times total employment = USD 10,500 per worker x 1,300,000 workers = USD 14,000 million (Robalino and Haneed, 2012, and Alloush et al., 2013; adjusted to 2015 USD). Number of households in 2010 = population / persons per household = 5.0 million ÷ 4.23 = 1.2. (Population from Ministry of Environment (2015), household size from Central Administration of Statistics (2015a)). Earnings per household = total earnings ÷ number of households = USD 14,000 million ÷ 1.2 million households = USD 12,000 per household.

Moore and Diaz (2015). The former summarizes recent literature regarding the models widely used to describe the economic costs of climate change. These models typically have captured the transient (annual) damage of climate change, but assumed this annual damage would have no long-term effects on the economy. Moore and Diaz (2015) represents an important landmark effort to capture the long-term reduction in GDP growth stemming from the effects of climate change on the productivity of labor and capital.

Finally, the analysis calculates the total costs, average cost per household, and government's share of the costs. The calculations involve these steps:

Step 1. Calculate the forgone GDP in 2020, 2040, and 2080. Begin with Lebanon's estimated 2014 GDP, USD 45,730 million (World Bank, 2015c). Estimate GDP in 2020, 2040, and 2080 under two scenarios regarding annual GDP growth: one assumes 3.2% and the other assumes 2.6%. The difference between the two represents the forgone GDP resulting from the cumulative effects of global GHG emissions in future years. Table 1 shows the results: USD 1,600 million in 2020, USD 14,100 million in 2040, and USD 115,700 million in 2080.

Step 2. Calculate the direct annual damage in 2020, 2040, and 2080. Assume that the direct damage in each year would be about one-fifth as large as the forgone GDP, based on comparison of Moore and Diaz (2015) with Interagency Working Group on Social Cost of Carbon (2015). Table 1 shows the results.

Step 3. Calculate total cost per year in 2020, 2040, and 2080. Add the forgone-GDP costs to the direct-damage cost to yield the total cost. Table 1 shows the results.

Step 4. Calculate the average cost per household. Annex II shows the calculation of the future number of households: 1.3 million in 2020, 1.4 million in 2040, and 1.4 million in 2080. Divide each year's total costs by number of households to yield the average cost per household. Table 1 shows the results.

Step 5. Calculate the government's share of the total cost. Assume government's share of the costs would be 32%, which is the ratio between its expenditures and GDP (Ministry of Finance, 2013: p. 3). Table 1 shows the results.

Discussion

The actual costs might be higher or lower than those shown in Table 1. It seems reasonable, however, to conclude that the actual costs likely would be higher. The two economic studies that form the foundation for this analysis, Interagency Working Group, (2015) and Moore and Diaz (2015), capture only a portion of the impacts of hotter temperatures and changes in precipitation on economic output. More recent research (Burke, Hsiang, and Miguel 2015) concludes that anticipated increases in climate warming will yield costs perhaps 100 times larger than indicated by prior estimates, with the largest costs occurring in regions, such as the Middle East, that already experience high temperatures. Researchers have not yet reconciled these different studies. The findings reported by (Burke, Hsiang, and Miguel 2015) suggest, however, that the actual reduction in GDP might be substantially larger than those derived from Interagency Working Group, (2015) and Moore and Diaz (2015).

Moreover, this analysis does not capture the persistent effects of global GHG emissions before 2015 (Solomon, 2010). It also does not capture the costs that economists have not yet reliably modeled. These include, but are not limited to, the costs associated with the effects of CO_2 emissions on ocean acidification (Secretariat of the Convention on Biological Diversity, 2014), or the costs that might materialize if global GHG emissions trigger catastrophic local, regional, or global outcomes (King et al., 2015).

Combined, these studies suggest that, if current trends continue, global GHG emissions likely would impose costs on Lebanon much larger than those shown in Table 1.

3.2. Potential costs from annual global GHG emissions

Description

This analysis considers the costs of global GHG emissions from a different perspective. Rather than describing the costs resulting from the cumulative effects on climate of all future emissions through 2020, 2040, and 2080, it looks at the costs that would result from the annual emissions in each of these years.

Consistent with the analysis in the preceding section, this analysis considers two types of costs. One is the direct economic damage that would materialize as these emissions contribute to future extreme weather events and other changes in climate that would destroy crops, impose heat stress on workers, etc. The other is the forgone GDP that would materialize as the economic damage reduces growth in the economy's ability to produce goods and services for consumers and income for workers and property owners. The indicated cost for each year is a single number equivalent in value to the stream of costs that would materialize in subsequent years as a result of that year's GHG emissions. Called the present value, this number is calculated using a process called discounting, through which the value of a cost some years in the future is reduced for each of those years by an annual discount rate. This analysis uses a discount rate of 3% per year, reflecting the core analysis of Interagency Working Group on Social Cost of Carbon (2015).

Results

The numbers in Table 2 represent the costs that the annual global GHG emissions in 2020, 2040, and 2080 potentially would impose on Lebanon under the IPCC's highest-emissions scenario, RCP8.5.

The analysis suggests that, if current trends continue, annual GHG emissions in 2020 would impose costs on Lebanon totaling USD 21,200 million. Of this total, about USD 17,600 million, would materialize as the climate change slows growth in GDP. The direct, annual economic damage from droughts, storms, heat waves, diseases, etc. would be smaller, about USD 3,600 million. Costs resulting from annual global emissions in 2040 and 2080 would total USD 80,700 million, and USD 1,009,700 million, respectively, with forgone GDP accelerating faster than direct damage costs. Dividing by the estimated number of households in each year indicates annual global emissions in 2020, 2040, and 2080 would impose costs per household, on average, of USD 16,400, USD 57,300, and USD 721,900, respectively. The present value of the costs borne by government would total USD 6,800 million for emissions in 2020, USD 25,800 million for emissions in 2040, and USD 322,000 million for emissions in 2080.

Table 2: Present value of economic costs that global GHG emissions in 2020, 2040, and 2080 would impose on Lebanon under the highest-emissions scenario, RCP8.5 (2015 USD)

	2020	2040	2080
Potential costs if global emissions follow the IPCC's highest-emissions scenario (RCP8.5)			
Direct annual damage from drought, etc. in Lebanon (millions)	USD 3,600	USD 11,300	USD 101,500
Forgone GDP in Lebanon (millions)	USD 17,600	USD 69,400	USD 908,200
Total cost to Lebanon (millions)	USD 21,200	USD 80,700	USD 1,009,700
Average cost per household in Lebanon	USD 16,400	USD 57,300	USD 721,900
Government's share (millions)	USD 6,800	USD 25,800	USD 322,000

Numbers reflect the rounding rules described in the Introduction.

Assumptions, data, and calculation

This analysis calculates first the total global economic costs that would result from global GHG emissions in 2020, 2040, and 2080, and then the share of the global total that would materialize in Lebanon. The calculation involves these steps:

Step 1. Estimate the additional tonnes of GHGs (CO_2-equivalent) that would be emitted in 2020, 2040, and 2080 under RCP8.5.[3] Results, in billion tonnes CO_2-equivalent per year: 25 in 2020, 66 in 2040, and 162 in 2080.

Step 2. Estimate the present value of the global economic cost that would materialize in subsequent years per tonne of annual global GHG emissions in 2020, 2040, and 2080. Present value is measured in the year of emissions, i.e., 2020, 2040, or 2080. That is, a cost shown for 2020 represents the present value in 2020 of all the costs that would materialize, in subsequent years, from GHG emissions in that year. To facilitate comparison among 2020, 2040, and 2080, all costs are shown in 2015 USD.

- Apply estimates of economic damage per tonne of expected CO_2-equivalent emissions (Interagency Working Group on Social Cost of Carbon, 2015), adjusted to 2015 USD: USD 69 in 2020, USD 176 in 2040, and USD 947 in 2080.
- Apply estimates of the global reduction in GDP per tonne of expected CO_2-equivalent emissions using results derived from Moore and Diaz (2015) and Moore (2015): USD 335 in 2020, USD 1,080 in 2040, and USD 8,480 in 2080.[4]

Step 3. Calculate the total present value of the global costs of future annual emissions. Multiply the tonnage of annual global GHG emissions in 2020, 2040, and 2080 times the cost per tonne for economic damage and reduced economic growth.

[3] Emissions of CO_2, CH_4, and N_2O come from IPCC (2013a). Emissions of CH_4 and N_2O converted to their CO_2-equivalent based on global warming potentials reported by Myhre et al. (2013).

[4] Moore and Diaz (2015) finds that, under a business-as-usual scenario, climate change likely would reduce the average annual growth rate from 3.2% to 2.6% in regions that lack the economic and institutional strength to recover from extreme events with no discernible negative effect on GDP. Values for emissions in 2020, 2040, and 2080 estimated by subtracting economic damage cost per tonne CO_2-e from estimates of the total cost (Moore 2015). Values in 2007 USD adjusted to 2015 USD with the personal consumption expenditures index from St. Louis Federal Reserve Bank (2015).

Step 4. Calculate Lebanon's share of global costs. Assume its share would be 0.06%, which is its share of both world population (World Bank, 2015e) and world GDP (World Bank, 2015c). Table 2 shows the results.

Step 5. Calculate the average cost per household. Annex III shows the calculation of the future number of households: 1.3 million in 2020, 1.4 million in 2040, and 1.4 million in 2080. Divide each year's total costs by number of households to yield the average cost per household. Table 2 shows the results.

Step 6. Estimate government's share of the total costs. Assume government's share of the costs would be 32%, which is the ratio between its expenditures and GDP (Ministry of Finance, 2013; p. 3). Table 2 shows the results.

Discussion

The actual costs might be higher or lower than those shown in Table 2. It seems reasonable to conclude that this analysis likely understates the overall costs future global GHG emissions would impose on Lebanon under the IPCC's highest-emissions scenario. Recently published research concludes that anticipated increases in climate warming will yield costs at least 2.5 times larger—and perhaps 100 times larger—than indicated by prior estimates, with the largest costs occurring in regions, such as the Middle East, that already experience high temperatures (Burke, Hsiang, and Miguel 2015). These findings suggest that, if current trends continue, global GHG emissions would impose costs on Lebanon of at least USD 53,000 million for emissions in 2020, USD 201,900 million for emissions in 2040, and USD 2,524,200 million for emissions in 2080.

Moreover, this analysis does not capture the costs that economists have not yet reliably modeled. These include, but are not limited to, the costs associated with the effects of CO_2 emissions on ocean acidification (Secretariat of the Convention on Biological Diversity, 2014), or the costs that might materialize if global GHG emissions trigger catastrophic local, regional, or global outcomes (King et al., 2015).

Note that the values shown in Table 2 represent the present value, in 2020, 2040, and 2080, respectively, of all the costs that would materialize in subsequent years from GHG emissions in each of those years. As such, they are not directly comparable to results of other analyses that show the costs that would materialize only in 2020, 2040, or 2080.

3.3. Potential savings if global GHG emissions slow to the IPCC's lowest-emissions scenario

Description

This analysis describes the potential reductions in Lebanon's economic costs from annual global GHG emissions in 2020, 2040, and 2080, if emissions follow the IPCC's lowest-emissions scenario, RCP2.6, rather than follow current trends represented by the IPCC's highest-emissions scenario, RCP8.5.

Results

The numbers in Table 3 represent the costs that annual global GHG emissions in 2020, 2040, and 2080 would impose on Lebanon under the IPCC's lowest-emissions scenario, RCP2.6. Most of the costs would materialize through reductions in economic growth, represented as forgone GDP, with smaller costs occurring as the GHG emissions lead to increases in economic damage from droughts, etc. Under the lowest-emissions scenario, emissions in 2020, 2040, and 2080 would impose costs of USD 15,000 million, USD 30,000 million, and USD 91,000 million, respectively.

The indicated cost for each year is a single number equivalent in value to the stream of costs that would materialize in subsequent years as a result of that year's GHG emissions. Called the present value, this number is calculated using a process called discounting, through which the value of a cost some years in the future is reduced for each of those years by an annual discount rate. This analysis uses a discount rate of 3% per year, reflecting the core analysis of Interagency Working Group on Social Cost of Carbon (2015).

Table 3 also shows the potential savings, relative to the expected costs (described in sub-section 3.2) under the highest-emission scenario, RCP8.5. The analysis suggests that taking appropriate actions to rein-in global emissions of greenhouse gases would potentially yield savings for Lebanon of USD 6,000 million in 2020, USD 49,900 million in 2040, and USD 918,400 million in 2080. These amounts represent average savings per household of USD 4,700, USD 35,500, and USD 656,600, respectively. If the government were to maintain its current general role in the economy, it would realize savings of USD 1,900 million, USD 15,900 million, and USD 292,900 million respectively.

Table 3: Present value of economic costs that global GHG emissions in 2020, 2040, and 2080 would impose on Lebanon under the lowest-emissions scenario, RCP2.6, and potential savings relative to the highest-emissions scenario, RCP8.5 (2015 USD)

	2020	2040	2080
Potential costs if global emissions follow the IPCC's lowest-emissions scenario (RCP2.6)			
Direct annual damage from drought, etc. in Lebanon (millions)	USD 2,600	USD 4,300	USD 9,200
Forgone GDP in Lebanon (millions)	USD 12,600	USD 26,500	USD 82,100
Total cost to Lebanon (millions)	USD 15,200	USD 30,800	USD 91,300
Average per household in Lebanon	USD 11,700	USD 21,900	USD 65,200
Government's share (millions)	USD 4,800	USD 9,800	USD 29,100
Potential savings from reducing global emissions to the lowest-emissions scenario			
Percentage of costs under RCP8.5	72%	38%	9%
Potential savings to Lebanon (millions)	USD 6,000	USD 49,900	USD 918,400
Average per household in Lebanon	USD 4,700	USD 35,500	USD 656,600
Government's share (millions)	USD 1,900	USD 15,900	USD 292,900

Numbers reflect the rounding rules described in the Introduction.

Assumptions, data, and calculation

This analysis applies the analytical process used in sub-section 3.2 to estimate what Lebanon's costs would be if emissions follow the path of RCP2.6. It then compares these costs to those under RCP8.5, reported in the preceding section. The difference in costs represents the economic savings Lebanon would potentially realize if it and other nations act quickly and aggressively to rein-in global GHG emissions.

Discussion

The actual savings from curtailing global GHG emissions might be higher or lower than those shown in Table 3. All else equal, however, it seems reasonable to conclude that the savings would be greater, insofar as the two scenarios do not capture all the potential costs global GHG emissions would impose on Lebanon.

Note that the values shown in Table 3 represent the present value, in 2020, 2040, and 2080, respectively, of all the costs that would materialize in subsequent years from GHG emissions in each of those years. As such, they are not directly comparable to results of other analyses that show the costs that would materialize only in 2020, 2040, or 2080.

3.4. Potential costs borne by rural and urban households with different levels of income

Description

This analysis describes the extent to which climate-related costs would affect the incomes of different groups within Lebanon. Specifically, it shows the potential percentage reduction, relative to 2010, in average income per household for urban, rural nonfarm, and rural farm households. It also describes, for each group, the percentage reduction in income for households with different levels of income, represented by income quintile.

Results

The numbers in Table 4 show the percentage reductions in average household income, relative to 2010, that would occur in 2020, 2040, and 2080 because of anticipated changes in climate. They embody an assumption that the findings from an assessment by Verner and Breisinger (2013; p. 44) of the potential impacts of climate change on household incomes in Syria apply to households in Lebanon. These findings reflect one of the medium-emissions scenarios, A1B, developed by the IPCC before it developed the RCP scenarios. Hence, if human-caused GHG emissions follow the path underlying IPCC's highest-emission scenario, RCP8.5, households likely would experience larger reductions in income than those shown in Table 4.

The top row of Table 4 indicates that, if current trends in global GHG emissions continue, the resulting changes in climate would reduce the average income in 2020 of the highest quintile of urban households by an amount equal to about 12%. The bottom row of the third section of Table 4 indicates that anticipated changes in climate would reduce the average income of the lowest quintile of rural nonfarm households equal to about 24% of the 2010 income by 2020, 56% by 2040, and 86% by 2080. Other households fall between the two extremes indicated by the top line and the bottom row of the third section.

The bottom section shows the potential monetary reductions in income, by quintile, for Lebanon as a whole. The top row of this section indicates that, if current trends in global GHG emissions continue, the resulting changes in climate would reduce the average income in 2020 of the highest quintile of all households by about USD 14,400, relative to 2010. By 2040 and 2080, the reductions for this quintile would grow to USD 37,200 and USD 65,700, respectively. The bottom row of this section shows that, for the lowest-income quintile, the potential changes in climate would reduce the mean household income by USD 3,900 in 2020, USD 9,300 in 2040, and USD 14,600 in 2080, relative to 2010.

Assumptions, data, and calculation

This analysis involves these steps:

Step 1. Assume that projections, from Verner and Breisinger (2013; p. 44), of the average annual percentage reduction, from 2010 to 2050, in household income for Syria apply to Lebanon for reductions from 2010 to 2020, 2040, and 2080.

Step 2. Calculate, for each group and quintile, the cumulative percentage reduction in household income by 2020, 2040, and 2080. Table 4 shows the results.

Step 3. Calculate, for all households and by income quintile, the mean monetary reduction in household income by 2020, 2040, and 2080.

- Calculate the mean household income in Lebanon. Assume mean annual gross national income per capita in Lebanon in 2010 was about USD 8,500 (World Bank, 2015d, adjusted to 2015 USD). Assume 4.23 persons per household (see Annex II for description of household size). Result: USD 35,800 per household.
- Assume that the distribution of income, by quintile, resembles the distribution of consumption expenditures (El-Laithy, Abu-Ismail, and Kamal Hamdan, 2008). Result: 8% of gross national income for quintile 1 (lowest income), 13% for quintile 2, 16% for quintile 3, 24% for quintile 4, and 44% for quintile 5 (highest income). [Note: percentages do not sum to 100% because of rounding.]
- Calculate the mean income per household for each quintile. Result: USD 17,900 for quintile 1 (lowest income), USD 29,100 for quintile 2, USD 35,800 for quintile 3, USD 53,800 for quintile 4, and USD 98,600 for quintile 5.
- Assume that the reduction in annual income because of climate change for each quintile in Lebanon as a whole is the average for urban, rural-farm, and rural non-farm households.
- Calculate the reduction in annual income for each quintile from 2010 to 2020, 2040, and 2080. Multiply the mean income for each quintile times the arithmetic mean of the percentage reduction in income (urban, rural farm, and rural nonfarm) for the quintile. Table 4 shows the results.

Discussion

Actual percentage and monetary reductions in income may be higher or lower than those shown in Table 4. The numbers in Table 4 illustrate some general patterns. Urban households generally would experience smaller percentage reductions in income, followed by rural farm households and rural nonfarm households. For each group, households with the lowest incomes would experience the largest percentage reductions, and those with higher incomes would experience smaller reductions. These patterns reflect expectations that urban households and high-income households generally will have greater resiliency to the effects of climate change. That is, they likely would have more opportunities to find replacement jobs and sources of income if they suffer a climate-related disruption of existing jobs. Similarly, rural farm households likely would have greater resiliency than rural nonfarm households insofar as higher crop prices resulting from climate change would boost their incomes and somewhat offset other impacts of climate change.

