



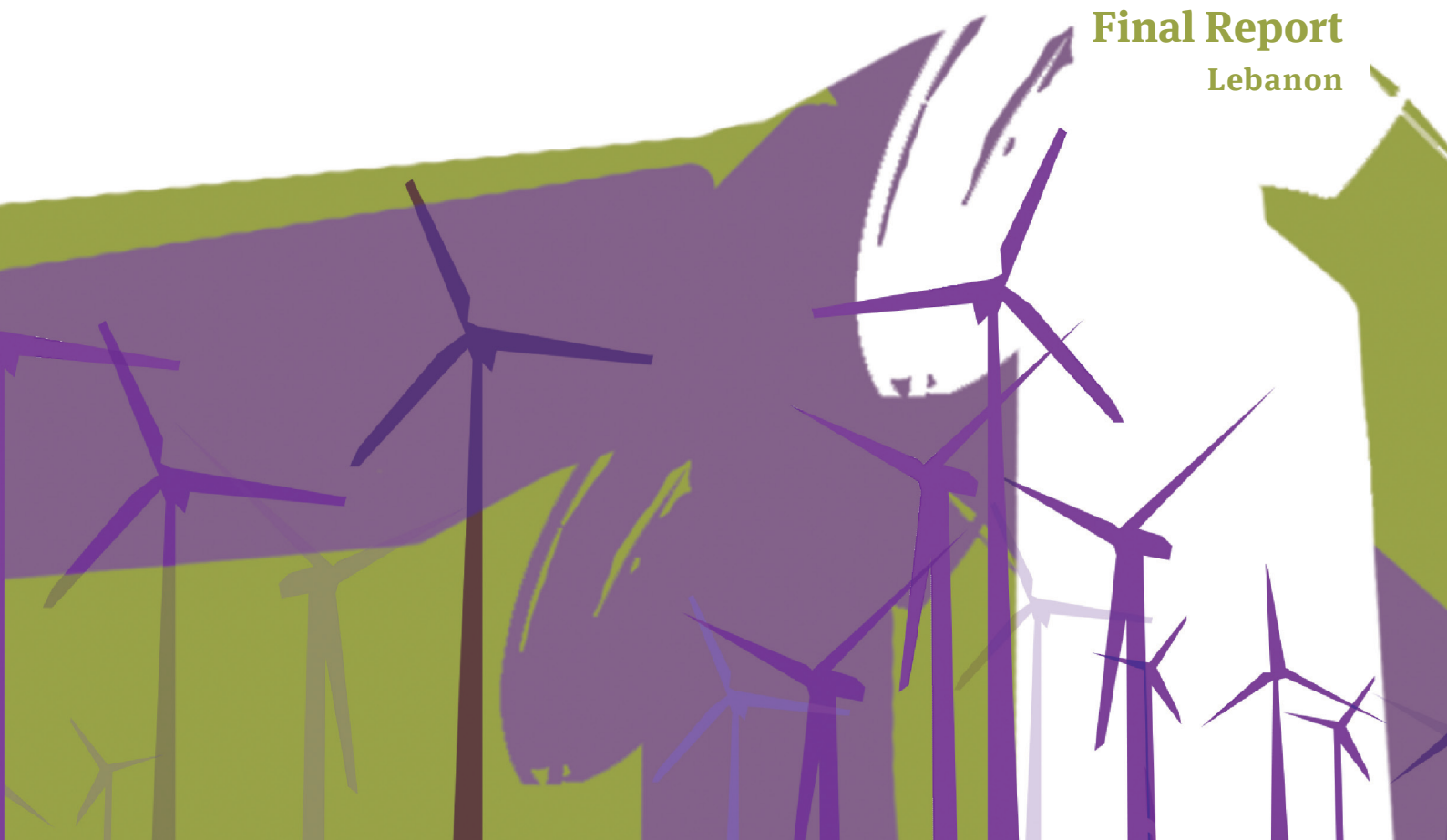
**Issam Fares Institute for Public Policy
and International Affairs**

Republic of Lebanon
Ministry of Environment

Issam Fares Institute for Public
Policy and International Affairs
American University of Beirut

The National Economic, Environment and Development Studies (NEEDS) for Climate Change Project

Final Report
Lebanon





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Final Report

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This Report is a result of gathering and analyzing scientific knowledge and a collective effort of Issam Fares Institute for Public Policy and International Affairs at the American University of Beirut and the Ministry of Environment. Although we have exerted our best efforts to present it accurately, the information contained in this brief is provided for reference only. The Issam Fares Institute for Public Policy and International Affairs at the American University of Beirut and the Ministry of Environment apologize for any inaccuracy or omission in connection with or resulting from the gathering of data. If the scientific knowledge on which this report is based changes with time, the Issam Fares Institute for Public Policy and International Affairs at the American University of Beirut and the Ministry of Environment are not responsible for such changes.

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1. Overview

Climate change has become an accepted reality. Its impacts have been recorded and documented throughout the world. The Centre for Research on the Epidemiology of Disasters (CRED) in Belgium has recorded 39 climatologic disasters¹ for Western Asia since 1969. Twelve disasters were recorded in the year 2000 alone. The majority of these disasters were droughts (16), followed by extreme temperatures (14), and wildfires (9). People's livelihood is mostly challenged by droughts, which have affected more than 51 million people in Western Asia in the last 40 years (CRED, 2009). The damage associated with all climatologic events is estimated at more than \$1.4 billion. Most of these costs occurred after 1990. Lebanon has only one entry in the CRED database, which is for 2007 under the wildfire category. Although the record indicates that no persons had been affected and no damage occurred, existing climate change models predict that the risk of climatologic disasters is increasing.

Estimates by Farajalla et al. (2009) indicate that Beirut's minimum temperature has increased by approximately 2.9oC over the last 125 years. Cline (2007) estimates for the Western Asian region that by the year 2100 precipitation and agricultural production will decrease by up to 15 and 25 percent, respectively. Preliminary results from Lebanon's Second National Communication (SNC) indicate that by 2036 the maximum temperature in some parts of Lebanon could increase by as much as 1.8oC while the minimum temperature would increase by 1.5oC. The same study estimates that precipitation countrywide would decrease by 15% to 20%. Initial findings of the greenhouse gases GHG inventory from the SNC indicate that Lebanon produces 18,307Gg of CO₂ equivalent. Nearly 78% of the emissions are related to the power generation energy industries accounting for 31% of the emissions; the transport sector for 22%; and manufacturing industries and construction for 15%. Nearly all of the CO₂ produced was from energy, transport, and industry. Agriculture accounted for 95% of the N₂O and solid waste for 87% of the CH₄. The country's Initial National Communication (INC) in 1999 estimated that CO₂ emissions and those of other GHG at different levels of control and these are shown in Table 1 below.

Table 1. Projections of Greenhouse Gases Emissions according to the INC

	1994 – 2004	2005 - 2040		
		4%	6%	8%
Carbon Dioxide	39644	741450	1200870	1952920
Carbon Monoxide	8.76	180	275	430
Nitrogen	117	2074	3343	5421
Sulfur	557	8459	14492	24362

¹ CRED will record an event as a disaster if there were ten or more fatalities, at least hundred people affected (for example, through the loss of the livelihood base or forced migration), a state of emergency is declared, or a call for international assistance issued.

Although these numbers are only estimates and different climate change models arrive at different conclusions, there is little doubt that Lebanon will be affected by climate change. The implications of climate change to a country like Lebanon are often seen in their potential to destabilize the country internally and externally. Externally, climate change may stir armed conflict over scarce water resources in the region (Brown and Crawford 2009). Internally, it may lead to an increase in rural-urban migration and social instability as livelihoods in rural communities deteriorate.

Lebanon has undertaken several steps in its efforts to combat climate change. It has ratified the United Nations Framework Convention on Climate Change (UNFCCC) in 1994 and acceded to the Kyoto Protocol in 2006. Lebanon has also been actively engaged in most of the climate change related meetings through the Ministry of Environment. It issued its first national communication in 1999 and the preparation of technology needs assessments report in 2002. In 2007, it commenced its second national communication.

Several efforts have been carried out by the government of Lebanon and by non-governmental organizations to study climate change and help develop adaptation and mitigation efforts and programs. For example, concerted efforts are underway to protect and preserve the country's forests. The ministry of agriculture (MoAg) and the ministry of environment (MoE) have various efforts aimed at reforestation, afforestation, and conservation and management of protected areas including key cedar forests such as the Ehden and Barouk forests. A study on the technology needs assessments for Lebanon identified the following five sectors as major contributors to greenhouse gas (GHG) emissions: (i) power, (ii) transport, (iii) industry, (iv) waste, and (v) building/construction.

The Intergovernmental Panel on Climate Change (IPCC) in its Fourth Assessment Report has emphasized that mitigation efforts in the next 15 to 20 years will have a large impact on opportunities to achieve lower stabilization levels and thus have the potential to minimize major climate change impacts (IPCC 2007).

This study focuses on two economic sectors that are directly impacted by climate change: (i) electric power sector and (ii) the agricultural sector. The former represents a sector in which mitigation measures are called for while the latter is a sector mainly geared for adaptation.

a. Mitigation: Electric Power Sector

As is common in most developing countries, electricity generation, transmission, and distribution in Lebanon is monopolized by a vertically-integrated public utility, Electricite du Liban (EDL). Electricity generation is limited to two types of power plants: thermal plants (2034 MW) and hydropower plants (273 MW), with a total capacity of 2307 MW (ALMEE 2006). Thermal power plants run on diesel oil, fuel oil, or natural gas depending on their turbine technology; steam turbines (1024 MW) use fuel oil, gas turbines (140 MW) use diesel oil, and combined cycle gas turbines (870 MW)² can either use diesel oil or natural gas. The shares of electric capacity by fuel type usually differ from the shares of electricity generated because not all generating units constantly operate at full capacity. Figures 1a and 1b show the percentages for 2006.

Figure 1a: Generating Capacity (2006)

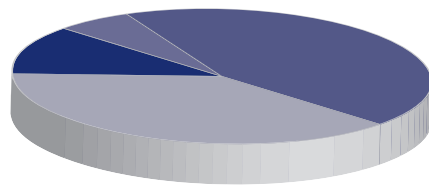
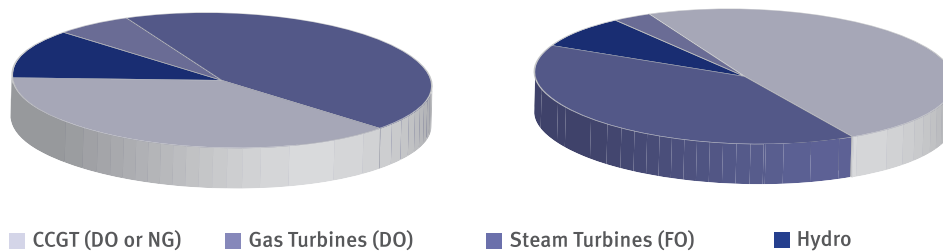


Figure 1b: Electricity Generation (2006)



Source: data from ALMEE, Wold Bank, and LCECP reports.

The choice of sector for our mitigation analysis is primarily based on the fact that the electric power sector is the largest single source of CO₂ emissions in Lebanon. In 2006, our base year³, total electricity produced was 9286 GWh and the resulting EDL emissions amounted to 6.39 MtCO₂, which represents approximately 48% of total CO₂ emissions (SNC, 2009). The power sector's contribution to CO₂ emissions has grown from 40% in 2000 to 48% in 2006 (SNC 2009). It should be noted here that according to the IPCC Guidelines, the national inventories of GHG define the power sector as being strictly limited to main activity producers, i.e. EDL, and thus under the sectoral approach the emissions from backup generators are not included under the "energy industries" category. Hence, in this study the main focus is on emissions resulting from electric power generation strictly by EDL.

The financial needs for appropriate climate change mitigation will be analyzed under two alternative scenarios; a reference or baseline scenario (BS) and a GHG emissions mitigation scenario (MS). On one hand, the BS reflects the business-as-usual state of affairs and thus describes the most likely evolution of the power sector in the absence of any climate-change related policies. Under this scenario, it is expected that EDL will expand its capacity between now and 2050, in step with the growth in electricity demand. The basic assumption being that the respective shares of each of the fuels used, namely fuel oil, diesel oil, and hydro will be preserved, i.e. fuel oil will continue to constitute 40% of all fuel used for electricity generation, diesel oil 52%, and hydro 8% (see Figure 1b).

² There are currently two combined-cycle power plants one at Beddawi and one at Zahrani, but only the one at Beddawi is currently physically connected to a gas pipeline. As of the end of 2008, Beddawi was still largely running on diesel oil; only one of the units was in the testing phase of burning natural gas instead.

³ Note that we chose to use 2006 as our base year because it is the most recent year for which a complete data set was available.

