CLIMATE-PROOFING LEBANON'S DEVELOPMENT PLANS

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This work was jointly conducted by Vivid Economics, Aether, CAOS and Earth Link & Advanced Resources Development (ELARD) for the UNDP, as part of its Climate Promise agenda, and the Lebanese Ministry of Environment. The Vivid team consisted of Jason Eis (Project Director), Karishma Gulrajani (Project Manager) and Alessa Widmaier. The Aether team consisted of Melanie Hobson, Laurence Opie and Henry Irvine. The CAOS team consisted of Inês Mourão. The ELARD team consisted of Ricardo Khoury and Antoine Waked.

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EXECUTIVE SUMMARY

Lebanon is expected to face significant impacts from climate change, including rising sea levels and an increase in temperature. Lebanon is a highly urbanized middle-income developing country located on the eastern shore of the Mediterranean Sea. The densely populated coastal urban areas that host critical infrastructure and industry are particularly vulnerable to climate change. The consequences of inaction include the direct damage from heat waves, droughts, and storms, as well as indirect damage from slower economic growth.

It also faces a multitude of economic, development and environmental challenges, all of which highlight the need for a low-carbon and resilient economic recovery. In 2019, the economy plunged into a still ongoing financial crisis, which has been fuelled further by the Covid-19 pandemic. Moreover, the population increase following the Syrian crisis has not only aggravated the development challenge of political instability and poverty, but also contributed to higher environmental stress.

In order to reduce emissions and avoid the most dangerous impacts of climate change, Lebanon has set out its climate goals in a Nationally Determined Contribution (NDC). As part of its updated NDC under the Paris Agreement, Lebanon pledged to reduce GHG emissions by 20% by 2030 as an unconditional target and by 31% by 2030 as a conditional target. As Lebanon is a developing country with scarce water resources and high population density, the NDC also highlighted the need to build resilience and improve adaptation in addition to reducing emissions.

At the same time, Lebanon has developed three national plans to outline its recovery from the recent financial crises and define future growth. The three plans analysed in this report include:

- **The 3-year development priorities of the Financial Recovery Plan.** The purpose of this plan is primarily to overcome short-term financial challenges.
- **Lebanon Economic Vision (LEV).** The LEV charts out a national strategy for reviving the economy through targeted investments in the sectors it has identified as core engine of growth.
- **The Capital Investment Programme (CIP).** The CIP outlines infrastructure projects that both align with national development goals and create opportunities for economic growth in the short and medium term.

This project aims to 'climate-proof' three Lebanese development plans, identifying how the planned projects can deliver GHG mitigation and build resilience to the impacts of climate change. Without careful consideration and planning, there is a risk that Lebanon's national development agenda could compromise its climate commitments. Conversely, the climate commitments also provide an opportunity to mainstream climate change in the national development agenda, which could enhance green economic growth. To this end, this project analyses planned priority projects for the coming years on their ability to contribute to Lebanon's climate commitments and identifies viable alternatives that can strengthen mitigation and adaptation efforts.

While the projects presented in the development plans will likely go a long way to meet Lebanon's NDC commitments, additional climate proofing will be necessary to meet the targets. Specifically, even if the projects assessed were implemented as outlined in the development plans, further initiatives would be needed to meet the conditional emissions reduction target and renewable electricity targets (conditions and unconditional). This finding is predominantly driven by planned interventions in the energy and transport sectors.

The analysis also finds that the planned projects are not sufficiently resilient to climate change, necessitating adaptation improvements particularly in the irrigation and water sectors. Our resilience assessment shows that current plans are inadequate to prepare Lebanon for the physical effects of climate change. Most areas or cazas are prone to erosion, floods, water scarcity or high temperatures. As a result, 49% of assessed projects were deemed to be vulnerable to climate change, or to exacerbate vulnerability elsewhere. Adaptation measures are particularly needed in the irrigation and water sectors, both of which include a large number of highly vulnerable projects.

A cost benefit analysis of approximately 100 selected projects across 14 categories shows that in most cases, the additional investment in climate proofing delivers significant benefits. Climate proofing of all selected projects delivers $3.2 for every $1 invested in mitigation and adaptation enhancement. In total, climate proofing brings an additional $5.4 billion in benefits for a cost of $1.7 billion, indicating that it is a sound investment (see Figure 1). The benefits as a result of mitigation interventions include improvements in air quality, health benefits, avoided climate change, and reduced loss of biodiversity. The benefits as a result of adaptation intervention include avoided future losses, avoided foregone economic activity, and avoided deaths or injuries. In fact, the ratio of benefits to costs is greater than 1 in almost all the projects assessed, both for baseline and climate-proofing options (see Figure 2).

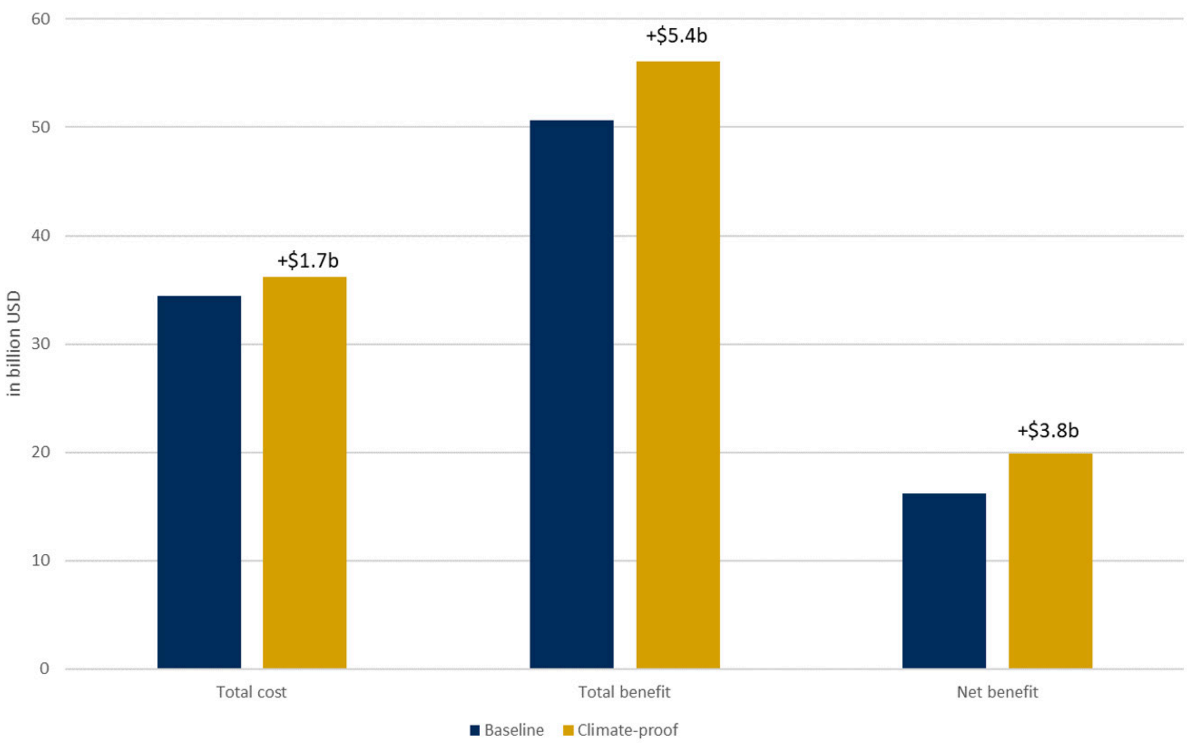


Figure 1: Discounted costs, discounted benefits, and NPV of all priority projects jointly
Source: Vivid Economics

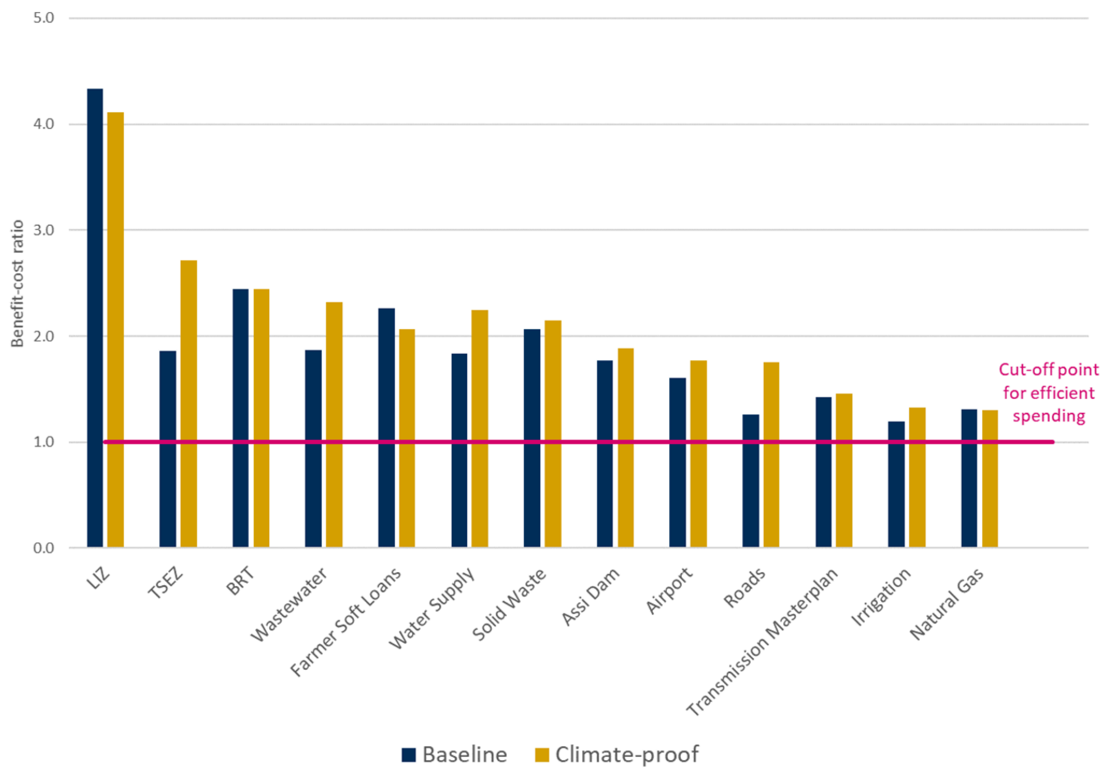


Figure 2: Benefits outweigh costs for all projects assessed (baseline and climate proofed)
Source: Vivid Economics

Even if policymakers focus entirely on economic benefit and do not include the social value of climate proofing interventions, at least 90% of total project costs are recovered over the next 20 years. The results show that the vast majority of capital and operational expenses are recouped in economic terms, as the investment cascades through the Lebanese economy. Most of the economic benefits are Gross Value Added (GVA) impacts, but the gains also include cost savings when compared to a "do nothing" or Business as Usual (BAU) approach. The total discounted economic benefits are more than $30 billion ($31 billion for baseline, $32 billion for the climate-proofed option).

Lebanon could rely on international mitigation and adaptation grant and loan pools in order to finance these climate proofed projects. These measures are typically funded through a combination of domestic public financing, domestic investment, and international assistance (see Annex 4). However, the current financial and debt crises in Lebanon means that domestic financing is not likely to be viable. Climate-proofing provides an opportunity for Lebanon to access larger international funding pools, as donors are more likely to invest in projects that support long-term climate change mitigation or adaptation efforts. For example, multilateral development banks dedicate increasing amounts of their total commitments to climate-related investments (World Bank: 30%[1], EBRD: 40%[2]), which resulted in a total of more than $40 billion in climate financing for low- and middle-income economies in 2019[3].

[1] *World Bank (2020). 'Climate finance' on The World Bank Website. Available at: https://www.worldbank.org/en/topic/climatefinance*

[2] *Bennett, V., (2020). 'EBRD unveils proposal to be majority green bank by 2025' on EBRD Website. Available at: https://www.ebrd.com/news/2020/ebrd-unveils-proposal-to-be-majority-green-bank-by-2025.html*

[3] *Bennett, V., (2020). 'MDBs' climate finance in low- and middle-income countries in 2019 reaches US$41.5 billion' on EBRD Website. Available at: https://www.ebrd.com/news/2020/mdbs-climate-finance-in-low-and-middleincome-countries-in-2019-reaches-us-415-billion.html*

The Lebanon Green Investment Facility (LGIF) is being developed with the objective of increasing financing flows into green projects and opportunities in Lebanon that will help meet Lebanon's NDC targets[4]. The design of the facility will aim to mitigate the current risks and barriers to leveraging green finance through innovative financial instruments and institutional design.

Climate-proofing can be mainstreamed into decision making using existing policies. In particular, the mandatory Strategic Environmental Assessment (SEA) of policies, plans and programs and Environmental Impact Assessment (EIA) of projects could be used to systematically ensure climate impacts are taken into consideration. For example, the SEA conducted in relation to offshore oil and gas exploration and production activities in Lebanon contained climate proofing requirements to mitigate and offset the sector's GHG emissions. While the SEA and EIA are already mandated by law, the climate-proofing analysis and recommendations they produce need to be strengthened. Additionally, the climate proofing measures identified as part of a project's development cycle should be included as requirements in procurement documents such as tenders and contracts.

This report lays out the case for climate proofing. Section 1 provides an introduction to the Lebanese context and the policy environment. Section 2 discusses the potential mitigation impact of the development plans, and Section 3 looks at the adaptation risks. Finally, Section 4 provides more detail on the costs and benefits of climate proofing for a selected shortlist of projects.

[4] *LGIF design and resource mobilization strategy are currently on-going and are financed by the NDC Partnership, implemented by the World Bank and the Islamic Development Bank in coordination with the Ministry of Environment and the Council for Development and Reconstruction as national focal points. The LGIF is part of the financial recovery plan of the Lebanese government.*

1. INTRODUCTION TO THE LEBANESE CONTEXT

This section provides a primer on the Lebanese context, with section 1.1 detailing Lebanon's climate commitments and section 1.2 describing the key national development plans assessed.

1.1 Lebanon's climate commitments and the cost of inaction

Lebanon is expected to face significant impacts from climate change, including rising sea levels and an increase in temperature. Lebanon as a highly urbanized developing country located on the eastern shore of the Mediterranean Sea. The densely populated coastal urban areas that host critical infrastructure and industry are particularly vulnerable to climate change. Estimates of the cost of climate inaction are therefore as high as $80.7 billion in 2040. This includes the direct damage from heat waves, droughts and storms, as well as indirect damage from slower economic growth. Table 1 summarises the potential impacts, and Figure 3 illustrates the economic cost of inaction.

Table 1 Potential impacts of climate change in Lebanon

Historical Climate	Future Climate
Increase in annual mean temperature of 0.11 °C per decade	Increases in mean annual temperatures between 1.2-1.7 °C by mid-century (RCP 4.5 and RCP 8.5, respectively)
Decrease in precipitation of 11 mm per month on average since 1950	Decrease in precipitation by 4-11 % by 2100 (RCP 4.5 and RCP 8.5, respectively)
Increase in the number of hot nights by 7	Reduced snow cover of 40-70% and decreased snow residence time from 110 days to 45 days
Increase in the amount of rainfall received during one day extreme rainfall event	Increased incidence of drought conditions
Rising of sea level of roughly 20 mm per year	Continued sea level rise, rising by a total of 30-60 cm in the next 30 years
Increase of 1.3 °C surface Mediterranean water since 1982	Increased frequency of heat waves and decreased number of frost days

Source: USAID (2016). Fact Sheet. Climate Change Risk Profile Lebanon; UNDP/MoE (2016). Third National Communication to the UNFCCC

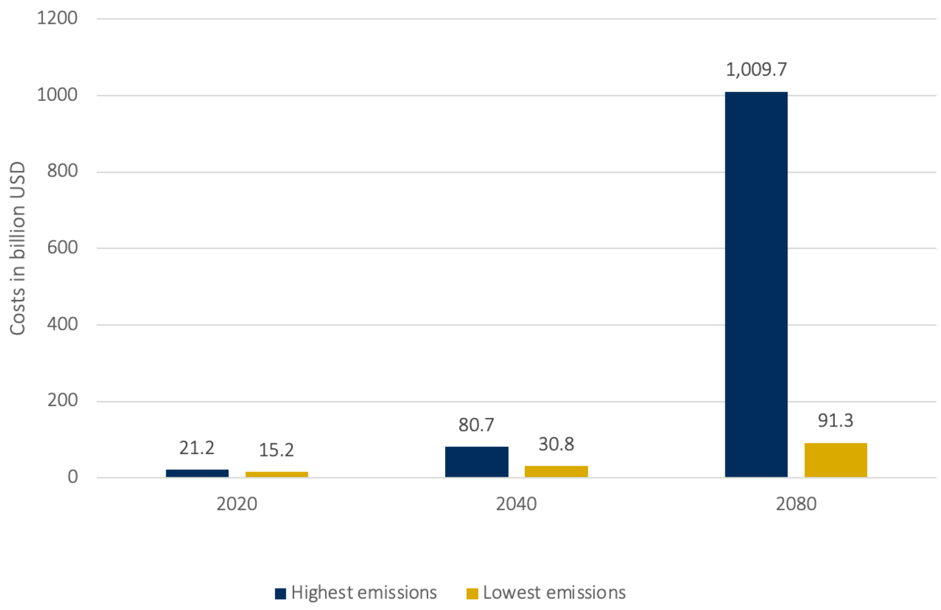


Figure 3: Potential Costs for Lebanon from Global GHG Emissions under Both the Highest and Lowest Emission Scenarios
Source: UNDP and Ministry of Environment (2015). Economic cost to Lebanon from climate change

Lebanon's emissions, primarily from the energy sector, are expected to grow significantly under a BAU scenario. Greenhouse Gas (GHG) emissions in 2015 were 27,107 Gg of carbon dioxide equivalent (CO_2e)[5]. The energy sector (including transport) is the predominant source and accounts for around 85% of total emissions followed by industrial processes (8%) and the waste (3%) and Agriculture Forestry and Other Land Use (AFOLU; 3%) sectors. On the other hand, the Land Use Change and Forestry Sector (LUCF) is a potential sink and accounted for a reduction of 12.2% (3,311 Gg CO_2e) of total Lebanon GHG emissions in 2015. Analysis of the historical trends in carbon emissions has shown an increase of 194% between 1994 and 2015. Future projections for 2030 and under the BAU scenario have shown that the emissions are expected to increase to 38,950 GgCO_2e if no mitigation actions are implemented[6].

In order to reduce future emissions and avoid the most dangerous impacts of climate change, Lebanon has ratified the Paris Agreement which aims to limit global temperature increase to below 2°C. As part of its updated NDC under the Paris Agreement, Lebanon pledged to reduce its GHG emissions by 20% by 2030 as an unconditional target and by 31% by 2030 as a conditional target (Table 2). As Lebanon is a developing country with scarce water resources and high population density, the commitment highlighted the need to build resilience and improve adaptation in addition to reducing emissions. The measures highlighted as part of the NDC for both mitigation and adaptation are summarized in Table 2 and Table 3, respectively.

[5] MoE/UNDP/GEF (2019). Lebanon's Third Biennial Update Report (BUR) to the UNFCCC. Beirut, Lebanon. Available at : https://www.lb.undp.org/content/lebanon/en/home/library/environment_energy/BUR3.html

[6] Republic of Lebanon (2021). Lebanon's Intended Nationally Determined Contribution under the United Nations Framework Convention on Climate Change. Available at: https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Lebanon%20First/Lebanon›s%202020%20Nationally%20Determined%20Contribution%20Update.pdf

Table 2 Key Mitigation Measures as Part of Lebanon's Updated NDC

Unconditional Target	Conditional Target
A GHG emission reduction of 20% compared to the BAU scenario in 2030	A GHG emission reduction of 31% compared to the BAU scenario in 2030
18% of the power demand (i.e., electricity demand) and 11% of heat demand (in the building sector) in 2030 is generated by renewable energy	30% of the power demand (i.e., electricity demand) and 16.5% of heat demand (in the building sector) in 2030 is generated by renewable energy
A 3% reduction in power demand through energy-efficiency measures in 2030 compared to the demand under the BAU scenario	A 10% reduction in power demand through energy-efficiency measures in 2030 compared to the demand under the BAU scenario

Note: The unconditional mitigation scenario includes the impacts of mitigation actions which Lebanon can nationally implement, and through international support in the form of loans or other repayable instruments. The conditional mitigation scenario covers the mitigation actions under the unconditional scenario, as well as further mitigation actions which can be implemented upon the provision of additional international support in the form of grants.

Source: Lebanon Nationally Determined Contribution to the UNFCCC (2021)

Table 3 Key Adaptation Measures as Part of Lebanon's Updated NDC

Biodiversity	Forestry and Agriculture	Water
• Value and sustainably manage Lebanon's terrestrial and marine biodiversity for the preservation and conservation of its ecosystems and habitats and the species they harbor, in order to adequately respond to anthropogenic and natural pressures and to ensure Lebanese citizens equal access to ecosystem goods and services.	• Strengthen the agricultural sector's resilience to enhance Lebanon's agricultural output in a climate-smart manner. • Promote the sustainable use of natural resources, restore degraded landscapes, and increase Lebanon's forest cover while meeting the ecological, social and economic needs of sustainable forest management.	• Structure and develop sustainable water services, including irrigation, in order to improve people›s living conditions.
Coastal Zones	**Public Health**	**Disaster Risk Reduction**
• Reduce the vulnerability of climate change impacts on coastal zones, especially in cities	• Ensure overall public health and safety through climate-resilient health systems	• Reduce disaster risk and minimize damages by mitigating and adapting to climate-related natural hazards and extreme weather

Source: Lebanon Nationally Determined Contribution to the UNFCCC (2021)

This is further complicated by political and economic circumstances. Lebanon suffers from a myriad of development challenges, mainly related to lack of security, political instability and high levels of poverty and inequality. The Syrian crisis has led to the arrival of around 1.13 million displaced people to the country increasing Lebanon's population by 30% in just over 2 years. This has led to an estimated 5% increase in road traffic and therefore in GHG emissions and air pollution. It has also added 251 MW to the country's power needs, an increase of over 10%. Noting that electricity purchasing from Syria dropped by around 88% during the same period, this additional demand can only be met through private generators leading to additional carbon emissions and air pollution. Furthermore, Lebanon continues to face a difficult economic situation with Gross Public Debt at record highs. Moreover, in 2019, the economy was plunged into a financial crisis brought about by a sudden stop in capital inflows, which precipitated banking, debt and exchange rate crises. The recession is likely to be arduous and prolonged.

Both these factors strengthen the case for a green recovery, which delivers economic growth alongside emissions reductions and increased resilience.

1.2 Lebanon's Development Plans

Lebanon has developed several national development plans aiming at supporting economy and social development. Three plans analysed for the purpose of this report include:

- **The 3-year development priorities of the Financial Recovery Plan.** The primary purpose of this plan is to overcome short-term financial challenges. Among the measures suggested are $10-15 billion in external financing, a planned devaluation in currency, and a combination of defaults and postponements on foreign currency debt. The plan also lists structural reforms among its objectives, including grid modernisation, anti-corruption measures and social protection.

- **Lebanon Economic Vision (LEV).** The LEV charts out a national strategy for reviving the economy through targeted investments in the sectors it has identified as core engine of growth. The strategy is based on comprehensive national and sectorial diagnostic assessments and a review of international best practice. It aims to increase GDP growth to 6% within three years of implementation and cut the unemployment rate by 50% in five to seven years. The LEV recommends investing in 5 promising sectors: agriculture, industry, tourism, financial services, and the knowledge economy.

- **The Capital Investment Programme (CIP).** The CIP outlines infrastructure projects that both align with national development goals and create opportunities for economic growth in the short and medium term. The document covers infrastructure projects in transport, water and irrigation, wastewater, electricity, telecommunications, solid waste, tourism and industrial sectors. For each sector, the programme plan presents an assessment and gap analysis, and identifies how the sector's infrastructure needs line up against SDGs.

A summary of the key projects/developments are highlighted in the table below.