Table 4: Percentage reductions, relative to 2010, in average Lebanese household income for urban, rural farm, and rural nonfarm households, by income quintile, 2020, 2040, and 2080

Year of emissions	2020	2040	2080
Urban households, percentage reductions by income quintile			
5 (highest income)	12%	32%	60%
4	16%	40%	69%
3	17%	43%	73%
2	18%	45%	75%
1 (lowest income)	20%	49%	80%
Rural farm households, percentage reductions by income quintile			
5 (highest income)	16%	41%	71%
4	19%	46%	77%
3	18%	45%	75%
2	18%	45%	75%
1 (lowest income)	20%	49%	80%
Rural nonfarm households, percentage reductions by income quintile			
5 (highest income)	16%	40%	69%
4	20%	49%	80%
3	20%	49%	80%
2	21%	51%	81%
1 (lowest income)	24%	56%	86%
All households, monetary reductions by income quintile[a]			
5 (highest income)	USD 14,400	USD 37,200	USD 65,700
4	USD 9,800	USD 24,300	USD 40,400
3	USD 6,600	USD 16,400	USD 27,200
2	USD 5,500	USD 13,600	USD 22,400
1 (lowest income)	USD 3,900	USD 9,300	USD 14,600

[a] Numbers reflect the rounding rules described in the Introduction.

4. Costs that climate change might impose on segments of Lebanon's economy and society

This section presents illustrative calculations of several types of economic costs that climate change might impose on different segments of Lebanon's economy and society in 2020, 2040, and 2080. Participants in a stakeholder consultation workshop in Beirut on 19 March 2015 separated into three groups, discussed different types of potential costs, and ranked their analytical priorities, as shown in Table 5. See Annex I for a list of the participants and affiliated institutions. The priorities generally reflect the participants' awareness of different ways in which climate change might impose costs on Lebanon based on their expertise, knowledge of information about their potential economic importance, and perceptions of the public's concern.

Table 5: Priorities for cost analysis recommended by stakeholder groups

High priority	Medium priority	Low priority
Group 1		
Water (availability and quality)	Energy (increased demand for heating and cooling, reduced hydropower)	Animal production
Flooding	Public health	Biodiversity (loss of species and ecosystem services, erosion, tourism)
Social impacts (rural livelihoods, conflict migration, poverty, economic growth)	Infrastructure (energy, coastal, buildings, transportation)	--
Agriculture (crop production)	--	--
Group 2		
Agriculture (crop production, loss of arable land)	Infrastructure (transportation, urban, new technologies, maintenance costs)	Public health (vector-borne diseases, heat waves, air pollution)
Water (cost of storage, pollution, falling water tables)	Energy (reduced hydropower, more demand for heating and cooling)	--
Ecosystem impacts (desertification, loss of biodiversity, loss of snow)	--	--
Social impacts (rural-urban migration, security problems)	--	--
Group 3		
Tourism (summer and winter, ski season, sandy beaches, water needs, forest fires)	Sea level rise	Energy (hydropower supplies)
Water (scarcity)	Biodiversity	--
Agriculture (rainfed, irrigation costs, labor costs)	Forest fires	--
--	Energy (increased demand in peak season)	--

Source | stakeholder meeting, 19 March 2015.

Beginning with this set of priorities, a subsequent review of the readily available, relevant information determined there is sufficient information to describe the potential costs to Lebanon from the potential impacts of climate change on:

1. Agriculture and food consumption
2. Water
3. Natural disasters
4. Tourism
5. Electricity
6. Human health
7. Society
8. Ecosystems

4.1. Costs from impacts of climate change on agriculture and food consumption

If global GHG emissions continue current trends, the resulting changes in climate would impose costs on Lebanon by reducing the productivity of farms, and by increasing the prices households pay for food. The following analyses describe:

1. Economy-wide costs associated with climate-related reductions in overall agricultural production.
2. Costs to producers from reductions in the production of wheat and maize.
3. Costs to the coastal fishing industry and aquaculture producers from reductions in fish harvest.
4. Costs to consumers from increases in the global price of food.

4.1.1. Reductions in Lebanon's overall agricultural production

Description

Anticipated changes in climate would reduce Lebanon's agricultural production by raising ambient temperatures and reducing precipitation to levels harmful to both crops and livestock. Further impacts on production might occur through the impacts of more severe storms and floods, and the effects of climate-related spreading of diseases and pests.

Results

Table 6 shows the economic costs that would materialize in 2020, 2040, and 2080 as changes in climate increasingly reduce agricultural output below what would otherwise occur. The estimated costs derive from Haddad et al. (2014), which modeled changes in agricultural production and their ripple-effects through the overall economy. The projections focus on the effects of climate change on five main crop types: cereals; fruit trees; olives; industrial crops, such as sugar beets[5] and tobacco; and vegetables, such as potatoes (a strategic crop).

In 2020, the value of farm production would fall about USD 80 million below the level that would occur without the anticipated changes in climate. This reduction would ripple through the economy, with the manufacturing and services sectors, combined, experiencing a reduction in

[5] Although Lebanon does not currently produce sugar beets, this analysis takes them into consideration because they were included in the data underlying Haddad et al. (2014), which serves as the basis for the analysis.

production of about USD 220 million. The overall reduction in GDP would total USD 300 million. Of this total reduction in GDP, USD 16 million would materialize as reductions in funds available for general spending on government programs. Reductions in economic activity—in agriculture and other sectors—would lead to reductions in household incomes. As a consequence, household consumption of food and other goods and services would fall throughout Lebanon by about USD 170 million, or USD 130 per household on average. Exports, primarily of agricultural products, would fall by USD 72 million; imports would increase by USD 10 million; and economy-wide investment would fall by USD 47 million. The total reduction in GDP from anticipated effects of climate change on Lebanon's agricultural sector would equal about USD 860 million in 2040, and USD 2,300 million in 2080.

Table 6: Potential economic costs per year from climate-related reduction in Lebanon's agricultural output (2015 USD)

Year	2020	2040	2080
Costs per year to crop and livestock producers in Lebanon (millions)	USD 80	USD 180	USD 480
Costs per year to manufacturing and service sectors in Lebanon (millions)	USD 220	USD 690	USD 1,900
Total costs (reduction in GDP) per year in Lebanon (millions)	USD 300	USD 860[a]	USD 2,300[b]
Reduced government expenditure in Lebanon (millions)	USD 16	USD 30	USD 80
Reduced household consumption in Lebanon (millions)	USD 170	USD 370	USD 1,000
Reduced consumption per household in Lebanon	USD 130	USD 260	USD 720
Reduced exports per year in Lebanon (millions)	USD 72	USD 160	USD 430
Increased imports per year in Lebanon (millions)	USD 10	USD 5	USD 14
Reduced investment per year in Lebanon (millions)	USD 47	USD 300	USD 810

Numbers reflect the rounding rules described in the Introduction.

[a] Because of rounding, the total, USD 860 million differs slightly from the sum of USD 180 million and USD 690 million.

[b] Because of rounding, the total, USD 2,300 million, differs slightly from the sum of USD 480 million and USD 1,900 million.

Figure 4 shows the components of the reduction in GDP in 2020 from two perspectives. The left graph shows the reductions in output in the agriculture, manufacturing, and service sectors. The right graph shows the reduction in expenditures by households, government, net exports (exports minus imports) and investment.

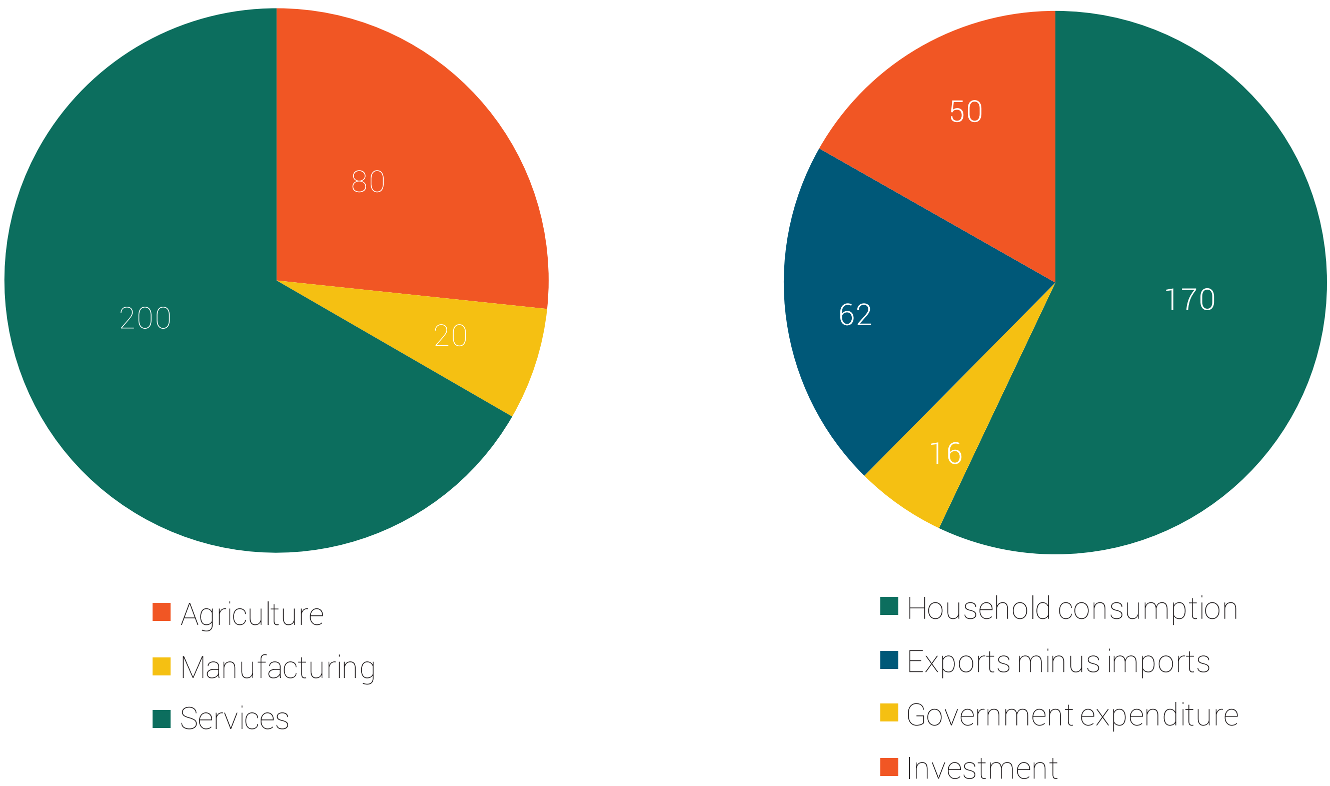


Figure 4. Components of the 2020 reduction in GDP, by sector of the economy and by expenditure category

Assumptions, data, and calculation

This analysis assumes the findings from Haddad, et al. (2014) provide a reasonable representation of the impacts on Lebanon's agricultural sector that would materialize under the highest-emissions scenario represented by the IPCC's highest-emissions scenario, RCP8.5. The study estimates the potential reduction in the value of Lebanon's agricultural output every five years from 2010 to 2030 under expectations that combine the scenarios described in Lebanon's Second National Communication (MoE/UNDP/GEF, 2011) and more recent projections from IPCC (2013a). Specific assumptions from the Second National Communication (SNC) that are embedded in Haddad et al. (2014) include expectations that, relative to the present:

- Average annual temperatures will increase by about 1°C on the coast and 2°C in the mainland by 2040, and by about 3.5°C and 5°C, respectively, by 2090.
- Average annual precipitation will decrease by 10-20% by 2040 and by 25-45% by the year 2090. This decrease will affect the availability of water for irrigation.
- Temperature and precipitation extremes will intensify.
- Throughout Lebanon, drought periods will become 9 days longer by 2040 and 18 days longer by 2090.

Haddad, et al. (2014) projects reductions in the value of agricultural production, relative to what would occur without the anticipated changes in climate. It then traces the impacts through the overall economy, as reduced farm production leads to lower income for farmers, who spend less on products from other sectors. It also tabulates the effects on government expenditures, investments, exports and imports, and household consumption. These effects would accumulate and intensify over time.

Calculation of the potential economic cost associated with the anticipated reduction in Lebanon's agricultural production resulting from GHG emissions under the high-emissions scenario involves these steps:

Step 1. Calculate the value of lost agricultural production. Employ directly the findings from Haddad, et al. (2014) for 2020, and extrapolate the findings for 2030 to estimate the effects of lost production in 2040 and 2080. Convert the estimates, measured in 2010 LBP, to 2010 USD using PPP currency conversion factors from World Bank (2015a), and to 2015 USD using the personal consumption expenditures index from U.S. Federal Reserve Bank of St. Louis (2015).Table 6 shows the results.

Step 2. Calculate the costs to the manufacturing and service sectors. Use findings from Haddad et al. (2014) to estimate the costs in 2020. Project GDP in 2040 and 2080 assuming that the 2010-2030 will grow 2.52% annually[6], the average annual growth rate reported by Haddad et al. (2014). Assume that the 2030 ratio of each sector's loss to GDP will remain unchanged in 2040 and 2080. Calculate the costs in each sector in 2040 and 2080 by multiplying this ratio times the projected GDP in those years, respectively. Table 6 shows the results.

Step 3. Calculate the total cost (reduction in GDP). Add the value of lost agricultural production plus the costs to the manufacturing and service sectors. Table 6 shows the results.

Step 4. Calculate the impacts on each activity. Use findings from Haddad et al. (2014) to estimate the costs in 2020. Assume that the 2030 ratio of the impact on each sector to GDP will remain unchanged in 2040 and 2080. Calculate the impact on each sector in 2040 and 2080 by multiplying this ratio times the projected GDP in those years, respectively. Table 6 shows the results.

Step 5. Calculate the per-household reduction in consumption. Divide the total reduction in household consumption by the number of households. Annex II shows the calculation of the future number of households: 1.3 million in 2020, 1.4 million in 2040, and 1.4 million in 2080.

Discussion

The actual costs might be higher or lower than those shown in Table 6. They might be higher, for example, if changes in temperature and precipitation were to occur, or to reduce agricultural production, more quickly than expected. Conversely, actual costs might be lower if farmers were to develop replacement crops resistant to these changes in climate. Some farmers have already undertaken steps to adapt to hotter and drier growing conditions by increasing the area of unirrigated vineyards, shifting from citrus to banana production, and shifting from sugar-beet production to the production of crops that require less water.

Reductions in agricultural production would reduce the net incomes of farmers, farmworkers, and those associated with related businesses. Costs directly linked to climate-related reductions in agricultural output would affect rural households most directly and deeply. Urban households

[6] This assumed growth rate does not take into consideration the effect of political instability and social unrest that might affect GDP growth.

would also be affected, insofar as they remain economically integrated with rural family relatives, pay more for locally produced food as it becomes more scarce, or see jobs disappear as urban businesses that handle farm products cut back as rural farm production dwindles.

4.1.2. Reductions in production of wheat and maize

Description

MoE/UNDP/GEF (2011) concludes that changes in temperature and rainfall will decrease productivity of lands currently used to produce most crops and fruit trees—especially wheat, cherries, tomatoes, apples, and olives—and may affect the quality of grapes. This analysis presents the anticipated reductions in Lebanon's production of wheat and maize. The focus on these two crops reflects the availability of data from relevant modeling of the anticipated effects of higher ambient temperature on irrigated lands and of higher ambient temperature and lower precipitation on unirrigated lands. Due to lack of relevant information, no cost has been estimated on the impacts of climate change on fruit trees, which represent more than half of Lebanon's agriculture area.

Results

The numbers in Table 7 rest on the results of modeling conducted by IFPRI (2009) for the Middle East and North Africa (MENA) region. The modeling compared production expected under one of the GHG emissions scenarios, A2, developed by the IPCC before it developed the RCP scenarios, relative to a scenario that assumes continuation of climate conditions that prevailed in 2000. Under this scenario, GHG emissions would grow more slowly than under RCP8.5. Hence, if human-caused GHG emissions follow the path underlying IPCC's highest-emission scenario, RCP8.5, households likely would experience larger reductions in income than those shown in Table 7.

The comparison shows the reductions in crop production intensify over time as temperatures increase and precipitation decreases. Maize is expected to experience the largest reductions: 23% in 2020, 40% in 2040, and 64% in 2080. Wheat would decline by 8% in 2020, 16% in 2040, and 30% in 2080. Insofar as the changes in climate under the IPCC's highest-emissions scenario, RCP8.5, would be greater, so too would be the percentage reduction in the production of the two crops.

Table 7: Reduction in value of Lebanon's production of wheat and maize, 2020, 2040, and 2080 (2015 USD)

Year	2020	2040	2080
Percentage reduction in volume of annual crop production in Lebanon			
Wheat	8%	16%	30%
Maize	23%	40%	64%
Value of reduction in value of annual crop production in Lebanon			
Wheat (millions)	USD 10	USD 17	USD 28
Maize	USD 85,000	USD 162,900	USD 299,500

Numbers reflect the rounding rules described in the Introduction.

Assumptions, data, and calculation

This analysis assumes the reductions in production projected by IFPRI (2009) for the MENA region provide a reasonable representation of the reductions that would occur in Lebanon. IFPRI (2009) projects reductions in 2050, relative to 2000, of 47% and 20% for maize and wheat, respectively, relative to the production that would occur without additional changes in climate. It also assumes recent global prices—USD 300 per tonne for each grain—provide a reasonable representation of the future value of reductions in production, insofar as Lebanon currently imports about 80% of the wheat and maize it consumes and, hence, is closely linked to global prices (FAO, 2012). Calculation of costs in 2020, 2040, and 2080 involves these steps:

Step 1. Calculate the average annual reduction in production: 0.44% for wheat, and 1.26% for maize.

Step 2. Calculate the cumulative reduction in production in 2020, 2040, and 2080. Table 7 shows the results.

Step 3. Calculate the price of wheat and maize in 2020, 2040, and 2080. Assume the inflation adjusted price of wheat and maize will increase 20% between 2005 and 2050 (Nelson et al., 2014). Assume this change would occur linearly and apply the per-year percentage change to the 2015 price, USD 300 per tonne, to calculate the price in future years. Result: USD 311 per tonne in 2020, USD 344 per tonne in 2040, and USD 506 per tonne in 2080.

Step 4. Calculate the reduction in value in 2020, 2040, and 2080 by multiplying the volume of the reduction in production times the global price per tonne. Table 7 shows the results.

Discussion

The actual costs might be higher or lower than those shown in Table 7. The impacts of climate change on wheat and maize production would be larger than indicated if, in the absence of climate change, farmers would adopt techniques that would increase their yield. All else equal, the value of the reduction in grain production would be greater to the extent that global prices increase more than projected. The impacts of climate change on wheat and maize production would be smaller than indicated if, absent climate change, Lebanon's crop production would decline for other reasons, such as the encroachment of urban land uses onto farmland. Farmers might be able to offset costs stemming from the effects of climate change on wheat and maize production by switching to other crops, such as barley, that are less sensitive to hotter and drier growing conditions. This analysis does not distinguish between costs that would be borne by the farmers who experience reductions in production and government, which might offset the loss through a crop subsidy or other compensation.

The costs to wheat and maize producers might differ substantially from the costs to other agricultural commodities, reflecting differences in the availability of water and other factors of production, sensitivity to changes in temperature and precipitation, and markets.

4.1.3. Reductions in fish harvest

Description

Increases in the temperature of inland and coastal waters, along with changes in nutrient flows, will reduce Lebanon's fish harvest from its aquaculture facilities and coastal fishery.

Results

The numbers in Table 8 represent the reductions in the value of Lebanon's fish harvest that would occur if the rate of decline projected for 2010–2030 (DARA and Climate Vulnerability Forum, 2012) were to extend through 2080. If current trends in GHG emissions continue, and fish stocks were unlimited, the costs in Lebanon would total USD 13 million in 2020, USD 93 million in 2040, and USD 4,500 million in 2080. These costs would soon outstrip the fish stocks, however, insofar as the Lebanese coastal harvest is about USD 28 million (Pinello and Dimech, 2013; p. 31, adjusted to 2015 USD), and annual aquaculture output in Lebanon has a value of about USD 4 million (FAO, 2015; p. 2). Hence, Table 8 shows costs hitting a ceiling of USD 32 million in 2040 and 2080.