On the other hand, the mitigation scenario incorporates new specific policies aimed at reducing GHG emissions. In the alternative scenario, the MS, it is assumed that EDL completely satisfies the growth in electricity demand up to 2050 by the introduction and expansion of renewable energy systems. A viable option would be to install several wind power plants, wind being the most mature renewable energy technology. Such a project has been under serious consideration during the last couple of years and some preliminary steps are being taken such as the development of a wind atlas for Lebanon. Initial evidence from this initiative as well as evidence from the existing wind speed database reveals several regions having wind potential.

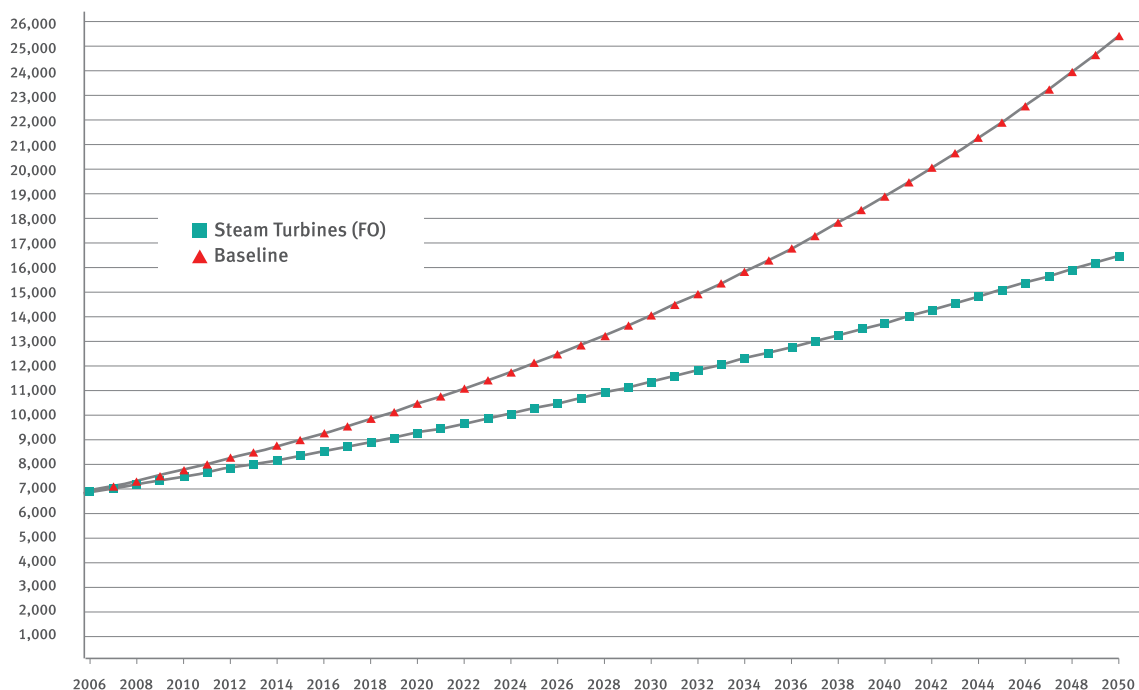
Under the MS, the basic assumption is that the respective shares of each of the fuels used, will change from 40% fuel oil, 52% diesel oil, and 8% hydro in 2006 to 26% fuel oil, 34% diesel oil, 5% hydro, and 35% wind in 2050. We have chosen the growth in the share of wind energy such that it agrees with the national plan to have 12% renewable energy in 2020.

The predominant rates of annual electricity demand growth in the literature vary between 3% and 5% (Schutz 1998, Chedid et al. 2001, Chedid and Ghajar 2004). For this analysis, a growth rate of 3% will be used which falls at the lower end of the range, and can hence be designated as a conservative growth estimate for Lebanon. Specific details on the modeling assumptions for both scenarios are provided in Appendix 2.

For this analysis, the Long range Energy Alternatives Planning System (LEAP) was used, which is an accounting and scenario-based modelling platform developed by the Stockholm Environment Institute (SEI, 2006). It is a user friendly, interactive, and widely-used software tool for energy policy analysis and climate change mitigation assessment. The United Nations recently announced that more than 85 countries have chosen to use LEAP as part of their commitment to report to the U.N. Framework Convention on Climate Change (LEAP 2009). Based on a bottom-up approach, the main concept is an end-use driven scenario analysis with a business-as-usual scenario and one or more alternative scenarios. It simulates alternative what-if energy futures along with environmental emissions under a range of user-defined assumptions. The built-in cost-benefit analysis tool can help rank and select between different energy-efficient scenarios.

As shown in Figure 2, under the business-as-usual scenario, the base year emissions of 6.39 MtCO₂ are expected to grow to 10.64 MtCO₂ by 2020, and 25.8 MtCO₂ by 2050. Under the mitigation scenario the measures taken can reduce emissions by 1.19 MtCO₂ in 2020, and 9 MtCO₂ in 2050, relative to the baseline case.

Figure 2. CO2 emissions from the electric power sector



b. Adaptation: Agriculture Sector

Agriculture contributes six to seven percent to GDP and employs 20-25 percent of the labor force (Ministry of Agriculture, 2004). Like many other countries, Lebanon’s policy makers have barely prioritized agricultural development (World Development Report 2008). Many years of falling food prices caused the illusion that food insecurity is a receding developmental problem. This illusion was considerably due to subsidies to the agricultural sector in industrialized countries, which led to an excess supply of basic food commodities being sold on world markets. The surge in bio-fuel, commodity speculation, and dollar depreciation, more frequent climate change events, however, have popped this illusion.

Agricultural underperformance in Lebanon is evidenced by the fact that relative to per capita income and after controlling for regional fixed effects, cereal yield (kg per hectare) and fertilizer consumption (100 grams of hectare per arable land) are below their predicted values (see Appendix 1- Item 1). Specifically, the results indicate that cereal yield and fertilizer consumption per ha are, respectively, 165 kg and 452 kg short of their predicted values.

Lebanon is in a vulnerable food security position. Successive governments since the early 1990s have allocated less than 3% of the national budget to the ministry of agriculture. Although the prevalence rate of undernourishment at 3% is very low, Lebanon’s food security bill is on the rise and with it the vulnerability to food price shocks. In light of future food price insecurities and climate change effects, the food import bill can be expected to increase and become more volatile. Within the Standard Industrial Trade Classification System (SITC) categories of agricultural raw materials, food, fuels, ores and metals, manufactures and services, Lebanon has only a positive trade balance in services. The biggest deficit position with 16% of GDP is

manufactures, followed by fuel with 7%. The combined deficit of agricultural raw materials (0.4 %) and food (5.6 %) is with 6 percent almost as high as the fuel trade deficit (see Table 2).

Table 2. Lebanon's Trade Share in Different Product Categories (2001-2005 Average, Percent of GDP)

Agricultural Raw Materials	Food	Fuel	Ores and Metals	Manufactures	Services
-0.42	-5.60	-7.17	-0.15	-18.48	10.33

Source: Authors' calculations from 2008 World Bank Development Indicator Database.

If agricultural productivity decreased by 25% between 2010 and the year 2100, a predictable event when holding everything else constant is that Lebanon's food import bill will increase. Other effects are likely, but much more difficult to forecast and simulate. These effects comprise social tensions, increase in horizontal and vertical inequality, migration from rural to urban centers, brain drain, unemployment, vulnerability to external macroeconomic shocks, pressure on social security systems, and a reduction of the tax base.

What are the various transmission mechanisms from lower agricultural productivity to socioeconomic cost? A rising food import bill must take into account that agricultural output shrinks while the population grows. Excess demand has to be met by food imports, whose price is likely to grow in real terms as climate change advances. Because rising food import bills hit poor people more than rich, poverty and inequality of economic opportunities and pressure for redistributive measures will increase.

In order to estimate the effects of climate change on Lebanon's food import bill and socioeconomic consequences, the following stylized scenario is simulated. The simulation starts in 2010 and ends in 2100. It is assumed that in 2010, Lebanon is a 30 billion dollar economy [in \$2005 Purchasing Power Parity (PPP)]. The size of the population is rounded to 4 million. Per capita income in 2010 is hence \$ 7,500. Agriculture contributes six percent to GDP or \$1.8 billion. If 20 percent of Lebanon's labor force of 1.5 million is employed in agriculture, average GDP per agricultural worker is \$6,000. Assuming that each agricultural worker supports three dependants, the average household income is \$1,500, which is close to the World Bank's upper poverty line of \$4 per day and person (Laithy et al. 2008). Average GDP per non-agricultural worker is \$23,500.

Total expenditures on agricultural products are \$ 3.6 billion, six percent or \$ 1.8 billion coming from agriculture's value added to GDP and another six percent or 1.8 billion coming from imports. Per capita food expenditures are thus \$900. Each person spends \$450 on agricultural products domestically produced and \$450 on imports. It is assumed that these expenditures reflect mostly basic food purchases.

The transitional dynamics to the year 2100 are defined by the following assumptions. The Lebanese economy grows at three and its population at one percent. Due to climate change, basic staples are subject to a two-percent annual increase of real prices. This scenario is then compared with an alternative one, which assumes that agricultural productivity remains unchanged. With this exercise, we want to answer the question: By how much does climate change increase the food import bill? Appendix 1- Item 2 describes the methodology underlying our system dynamic framework.

The results can be summarized as follows:

- The economic effect of climate change on Lebanon’s food import bill is economically irrelevant.
- An increase of Lebanon’s food import bill is almost exclusively the result of population growth and exogenous food price inflation.

Table 3 summarizes the predicted variables for the various model parameters for the year 2020 and 2050.

Table 3. Simulation Results – Climate Change and Food Security in Lebanon

	Year 2020 Snapshot			Year 2050 Snapshot		
	Without Climate Change	With Climate Change	Climate Change Effect	Without Climate Change	With Climate Change	Climate Change Effect
GDP	\$40.3 bill.	\$40.3 bill.	0	\$97.9 bill.	\$97.9 bill.	0
Population	4.4 mill.	4.4 mill.	0	6.0 mill.	6.0 mill.	0
GDP per capita	\$9,125	\$9,125	0	\$16,432	\$16,432	0
Per capita food expenditure bill total	\$1,097	\$1,097	0	\$1,987	\$1,987	0
Agriculture value added to GDP	\$1.8 bill.	\$1.74 bill.	-\$56.6 mill.	\$1.8 bill.	\$1.59 bill.	-210 mill.
Per capita food expenditure bill domestic	\$407	\$394	-\$13	\$302	\$266	-\$36
Per capita food expenditure bill import	\$690	\$703	+\$13	\$1,685	\$1,721	+\$36
Total food expenditures as a percentage of GDP	12%	12%	0	12%	12%	0
Total food import bill as a percentage of GDP	7.6%	7.7%	0.1	10.3%	10.5%	0.2

Appendix 1- Item 3 summarizes the simulations results visually in more detail.

The Cost of Climate Change to Rural Society

Available data suggests that families of agricultural workers are statistically just slightly above the upper poverty line of \$4 per person and day, assuming that every agricultural worker supports three dependants. With the per capita value added of agriculture to GDP to decrease due to climate change and population growth, the question is again which factor contributes how much to the decrease of farming communities’ livelihood. Specifically, we would like to know how many agricultural workers will fall below the poverty line of \$6,000 (\$2005 PPP - purchasing power parity in 2005 USD value) per year, by how much, and how big the social safety net will have to be in order to accommodate vulnerable families.

In order to answer these questions, the following assumptions were simulated:

- In 2010, the agricultural labor force is 300,000; on average, every worker supports three dependants.
- The agricultural labor force is expected to grow by an annual rate of one percent (given that current general population growth rate is around 0.7%).
- A GDP per agricultural worker of below \$6,000 is considered vulnerable in the sense that incomes prevent households from meeting all their basic needs.
- A sustainable agricultural labor force is defined as

$$\text{Sust. Agricult. Labor Force} = \frac{\text{Agriculture Value Added to GDP (\$2005PPP)}}{6,000 (\$2005 \text{ PPP})}$$

- The vulnerable agricultural population is thus

$$\text{Vulnerable Agricult. Pop.} = \text{Agricult. Pop.} - \text{Sust. Agric. Pop.}$$

The answers to this question are again developed using a system-dynamic simulation model (see Appendix 1- Item 4). The simulation results illustrate that Lebanon's farming communities are vulnerable, but that their vulnerability is predominantly the result of population growth in the absence of commercialized farming. The climate change effect is negligible. Table 4 summarizes the simulation results for the year 2020 and 2050. Appendix 1- Item 5 gives a detailed graphical summary of the "with climate change" and "without climate change" simulation runs.