Table 4 Summary of Key Projects assessed from the three development plans

Developments Plans	Key Projects/Developments
CIP	✓ Solid Waste Management to cover all of Lebanon including collecting, sorting, treatment and landfill sites ✓ New Power Plant on Longer Term (Zouk and Jiyeh capacity of 1000 MW) ✓ Construction of irrigation and water supply dam on the Khardati segment on the Litani river ✓ New Power Plants on Medium Terms (Selaata 1 and Zahrani; Capacity of 1000 MW) ✓ New Power Plants of Longer Term (Selaata 2 capacity of 500 MW) ✓ Southern Coastal Highway ✓ Rehabilitation of Classified Roads ✓ Rehabilitation and Development of Beirut Rafic Hariri International Airport ✓ Bus-rapid-Transit System-Greater Beirut Public Transport Project ✓ Beirut Damascus Highway Completion ✓ New Power Plant Jiyeh (capacity of 500 MW) ✓ New Power Plant Zouk (capacity of 500 MW) ✓ Dbaye-Nahr Ibrahim Motorway ✓ Construction of Assi Water and Irrigation Dam ✓ Upgrade of Daoura WWTP ✓ Construction of El-Bared Water Supply Dam ✓ Construction of Distribution Networks for irrigation and Water Supply on the Litani River ✓ Construction of geothermal and hydro power plants
LEV	✓ **Agriculture** 1. Promote and support the application of modern methods and technologies 2. Improve local and regional food markets 3. Support transition towards high value crop 4. Facilitate access toward international markets 5. Explore legalization of cannabis cultivation ✓ **Industry** 1. Prioritizing high potential subsectors such as food processing, high-end design (i.e. cosmetics, jewellery, etc…) and marketing and high skills products (i.e. pharmaceuticals) 2. Developing national integrated industrial parks to serve as areas of excellence and overcome comparative disadvantages ✓ **Tourism** 1. Focus on attracting leisure tourists from 15 Arab countries by building core offering in three cities (Beirut, Byblos and Tyr) and develop ultra-luxury eco-tourism hubs 2. Grow the meeting and incentive segment 3. Position Lebanon as a convenient destination for regional medical tourists by offering specialized services

	✓ **Knowledge economy** 1. Becoming a highly productive digital economy 2. Become a regional creative hub and educational hub ✓ **Financial Services** 1. Develop centres of excellence in specific niches 2. Position Lebanon as an investment management and off-shoring hub (Diaspora, Levant, Africa, and the Caspian region) ✓ **Diaspora** 1. Prepare the next generation and monitor emigration 2. Develop a solid diaspora database and promote national identity 3. Encourage productive investments, opening access to exports markets and transferring knowledge
3-year development priorities of the Financial Recovery Plan	✓ $10-15 billion in external financing ✓ Planned devaluation in currency ✓ Structural reforms including grid modernisation, anti-corruption measures and social protection

Source: ELARD

Lebanon's National Plans for development set out proposals for how activity, systems and infrastructure are likely to change in the coming years. Therefore, they have the potential to profoundly shape the country's GHG emissions trajectory. Planned projects could aid or hinder efforts for climate mitigation – and Lebanon's ability to satisfy their NDC mitigation targets.

Without careful consideration and planning, there is a risk that Lebanon's national development agenda could compromise its climate commitments. For example, the LEV aims to develop the country's industrial sector and become a manufacturing hub for several emissions intensive industries, including of construction materials, food processing, and consumer goods. Lebanon is also seeking to become an oil and gas producing country. While Lebanon is yet to establish proven resources (its first ever offshore exploration well drilled by French E&P Company Total in Block 4 did not find commercial results), development of this sector alone could significantly affect its climate targets.

Furthermore, the efficacy of the development plans could be enhanced due to the benefits of climate-proofing. In addition to economic benefits which directly boost GDP and growth, climate-proofing often brings social benefits which may increase productivity, health, and security. Increasing the resilience of infrastructure also protects investments from climate events. In the context of the current economic crisis, climate-proofing offers a way to a green recovery which not only reduces emissions but also minimises future financial losses.

This project aims to 'climate-proof' the three development plans, identifying how the projects outlined in the plan can deliver GHG mitigation and build resilience to the impacts of climate change. The aim of this report is to demonstrate how climate considerations can be woven into national development planning, and to mainstream the idea of climate proofing. More specifically, this report assesses the mitigation and adaptation impacts of projects included in the three development plans identified and suggests appropriate measures to promote climate resilience development. This is particularly in line with article 2.1c of Law 115/2019, which stipulates "making finance flows consistent with a pathway towards low-carbon and climate resilient development".

It should be noted that climate-proofing can and should be undertaken for projects not included in these development plans. While the scope of the analysis performed for this report is limited, the objective is to demonstrate the principle of climate-proofing. There is a wide array of projects, regulations and processes outside these plans that can benefit from applying a climate-proofing lens. For example, taking climate considerations into account when setting up government taxes (VAT, customs, and income tax) could bring about lasting changes by creating the right incentives around consumption of resources like energy and water.

2. MITIGATION IMPACT OF DEVELOPMENT PLANS

This chapter lays out the effects of Lebanon's major development plans in terms of climate mitigation. Through a process of screening, the projects with the largest (positive or negative) potential for impact were identified, and their impacts on GHG emissions, energy efficiency and renewable energy contribution are quantified. Where different projects shared many common characteristics, they were grouped together, and their likely cumulative impact was considered. For example, 36 individual irrigation projects, each with a likely small impact on emissions, were grouped together and deemed to have potential for high cumulative impact (for further information, please see Annex I). Section 2.1 summarises the impacts and Annex 1 provides methodological details. While subject to assumptions and uncertainties, the results enable an assessment of development plans against the NDC targets for mitigation, laid out in section 2.2. Finally, recommendations for 'climate proofing' Lebanon's development projects are presented in Section 2.3 to improve the mitigation potential of the projects considered and to maximise opportunities for mitigation.

2.1 Impact of projects

Most projects are estimated to result in mitigation savings on the BAU scenario in 2030. Projects affecting the energy sector have the largest overall impact on emissions, accounting for a large proportion of projected savings (see Figure 4). Considerable savings also come from projects in the transport sector. The largest contributors to emissions additional to the BAU scenario are projects within the industrial and waste sectors. It is worth noting that the GHG impact of the waste projects are indicative of the estimated emissions arising in 2030 and do not take into account emissions arising in subsequent years from the amount of waste landfilled in 2030. Further analysis would be required to ascertain the GHG emissions over the lifetime of the waste decomposing in a landfill.

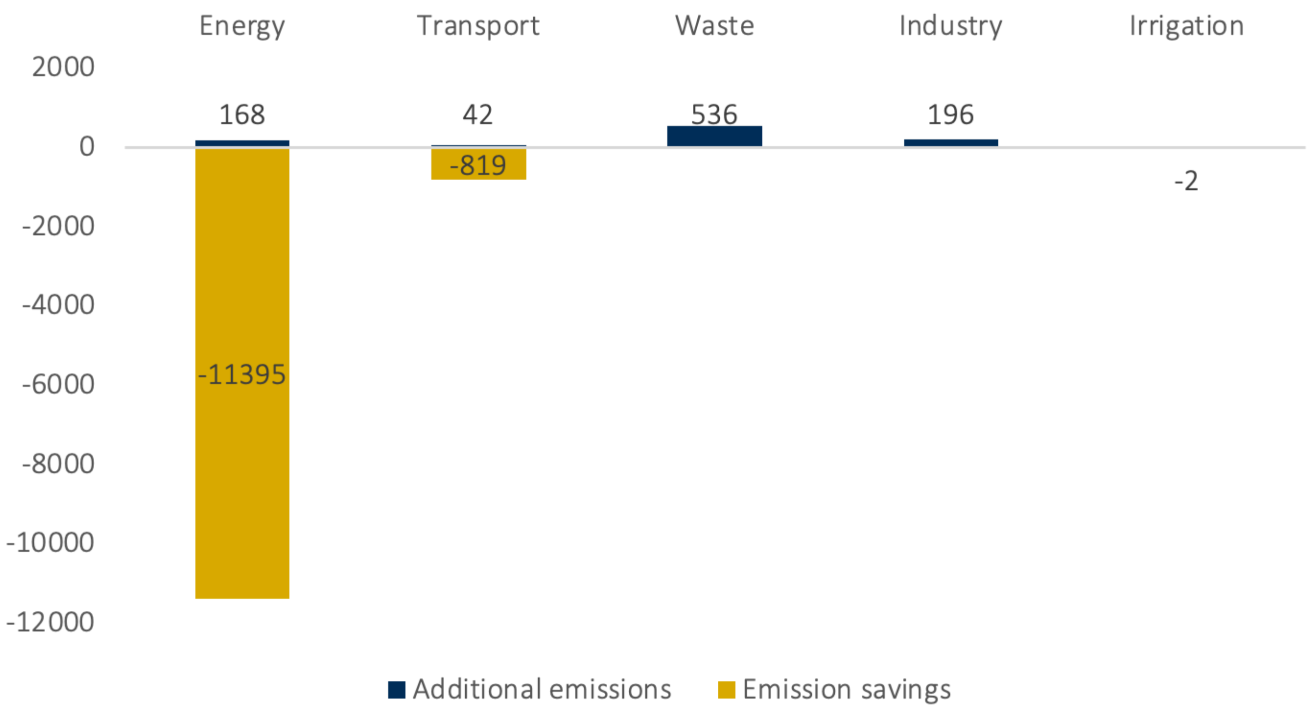


Figure 4 The cumulative impact of quantified projects on GHG emissions by 2030, relative to the BAU scenario, grouped by sector
Source: Aether

The key sectors driving potential mitigation savings implied by the plans include:

- **Energy:** Combined efficiency projects, which aim to reduce technical and non-technical losses in power transmission and distribution networks (from 34% to 11% in 2030), are estimated to be the most impactful of all quantified projects. These projects include the distribution service provider (DSP) project, installation of real-time energy use meters and the Transmission Master Plan. Replacing the use of heavy fuel oil with natural gas (through new power plants and conversions) and renewable energy sources also make large contributions to savings in the energy sector.

- **Transport:** The savings in the transport sector, achieved through the Greater Beirut Public Transport Project, are partially offset by the planned development of Beirut Rafic Hariri Airport and rehabilitation of roads. These are both projected to generate additional road traffic, and therefore additional GHG emissions.

The largest increases in GHG emissions, relative to the BAU scenario, come from the waste sector and city-based projects for specialised economic or industrial zones. Floating storage regasification units, which would enable greater use of natural gas in Lebanon, are also projected to cause a sizeable increase in emissions, through increasing energy demand and fugitive emissions. Table 5 summarises the projects assessed, and their estimated additions and savings compared to the BAU scenario.

Table 5 The estimated GHG impact in 2030 per quantified project, relative to the BAU scenario.

Name	Estimated GHG Impact in 2030 ($GgCO_2e$)
Combined projects to reduce technical and non-technical transmission and distribution losses from the grid	-4,215
Zouk power plant	-2,034
Jiyeh power plant	-2,034
New Power Plants on Medium Term - IPP-1000MW	-2,016
Bus Rapid Transit System - Greater Beirut Public Transport Project	-819
Hydro power plants (331.5 MW)	-741
Hydro power plants (141.5 MW)	-316
Additional geothermal	-37
Geothermal Plant of 1.3MW	-3
Irrigation schemes	-2
Rehabilitation and Development of Beirut Rafic Hariri Airport - Phase 1	1
Rehabilitation of classified Roads and Municipal Roads	41

Name	Estimated GHG Impact in 2030 ($GgCO_2e$)
Infrastructure for the Tripoli Special Economic Zone	65
Floating Storage Regasification Units	168
Infrastructure for the 3 industrial cities, Alkaa (Phase 2), Baalbek (Phase 2) and Terbol (Phase 2)	131
Combined waste projects	+536
Total GHG impact	**-11,274**

Source: Aether

2.2 Assessment against NDC targets

If the projects assessed are implemented, it is estimated that the Development Plans substantially contribute to the achievement of Lebanon's updated NDC targets (see Table 6 below). Renewable energy projects are climate-positive and therefore do not need climate-proofing. The contribution of the projects in the development plans to the NDC does not constitute the entirety of climate action planned (specially electricity generation from renewable energy; 18%-30%) to meet the NDC targets. Unfortunately, it was not possible to assess the contribution of renewables to the building's heat demand and therefore this aspect is excluded from Table 6 below.

Table 6 Impact of assessed mitigation measures on NDC Updated targets

Target	Estimated impact of assessed projects, by 2030	Unconditional	Conditional
GHG emissions reduction	29% reduction on BAU	✓	
Energy efficiency improvements	18% reduction in demand	✓	✓
Electricity generated by renewable energy	10% contribution		

Source: Aether

Implementing the projects in the development plans will result in a significantly smaller increase in emissions compared to BAU. In the BAU scenario, GHG emissions are projected to almost double between 2011 and 2030. However, with the implementation of assessed projects, it is estimated that emissions would rise by only 32% (6,663 $GgCO_2e$) over the same period. Figure 5 demonstrates the difference between a 2030 scenario with and without the assessed projects being implemented.

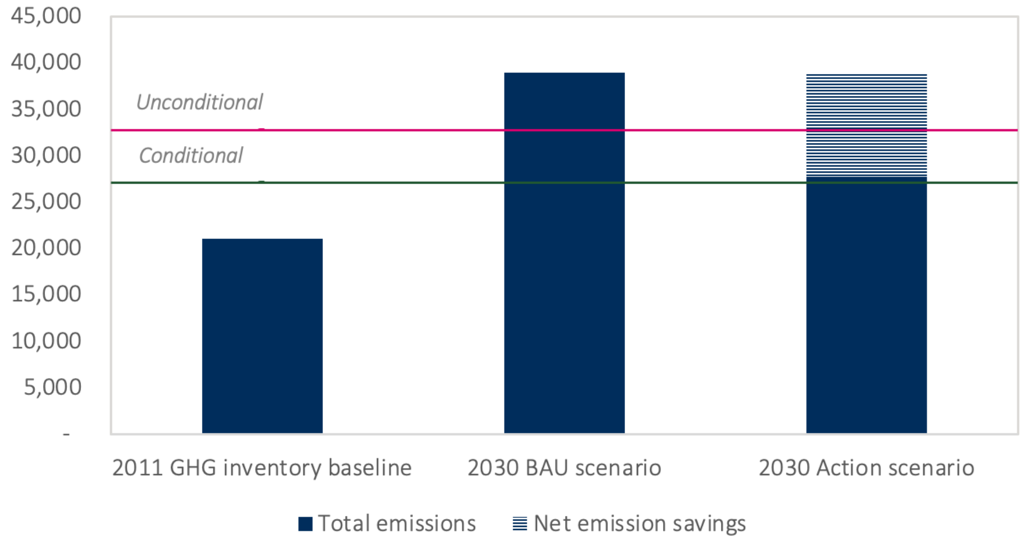


Figure 5: GHG emissions in 2011, and two projections for 2030
Source: Aether

Note: The "Action" scenario represents the total estimated impact of the projects quantified in this work, accounting for projected emission savings and additional emissions

The reduction in energy demand, due to improved efficiency, is largely achieved through the combined efficiency project. The combined irrigation schemes also provide a small contribution of 2 GgCO_2e reduction (see Table 5). The estimated 18% reduction achieved surpasses the unconditional and conditional target (3% and 10% respectively).

Reduction in energy demand also aids progress towards the renewable energy targets, as it lowers the capacity that renewable sources would need to cover. Given the BAU-projected energy demand and renewable energy capacity, it is estimated that renewable sources would cover 3% of energy demand under BAU conditions. However, the implementation of assessed projects would see a fall in energy demand on BAU levels, coupled with increased hydro and geothermal power capacity. These projects are estimated to bring the renewable contribution to 10% by 2030.

It is important to note that these results rely on assumptions and there are significant uncertainties associated with each estimation (see Annex 1). The projected performance against targets is dependent on these assumptions and uncertainties. Furthermore, it was not possible to allocate projects to an unconditional or conditional scenario. Therefore, the assessment presented in Table 5 works from the same set of projects for the unconditional and conditional targets. In reality, certain projects may only be feasible in a conditional scenario, which would lower the projected progress towards targets in an unconditional scenario.

2.3 Recommendations for Climate Proofing

While the analysis shows that Lebanon's existing initiatives have the potential to match up to the country's energy efficiency targets and ambitions, projects from other strategies will play a role in meeting the electricity sector's renewable energy target and the overall GHG reduction in the conditional scenario. However, these results are caveated by the fact that the analysis was not able to consider whether projects are conditional or unconditional.

As such, there is an opportunity to enhance the climate mitigation potential of Lebanon's development projects to 'climate proof' national development strategies. For instance, more energy efficient technology could be used, or cleaner fuel sources may be available. Equally, the same type of measures could limit the additional emissions that a project has the potential to cause. Climate proofing projects can reduce GHG emissions, improve overall efficiency and increase renewable contributions as well as contributing to a range of other co-benefits. This would help to ensure that national mitigation targets, as set out in the NDC, are met and surpassed.

A range of suggestions has been provided to climate-proof projects and further enhance the likelihood of meeting the NDC targets. Key examples include:

- Use of hybrid buses in place of conventional diesel buses for the Bus Rapid Transit System
- That the additional energy demand at the Tripoli Industrial Site is met with additional renewable energy
- That emissions from proposed natural gas plants are offset using a domestic carbon offsetting scheme
- A requirement to contribute 18% of new gas power plants' cost to a fund to set up more renewable energy
- Installation of carbon capture technology at natural gas plants[8]
- Implementation of energy efficient public street lighting
- Introduction of mandatory minimum standards of energy efficiency for common household appliances

The estimated impact on GHG emissions is shown in the table below, and full cost-benefit analysis of selection projects is presented in Section 4.

[8] *Carbon Capture and Storage (CCS) is the process of capturing and storing carbon dioxide before it is released into the atmosphere. It is a relatively new technology and there are currently 65 commercial CCS facilities worldwide in various stages of development. https://www.globalccsinstitute.com/resources/global-status-report/*

Table 7 The additional impact on GHG emissions of climate proofing recommendations, where quantification was possible.

Climate proofing recommendation	Additional GHG Impact in 2030 ($GgCO_2e$)
Install carbon capture technology at natural gas plants	-5,300
Introduction of mandatory minimum standards of energy efficiency for common household appliances	-1,294
Energy demand at the Tripoli Industrial Site met with additional renewable energy	-63
Use of hybrid buses in place of conventional diesel buses	-11
Implementation of energy efficient public street lighting	-2
Total additional GHG impact	**-6,671**

Note: These estimates of impact are entirely additional to the impact of projects as quantified above
Source: Aether

It is estimated that, with the implementation of the projects listed above, Lebanon would surpass its GHG emission reduction and energy efficiency targets. The significant additional GHG savings, as shown in Table 7 are estimated to contribute to a 46% reduction on BAU emissions in 2030 (see Figure 6). Further improvements in energy efficiency, largely achieved through more efficient household appliances, would bring the reduction in power demand on BAU levels to 24%. Through this reduced demand and an additional renewable energy project, renewable energy sources would meet 12% of national demand by 2030. As with other projects with impact quantified, there are uncertainties in the projections of activity data and emission factor used. However, the results indicate that, with a wider scope of action and greater consideration of climate proofing measures, Lebanon could be more confident of reaching their NDC mitigation targets.

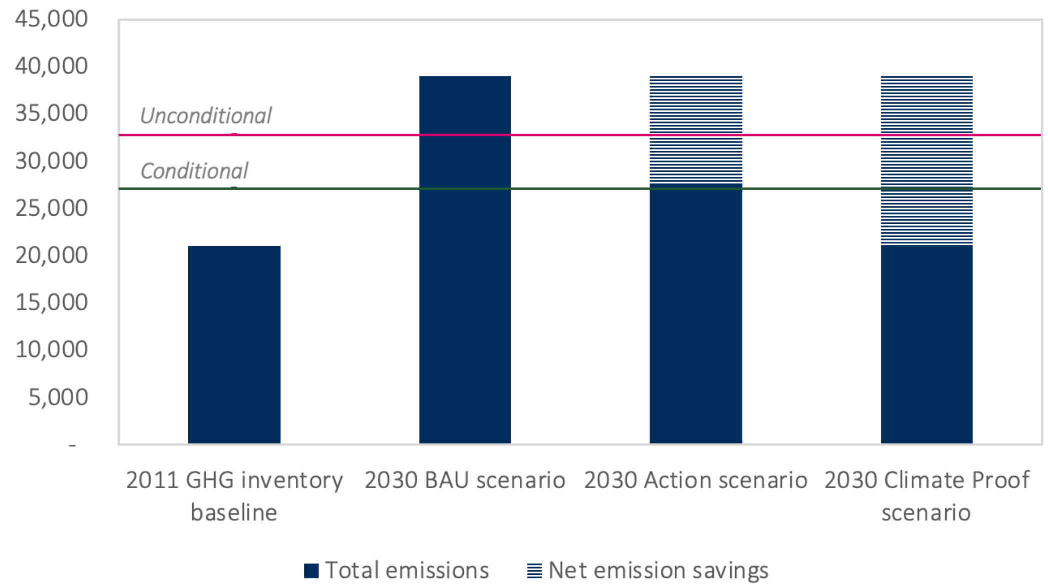


Figure 6 GHG emissions in 2011, and three projections for 2030
Source: Aether

Note: The "Action" scenario represents the total estimated impact of the projects considered in their current proposed form (CIP/LEV/recovery plan), while the "Climate Proof" scenario achieves additional savings through the recommendations listed

These projects are a suggested list, and do not encompass the universe of climate proofing options available. It was not always possible to identify appropriate climate proofing measures (where project descriptions lacked detail). Further, there was often insufficient information to quantify the impact of climate proofing measures. However, it is clear – without quantification – that certain measures in certain projects could contribute significantly to climate mitigation. In these cases, the following recommendations are made (Table 8).

Table 8 Climate proofing recommendations for projects where quantification of impact – with or without recommended climate proofing measures – was not possible

Biodiversity	Forestry and Agriculture	Water
Soft loans to farmers	Increase in energy demand and agricultural activity	Ensure recipients are trained in sustainable agricultural practices; encourage use of locally sourced renewable energy where possible
High value crops	Increase in energy and water requirement	Consider renewable energy sources and sustainable water management (to limit demand)
Cannabis cultivation	Increase in energy and water requirement	Consider renewable energy sources and sustainable water management (to limit demand)
Oil & gas Block 4	Emissions directly from hydrocarbon exploration, and indirectly from the users of the oil/gas extracted	Advise against exploration of fossil fuel reserves, instead focussing on developing renewable energy sources
Develop package offerings for ‹medical tourism›	Additional journeys by surface (and air) transport	Enable and promote shared transport options, including public transport
Encourage the development of authentic eco-tourism offering	Additional journeys by surface (and air) transport	Enable and promote shared transport options, including public transport (and, where possible, active travel)

Source: Aether

3. ADAPTATION IMPACT OF DEVELOPMENT PLANS

This chapter identifies the projects in Lebanon's major development plans that are vulnerable to the effects of climate change. Similar to the mitigation analysis, a pre-screening of projects was conducted in order to identify the most relevant projects. The vulnerability of these screened projects was then assessed, with different criteria for physical projects and regulatory instruments. Section 3.1 lays out the key results with methodological details provided in Annex 2. While the NDC acknowledges how important adaptation measures are, there are no quantifiable targets in this aspect. Section 3.2 therefore focuses on identifying high vulnerability projects, and providing suggested climate proofing options to make them more resilient to the impacts of climate change.

3.1 Identification of vulnerable projects

The analysis shows that current plans are inadequate to prepare Lebanon for the effects of climate change. Most areas or cazas are prone to erosion, floods, water scarcity or high temperatures. As a result, 49% of the 197 projects assessed were deemed to be vulnerable to climate change, or to exacerbate vulnerability elsewhere. Of these, physical projects are more likely to be highly vulnerable (see Figure 7).

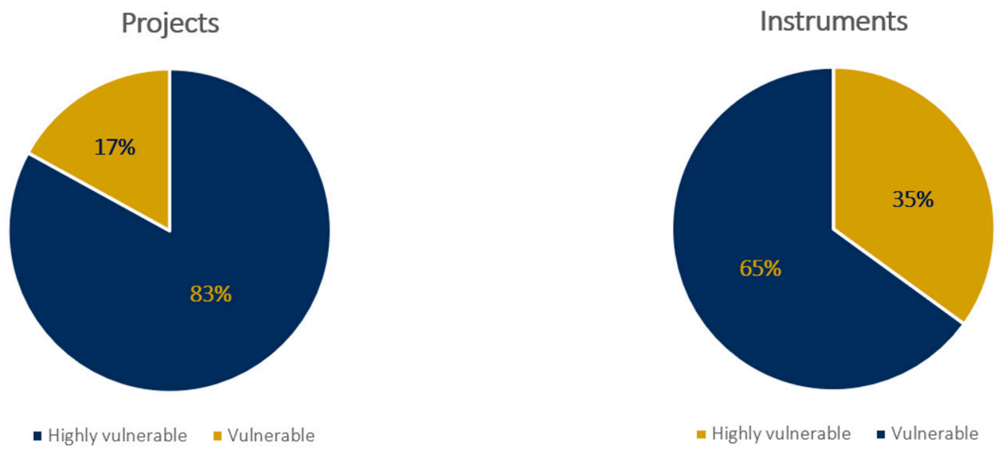


Figure 7 Degree of vulnerability of projects and regulatory instruments
Source: CAOS

Both physical projects and regulatory instruments across sectors require adaptation interventions. In total, 128 physical projects and 74 regulatory instruments can increase their climate resilience. Key sectors that require focus based on the number of vulnerable projects (20 or more) are environment, water, irrigation, and agriculture. Figure 8 depicts the distribution graphically, and Table 9 summarises priorities by sector.