Table 8: Potential costs from climate-related reductions in Lebanon's fish harvest (2015 USD)

Year	2020	2040	2080
Value of reduction in fish harvest per year in Lebanon (millions)	USD 13	USD 32	USD 32

Numbers reflect the rounding rules described in the Introduction.

Assumptions, data, and calculation

This analysis assumes DARA and Climate Vulnerability Forum (2012) provides a reasonable representation of the climate-related costs (2015 USD) in this sector in 2010 (USD 5 million) and 2030 (USD 38 million). It then interpolates and extrapolates from these estimates to calculate costs in 2020, 2040, and 2080. Calculation of these costs involves these steps:

Step 1. Calculate the average annual increase in lost production between 2010 and 2030. Result: about 10%.

Step 2. Calculate the expected cost in 2020, 2040, and 2080. Assume that the average annual growth rate for lost production would continue. Results: USD 13 million in 2020, USD 93 million in 2040, and USD 4,500 million in 2080.

Step 3. Assume costs would not exceed USD 32 million. Table 8 shows the results.

Discussion

The actual costs might be higher or lower than those shown in Table 8. Costs might be higher, for example, if changes in climate reduce fish stocks faster than anticipated. They might be smaller, though, if the reductions were to occur more slowly or if other fish species were to move into local waters to replace those depleted by climate change. In-migration of species might occur, for example, if an increase in sea temperature, coupled with the enlargement of the Suez Canal, leads to the introduction from the Red Sea of species that are more adapted to higher temperatures. While the impact on marine biodiversity is surely negative, it is difficult to exactly assess the economic impact of the decrease in fish stocks caused by climate change.

4.1.4. Increases in the prices Lebanon's consumers pay for food because of climate-related increases in global food prices

Description

Anticipated changes in global climate are expected to reduce world food supplies and increase food prices. Reductions in production would occur in response to increases in ambient temperatures, changes in annual and seasonal precipitation, and increases in extreme weather events. Higher temperatures would generally reduce growth rates for livestock, and for all crops experiencing more than 3°C of local warming, although some crops might show variation in effects from lower temperature increases (Porter et al., 2014). The resulting increases in world food prices would resonate in Lebanon, increasing costs for Lebanon's consumers.

Results

Table 9 shows the potential economic cost to Lebanon's consumers that would materialize as global GHG emissions under the highest-emissions scenario increase global food prices relative to prices expected with unchanging climate. The average cost per household ranges from USD 360 in 2020, to USD 3,600 in 2080.

Table 9: Potential costs to Lebanon's consumers from climate-related increases in global food prices (2015 USD and 2015 LBP)

Year	2020	2040	2080
Climate-related increase in food prices	1.6%	12%	44%
Total cost to Lebanese consumers per year (millions)	USD 470	USD 1,700[a]	USD 5,000[b]
Price-induced reduction in food consumption (millions)	USD 310	USD 340	USD 330
Increase in cost of food that is consumed (millions)	USD 160	USD 1,300	USD 4,700
Cost per Lebanese household per year	USD 360	USD 1,200	USD 3,600

Numbers reflect the rounding rules described in the Introduction.

[a] Because of rounding, the total, USD 1,700 million differs slightly from the sum of USD 340 million and USD 1,300 million.

[b] Because of rounding, the total, USD 5,000 million, differs slightly from the sum of USD 330 million and USD 4,700 million.

Assumptions, data, and calculation

This analysis assumes that the results from Nelson et al. (2014) reliably estimate the potential impacts of climate change on global food prices and that these impacts reflect potential increases in consumers' food costs in Lebanon. That study integrated climate, crop, and economic models to assess how global crop production and prices likely would respond from 2005 through 2050 under the IPCC's highest-emissions scenario, RCP8.5. Lebanon's households would incur costs through two, related mechanisms: higher food prices would cause them to reduce their food consumption, and raise the costs of the food they do consume. Calculation of the potential economic cost to Lebanon's households from the anticipated reduction in global agricultural production resulting from GHG emissions under a high-emissions scenario involves these steps:

Step 1. Assume that Nelson et al. (2014) reliably estimates the potential impacts of rising temperatures on consumers' food consumption and costs in Lebanon. That study concluded that, under RCP8.5, changes in climate would cause global crop prices to increase 20% from 2005 to 2050, and the increase in food prices would cause food consumption to drop 3%.

Step 2. Estimate the global increase in temperature from 2005: 0.15°C in 2020, 1.15°C in 2040, 1.9°C in 2050, and 4.15°C in 2080. (See Annex II for estimates of temperature.)

Step 3. Calculate the percentage increase in global food prices in 2020, 2040, and 2080. Linearly interpolate and extrapolate based on estimated increases in temperature, relative to the estimated increase between 2005 and 2050. Table 9 shows the results.

Step 4. Estimate what Lebanon's consumers would pay for food without the effects of future climate change. Assume per-person expenditures on food and non-alcoholic beverages were LBP 1,586,000 in 2012 (Central Administration of Statistics, 2015b). Assume this level remains constant so that total expenditures would change proportionate to the expected population, 5.5 million in 2020, 6.0 million in 2040, and 5.9 million in 2080. (See Annex II for estimation of population). Results: LBP 8.7 trillion in 2020, LBP 9.5 trillion in 2040, and LBP 9.4 trillion in 2080. Convert these amounts to 2012 USD by dividing by 869 LBP/USD (World Bank, 2015a) and to 2015 USD using the personal consumption expenditures index (Federal Reserve Bank of St. Louis, 2015). Results: USD 10,300 million in 2020, USD 11,300 million in 2040, and USD 11,100 million in 2080.

Step 5. Assume the expected increases in prices will reduce food consumption by 3%. Table 9 shows the results.

Step 6. Calculate the expected increases in the cost of consumers' reduced food consumption. Multiply the estimated, climate-related percentage increase in prices times 97% of the estimated expenditures absent climate change. Table 9 shows the results.

Step 7. Calculate total cost to consumers by adding the reduction in consumption plus the additional cost of the reduced consumption. Table 9 shows the results.

Step 8. Calculate the increase in food costs per household. Divide the overall increase in consumers' food costs by the estimated number of households: 1.3 million in 2020, 1.4 million in 2040, and 1.4 million in 2080. (See Annex II for estimation of population). Table 9 shows the results.

Discussion

The actual costs from the impacts of climate change on global food prices might be higher or lower than those shown in Table 9. Uncertainty about the costs arises largely because this analysis lacked sufficient information and resources to account for all the climate-related effects on crop production. For example, it overlooks the potentially offsetting effects of increased crop production from higher CO_2 concentrations and decreased production from increased ozone concentrations, increased attacks from pests, and more frequent extreme weather events. There are reasons, however, to believe that, overall, the omitted effects will, in actuality, push costs higher. Recent research suggests that the higher CO_2 concentrations generally will not result in the higher crop yields previously anticipated because soils generally will have insufficient nutrients to support the higher yields (Weider et al., 2015). Some field research has found that the productivity of some crops falls markedly if temperatures surpass some threshold; a warming of 1°C, for example, might render 40% of the area currently used to grow maize no longer suitable for this crop (Potsdam Institute, 2013; p. xviii). An overall assessment of climate-related risks to crop production concluded that, “Most of the factors not taken into account in the models – and the projections – are likely on balance to have a negative effect” (Porter, Montesino, and Semenov, 2015; p. 67).

4.2. Costs from impacts of climate on water

If current trends in global GHG emissions continue, the resulting changes in climate would reduce the quantity and quality of Lebanon’s freshwater supplies. These reductions would, in turn, impose costs on Lebanon’s households, farms, businesses, communities, and government. The costs would materialize in several ways. Some consumers would pay extra to secure additional supplies of water for domestic/industrial uses, or to obtain supplies with the desired quality characteristics. As changes in climate reduce the stream flows that generate hydroelectricity, some consumers would pay extra to secure electricity from other sources. Insofar as replacement supplies of water and electricity remain unavailable, consumers would experience a loss in wellbeing from their unmet demands.

The following analyses describe costs associated with climate-related reductions in:

1. Agricultural and domestic/industrial water supply.
2. Water supply for generation of hydroelectricity.

4.2.1. Reductions in agricultural and domestic/industrial water supply

Description

Reductions in Lebanon’s water supply would materialize as changes in climate diminish the amount of precipitation falling in Lebanon and higher temperatures accelerate evapotranspiration. This analysis describes one indicator of the resulting economic cost: the cost of securing replacement quantities of water for domestic/industrial uses.

Results

Table 10 shows the potential, climate-related reduction in water supplies in Lebanon from anticipated declines in precipitation and increases in evapotranspiration, as well as the costs of replacing the lost water. Anticipated changes in climate would reduce the nation’s exploitable supplies of water by about 1% in 2020, 8% in 2040, and 29% in 2080 (MoE/UNDP/GEF, 2011). The analysis assumes that, for 2020, the impact of the lost water on supplies available to consumers would be offset at a cost of USD 1 per cubic meter. This amount represents the cost of investments that would reduce leakage from the water system and improve water conservation (adapted from World Bank, 2010; p. 48). For 2040 and 2080, the analysis assumes that offsetting the impact of the lost water on supplies available to consumers would require investments in wastewater reuse or desalination, at a cost of USD 2 per cubic meter (adapted from World Bank, 2010; p. 45).

The data also show the potential distribution of costs between households and government. Households would realize costs by forgoing productive uses of water no longer available and through the environmental degradation that would accompany efforts to offset the decline in water supplies; government would realize a reduction in revenues and increases in costs.

The analysis assumes a distribution of costs—60% and 40%, respectively—which reflects the current distribution of costs associated with inadequacies in the water system (adapted from World Bank, 2010; p. ii) and assumes it would extend into the future.

Table 10: Climate-related reductions in water supply and costs to replace the lost water in Lebanon (2015 USD)

Year	2020	2040	2080
Reduction in exploitable water supply per year in Lebanon			
Percent	1	8	29
Volume (million cubic meters per year)	20	160	580
Cost per year to replace the lost water in Lebanon			
Total (millions)	USD 21	USD 320	USD 1,200
Households (millions)	USD 12	USD 190	USD 720
Government (millions)	USD 8	USD 130	USD 480

Numbers reflect the rounding rules described in the Introduction.

Assumptions, data, and calculation

This analysis assumes that Lebanon's total annual exploitable water supply is 2,000 million m^3 (MoE/UNDP/GEF, 2011; pp. 7, 9) and that the supply would diminish about 7% per degree Celsius increase in temperature from 2010 (MoE/UNDP/GEF, 2011; p. xv). Calculation of the potential costs of the reductions in supply involves these steps:

Step 1. Estimate the total climate-related increase in temperature since 2010: 0.15°C in 2020, 1.15°C in 2040, and 4.15°C in 2080. (See Annex II for estimation of temperature increase.)

Step 2. Calculate the reduction in exploitable water supply. Multiply the change in temperature times the 7% reduction in water supplies per degree. Table 10 shows the results.

Step 3. Calculate the cost of replacing the lost water. Assume the cost would be USD 1 per m^3 in 2020, reflecting the estimated cost of reducing leakage in the water system and increasing water conservation (World Bank 2010; p. 48, adjusted to 2015 USD). Assume the replacement cost would be USD 2 per m^3 in 2040 and 2080, reflecting the cost of wastewater reuse (adapted from World Bank 2010; p. 45, adjusted to 2015 USD) and desalination (Fichtner, 2011; pp. 6-78 – 6-80). Table 10 shows the results.

Step 4. Calculate the distribution, between households and government, of the costs of inadequate provision of public water supplies. Assume the current 60:40 distribution (World Bank 2010; p. ii) would apply in the future. Table 10 shows the results.

Discussion

The actual costs might be higher or lower than those shown in Table 10. All else equal, costs would likely be higher, insofar as insufficient information exists for this analysis to describe other potential costs from the impacts of climate change on water, such as these:

- Climate-related reductions in water quality.
- Climate-related changes in the spatial and temporal distribution of precipitation.

Several factors might intensify the costs of climate-related reductions in water supplies. With higher temperatures and tighter water scarcity, for example, the value of each incremental reduction in water supplies might increase, perhaps steeply. Greater variability in precipitation, temperatures, and evapotranspiration might result in periods and places with extreme mismatches between water supply and demand, with severe shortages causing abnormally high economic costs.

4.2.2. Reductions in water supply for generation of hydroelectricity

Description

Lebanon's supply of hydroelectricity will diminish as changes in climate declining precipitation and rising temperatures reduce the water in rivers available to drive hydropower plants. The electricity sector and consumers will incur costs to secure replacement supplies of electricity.

Results

Table 11 shows that the anticipated climate-related reductions in water flows would reduce Lebanon's hydroelectricity generation by 15 gigawatt-hours (GWh) in 2020, 150 GWh in 2040, and 540 GWh in 2080. The electricity sector and its customers would incur costs of USD 3 million in 2020, USD 30 million in 2040, and USD 110 million to obtain replacement electricity from other sources.

Table 11: Climate-related reduction in hydroelectricity generation and replacement cost in Lebanon (2015 USD)

Year	2020	2040	2080
Reduction in water flow in Lebanon per year (%)	1	8	29
Reduction in hydroelectricity generation (%)	1	8	29
Reduction in hydroelectricity generation (GWh)	15	150	540
Cost to replace lost electricity per year (millions)	USD 3	USD 31	USD 110
Cost per year per household in Lebanon	USD 2	USD 31	USD 110

Numbers reflect the rounding rules described in the Introduction.

Assumptions, data, and calculation

This analysis assumes that Lebanon's total annual exploitable water supply is 2,000 million m^3 (MoE/UNDP/GEF, 2011; pp. 7, 9) and that the supply will diminish about 7% per degree Celsius increase in temperature (MoE/UNDP/GEF, 2011; p. xv). Calculation of the potential costs of the reductions in supply involve these steps:

Step 1. Assume changes in climate had raised temperature 0.85°C by 2010 and that anticipated changes in climate will increase temperatures an additional 0.15°C in 2020, 1.15°C in 2040, and 4.15°C in 2080 (See Annex II for estimation of temperature increase).

Step 2. Estimate future hydroelectricity generation, absent reductions in stream flow. Assume hydroelectricity capacity would increase 3% per year until 2030, under the mitigation scenario 2 developed in Lebanon's SNC (MoE/UNDP/GEF, 2011; p. 51), then level off because there would be insufficient stream flows for further growth. Assume hydroelectricity generation would increase from 1,025 GWh in 2010, in parallel with the increase in generating capacity. Results: 1,390 GWh in 2020, 1,870 GWh in 2040, and 1,870 GWh in 2080.

Step 3. Calculate the percentage reduction in stream flow and assume that the same percentage reductions would occur in electricity generation. Assume stream flows would fall 7% per increase of 1°C since the SNC (MoE/UNDP/GEF, 2011; p. xv). Table 11 shows the results.

Step 4. Calculate the cost of replacing the lost electricity. Assume the replacement electricity would come from burning heavy fuel oil at a cost of about USD 210,000 per GWh (adapted from World Bank, 2008; p. 25, adjusted to 2015 USD). Table 11 shows the results.

Step 5. Calculate the average cost per household. Divide the overall increase in consumers' food costs by the estimated number of households: 1.3 million in 2020, 1.4 million in 2040, and 1.4 million in 2080. (See Annex II for estimation of population.) Table 11 shows the results.

Discussion

The actual costs might be higher or lower than those shown in Table 11. The actual impact of climate change on hydroelectricity production would depend not just on the reduction in stream flows but also on the quantity and configuration of the hydroelectric dams. The actual cost of replacement supplies of electricity would depend on the type(s) of generation employed. The costs of replacement electricity from other sources might rise initially, for example, but then decline as new technologies, such as solar, become more efficient. Costs also will be sensitive to changes in the supply and prices of natural gas and other fuels. Government likely would directly bear the costs of central generating facilities integrated into the grid. Households and businesses likely would indirectly bear some of these costs through payments for electricity consumed from the grid. They also would directly bear costs of generating replacement supplies of electricity from privately-owned generators.

4.3. Costs from climate-related natural disasters

Description

Lebanon will experience economic costs as anticipated changes in climate cause natural-resource disasters, such as more severe storms, floods, droughts, wildfires, and outbreaks of disease and insects. The costs will materialize in several ways. Direct costs would materialize as disasters destroy buildings, homes, equipment, bridges, and other physical capital. Some disasters might kill and injure humans, livestock, fish, or wildlife. Most will require clean-up. All will divert the attention and efforts of workers, families, businesses, and communities that otherwise could have been productive doing other things. Additional costs will materialize as affected individuals endure short-term suffering and the long-term effects of anxiety and post-traumatic stress, reducing the wellbeing and productivity of themselves, their families, and their communities.

Results

Table 12 shows the potential costs Lebanon would experience from climate-related droughts, floods/landslides, and storms, if recent trends in the global GHG emissions continue unabated. The costs reflect the value of lost crops, damage to structures, and other damage, as well as the value of disaster-related deaths.

Table 12: Potential costs to Lebanon from climate-related natural disasters (2015 USD)

Year	2020	2040	2080
Total cost of damage from natural disasters in Lebanon (millions)	USD 7[a]	USD 36	USD 1,600[b]
Damage from droughts, floods, landslides, and storms (millions)	USD 5	USD 35	USD 1,600
Damage related to deaths caused by disasters (millions)	USD 1	USD 1	USD 1

Numbers reflect the rounding rules described in the Introduction.

[a] Because of rounding, the total, USD 7 million differs slightly from the sum of USD 5 million and USD 1 million.

[b] Because of rounding, the total, USD 1,600 million, differs slightly from the sum of USD 1,600 million and USD 1 million.

Assumptions, data, and calculation

This analysis calculates the potential economic costs of three types of climate-related natural disasters: droughts, floods/landslides, and storms. The calculation involves these steps:

Step 1. Assume the average annual rate of growth between 2010 and 2030 in Lebanon's costs from climate-related natural disasters (DARA and Climate Vulnerability Forum, 2012) provides a reasonable basis for calculating the costs in 2020, 2040, and 2080. Results: direct costs will continue to grow about 10% annually; mortality will remain unchanged, at 1 death per year.

Step 2. Calculate the costs for 2020, 2040, and 2080. Assume the value per death is USD 1.35 million (IPCC, 2001, adjusted to 2015 USD). Table 12 shows the results.

Discussion

The actual costs from climate-related natural disasters might be higher or lower than those shown in Table 12. All else equal, however, it seems reasonable to conclude that actual costs likely would be higher, insofar as this analysis does not describe all the ways in which these disasters would impose costs on Lebanon. For example, these disasters would create psychological distress for most of those directly affected and a long-term legacy of post-traumatic stress for many (Doppelt, forthcoming), but the currently available information on these effects cannot support calculation of the associated economic costs. Other long-term costs of these disasters likely would materialize as they diminish education, productivity, and earnings for individuals who are children when a disaster strikes (Vivid Economics, 2010).

This analysis does not include the costs from flooding associated with climate-related rise in sea levels. These are incorporated into the description of the overall costs of sea-level rise in Section 4.7.

4.4. Costs from impacts of climate change on tourism

Description

If current trends in global GHG emissions continue, the resulting changes in climate would likely reduce the quantity and quality of Lebanon's natural-resource attractions for tourists. This analysis describes the reduction in GDP that might result as changes in climate reduce the intrinsic recreational and environmental attractiveness of Lebanon's coastal areas to domestic and international tourists (Bosello and Eboli, 2013). This outcome would materialize as changes in climate reduce biodiversity—the number of coastal terrestrial species, especially birds and mammals, and the richness of coastal habitat—and the attractiveness of coastal cultural heritage sites (Onofri, Nunes, and Bosello, 2013).