Table 4. Simulation Results – Climate Change and Food Security in Lebanon

	Year 2020 Snapshot			Year 2050 Snapshot		
	Without Climate Change	With Climate Change	Climate Change Effect	Without Climate Change	With Climate Change	Climate Change Effect
Agricultural Labor Force	331,387	331,387	0	446,659	446,659	0
Value added per agricultural worker	\$5,432	\$5,261	-\$171	\$4,030	\$3,546	-\$484
Supported agricultural labor force	300,000	290,562	-9,438	300,000	263,993	-36,007
Vulnerable agricultural labor force	31,387	40,824	9,438	146,659	182,666	36,007
Subsistence income gap	\$17.8 mill.	\$30.2 mill.	\$12.4 mill.	\$288.9 mill.	\$448.2 mill.	\$159.3 mill.
Vulnerable agricultural labor force as percent of total	9.5%	12.3%	2.8%	32.8%	40.9%	8.1%

The results may be summarized as follows:

- Farming communities are vulnerable mostly because of declining value added to GDP per agricultural worker. By 2020, agricultural output per worker will be \$5,432 and by 2050 to \$4,030. From the 2010 value of \$6,000, these are declines by \$560 and \$1,970, respectively. Climate change would decrease agricultural output per worker in 2020 by another \$171 and by 2050 by another \$484. The contribution of climate change to output per agricultural labor force participant (whether employed or not) is thus much less than the one from the population growth rate.
- Lebanon's agriculture supports 300,000 agricultural workers in 2010, the starting date of the simulation. Of course, without climate change, Lebanon's 2010 agricultural profile keeps on supporting 300,000 workers. The climate change induced reduction of agricultural productivity then accounts for 9,438 jobs by 2020 and 36,007 jobs by 2050. Alternatively, because of climate change 2.8 percent of the agricultural labor force will become vulnerable by 2020, and eight percent by 2050.
- If one takes the difference between agricultural GDP per worker in the labor force and \$6,000, which is necessary to prevent vulnerabilities in farming communities, population growth will cause a subsistence income gap of \$17.8 million by 2020. Climate change will add another \$12.4 million. By the year 2050, population growth will account for a subsistence income gap of \$289 million while climate change will account for another \$159 million.
- Lastly, in 2020, 12.3 percent of the agricultural labor force will be vulnerable, 2.8 percent of which can be attributed to climate change. In 2050, 40.9 percent of farming communities will be vulnerable, 8.1 percent of which climate change accounts for.

2. Key Findings on costs of implementing priority mitigation and adaptation measures

The following sections describe costs of various measures in both targeted sectors in adaptation and mitigation.

a. Cost of implementing priority mitigation measures

Under the BS, the fuel mix remains the same up to the year 2050; fuel oil, diesel oil, and hydro represent 40%, 52%, and 8% respectively of the total GWh produced. Figure 3 presents the breakdown by fuel and by year of the total electricity generated. Under this scenario, the CO₂ emissions from the electricity sector will grow from 7 MtCO₂ in 2006 to 10.6 MtCO₂ by 2020, and 25.8 MtCO₂ by 2050.

Figure 3. Breakdown of electricity generation by fuel (BS)

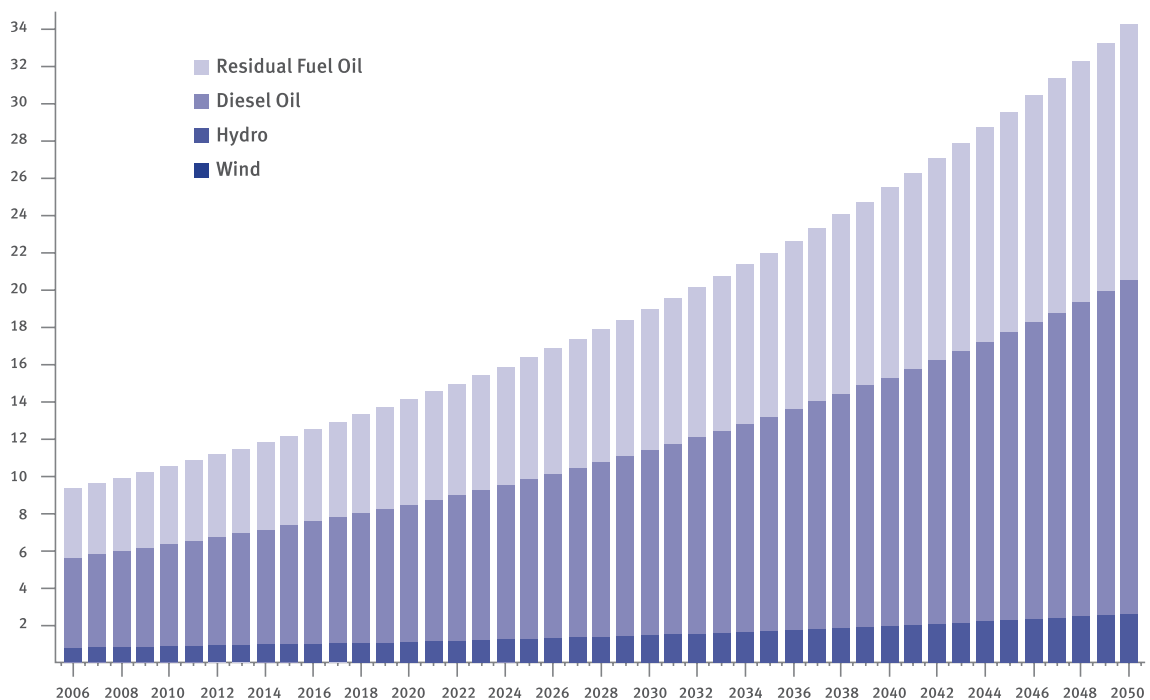
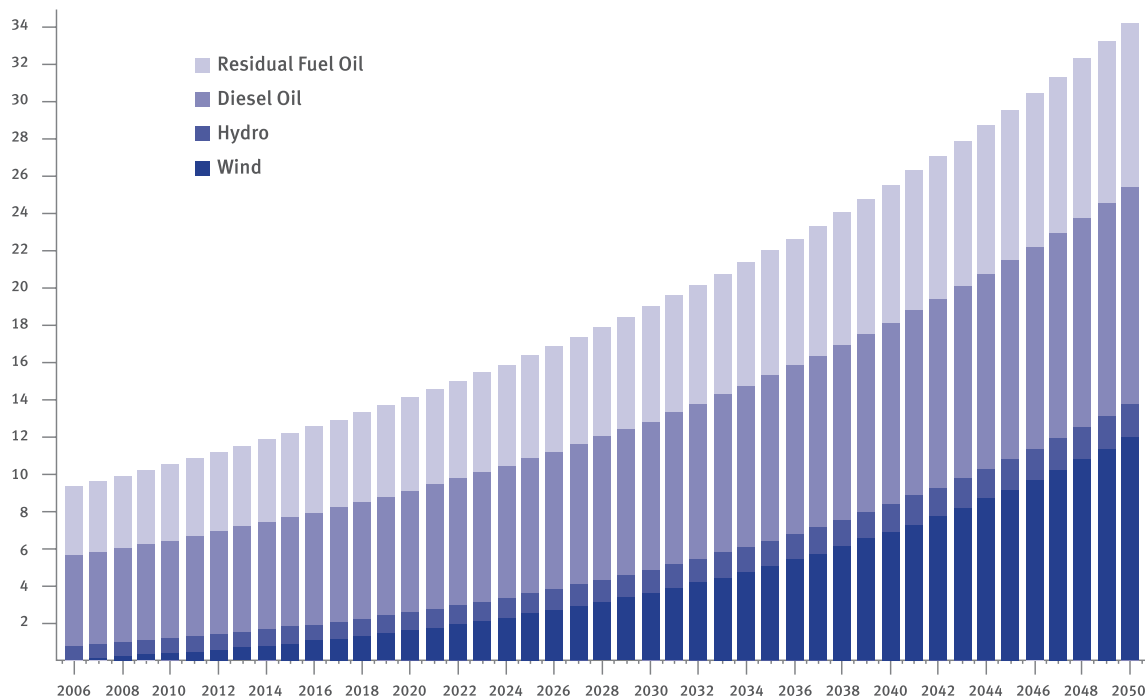


Figure 4. Breakdown of electricity generation by fuel (MS)



Under the MS, the fuel mix changes such that wind provides 35% of the electricity generated in 2050 and the remaining fuels' shares are 26%, 34%, and 5% for fuel oil, diesel oil, and hydro respectively. As noted before, we have chosen the growth in the share of wind energy such that it agrees with the national plan to have 12% renewable energy in 2020. Figure 4 presents the breakdown by fuel and by year of the total electricity generated. Under this scenario, the CO₂ emissions from the electricity sector will grow from 7 MtCO₂ in 2006 to 9.5 MtCO₂ in 2020, and 16.7 MtCO₂ in 2050, which is 9 MtCO₂ lower than the BS.

The net present value of investments needed until 2030 (2050) are \$1.11 (\$1.63) billion and \$1.41 (\$2.07) billion for the baseline and the mitigation scenarios respectively. However, these costs for the mitigation scenario are more than offset by the savings achieved in fuel costs. These savings are in the order of \$2.9 billion between 2007 and 2050.

A cost-benefit analysis reveals that the mitigation scenario has a negative net present value of 2,436 million USD (in 2007 dollars) compared to the baseline scenario. Hence, the analyzed mitigation policy can be considered to be a no regrets policy as long as the assumptions underlying the model hold (see Appendix 2). The mitigation benefit is thus computed to be \$270.6/tCO₂. This is a very interesting finding confirming the attractiveness of wind power in the short term and more so in the long term; the calculations show that the extra capital costs for wind capacity versus traditional steam turbines is outweighed by the fuel costs, even in year 1. This result has clear policy implications and is of potential use for any future government legislation regarding greenhouse gas mitigation in the power sector. The MS assumes a substantial shift in the electricity generation mix in 2030, which is expected to pose several challenges that will be discussed in the next sections.

b. Cost of implementing priority adaptation measures

Despite the fact that climate change poses a global threat, little attention is given to the possibility that many countries may actually benefit from it either directly or indirectly. Some countries may benefit directly from climate change through better agricultural conditions or indirectly through making meaningful contributions to climate change adaptation and mitigation research. Lebanon has the potential to become part of the latter. Although Lebanon will be hit hard by climate change in terms of decreased precipitation, greater water scarcity, rising temperatures, and a reduction of the livelihoods for traditional farming communities, Lebanon has the advantage that its agricultural base is too small for climate change to have a meaningful impact on economic activity and food security. Simulations conducted for this study clearly indicate that even if climate change had been unheard of, food insecurity will be mainly of a Malthusian nature, meaning that population growth is the biggest challenge to food security. Other food security threats are likely to come from food price shocks on international markets. Lebanon's agricultural sector is mainly traditional small holder farming, with some economically viable niche productions, such as the wine industry, poultry, etc. Even commercialized farming would be unlikely to impact positively food security, mostly because water constraints will build up under rising temperatures. Lebanon's vegetative diversity with coastal, inland, and mountainous terrains in combination with climate change, however, may give it an advantage in developing climate change adaptation research hubs. Developing such industries is largely cost neutral and has the potential to become a high tech sector for Lebanon.

Lebanon's agricultural sector is already too small in the first place for climate change to have a substantial impact on food security or the livelihood of farming communities. Although agriculture is a source of social costs, these costs are predominantly triggered by population growth or an increased vulnerability to exogenous shocks (which in turn may be the result of climate change). The question now is: What is a good adaptation strategy if climate change is physically present but does not cause major economic disruptions? We argue that in the Lebanese context, climate change can give rise to the emergence of a comparative advantage in the development of an agricultural climate change adaptation research hub. The advantages of Lebanon are that agricultural climate change adaptation can be studied in diverse micro-climatic settings. Lebanon has coastal, elevated, and inland agriculture. There are several universities with a good track record in agricultural research. Moreover, Lebanon has a well educated labor force, from which biotechnology industries or start-up firms could benefit from.

How big is the potential capacity of a climate change adaptation research industry in Lebanon? The best reference model to estimate its development potential is the biotechnology sector. Detailed data about the global market size, sales, employment, and industry outlook is scarce and inferences therefore difficult. Beuzekom and Arundel (2009), is a good starting point though. Table 5 summarizes some numbers from their report, which although for a selected OECD countries only, may be used for some rough insights into the development potential of a climate change adaptation research industry.

Table 5. Biotechnology Indicators for Selected OECD Countries

Country	Year	Tot. Emp.	Firms	Sales (mill.)	GDP (bill.)		Pop (mill.)
						y cap	
					(\$2000 PPP)		
Austria	2006	10,161	77	2,569	215	25,940	8.28
Belgium	2006	17,208	136	7,596	257	24,405	10.54
Czech Rep.	2007	9,329	82	n/a	72	7,056	10.27
Finland	2007	34,510	141	n/a	146	27,660	5.27
France	2006	237,244	824	n/a	1,468	23,970	61.26
Ireland	2005	1,151	100	n/a	131	30,736	4.27
Italy	2006	43,021	146	n/a	1,157	19,663	58.84
Korea	2006	130,767	627	n/a	671	13,865	48.42
Portugal	2006	5,258	52	4,751	119	11,196	10.59
Spain	2006	65,118	467	n/a	707	16,025	44.12
USA	2006	1,360,000	3,301	474,968	11,315	37,791	299.40

Sources: Beuzekom v. and Arundel, A. (2009), p. 46 and 54, WDI (2008).