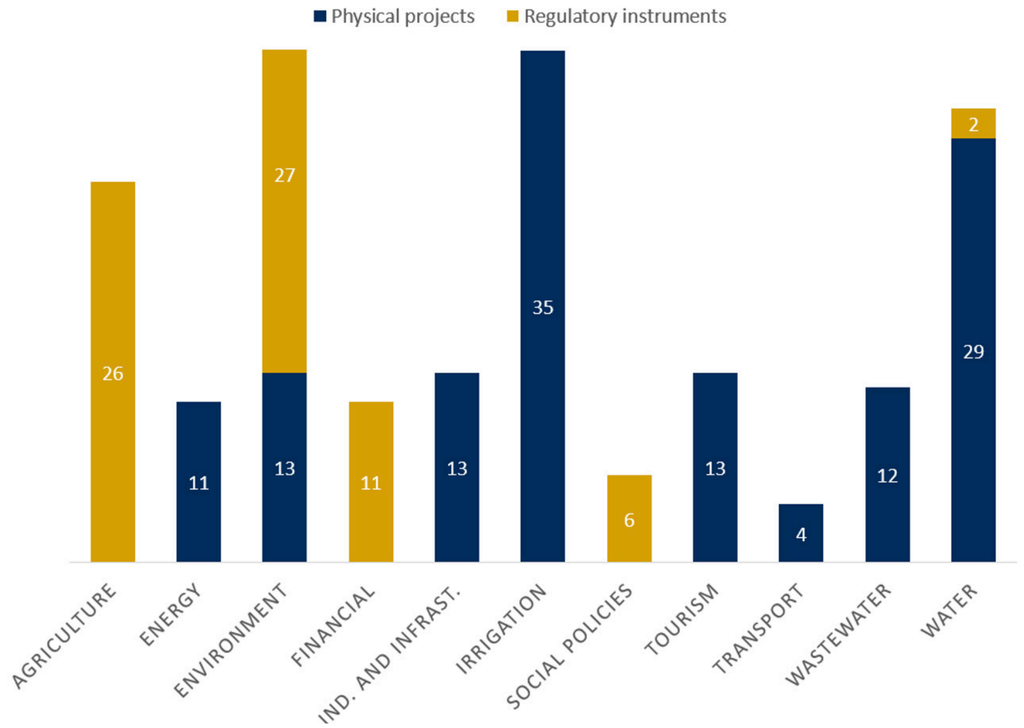


Figure 8: Number of projects requiring adaptation interventions across different sectors
Source: CAOS

Taking into account both the number of projects requiring climate-proofing as well as their respective vulnerability scores, we find that water and irrigation are the sectors most in need of adaptation. Table 9 summarises the average vulnerability scores for physical projects and regulatory instruments. The higher the score is, the more vulnerable the project is. Physical projects are scored out of a maximum of 12 and regulatory instruments out of a maximum of 8. Key sectors that require focus based on the average vulnerability score (10 or higher for project score, 7 or higher for instrument score) are irrigation, water, tourism, and social policies. Of these, irrigation and water have the largest number of projects screened as being at risk.

Table 9 Vulnerability scores and assessment by sector

	Agriculture	Energy	Environment	Financial	Industry & infrastructure	Irrigation	Social policies	Tourism	Transport	Wastewater	Water
Number of projects/ instruments requiring adaptation	26	11	40	11	13	35	6	13	4	12	31
Average score for projects (out of 12)	N/A	9	7	N/A	6	12	N/A	10	8	7	11
Average score for instruments (out of 8)	4	N/A	6	4	N/A	N/A	8	N/A	N/A	N/A	8

Source: CAOS

The results of this study reflect a preliminary analysis of the large number of projects within the three development plans, but detailed vulnerability studies are required to develop a more accurate picture. Resilience of a project depends to a large extent on exact location and design of the project. Unlike mitigation quantification, adaptation impacts may vary greatly between similar projects in similar sectors. It is therefore advised that a vulnerability study be conducted into each project before implementation.

3.2 Recommendations for climate proofing

Addressing these adaptation risks and increasing resilience has significant economic benefits. Damage to infrastructure, crops, water, and electricity supply networks, etc. as a consequence of natural disasters can be extremely costly to repair, and may compromise supply security of basic goods and services. Additionally, the financial costs of emergency repairs and maintenance (and in some cases the sums to be paid out as compensation for damages) are typically much larger than climate-proofing in advance.

A long-list of policies to increase resilience has therefore been identified based on the requirements of the projects in the development plan and the NDC ambition. For each category of adaptation mentioned in the NDC, a list of potential climate proofing options has been identified based on expert judgement and recommendations from the ADB[9]. Not all sectors identified in the NDC have an exact match in this classification as biodiversity is included in environment, and human health indirectly in social policies. The full list of proposed interventions is summarized in the table below.

We recommend prioritising adaptation interventions in the water and irrigation sectors based on the above assessment (Figure 8 and Table 9).

Table 10 Potential priority adaptation interventions – sectors included in the NDC and in the analysed plans

Sector	Potential priority adaptation interventions
Cross-cutting	• Introduce climate change vulnerability and adaptation considerations to criteria used for selecting projects for implementation and financing • Develop sector-specific and country-specific screening tools to identify projects at risk • Incorporate contingency budgets for specific adaptation interventions as the need arises • Adjust zoning regulations for sector infrastructure • Design flexible planning and development instruments that can accommodate incremental changes over time • Develop adaptation standards for the sectors • Incorporate climate change indicators into sector planning and budgeting frameworks to ensure accountability • Support awareness and knowledge exchange and capacity building • Assess potential climate impacts when retrofitting existing infrastructure

[9] *Asian Development Bank. 2016. Guidelines for climate proofing investment in the water sector: Water supply and sanitation.*

Sector	Potential priority adaptation interventions
	• Create an enabling environment leading to greater resilience in the environmental, social and economic activities and sectors • Institutional strengthening/programme of technical assistance on climate mainstreaming on planning and budgeting processes • Mainstream climate risk assessment. The risk to be assessed is put by current and future climate and extremes, into the project design cycle, including the evaluation and choice of the sitting, project's inputs and outputs (including materials), schedule and cost of maintenance, performance of the outputs and project's climate impacts (potentially leading to increased vulnerability or maladaptation or missed opportunities) • Greater hydro-met and sediment monitoring across the country • Weather and climate information systems
Biodiversity	• Conducting needs assessment and defining pilot national monitoring sites and species. Coastal zones are considered a priority • Designing and implementing pilot action plans
Forestry and Agriculture	• Raising tree nurseries' productivity • Planting trees • Implementing the forest fire fighting strategy • Rehabilitating irrigation canals • Promoting Good Agricultural Practices through the support of organic farming and obtaining quality certificates • Applying forest integrated pest management • Developing an early warning system for agricultural pests and climatic conditions • Implementing forest management plans for each valuable forest (which might still include sustainable harvesting for energy generation from biomass).
Water and Wastewater	• Integrated watershed management • Improving water security such as through increasing artificial recharge of groundwater aquifers and increasing surface storage dams and hill lakes • Optimizing the use of the current water resources through the rehabilitation of the existing network and the installation of water meters • Increasing wastewater collection and treatment • Increasing water reuse, especially after wastewater treatment • Improving water efficiency and decrease water loss in irrigation
Transport, Infrastructures, Buildings	• Classify vulnerable areas and define the sitting to avoid exposure • Choose construction materials that are more resistant to extreme temperatures and rainfall • Consider options of natural and energy efficient climatization • Insulation • Creation of green zones and green buffers

Source: CAOS

4. COST-BENEFIT ANALYSIS OF CLIMATE PROOFING

In addition to delivering environmental benefits, climate proofing often makes fiscal sense as an investment. Reducing emissions and increasing resilience often go hand in hand with avoiding costs associated with the physical damage that climate change can cause (for example, as a result of extreme weather events). Furthermore, the social benefits of avoided emissions have significant value.

This report presents a cost benefit analysis (CBA) of selected projects across a range of sectors in order to demonstrate the economic and social rational for climate proofing. Fourteen priority projects in seven sectors were selected for the analysis, including a mixture of mitigation and adaptation climate-proofing measures. The projects are from different sectors including agriculture, energy, infrastructure, mining, transport, waste, and water. The climate proofing option has been chosen based on expert judgement and to illustrative a range of potential benefits. The best climate proofing option should be decided based on a thorough review of the project details. Table 11 provides a summary of the projects and climate proofing options chosen.

Projects were selected based on three criteria:

- **Importance:** The shortlist prioritises projects that are critical to Lebanon's economy in the next 10 years (mitigation) or which are the most substantial in terms of sector and size (adaptation).
- **Variation:** Projects in the shortlist represent a mix of different sectors of the Lebanese economy. They also represent a mix of climate-negative and climate-positive interventions (mitigation), and a mix of geographical location including coast, mountains, and plains (adaptation).
- **Information availability:** Projects were only shortlisted if sufficient information was available to conduct a meaningful CBA.

Section 4.1 outlines the rationale behind a cost-benefit analysis. Section 4.2 then provides a high-level overview of the results, and Section 4.3 provides detailed information on the results for each project.

4.1 Introduction to cost-benefit analysis

The CBA relies on quantifying or expressing in monetary terms three core components:

- **Costs:** This includes capital expenditures (CAPEX) and operational expenditures (OPEX), where available of the project options. Costs were quantified through a mix of development plans, project-specific documents, and information provided by stakeholders.
- **Economic benefits:** This includes the direct and indirect Gross Value Added (GVA) from the intervention. It also accounts for the job creation associated with these effects. Where sufficient costing information was available (details regarding expenditures over time and cost components), Vivid's in-house Investment Impact Model (IIM) was used to quantify the economic benefits (see Box 1). This method has the advantage that the results are Lebanon-specific. If detailed costing information was unavailable, an estimate of the benefits was developed based on a review of literature.

• **Social benefits:** This includes (but is not limited to) environmental benefits, health benefits, avoided future losses, and time savings. Social benefits were quantified through a literature review. While efforts have been made to ensure that only those social benefits that are experienced by Lebanon are quantified, this is difficult to achieve in the case of environmental benefits. GHG abatement produces global benefits in the region of USD50-100 per ton[10] beyond the country that enforces the mitigation effort. While the country reducing emissions does benefit more than other nations (in the form of localised health benefits, reduced air pollution, and lower biodiversity losses) it is difficult to pinpoint the exact split. In our CBAs, we utilise the lower end of the above-mentioned global range to represent abatement benefits for Lebanon (USD50/ton).

Box 1 Vivid's Investment Impact Model (IIM)

IIM estimates the impact of investment projects on the economy using Lebanon-specific, sectorally explicit input-output (I/O) tables and wage data. The model represents four economic agents, namely firms, households, the government, and the foreign sector.

From the Lebanese I/O table we can derive the interaction between sectors by quantifying the value of inputs each sector provides to produce one unit of output in a specific sector. The total output in Lebanon can be derived as the sum of final demand and required inputs to produce this demand.

We then derive two outputs from the model:

• Direct and indirect Gross Value Added (GVA): The direct GVA impact is the total value of the shock minus the total value of inputs needed to produce it. The indirect impact exhaust all the higher-order effects to account for the way in which the economic benefits of interventions cascade through the economy.

• Employment: Job creation can be derived by combining the estimated increase in total labour payments in each sector with sector-specific average salary data. Employment estimates can be produced for direct and indirect economic activities (as specified above).

The key model assumptions are:

• Exogenous government spending, saving demand and exports demand from abroad

• Constant returns to scale as production is increased

• Sufficient slack capacity to scale up production without requiring additional investment

• Fixed prices

The workings of IIM are described in more detail in the Appendix.

[10] *Hamilton, K., 2017. 'Economic co-benefits of reducing CO_2 emissions outweigh the cost of mitigation for most big emitters' in LSE Grantham Research Institute on Climate Change and the Environment Commentaries.*
Carbon Pricing Leadership Coalition, 2017. Report of the High-Level Commission on Carbon Prices.

An economic rationale for climate proofing exists if the total cost of climate proofing is less than the total discounted value of benefits. The cost-effectiveness of interventions is influenced by our choice of annual discount factor (12%, see Box 2 for more details on our choice of discount factor) and timeframe (20 years). Both costs and benefits are discounted depending on their time of incurrence to account for the difference in future and present value of a sum of money. This means that inflows and outflows far in the future matter less for current decisions. This is particularly important in the Lebanese context, as the current crisis aggravates this difference. Costs and benefits were accounted for over a period of 20 years from inception except for interventions where project-specific information suggested a different timeframe. The results in this report rely on a discount factor of 12%, however, the CBA spreadsheets include an in-built tool to alter this figure. In deducting discounted costs from discounted benefits, the Net Present Value (NPV) of each project option was determined. The intervention is deemed to be cost-effective if and only if NPV is positive. By comparing the NPV of baseline and climate-proofed options, we derived the preferrable intervention (i.e. the option with the highest NPV).

Box 2 Annual discount factor

The annual discount rate is a figure used to discount future costs and benefits back to their present value. The rate is used to account for the time value of money and the opportunity cost of the investment. It helps to decide whether a specific intervention is sound (NPV > 0) and makes different investments comparable. The discount rate is typically aligned with the cost of capital and/or debt of the implementing actor[11].

In this analysis, costs and benefits are discounted by 12% per annum based on Lebanon's average discount rate during 1964-2017 reported by the International Monetary Fund[12]. This figure is closely related to the rate at which the Lebanese government borrows to reflect the opportunity cost of investment in the priority projects. The historical average of the discount rate is used to avoid observations in a single year biasing the results; this is particularly important because the analysis covers a time horizon of 20 years.

Other papers relevant for this analysis tend to apply rates between 7%-13%, for example:

- MoEW, LCEC and IRENA use a discount rate ranging from 7% (good conditions) to 13% (poor conditions) to compute the levelized cost of electricity (LCOE) in Lebanon[13]. They state that the worst case (associated with a 13% discount rate) is the scenario that is expected today in the Lebanese market.

- World Bank and ESMAP use a discount rate of 8% for solar PV companies and private diesel generators in Lebanon in their 2020 report[14].

[11] *Corporate Finance Institute (no date). What is a Discount Rate? Available at: https://corporatefinanceinstitute.com/resources/knowledge/finance/discount-rate/*

[12] *CEIC (2017). Lebanon Discount Rate: End of Period. Available at: https://www.ceicdata.com/en/lebanon/money-market-and-policy-rates-annual/lb-discount-rate-end-of-period*

[13] *MoEW, LCEC and Irena (2020). Renewable Energy Outlook Lebanon. Available at: https://www.irena.org/publications/2020/Jun/Renewable-Energy-Outlook-Lebanon*

[14] *World Bank, ESMAP (2020). Distributed Power Generation for Lebanon. Available at: http://documents1.worldbank.org/ curated/en/353531589865018948/pdf/Distributed-Power-Generation-for-Lebanon-Market-Assessment-and-Policy-Pathways.pdf*

• GIZ use a discount rate of 10% for solid waste management projects in Lebanon in their 2014 report[15].

• WRI use a discount rate of 12% for BRT systems around the world (Colombia, Mexico, South Africa, Turkey) in their 2013 report[16].

We believe that it is reasonable to use a figure close to the upper end of the discount factor range (12%) because:

• Current developments in Lebanon (such as government default on debt, Covid-19, Beirut blast) have increased the cost of borrowing for the Lebanese government but have not been taken into account in the aforementioned sources. This indicates that the figures likely underestimate the discount rate for Lebanon.

• Using the upper end of the discount value ensures that benefits are not overstated, thereby providing a conservative estimate of NPV rather than an overly optimistic outlook.

It is important to note that it is not possible to quantify all potential social benefits of climate proofing, nor are these quantifications always exact. Furthermore, the results here are based on preliminary estimates of costs and benefits, and are indicative of a trend rather than precise figures for a particular project. Each project should be assessed individually when exact details on design are known.

4.2 Summary of results across projects

This sub-section presents a summary of the analysis by evaluating the costs and (economic) benefits of all priority projects jointly. Descriptions of the projects included in the analysis, along with details on the analysis type and methodology used, are collated in Table 11.

[15] *GIZ (2014). Cost of environmental degradation due to solid waste management practices in Beirut and Mount Lebanon. Available at: https://wmclebanon.org/wp-content/uploads/2019/06/GIZ-Lebanon-Cost-of-environmental-degradation-due-to-solid-waste-management-practices-in-Beirut-and-Mount-Lebanon-2014.pdf*

[16] *WRI (2013). Social, Environmental and Economic Impacts of BRT Systems – Bus Rapid Transit Case Studies from Around the World. Available at: https://www.wrirosscities.org/sites/default/files/Social-Environmental-Economic-Impacts-BRT-Bus-Rapid-Transit-EMBARQ.pdf*

Table 11 Description of priority projects

Project		Number of CIP/ ECV/DVP sub-projects	Development plan	Baseline Option	Climate-Proof Option	Analysis Type	Method
AG1	Farmer Soft Loans	1	DVP	Agricultural soft loan programme	Investment in climate-smart agriculture (initiative to improve water productivity)	Adaptation	Literature review
EN1	Natural Gas	3	CIP, DVP	Construction of NG powerplants, conversion of some existing powerplants to NG, deployment of FSRUs	Offset FSRU emissions by investing in domestic solar water heating subsidy programme	Mitigation	IIM
EN2	Transmission Masterplan	3 + 2 (climate-proof option)	CIP	Energy generation as usual, enhanced by the transmission masterplan and digital signal processing	Replace some of the baseline energy generation with renewable sources, including hydro, wind, solar, geothermal	Mitigation	IIM
IN1	TSEZ	1	CIP, DVP	Tripoli Special Economic Zone at Port Site and RKF Site	Port Site energy generation from renewable sources; seawall at Port Site	Mitigation & adaptation	IIM
IN2	LIZ	3	CIP	Implementation of industrial zones in three major Lebanese cities	LIZ energy demand is met through additional renewable sources	Mitigation	IIM
QU1	Quarries	1	DVP	Abandoned quarries are rehabilitated	N/A	N/A	Literature review
TR1	BRT	1	CIP	Investment in BRT to enhance public transportation in Greater Beirut	Diesel BRT and feeder buses are replaced by hybrid buses	Mitigation	IIM

Project		Number of CIP/ ECV/DVP sub-projects	Development plan	Baseline Option	Climate-Proof Option	Analysis Type	Method
TR2	Roads	2	CIP	Rehabilitation of classified (municipal) roads; service road for coastal highway	Road construction incorporates drainage systems and uses permeable materials	Adaptation	Literature review
TR3	Airport	1	CIP	Investment in Beirut airport increases passenger capacity in existing terminal and adds additional terminal	Reduce airport›s operational emissions by %90 compared to baseline; protective infrastructure against floods (incl. seawall), raised floor levels	Mitigation & adaptation	Literature review
WA1	Assi Dam	1	CIP	Complete construction of Assi diversion and storage dam (including powerplant and pipes)	Carry out and implement Environmental and Social Management Plan (ESMP)	Adaptation	IIM
WA2	Water Supply	31	CIP	Expansion and upgrade of water infrastructure in 31 regional systems	Resilience measures to protect assets against floods and liquefaction	Adaptation	Literature review
WA3	Irrigation	37	CIP	Investment in 37 irrigation schemes across Lebanon	Resilience measures to protect assets against floods and liquefaction	Adaptation	Literature review
WA4	Wastewater	4	CIP	Upgrade of Daoura and Ghadir treatment plants; investment in Ghadir and Tripoli collection networks	Resilience measures to protect assets against floods and liquefaction	Adaptation	Literature review
WS1	Solid Waste	2	CIP, DVP	Investment in solid waste management and infrastructure to improve waste recovery	Install methane capture and waste-to-energy facilities to recover remaining waste	Mitigation	Literature review

Source: Vivid Economics

The analysis suggests that the priority projects are beneficial as a baseline, producing $50.6 billion in benefits for a total cost of $34.4 billion even without climate proofing. Figure 9 summarises the total cost, total benefit, and net benefit of all priority projects jointly. Every $1 invested in planned interventions brings about $1.5 in gains, resulting in a total net benefit of $16.2 billion. This finding highlights the added value the priority projects would bring to Lebanon.

Climate proofing has an even higher benefit, delivering $3.2 for every $1 invested in mitigation and adaptation enhancement. Implementing the climate proofing interventions delivers an additional $5.4 billion in benefits for a cost of $1.7 billion, indicating that it is a sound investment. The benefits as a result of adaptation intervention include avoided future losses, avoided foregone economic activity, and avoided deaths or injuries. The benefits as a result of mitigation interventions include improvements in air quality, health benefits, avoided climate change, and reduced loss of biodiversity.

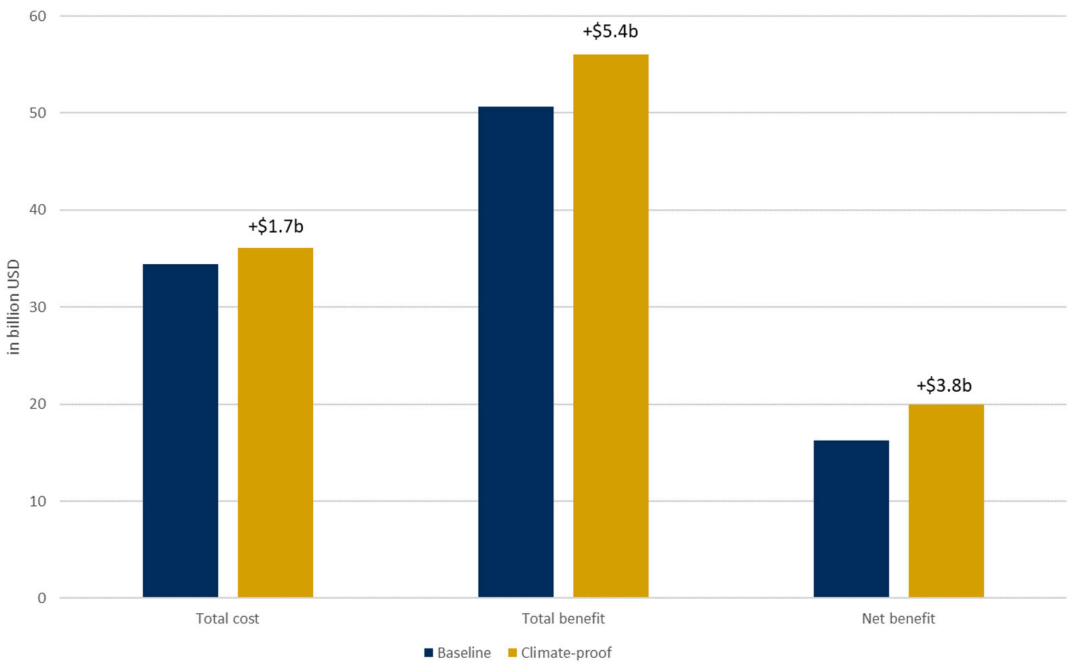


Figure 9 Discounted costs, discounted benefits, and NPV of all priority projects jointly
Source: Vivid Economics

Even if policymakers focus entirely on economic benefit and do not include the social value of climate proofing interventions, at least 90% of total project costs are recovered through GVA gains over the next 20 years. The results show that despite the high discount rate, the vast majority of capital and operational expenses are recouped in economic terms, as the investment cascades through the Lebanese economy. Most of the economic benefits are GVA impacts, but the gains also include cost savings when compared to a "do nothing" or business as usual approach. The benefit-cost ratio of climate-proofed projects is slightly lower than the baseline counterpart (0.89 compared to 0.90). This finding is in line with expectations, as climate-proofing focuses more on Lebanon's social than economic gains. The total discounted economic benefits are more than $30 billion ($31 billion for baseline, $32 billion for climate-proofed option).