Regional analyses representative of Lebanon have found that potential climate-related reductions in biodiversity might reduce tourism demand by about 1.4% in 2050 (Bosello and Eboli, 2013; p. 7). Reduced tourism spending in coastal areas has ripple effects throughout the economy. Some of these effects depress spending in sectors linked to coastal tourism, such as transportation and the production of food for international tourists. To some extent, though, lower coastal spending might be offset if tourists spend more in other parts of the country.

A search for relevant information found too little to support a reliable analysis of the potential effects of climate change on other elements of tourism in Lebanon. This is especially the case for the winter tourism industry. General assessments have concluded that anticipated changes in climate likely would have mixed impacts on the industry (Burki, Elassser, and Abegg, 2003). It would exacerbate uncertainty about the availability of suitable levels of snow at low-elevation ski areas, but perhaps increase the attractiveness of existing and proposed ski areas at medium- and high-elevation locations.

A reliable analysis of the overall effects and costs would require an estimate of the quantity and the value of winter tourism that would be lost, solely because of climate change, in 2020, 2040, and 2080. These data do not seem to be readily available. Existing data describe, at best, the number of visitors to ski resorts in past years. They do not provide a reliable baseline estimate of the expected number of visitor-days, absent climate change, or of the number of visitor-days that would be displaced by anticipated changes in climate. Existing data also do not support reliable quantification of the two components of value important to economic analysis: the spending per visitor-day, and the extent to which the benefit consumers enjoy per visitor-day exceeds what they spend.

Results

Table 13 shows the potential effect of climate change on GDP if current trends in global GHG emissions continue to reduce the terrestrial biodiversity and, hence, attractiveness, of Lebanon's coastal areas.

Table 13: Potential reduction in GDP that would occur as changes in climate reduce the attractiveness to tourists of Lebanon's coastal resources (2015 USD)

Year	2020	2040	2080
Reduction in GDP from fewer tourists in Lebanon's coastal area (millions)	USD 22	USD 160	USD 1,800

Numbers reflect the rounding rules described in the Introduction.

Assumptions, data, and calculation

The calculation of the costs associated with potential reductions in coastal tourism because of the effects of climate change on biodiversity involves these steps:

Step 1. Assume that Lebanon's GDP would, on average, grow 3.2% per year, absent the effects of global GHG emissions in 2015 and subsequent years (Moore and Diaz, 2015). Results (2015 USD): 55,000 million in 2020, 160,000 million in 2040, and 370,000 million in 2080.

Step 2. Assume that the "Reference Scenario" estimates of the reduction in coastal tourism demand and the resulting effects on GDP, estimated for the Middle East Region (Bosello and Eboli 2103) provide reasonable estimates applicable to Lebanon. Results: reduction in GDP of 0.04% in 2020, 0.15% in 2040, and 0.61% in 2080.

Step 3. Calculate the reduction in GDP resulting from the potential reductions in coastal tourism because of the effects of climate change on biodiversity. For each year, multiply the estimated GDP times the percentage reduction. Table 13 shows the results.

Discussion

The actual costs might be higher or lower than those shown in Table 13. They might be lower, for example, if climate change has greater impacts on coastal biodiversity in other countries, thereby improving Lebanon's relative attractiveness to tourists. They might be higher, for example, if global GHG emissions cause sea levels to rise more than indicated by previous research (Hansen et al. in review). Higher temperatures resulting from global GHG emissions also might reduce the attractiveness of Lebanon's coastal areas relative to comparable sites further from the equator that experience smaller increases in temperature. Potentially negative impacts on other components of Lebanon's tourism sector, a reduction in snow on its mountains in winter, also likely would increase the negative impacts on GDP.

4.5. Costs from impacts of climate change on electricity consumption

Description

Anticipated changes in climate will impose costs on Lebanon as higher temperatures increase the demand for air-conditioning, refrigeration, and other forms of cooling. The costs will materialize as producers generate, and consumers pay for, the additional electricity necessary to satisfy the demand.

According to MoE/UNDP/GEF (2011), as the increase in temperature will take place in both winter and summer seasons, a reduction in heating demand can be expected. However, the increase of occurrence of extreme events, notably cold spells, would increase peaks in heating, which would balance the overall yearly demand. Therefore, the analysis below focuses only on the increase in cooling demand.

Results

Table 14 shows that anticipated climate-related increases would increase electricity use for cooling by 0.5 billion kilowatt-hours (kWh) in 2020, 4.3 billion kWh in 2040, and 167 billion kWh in 2080. Lebanon's electric utilities and consumers would incur costs of USD 110 million in 2020, USD 900 million 2040, and USD 34,800 million 2080 to generate the electricity required to meet climate-related demand for cooling.

Table 14: Cost of electricity to meet climate-related increase in demand for cooling (2015 USD)

Year	2020	2040	2080
Increased electricity consumption for cooling in Lebanon (billion kWh)	0.5	4.3	168
Cost of additional electricity consumption in Lebanon (millions)	USD 110	USD 900	USD 34,800

Numbers reflect the rounding rules described in the Introduction.

Assumptions, data, and calculation

The calculation of the cost of electricity to meet climate-related demand for cooling involves these steps:

Step 1. Estimate the additional electricity per 1°C increase in average annual temperature in Lebanon. MoE/UNDP/GEF (2011) indicates an increase of 1.8% in electricity consumption for a 1°C increase in temperature, and a further increase of 2% in electricity consumption for each additional 1°C increase in temperature.

Step 2. Estimate the expected climate-related increase in temperature. Assume an increase of 0.85°C in 2010 and 1°C in 2020 (IPCC, 2013b; pp. 5 and 18), growing to 2°C in 2040 and to 5°C in 2080 (MoE/UNDP/GEF, 2011; p. ix).

Step 3. Estimate what total electricity consumption would be in 2020, 2040, and 2080 without climate-related demand for cooling. Assume electricity consumption was 15 billion kilowatt hours (kWh) in 2010 (World Bank, 2015e), climate-related demand was an insignificant component of the demand, and consumption would grow 7% annually (MoE/UNDP/GEF, 2011; p. xii.). Results, in billion kWh per year: 30 in 2020, 120 in 2040, and 1,700 in 2080.

Step 4. Calculate the climate–related increase in electricity demand for cooling. Multiply the estimated electricity consumption without climate-related cooling times 1.8% in 2020, 3.8% in 2040, and 5.8% in 2080. Table 14 shows the results.

Step 5. Calculate the cost of producing the additional electricity. Assume a cost of USD 0.21 per kWh, the recent cost of significant incremental increases (from industrial self-generation using heavy fuel oil) in electricity generation (World Bank, 2008; p. 25 adjusted to 2015 USD using the personal consumption expenditures index). Table 14 shows the results.

Discussion

The actual costs might be higher or lower than those shown in Table 14. Future generation of additional electricity will likely involve technologies other than combustion of heavy fuel oil, but it is not clear if the generation costs would be higher or lower. The demand for cooling and, hence the cost of producing the necessary electricity may be higher than indicated if demand grows faster than temperatures.

Increased average annual temperatures will impose costs other than those linked to higher demand for cooling. They generally will lower the efficiency of thermal power plants, increase electricity losses in transmission lines, and reduce the efficiency of electrical motors and devices. An energy audit check list for all the possible effects of a change in the average temperature on all the types of electromechanical equipment would set the path for a more precise assessment on quantified effects of temperature increase on the entirety of the electricity sector.

4.6. Costs from impacts of climate change on the health of Lebanon's citizens

The changes in climate anticipated under the IPCC's highest-emissions scenario, RCP8.5, likely would increase the risks of mortality (deaths) and morbidity (illness and disability). The resulting economic costs would include increased healthcare costs, the individual's lost productivity at work and home, and reduced quality of life while ill. It also includes reductions in welfare associated with increased risk of mortality or morbidity, even if one does not actually experience death, illness, or disability. This section separately describes the potential costs associated with climate-related increases in:

1. The risk of death.
2. The risk of illness and disability.

4.6.1. Risk of death

Description

Lebanon will experience economic costs as climate change increases the risk of death. These costs include the lost enjoyment of life, forgone contributions to family and community, as well as lost labor production.

Available information supports calculation of these costs for two ways in which climate change would increase the risk of death. One would occur when higher temperature and humidity increases the risk of death directly, through hyperthermia, and indirectly, through respiratory or cardiovascular malfunctions. Most of this increase in mortality risk would fall on people over age 65. The other would occur when changes in climate increase the risk of death through malnutrition, diarrhea, malaria, floods, and cardio-vascular disease. This type of mortality risk can affect people of different ages, although children constitute the bulk of those who die from diarrhea and malaria. There may be some overlap between the two types of estimates, insofar as they both consider interactions between climate change and cardiovascular disease.

By estimating the value of the increased risk of death, this analysis is not placing a monetary value on the lives of the individuals who may die prematurely because of climate change. Instead, it reflects the overall risk to society. The cost estimates represent how much people throughout society are willing to pay for small reductions in their risk of dying, or, alternatively, how much compensation they would require to willingly accept an increase in risk.

Studies have found that the willingness to pay for risk reductions generally is lower in poor countries than in rich countries not because poor people value life less but because their ability to pay is lower. This difference raises concerns when choosing any value to represent the value of mortality risk, especially when rich countries emit much of the GHGs that increase mortality risk, and most of the risk of climate-related deaths occurs in poor countries. These concerns have prompted protracted debate about whether to choose a value from studies conducted in poor countries or from studies conducted in rich countries. Accordingly, the IPCC (2001: p. 483) has recognized that it might be appropriate to use an "equity-adjusted" average value across all countries of about USD 1.35 million per potential death (adjusted to 2015 USD). The costs would be three times larger if the analysis applied the value the OECD (2011; p. 24) uses to evaluate mortality risk in rich countries as a whole, and six times larger if it applied the value the U.S. Environmental Protection Agency (2015) uses to evaluate mortality risk in the U.S.

Results

The numbers in Table 15 represent the potential economic costs associated with the increased risk of death that changes in climate anticipated under the IPCC's highest-emissions scenario would impose on Lebanon. Regional estimates of mortality risk developed by the World Health Organization (Campbell-Lendrum and Woodruff, 2007) indicate that, if current trends in GHG emissions continue, climate change might cause about 34,900 deaths per year in Lebanon by 2020, 40,500 by 2040, and 45,500 by 2080. Most of these would occur through increases in malnutrition, diarrhea, malaria, and floods, and interactions with cardiovascular disease. The costs associated with climate-related increases in mortality risk total USD 47,200 million in 2020, USD 54,700 million in 2040, and USD 61,400 million in 2080.

Table 15: Potential economic costs of climate-related risk of death in Lebanon (deaths per year and 2015 USD)

Year	2020	2040	2080
Number of climate-related deaths per year in Lebanon			
Heat stress	3,900	6,600	12,200
Malnutrition, diarrhea, malaria, floods, cardiovascular disease	31,100	33,900	33,300
Total	34,900[a]	40,500	45,500
Costs of increased risk of death in Lebanon			
Heat stress (millions)	USD 5,200	USD 9,000	USD 16,400
Malnutrition, diarrhea, malaria, floods, cardiovascular disease (millions)	USD 41,900	USD 45,800	USD 45,000
Total (millions)	USD 47,200[b]	USD 54,700[c]	USD 61,400

Numbers reflect the rounding rules described in the Introduction.

[a] Because of rounding, the total, 34,900 differs slightly from the sum of 3,900 and 31,100.

[b] Because of rounding, the total, USD 47,200 million differs slightly from the sum of USD 5,200 million and USD 41,900 million.

[c] Because of rounding, the total, USD 54,700 million differs slightly from the sum of USD 9,000 million and USD 45,800 million.

Figure 5 visually depicts the potential death-related costs from heat stress and from malnutrition, diarrhea, malaria, floods, and cardiovascular disease.

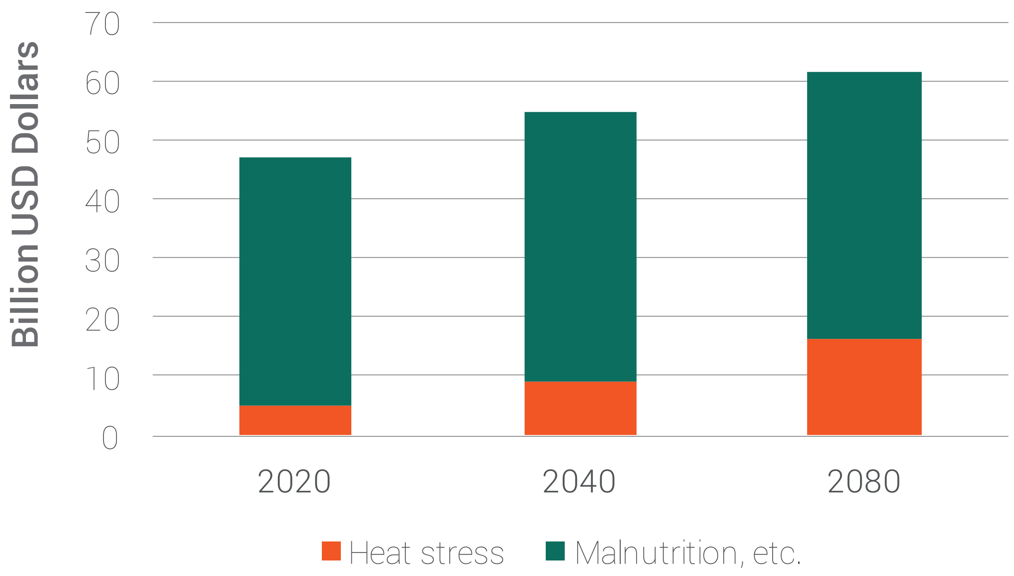


Figure 5. Potential costs from climate-related risk of death

Assumptions, data, and calculation

This analysis first estimates the increased risk of climate-related deaths in 2020, 2040, and 2080 from heat stress, or from malnutrition, diseases, and other effects of climate change. It then multiplies each number by an estimate of the economic value society places on a one-death increase in risk. The calculation involves these steps:

Step 1. Calculate the number of potential climate-related deaths associated with heat stress in 2020, 2040, and 2080. MoE/UNDP/GEF (2011; pp. 144-145) estimates expected deaths in 2010 and 2030. Linear interpolation and extrapolation yields the estimates shown in Table 15.

Step 2. Calculate the number of potential climate-related deaths associated with malnutrition, diarrhea, malaria, floods, and cardiovascular disease in 2020, 2040, and 2080. Campbell-Lendrum and Woodruff (2007) found, for the Eastern Mediterranean Region in 2000, there have been 5,650 deaths attributable to climate change per million population. Assume this ratio would apply in the future to Lebanon's projected population. Estimates of population are 5.5 million in 2020, 6.0 million in 2040, and 5.9 million in 2080 (Annex II describes the estimation of population). Table 15 shows the results.

Step 3. Calculate the economic cost associated with the projected climate-related risk of death. Assume the cost (2015 USD) per potential death is USD 1.35 million (IPCC 2011; p. 483). Multiplying this value times the climate-related increase in expected deaths yields the results shown in Table 15.

Discussion

The actual costs might be higher or lower than those shown in Table 15. If temperatures rise higher than expected, the resulting increase in heat stress, malnutrition, and disease might increase the risk of death. Anticipated changes in climate may increase the risk of heat-stress mortality more than indicated in this analysis. Researchers examining climate-related mortality risk in the Los Angeles, USA, area, for example, conclude that heat-stress deaths may increase seven-fold by mid-century, relative to the 1990s (Hayhoe et al., 2004). Changes in Lebanon's demographic profile, with elderly cohorts becoming a larger percentage of the total population, also may have an effect, insofar as elderly people often are more sensitive to heat stress (Sheridan and Allen, 2015). To the extent that anticipated changes in climate would yield warmer temperatures in winter, this effect may reduce the risk of cold-related mortality (Sheridan and Allen, 2015). Some research suggests, though, that this reduction may be minimal (Kinney et al., 2015).

Several factors would likely affect the impacts of temperature and humidity on human mortality. For example, investment in air conditioning may diminish the number of people exposed to heat and development of appropriate health-care facilities and technologies may diminish the effects of heat stress. This analysis, however, describes the increased risk of death from global GHG emissions and does not account for defensive investments and actions that might be taken to offset the increased risk.

Most of the health costs likely would be borne by individuals and family, with some borne by community and government.

4.6.2. Risk of illness and disability

Description

Economic costs would materialize as anticipated changes in climate increase the risk of illness and disability for Lebanon's citizens. These costs include direct costs associated with an illness or disability, such as healthcare expenses. They also include indirect costs, such as the affected individuals' forgone enjoyment of life, their reduced ability to earn income, their inability to contribute to the wellbeing of family and community, and the forgone earnings of family members who provide them with in-home healthcare. By estimating the value of the increased risk of illness and disability, this analysis is not placing a monetary value on the wellbeing of the specific individuals who may become ill or disabled because of climate change.

Available information supports estimation of costs associated with two general ways in which climate change can increase the risk of illness and disability. One involves the increase in heat stress from higher temperatures and humidity. The other involves increases in malnutrition, diarrhea, malaria, and flooding.

This analysis measures climate-related risk of illness and disability using a widely accepted metric, the Disability-Adjusted Life Year (DALY) for people living with the illness or disability or its consequences. One DALY represents one person losing one year of a healthy life, or two persons each losing a half-year, or three persons each losing a one-third year, etc. Costs measured using estimates of the value of a DALY indicate the treatment costs and pain and suffering associated with illness or disability.

This analysis calculates the economic cost associated with climate-related risk of illness and disability using an estimate of the average treatment cost per DALY. The analytical results therefore do not account for other costs, such as the reduction in the affected individuals' quality of life and earnings.

Results

The numbers in Table 16 represent the costs climate change potentially would impose on Lebanon by increasing the risk of illness and disability. The loss of healthy lives, measured in DALYs would total 812,300 in 2020, 886,800 in 2040, and 874,000 in 2080. Most of this loss would occur because of climate-related increases in malnutrition, diarrhea, malaria, and floods. The economic costs associated with these losses of a healthy life would total USD 177,900 million in 2020, USD 194,300 million in 2040, and USD 191,500 million in 2080.

Table 16: Potential costs of climate-related risk of illness or disability in Lebanon (2015 USD)

Year	2020	2040	2080
Number of disability-adjusted life years (DALY) lost per year in Lebanon			
Heat stress	620	1,300	3,300
Malnutrition, diarrhea, malaria, floods	811,600	885,400	870,700
Total DALY	812,300[a]	886,800[b]	874,000
Costs of increased risk of illness and disability in Lebanon			
Heat stress (millions)	USD 140	USD 300	USD 730
Malnutrition, diarrhea, malaria, floods (millions)	USD 177,800	USD 194,000	USD 190,700
Total (millions)	USD 177,900[c]	USD 194,300	USD 191,500[d]

Numbers reflect the rounding rules described in the Introduction.

[a] Because of rounding, the total, 812,300 differs slightly from the sum of 620 and 811,600.

[b] Because of rounding, the total, 886,800 differs slightly from the sum of 1,300 and 885,400.

[c] Because of rounding, the total, USD 177,900 million differs slightly from the sum of USD 140 million and USD 177,800 million.

[d] Because of rounding, the total, USD 191,500 million differs slightly from the sum of USD 730 million and USD 190,700 million.

Assumptions, data, and calculation

This analysis first estimates the increased risk of climate-related illness and disability, measured in DALY, in 2020, 2040, and 2080, and then multiplies each number by an estimate of the economic value per DALY. The calculation involves these steps:

Step 1. Estimate the number of potential lost DALYs associated with heat stress in 2020, 2040, and 2080. This analysis assumes:

- DALY would increase 3% per °C increase in temperature, applying research findings for Gulf States (Husain and Chaudhary, 2008).
- The 2009 DALY in Lebanon (World Health Organization, 2011), adjusted for an increase in temperature of 0.85°C since 1880 (IPCC, 2013b: p. 5), was 18,409.