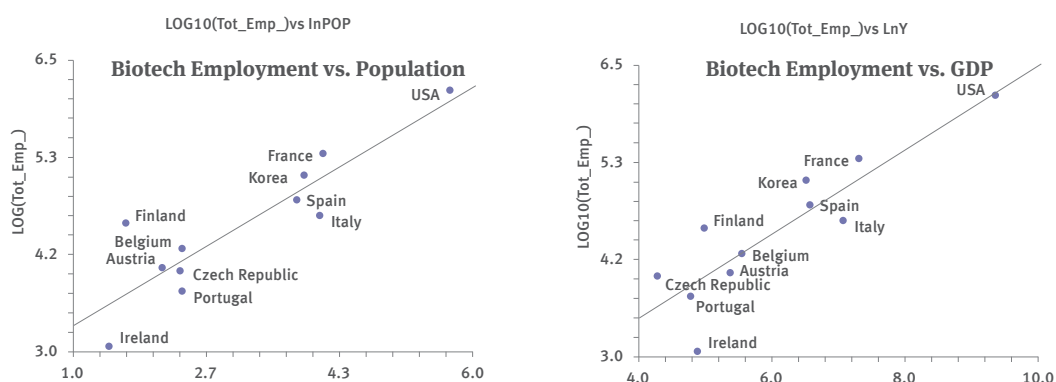
It seems to be plausible to assume that the size of the biotechnology sector within a given country depends on the size of the population and the size of the market. Proxying the size of the biotechnology sector by total employment and size of the market by GDP, the following two scatter plots illustrate that both size of the population and GDP are indeed good predictors of total biotechnology employment.

Using the following equation

$$\text{Biotech Employment}_i = \beta_0 + \beta_1 \text{Population}_i + \beta_2 \text{GDP}_i + \varepsilon_i$$

will allow for a very simple estimation of Lebanon's absorption potential of a climate change adaptation research industry. The estimation results are illustrated in Figure 5 and summarized in Appendix 1- Item 6.

Figure 5. Biotechnology Employment vs. Population and GDP. Source: Authors' illustration using data of Table 5.



Using the regression results of Appendix 6 and matching it with Lebanon's current population of roughly 4 million and a GDP (in \$2000 PPP) of 20 billion for 2006, Lebanon would have the potential to develop a biotechnology sector that employs 1,832 people (Biotech Employment = $\text{EXP}[4.89+0.79(\ln 4)+0.51(\ln 20)]$; see Appendix 1- Item 6). This estimate is very similar to that of Ireland which has a population of 4.27 million and employs 1,511 people in biotech. Table 5 suggests moreover that the average sales per biotechnology worker are around \$350,000 (\$2000 PPP). Today's potential value added in Lebanon of a biotechnology industry is therefore, conservatively estimated, \$ 641 million (\$2000 PPP). Assuming an annual three percent growth rate of GDP and a population growth rate of one percent, then Lebanon's potential for a biotechnology industry could, holding everything else constant, grow into an industry worth \$806 million and employ some 2,300 experts by 2020. By 2050, biotechnology could create a value added of almost \$1.6 billion and create 4,400 jobs.

The value added potential of developing a biotechnology industry can be moreover put into relationship to the 2050 food import bill due to climate change (Table 2) and the 2050 subsistence income gap due to climate change (Table 3). This is done in the following Table 6, which shows that developing a climate change adaptation research center in Lebanon would far outweigh the social costs from climate change.

Table 6. Value Added of Biotechnology vs. Social Cost from Climate Change

	2020 (million)	2050 (million)
Food Import Bill due to Climate Change*	~ 40.3*	~ 196*
Climate change induced subsistence income gap among agricultural workers*	~12.4*	~159.3*
Total climate change induced social costs*	~57.2*	~355.3*
Value added potential of a Lebanese Biotechnology Sector+	~806	~1,568

* \$2005 PPP + \$2000 PPP. Source: Authors' estimates.

3. Key Findings on Financial and Policy instruments for addressing climate change

Implementing the discussed measures requires development of enabling financial and policy instruments. The sections below list and briefly describe some of these instruments for both mitigation and adaptation.

a. Financial Instruments

1. Mitigation

Instruments described herein focus on two financial aspects related to renewable wind energy: economic efficiency and business profitability.

Economic efficiency

- Relate variability of economic growth with environmental degradation: economic externalities are inherent to economic growth. Environment related externalities can be assessed and value ranked in terms of correlation with growth.
- Relate potential benefits of energy use efficiency to new energy sources: Application as well storage efficiencies of wind energy use represent business as well as consumer incentives for shifting to alternate new sources
- Assess start up costs of wind powered building codes: Construction costs per unit or per area of finished space show economic value as well start up and hook up installations costs for new as well as for already existing buildings.
- Participate in regional fund for wind energy technology: Multi country regional strategy for wind energy production may result in economies of scale as well as economies of scope.
- Start institutional structure supporting integration of new practices in existing economic modes. Urban zoning and semi private institutions accommodate transfer of new technology into existing energy consumption practices.
- Organize financial instruments at local, national and international levels: Financial schedules for supporting development of wind stations are made available through financial institutions, domestic, regional and global.

Business profitability

- Establish initial investment costs of wind farming: Calculations of capital investments for joints stations, and start up costs for individual units allow clear guidelines for break even parameters as well as amortization schedules for long term operation.
- Provide sensitivity analysis on a range of scenarios based on cost benefit ratios: Unfavorable conditions are compared with favorable scenarios to provide sensitivity of financial ratios for a range of market and reality conditions. Back up planning is possible in order to alleviate adverse circumstances. Also favorable financial scenarios allow for pursuit of desirable outcomes.
- Assess business rates of return and net present values on micro wind production units: Wind energy production may be soon and fast entirely self supported. Business profitability considerations will show survival and self sufficiency in addition to overall economic gains.
- Assess annuity costs of operation and maintenance of wind energy production: Business costs and operating budgets demonstrate feasibility of wind energy production on an annual budgeting basis.

Other financial instruments for the energy sector that could be utilized are:

- Internalize market economies for off-grid electric generators: illegal and private electric generators produce the most expensive form of power. After adding social cost of pollution, noise, and abuse of existing grids, such generators will lose all incentive for their users.
- Assess third party spill over costs for pollution control: Adding costs of pollution, and loss of ecological quality of life, make actual user rather than all of society pay for the actual costs of production.
- Motivate institutional upgrading with financial incentives: Differential rates of productions and consumption fees support household use as well as industrial survivability of business users.
- Explore privatization options of the energy sector in Lebanon: EDL monster operational deficits can be addressed on the grounds of organizational restructuring

2. Adaptation

Financial instruments that will aid in turning Lebanon into a research hub on adaptation are simple and somewhat limited. The key element is to increase the government's budget allocation to research. This should go hand-in-hand with government incentives aimed at facilitating the launching and survivability of start-ups. An important component in this would be:

- Substantially reduce or eliminate import tariffs on equipment required in the biotech industry
- Provide tax incentives for biotech start-ups
- Provide widespread access to micro credit financing

Other agribusiness developments may help in providing the agricultural labor force with an alternative employment or within same sector employment. Niche agriculture is such a development whereby certain cultural practices such as growing grapes for wine and winemaking, saffron cultivation, certain fruit tree production, seed production etc. could benefit from some of the following financial instruments:

- Channel agricultural public expenditure into research and extension
- Enforce market economies for efficient utility of agriculture
- Empower cooperatives for business survival

b. Policy Instruments

1. Mitigation

Policy elements for implementing the renewable wind energy option may be addressed at two scales: national scale or macro aggregation and a finer business scale or micro aggregation

Macro aggregation: at country level

- Promote private public partnerships at national level. Mixed business arrangements provide a balance between economic efficiency and social equity
- Develop positive synergy between environment and economy: ecological quality translates into economic value that is reflected in consumer demand for environmental friendliness
- Provide international negotiation framework for bilateral and/or multilateral cooperation: Recipient and financial development partners can achieve more effective cooperation when grants are negotiated based on agreed criteria.

- Disseminate information at user level for public awareness on new energy technologies: Transfer information on new wind energy from research and development mode to consumer advertising and marketing campaign.
- Centralize formatting of data collection and storage on wind technology applications: Planning and industrial guidance are enhanced when information is made available in a directly applicable useful mode

Micro scoping: at business level

- Establish specialized research entity in wind energy production: business innovation translates technical research into economic value.
- Identify energy innovation funding from financial development partners by energy source. Specific donor agenda is matched best when recipient needs are specific, and well defined
- Start balance scorecard for strategic planning of energy mitigation: strategic management implies verifying that performance is coherent with pre set objectives. The score card is balanced through an exhaustive process at the business level.
- Implement logical framework for wind energy management: Financial development partners can verify effectiveness of grants and support programs by pursuing logical framework of organizational management.
- Reach critical mass of expertise: Available know-how becomes consumer friendly when enough expertise is translated into daily mechanisms of knowledge transfer.
- Establish competent authorities: Both public as well as private agencies of competence contribute to total quality management.
- Train staff: Human resources remain key factor of success in implementation of new technology.

Other policy instruments available for the energy sector in general are:

- Secure reliability of data on energy consumption by user category: Uniform formatting of data allows user access as well long term planning
- Support development of wind atlas for aeolian energy production: National as well regional wind patterns are historically consistent. Mediterranean currents can be documented appropriately and relied upon for wind energy production design and operation.
- Upgrade emissions regulations: Match regional and international standards of air quality and environmental safety.
- Enhance implementations tools: Local implementation of ecologic standards as well energy regulations depends on institutionalized support of energy production and consumption

2. Adaptation

Adaptation research hubs benefit tremendously from policies that protect intellectual property rights and patents. The government should provide a business environment in which these rights are protected. Moreover it is imperative that relevant existing laws should be applied effectively and universally across the nation. Another important element is the building of both human and institutional capacities in the public sector involved in all aspects of adaptation research.

Other policies that could benefit the agricultural sector in general are:

- Reinforce marketing of harvests
- Implement reliable metering of resources for agricultural production
- Build institutional capacity
- Capitalize on human resources
- Integrate management of agricultural networks

4. Institutional framework

Currently, there are two government-led programs aimed at reducing GHG emissions. One is the 'Lebanon cross-sectoral energy efficiency and removal of barriers to ESCO operation' that targets GHG emission reduction resulting from inefficient end-use energy consumption in all sectors of the economy. The other is 'The climate change project' designed to address GHG issues in Lebanon. The former effort is implemented by the Ministry of Energy and Water and the latter is implemented by the Ministry of Environment. Moreover, Lebanon can take advantage of some international schemes such as the Clean Development Mechanism (CDM). In theory, funding and implementation of renewable energy projects could be done under the Kyoto Protocol's clean development mechanism.

The Lebanese Center for Energy Conservation Project is working to set up a national fund for energy efficiency and renewable energy and another fund for residential solar water heaters. This fund could eventually be used for financing in part the wind energy farms proposed in the mitigation scenario. Ideally, and similarly to many developed countries, a renewable energy fee could be imposed on electricity consumers by working it into the Lebanese electricity tariff. These funds could also be used for financing wind energy farms.

The Lebanese Agricultural Research Institute (LARI) is currently the only government funded agency involved in agricultural research that focuses on climate change. LARI's current administrative structure and geographic distribution are suitable to carry on a more focused effort on adaptation research. Most universities (public and private) with active agricultural research programs do have the institutional and geographic distribution to allow support of biotech start-ups.

5. Lessons learned

The limited scope of the study presented has led to some understandings of the challenges facing Lebanon in its attempt to reduce emissions and try to adapt to climate change. Along with challenges there were apparent some opportunities that might prove helpful and useful for Lebanon. The sections the follow describe some of these.

a. Challenges

The investments in power plants needed to satisfy demand for the coming 20 to 40 years are substantial. The net present value of investments needed until 2030 (2050) are \$1.11 (\$1.63) billion and \$1.41 (\$2.07) billion for the baseline and the mitigation scenarios respectively. However, it's important to note that these costs for the mitigation scenario are more than offset by the savings achieved in fuel costs. These savings are in the order of \$2.9 billion between 2007 and 2050, making the mitigation scenario more appealing from an economic point of view. Public debt reached 163.5% of GDP in 2008 making Lebanon's debt to GDP ratio the third highest in the World (CIA World Factbook, 2009). Consequently, funding for any large-scale project, such as a power plant is more difficult to achieve and will need to be mostly funded by foreign sources. However, the state-controlled monopoly, EDL, can be a major disincentive to foreign direct investment (Kagiannas et al., 2003) and in fact there has been a lot of pressure by international lenders to privatize the electricity sector. Whether this will happen in the near future remains to be seen.

Climate change induced adaptation needs are mostly exogenous. Climate change does not account for an increase in Lebanon's food import bill, but it will account for greater food price shocks. The most important adaptation need (as opposed to opportunities) is thus the development of fiscal capacity and economic diversification. Unless Lebanon increases its tax base considerably, it will be ill prepared to provide these social safety nets.