Figure 10 summarises the economic trade-offs of implementing all priority projects. The difference between Figure 9 and Figure 10 is that the (net) benefits in this chart only take into account economic gains to the government, such as GVA impacts and cost savings. They exclude social gains, such as time savings, increases in consumer surplus, avoided emissions, or health benefits. The purpose of this chart is to illustrate how much of the total costs is recouped over the lifetime of the projects in economic terms. It is also useful to distinguish between economic and social benefit estimates as the latter is more difficult to quantify and may hence be less accurate.

Note that the economic benefits presented in Figure 10 are lower-bound estimates because two factors are counted as social benefits despite their (potential) economic nature:

- **Expected cost savings and avoided future losses from adaptation measures:** These gains cannot be separated from other benefits (such as avoided deaths). They are therefore part of the 'social benefits' category to avoid overestimation of economic gains.
- **Emission abatement benefits:** Reduced emissions first and foremost contribute to better air quality and improved health outcomes, while their local economic benefits are less tangible. However, GHG abatement does have the potential to be translated into economic savings if the Lebanese government decided to participate in carbon markets in the future.

This implies that economic benefits are likely to recoup more than 90% of priority project costs.

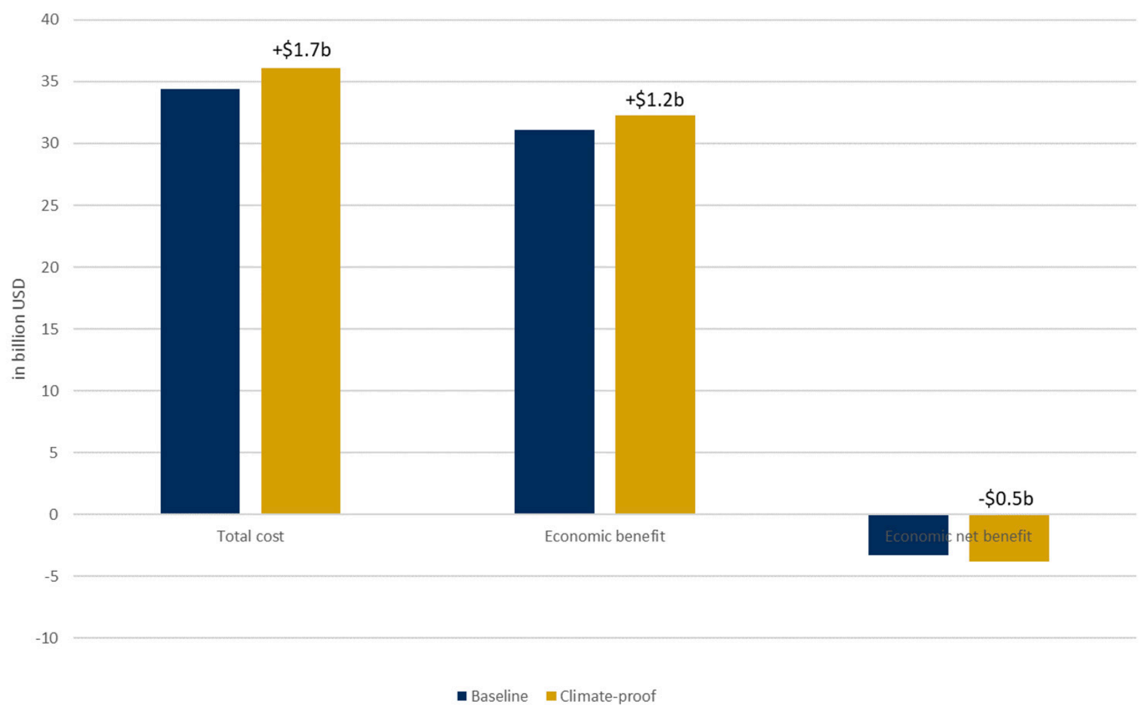


Figure 10 Discounted costs, discounted economic benefits, and economic NPV of all priority projects jointly
Source: Vivid Economics

Note: For the agricultural project (farmer soft loans), the additional benefits cannot be separated into 'economic' and 'social'. They have been assumed to be economic for this chart, but the effect is negligible (accounts for only 0.06% of total climate-proof benefits).

The analysis finds that infrastructure interventions have the highest per-dollar return. Figure 11 illustrates the benefit-cost ratio of each project, showing which projects produce the greatest benefits for each $1 invested. Baseline Lebanon Industrial Zones as planned have by far the highest overall benefit-cost ratio (4.3), followed by climate-proofed TSEZ (2.7), BRT (2.4) and wastewater schemes (2.3). Infrastructure projects also have the highest economic benefit-cost ratio when social benefits are excluded (4.3 and 1.8, respectively), followed by climate-proofed airport (1.5), solid waste (1.3) and roads (1.1). These projects have an economic ratio greater than one, suggesting that the government can economically recoup more than the initial costs over the projects' lifetimes, even if social benefits are not taken into account.

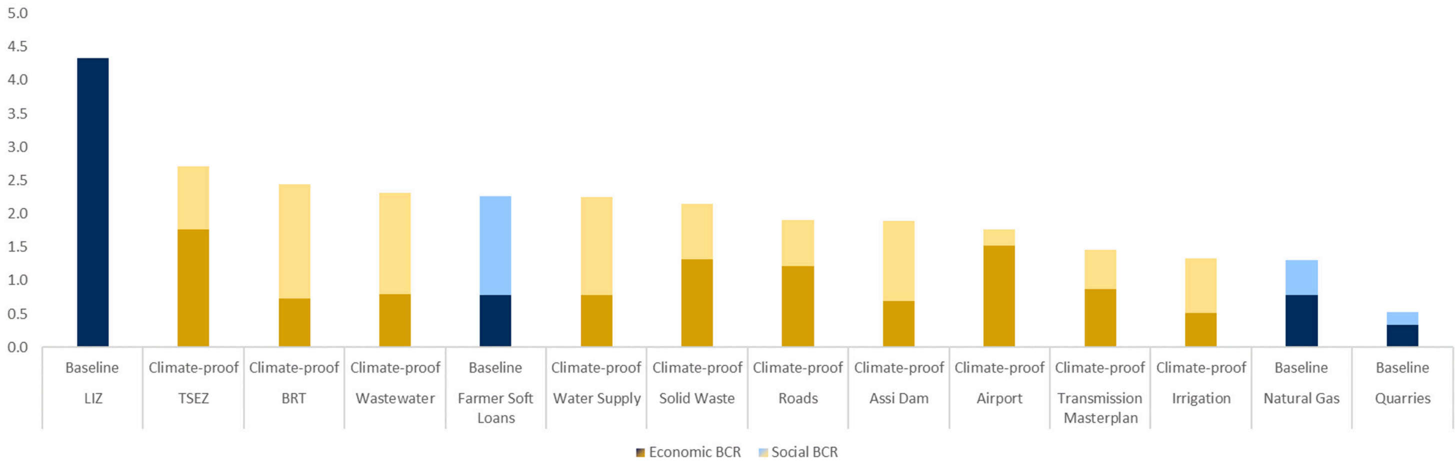


Figure 11 Priority ordering of assessed projects by benefit-cost ratio (highest to lowest)
Source: Vivid Economics

Note: Only the option (baseline vs climate-proof) with the highest per-dollar return has been listed; for example, the BCR of baseline LIZ is higher than that of climate-proof BCR, hence only the baseline option is shown in the chart. Note that for LIZ, Farmer Soft Loans and Natural Gas, the climate-proof BCR is >1, suggesting that climate-proofing is still a sound investment but should be of lower priority than implementing the project as planned.

4.3 Results of project level cost-benefit analyses

This analysis reviewed 100 projects combined into 14 different categories. The results of cost-benefit analysis for each category are described in the section below.

4.3.1 Agriculture I: Soft loans for farmers (adaptation)
Climate-proofing measure: Investment in climate-smart agriculture

The following analysis evaluates the net benefits of implementing the agricultural soft loan programme as planned, as well as supplementing the programme with an initiative to improve water productivity. As laid out in its 3-year development priorities of the Financial Recovery Plan, Lebanon is planning to invest $86 million (LBP130 billion) in soft loans for farmers, supporting 30,000 beneficiaries in expanding their agricultural production. The CBA compares this baseline soft loan programme against the climate-proofed option of additionally investing in a climate-smart agriculture initiative for the same farmers. The initiative aims to enhance water productivity through irrigation technology improvements, thereby reducing vulnerability to water scarcity.

While the project cost more with water productivity improvements than without (+$17 million), benefits are significantly higher for the climate-proof option (+$34 million). Figure 12 summarises the costs and benefits of the soft loan programme and its adaptation measure. Both options are preferable to BAU as they have a positive NPV. The climate-proofed option outperforms the baseline option with $16 million in additional net benefits and is hence the recommended course of action.

The baseline and climate-proofed options incur a discounted cost of $10 million and $27 million, respectively. With an annual interest rate of 5% and a repayment period of 2 years, the discounted net costs (present value of upfront cost – present value of repayment and interest) of the baseline is $10 million. This cost increases by $17 million when factoring in the climate-smart agriculture programme cost of the climate-proofed option.

The baseline soft loan programme generates $23 million in benefits compared to $57 million for the climate-proofed option. Based on a literature review, agricultural soft loans are expected to increase annual wheat and barley production by 3,700t and 750t, respectively, leading to a discounted economic benefit of $8 million and 1,580 job years. Additional welfare gains to beneficiaries (social benefits) amount to $15 million. Adding water productivity improvements to this programme increases benefits by $34 million and almost doubles employment effects (+1,460 job years). The benefits of climate-proofing incur in the form of productivity increases, as well as reduced water use and the resulting food security.

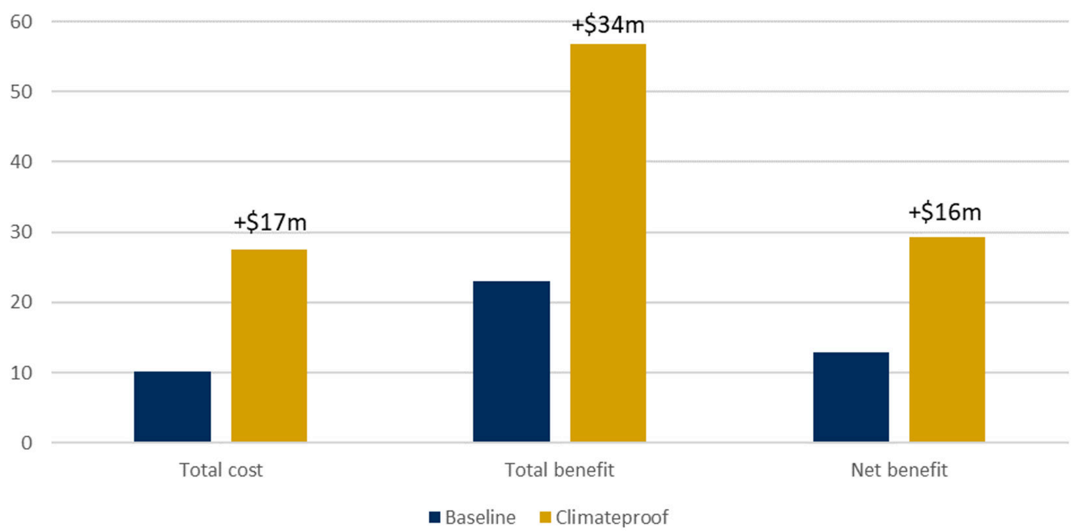


Figure 12 Discounted costs, discounted benefits, and NPV of soft loans for farmer
Source: Vivid Economics

Note: For the climate-proofed option, benefits cannot be separated into economic and social. Hence, a second chart for the economic trade-off only is not possible.

4.3.2 Energy I: Natural gas powerplants (mitigation)

Climate-proofing measure: Offset FSRU emissions by investing in domestic solar water heating subsidy programme

This CBA considers whether investment in natural gas powerplants and floating storage regasification units (FSRUs) is sound, and conducts a similar exercise for an additional offsetting programme. The switch to natural gas powerplants is a critical and ambitious part of Lebanon's development plans as it drastically reduces emissions compared to BAU. This CBA assesses the cost and benefits associated with the transition, as well as the climate-proofed option of offsetting emissions produced by FSRUs through a domestic solar water heating subsidy programme. The timeframe of this project is 12 years, equivalent to the expected duration of the FSRU contract.

Due to the opposing effects of CAPEX and OPEX, the two alternative options exhibit similar cost requirements ($2.82 billion for baseline, $2.89 billion for climate-proof). The capital expenses of constructing the planned natural gas powerplants, FSRUs and supporting infrastructure amounts to a discounted value of $2.9 billion. Operational expenses are negative compared to BAU (-$53 million), as it is cheaper to build new natural gas powerplants than to purchase this energy from private producers. Baseline costs add to a total of $2.8 billion. The climate-proofed subsidy programme costs $116 million (discounted), supporting the purchase of more than 450,000 solar water heaters[17] (if the subsidy is set at 20%) over seven years. However, part of this additional expense is counterbalanced by a reduction in OPEX (solar water heaters reduce electricity consumption and thereby subsidy payments from the government), leading to an increase in cost of only $64 million compared to baseline.

The climate-proofed option leads to an additional benefit of $72 million compared to the baseline, an increase of 2%. The IIM model predicts the baseline economic benefit to be $2.2 billion, with a job creation of 130,100 over 12 years. Equivalent figures for the climate-proofed scenario are marginally higher, with an additional $40 million and 1,550 jobs, respectively. Approximately 78% of total investment costs are recouped economically throughout the lifetime of the project for both options. This implies that the NPV is negative if only economic benefits are considered. Social benefits accrue in the form of avoided emissions. In the baseline case, they are calculated as the value of avoided emissions from switching to natural gas minus the additional emissions produced by FSRUs, amounting to $1.5 billion (on average 5,300 Gg of avoided CO_2e annually). In the climate-proof case all emissions from FSRUs are offset, increasing benefits by $33 million (additional 100 Gg of avoided CO_2e per year).

The analysis suggests that the switch to natural gas is sensible from a cost-benefit perspective, both with and without the offsetting programme. The CBA results are summarised in Figure 13. Both options exhibit a positive NPV of $0.9 billion and are hence preferred to BAU. 60% of total benefits are of economic nature, implying that 78% of total investment cost is recouped economically. The additional net benefit of climate-proofing, approximately $9 million, is relatively small but shows that climate proofing still a sound investment choice.

[17] The solar water heater programme is given as an example – while any other technology (e.g., decentralised photovoltaic, utility scale photovoltaic or wind) can be applied, the results would generate different results which were not analysed.

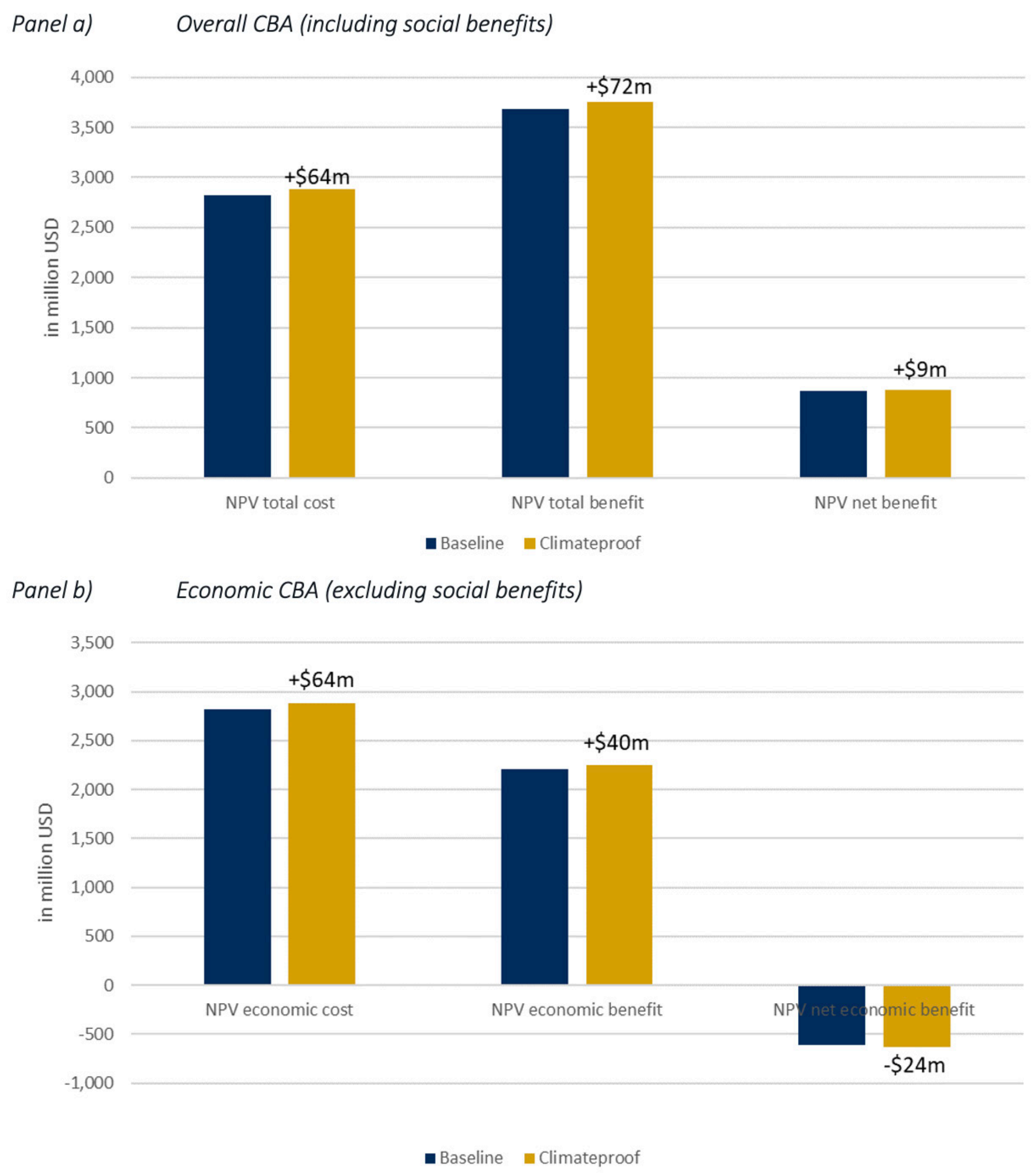


Figure 13 Discounted costs, discounted benefits, and NPV of natural gas powerplants and FSRUs
Source: Vivid Economics

4.3.3 Energy II: Transmission masterplan (mitigation)
Climate-proofing measure: Replace some baseline energy generation with renewable sources

In this subsection, we analyse the NPV of investing in transmission, distribution, and digital signal processing in the baseline, and the net benefit of additionally shifting some energy generation capacity to renewables. The baseline case for this analysis consists of BAU energy generation, plus the implementation of the Transmission Masterplan (upgrade and installation of substations and underground cables) and additional distribution infrastructure. It also includes the installation of 1,000,000 smart meters in 2022. The climate-proof scenario, on the other hand, replaces some of the baseline power purchases (reaching 6,600 GWh after 10 years) with hydro and geothermal energy generation (as lined out in CIP) as well as other renewable energy sources.

While the climate-proofed case incurs higher capital expenses, part of this premium is counterbalanced by lower OPEX, leading to an additional expense of $0.2 billion (<1%) over the 20-year time horizon. The capital expenses associated with transmission, distribution, and digital signal processing investments amount to approximately $1.2 billion. Switching to renewables increases this capex more than four-fold through the significant up-front expenditure that is associated with the mitigation action. However, the largest part of total expenditure is OPEX, as this factors in the cost of generating and/or purchasing all of Lebanon's energy. The average annual (discounted) figure is $1.3 billion for the baseline case, but 13% lower when switching to the climate-proof scenario as renewable energy is cheaper to operate than purchasing power from thermal plants.

The baseline scenario generates a total benefit of $37.7 billion, whereas the equivalent figure for the climate-proofed scenario is $1.1 billion higher. The economic benefit of both scenarios – estimated by the IIM model – is approximately the same, recouping 88% (or $23 billion) of total expenditure. In the baseline case, this is equivalent to a total of 1.2 million jobs in the energy sector over the 20-year period. While the analysis predicts 5.8% fewer jobs under the switch to renewable energy, this is likely overestimated due to the fact that the underlying, Lebanon-specific data for IIM is not differentiated enough to account for the full set of differences between the two cases. Based on a literature review, experts tend to postulate that renewable energies result in the same or a greater number of jobs on the long run, with some structural unemployment in the transition period. Approximately 88% of total investment costs are recouped economically throughout the lifetime of the project for both options. This implies that the NPV is negative if only economic benefits are considered. In terms of social benefits, the baseline scenario results in significant energy savings, up to 7,200 GWh per annum by the end of the period. This reduces both the associated energy generation costs (accounted for in economic benefits) and GHG emissions. Together with the consumer benefit of power provision, the baseline social benefits amount to $14.4 billion. In the climate-proof scenario, these benefits are higher by $1 billion due to the value of additional avoided emissions, reaching approximately 4,000 Gg of CO_2e per annum.

The net benefits of both scenarios are positive and significant in magnitude, but the climate-proofed case is preferrable for Lebanon. The results of the CBA are summarised in Figure 14. Both scenarios have a positive NPV, indicating that they are beneficial for Lebanon. More than 60% of total benefits are of economic nature, implying that 88% of total investment cost is recouped economically. While the switch to renewable energy only costs $0.2 billion extra, it generates a benefit more than five times in size. Therefore, the climate-proofed scenario outperforms the baseline case.

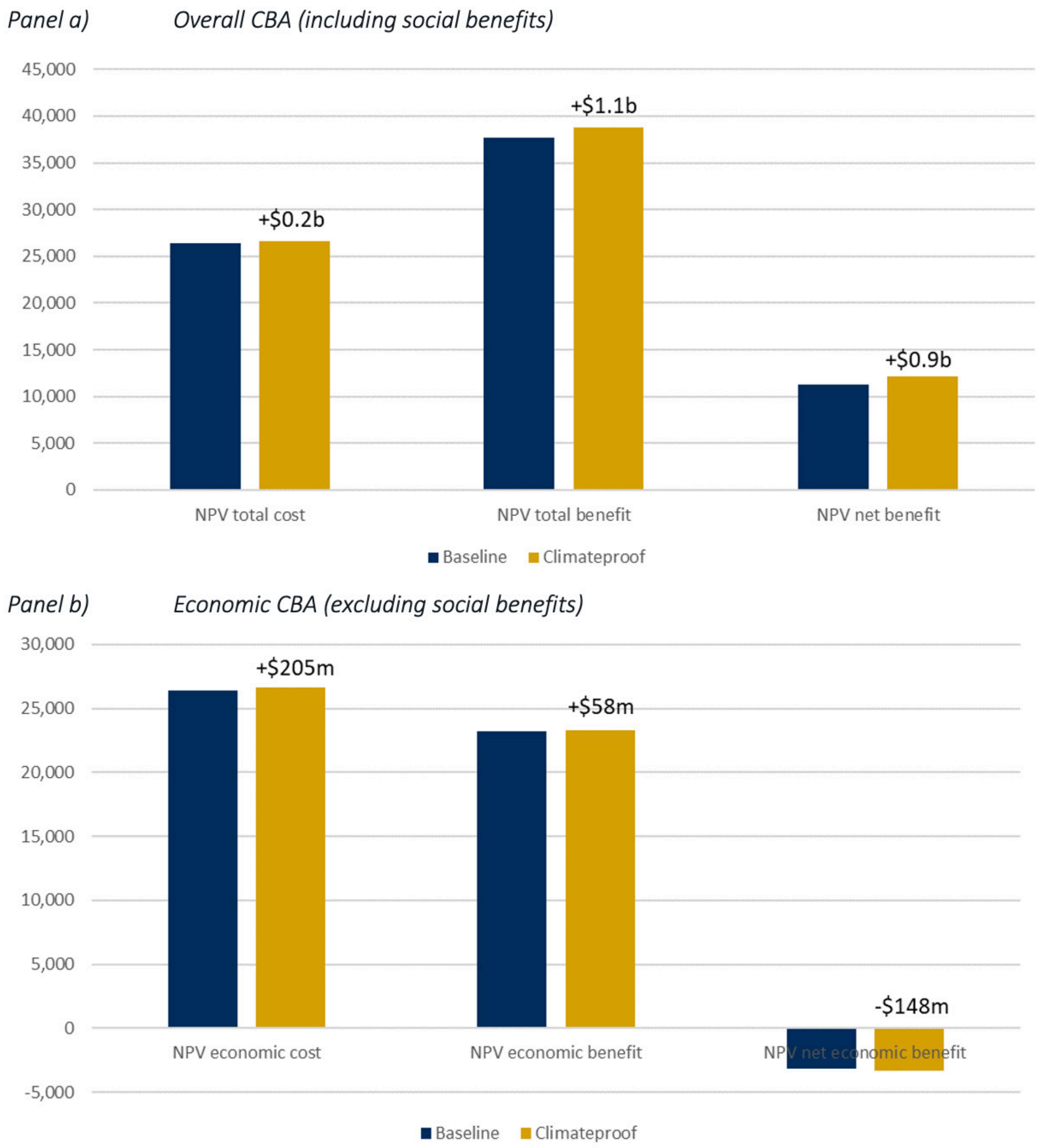


Figure 14 Discounted costs, discounted benefits, and NPV of the transmission masterplan
Source: Vivid Economics

4.3.4 Infrastructure I: Tripoli Special Economic Zone (mitigation & adaptation)

Climate-proofing measure: Port Site energy generation from renewable sources; seawall at Port Site

The following CBA analyses the costs and benefits of the Tripoli Special Economic Zone (TSEZ), along with the climate-proofed option of adding a renewable powerplant and seawall for Port Site. Lebanon's 3-year development priorities of the Financial Recovery Plan presents the goal to create a Special Economic Zone in Tripoli. This project envisions an industrial centre near the port (Port Site) and an ICT and creative sector hub at Rachid Karami Fairground (RKF Site) with a total area of 60 ha. In the climate-proofed scenario, the additional powerplant that has been recommended to be built to provide Port Site with energy is replaced with a renewable alternative. Moreover, a seawall is built to protect Port Site from coastal flooding. The time horizon is assumed to be 15 years.