- DALY in Lebanon would increase proportional to climate-related increase in temperature: 1°C in 2020, 2°C in 2040, and 5°C in 2080 (IPCC, 2013b, and MoE/UNDP/GEF, 2011).
- DALY would increase from 2009 proportional to population: 4.9 million in 2009, 5.5 million in 2020, 6.0 million in 2040, and 5.9 million in 2080 (Annex II describes the estimation of population). Table 16 shows the results.

Step 2. Estimate the number of potential lost DALYs associated with climate-related effects on malnutrition, diarrhea, malaria, and floods in 2020, 2040, and 2080. This analysis assumes 147,570 DALYs attributable to climate change per million population, based on findings for the Eastern Mediterranean Region (Campbell-Lendrum and Woodruff, 2007). It applies this ratio to Lebanon's projected population—5.5 million in 2020, 6.0 million in 2040, and 5.9 million in 2080 (Annex II describes the estimation of population). Table 16 shows the results.

Step 3. Calculate the overall economic cost associated with the projected climate-related increases in illness and disability. Assume the cost would be USD 219,060 per DALY (Eggleston et al. 2011, and Highfill and Bernstein, 2014). Multiply the cost per DALY times the number of lost DALYs. Table 16 shows the results.

Discussion

The actual costs might be higher or lower than those shown in Table 16. Illness-related costs not reflected in this analysis may occur through increases in vector-borne diseases, such as malaria, dengue fever, and yellow fever. DARA and Climate Vulnerable Forum (2012) conclude, however, that the increases in these diseases would be negligible in Lebanon through 2030. Changes in climate would likely impose additional costs on Lebanon through other types of illness/disability, such as short-term water shortages and long-term effects of depression, anxiety, and post-traumatic stress disorder among people who have suffered severe floods and storms (Watts et al. 2015).

Most of these costs would be borne by individuals and family, with some borne by community and government. Most of this increase in heat-related risk likely would fall on elderly individuals. People of all ages would experience the risk of illness and disability from the other causes, although children constitute to bulk of those who suffer from diarrhea and malaria.

4.7. Costs from impacts of climate change on ecosystems

Lebanon's aquatic and terrestrial ecosystems provide many valuable services that contribute to human wellbeing (Millennium Ecosystem Assessment 2005). For example, a healthy watershed ecosystem can collect, store, and regulate the flow of water better than one that has been degraded. Ecosystems also can reduce and cleanse pollutants from the air and water, provide fish and other foods for human consumption, and enable farmers to grow larger crops. Residents and visitors depend on Lebanon's ecosystems for subsistence, recreational activities, aesthetic pleasure, and spiritual renewal. These and other services derived from ecosystems directly improve the quality of life and reduce the cost of living for Lebanon's citizens, reduce costs and increase profits for many businesses, and lower government's costs of providing healthcare and other services. The availability of ecosystem services also affects the overall level of economic development and levels of poverty (Roe and Elliot 2004).

As the climate changes in response to global GHG emissions, it would alter the ecosystems and reduce their ability to provide these services. Anticipated changes in temperature and precipitation also would increase soil erosion, stimulate outbreaks of pests and diseases, encourage the proliferation of invasive species, and increase the risks associated with wildfires. As a result, households, businesses, communities, and government would either go with the contribution these services would have made to their wellbeing or incur costs to replace the lost services. Limitations in relevant data prevent a comprehensive analysis of the potential effects on services derived from Lebanon's ecosystems, and the associated economic costs. This analysis examines only the economic costs associated with three categories of ecosystem change: the loss of biodiversity; land degradation and its impacts on the productivity of cropland, rangeland, and forests; and rising sea levels.

Description

This analysis builds on previous efforts that estimated Lebanon's potential economic costs in 2010 and 2030 from the impacts of climate change on ecosystems (DARA and Climate Vulnerability Forum 2012). It describes three types of impacts:

- **Reduction in biodiversity.** This component of economic costs reflects the potential contraction in the distribution, and even the extirpation or extinction, of species. Costs can materialize directly through the loss of species as well as through the associated changes in ecosystem structure and function. For example, in aquatic habitats, the loss of an edible fish in Lebanon's coastal waters could directly reduce the country's supply of food or increase its cost. Similar outcomes could follow indirectly from the loss of a species on which the fish preys. Additional costs can occur in many ways. For example, the loss of biodiversity can reduce an ecosystem's overall rate of photosynthesis, its ability to recover from a severe storm or other shock, or its resilience to pathogens. The economic value of these effects comes from an analysis (DARA and Climate Vulnerability Forum, 2012) that builds on descriptions, e.g., Costanza et al. (1997), of the global value of the goods and services derived from different types of ecosystems.

- **Land degradation.** Protracted, severe drought can leave land unable to support vegetation, converting it to desert. This process can generate economic costs through multiple pathways. For example, degradation from drought can reduce the land's biological productivity and decrease soil fertility and groundwater, limiting the growth of grass, bushes, and trees (Global Risk Forum GRF Davos, 2013). Constriction in the supply of forage for livestock and wildlife can reduce the supply of food for subsistence use and commercial sale. Expansion of degraded areas can reduce opportunities for birding and other recreational activities that otherwise would be available in association with wetlands, irrigated farmlands, and other ecosystems.

- **Sea-level rise.** The Second National Communication (MoE/UNDP/GEF, 2011; p. xv) offers this summary of the potential costly effects of sea level rise:

  > "Sea levels have been continuously rising at an average rate of approximately 20 mm/yr in the Levantine basin. If it were to continue in the future, it can reach up to 30-60 cm in 30 years, which will have an impact on the sand beaches in the south, and on the coastal natural reserves such as the Palm Islands and the Tyre nature reserves. This will also lead to seawater intrusion into aquifers which will affect not only urban areas but also coastal irrigated agriculture. The potential impacts of climate change on the coastal zone include coastal flooding and inundation during

storms, sea water intrusion and salinization of coastal aquifers, coastal erosion and loss of sand beaches, degradation of coastal ecosystems and nature reserves and economic losses in coastal and marine activities such as tourism, agriculture, fisheries, transportation and other essential services."

Results

Table 17 shows the potential economic costs Lebanon's households, communities, and government would realize as future global GHG emissions reduce the country's biodiversity, intensify land degradation, and raise sea levels. In 2020, the three categories of costs would total about USD 150 million, with rising sea levels and the loss of biodiversity each imposing costs of about USD 60 million in 2020, and desertification imposing costs about half that amount.

Table 17: Potential economic costs from the effects of global GHG emissions on Lebanon's ecosystems (2015 USD)

Year	2020	2040	2080
Total economic costs from effects on Lebanon's ecosystems (millions)	USD 150	USD 380[a]	USD 830[b]
Biodiversity (millions)	USD 62	USD 150	USD 330
Land degradation (millions)	USD 29	USD 78	USD 170
Sea-level rise (millions)	USD 59	USD 140	USD 320

Numbers reflect the rounding rules described in the Introduction.

[a] Because of rounding, the total, USD 380 million differs slightly from the sum of USD 150 million, USD 78 million, and USD 140 million.

[b] Because of rounding, the total, USD 830 million differs slightly from the sum of USD 330 million, USD 170 million, and USD 320 million.

Figure 6 provides a visual representation of the three different types of ecosystem-related costs. Due to data limitations, this chart shows only a limited portion of the overall costs that global GHG emissions likely would impose on Lebanon's ecosystems if current trends continue.

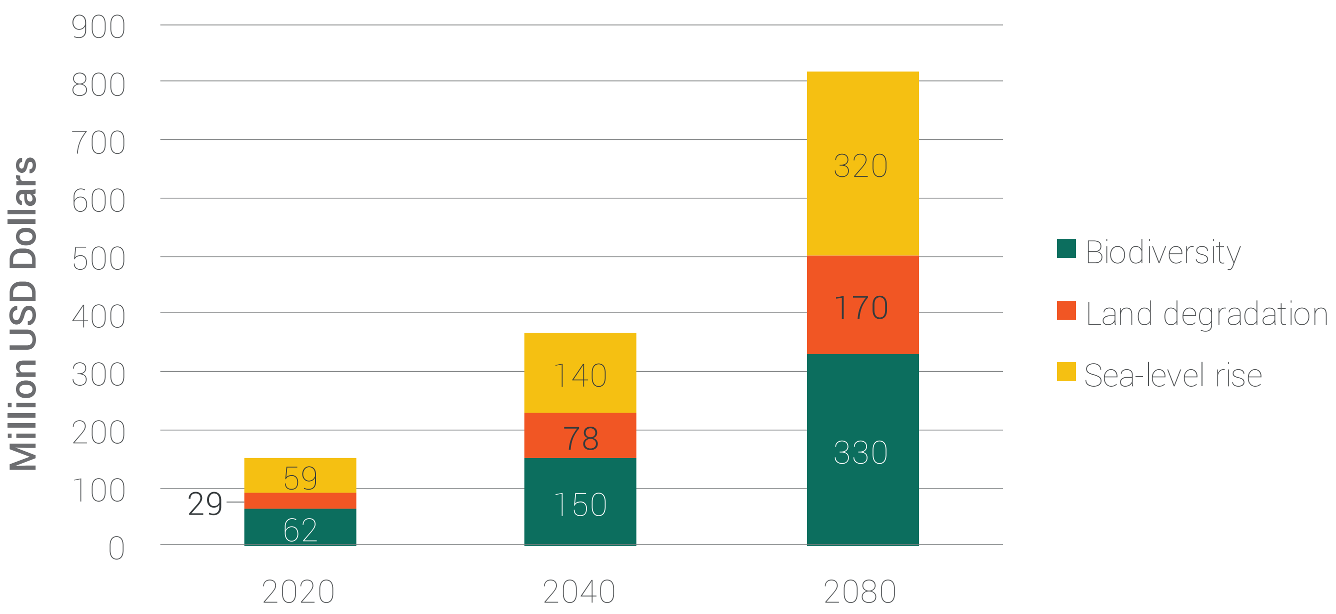


Figure 6. Potential costs from some of the effects of global GHG emissions on Lebanon's ecosystems

The calculation of the potential ecosystem-related costs involves these steps:

Step 1. Assume that findings reported by DARA and Climate Vulnerability Forum (2012) provide reasonable estimates of each category of costs in 2010 and 2030. Estimates for 2010 (adjusted to 2015 USD): USD 16 million for biodiversity loss, USD 5 million for land degradation, and USD 16 million for sea-level rise.

Step 2. Calculate the average annual growth for the period, 2010-2030, in each category of cost. Results: USD 4.56 million for biodiversity loss, USD 2.41 million for land degradation, and USD 4.29 million for sea-level rise.

Step 3. Calculate the potential cost for each category in 2020, 2040, and 2080. Table 17 shows the results.

Discussion

The actual costs might be higher or lower than those shown in Table 17. Mounting evidence suggests it would be reasonable to conclude that the costs likely would be higher. Hansen et al (in review), for example finds that, if global GHG emissions continue current trends, sea level might rise faster and generate greater economic damage than indicated by prior research. Estimates of costs associated with reductions in biodiversity reflect the use, by DARA and Climate Vulnerability Forum (2012), of the average per-hectare values reported by Costanza et al. (1997). More recent research, e.g., DeGroot et al. (2012) and Costanza et al. (2014), suggests that the ecosystem actual costs likely would be higher, but the DARA Climate Vulnerability Forum has not yet integrated this research into its analytical framework. Even higher estimates would result if the per-hectare value rises as services derived from ecosystems become scarcer.

4.8. Costs from impacts of climate change on society

Some of the costs that future changes in climate will impose on Lebanon will materialize through changes in society's structures, practices, and security. This section describes the potential costs associated with some of these changes:

1. Increases in violence resulting from increases in temperature.
2. Effects of climate-related heat stress on the productivity of Lebanon's workers.
3. Effects of climate-related undernourishment of children on their productivity and earnings as adults.
4. Increases in climate-related displacement and migration of groups within Lebanon's population.

Insufficient information exists to describe other potential costs from the impacts of climate change on society, such as increases in poverty and in conflict and threats to human security.

4.8.1. Costs from the effects of climate change on violence

Description

Increases in temperature and changes in precipitation resulting from global GHG emissions would likely stimulate increases in violence in Lebanon. Some of the increases in violence would occur between individuals, e.g., domestic violence and homicides. Additional increases in violence would occur between groups. Intergroup violence could materialize within Lebanon's borders, e.g., between groups living near one another within Lebanon, or between Lebanon and its neighbors.

Systematic data on the relationship between climate change and violence in Lebanon do not exist. A large body of research from throughout the world, however, indicates higher temperatures and precipitation stimulate an increase in human conflict (Hsiang, Burke, and Miguel, 2013). This effect occurs at different spatial scales, from two people jousting with one another at home, at work, or on a street, to regional warfare. Increases in violence generate costs via multiple pathways (Patel and Taylor, 2012 and Institute for Economics and Peace, 2014). Individuals can be killed or injured. Their families can endure the loss of loved ones and incur costs for healthcare for those injured, and to repair damage to homes and property. Communities can experience damage to infrastructure and disruption of community development. They also can bear the costs of gender inequality in the victims of some types of violence, the marginalization of some groups, fractured social capital, degraded public spaces, and the continuation of conditions that perpetuate violence. Government can incur costs associated with increased burdens on the criminal justice, healthcare, social service, and military systems.

Anecdotal evidence suggests that higher temperatures and changes in precipitation in Lebanon already are setting the stage for more violence. Conflict has occurred, for example, during water shortages resulting from heat waves, reduced precipitation, or flooding that disrupts water lines. Temperatures hotter than usual may have decreased the level of civility during public demonstrations or increased the severity of the response to the demonstrations by security officials. Extraordinarily hot days also may have contributed to flare-ups of conflict among motorists stuck in traffic, or even during sporting events. The loss of assets, such as cars, homes, and crops during climate-augments flooding or storms may have been associated with increases in domestic violence within families or with reductions in the ability of neighbors and communities to resolve disagreements amicably.

The Institute for Economics and Peace (2015) estimated that, in 2014, violence imposed costs on Lebanon totaling USD 6,713 million. This amount represents costs incurred as the result of or to prevent violence. The report identifies thirteen different categories of costs, acknowledging that the lines between them often are cloudy. Five categories generally are associated more closely with interpersonal violence: violent crime, fear, private security, homicides, and incarceration. Ten categories relate more closely with intergroup violence: military expenditures, deaths from external conflict, internally displaced people and refugees, UN peacekeeping, GDP losses from conflict, internal security, terrorism, and internal conflict. At the global level, interpersonal violence accounts for 32%, and intergroup violence accounts for 68% of the total costs.

Results

Lacking appropriate information regarding the effects of other factors, such as climate-related changes in precipitation, this analysis focuses only on the effects of higher temperatures on violence. Table 18 shows the potential costs that might materialize in Lebanon as higher temperatures stimulate increased violence. Costs associated with anticipated increases in intergroup violence outweigh those associated with increases in interpersonal violence by more than ten-to-one. Costs increase nonlinearly as anticipated increases in temperature stimulate additional violence as Lebanon's population and economy grow.

Table 18: Potential costs associated with violence resulting from climate-related increases in temperature (2015 USD)

Year	2020	2040	2080
Total (millions)	USD 38	USD 840[a]	USD 8,600[b]
Interpersonal violence (millions)	USD 3	USD 64	USD 660
Intergroup violence (millions)	USD 35	USD 780	USD 8,000

Numbers reflect the rounding rules described in the Introduction.

[a] Because of rounding, the total, USD 840 million differs slightly from the sum of USD 64 million and USD 780 million.

[b] Because of rounding, the total, USD 8,600 million differs slightly from the sum of USD 660 million and USD 8,000 million.

Assumptions, data, and calculation

Calculation of the potential economic costs from violence related to climate-related increases in temperature involves these steps:

Step 1. Calculate the costs of interpersonal and intergroup violence in Lebanon in 2014. Assume the global ratio between these two categories, 32:68 (Institute for Economics and Peace, 2015), applies to Lebanon. Apply the ratio to the estimated total cost, USD 6,713 million and adjust to 2015 USD. Results: interpersonal costs of USD 2,200 million, intergroup costs of USD 4,600 million.

Step 2. Assume that an increase in temperature equivalent to one standard deviation in the temperature pattern of recent years would increase interpersonal conflict by 2.3% and intergroup conflict by 13.2% (Hsiang, Burke, and Miguel, 2013; p. 10).

Step 3. Calculate the anticipated increase in temperature, measured in standard deviations from the current pattern. Assume that one standard deviation in maximum temperature is equivalent to 1.8°C (ASHRAE, 2005). Assume climate-related increases in temperature (in standard deviations) of 0.1 by 2020, 0.6 by 2040, and 2.3 by 2080. (See Annex II for estimation of temperature increase.)

Step 4. Calculate the increase in violence-related costs resulting from anticipated increases in temperature, assuming that Lebanon's population and economy remain unchanged. Results: total costs would increase by USD 33 million in 2020, USD 400 in 2040, and USD 1,500 million in 2080.

Step 5. Calculate the increase in violence-related costs, accounting for anticipated changes in population and GDP. Assume population would increase from 5.5 million in 2020, to 6.0 million in 2040, and 5.9 million in 2080. (See Annex II for estimation of population increase). Assume GDP would grow 2.6% per year (Moore and Diaz 2015), from USD 46,000 million in 2014 to USD 54,000 million in 2020, USD 89,000 million in 2040, and USD 250,000 million in 2080. Table 18 shows the results.

Discussion

The actual costs might be higher or lower than those shown in Table 18. In general, it seems reasonable to assume that actual costs would likely be higher, insofar as anticipated changes in extreme levels of precipitation—droughts or floods—likely would increase the levels and costs of violence even further, but to a degree less than occurs with increases in temperature (Hsiang, Burke, and Miguel, 2013; p. 1). Moreover, as temperatures rise, each incremental increase might stimulate proportionately more violence. If temperatures become sufficiently extreme to force people to curtail their activities, however, each additional increase in temperature might yield a decline in some types of violence.

4.8.2. Costs from the effects of climate-related heat stress on the productivity and earnings of Lebanon's workers

Description

The heat stress on workers from climate-related increases in temperatures and humidity will lower their productivity and reduce their earnings. These costs will materialize as higher temperatures and humidity reduce workers' capacity to complete physical work, increase the risk of mental errors and accidents, and lower their overall productivity. Productivity also can fall when workers, of their own volition or under directions from supervisors, reduce the intensity of their work-effort or increase the frequency of their rest periods. Heat-stress reductions in productivity can affect those working outdoors, especially workers directly exposed to sunlight, as well as those working indoors in spaces that are not air-conditioned. If workers bear the full burden of these effects, then their earnings would fall by an amount equal to the reductions in productivity.

Results

Table 19 shows the costs that climate-related heat stress would potentially impose on Lebanon by reducing workers' productivity if current trends in global GHG emissions continue. Total costs to all affected workers would rise from about USD 43 million in 2020 to USD 1,400 million in 2080. The average cost per worker (employed in the formal sector and self-employed) would rise from about USD 30 in 2020 to USD 930 in 2080.

Table 19: Potential economic costs to Lebanon from reductions in workers' productivity and earnings associated with climate-related heat stress (2015 USD)

Year	2020	2040	2080
Total reduction in productivity and earnings per year in Lebanon (millions)	USD 43	USD 160	USD 1,400
Cost per worker per year in Lebanon	USD 30	USD 100	USD 930

Numbers reflect the rounding rules described in the Introduction.