Whereas niche production and adaptation research hubs are adaptation opportunities, the expansion of social safety nets is an adaptation necessity. Although the value added of agriculture to GDP is quite small, it still employs a substantial percentage of the work force. Climate change will challenge traditional farming communities' livelihood, which government needs to be prepared for accordingly. The development of unemployment insurances is one priority in this regard.

b. Opportunities

By examining the recently developed wind atlas one can discern several areas along the mountain ranges that have average wind speeds higher than 5 m/s such as Akkar, Marjeyoun, and others. In general, these areas that have high sustained wind speeds have a very low population concentration and land is abundant at very cheap prices to buy or lease for such projects (Dagher and Ruble 2009).

Expanding the supply of electricity by introducing renewable energy has several more advantages in comparison to an expansion with conventional power plants. It will help in reducing Lebanon's dependency on fuel imports and thereby contribute to the diversification of our energy mix. Second, if the introduction of renewable energy takes the form of numerous distributed providers this would enhance the security of supply in times of conflict which are all too common in this region, especially that electric power facilities have been directly targeted in the last two decades (Dagher and Ruble, 2009).

A priority that is also an opportunity is to facilitate vertical and horizontal mobility through public investments in technological (internet, telecommunication) and transportation (roads, public transportation) capacity. Such investments will complement adaptation opportunities as well as they improve Lebanon's business climate. Infrastructure projects are moreover ideally pursued on a regional level.

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Appendix 1

Appendix 1- Item 1: Underperformance of Lebanon's Agricultural Output

In order to test the hypothesis that Lebanon's agricultural output is suboptimal, we estimate the following equation

$$\text{CerYield}_i = \beta_0 + \beta_1 \ln y_i + \sum_{j \neq i} \beta_j \text{Reg.Dummy}_j + \varepsilon_i$$

where

CerYield = Cereal yield (kg per hectare).

Definition: Cereal yield, measured as kilograms per hectare of harvested land, includes wheat, rice, maize, barley, oats, rye, millet, sorghum, buckwheat, and mixed grains. Production data on cereals relate to crops harvested for dry grain only. Cereal crops harvested for hay or harvested green for food, feed, or silage and those used for grazing are excluded.

Source: Food and Agriculture Organization, Production Yearbook and data files.

$\ln y$ = Natural logarithm of GDP per capita (constant 2000 US\$).

Definition: GDP per capita is gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in constant U.S. dollars.

Source: World Bank national accounts data, and OECD National Accounts data files.

The data is available in the 2008 World Bank Development Indicator Database. The definitions of the variables are taken from the same source. The variables are the five-year average of the period between 2001 and 2005.

The various regional dummies are defined as follows:

- Diversified Middle East and North Africa (DivMENA)
- Djibouti, Egypt, Israel, Jordan, Lebanon, Morocco, Syria, Tunisia, Palestine, Yemen.
- East Asia and the Pacific (EAP)
- American Samoa, Australia, Brunei, Cambodia, China, Fiji, French Polynesia, Guam, Indonesia, Japan, Kiribati, Marshall Islands, Micronesia, New Caledonia, New Zealand, N. Korea, Lao PDR, N. Mariana Islands, Mongolia, Myanmar, Palau, Papua New Guinea, Philippines, Samoa, Solomon Islands, Thailand, Timor-Leste, Tonga, Vanuatu, Vietnam.
- East Asian Tigers (EAT)
- Hong Kong, Korea, Rep., Macao, Malaysia, Singapore

- Eastern and Central Europe (ECE)
- Albania, Armenia, Azerbaijan, Belarus, Bosnia H., Bulgaria, Croatia, Czech Rep., Estonia, Georgia, Hungary, Kazakhstan, Kyrgyz Rep., Latvia, Lithuania, Macedonia, Moldova, Poland, Romania, Russia, Serbia, Slovak Rep., Slovenia, Tajikistan, Turkey, Turkmenistan, Ukraine, Uzbekistan.
- Latin America and the Caribbean (LAC):
- Antigua & Barbuda, Argentina, Aruba, Bahamas, Barbados, Belize, Bolivia, Brazil, Cayman Islands, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Rep., Ecuador, El Salvador, Grenada, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, Puerto Rico, St. Kitts & Nevis, St. Lucia, St. Vincent & Gren., Suriname, Trinidad & Tobago, Uruguay, Venezuela, RB, Virgin Islands (U.S.).
- North America (NAM):
- Bermuda, Canada, United States.
- Oil Economies of the Middle East and North Africa (OilMENA):
- Algeria, Bahrain, Iran, Iraq, Kuwait, Libya, Oman, Qatar, KSA, UAE
- Sub Saharan Africa (SSA):
- Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central Afr. Rep., Chad, Comoros, Congo, Dem. Rep., Congo, Rep., Cote d'Ivoire, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, The, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mayotte, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, São Tomé & Príncipe, Tanzania, Togo, Uganda, Zambia, Zimbabwe.
- South Asia (SA):
- Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, Sri Lanka.
- Western Europe (WE):
- Andorra, Austria, Belgium, Channel Islands, Cyprus, Denmark, Faeroe Islands, Finland, France, Germany, Greece, Greenland, Iceland, Ireland, Isle of Man, Italy, Liechtenstein, Luxembourg, Malta, Monaco, Netherlands, Norway, Portugal, San Marino, Spain, Sweden, Switzerland, United Kingdom.

Table: OLS Regression Results “Suboptimal Cereal Yield Hypothesis”

DV=Cereal Yield	Regression Coefficient	Standard Error	t-stat	p-value
Intercept	552.25	1,109.33	0.50	0.62
lny	473.86***	106.53	4.45	0.00
(Region=»DIVMENA«)	-1,774.80***	575.06	-3.09	0.00
(Region=»EAP«)	-745.52	585.88	-1.27	0.21
(Region=»EAT«)	2.32	977.30	0.00	1.00
(Region=»ECE«)	-1,120.63**	476.13	-2.35	0.02
(Region=»LAC«)	-1,714.62***	434.50	-3.95	0.00
(Region=»NAM«)	-974.21	969.83	-1.01	0.32
(Region=»OCE«)	-1,428.94**	607.42	-2.35	0.02
(Region=»OILMENA«)	-2,228.35***	589.81	-3.78	0.00
(Region=»SA«)	-421.76	688.32	-0.61	0.54
(Region=»SSA«)	-2,122.86***	557.77	-3.81	0.00
N	164			
R2	0.51			

*** = significant at 1% and ** = significant at 5%, * = significant at 10%.

The results show that agricultural output is positively correlated with per capita income. This is most likely the consequence of a transition from traditional to commercialized agriculture in the process of economic development. Both the regional dummies for the diversified and oil economies of the Middle East and North Africa indicate a significantly negative cereal yield. Lebanon’s cereal yield is 2635.22. Its predicted value is 165.28 higher. The standard error of all residuals is 98.3. The negative residual of Lebanon is therefore significant at the 10% level.

In order to test the hypothesis that Lebanon is possibly short of capital, proxied by use of fertilizers, we also estimated

$$\text{Fert}_i = \beta_0 + \beta_1 \ln y_i + \sum_{j \neq i} \beta_j \text{Reg.Dummy}_j + \varepsilon_i$$

where

Fert = Fertilizer consumption (100 grams per hectare of arable land)

Definition: Fertilizer consumption (100 grams per hectare of arable land) measures the quantity of plant nutrients used per unit of arable land. Fertilizer products cover nitrogenous, potash, and phosphate fertilizers (including ground rock phosphate). Traditional nutrients--animal and plant manures--are not included. The time reference for fertilizer consumption is the crop year (July through June). Arable land includes land defined by the FAO as land under temporary crops (double-cropped areas are counted once), temporary meadows for mowing or for pasture, land under market or kitchen gardens, and land temporarily fallow. Land abandoned as a result of shifting cultivation is excluded.

Source: Food and Agriculture Organization, Production Yearbook and data files.

The data is available in the 2008 World Bank Development Indicator Database. The definition of the variable is taken from the same source. The variable is again the five-year average of the period between 2001 and 2005.

Table: OLS Regression Results “Suboptimal Fertilization Hypothesis”

DV=Fertilizer use	Regression Coefficient	Standard Error	t-stat	p-value
Intercept	-18,015.14	9,419.24	-1.91	0.06
lny	2,152.45**	913.18	2.36	0.02
(Region=»DIVMENA«)	6,218.47	4,466.75	1.39	0.17
(Region=»EAP«)	4,414.58	4,719.38	0.94	0.35
(Region=»EAT«)	43,852.73***	5,825.57	7.53	0.00
(Region=»ECE«)	2,556.02	3,599.93	0.71	0.48
(Region=»LAC«)	2,490.98	3,468.03	0.72	0.47
(Region=»NAM«)	-3,284.37	6,922.27	-0.47	0.64
(Region=»OCE«)	2,084.12	4,703.88	0.44	0.66
(Region=»OILMENA«)	4,774.35	4,049.89	1.18	0.24
(Region=»SA«)	5,477.92	5,461.66	1.00	0.32
(Region=»SSA«)	5,165.23	4,599.07	1.12	0.26
N	133			
R2	0.38			

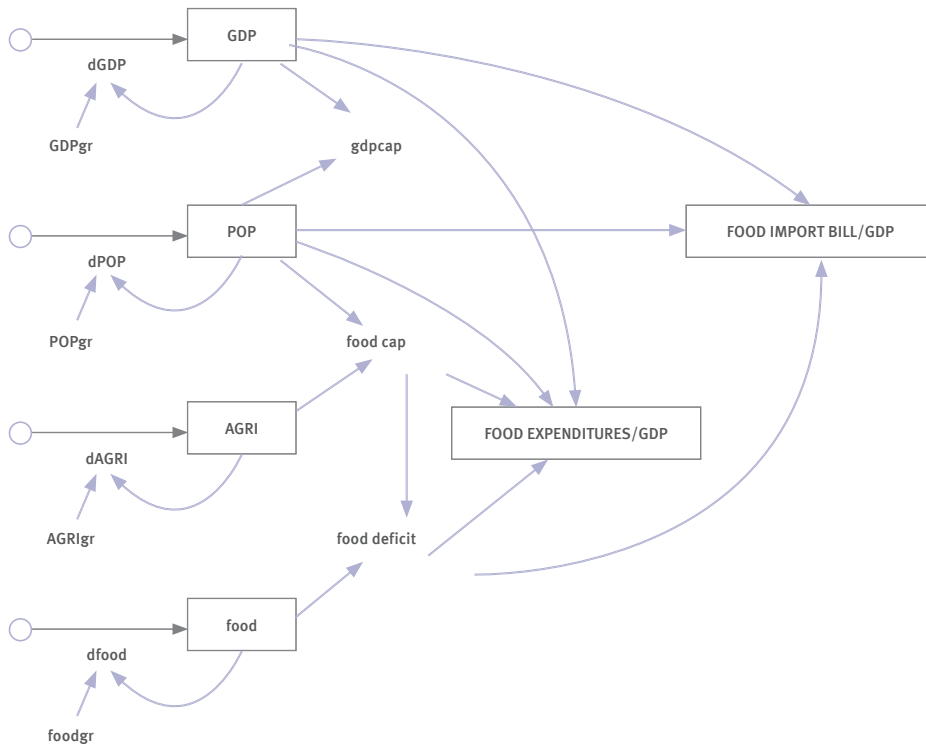
*** = significant at 1% and ** = significant at 5%, * = significant at 10%.

The results show that the use of fertilizer, which can be used as a proxy for access to capital, is positively correlated with per capita income. Except the regional dummy for the “East Asian Tigers” dummy, no other variable is significant. Lebanon’ fertilizer use is 1,860 kg per ha of arable land. The predicted value would be 461 kilograms higher. Lebanon’s fertilizer use deficit is statistically highly significant.

Appendix 1 - Item 2: Simulation of Climate Change Impacts on Lebanon’s Food Import Bill

The simulation is programmed using a system-dynamic model, graphically illustrated below:

Figure: Programming of Lebanon’s Impacts to Climate Change



Stock variables:

GDP = National GDP in \$ 2005 PPP, 2010 value = \$ 30 billion, growth rate GDPgr = 0.03.