The investment requirement for the climate-proofed TSEZ is $107 million, $10 million more than in the baseline scenario. Total discounted cost in the baseline case is expected to be $98 million, including the capex for initial development ($38 million) and the cost of providing energy and water over the years ($60 million). Renewable power generation and seawall incur additional up-front expenses ($6.9 million and $7.3 million, respectively), but require $4.4 million less in power generation costs.

Baseline TSEZ generates $182 million in total benefits but mitigation and adaptation measures significantly increase this figure, with $109 million in additional gains. TSEZ creates two types of economic benefits: a) the GVA impact and job creation from construction of the zone (estimated through IIM), and b) the GVA impact and job creation through the creation of an enabling environment (estimated from project-specific documents). Regarding the construction of the zone itself, baseline economic benefits from construction amount to $71 million and 4,050 jobs. The equivalent figures for the climate-proof case are $8 million and 360 jobs higher, respectively. The benefit of the enabling environment is the same for both scenarios, as this is not affected by the mitigation and adaptation measures. It is estimated at $110 million and 3,560 jobs. More than the total investment costs are recouped economically throughout the lifetime of the project for both options (186% for baseline, 177% for climate-proof). This implies that the NPV is positive if only economic benefits are considered. In addition, climate-proof TSEZ also creates social benefits: the renewable plant results in emission savings valued at $17 million (37.8 $GgCO_2e$ per annum) and the seawall in $85 million of avoided future losses.

While both scenarios are preferable to not implementing TSEZ, the net benefits of climate-proofing are sizeable. Figure 15 displays the costs and benefits of the two alternative scenarios graphically. Both have a positive NPV and hence are sound. However, the net benefits of the suggested mitigation and adaptation measures outweigh those of baseline TSEZ by $100 million, indicating that climate-proofing TSEZ is preferable to not doing so. The majority of benefits are of economic nature (100% for baseline, 65% for climate-proof), implying that total investment cost is more than recouped economically.

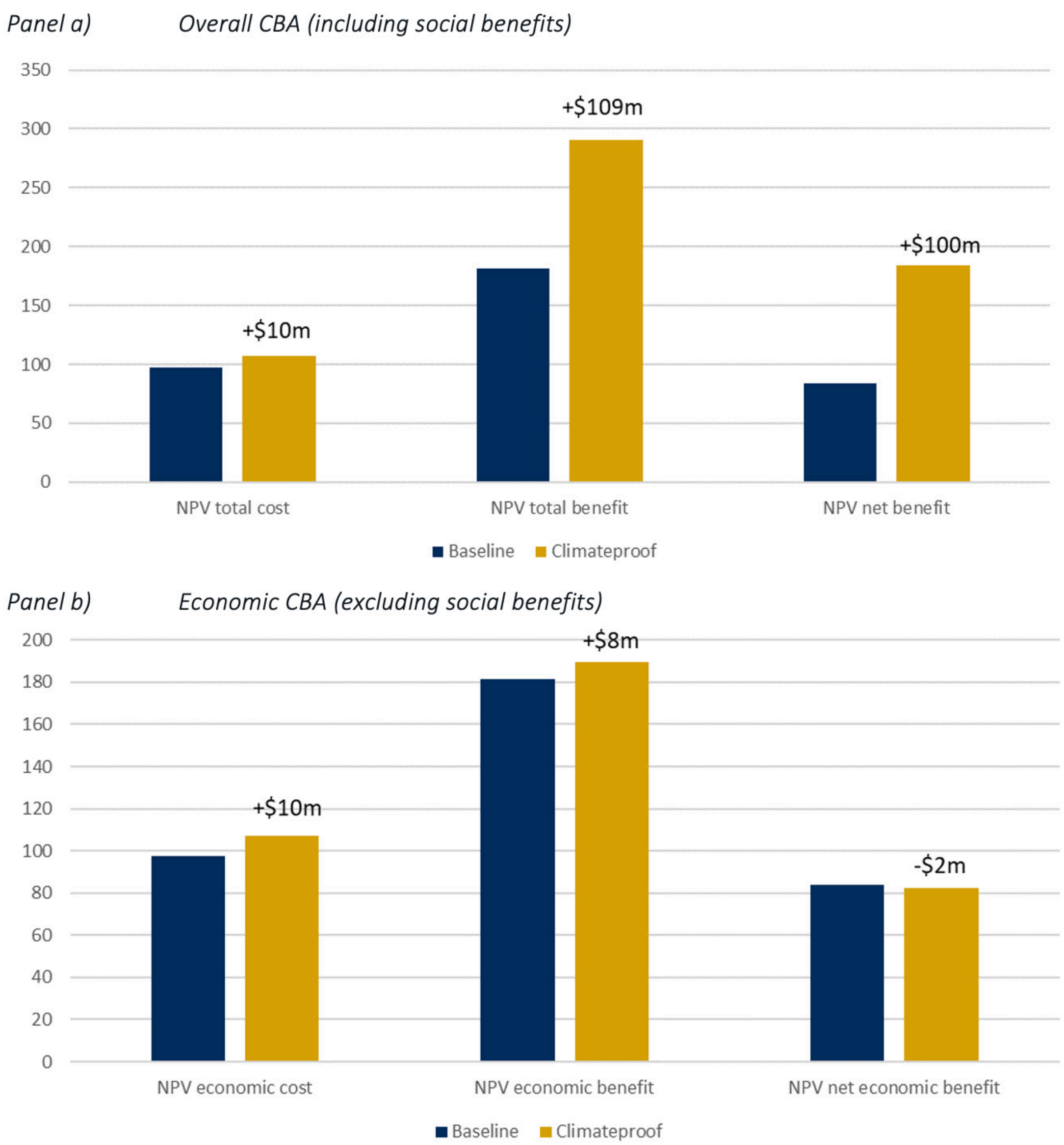


Figure 15 Discounted costs, discounted benefits, and NPV of TSEZ
Source: Vivid Economics

4.3.5 Infrastructure II: Lebanon Industrial Zones (mitigation)
Climate-proofing measure: LIZ energy demand is met through additional renewable sources

This analysis looks at whether the creation of three industrial zones in Lebanon (LIZ) is a sound investment, and whether climate proofing through renewable energy generation for the sites is beneficial. The CIP describes plans to support enterprise development in three industrial cities – Alkaa, Baalbek, and Terbol – by creating favourable conditions for businesses to flourish, including good accessibility and utility provision. The below analysis assesses the costs and benefits of this baseline scenario against the climate-proofed option of meeting all additional energy demand with renewable energies over a 20-year period.

Setting up and running the enabling infrastructure for LIZ costs approximately $146 million, or $162 million if energy is renewable. Capital expenses are required for the construction of roads, water distribution pipes, wastewater collection pipes, and energy distribution infrastructure. These costs amount to a total of $87 million for baseline LIZ. Additionally, energy and water provision (including wastewater collection) cost approximately $12.8 million annually (undiscounted). While the renewable energy plant in the climate-proofed scenario incurs an additional $20 million upfront, the mitigation measure reduces annual OPEX by $1 million, slightly narrowing the gap in total cost.

Both scenarios generate significant benefits, most of which arise from the stimulation of business activities in the three industrial zones. Similar to TSEZ, economic benefits are generated through both construction activities and the provision of an enabling environment for enterprises. For baseline LIZ, construction engenders $108 million in GVA benefits and 7,010 jobs. The equivalent figures for the climate-proofed scenario are $121 million and 7,630 jobs, respectively. The benefits derived from stimulating business activities are the same for both alternatives, adding $525 million in gains and 9,390 jobs. Total investment costs are recouped economically several times over throughout the lifetime of the project for both options (433% for baseline, 399% for climate-proof). This implies that the NPV is significantly positive even if only economic benefits are considered. Beyond that, the mitigation measure in climate-proofed LIZ reduces emissions by 54 GgCO_2e annually, valued at a total of $20 million.

Figure 16 below shows, that net benefits of both options are large when compared to the required investment, suggesting that the creation of industrial zones is very beneficial for Lebanon. The chart shows that for every $1 million in investment baseline LIZ create $4.3 million in benefits. While this figure is slightly smaller for the climate-proofed scenario ($4.1 million), it is still beneficial to implement the mitigation measure, adding $17 million in net benefits. Almost all of the benefits incurred are of economic nature (100% for baseline, 97% for climate-proof), implying that total investment cost is more than recouped economically.

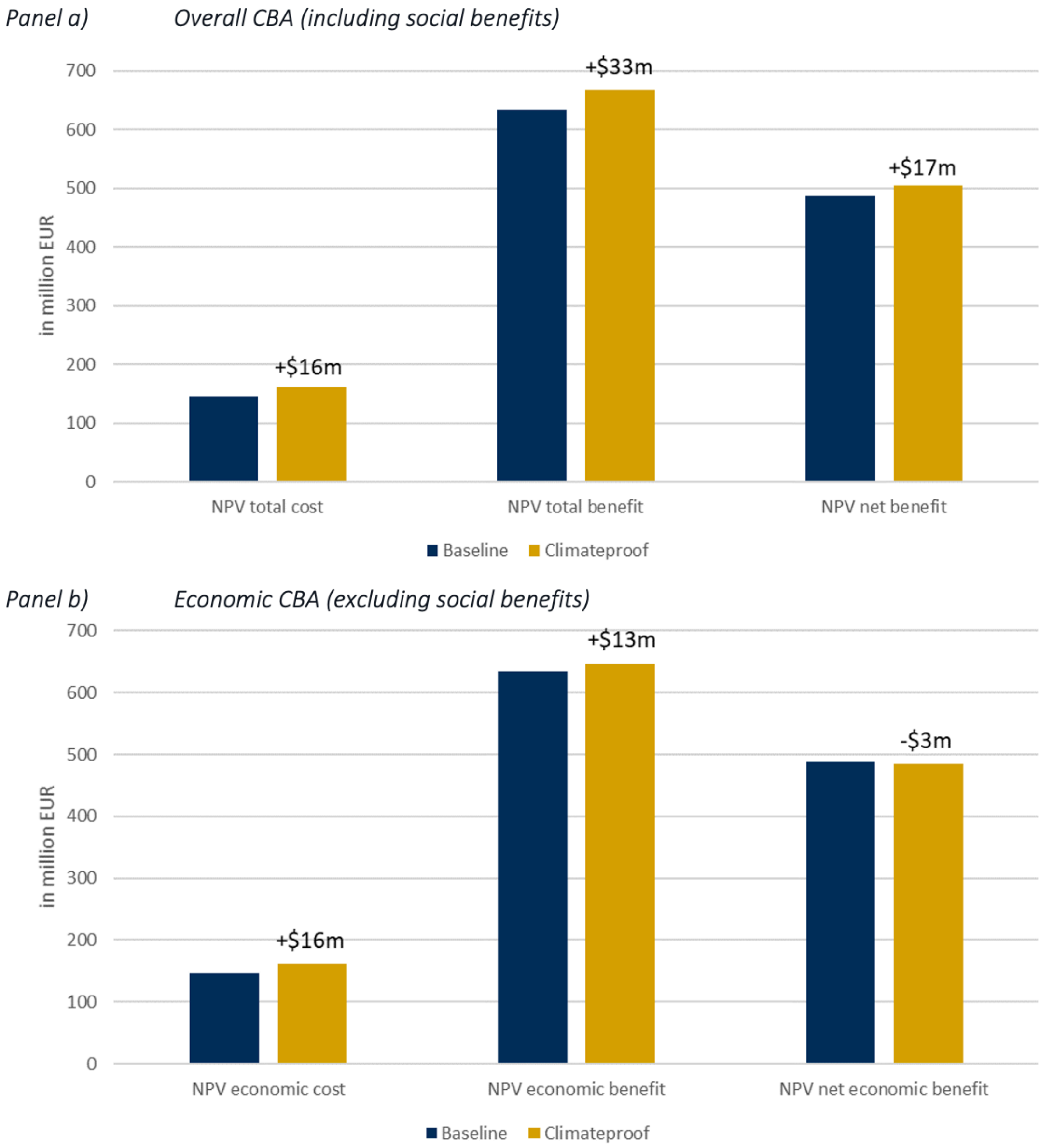


Figure 16 Discounted costs, discounted benefits, and NPV of LIZs
Source: Vivid Economics

4.3.6 Mining: Rehabilitation of quarries
Climate-proofing measure: N/A

Lebanon's 3-year development priorities of the Financial Recovery Plan also envisions to rehabilitate publicly owned quarries and enforce rehabilitation of privately owned quarries by the owners. Unofficial studies report at least 1,300 quarries in Lebanon, most of which have been abandoned. The document recommends for these quarries to be ecologically rehabilitated.

Rehabilitation of quarries is expected to incur approximately $524 million in discounted costs but recoup only 53% of this in benefits (equivalent to $278 million). Costs of quarry rehabilitation ($524 million) are expected to incur in the first five years of the investment, whereas benefits increase over time. The economic benefits accrue in the form of restored housing and land value, as property prices near quarries are depressed but expected to recover slowly through rehabilitation efforts. Moreover, quarry rehabilitation can restore the recreational value in the neighbourhood. Overall, economic and social benefits of quarry rehabilitation are estimated at $175 million and $102 million, respectively.

As can be discerned from Figure 17 the NPV of quarry rehabilitation is negative even with and without social benefits, indicating that this investment is not currently sound in Lebanon. As benefits are much more pronounced in the long run and the discount factor is estimated to be fairly high in Lebanon at the moment (12%), the net benefits of quarry rehabilitation are projected to be negative. Note, however, that this could change in the future: As Lebanon recovers from the crisis, it is possible that the discount factor drops. If it falls below 4.4%, quarry rehabilitation becomes a sound investment choice.

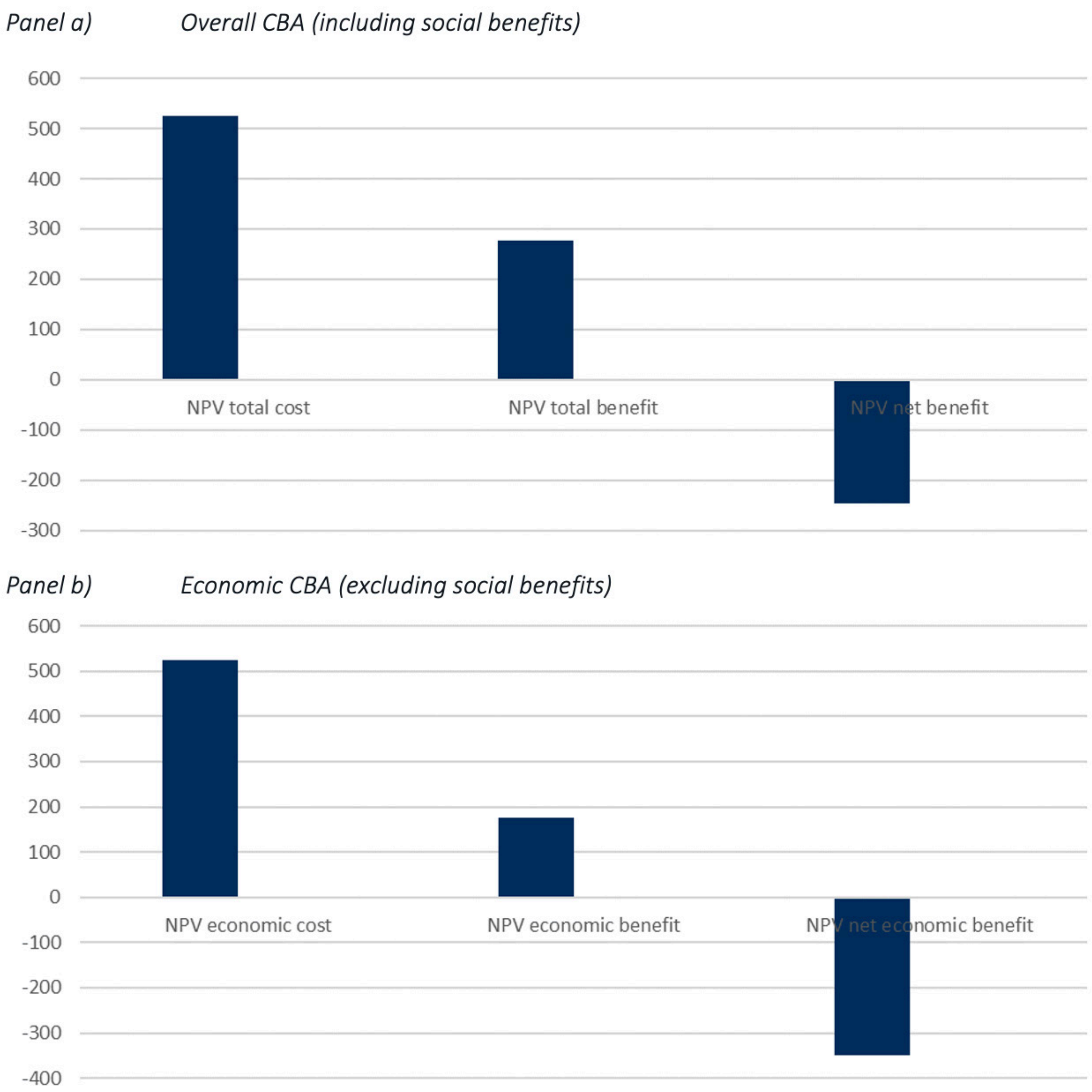


Figure 17 Discounted costs, discounted benefits, and NPV of quarry rehabilitation
Source: Vivid Economics

4.3.7 Transport I: Bus Rapid Transit system (mitigation)
Climate-proofing measure: Diesel BRT and feeder buses are replaced by hybrid buses

The planned Bus Rapid Transit (BRT) system for Greater Beirut is powered by diesel buses, but these could be replaced with hybrid vehicles. The CIP lays out the Lebanese government's intention to design and construct dedicated bus routes and stations within Greater Beirut as part of a BRT system. Both the BRT and feeder bus fleets are planned to be powered by a diesel combustion engine. As part of Lebanon's climate change mitigation efforts, BRT vehicles could instead be fitted with hybrid engines to reduce the system's carbon emissions. The CBA below compares a baseline diesel BRT with a climate-proofed hybrid BRT. The timeframe of this analysis is 15 years in line with the expected construction period (five years) and bus lifetime (ten years).

Higher CAPEX expense of a hybrid BRT compared to a diesel BRT outweighs the effect of lower OPEX, resulting in $22 million additional (discounted) cost. The diesel BRT is expected to amount to $345 million in capital expenses and $88 million in annual operational expenditures, leading to a total discounted cost of $536 million. Hybrid buses incur a premium of approximately 60%, mostly due to the high battery cost, resulting in an additional CAPEX of $62 million. However, their enhanced fuel efficiency compared to diesel buses reduces annual OPEX to $83 million[18]. The total discounted cost of a hybrid BRT is $557 million.

The baseline BRT creates total discounted benefits of $1.3 billion, including 38,200 jobs. The equivalent figures for the hybrid system are $54 million and 270, respectively, higher. The diesel BRT results in $398 million GVA (discounted), more than 60% of which are direct impacts whereas the remainder occurs as benefits cascade through the economy. The associated job creation is approximately 38,200. The hybrid BRT generates an additional $10 million in economic benefits and 270 jobs. These figures were derived using Vivid's in-house IIM model. Approximately 74% of total investment costs are recouped economically throughout the lifetime of the project for both options. This implies that the NPV is negative if only economic benefits are considered. The social benefits of a BRT in Lebanon are also substantial, as the system reduces passengers' travel time, expenses, and CO_2 emissions, and increases road safety and physical activity. For the BRT as planned, this translates into $911 million in discounted social benefits. Emission reductions under the hybrid BRT are 19% higher (226 $GgCO_2e$ annually), increasing benefits by $43 million.

Both diesel and hybrid BRTs are sound options when compared to not investing in this public transport system – however, the hybrid BRT is the preferable option for Lebanon. The CBA results are summarised in Figure 18. Both options have a positive NPV and are hence preferable to BAU (i.e. no BRT). 30% of total benefits are of economic nature, implying that 74% of total investment cost is recouped economically. As the hybrid BRT generates a higher discounted net benefit than the diesel BRT, it is recommended to implement the former.

[18] This analysis does not take into account battery replacement as the life-time of the battery is considered to be 10 years (similar to the life-time of the bus)

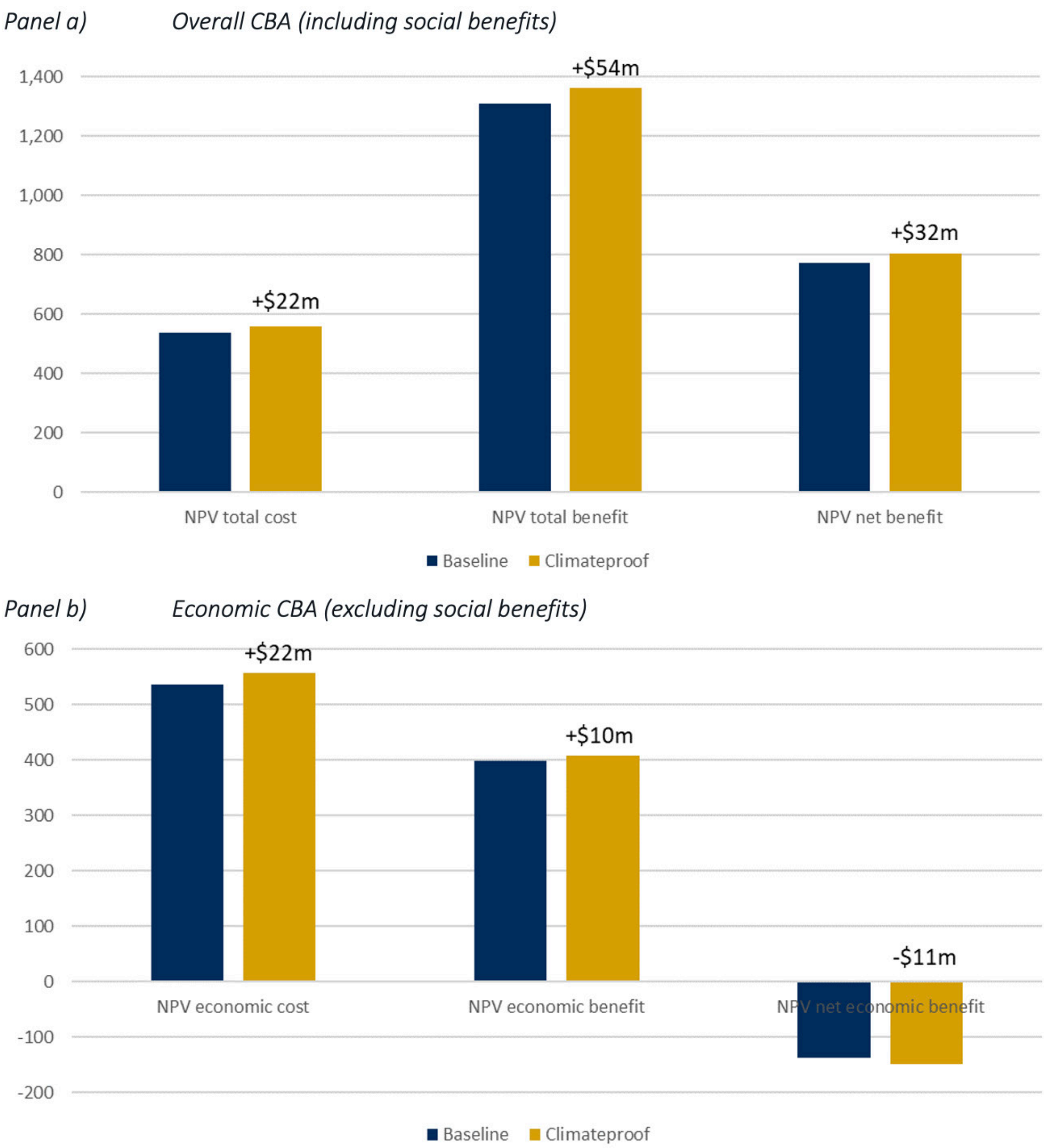


Figure 18 Discounted costs, discounted benefits, and NPV of BRT
Source: Vivid Economics

4.3.8 Transport II: Roads (adaptation)
Climate-proofing measure: Road construction incorporates drainage systems and uses permeable materials

The following CBA considers the costs and benefits of road investments going ahead as planned and of additional adaptation measures being incorporated in their design. As stated in CIP, the government plans to rehabilitate the Lebanese road system and construct a new service road for the coastal highway. Our analysis sheds light on the costs and benefits of these investments. Moreover, it assesses whether additional resilience measures, such as the incorporation of drainage systems or the utilisation of permeable materials, are sound considerations. Adaptation enhancements increase the chance of roads remaining intact during a natural disaster, thereby decreasing foregone economic activity and increasing emergency response capacity.