Assumptions, data, and calculation

Calculation of the potential economic cost to workers from the impacts of climate-related heat stress on labor productivity involves these steps:

Step 1. Assume that, in 2010, all workers in Lebanon, including those in the formal sector and those who were self-employed, earned USD 13,000 million (Alloush et al., 2013 and Robalino and Sayed, 2012) and that climate-related heat stress reduced workers' total productivity and earnings by USD 25 million in Lebanon (DARA and Climate Vulnerable Forum, 2012). Result: the reduction in earnings was 0.19%.

Step 2. Calculate the total reduction in productivity and earnings. Assume that, if global GHG emissions do not follow current global trends, GDP would grow 3.2% annually (Moore and Diaz, 2015) and that earnings and lost earnings would grow at the same rate. Assume that, if global GHG emissions do follow current trends, the climate-related increase in temperature would grow from 0.85°C in 2010 to 1°C in 2020, 2°C in 2040, and 5°C in 2080 (see Annex II for temperature estimation), and that lost earnings would grow proportionate to the increase in temperature. Table 19 shows the total reduction in productivity and earnings for 2020, 2040, and 2080.

Step 3. Assume the number of workers would grow from 1.3 million in 2010 (Robalino and Sayed, 2012) proportionate to the increase in population (see Annex II for estimation of population). Results: 1.43 million in 2020, 1.56 million in 2040, and 1.54 million in 2080.

Step 4. Calculate the cost per worker. Divide the total reduction in productivity/earnings by the number of workers. Table 19 shows the results.

Discussion

This analysis shows the potential effects of climate-related heat stress on workers' productivity. The actual costs might be higher or lower than those shown in Table 19. For example, costs might be lower than those shown in the table if labor-market characteristics, such as the incidence of outdoor work and indoor air-conditioning, would lower the number of workers exposed to high temperatures. This outcome would materialize if the number of workers in outdoor industries, such as agriculture and construction, were to decline as the number of workers in air-conditioned building increased. Costs might be higher, however, if, as temperatures increase, Lebanon's electricity sector would be unable to meet the rising demand for air-conditioning so that more indoor workers would experience heat stress. This analysis calculates the costs assuming that 2010's labor-market characteristics remain unchanged.

All else equal, however, actual costs would likely be higher, insofar as this analysis does not consider other, related costs stemming from the effects of climate change on workers' productivity. For example, climate-related increases in disease might complement or magnify the effects of heat stress on productivity and earnings.

4.8.3. Costs from the effects of climate-related undernourishment of children on their productivity and earnings as adults

Description

Changes in climate can increase the number of children suffering from undernourishment by reducing crop production, disrupting food–production and –distribution systems, increasing food prices, displacing families from their farms, and increasing poverty. As these effects become more intense, they will increase the number of people who persistently consume too little food, or not the right kinds of food, to satisfy minimum dietary requirements for a healthy life. Lack of sufficient nourishment for pregnant women and young children will increase the number of babies born with low birth weight and infant deaths. The stunted development of children who survive but endure persistent undernourishment will, relative to other individuals, experience greater incidence of disease, more extensive learning disabilities, reduced physical capabilities. These effects will lower their productivity at home and work, increase their healthcare costs, shorten their work life, and reduce their earnings.

This analysis describes only one of these effects: the reduction in productivity and earnings that materialize as undernourished children become adults.

Results

Table 20 shows the potential number of workers in 2020, 2040, and 2080 who experienced persistent climate-related undernourishment as children. It also shows the reductions in productivity/earnings that they would realize because of the effects of the undernourishment. The percentage of workers affected by climate-related undernourishment would grow, from about 0.57% in 2020, to 0.72% in 2040, and 1.12% in 2080.

Table 20: Reduction in productivity and earnings of workers who experienced climate-related undernourishment as children in Lebanon (2015 USD)

Year	2020	2040	2080
Percent of workers undernourished as children in Lebanon	0.57	0.72	1.12
Number of workers undernourished as children in Lebanon	8,200	11,200	17,200
Total earnings lost (millions)	USD 22	USD 51	USD 280
Earnings lost per worker	USD 2,600	USD 4,500	USD 16,300

Numbers reflect the rounding rules described in the Introduction.

Assumptions, data, and calculation

Calculation of the potential economic costs that would occur as climate-related undernourishment of babies and children reduces their adult earnings involves these steps:

Step 1. Estimate the percentage of children aged under five years that experience persistent undernourishment attributable to climate change. Extrapolation from World Health Organization, (2014; pp. 83-84) yields: 0.57% in 2000, 0.72% in 2020, 0.89% in 2040, 1.12% in 2060, and 1.40% in 2080.

Step 2. Calculate the percentage of adult workers who suffered the effects of persistent undernourishment as children. Assume that, on average, the percentage of the workforce affected by childhood undernourishment equals the percentage of children who were undernourished 20 years earlier: 0.57% in 2020, 0.72% in 2040, and 1.12% in 2080.

Step 3. Calculate the number of adult workers in 2020, 2040, and 2080 who suffered the effects of persistent undernourishment as children. Assume that the number of workers in 2010, 1.3 million (Robalino and Hayeed, 2012) would grow proportional to growth in population (see Annex II for estimation of population). Results: 8,200 workers in 2020, 11,200 workers in 2040, and 17,200 workers in 2080.

Step 4. Calculate the lost productivity and earnings per worker. Estimate the average total earnings per worker by adjusting the estimate for 2010, USD 9,900 from Alloush et al., (2013) to reflect expected growth in productivity without climate change, 3.2% per year (Moore and Diaz 2015; p. 2) and convert to 2015 USD. Assume that the reduction in earnings for workers who experienced persistent undernourishment as children equals 20%, the reduction in productivity (Crosby et al., 2013; p. 7). Table 20 shows the results.

Step 5. Calculate the total earnings lost. Multiply the number of workers affected by persistent undernourishment as children times the average reduction in earnings per worker. Table 20 shows the results.

Discussion

The actual costs might be higher or lower than those shown in Table 20. All else equal, however, they likely would be higher, insofar as this analysis does not consider several types of costs that would accompany climate-related undernourishment of children. These costs would materialize in several ways:

- Increased risk of infant death.
- Increased neonatal care.
- Increased risk of subsequent illness and disability.
- Loss of lifetime productivity and earnings because of smaller stature.
- Loss of lifetime productivity and earnings because of limited education and impaired mental development.
- Increased risk that children, born of parents who have diminished earnings because they were undernourished when they were children, will also experience diminished earnings.

4.8.4. Costs from climate-related internal migration

Description

If current trends in global GHG emissions continue, the resulting changes in climate, such as droughts, storms, diseases, malnutrition, and higher sea levels, would leave some of Lebanon's households unable to sustain their livelihoods and force them to relocate. Some may relocate to live with relatives or friends, but others may lack such options. Relocating households likely would realize a loss of income and incur other economic costs, such as loss of assets.

Climate change could induce households throughout Lebanon to migrate, wherever they are vulnerable to storms, sea-level rise, water scarcity, etc. Because of limitations in data regarding the potential number of households that might be displaced by climate change, this analysis focuses on just a subset of those households. It draws on the research (Haddad et al., 2014) underlying the analysis of climate-related reductions in Lebanon's overall agricultural production. As that research estimated the reduction in agricultural output and the earnings of farmers and workers in related industries, it also estimated the number of individuals that would have to relocate for the overall level of average income of the remaining households to equal what it would have been without the effects of climate change.

Reliable research regarding the economic costs borne by forced migrants is very limited, but it suggests that, on average, they experience a loss of income of about 45% (World Bank et al., 2012).

Results

Table 21 shows the potential number of individuals who would migrate in 2020, 2040, and 2080, as anticipated changes in climate reduce Lebanon's food production, causing farmers and workers in agriculture-related industries to migrate to other areas and consequently lose their livelihood and jobs. It also shows the costs they would incur as they experience losses in their income.

Table 21: Potential number of internal migrants and their loss of income from climate-related impacts on Lebanon's food production (2015 USD)

Year	2020	2040	2080
Potential number of internal migrants[a]			
Lebanon	6,900	14,600	35,600
Beirut	970	2,100	5,000
Mount Lebanon	2,800	6,000	14,700
Northern Lebanon	1,200	2,500	6,000
Bekaa	800	1,700	4,100
Southern Lebanon	740	1,600	3,800
Nabatieh	380	800	2,000
Potential lost income for migrants (millions)[b]			
Lebanon	USD 57	USD 130	USD 320
Beirut	USD 10	USD 23	USD 51
Mount Lebanon	USD 26	USD 60	USD 148
Northern Lebanon	USD 9	USD 21	USD 52
Bekaa	USD 6	USD 13	USD 30
Southern Lebanon	USD 5	USD 11	USD 24
Nabatieh	USD 3	USD 7	USD 16

Numbers reflect the rounding rules described in the Introduction.

[a] Because of rounding, the total number of migrants for Lebanon differs slightly from the respective sum of the regional numbers.

[b] Because of rounding, the total lost incomes for Lebanon differ slightly from the respective sum of the regional losses.

Assumptions, data, and calculation

This analysis calculates the potential economic losses in income that would occur as people migrate when changes in climate that reduce Lebanon's agricultural production threaten their livelihoods and jobs. The calculation involves these steps:

Step 1. Assume that the findings of Haddad et al. (2014) provide reasonable estimates of the total number of migrants between 2010 and 2030, the reductions in household consumption during this period, and GDP per capita.

Step 2. Calculate the number of potential migrants in 2020, 2040, and 2080. Estimate the number of migrants in 2020 and 2030 by disaggregating the total number for 2010-2030 in proportion to the annual reductions in household consumption. Estimate the number of migrants in 2040 and 2080 assuming that the number of migrants would grow in parallel to the reduction in household consumption and that the average annual reduction in household consumption for 2025-2030 would extend into the future. Table 21 shows the results.

Step 3. Calculate the migrants' loss of income. Assume the estimates from Haddad et al. (2014) of per capita GDP represent 2020 and 2030 per capita income for each region. Assume per capita income for each region would grow from the 2030 level at the average annual growth rate from 2020-2030. Assume migrants would typically come from households that earn income in the informal sector, and assume the per capita income of this group is 77% of the overall average (Alloush et al., 2013; p. 13).

Step 4. Calculate the per capita loss of income for (informal-sector) migrants, assuming they would lose 45% (World Bank et al., 2012; pp. 80-81). Multiply the per capita loss times the number of migrants to calculate migrants' total loss of income. Table 21 shows the results.

Discussion

The actual costs might be higher or lower than those shown in Table 21. This analysis considers only the potential loss of income Lebanese citizens might incur if climate-related reductions in the country's food production displace them from their homes. Displacement might occur as farm households lose their livelihood and workers in related industries lose their jobs. Because of limitations in the available data, the analysis does not consider other potential costs, such as the loss of assets these individuals might incur, nor does it consider costs family members, the government, or others might incur as these people are displaced. It also does not consider the potential costs that would materialize when other effects of climate changes, such as storms and floods, induce Lebanese people to migrate. This analysis does not consider potential costs associated with climate-related migration of people from other countries to Lebanon.

Most elements of the analysis are internally consistent insofar as they all come from Haddad et al. (2014). The estimate from Alloush et al. (2013), of the relationship between overall average earnings and earnings in the informal market, comes from survey research of workers in Lebanon.

5. Potential approaches for reducing the costs of climate change

This section describes some approaches appropriate for lowering the costs global GHG emissions might impose on Lebanon. It incorporates a capital-based framework for measuring long-term economic wellbeing (Wu and Wu 2012, and UNESA 2007). Capital is a term economists use to represent things that have the ability to improve wellbeing in the future by producing goods or services. To the extent that global GHG emissions would reduce Lebanon's capital stock, they would impose costs on its households, businesses, communities, and government. Conversely, to the extent that adaptive actions would enable Lebanon to avoid these reductions, they would lower the costs.

It is useful to separate Lebanon's capital into five categories:

- **Human capital** represents the capacity of the Lebanese to produce goods and services, and reflects their knowledge, skills, health, and similar characteristics.
- **Natural capital** represents the ecosystem's ability to provide goods and services and incorporates Lebanon's natural resources as well as the ecosystem's structure, function, and productivity.
- **Physical capital** represents the roads, buildings, electricity systems, etc. that have been developed by Lebanon's households, businesses, communities, and government.
- **Social capital** represents the relationships and institutions, both formal and informal, that help human interactions among Lebanon's households, businesses, communities, and government proceed smoothly.
- **Cultural capital** represents the ideas, traditions, beliefs, and customs shared by the Lebanese people; the intellectual capital, which exists as language, literature, music, etc.; and the buildings, etc. with historical and other attributes that embody the nation's store of cultural value.

Table 22 illustrates actions that might be appropriate for lowering the potential impacts of global GHG emissions on Lebanon's capital stock. Some of these actions would involve developing a better and broader understanding of potential changes in climate and how they might affect the different types of capital. Some would entail taking steps to diminish or even block a particular type of risk to a specific asset. For example, a household, business, community, or the government might reinforce a building against potential storms or increase its capacity to store water for emergency use should a storm occur. Some would focus not on reducing the vulnerability of existing capital but, instead, on making investment decisions in a manner to diminish the vulnerability of new capital. Education and training programs, for example, might be altered to include sections on risk-management.

Some adaptive actions would yield a better and broader understanding of potential changes in climate and the risks they pose for households, businesses, communities, and the government. These actions also might include providing information about potentially appropriate individual and collective actions for reducing the risk. Other adaptive actions might focus on shielding existing capital from climate-related risks. These might include, for example, reducing non-climate stressors, such as pollution, on ecosystems so they can better withstand stresses stemming from changes in climate. They also might involve reinforcing homes, business facilities, and government infrastructure against storms. Some actions might aim to lower the exposure of new capital to climate-related risk. These might include, for example, adapting educational and training programs to include sections on risk management, or locating new development away from areas susceptible to coastal flooding.

Table 22: Adaptive approaches for reducing the costs climate change will impose on Lebanon

Approach	Illustrative actions
1. Strengthen human capital	- Improve individual awareness of climate-related risks. - Improve education, nutrition, health, etc. - Reduce marginalization of women and others. - Reduce number of people in poverty. - Diversify economic skills and activities. - Strengthen resilience skills for responding to climate-related stresses that will occur.
2. Conserve natural capital	- Reduce non-climate stressors on ecosystems. - Conserve wetlands, soils, aquifers, and other core resources. - Implement ecosystem- and community-based management of natural resources. - Reduce risks of species extinction and loss of habitat. - Strengthen ecosystems' resilience to climate-related stresses that will occur.
3. Reduce vulnerability of physical capital	- Improve community understanding and awareness of climate risks, in general and to specific types of built capital. - Withdraw development from high-risk areas, such as floodplains. - Reinforce housing and work places against climate risks, such as storms. - Reduce risk of impairment of essential infrastructure: communication, transportation, water, wastewater, healthcare, electricity, etc. - Strengthen resilience of essential infrastructure to climate-related stresses that will occur.
4. Strengthen social capital	- Improve community understanding and awareness of climate risks, in general and to specific institutions and human relationships. - Improve adaptation plans and disaster-risk management systems. - Reduce risk of impairment of essential services. - Encourage development of and participation in insurance programs. - Improve access to information, finance, and technology. - Strengthen resilience of social systems to climate-related stresses that will occur.
5. Strengthen cultural capital	- Improve community understanding and awareness of climate risks to culturally important resources and activities. - Reduce risk to heritage sites and other cultural resources important to different cultural groups and communities (rural and urban). - Strengthen resilience of cultural capital to climate-related stresses that will occur.

Source | Adapted from IPCC (2014; p. 27)

Lowering climate-related risks to Lebanon's capital stock will require learning from the past and looking forward to develop and implement appropriate plans. There is widespread agreement (Chan et al. 2012; IPCC 2014; pp. 26-28; and King, et al. 2015) that effective planning and implementation require:

- Involvement by all stakeholders and institutions, with respectful recognition of their diverse circumstances, interests, resources, adaptability, and decision-making processes.
- Cooperative efforts at all spatial, institutional, communal, and governmental levels.
- Response to concerns about both the efficiency and the equity of risk-management actions.
- Recognition that, although some climate-related risks involve abrupt, severe events, such as extreme weather, others do not. Gradual increases in average annual temperature, for example, might, over time, affect the wellbeing of workers and families as much or more than extreme storms and heat waves.
- Application of the principles of risk-assessment and –management. These include assessing and taking actions to reduce risks in the context of clear objectives, considering the full range of probabilities and undesirable outcomes, using the best available information, considering both systemic and direct risks, and making transparent decisions.
- Use of both incentives and requirements to encourage risk-reducing behaviors. Incentives might involve market-based structures and tools, when appropriate, and recognize that alternatives may be required when significant market failures are present.
- Utilization of risk-oriented financial tools, such as appropriately scaled insurance, risk pooling, and access to financial resources during and after climate emergencies.

It is important to recognize that, although Lebanon might be able to reduce its vulnerability to climate-related risks, it cannot avoid them entirely. Global GHG emissions will, inevitably, have adverse effects on Lebanon's households, businesses, communities, and government. Hence, efforts to reduce the costs that these emissions impose on Lebanon should include elements that increase the ability of households, businesses, communities, and the government to respond to and recover from changes in climate. In other words, adaptive actions should focus not just on reducing vulnerability to climate-related risks but also on strengthening resilience to adverse events when they occur.

Some argue that the unavoidable impacts of climate change will be so widespread and severe that strengthening resilience should be a top priority (Doppelt forthcoming). The imperative for strengthening resilience comes about, in part, from the experiences of communities that have responded to extreme weather events in ways that made things worse: increasing the number of people suffering prolonged traumatic stress, disabling public and private organizations, and increasing levels of discord and violence. Other communities, in contrast, have responded to stressful events by capitalizing on them as opportunities to reinforce inherent strengths. For example, they have set aside internal conflict and increased their dedication to respectful, cooperative processes for solving problems, climate-related and otherwise.

The Second National Communication (MoE/UNDP/GEF, 2011) has identified potential adaptation efforts consistent with these general concepts and principles, but specific to Lebanon. These potential efforts generally aim to reduce the vulnerability of Lebanon's capital resources to climate change and increasing their resilience, with a focus on these areas:

- **Agricultural sector.** Potential options include: increasing the water-use efficiency of irrigation systems; developing species and hybrids more tolerant of high temperatures and drought; changing the timing of planting, irrigation, and harvesting; adopting sustainable agricultural practices and integrated pest management techniques; developing rangeland-management practices that recognize the effects of climate change; and providing farmers with better, timely information about pending extreme weather events.
- **Electricity sector.** Potential options include: improving the energy-use efficiency of buildings and transportation systems; and developing energy-supply systems that are less vulnerable to the disruptions of extreme weather events, higher average temperatures, and other aspects of climate change.
- **Water resources.** Potential options include: reducing the likelihood that coastal freshwater aquifers will experience saltwater intrusion as sea level rises; increasing the water-use efficiency of domestic, industrial, and agricultural sectors, developing watershed-managed plans appropriate for expected changes in climate; investigating the feasibility of alternative sources of water supply; and improving the available information about Lebanon's water resources and water systems.
- **Coastal communities and ecosystems.** Potential options include: developing and implementing plans for pulling human activities back from coastal areas that will be exposed to expected rises in sea level; creating coastal marine reserves to strengthen the ability of coastal habitats and species to adapt to changes in climate; reducing the stress on coastal resources from the emission of pollutants and other human activities; developing and implementing a strategy for protecting capital and people unlikely to move, e.g., essential transportation structures and highly urbanized areas; and providing coastal residents with better, timely information about pending extreme weather events.
- **Forest resources.** Potential options include: reducing fragmentation; protecting biodiversity; developing and implementing appropriate strategies for managing increased risk of fire, pest, and disease; and improving knowledge about and awareness of the ecosystem services derived from forests.
- **Public health.** Potential options include: improving knowledge about and awareness of the interactions between climate change and public health; strengthen systems for monitoring and responding to the effects of climate change on public health; encouraging development strategies that protect and promote health; and strengthen institutions responsible for preparing for and responding to the effects of climate change on public health.
- **Tourism sector.** Potential options include: developing better insurance and other short-run tools for managing risks to tourism, such as disruptions from coastal storms or lack of snowfall at mountain resorts; developing appropriate long-run plans for managing risks, such as moving coastal tourism facilities away from potential storm surges and winter facilities to higher altitudes; reducing the stress on climate-sensitive natural resources important to tourism from e.g., erosion and urban sprawl; providing the tourism sector with better, timely information about pending extreme weather events.
- **Human settlements and infrastructure.** Potential options include: facilitating the movement of existing structures and activities out of areas at high risk to climate-related events, such as flooding; discouraging new development in such areas; developing and implementing changes in the design of communities and building appropriate for anticipated climate-related risks; and improving the ability of emergency-relief and other systems to anticipate and respond to climate-related disasters.