POP = Population, 2010 value = 4 Million, population growth rate POPgr = 0.01

AGRI = Agricultural value added to GDP, 2010 value = \$1.8 billion. Two alternative runs: "With climate change" and "without climate change." With climate change: AGRIgr = -0.003191; "Without climate change:" AGRIgr = 0.

food = Per capita food expenditures (both domestic consumption and imports), 2010 value = \$900, exogenous food price inflation foodgr = 0.02.

dGDP = GDP*GDPgr

dPOP = POP*POPgr

dAGRI = AGRI*AGRIgr

dfood = food*foodgr

Auxiliary variables:

gdpcap = GDP per capita (\$2005 PPP)

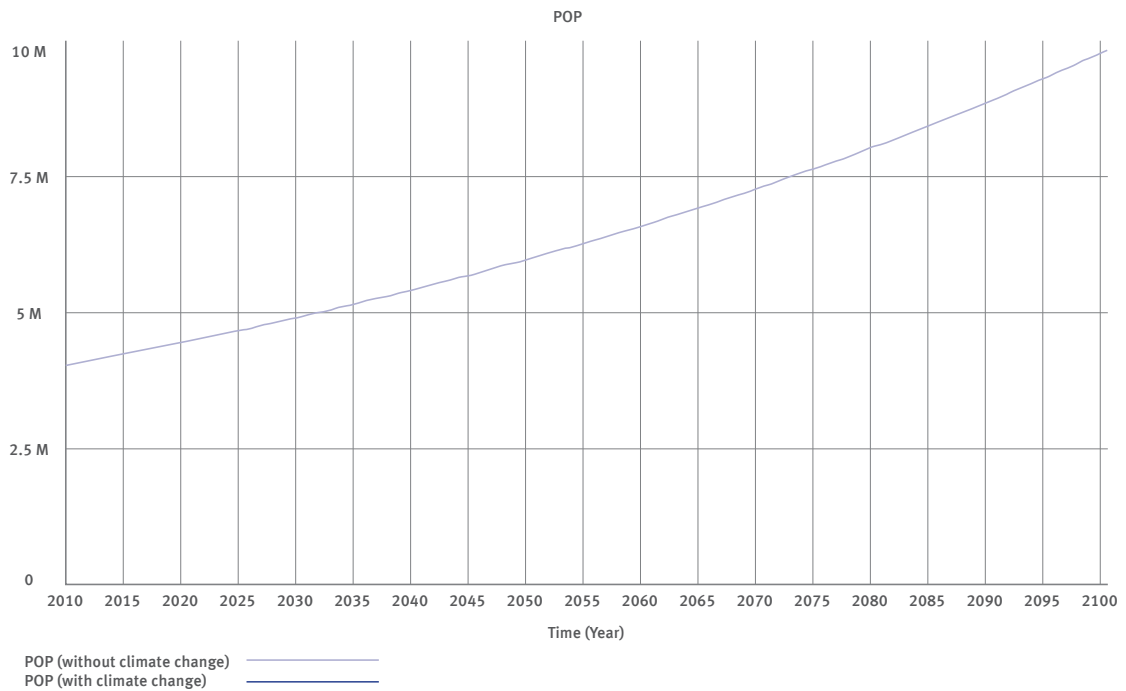
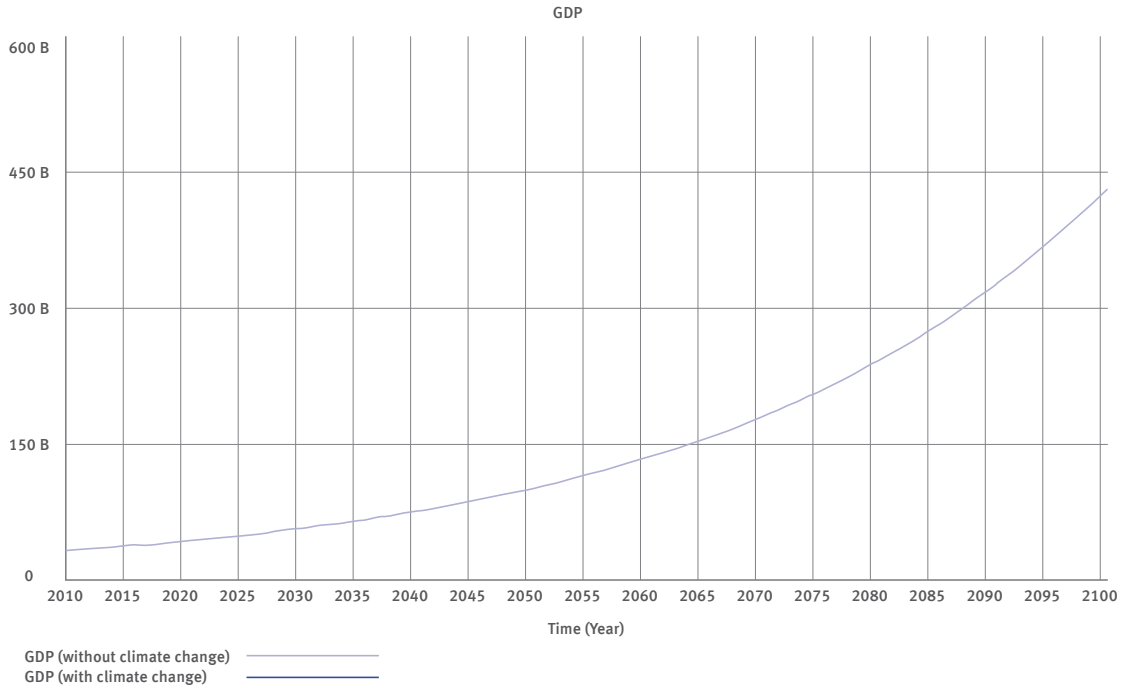
foodcap = Value of domestically available food production (\$2005 PPP)

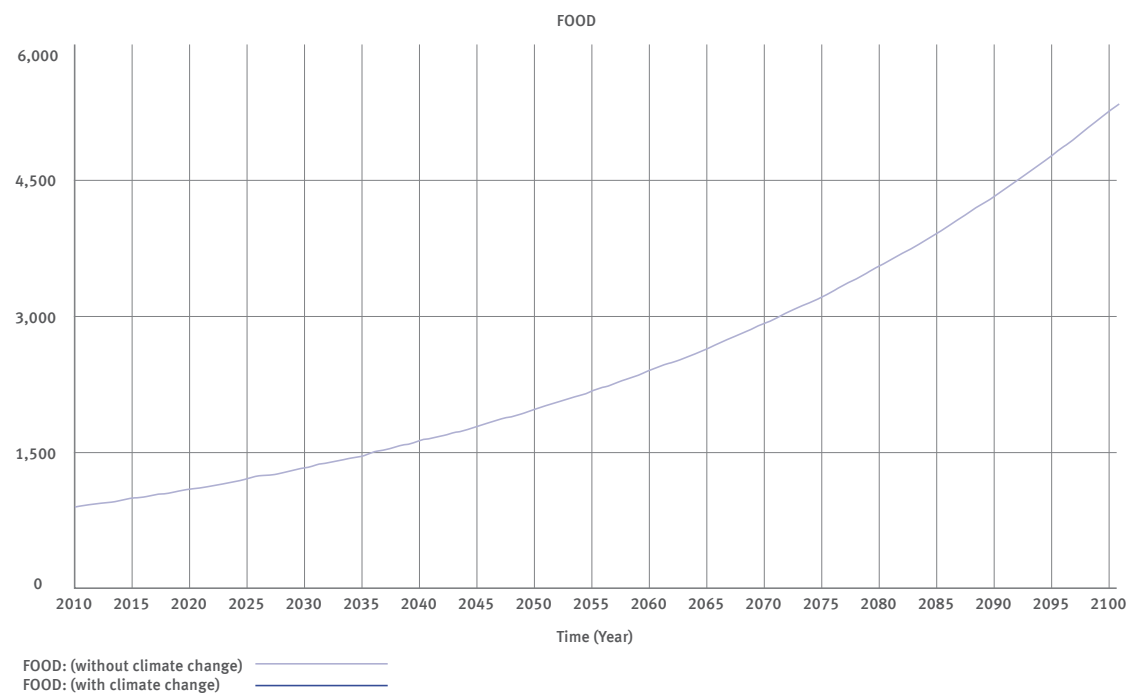
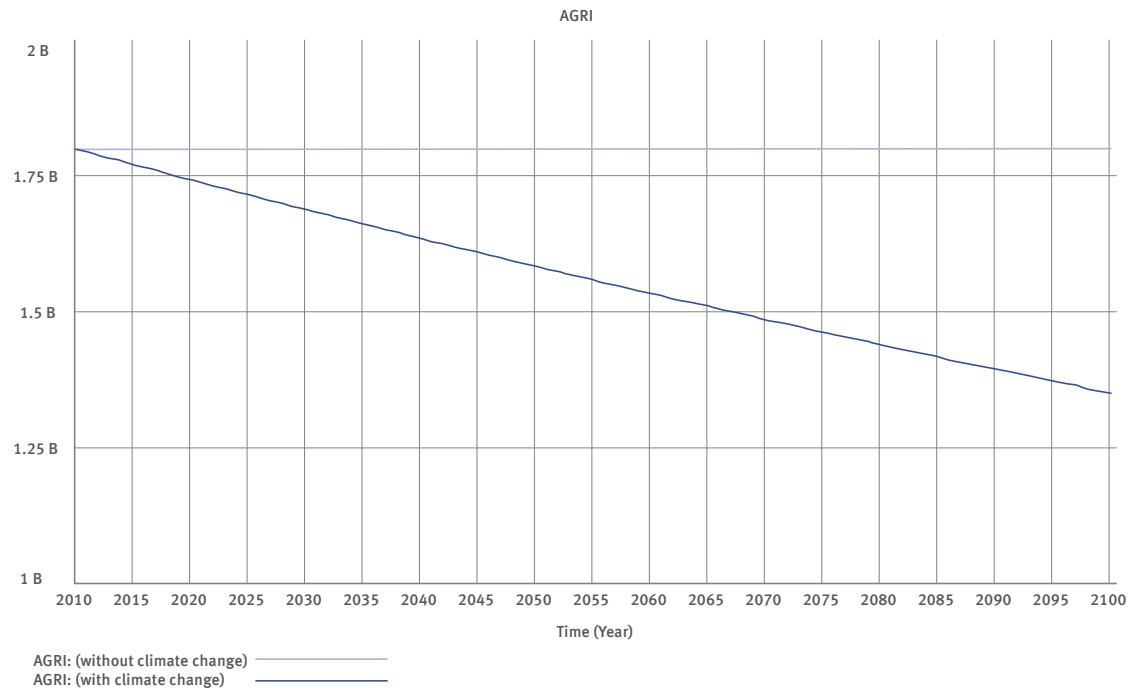
fooddef = Value of food deficit to keep real per capita food consumption constant (\$2005 PPP)

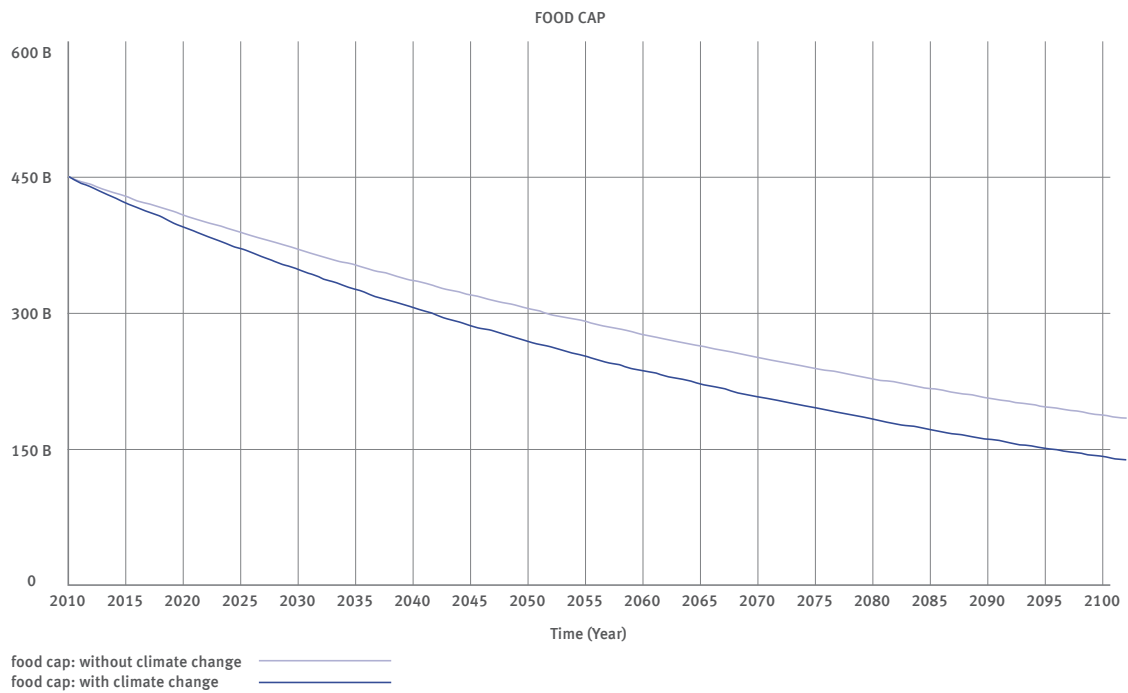
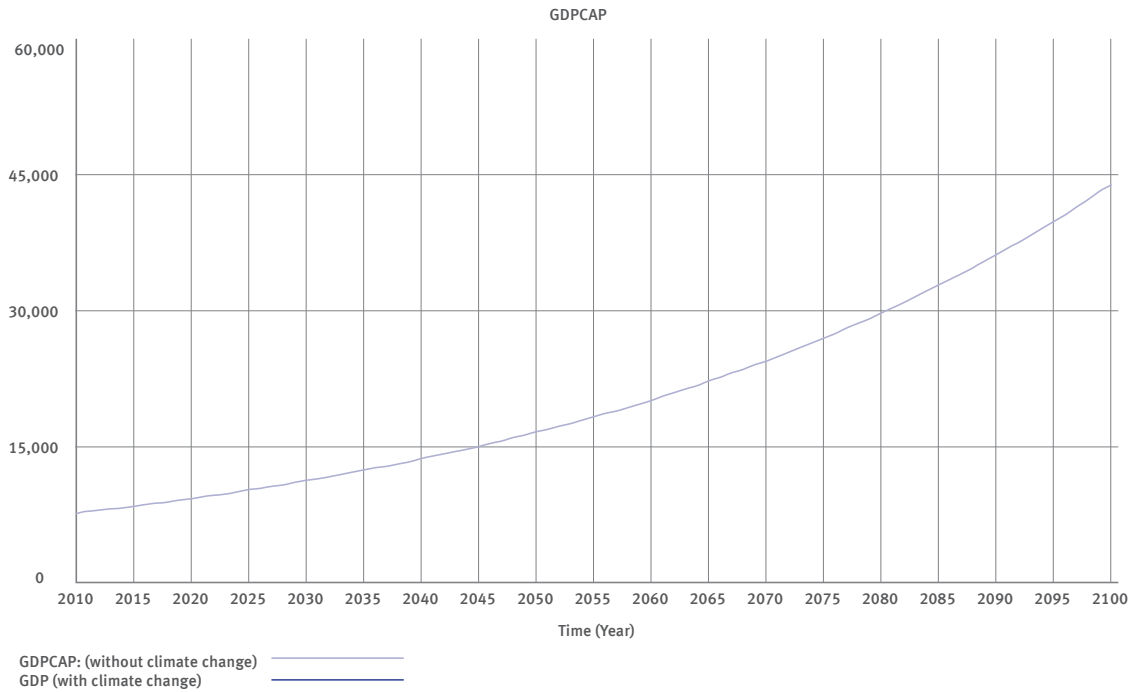
FOOD EXPENDITURES/GDP = Total food expenditures as a percentage of GDP (value added of agriculture to GDP plus food imports)