Climate-proofing roads adds 42% in upfront expenditure. The cost of road investments as planned are $547 million. Adaptation measures add $232 million more in capex to cover the expenses of additional or more costly materials and construction activities.

Road investments as planned generate a total benefit of $776 million but is surpassed by the climate-proofed option by 92% ($711 million). The baseline economic benefits amount to $765 million and 53,060 jobs over the 20-year time horizon. These are measured as a) GVA and jobs from construction activity, and b) GVA and jobs generated through the creation of an enabling environment for economic activity. As adaptation measures increase construction efforts, construction activity delivers $178 million and 12,360 jobs larger in the climate-proofed case. The enabling environment created by road infrastructure is the same with and without resilience measures (apart from the case in which a disaster occurs – this is accounted for in social benefits), hence the associated economic benefits are the same for both scenarios. More than the total investment costs are recouped economically throughout the lifetime of the project for both options (140% for baseline, 121% for climate-proof). This implies that the NPV is positive if only economic benefits are considered. Improved road infrastructure further engenders social benefits, such as time savings and emission reductions as vehicles can drive at higher and more fuel-efficient speeds. These amount to $11.5 million and $0.1 million, respectively. Adaptation measures bring about an additional staggering $533 million in resilience benefits, a figure that accounts for the decrease in foregone economic activity and increase in emergency response capacity in case of a natural disaster.

Both options have a positive NPV, but adaptation measures increase net benefits by $479 million and are hence extremely worthwhile. Figure 19 summarises the results of the CBA. The net benefits of baseline road improvements are positive but, with $161 million, relatively small. On the other hand, the NPV associated with the climate-proofed option is almost three times higher. Most of the benefits incurred are of economic nature (99% for baseline, 63% for climate-proof), implying that total investment cost is more than recouped economically.

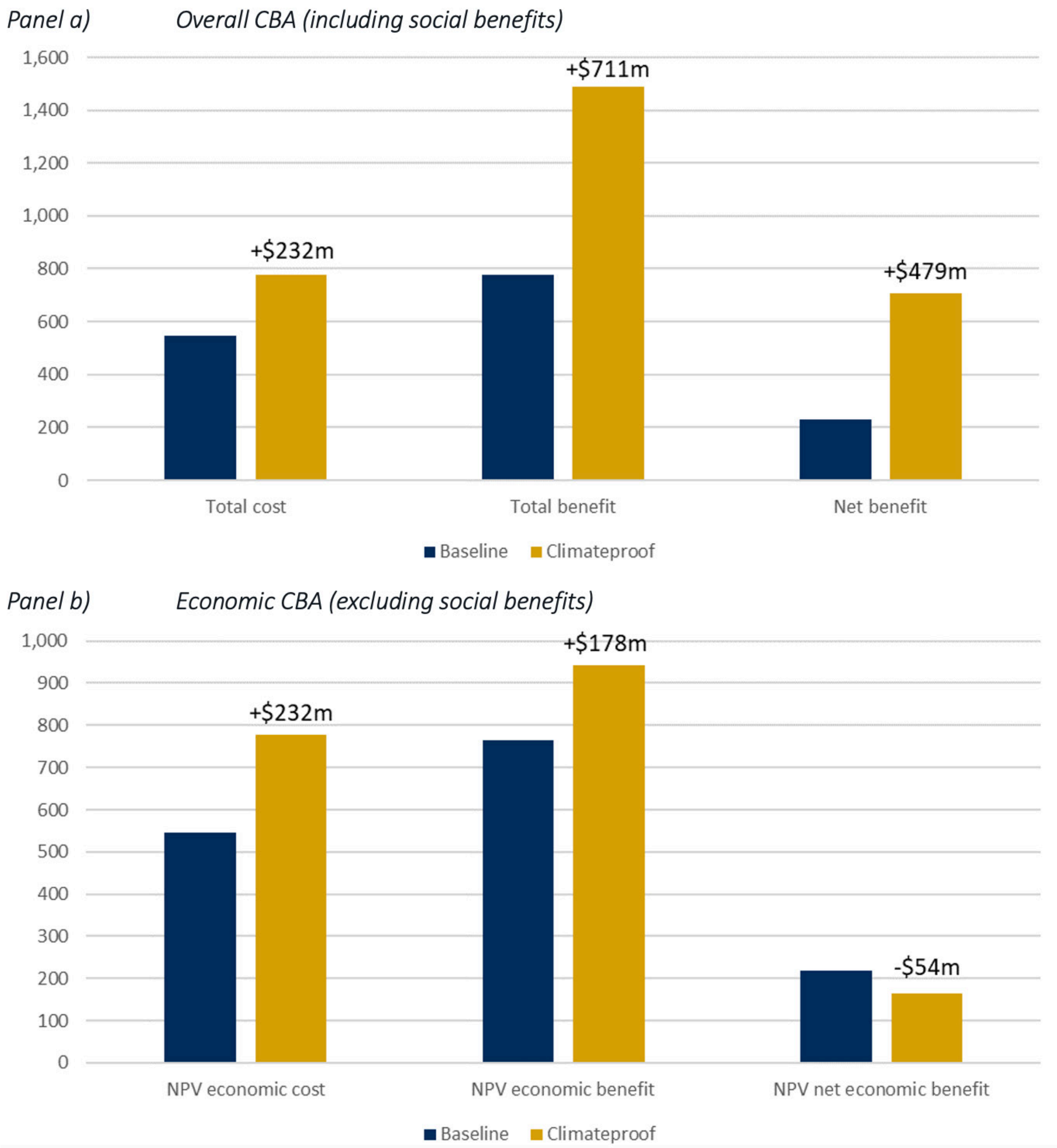


Figure 19 Discounted costs, discounted benefits, and NPV of road schemes
Source: Vivid Economics

4.3.9 Transport III: Beirut airport expansion (mitigation & adaptation)
Climate-proofing measure: Reduce the airport's operational emissions; build protective infrastructure against floods

The following analysis derives the NPV of the planned airport expansion, as well as of multiple mitigation and adaptation enhancements. Beirut Rafic Hariri airport is currently almost 50% beyond its passenger capacity. To resolve this issue, the government plans to expand the current terminal's capacity as well as add a new terminal (baseline option). This overhaul of the airport layout further presents the opportunity to implement mitigation and adaptation measures (climate-proofed option): the airport could aspire to reduce its operational emissions by 90% and repair its aged seawall, as well as raise floor levels and build additional protective infrastructure to avoid flood damages.

Climate-proofing adds 18% in upfront expenditure to the airport expansion project. The total cost of baseline implementation is $500 million. For the climate-proofed scenario, the reduction in operational emissions and flood defence mechanisms cost an additional $17 million and $74 million, respectively.

The benefits of the airport expansion as planned and its climate-proofed equivalent amount to $0.8 billion and $1.0 billion, respectively. Using literature review, we find that baseline economic benefits amount to $867 million. 80% of these gains ($691 million) are due to increased passenger capacity which boosts, for example, the Lebanese tourism industry. The remainder ($176 million) is the GVA generated from construction activities. This figure is higher for the climate-proofed scenario, adding a further $32 million in economic benefits. Construction job creation for baseline and climate-proofed options amounts to 8,000 and 9,460, respectively. The number of new jobs for permanent airport staff is estimated at 7,650 for both options. More than the total investment costs are recouped economically throughout the lifetime of the project for both options (173% for baseline, 152% for climate-proof). This implies that the NPV is positive if only economic benefits are considered. The baseline social benefit is negative, as the airport expansion increases emissions. Here, we account for airport operational emissions (excluding flight emissions) and emissions from car journeys to/from the airport. These are estimated at a value of -$65 million. In the climate-proofed scenario, the mitigation measure reduces operational emissions by 90%, resulting in emissions valued at -$6 million only. Moreover, the seawall repair and additional flood protection measures add a benefit of $152 million in avoided future losses.

Figure 20 shows that the airport expansion project is a worthwhile investment, and every $1 spent on climate-proofing can add a further $2.7 in benefits. Weighing up the costs and benefits of different airport expansion options, the conclusions are that current plans have a net benefit of $302 million (making it a sound investment choice) and that adaptation and mitigation measures can increase this net benefit by another 50%. Most of the benefits incurred are of economic nature (100% for baseline, 86% for climate-proof), implying that total investment cost is more than recouped economically.

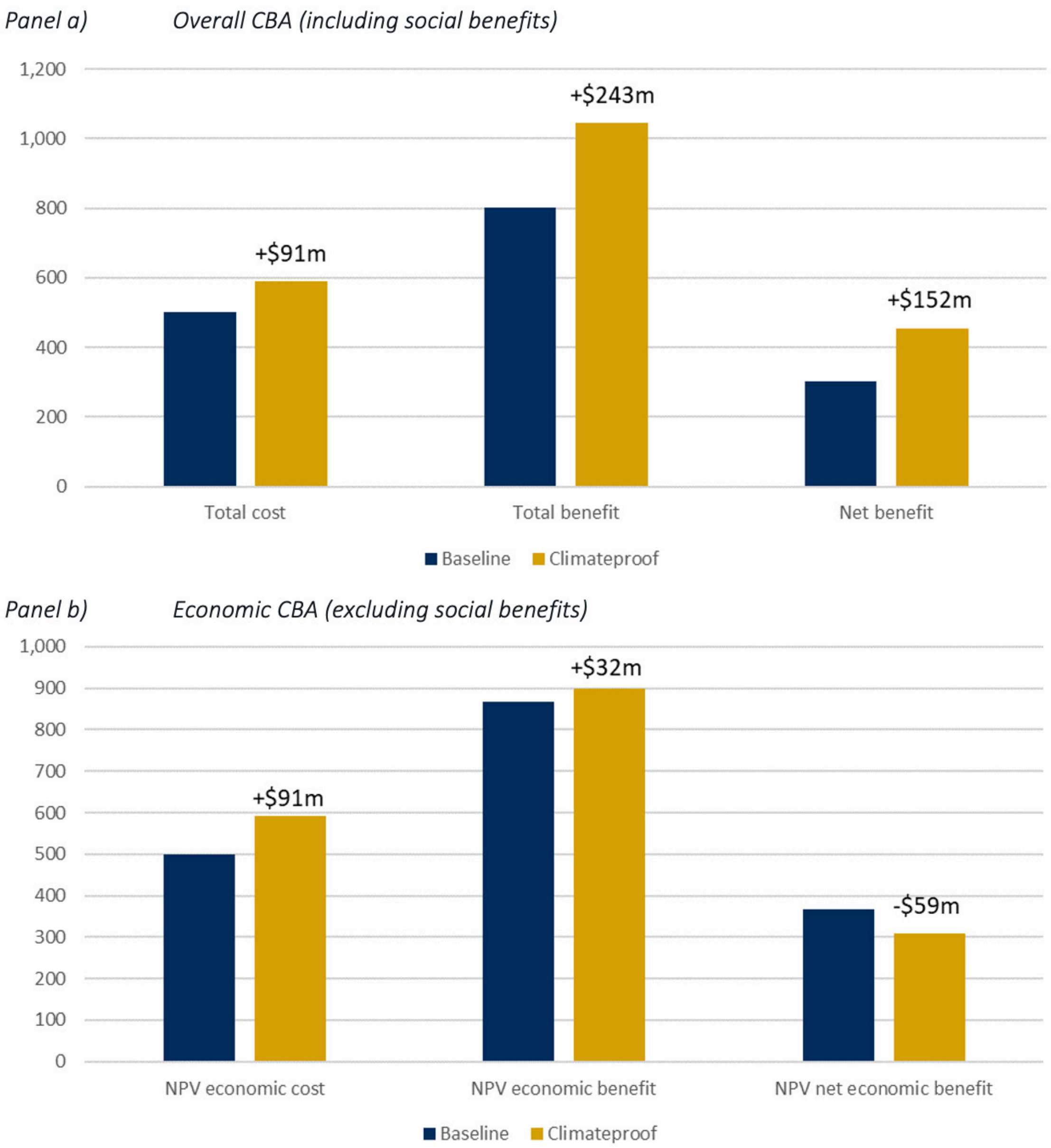


Figure 20 Discounted costs, discounted benefits, and NPV of airport expansion
Source: Vivid Economics

4.3.10 Waste: Solid waste management and infrastructure (mitigation)
Climate-proofing measure: Methane capture facilities and energy generation

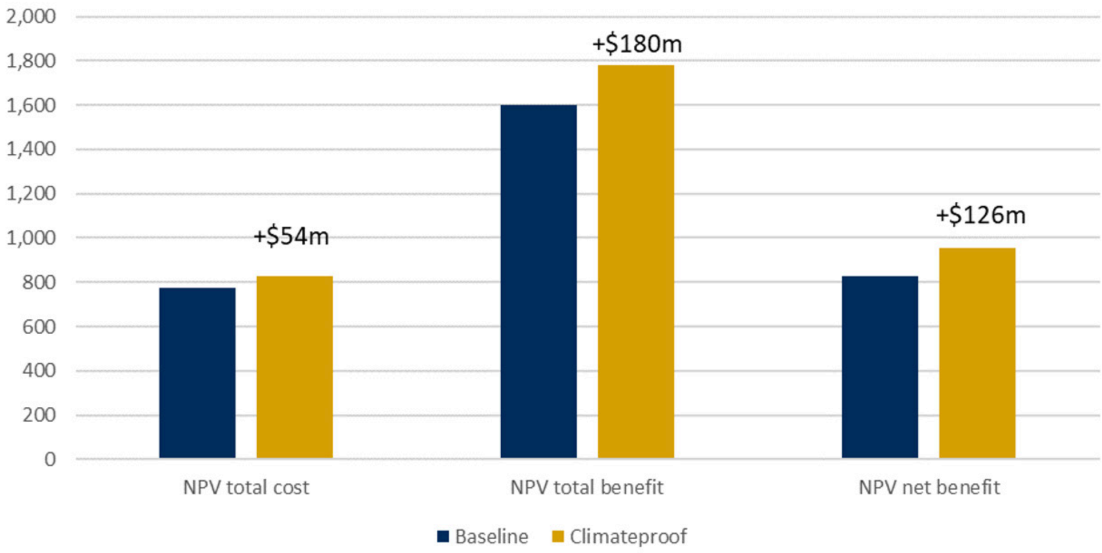
The following analysis evaluates the planned solid waste investments along with potential mitigation enhancements through methane capture facilities and energy generation. In recent years, Lebanon has experienced a solid waste crisis from which it has not fully recovered. As a result, CIP and 3-year development priorities of the Financial Recovery Plan lay out the necessary investments in solid waste management and infrastructure that are required to bridge the current gap (baseline). To further enhance sustainability of the Lebanese waste sector, the government could consider installing methane capture and waste-to-energy facilities for the share of total waste tonnage that is not recovered in the plants (climate-proof).

The mitigation option increases capital expenses by $54 million. The planned upfront cost of improvements to solid waste management and infrastructure is $775 million. This increases to $830 million if methane capture facilities with built-in energy generation are installed for the waste tonnage that is unrecovered in the baseline option.

The planned solid waste investments engender a total benefit of $1.6 billion, and climate-proofing increases gains to $1.8 billion. Baseline economic benefits amount to $1.1 billion and 31,510 additional jobs, whereas the equivalent figures for the climate-proofed option are $42 million and 70 jobs higher. These additional gains arise from the value added and permanent employment opportunities in the waste-to-energy sector. More than the total investment costs are recouped economically throughout the lifetime of the project for both options (136% for baseline, 132% for climate-proof). This implies that the NPV is positive if only economic benefits are considered. Social benefits occur mostly through avoided emissions. Annual GHG savings amount to up to 1,800 $GgCO_2e$ in the baseline scenario and are 25% higher in the climate-proofed option. The associated monetary gains are $548 million and $687 million, respectively.

Projects in solid waste management and infrastructure are worthwhile for Lebanon's economy, particularly if part of the initial expenditure is directed towards mitigation efforts. Due to the chronic problems Lebanon's waste sector has experienced in recent years, it is unsurprising that investment in solid waste management and infrastructure is highly beneficial to the country. This is true for both the baseline and climate-proofed investment options. The net benefits of planned investments reach $827 million. Climate-proofing can further increase the NPV of the project, with $2.1 million of benefits accruing for every $1 million invested in methane capture and waste-to-energy facilities. Almost two-thirds of the benefits incurred are of economic nature for both options, implying that total investment cost is more than recouped economically.

Panel a) *Overall CBA (including social benefits)*



Panel b) *Economic CBA (excluding social benefits)*

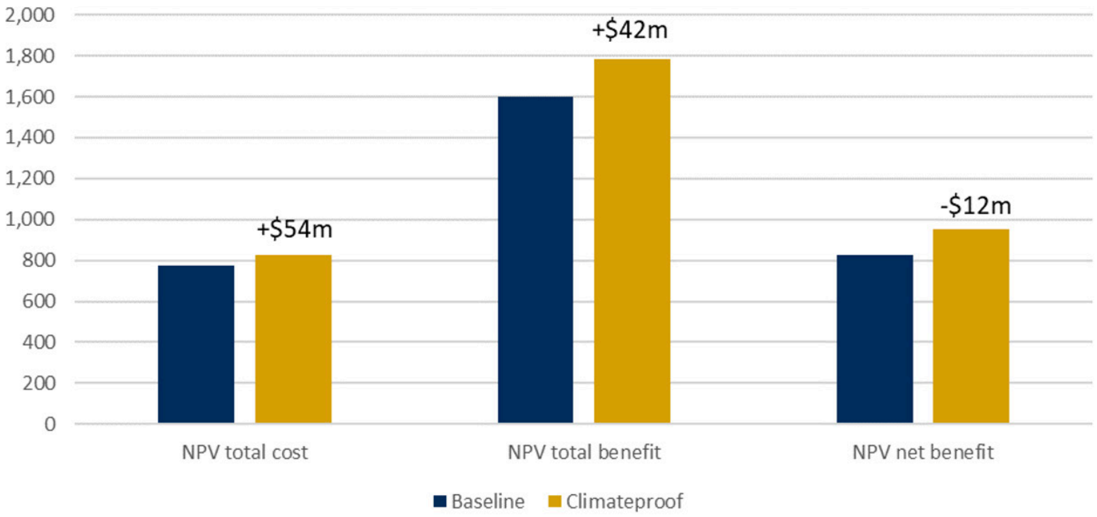


Figure 21 Discounted costs, discounted benefits, and NPV of waste schemes
Source: Vivid Economics

4.3.11 Water I: Assi dam (adaptation)

Climate-proofing measure: Carry out and implement Environmental and Social Management Plan (ESMP)

The Lebanese Assi dam could be constructed as planned or enhanced by implementing the recommendations of an Environmental and Social Management Plan (ESMP). Lebanon had previously started constructing the Assi dam, but works stopped in 2006. The CIP outlines new plans to complete the construction of a diversion and storage dam, including powerplant and transmission pipes (baseline). Furthermore, an ESMP could be drafted and implemented (climate-proof) to enhance Lebanon's climate change adaptation efforts. The ESMP can alleviate climate-related issues in watershed management, biodiversity and habitats, and sedimentation, among others.

The baseline discounted capital expenditure totals $147 million whereas an ESMP would add further $13 million to the bill. The figure for Assi dam as planned includes a diversion dam (cycle I of CIP) costing $44 million and a storage dam (cycle III of CIP) costing $103 million. The respective figures including ESMP are $49 million and $111 million, respectively.

Investments in the Assi dam as planned in CIP yield $259 million in benefits, with an additional $42 million if an ESMP is drafted and implemented. Economic benefits in the form of GVA from construction of the dam are calculated using the in-house IIM model. They amount to $100 million in the baseline option (with 7,380 jobs) and $110 million in the climate-proofed option (with 8,160 jobs). Approximately two-thirds of total investment costs are recouped economically throughout the lifetime of the project for both options. This implies that the NPV is negative if only economic benefits are considered. Note that the above figures do not include benefits to farmers. Irrigation benefits (including subsequent value-chain gains) are valued at $158 million. Moreover, there hydro powerplant generates modest emission savings worth $2 million (up to 18 Gg per annum). Irrigation and emission avoidance benefits are the same for both baseline and climate-proofed scenarios. However, the latter also incurs benefits from avoided future damages and resulting disruptions to irrigation and the agricultural supply chain as a result of climate change. These gains are estimated to amount to an additional $32 million.

The NPV of both baseline and climate-proofed Assi dam are positive, indicating that investment in the dam is worthwhile compared to leaving the structure unfinished. Figure 22 displays the result of the CBA graphically. Both the planned Assi dam and the ESMP are sound investments, though the latter yields $53 million in additional net benefits and is therefore the preferable option. Approximately 37% of total benefits are of economic nature, implying that two-thirds of total investment cost is recouped economically.