All segments of Lebanon's society and economy have roles to play in reducing vulnerability to climate change and strengthening resilience to changes that will occur. This report, however, does not address their respective responsibilities, leaving that task to other processes.

6. References

Alloush, Mohamad, Carole Chartouni, Roberta Gatti, and Joan Silva, (2013). "Informality and Exclusion: Evidence from Matched Employer-Employee Data for Lebanon and Syria." IZA Journal of Labor Policy. 2:18. http://www.izajolp.com/content/pdf/2193-9004-2-18.pdf.

American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE), (2005). "Design conditions for BEIRUT (CIV/MIL), Lebanon." ASHRAE Handbook - Fundamentals (SI). http://cms.ashrae.biz/weatherdata/STATIONS/401000_s.pdf.

ASHRAE, (2005). "Design Conditions for Beirut (CIV/MIL), Lebanon." http://cms.ashrae.biz/weatherdata/STATIONS/401000_s.pdf.

Bosello, Francesco, and Fabio Eboli, (2013). Economic Impacts of Climate Change in the Southern Mediterranean. MEDPRO Technical Report No. 25 (February). http://www.medpro-foresight.eu/system/files/MEDPRO%20TR%20No%2025%20WP4a%20Bosello.pdf.

Burke, Marshall, Solomon M. Hsiang, and Edward Miguel, (2015). "Global non-linear effect of temperature on economic production." Nature. http://www.nature.com/nature/journal/vaop/ncurrent/full/nature15725.html.

Burki, Rolf, Hans Elsasser, and Bruno Abegg, (2003). "Climate change and winter sports: environmental and economic threats.: 5th World Conference on Sport and Environment. Turin. December. http://www.unep.org/sport_env/Documents/torinobuerki.doc.

Campbell-Lendrum, Diarmid, and Rosalie Woodruff, (2007). Climate Change: Quantifying the Health Impact at National and Local Levels. http://whqlibdoc.who.int/publications/2007/9789241595674_eng.pdf?ua=1.

Central Administration of Statistics, (2015a). "The average household size in Lebanon was 4.23 in 2007." http://www.cas.gov.lb/index.php/en/did-you-know-category-en/100-did-you-know-11

Central Administration of Statistics, (2015b). "Consumer Price Index." http://www.cas.gov.lb/index.php/economic-statistics-en/cpi-en#cpiresults.

Chan, Kai M. A., Anne D. Guerry, Patricia Balvanera, Sarah Klain, Terre Satterfield, Xavier Basurto, Ann Bostrom, Ratana Chuenpagdee, Rachelle Gould, Benjamin S. Halpern, Neil Hannahs, Jordan Levine, Bryan Norton, Mary Ruckelshaus, Roly Russell, Jordan Tam, and Ulalia Woodside, (2012). "Where Are Cultural and Social in Ecosystem Services? A Framework for Constructive Engagement." BioScience. 62:8 (August). http://www.jstor.org/stable/10.1525/bio.2012.62.8.7?origin=JSTOR-pdf&seq=1#page_scan_tab_contents.

Climate Change in Australia, (2015). "Emissions Scenarios." http://www.climatechangeinaustralia.gov.au/en/climate-projections/climate-futures-tool/experiments/.

Costanza, R., R. dArge, R. de Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R.V. Oneill, J. Paruelo, R.G. Raskin, P. Sutton, and M. van den Belt, (1997). "The Value of the World's Ecosystem Services and Natural Capital." Nature. 387, 253–260. http://www.esd.ornl.gov/benefits_conference/nature_paper.pdf.

Costanza, R., R. de Groot, P. Sutton, S. van der Ploeg, S.J. Anderson, I. Kubiszewski, S. Farber, and R.K. Turner, (2014). "Changes in the Global Value of Ecosystem Services." Global Environmental Change. 26: 152-158. http://ac.els-cdn.com/S0959378014000685/1-s2.0-S0959378014000685-main.pdf?_tid=0e469544-2fcf-11e5-ae7f-00000aab0f02&acdnat=1437500384_710b2753b659f0644b659e0cdfe8146a.

Crosby, Liam, Daphne Jaysinghe, and David McNair. 2013. Food for Thought: Tackling Child Malnutrition to Unlock Potential and Boost Prosperity. Save the Children. p. 7. http://www.savethechildren.org.uk/sites/default/files/images/Food_for_Thought_UK.pdf.

DARA and Climate Vulnerability Forum, (2012). "Lebanon." Climate Vulnerability Monitor. http://daraint.org/climate-vulnerability-monitor/climate-vulnerability-monitor-2012/country-profile/?country=Lebanon.

Doppelt, Bob. Forthcoming. How Building Human Resilience Can Safeguard Society: and provide New Meaning, Purpose, and Hope. London: Earthscan.

Eggleston, Karen N., Nilay D. Shah, Steven A. Smith, Ernst R. Berndt, and Joseph P. Newhouse, (2011). " Quality Adjustment for Health Care Spending on Chronic Disease: Evidence from Diabetes Treatment, 1999–2009." American Economic Review: Papers & Proceedings. 101:3, 206-211. http://dspace.mit.edu/openaccess-disseminate/1721.1/87608.

FAO, (2012). "Global Food Price Monitor." 12 September. http://www.fao.org/giews/english/gfpm/GFPM_09_2012.pdf.

FAO, (2015). Lebanon: National Aquaculture Sector Overview. http://www.fao.org/fishery/countrysector/naso_lebanon/en.

Fichtner, (2011). MENA Regional Water Outlook. Part II: Desalination Using Renewable Energy. March. http://siteresources.worldbank.org/INTMNAREGTOPWATRES/Resources/Use_of_Desalination_and_Renewable_Energy_to_Close_the_Water.pdf. pp. 6-78 – 6-80.

Global Risk Forum GRF Davos, (2013). The Economics of Desertification, Land Degradation, and Drought: Methodologies and Analysis for Decision-Making. United Nations Convention to Combat Desertification. 2nd Scientific Conference, 9-12 April, Bonn, Germany. http://2sc.unccd.int/fileadmin/unccd/upload/documents/Background_documents/Background_Document_web3.pdf.

de Groot, Rudolf, Luke Brander, Sander van der Ploeg, Robert Costanza, Florence Bernard, Leon Braat, Mike Christie, Neville Crossman, Andrea Ghermandi, Lars Hein, Salman Hussain, Pushpam Kumar, Alistair McVittie, Rosimeiry Portela, Luis C. Rodriguez, Patrick ten Brink, Pieter van Beukering, (2012). "Global Estimates of the Value of Ecosystems and their Services in Monetary Units. Ecosystem Services. 1:1 (July), pp. 50-61. http://www.sciencedirect.com/science/article/pii/S2212041612000101.

El-Laithy, Heba, Khalid Abu-Ismail, and Kamal Hamdan, (2008). Poverty, Growth and Income Distribution in Lebanon. http://www.lb.undp.org/content/dam/lebanon/docs/Poverty/Publications/Poverty,%20Growth%20and%20Income%20Distribution%20in%20Lebanon.pdf.

Haddad, Eduardo A., Nadim Farajalla, Marina Camargo, Ricardo Lopes, and Flavio Vieira, (2014). Climate Change in Lebanon: Higher-Order Regional Impacts from Agriculture. http://www.usp.br/nereus/wp-content/uploads/TD_Nereus_02_2014.pdf.

Hansen, J., M. Sato, P. Hearty, R. Ruedy, M. Kelley, V. Masson-Delmotte, G. Russell, G. Tselioudis, J. Cao, E. Rignot, I. Velicogna, E. Kandiano, K. von Schuckmann, P. Kharecha, A. N. Legrande, M. Bauer, and K.-W. Lo. In review. "Ice Melt, Sea Level Rise and Superstorms: Evidence from Paleoclimate Data, Climate Modeling, and Modern Observations that 2°C Global Warming is Highly Dangerous." Atmos. Chem. Phys. Discuss., 15, 20059–20179. http://www.atmos-chem-phys-discuss.net/15/20059/2015/acpd-15-20059-2015.pdf.

Hayhoe K, D. Cayan, C.B. Field, P.C. Frumhoff, E.P. Maurer, N.L. Miller, et al, (2004). "Emissions Pathways, Climate Change, and Impacts on California." Proceedings of the National Academy of Sciences. 101(34):12422–12427. http://www.pnas.org/content/101/34/12422.full.pdf.

Highfill, Tina, and Elizabeth Bernstein, (2014). "Using Disability Adjusted Life Years to Value the Treatemnt of Thirty Chronic Conditions in the U.S. from 1987-2010." U.S. Bureau of Economic Analysis. http://www.bea.gov/papers/pdf/highfill_bernstein_2014_dalysall.pdf.

Hsiang, Solomon M., Marshall Burke, and Edward Miguel, (2013). "Quantifying the Influence of Climate on Human Conflict." Science. Vol. 341: 1235367. Hsiang, Solomon M., Marshall Burke, and Edward, Miguel. 2013. "Quantifying the Influence of Climate on Human Conflict." Science, 10.1126/science.1235367.

Husain, Tahir, and Junaid Rafi Chaudhary, (2008). "Human Health Risk Assessment due to Global Warming – A Case Study of the Gulf Countries." Int J Environ Res Public Health. 2008 Dec; 5(4): 204–212. Nov 28. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2672314/.

Interagency Working Group on Social Cost of Carbon, United States Government. (2015). Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis - Under Executive Order 12866: Update. July. https://www.whitehouse.gov/sites/default/files/omb/inforeg/scc-tsd-final-july-2015.pdf.

International Food Policy Research Institute (IFPRI), (2009). “Impact of Climate Change on Agriculture–Factsheet on Middle East and North Africa.” http://www.agrifeeds.org/en/news/impact-climate-change-agriculture-factsheet-middle-east-and-north-africa

Institute for Economics & Peace, (2014). The Economic Cost of Violence Containment: A Comprehensive Assessment of the Global Cost of Violence. http://economicsandpeace.org/wp-content/uploads/2015/06/The-Economic-Cost-of-Violence-Containment.pdf.

Institute for Economics & Peace, (2015). Global Peace Index: 2015. http://economicsandpeace.org/wp-content/uploads/2015/06/Global-Peace-Index-Report-2015_0.pdf.

IPCC, (1997). ”Middle East and Arid Asia.” The Regional Impacts of Climate Change: An Assessment of Vulnerability. [O. Pilifosova, B. alijani, and U.N. Safriel. R.T.Watson, M.C.Zinyowera, R.H.Moss (Eds). http://www.ipcc.ch/ipccreports/sres/regional/index.php?idp=153.

IPCC, (2000). Emissions Scenarios: Summary for Policymakers. https://www.ipcc.ch/pdf/special-reports/spm/sres-en.pdf

IPCC, (2001). “Costing Methodologies.” [Markandya, M., K. Halsnaes, A. Lanza, Y. Matsuoka, S. Maya, J. Pan, J. Shogren, R.S. de Motta, and T. Zhang]. Climate Change 2001: Mitigation. Contributions of Working Group III to the Third Assessment Report of the Intergovernmental Panel on Climate Change. pp. 451-498. http://www.ipcc.ch/ipccreports/tar/wg3/pdf/7.pdf.

IPCC, (2013a). “Annex II: Climate System Scenario Tables.” [Prather, M., G. Flato, P. Friedlingstein, C. Jones, J.-F. Lamarque, H. Liao and P. Rasch (eds.)]. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. pp. 1410-1412. http://www.climatechange2013.org/images/report/WG1AR5_AnnexII_FINAL.pdf.

IPCC, (2013b). “Summary for Policymakers.” In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)].

IPCC, (2014). “Summary for Policymakers.” pp. 12-20. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)].

King, David, Daniel Schrag, Zhou Dadi, Qi Ye, and Arunabha Ghosh, (2015). Climate Change: A Risk Assessment. http://www.csap.cam.ac.uk/media/uploads/files/1/climate-change--a-risk-assessment-v9-spreads.pdf

Kinney, Patrick L, Joel Schwartz, Mathilde Pascal, Elisaveta Petkova, Alain Le Tertre, Sylvia Medina, and Robert Vautard, (2015). “Winter Season Mortality: Will Climate Warming Bring Benefits?” Environmental Research Letters. 19 June. http://iopscience.iop.org/1748-9326/10/6/064016/pdf/1748-9326_10_6_064016.pdf.

Millennium Ecosystem Assessment, (2005). Ecosystems and Human Well-being: Synthesis. http://www.millenniumassessment.org/documents/document.356.aspx.pdf.

Ministry of Environment, United Nations Development Programme, and GEF (MoE/UNDP/GEF), (2011). Lebanon’s Second National Communication to the UNFCCC. http://www.lb.undp.org/content/dam/lebanon/docs/Energy%20and%20Environment/Publications/Lb_SNC_final.pdf.

Ministry of Finance, (2013). Lebanon Country Profile 2013. http://www.finance.gov.lb/en-US/finance/ReportsPublications/DocumentsAndReportsIssuedByMOF/Documents/Sovereign%20and%20Invensment%20Reports/Country%20Profile/Lebanon%20Country%20Profile%202013.pdf.

Moore, Frances, (2015). Personal communication. 19 May.

Moore, Frances, C., and Delavane B. Diaz, (2015). "Temperature Impacts on Economic Growth Warrant Stringent Mitigation Policy." Nature Climate Change. 12 January. http://www.nature.com/nclimate/journal/v5/n2/full/nclimate2481.html.

Myhre, G., D. Shindell, F.-M. Bréon, W. Collins, J. Fuglestvedt, J. Huang, D. Koch, J.-F. Lamarque, D. Lee, B. Mendoza, T. Nakajima, A. Robock, G. Stephens, T. Takemura and H. Zhang, (2013). "Anthropogenic and Natural Radiative Forcing." In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)].

Nelson, Gerald C., Hugo Valin, Ronald D. Sands, Petr Havlík, Helal Ahammad, Delphine Deryng, Joshua Elliott, Shinichiro Fujimori, Tomoko Hasegawa, Edwina Heyhoe, Page Kyle, Martin Von Lampe, Hermann Lotze-Campen, Daniel Mason d'Croz, Hans van Meijl, Dominique van der Mensbrugghe, Christoph Müller, Alexander Popp, Richard Robertson, Sherman Robinson, Erwin Schmid, Christoph Schmitz, Andrzej Tabeau, and Dirk Willenbocke, (2014). "Climate change effects on agriculture: Economic responses to biophysical shocks." Proceedings of the National Academy of Sciences. 4 March. pp. 3274-3279.

OECD, (2011). "Valuing Mortality Risk Reductions in Regulatory Analysis of Environmental, Health and Transport Policies: Policy Implications." www.oecd.org/env/policies/vsl.

Onofri, Laura, Paulo A.L.D. Nunes, and Francesco Bosello, (2013). Economic and Climate Change Pressures on Biodiversity in Southern Mediterranean Coastal Areas. MEDPRO Technical Report No. 24 (February) http://www.medpro-foresight.eu/fr/system/files/MEDPRO%20TR24%20Onofri%20et%20al%20Pressures%20on%20Biodiversity.pdf.

Patel, Deepali S., and Rachel M. Taylor, (2012). Social and Economic Costs of Violence: Workshop Summary. U.S. National Research Council. http://www.ncbi.nlm.nih.gov/books/NBK189999/pdf/Bookshelf_NBK189999.pdf

Pinello, Dario, and Mark Dimech, (2013). Socio-Economic Analysis of the Lebanese Fishing Fleet. http://www.fao.org/docrep/018/ar250e/ar250e.pdf.

Porter, J.R., L. Xie, A.J. Challinor, K. Cochrane, S.M. Howden, M.M. Iqbal, D.B. Lobell, and M.I. Travasso, (2014). "Food Security and Food Production Systems." In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 485-533. https://ipcc-wg2.gov/AR5/images/uploads/WGIIAR5-Chap7_FINAL.pdf.

Porter, John R., Manuel Montesino, and Mikhail Semenov, (2015). "The Risks of Climate Change for Crop Production." In King, David, Daniel Schrag, Zhou Dadi, Qi Ye, and Arunabha Ghosh. 2015. Climate Change: A Risk Assessment. pp. 65-73. http://www.csap.cam.ac.uk/media/uploads/files/1/climate-change--a-risk-assessment-v9-spreads.pdf.

Potsdam Institute for Climate Impacts Research and Climate Analytics (Potsdam Institute), (2013). Turn Down the Heat: Climate Extremes, Regional Impacts, and the Case for Resilience. World Bank. June. http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2013/06/14/000445729_20130614145941/Rendered/PDF/784240WP0Full00D0CONF0to0June19090L.pdf.

RCP Database, (2015). "Data Downloads – emissions for the RCPs." http://tntcat.iiasa.ac.at:8787/RcpDb/dsd?Action=htmlpage&page=download.

Robalino, David, and Haneed Sayed, (2012). Republic of Lebanon: Good Jobs Needed. Report No. 76008-LB World Bank Middle East and North Africa Human Development Group. http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2013/03/20/000425962_20130320133437/Rendered/PDF/760080ESW0GRAY0C0Disclosed030200130.pdf

Roe, Dilys, and Joanna Elliot, (2004). "Poverty Reduction and Biodiversity Conservation: Rebuilding the Bridges." Oryx. 38: 2. (April) http://pubs.iied.org/pdfs/G01274.pdf.

Secretariat of the Convention on Biological Diversity, (2014). An Updated Synthesis of the Impacts of Ocean Acidification on Marine Biodiversity (Eds: S. Hennige, J.M. Roberts & P. Williamson). Montreal, Technical Series No. 75. https://www.cbd.int/doc/publications/cbd-ts-75-en.pdf.

Sheridan, Scott C., and Michael J. Allen, (2015), "Changes in the Frequency and Intensity of Extreme Temperature Events and Human Health Concerns." Current Climate Change Reports. 11 June. http://download.springer.com/static/pdf/718/art%253A10.1007%252Fs40641-015-0017-3.pdf?originUrl=http%3A%2F%2Flink.springer.com%2Farticle%2F10.1007%2Fs40641-015-0017-3&token2=exp=1435087459~acl=%2Fstatic%2Fpdf%2F718%2Fart%25253A10. 1007%25252Fs40641-015-0017-3.pdf

Solomon, Susan, John S. Daniela, Todd J. Sanford, Daniel M. Murphya, Gian-Kasper Plattnerc, Reto Knuttid, and Pierre Friedlingsteine, (2010). "persistence of Climate Changes Due to a Range of Greenhouse Gases." PNAS. 107: 43 (August). http://www.pnas.org/content/107/43/18354.full.pdf?with-ds=yes.