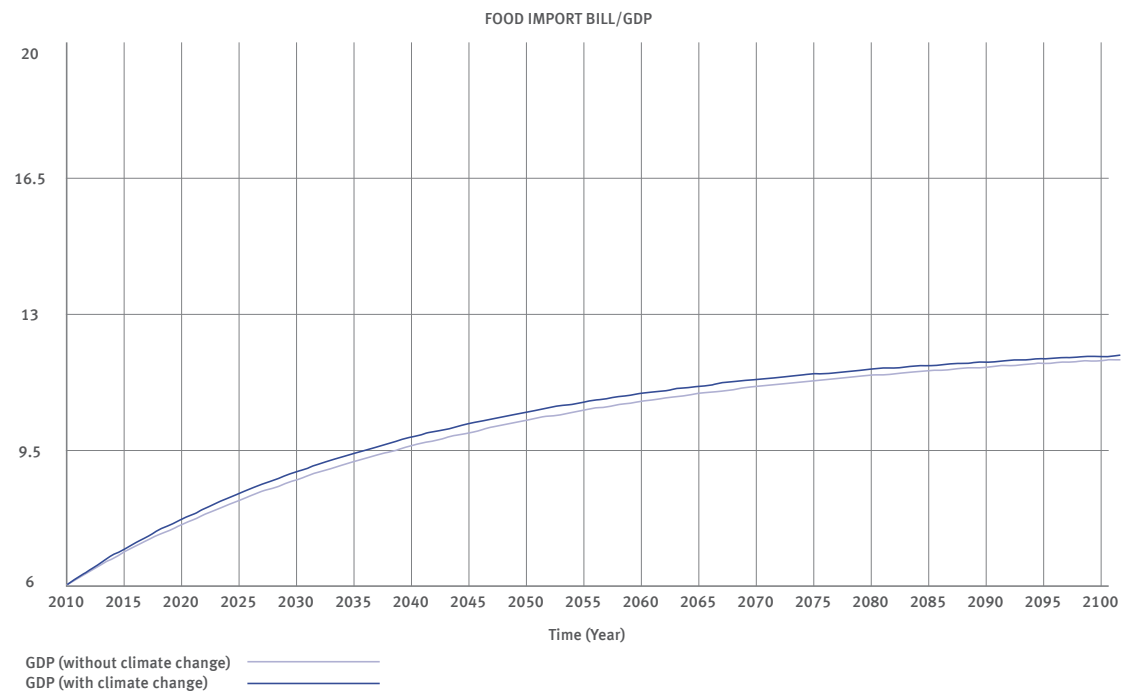
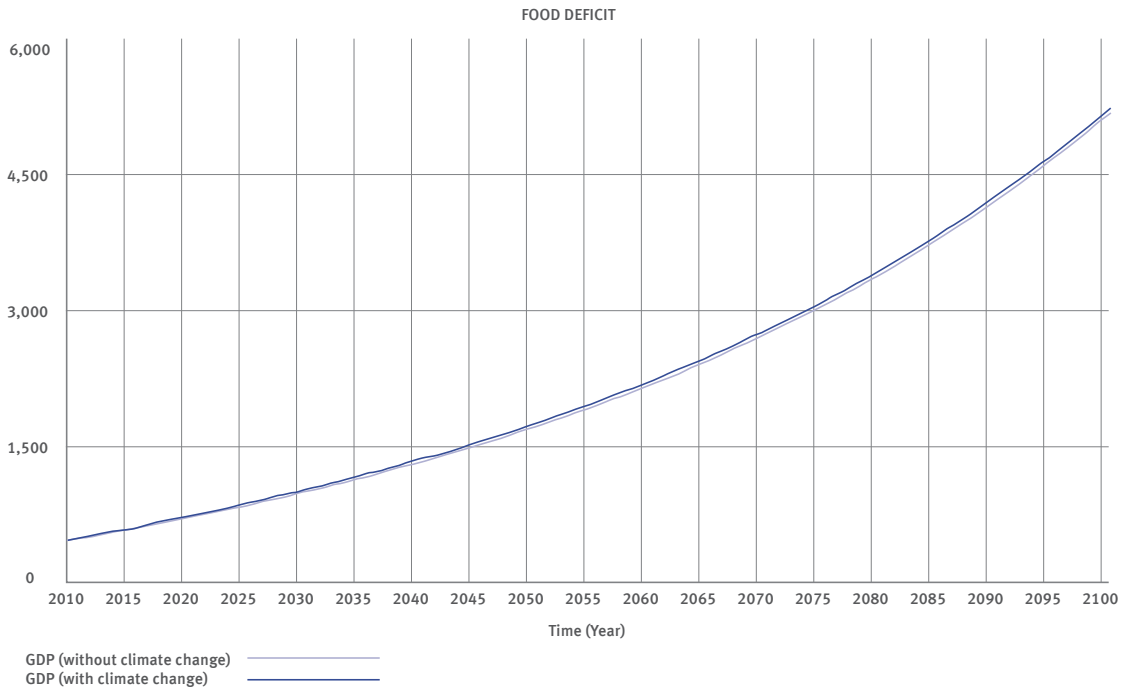
FOOD IMPORT BILL/GDP = Food imports bill as a percentage of GDP

Appendix 1 - Item 3: Simulation Results of Climate Change Impacts on Lebanon’s Food Import Bill





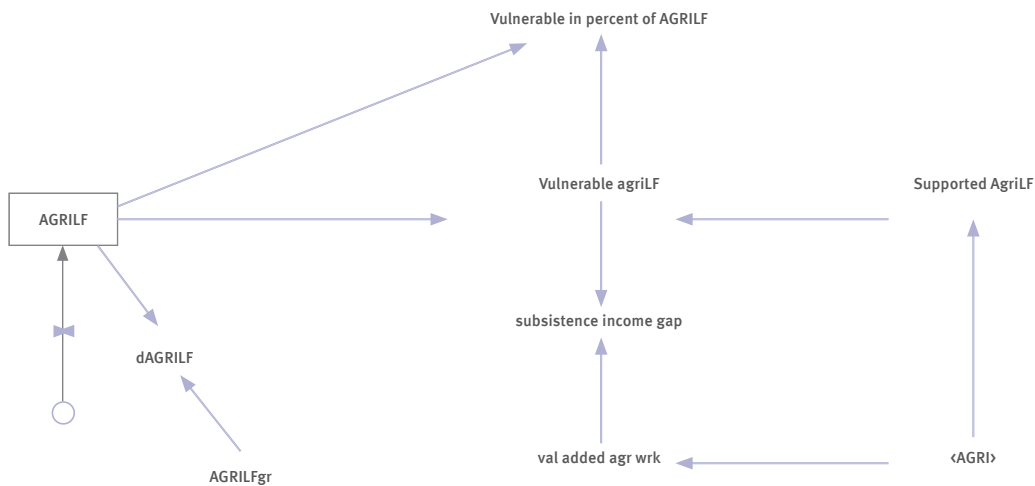




Appendix 1 - Item 4: Simulation Methodology “Agricultural Livelihood”

The following Figure illustrates the dynamics of climate change and agricultural population growth on farming communities’ livelihood.

Figure: Programming of Farming Communities’ Exposure to Climate Change and Population Growth



where

AGRILF = Agricultural labor force; 2010 value: 300,000; annual agricultural labor force population growth rate AGRILFgr = 1%.

$$dAGRILF = AGRILF * AGRILFgr$$

<AGRI> = Agricultural value added to GDP, 2010 value = \$1.8 billion. Two alternative runs: “With climate change” and “without climate change.” With climate change: AGRIGr = -0.003191; “Without climate change:” AGRIGr = 0. Shadow variable from “Food Security” simulation.

$$val\ added\ agr\ wrk = Value\ added\ per\ agricultural\ worker\ (AGRI/AGRILAF)$$

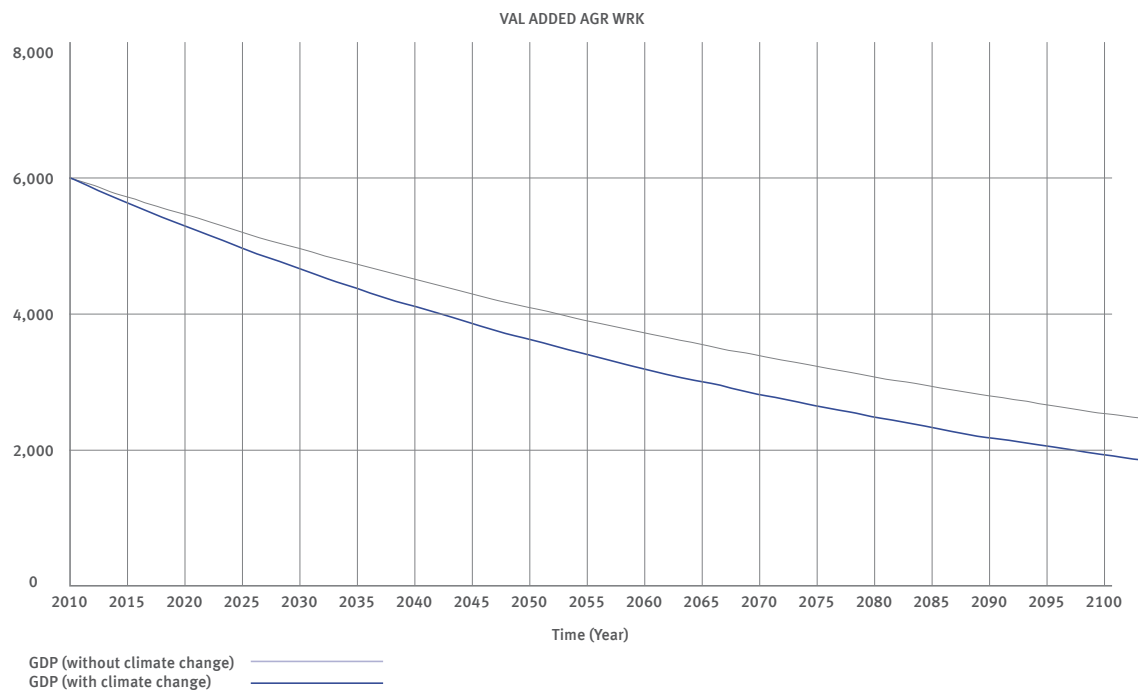
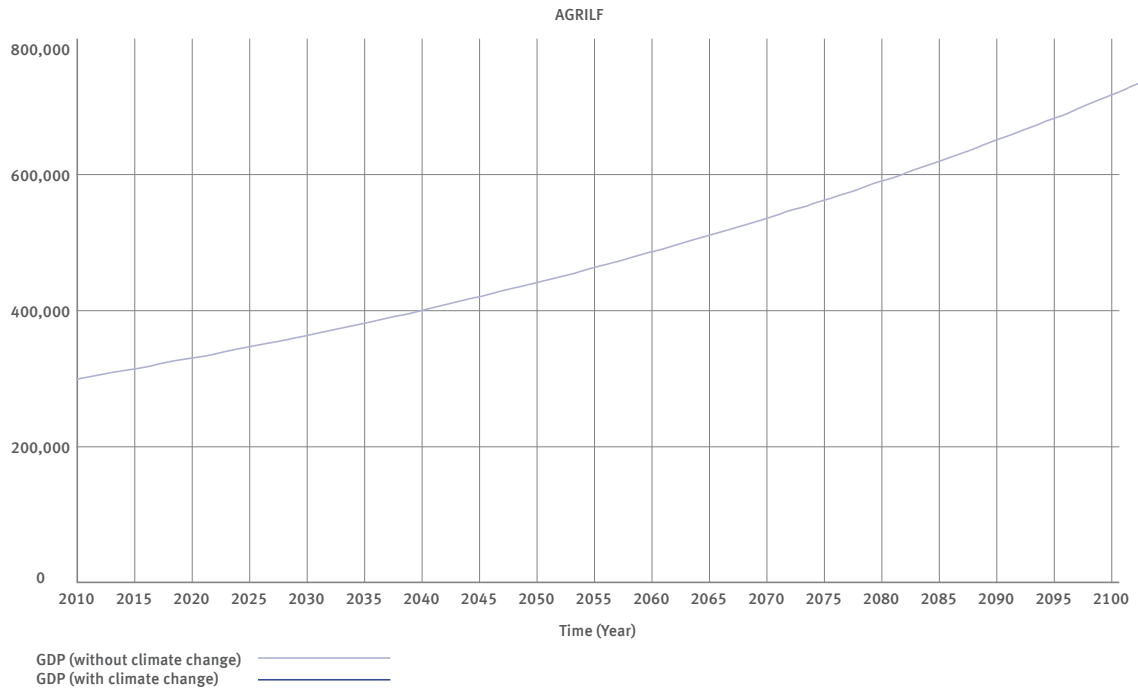
$$subsistence\ income\ gap = (\$6,000 - val\ added\ agr\ wrk) * AGRILF$$