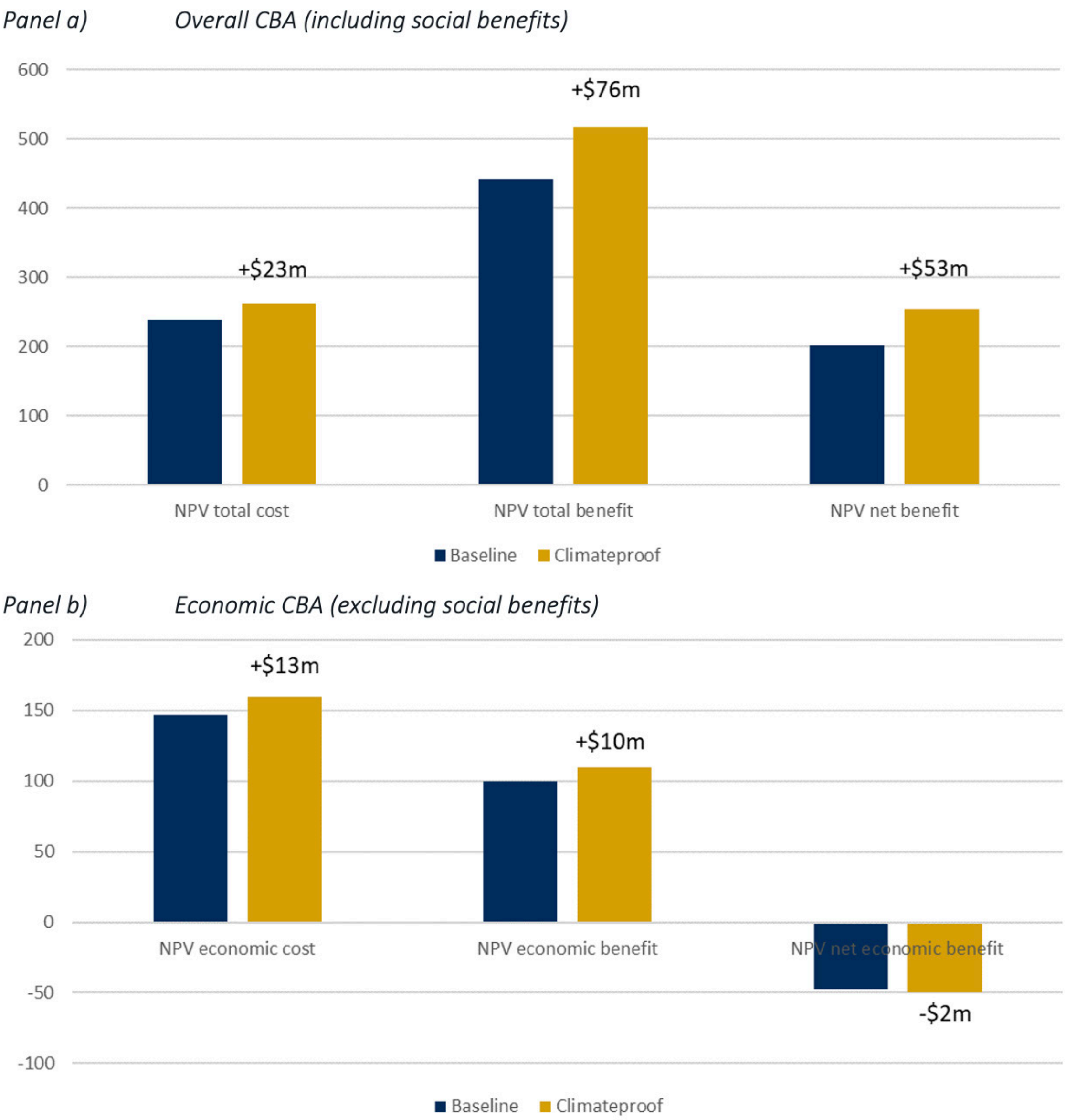


Figure 22 Discounted costs, discounted benefits, and NPV of Assi dam
Source: Vivid Economics

4.3.12 Water II: Water systems (adaptation)

Climate-proofing measure: Resilience measures to protect assets against floods and liquefaction

An NPV assessment has been conducted for planned investments in water systems, as well as for additional climate change adaptation measures. The CIP's long list of planned investments in water supply systems evidences the government's focus on the sector. The document describes Lebanon's intention to invest in the expansion and upgrade of water infrastructure in 31 different regional systems. Beyond these baseline investments, the government could consider enhancing these works with resilience measures to protect assets against floods and liquefaction. Possible adaptation options include deeper foundations, drenching, and elevation of water system assets.

The capex for baseline water system investments totals $1.4 billion, but expenses increase by 48% when resilience improvements are added. If investments go ahead as planned, $1.3 billion will be required for infrastructure and a further $26 million for land acquisition. Premia for adaptation improvements heavily depend on infrastructure type and risk factor. Enhancing assets against flood risks incurs between 0% (storage tank reservoirs) and 10% (water treatment plants) in additional cost. Liquefaction resilience is more expensive, with premia ranging from 20% (impounding reservoirs and water treatment plants) to 55% (distribution pipes). Overall, these resilience measures increase the bill by $651 million.

Investments as planned are expected to generate total benefits in the region of $1.4 billion, but these gains can be more than doubled if assets are climate proofed. Baseline investments in water supply systems yield $1.1 billion in economic benefits and 48,580 additional jobs. The equivalent figures for the climate-proofed option are $1.6 billion and 72,510 jobs. Approximately 78% of total investment costs are recouped economically throughout the lifetime of the project for both options. This implies that the NPV is negative if only economic benefits are considered. The above figures do not include benefits from more stable and hygienic water supply to households. These gains amount to further $1.4 billion and are the same for both options under assessment. Resilience improvements further reduce expected future damages and resulting disruptions to the water supply, thereby increasing benefits by $1.5 billion.

Climate-proofing planned investments in the water system would be extremely beneficial for Lebanon as the resulting net benefits could be increased by $1.4 billion. Figure 23 summarises the results of the water system CBA. Both options have positive NPVs, but the climate-proofed scenario is clearly superior, with net benefits estimated to be more than twice as large compared to those generated by planned investments. 42% (baseline) or 35% (climate-proof) of total benefits are of economic nature, implying that 78% of total investment cost is recouped economically.

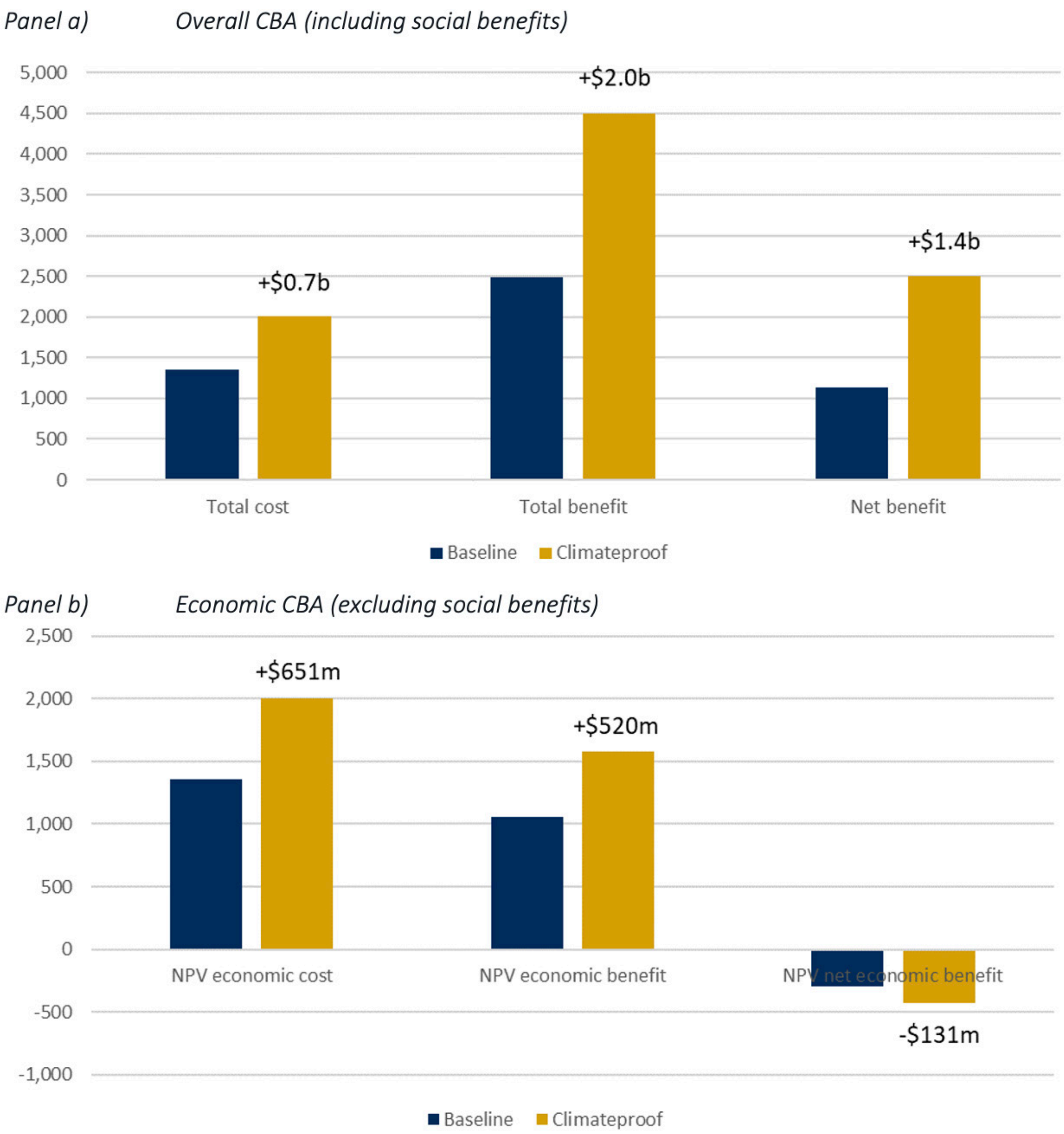


Figure 23 Discounted costs, discounted benefits, and NPV of water systems
Source: Vivid Economics

4.3.13 Water III: Irrigation schemes (adaptation)

Climate-proofing measure: Resilience measures to protect assets against floods and liquefaction

This sub-section evaluates the cost-return profile of irrigation investments in Lebanon and potential options to alleviate the impact of climate change on them. Beyond water supply systems, irrigation schemes are another core priority of the Lebanese government judging by the CIP's focus on investments in the sector. A total of 37 irrigation projects across the country are named in the document. Beyond these baseline investments, the government could consider enhancing these works with resilience measures to protect assets against floods and liquefaction. Possible adaptation options include floodgates, dry canals, and soil improvements.

The estimated upfront cost of irrigation investments totals $64 million, with a further $13 million added when resilience measures are implemented. Each suggested irrigation scheme costs on average $1.7 million. Improving flood resilience of assets incurs premia between 2% (distribution pipes) and 15% (canals). Enhancements against liquefaction risks are more costly, with additional upfront expenses ranging from 3% (canals) to 55% (distribution pipes). All in all, these adaptation measures amount to $13 million.

Planned irrigation schemes yield $120 million in benefits; adaptation measures can increase these gains by one-third. Based on a literature review, the implementation of baseline investments is estimated to generate $51 million in economic benefits, including 2,350 jobs. Resilience measures yield an additional $10 million and 470 employment opportunities. Between 51% (climate-proof) and 79% (baseline) of total investment costs are recouped economically throughout the lifetime of the project. This implies that the NPV is negative if only economic benefits are considered. Similar to the Assi dam, irrigation improvements benefit farmers and the whole agricultural supply chain; these gains have not yet been accounted for in the above figures. Both baseline and climate-proofed schemes are expected to yield $69 million in irrigation benefits. Additionally, resilience improvements reduce expected losses from climate disasters. This includes losses from asset damage, reduced agricultural yields, and supply chain effects. These adaptation benefits are estimated at $29 million.

Making irrigation systems more resilient to climate hazards leads to net benefits of $27 million on top of the NPV of baseline investments ($56 million). The CBA results are graphically displayed in Figure 24. Weighing up costs and benefits leads to a positive NPV for both alternative options, indicating that irrigation investments are preferable to a 'do-nothing' BAU approach. Resilience measure do pay off, however, as every $1 million spent in climate-proofing yields three times as much in benefits. 66% (baseline) or 38% (climate-proof) of total benefits are of economic nature, implying that 79% or 51%, respectively, of total investment cost is recouped economically.

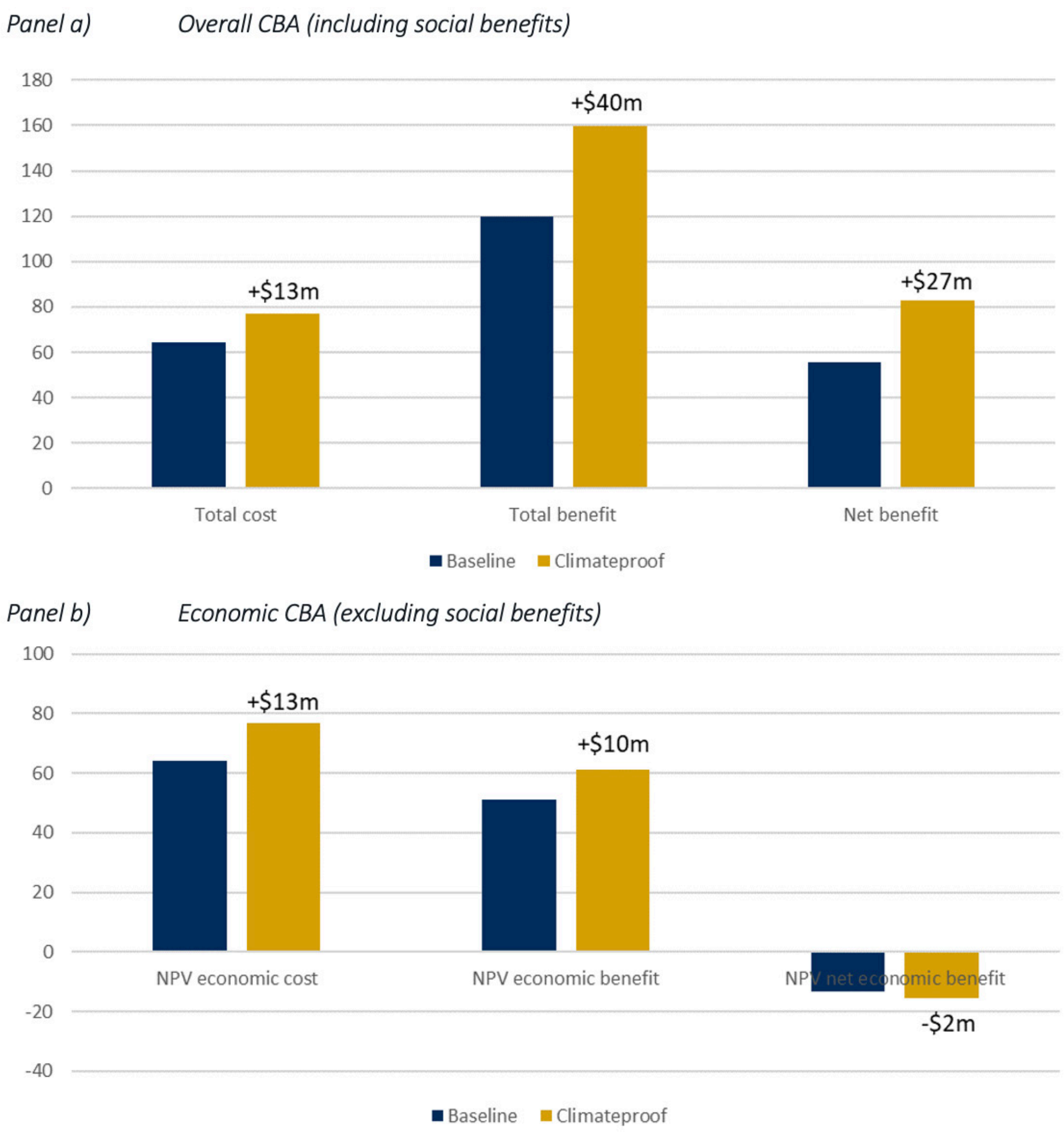


Figure 24 Discounted costs, discounted benefits, and NPV of irrigation schemes
Source: Vivid Economics

4.3.14 Water IV: Wastewater systems (adaptation)

Climate-proofing measure: Resilience measures to protect assets against floods and liquefaction

The following CBA assesses the costs and benefits of the planned wastewater investments, along with potential resilience measures. The Lebanese government is furthermore planning to invest in its wastewater systems. Priority projects (baseline) in this sector are a) the upgrade of Daoura and Ghadir wastewater treatment plants, b) the extension and upgrading of collection networks within Ghadir drainage basin, and c) the completion of missing networks and collectors within Tripoli service area. Decision-makers could also consider enhancing these infrastructure projects to be better able to withstand climate hazards, particularly floods and liquefaction. Potential adaptation measures include elevation of assets, barrier installation, and soil improvement or compaction.

Wastewater investments as planned cost almost half a billion USD, and resilience measures increase these upfront expenses by more than 50%. Baseline upfront expenditure amounts to $450 million, 54% of which is dedicated to the upgrade of wastewater treatment plants and the remainder to sewage networks. Adaptation measures are significantly cheaper to implement for the former: Flood and liquefaction resilience enhancements incur a premium of 5% and 20%, respectively, for wastewater treatment plants, adding $61 million to the bill. On the other hand, these measures cost 40% and 55% of baseline investment for sewage networks, amounting to a further $198 million.

The total benefits of wastewater projects as planned are $847 million; climate-proofing has the potential to almost double these gains. Baseline wastewater investments yield $360 million in GVA, as well as 16,550 jobs. Resilience measures add further $207 million and 9,510 jobs. Almost 80% of total investment costs are recouped economically throughout the lifetime of the project for both options. This implies that the NPV is negative if only economic benefits are considered. The social benefits of enlarging and improving wastewater collection for households brings further gains in the region of $487 million for both options. However, the climate-proof scenario further adds $595 million in benefits. These account for the avoided climate-related losses due to increased resilience, including reduced repair costs and avoided disruptions to wastewater collection (plus associated hygiene and health benefits).

As is discernible from Figure 25, climate-proofing wastewater investments is highly beneficial, with net benefits more than doubling if appropriate resilience measures are implemented. The NPV of both investment options is positive, indicating that they are sound and (one of them) should be undertaken. The baseline wastewater investment generates almost $0.4 billion in net benefits. The equivalent figure for the climate-proofed scenario is $0.9 billion – as this is much larger, adaptation options should be considered preferable by the Lebanese government. 42% (baseline) or 34% (climate-proof) of total benefits are of economic nature, implying that almost 80% of total investment cost is recouped economically.

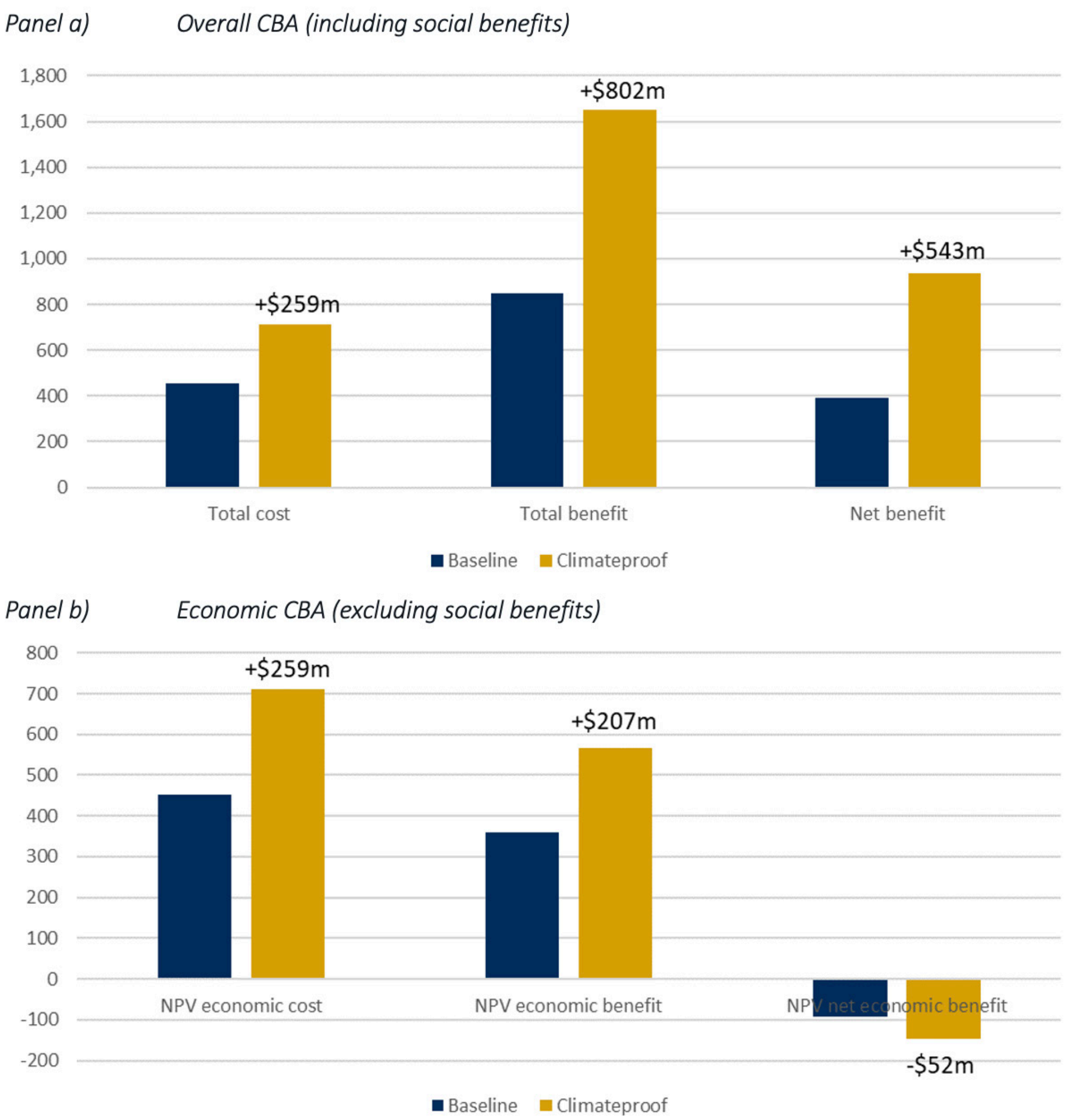


Figure 25 Discounted costs, discounted benefits, and NPV of wastewater systems
Source: Vivid Economics

ANNEX 1 – MITIGATION IMPACT METHODOLOGY

4.4 Project screening

Three national development plans were consulted to compile a long list of future actions and interventions in Lebanon. This included the Reprioritised Capital Investment Programme, Lebanon Economic Vision and 3-year development priorities of the Financial Recovery Plan.

Of the 417 projects in the original long list, an initial screening identified 239 with some potential for (positive or negative) impact on climate mitigation. Where the impacts of a project were unclear, due to a lack of information, the project was not considered as having mitigation impacts.

The remaining projects were then re-screened, to identify the projects which – according to expert judgement – were likely to have the largest direct impact on greenhouse gas emissions (relative to BAU). The projects were sorted into three categories: high impact (11 projects), medium impact (80 projects) and low impact (105 projects). Those in the high impact category were deemed likely to hold the greatest influence on national emissions totals leading up to 2030.

Where different projects shared many common characteristics, they were grouped together. Their likely cumulative impact was considered. In some cases, this resulted in low or medium impact projects being combined and re-evaluated as high impact. For example, 36 individual irrigation projects, each with a likely small impact on emissions, were grouped together and deemed to have potential for high cumulative impact. Otherwise, the impact of those in the lowest category was deemed either negligible or too indirect, so these projects were not considered in further analysis.

4.5 Project assessment

First, the projects with potential high impact were assessed in detail. Further information and data were requested for these projects, so that the quantification of impact could be based on the best available evidence. Following the high impact projects, those with potential for medium impact were investigated. Where there was sufficient data availability to support quantification, an estimate of impact was made. However, in the majority of cases, insufficient detail and data available for the project prevented an estimate from being made.

In total, the impacts of 16 projects (including combined projects) were quantified. 9 concern the energy sector (including 1 combined energy efficiency project), 3 the transport sector, 2 the industrial sector (including 1 combined industrial city infrastructure project) and 1 combined project for each of the irrigation and waste sectors.

Table 12 The list of projects where impact on mitigation was quantified, and the most significant, direct ways in which they affect GHG emissions

ID in mitigation analysis sheet	ID(s) in project database	Development plan	Name	Reason for GHG impact
EFF_comb	CIP_008	CIP	Combined projects to reduce technical and non-technical losses	Reducing energy wastage and fuel consumption
ELE_001	CIP_005	CIP	New Power Plants on Medium Term - IPP-1000MW	Replacing diesel fuelled private generation with natural gas source
ELE_002	CIP_006	CIP	Hydro power plants (331.5 MW)	Replacing diesel fuelled private generation with hydropower
ELE_003	CIP_007	CIP	Geothermal Plant of 1.3MW	Replacing diesel fuelled private generation with geothermal power
ELE_007	DVP_007	DVP	Floating Storage Regasification Units	Emissions from combustion of gas for regasification process and fugitive emissions from handling of natural gas
ELE_010	ADD_001	CIP	Zouk power plant (550 MW)	Replacing heavy fuel oil with natural gas
ELE_011	ADD_002	CIP	Jiyeh power plant (550 MW)	Replacing heavy fuel oil with natural gas
ELE_012	ADD_003	CIP	Hydro power plants (141.5 MW)	Replacing diesel fuelled private generation with hydropower
ELE_013	ADD_04	CIP	Additional geothermal (13.7 MW)	Replacing diesel fuelled private generation with geothermal power

ID in mitigation analysis sheet	ID(s) in project database	Development plan	Name	Reason for GHG impact
ENV_001, ENV_003, ENV_025	CIP_072, DVP_084 & DVP_165	CIP, DVP	Combined waste projects	Increased recovery of waste, lowering emissions from landfill but increasing emissions from energy and material recovery
IND_001	CIP_068	CIP	Infrastructure for the Tripoli Special Economic Zone	Emissions from fuel consumption due to energy consumption and vehicle journeys
IND_002, IND_003, IND_004	CIP_069, CIP_070, CIP_071	CIP	Infrastructure for the 3 industrial cities, Alkaa-Phase 2, Baalbek-Phase 2 and Terbol-Phase 2	Emissions from fuel consumption due to energy consumption and vehicle journeys
IRR_001 to IRR_036	CIP_073 to CIP_108	CIP	Irrigation schemes	Improved efficiency related to water and energy demand
TRA_001	CIP_001	CIP	Rehabilitation of classified Roads and Municipal Roads	Increase in distance driven per vehicle
TRA_002	CIP_002	CIP	Bus Rapid Transit System - Greater Beirut Public Transport Project	Avoided emissions from personal vehicles and efficiency of vehicle emission standards
TRA_003	CIP_003	CIP	Rehabilitation and Development of Beirut Rafic Hariri Airport - Phase 1	No direct effect on domestic aviation, increase in passenger vehicle use[19]

Source: Aether

[19] *While aircraft movements would increase under current proposals, their emissions would only count in the International Aviation category, which is excluded from national GHG inventories. The direct impact on domestic aviation, which is included in national GHG inventories, is assumed to be negligible.*

GHG emissions projections are calculated based on activity changes in relation to the BAU scenario. This can include changing the intensity, frequency or extent of a carbon emitting activity – as demonstrated in Figure 13.