United Nations, Economic and Social Affairs (UNESA), (2007). Indicators of Sustainable Development: Guidelines and Methodologies, 3rd Edition. http://www.un.org/esa/sustdev/natlinfo/indicators/guidelines.pdf.

U.S. Environmental Protection Agency, (2015). "Frequently Asked Questions on Mortality Risk Valuation." March 27. http://yosemite.epa.gov/EE%5Cepa%5Ceed.nsf/webpages/MortalityRiskValuation.html.

U.S. National Research Council, (2004). Valuing Ecosystem Services: Toward Better Decision-Making. http://www.nap.edu/catalog/11139/valuing-ecosystem-services-toward-better-environmental-decision-making.

U.S. St. Louis Federal Reserve Bank, (2015). Personal Consumption Expenditures: Chain-type Price Index. https://research.stlouisfed.org/fred2/data/PCEPI.txt.

Verner, Dorte, and Clemens Breisinger (eds.), (2013). Economics of Climate Change in the Arab World: Case Studies from the Syrian Arab Republic, Tunisia, and the Republic of Yemen. World Bank. http://www-wds.worldbank.org/external/default/WDSContentServer/IW3P/IB/ 2013/04/03/000445729_20130403130952/Rendered/PDF/763680PUB0EPI0001300PUBDATE03021013.pdf.

Vivid Economics, (2010). Promoting Economic Growth when the Climate is Changing. UK Department of International Development. July. p. 21. http://www.vivideconomics.com/wp-content/uploads/2015/03/Vivid_Econ_Adaptation_and_Growth.pdf.

Watts, Nick, W Neil Adger, Paolo Agnolucci, Jason Blackstock, Peter Byass, Wenjia Cai, Sarah Chaytor, Tim Colbourn, Mat Collins, Adam Cooper, Peter M Cox, Joanna Depledge, Paul Drummond, Paul Ekins, Victor Galaz, Delia Grace, Hilary Graham, Michael Grubb, Andy Haines, Ian Hamilton, Alasdair Hunter, Xujia Jiang, Moxuan Li, Ilan Kelman, Lu Liang, Melissa Lott, Robert Lowe, Yong Luo, Georgina Mace, Mark Maslin, Maria Nilsson, Tadj Oreszczyn, Steve Pye, Tara Quinn, My Svensdotter, Sergey Venevsky, Koko Warner, Bing Xu, Jun Yang, Yongyuan Yin, Chaoqing Yu, Qiang Zhang, Peng Gong, Hugh Montgomery, and Anthony Costello, (2015). "Health and Climate Change: Policy Responses to Protect Public Health." The Lancet Commissions. http://press.thelancet.com/Climate2Commission.pdf.

Wieder, William R., William R., Cory C. Cleveland, W. Kolby Smith, and Katherine Todd-Brown, (2015). "Future Productivity and Carbon Storage Limited by Terrestrial Nutrient Availability." Nature Geoscience. 20 April. http://www.nature.com/ngeo/journal/vaop/ncurrent/full/ngeo2413.html.

World Health Organization, (2011). "Lebanon." Global Observatory for eHealth." http://www.who.int/goe/publications/atlas/lbn.pdf?ua=1.

World Health Organization, (2014). Quantitative Risk Assessment of the Effects of Climate Change on Selected Causes of Death, 2030s and 2050s. http://apps.who.int/iris/bitstream/10665/134014/1/9789241507691_eng.pdf.

World Bank, (2008). Republic of Lebanon: Electricity Sector Public Expenditure Review Report No. 41421-LB. January 31. https://openknowledge.worldbank.org/bitstreamhandle/10986/7990/414210REPLACEM1closed0April01502008.pdf?sequence=1.

World Bank, (2010). Republic of Lebanon Water Sector: Public Expenditure Review. Report No. 52024-LB. 17 May. https://openknowledge.worldbank.org/bitstream/handle/10986/2877/520241LB0ESW0B110Disclosed0July0141.pdf?sequence=1

World Bank, (2014). Natural Disasters in the Middle East and North Africa: A Regional Overview. January. pp. 14-15. http://documents.worldbank.org/curated/en/2014/01/19203331/natural-disasters-middle-east-north-africa-regional-overview

World Bank, (2015a). "PPP Conversion Factor, GDP (LCU per International $)." http://data.worldbank.org/indicator/PA.NUS.PPP.

World Bank, (2015b). "World Development Indicators: GNI per capita, Atlas method (current US$)." http://data.worldbank.org/indicator/NY.GNP.PCAP.CD/countries/LB-XQ-XT?display=graph.

World Bank, (2015c). "World Development Indicators: Electricity Production, Sources, and Access." http://wdi.worldbank.org/table/3.7

World Bank, (2015d). "World Development Indicators: Size of the Economy." http://wdi.worldbank.org/table/1.1.

World Bank, (2015e). "World Development Indicators: Population Dynamics." http://wdi.worldbank.org/table/2.1.

World Bank, Refugee Centre at the University of Oxford, PRIO, and FAFO, (2012). Assessing the Impacts and Costs of Forced Displacement. May 1. pp. 80-81. http://siteresources.worldbank.org/EXTSOCIALDEVELOPMENT/Resources/244362-1265299949041/6766328-1265299960363/ImpactCostStudy-VolumeI2.pdf

Wu, Jianguo, and Tong Wu, (2012). "Sustainability Indicators and Indicies: and Overview." In Madu, Christian N. and Chu-Hua Kuei (eds.). Handbook of Sustainability Management. March pp. 65-86.

Annex I: Participants in stakeholders' planning session

Name	Affiliation
Amal Salibi	Ministry of Agriculture
Charbel Mansour	Lebanese American University
Dany Lichaa	Independent agriculture consultant
Eliane Charbel	Lebanon Reforestation Initiative
Hadi Tabbara	Independent agriculture consultant
Hassan Harajli	United Nations Development Programme
Jaoudat Abou Jaoude	Council for Development and Reconstruction
Kawthar Dara	Independent finance consultant
Leila el Sayed	United Nations Development Programme – Ministry of Environment
Mary Awad	United Nations Development Programme – Ministry of Environment
Nabil Amacha	Lebanese University
Nader Hajj Shehade	Independent energy consultant
Perla Obeid	Ministry of Tourism
Rima Habib	American University of Beirut
Sabine Saba	University of Balamand
Tarek Sadek	United Nations Economic and Social Commission for West Asia
Vahakn Kabakian	United Nations Development Programme – Ministry of Environment
Walid Sayegh	United Nations Development Programme – Ministry of Finance
Yara Daou	United Nations Development Programme – Ministry of Environment
Yasmine Ibrahim	United Nations Development Programme – Ministry of Finance
Ziad Nakat	World Bank

Annex II: Population, households, and temperature estimates

This annex describes data, assumptions, and calculations to estimate the population, number of households, and effects of climate change on temperature.

1. Population

This analysis assumes these estimates, from Ministry of Environment (2015), accurately represent Lebanon's population (millions) for 2007–2012:

2007	4.8
2008	4.9
2009	5.0
2010	5.0
2011	5.1
2012	5.2

To estimate population for years following 2012, the analysis employs these projections of annual growth, from Economic and Social Commission for Western Asia (2012), applied to the estimate for 2012:

2010-2015	3.04%
2015-2020	-0.71%
2020-2025	0.67%
2025-2030	0.50%
2030-2035	0.33%
2035-2040	0.18%
2040-2045	0.07%
2045-2080	-0.03%

This approach yields these estimates of future population (millions):

2020	5.5
2040	6.0
2080	5.9

2. Households

The Central Administration of Statistics (2015a) estimates that, on average, each household in Lebanon has 4.43 persons. This analysis assumes that this average household size will persist through 2080. Dividing the estimated population by the average household size yields these estimates of the number of households (millions) in future years:

2020	1.3
2040	1.4
2080	1.4

3. Temperature

This analysis assumes these increases, relative to 1880-1919, in average annual temperature in Lebanon from human-caused climate change:

2010 0.85°C

This estimate represents the globally averaged combined land and ocean surface temperature data (IPCC 2013; p. 5). This analysis applies this estimate to nearby years, such as 2005, 2009, 2011, and 2012.

2020 1°C

This estimate comes from IPCC (2013; p. 18), which assumes the total, human-caused increase in average annual temperature will equal or exceed 1°C for Africa, Europe and Asia.

2040 2°C

This estimate reflects the assessment, from MoE/UNDP/GEF (2011; p. ix) that uses the lower bound from climate-change scenarios developed for Lebanon through application of the PRECIS model. The scenarios predict that, relative to the present climate, "by 2040 temperatures will increase from around 1°C on the coast to 2°C in the mainland…."

2080 5°C

This estimate assumes an additional increase, relative to 2020, of 4°C, which represents a rough approximation of the scenarios from the PRECIS model, which indicates that relative to the present climate, average annual temperatures in Lebanon will be 3.5°C to 5°C higher by 2090 (MoE/UNDP/GEF 2011; p. ix).

Some elements of the analysis consider the effects of changes in temperature from 2010 and nearby years. The changes in temperature are:

2010–2020 0.15°C

2010–2040 1.15°C

2010–2080 4.15°C

Annex III: Economic costs that activities contributing to climate would impose on lebanon

This section turns attention away from the costs resulting from climate change to the parallel costs from activities that contribute to climate change, such as the combustion of fossil fuels. The calculations rely on currently available information to develop separate estimates of individual costs that would result as expected changes in climate:

1. Expose workers to hazardous substances.
2. Expose the public to hazardous substances.
3. Increase the risk of oil spills.

1. Costs from workers' increased risk of death from exposure to hazardous substances

Description

This analysis describes the costs that would materialize in the future as activities, such as importing fossil fuels for automobiles and burning fossil fuels to generate electricity, increase workers' exposure to harmful pollutants. Workers' exposure to harmful pollutants associated with the shipment, handling, storage, and combustion of fossil fuels can result in illness, disability, and death from asthma, chronic obstructive pulmonary disease, and skin cancer. This analysis describes the economic costs associated with an increased risk of death.

By estimating the value of the increased risk of death for workers from occupational hazards, this analysis is not placing a monetary value on the lives of the individuals who may die prematurely. Instead, it reflects the overall risk to society. The cost estimates represent how much people throughout society are willing to pay for small reductions in their risk of dying, or, alternatively, how much compensation they would require to willingly accept an increase in risk.

Studies have found that the willingness to pay for risk reductions generally is lower in poor countries than in rich countries not because poor people value life less but because their ability to pay is lower. This difference raises concerns that have prompted protracted debate about whether to choose a value from studies conducted in poor countries or from studies conducted in rich countries. Accordingly, the IPCC (2001: p. 483) has recognized that it might be appropriate to use an "equity-adjusted" average value across all countries of about USD 1,350,000 per potential death (adjusted to 2015 USD).

Results

Table 23 shows the potential deaths and economic costs that might materialize if Lebanon were to extend current trends in activities that contribute to climate change and increase workers' exposure to hazardous substances. These activities would cause about 83 premature deaths in 2020, 160 in 2040, and 580 in 2080. The economic costs associated with these deaths would total about USD 110 million in 2020, USD 220 million in 2040, and USD 790 million in 2080.

Table 23: Potential deaths and costs in Lebanon associated with workers' increased risk of death from exposure to hazardous substances associated with activities that contribute to climate change (2015 USD)

Year	2020	2040	2080
Additional potential deaths of workers from occupational hazards related to climate change in Lebanon	83	160	580
Costs of increased risk of death (millions)	USD 110	USD 220	USD 790

Numbers reflect the rounding rules described in the Introduction.

Assumptions, data, and calculation

The calculation of the potential costs involves these steps:

Step 1. Assume that estimates of deaths in 2010 (60 additional deaths) and 2030 (115 additional deaths) from occupational hazards and skin cancer associated with activities that contribute to climate change (DARA and Climate Vulnerability Forum, 2012) provide reasonable estimates of the levels of and average annual growth in workers' risk of death, and that these findings apply for calculating costs in 2020, 2040, and 2080.

Step 2. Calculate the costs of workers' increased risk of death. Apply the estimated average annual growth rate, 3% (DARA and Climate Vulnerability Forum, 2012), to the 60 estimated number of deaths in 2010. Results (additional deaths per year): 83 in 2020, 160 in 2040, and 580 in 2080. Multiply times USD 1.4 million per death (2015 USD), the estimated economic cost per death (IPCC 2001). Table 23 shows the results.

Discussion

The actual costs might be higher or lower than those shown in Table 23. The costs would be three times larger if the analysis applied the value the OECD (2011) uses to evaluate mortality risk in rich countries as a whole, and six times larger if it applied the value the U.S. Environmental Protection Agency (2015) uses to evaluate mortality risk in the U.S.

2. Costs from the public's increased risk of death from exposure to hazardous substances

Description

This analysis describes the costs that would materialize in the future as activities, such as importing fossil fuels for automobiles and burning fossil fuels to generate electricity, increase the public's exposure to harmful pollutants. Exposure to harmful pollutants, such as smoke from the combustion of fossil fuels, can result in chronic obstructive pulmonary disease, tuberculosis, visual impairment, and cancer. This analysis describes the economic costs associated with an increased risk of death.

By estimating the value of the increased risk of death for people exposed to hazardous substances, this analysis is not placing a monetary value on the lives of the individuals who may die prematurely. Instead, it reflects the overall risk to society. The cost estimates represent how much people throughout society are willing to pay for small reductions in their risk of dying, or, alternatively, how much compensation they would require to willingly accept an increase in risk. Studies have found that the willingness to pay for risk reductions generally is lower in poor countries than in rich countries not because poor people value life less but because their ability to pay is lower. This difference raises concerns that have prompted protracted debate about whether to choose a value from studies conducted in poor countries or from studies conducted in rich countries. Accordingly, the IPCC (2001; p. 483) has recognized that it might be appropriate to use an "equity-adjusted" average value across all countries of about USD 1,350,000 per potential death (adjusted to 2015 USD).

Results

Table 24 shows the potential deaths and economic costs that might materialize if Lebanon were to extend current trends in activities that contribute to climate change and increase the public's exposure to hazardous substances. This exposure would cause about 1,700 premature deaths in 2020, 2,000 in 2040, and 2,700 in 2080. The economic costs associated with these deaths would total about USD 2,300 million in 2020, USD 2,700 million in 2040, and USD 3,600 million in 2080.

Table 24: Potential economic costs from the public's exposure to hazardous substances in Lebanon (2015 USD)

Year	2020	2040	2080
Additional potential deaths from public exposure to hazardous substances in Lebanon	1,700	2,000	2,700
Costs of increased risk of death (millions)	USD 2,300	USD 2,700	USD 3,600

Numbers reflect the rounding rules described in the Introduction.

Assumptions, data, and calculation

The calculation of the potential costs involves these steps:

Step 1. Assume that estimates of deaths from air pollution and indoor smoke for 2010 (1,600 additional deaths) and 2030 (1,850 additional deaths) (DARA and Climate Vulnerability Forum 2012) provide reasonable estimates of the levels of and average annual growth in the public's risk of death, and that these findings apply for calculating costs in 2020, 2040, and 2080.

Step 2. Calculate the costs of the public's increased risk of death. Apply the estimated average annual growth rate, 1%, to the 1,600 estimated number of deaths in 2010. Multiply times USD 1.35 million per death (2015 USD), the estimated economic cost per death (IPCC 2001). Table 24 shows the results.

Discussion

The actual costs might be higher or lower than those shown in Table 24. The costs would be three times larger if the analysis applied the value the OECD (2011) uses to evaluate mortality risk in rich countries as a whole, and six times larger if it applied the value the U.S. Environmental Protection Agency (2015) uses to evaluate mortality risk in the U.S.

3. Costs from oil spills

Description

This analysis describes the costs that would materialize in the future as activities, such as importing fossil fuels for automobiles and the generation of electricity, increase the risk of oil spills. Oil-spill costs can materialize directly, through clean-up activities and as hazardous materials and clean-up activities damage the environment. Cost also can materialize indirectly, as the spill disrupts economic activities that otherwise would occur.

Results

Table 25 shows the potential economic costs that might materialize if Lebanon were to extend current trends in activities that involve the risk of oil spills. These costs would total about USD 140 million in 2020, USD 530 million in 2040, and USD 7,800 million in 2080.

Table 25: Potential economic costs from the increased risk of oil spills in Lebanon (2015 USD)

Year	2020	2040	2080
Costs of additional oil spills in Lebanon (millions)	USD 140	USD 530	USD 7,800

Numbers reflect the rounding rules described in the Introduction.

Assumptions, data, and calculation

The calculation of the potential costs involves these steps:

Step 1. Assume that costs reported for 2010 (USD 65 million) and 2030 (USD 250 million) by DARA and Climate Vulnerability Forum (2012) provide reasonable estimates of the levels of and average annual growth in oil-spill costs, and that these findings apply for calculating costs in 2020, 2040, and 2080.

Step 2. Calculate oil-spill costs. Apply the estimated average annual growth rate, 7%, to the estimated costs in 2010, USD 65 (2010 USD), and adjust to 2015 USD. Table 25 shows the results.

Discussion

The actual costs might be higher or lower than those shown in Table 25. Costs would be higher, for example, if multiple spills damaged ecosystems so that services society derives from them become scarcer and more valuable. Costs could be lower if clean-up systems become more effective and efficient.

Annex IV: Frequently asked questions

1. What are Greenhouse Gases (GHGs)?

Atmospheric gases that have a greenhouse effect on the global climate by impeding the planet's ability to release back into space some of the heat it absorbs from the sun. Much of the concern about climate change focuses on human-caused emissions into the atmosphere of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).

2. What percentage of global GHG emissions does Lebanon emit?

In 2011, Lebanon's total emissions amounted to 24,652 Gg CO_2eq., which constitutes only 0.07% of global GHG emissions. The most significant greenhouse gas emitted in Lebanon is carbon dioxide, primarily produced from the burning of fossil fuels. The main contributor to greenhouse gas emissions is the energy sector with 74% GHG emissions, followed by the waste sector (11%) and industrial processes (10%).

3. What percentage of the global costs of climate change will Lebanon experience?

The analysis of the total costs to Lebanon assumes that its share of global costs from climate change would be about 0.06%, which is its share of both world population (World Bank, 2015b) and world GDP (World Bank, 2015a).

4. Why does the title of this report say it is "A First Look" at the potential costs climate change might impose on Lebanon? Haven't other studies estimated climate-related costs for Lebanon?

This report represents the first Lebanon-specific effort to describe the total costs climate change might impose on Lebanon and on different segments of the economy and society, as well as the potential reductions in costs if meaningful actions are taken to constrain global GHG emissions. Where appropriate, this report directly presents the results of previous studies. For example, to describe the costs associated with the effects of climate change on Lebanon's agricultural sector, it relies directly on a study of (Haddad et al 2014). Most of the cost estimates in the report, however, represent a first-of-its-kind analysis.

5. Did stakeholders have an opportunity to participate in the design of the research that underlies the report? Did they have an opportunity to review the analytical findings?

Yes. The individuals identified in Annex I participated in a stakeholders' planning session to provide advice and other assistance during the development of the research design. Each individual also was invited to review a draft of the report.

6. Does the analysis underlying this report rely solely on information from Lebanon?

Each element of the analysis relies on data specific to Lebanon, such as estimates of the country's past and current levels of agricultural output and GDP, and projections of future population and climate-related increase in temperature. Where appropriate, the analysis integrates this Lebanon-specific information with information from elsewhere. For example, it uses some regional data from the Middle East and North Africa, and it employs the findings from global studies that have estimated the annual costs of the damage from droughts, heat waves, etc. resulting from the emission of one tonne of CO_2, and the effects of this damage on GDP growth.

http://climatechange.moe.gov.lb/