For each project, the GHG impact described from the activity in question was quantified, relative to the BAU scenario constructed in the NDC[20]. The underlying assumptions of the NDC's BAU scenario were reviewed, to ensure that each project's impact assessment was entirely additional to BAU assumptions. Where activity data was not directly available, proxy data was used to characterise the change in activity levels. Estimations of activity changes, relative to BAU, were made for 2030, as this year is the focal point for the NDC targets.

A range of data sources was used to inform these calculations. These include:

- The development plans, where the projects were initially listed
- NDC reconstruction" – a document outlining the data and assumptions used to construct the NDC's BAU, unconditional and conditional emissions scenarios
- National GHG Inventory and Mitigation Analysis reports, per sector, as used in the Third National Communication
- Updated Policy Paper for the Electricity Sector (March 2019)
- Independent appraisals, impact assessments and studies of individual project proposals
- Research and statistical outputs, from academia, global organisations (the World Bank and UN ESCWA), local organisations (Beirut Airport) and private consultancies
- Input from Lebanon government officials

With the changes in activity estimated, emissions could be estimated in accordance with the 2006 Intergovernmental Panel on Climate Change Guidelines for National Greenhouse Gas Inventories. Lebanon-specific emission factors or implied emission factors (IEFs), based on national data sources, were used where possible. If the carbon intensity of an activity was altered by the implementation of the project, an IEF was calculated and used to reflect this. Otherwise, IPCC default factors were used.

The analysis calculated the difference in the emissions between the BAU conditions and as a result of project activities. There was insufficient information to determine whether actions should be included in an unconditional or conditional NDC scenario. Therefore, the impact of all projects was included in an "Action" scenario, for assessment against NDC targets.

[20] *This was based on the 2011 GHG inventory, as published in the Third National Communication, and runs from 2011 to 2030. This scenario is thought to be an overestimate of emissions, as its base year (2011) emissions are 11% higher than the 2011 emissions in the GHG inventory.*

As more information became available about the design of individual projects, the magnitude of their impact deviated from that expected after the initial screening (see chapter 4.4). For example, as the details of improvements planned to the irrigation network became available, it became clear that the estimated impact would be relatively small. As there was sufficient information available for a quantified estimate of impact, this was not excluded from the overall analysis. In other cases, the opposite effect was true – the estimated impact exceeded that expected after the initial screening.

4.6 Projects not quantified

It was not possible to quantify the impact of a number of projects which had been initially identified as "medium impact". This was due to a lack of relevant data or information to inform estimates:

- In some cases, it could not be determined how the project would affect activity, and therefore GHG emissions.
- In all cases, there was insufficient data available to characterise the change in activity, and therefore to quantify the change in emissions.

As the potential impact of other projects was judged to be greater, they were prioritised for further data/information requests. Projects with potential to increase emissions were also prioritised. Although this left a number of "medium impact" projects unquantified, they were included for consideration in creating recommendations for climate proofing (see chapter 2.3).

4.7 Key assumptions

In the absence of comprehensive information, many assumptions underlie the estimates of project impact. In general, assumptions concern the most appropriate emission factor to be used, or the extent of change in activity brought about by the project under consideration. Unless there is clear crossover between the direct effect of projects (as in the energy sector), the impact assessment of each project is conducted in isolation from any other projects. More detail is provided in the excel spreadsheet accompanying this report.

ANNEX 2 – ADAPTATION RISK IDENTIFICATION METHODOLOGY

4.8 Project screening

Out of an initial list of 417 projects compiled from the three development plans, 197 were deemed to have potential adaptation risks or impacts. These 197 projects were either themselves vulnerable to the effects of climate change and needed to be climate proofed, and/or caused potential vulnerabilities elsewhere.

Projects identified as potentially vulnerable spanned several sectors. Sectors included agriculture & irrigation, electricity, financial policies, social policies, tourism, transport, wastewater and water.

The interventions in pharmaceuticals, culture, diaspora, governance, trade and technology were excluded from this analysis due to the lack of available data. Most of these projects were classified to have a low to moderate impacts and were only indirectly affected by the analysis of the other relevant sectors (i.e., industry, tourism, etc.).

4.9 Quantification and categorisation of climate vulnerabilities

These screened projects could then be classified as physical projects and regulatory instruments, with a separate vulnerability scoring criteria for each. Regulatory instruments were assessed based on their comprehensiveness, amendment requirements and risks (see table 13). Physical projects were assessed based on their location, design, materials, maintenance, performance, and risks (see table 14). This methodology is based on the Asian Development Bank (ADB)'s Guidelines for climate proofing investment in the water sector: Water supply and sanitation, published in 2016.

Regulatory instruments were scored out of a maximum of 8 points, with any instrument scoring more than 5 being classified as highly vulnerable. Each of the questions presented in the checklist in Table 13 is scored with 0 (not likely), 1 (likely), or 2 (very likely). In the case of instruments, when all scores are added together, a total score of 0 indicates an instrument at no or low risk to climate change. A total score of 1-4 indicates an instrument at medium risk to climate change, provided that no individual question has received a score of 2. A score of 2 to any individual question indicates an instrument at high risk to climate change. Similarly, a total score of 5 or more indicates an instrument project at high risk to climate change. To be conservative, where there was no information for a particular descriptor, a value of 1 was awarded.

Table 13 Checklist for climate risk screening of regulatory instruments

Screening questions for regulatory instruments	
Vulnerability of the instrument	Can the instrument under consideration be vulnerable to risks arising from climate variability and change?
Mainstreaming of climate risks	Have climate change risks have been taken into consideration in its formulation?
Risks posed by the instrument	Can it lead to increased vulnerability, to maladaptation or, conversely, to missing important opportunities arising from climate change?
Potential increase of the resilience	For pre-existing instruments that are being revised, what amendments might be warranted in order to address climate risks and opportunities?

Source: CAOS

Physical projects were scored out of a maximum of 12 points, with any project scoring 7 or more being classified as highly vulnerable. Each of the questions presented in the checklist in Table 14 is scored with 0 (not likely), 1 (likely), or 2 (very likely). When all scores are added together, a total score of 0 indicates a project at no or low risk to climate change. A total score of 1-6 indicates a project at medium risk to climate change, provided that no individual question has received a score of 2. A score of 2 to any individual question indicates a project at high risk to climate change. Similarly, a total score of 7 or more indicates a project at high risk to climate change. To be conservative, where there was no information for a particular descriptor, a value of 1 was awarded.

Table 14 Checklist for climate risk screening of projects on the ground

Screening questions for physical projects	
Location and design of project	Is siting and/or routing of the project (or its components) likely to be affected by climate conditions, including extreme weather-related events such as droughts, storms and landslides?
	Would the project design (e.g., the clearance for bridges) need to consider any hydrometeorological parameters (e.g., sea-level, peak river flow, reliable water level, peak wind speed)?
Materials and Maintenance	Would weather, current and likely future climate conditions (e.g., prevailing humidity level, temperature contrast between hot summer days and cold winter days, exposure to wind), and humidity hydrometeorological parameters likely affect the selection of project inputs over the life of project outputs (e.g., construction material)?
	Would weather, current and likely future climate conditions, and related extreme events likely affect the maintenance (scheduling and cost) of project output(s)?
Performance of project outputs	Would weather/climate conditions and related extreme events likely affect the performance (e.g., annual power production) of project output(s) (e.g., hydropower generation facilities) throughout their design lifetime?
Risks posed to the project	Can the project lead to increased vulnerability, leading to maladaptation or to missing adaptation opportunities?

Source: CAOS

In order to score each project, biophysical indicators of vulnerabilities were assessed using maps. As the UNDP explains, "Some biophysical drivers of vulnerability include poor land management, deforestation, slash-and-burn agriculture, monoculture cropping, slope instability, and geophysical instabilities. Some ecosystems are also inherently more sensitive to changes, such as mountain ecosystems, while others are more exposed to climate changes and risks, such as low-lying coastal areas. The mapping can point out areas that are vulnerable through their geographic and socioeconomic characteristics."[21] When the specific location of the projects was not easily accessible, maps were created based on vulnerability assessments performed by ELARD and included in the Second National Communication to the UNFCCC, and the location of hydro power plants from the study Hydro Power Electricity in Lebanon, Ministry of Energy and Water, CEDRO (Country Energy Efficiency and Renewable Energy report 2013). The set of layers that was obtained as part of the adaptation analysis is summarised in Table 15.

[21] *See http://hdr.undp.org/en/countries/*

Table 15 Summary of layers

	Cazas	Elevation	Temperature	Precipitation	Evapotranspiration	Population	Ground water basins under stress	Forest areas	Agriculture areas	Industries	Erosion	Floods	Powerplants
Cazas with		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Bovin with	✓		✓	✓	✓		✓				✓	✓	
Ovin with	✓		✓	✓	✓		✓				✓	✓	
Ruche with	✓		✓	✓	✓		✓				✓	✓	
Olive with	✓		✓	✓	✓		✓				✓	✓	
Irri with	✓		✓	✓	✓		✓				✓	✓	
Fruit with	✓		✓	✓	✓		✓				✓	✓	
Cereals with	✓		✓	✓	✓		✓				✓	✓	
Power plants with	✓		✓	✓	✓		✓				✓	✓	

Source: CAOS

ANNEX 3 – VIVID'S INVESTMENT IMPACT MODEL (IIM)

Vivid's IIM proprietary tool has been applied to assess the economic impact of investments in various sectors in Lebanon throughout the supply chain. The model is based on a sectorial disaggregation of economic activity encompassing 26 sectors in the economy. We acquired an input-output table (I/O table) for Lebanon and sectorally specific wage data to carry out the analysis.

IIM estimates the economic impact of specific investments, based on the existing average technology observed in the I/O table. The table take the form of a square matrix, where outputs are calculated down the columns of the matrix, and inputs fed in via rows (that is column X gives the output of sector X, while row X gives the sectors that use sector X as an input). The I/O table provides a complete picture of the Lebanese economy, including economic activity in 26 sectors, household consumption, indirect tax payments and exports to imports from other countries. GVA or GDP effects can also be extracted using both the final demand approach or the factor payments approach.

From the I/O tables, we built a schematic representation of all transactions happening in the Lebanese economy, in the form of a Social Accounting Matrix (SAM). The SAM is easier to interpret as all economic agents are represented in a single matrix: firms, households, government and foreign sector. Yet, the relationships are the ones provided by the I/O tables, so both terms can be used interchangeably. The SAM displayed in Figure 26 reads as follows. The column header is the buyer while the row header the seller. Hence, activities (firms), buy inputs from domestic output and imported goods, which taken together amount to the total intermediate demand. Similarly, activities need inputs from the factors of production to produce (labour and capital). The columns of activities provide payments to factors accounting for these transactions.

Given the sectorial disaggregation, we have 26 sectors covered in imported commodities, as well as in domestic commodities. The 'activities' label covers the production units that produce domestic output across the 26 sectors considered. 'Regional household' is a construct that simplifies tracking of consumption and saving. In effect, the regional household is the unit making the saving decision at the aggregate level. It distributes income to the private household (who exclusively consumes it), determines government consumption and aggregate savings. There are two factors of production, labour and capital, that are combined with inputs by activities to produce domestic output. Factor incomes are paid into the regional household as can be seen in in Figure 26. The SAM also considers flows of income collected by sales taxes (VAT), production taxes (i.e. taxes on extractive industries), consumption by the government, demand for investment ('capital' column) and demand for exports by the rest of the world ('world' column).

The red square represents the set of relationships that IIM endogenizes. It is assumed that government spending, saving demand and exports demand from abroad are exogenous. In practical terms, when an exogenous increase in demand occurs (e.g. driven by FDI), IIM estimates the impacts on the endogenous variables only.

	Imported commodities	Domestic commodities	Activities	Factors	Regional household	Private household	Sales tax	Production tax	Government	Capital	World
Imported commodities			Intermediate inputs			Private demand			Government demand	Investment demand	
Domestic commodities			Intermediate inputs			Private demand			Government demand	Investment demand	Exports
Activities		Supply matrix									
Factors			Payments to factors								
Regional household				Factor incomes			Sales taxes	Production taxes			
Private household					tot priv						
Sales tax			Sales taxes			Sales taxes			Sales taxes	Sales taxes	Sales taxes
Production tax			Production taxes								
Government					Government income						
Capital					Savings						Trade balance
World	Imports										

Figure 26 Social accounting matrix derived from the I/O table
Source: Vivid Economics

The value chain relationships observed in the SAM allow to extract the technical coefficients in each of the considered sectors as shown in Figure 27. This is the ratio of inputs from each sector, factors and taxes to a given sector's output activity. For a given sector we then know how much imported and domestic inputs are required to scale up production, as well as how much labour and capital (the A matrix).

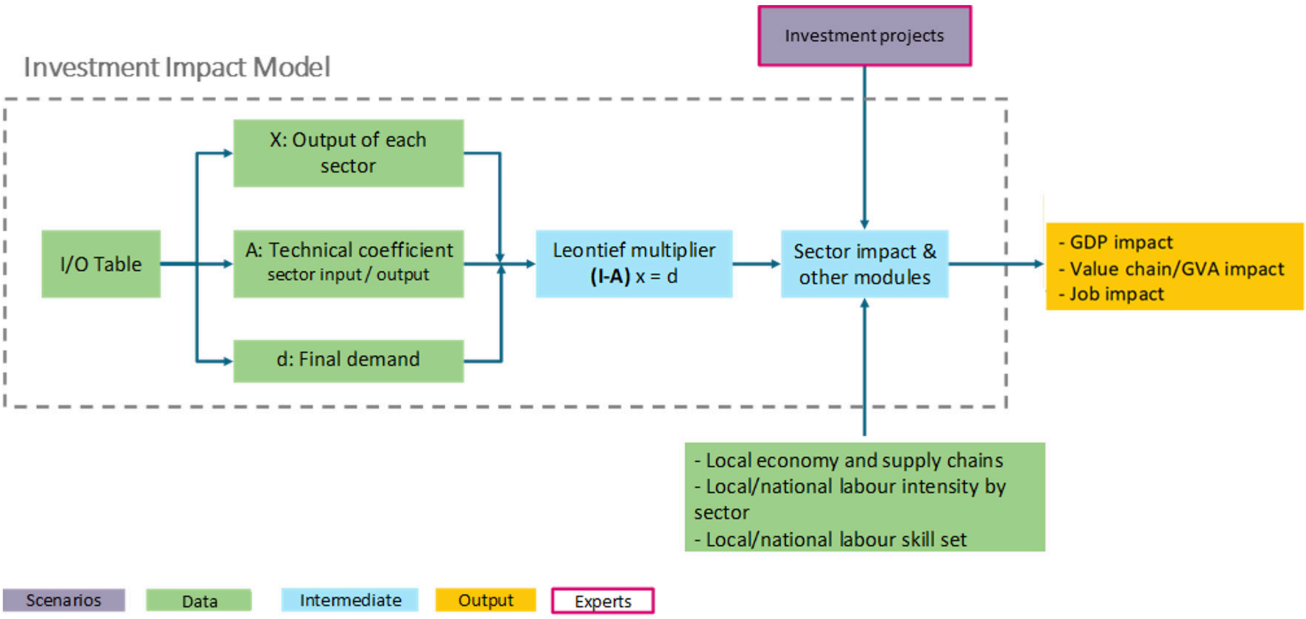


Figure 27 IIM blueprint
Source: Vivid Economics

We compute the Leontief multipliers from the technical coefficients[22]. These multipliers reveal the multiplier effect that each sector has in the economy, accounting for supply chain effects and induced effects based on existing consumption patterns, until all effects die out. In practice, after the shock there is an initial first order effect, where there is an increase in demand for the inputs required to produce the shock. The second order effect will in turn account for the inputs required to produce the very same inputs required in the first order effect. Moreover, the initial shock has also made payments to households in the form of salaries and profits. In the second order effect, these translate into higher consumption (based on the propensities to consume and consumption basket observed in I/O tables), thus adding additional demand to domestic production. Third and higher order effects follow the same logic until they die out. The Leontief coefficients account for all of them simultaneously. These coefficients can be interpreted as giving by how much total demand in the economy must increase to meet the increased production from the shock induced effects in each sector.

In technical terms, the I/O table gives the matrix of technical coefficients A, and the economy can be described as follows:

$$X = AX + d$$

where:

- X is the vector of total outputs in the economy. It includes domestic production, imports, consumption by private households, etc… for both intermediate and final demand,
- d the vector of final demand of output by all agents, and
- A the matrix of technical coefficients.

From this relationship, the Leontief coefficients can be found as the factor that will ensure a given vector of final demand is produced, given the technology. Modifying slightly the above equation we get:

$$X = (I - A)^{-1}d$$

where $L = (I - A)^{-1}$ is the matrix of Leontief coefficients, I being the identity matrix. It shows that to produce (or increase) final demand d, the economy needs to produce $(I - A)^{-1}d$, giving the total vector of impacts X in each sector.

The model implicitly makes three major assumptions:

Constant returns to scale as production is increased. In other words, the empirical technology observed the I/O tables is assumed to be the same at any level of production.

Slack capacity: there is enough underused capacity in the economy to scale up production without requiring additional investment.

Fixed prices: the model does not allow for price adjustments. This assumption is critical, as the model does not consider substitution effects between inputs, but rather assumes they will always be used in the same proportions. In the short run this is a reasonable assumption, yet in the longer run, prices will reflect the increase in demand through an upward movement. As a result, the estimated impact is likely to be slightly larger than the actual effect after prices react (upwards) and should be taken as an upper bound estimate in the long run.

[22] *Leontief, W. W. (1951) 'The structure of the American economy, 1919-1939: an empirical application of equilibrium analysis', Oxford University Press.*

After calculating the Leontief coefficients, we calibrate modules to assess distributional effects of the shock:

Gross Value Added: we transform the total impact on domestic production into GVA. The model nets out all domestic and imported inputs required to produce the total domestic impact. This is equivalent to adding factor payments together, that is labour and capital, and adjusting for indirect taxes. We split the effect between direct and indirect impact to assess the relative magnitudes of each one. Direct GVA impact is straightforward as it equals the total value of the shock minus the total value of inputs needed to produce it. Indirect impact is more delicate as it requires to exhaust all the higher-order effects (i.e. remove the value of the inputs of the inputs of the inputs, etc). This exercise also allows to isolate the total increase in domestic demand for intermediate inputs.

Employment: the Leontief coefficients allow to estimate the increase in total labour payments in each sector. We combine this output with the latest data on average salaries per sector from a desk-based research[23] to estimate the employment impact. Using the direct and indirect effects describe above, we also produce the job estimates using that level of disaggregation.

[23] *Average sectoral salaries in Lebanon were taken from LFHLCS, Arab Development Portal, Paylab, and Salary Explorer and adjusted for wage growth*

ANNEX 4 – ASSESSMENT OF FUNDING OPTIONS

Climate proofing measures are typically financed through a combination of domestic government financing, domestic investment (by private businesses or households) and overseas development aid (ODA). Vivid Economics' internal database of climate-proofing interventions contains examples of funded interventions from a range of countries and sectors. We have used expert judgement to match the climate-proofing measures suggested as part of this project against comparable measures in our internal database. The table below provides a description of how the matched measure in the database was funded.

However, the current financial and debt crises in Lebanon means that these funding approaches are not likely to be applicable. We have therefore elicited expert opinion on funding sources that are likely to be more viable under the current circumstances (see last column of Table 16 below).

Table 16 Funding sources for similar climate-proofing interventions

CBA	Climate proofing measure	Comparable project	Source of funding				Likely funding in Lebanon (based on expert opinion)
			Domestic - public	Domestic – investment	Domestic - households	ODA	
Farmer Soft Loans (AG1)	Investment in climate-smart agriculture (initiative to improve water productivity)	Climate smart agriculture	40%	40%	0%	20%	International adaptation financing grants.
Natural Gas (EN1)	Offset FSRU emissions by investing in domestic solar water heating subsidy programme	Off-grid investment programme for Ethiopia Universal Access by 2025	18%	0%	23%	60%	PPP contracts or international assistance from donors like the World Bank.
Transmission Masterplan (EN2)	Replace some of the baseline energy generation with renewable sources, including hydro, wind, solar, geothermal	Biogas Dissemination Scale-Up Project - NBPE+	15%	50%	25%	10%	Financed by DFIs and MDBs to private developers.

CBA	Climate proofing measure	Comparable project	Source of funding				Likely funding in Lebanon (based on expert opinion)
			Domestic - public	Domestic – investment	Domestic - households	ODA	
TSEZ (IN1)	Port Site energy generation from renewable sources; seawall at Port Site	Grid investment programme for Ethiopia Universal Access by 2025 & USAID Disaster Readiness	9%	0%	12%	80%	International mitigation and adaptation financing grants or loans.
LIZ (IN2)	LIZ energy demand is met through additional renewable sources	Grid investment programme for Ethiopia Universal Access by 2025	18%	0%	23%	60%	Financed by DFIs and MDBs to private developers.
BRT (TR1)	Diesel BRT and feeder buses are replaced by hybrid buses	Addis Ababa Sustainable Transport System	0%	0%	0%	100%	Additional costs could be added to PPP.
Roads (TR2)	Road construction incorporates drainage systems and uses permeable materials	Develop climate resilient roads in Addis Ababa	100%	0%	0%	0%	Additional costs can be added to contractor's costs into the tender documents and be covered from additional loans or be co-financed through adaptation funds or climate financing.

CBA	Climate proofing measure	Comparable project	Source of funding				Likely funding in Lebanon (based on expert opinion)
			Domestic - public	Domestic – investment	Domestic - households	ODA	
Airport (TR3)	Reduce airport's operational emissions by 90% compared to baseline; protective infrastructure against floods (incl seawall), raised floor levels	Addis Ababa Sustainable Transport System & USAID Disaster Readiness	0%	0%	0%	100%	Additional costs can be added to the PPP costs. Adaptation funds can be mobilized for the adaptation measures.
Assi Dam (WA1)	Carry out and implement Environmental and Social Management Plan (ESMP)	Develop sustainable public procurement plan/policy	0%	0%	0%	100%	Can be financed through a Technical Assistance support from an MDB or bilateral development agency.
Water Supply (WA2)	Resilience measures to protect assets against floods and liquefaction	Strengthen urban water supply	45%	5%	10%	40%	Climate adaptation financing.
Irrigation (WA3)	Resilience measures to protect assets against floods and liquefaction	Smallholder irrigation development	40%	40%	0%	20%	Climate adaptation financing.
Wastewater (WA4)	Resilience measures to protect assets against floods and liquefaction	Strengthen urban water supply	45%	5%	10%	40%	Climate adaptation financing.

CBA	Climate proofing measure	Comparable project	Source of funding				Likely funding in Lebanon (based on expert opinion)
			Domestic - public	Domestic – investment	Domestic - households	ODA	
Solid Waste (WS1)	Install methane capture and waste-to-energy facilities to recover remaining waste	Biogas Dissemination Scale-Up Project - NBPE+	15%	50%	25%	10%	Climate mitigation financing (for example through an international offset or crediting scheme).

Source: Vivid Economics

UNDP is the leading United Nations organization fighting to end the injustice of poverty, inequality, and climate change. Working with our broad network of experts and partners in 170 countries, we help nations to build integrated, lasting solutions for people and planet.