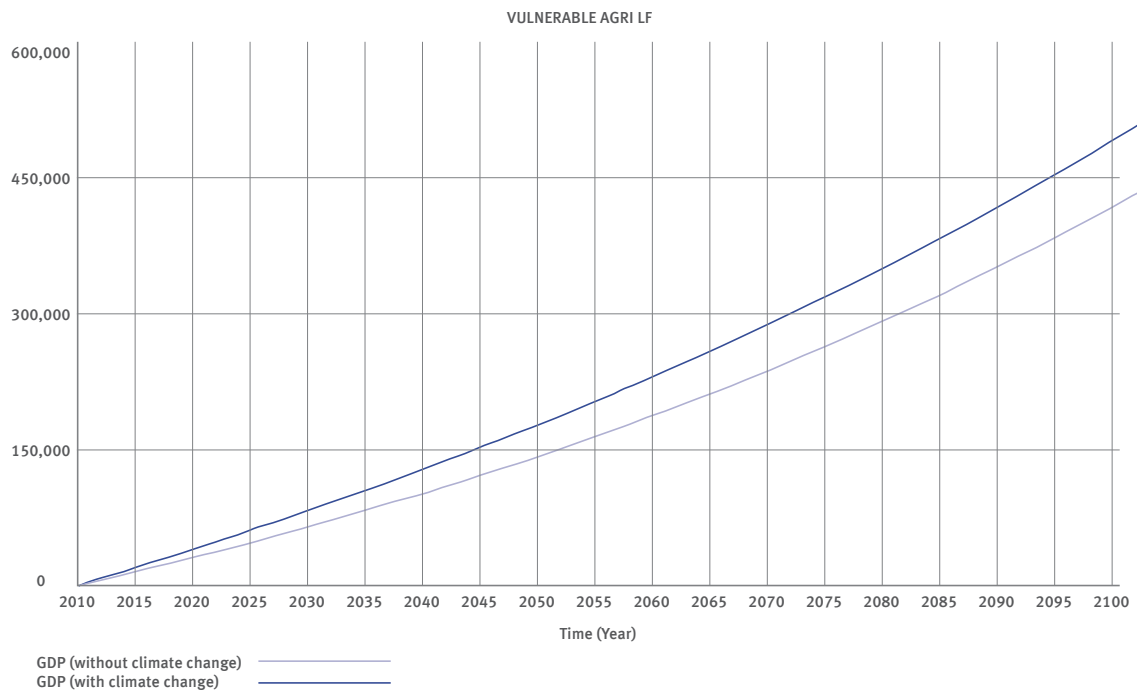
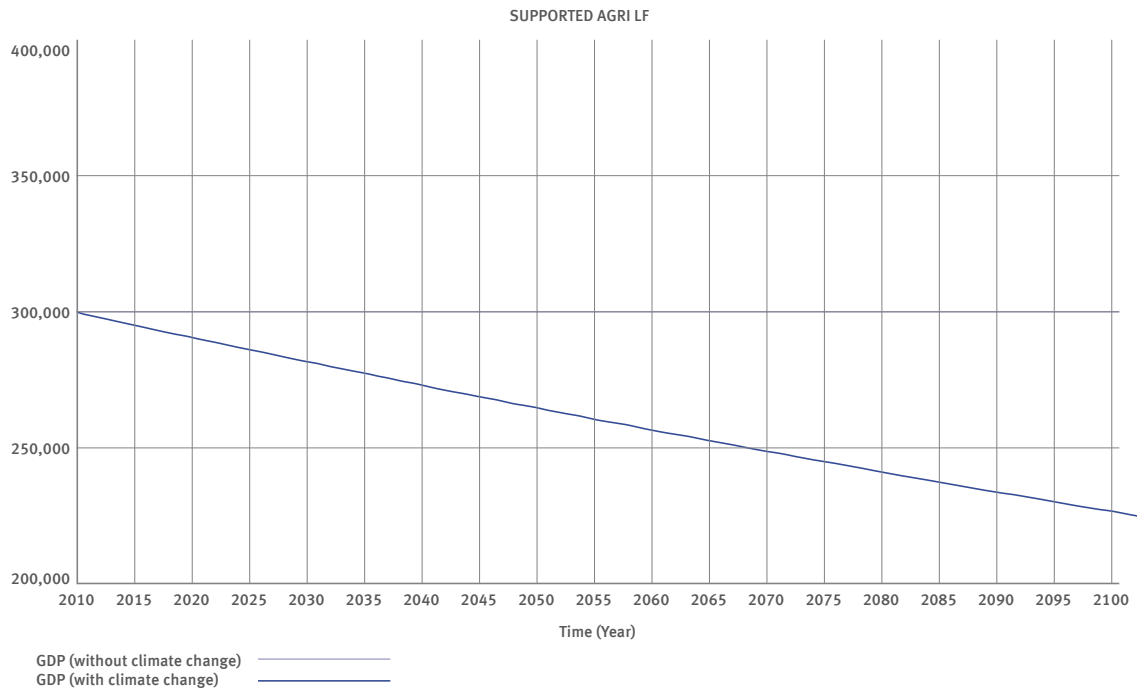
$$Supported\ Agri\ LF = AGRI / 6000$$

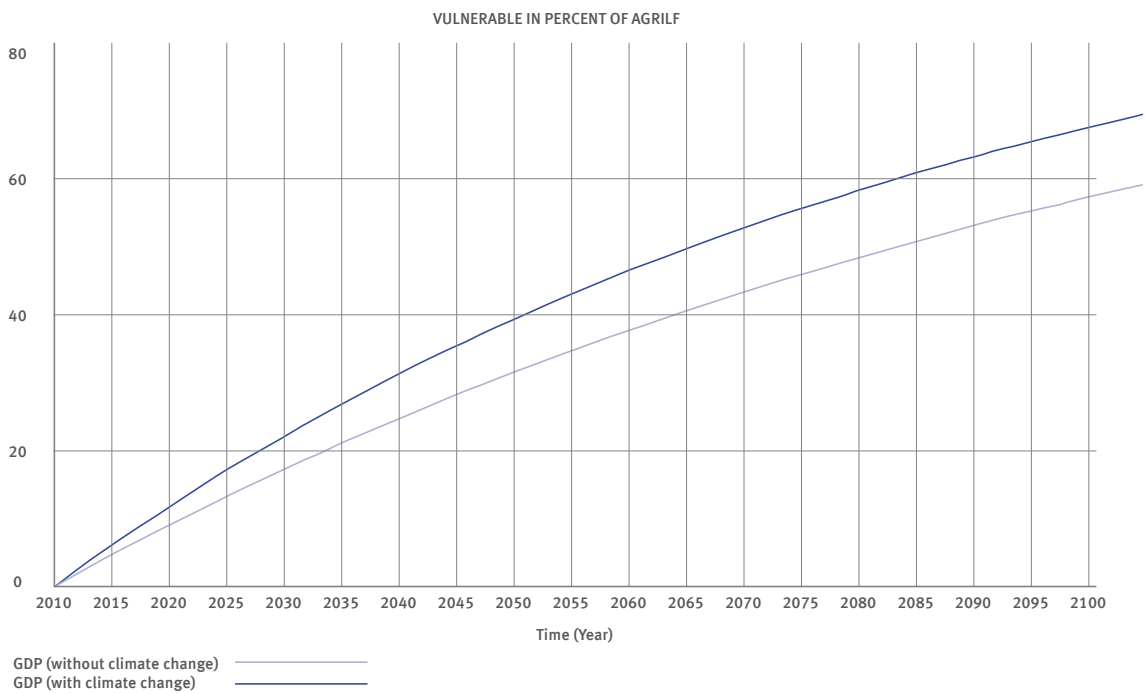
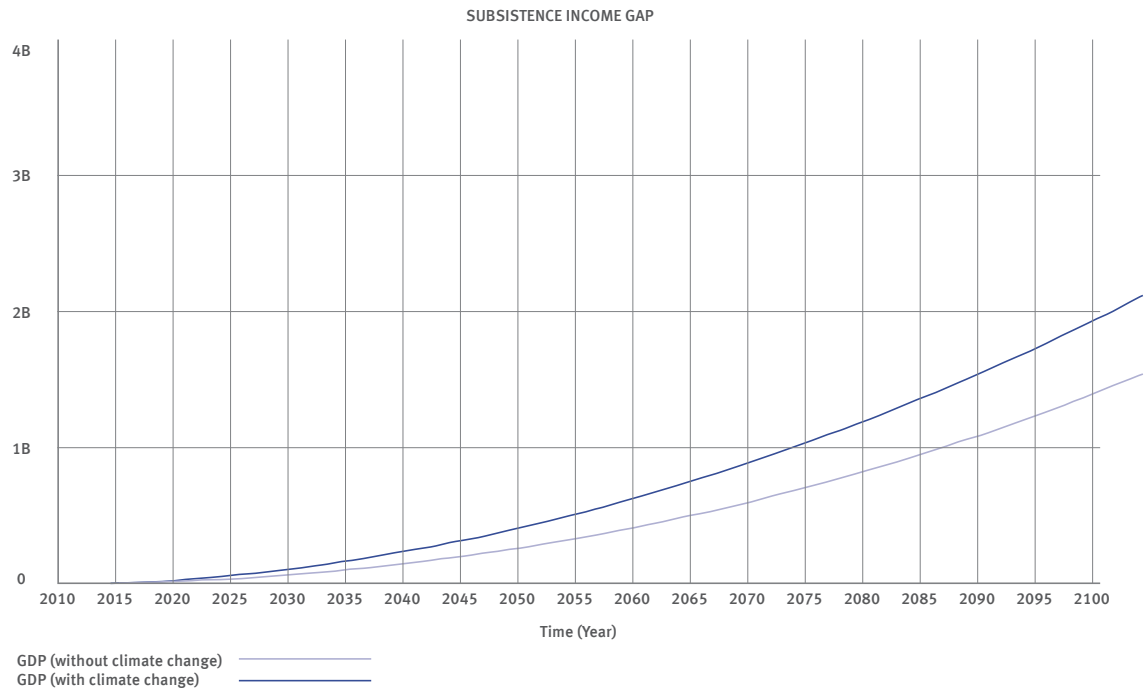
$$vulnerable\ agri\ LF = vulnerable\ agricultural\ labor\ force = AGRILF - Supported\ Agri\ LF$$

$$Vulnerable\ in\ percent\ of\ AGRILF = vulnerable\ agri\ LF / AGRILF$$

Appendix 1 - Item 5: Simulation Runs “Agricultural Livelihood”







Appendix 1 - Item 6: Simple OLS Regression Results “Biotech Employment”

$$\text{Biotech Employment}_i = \beta_0 + \beta_1 \text{Population}_i + \beta_2 \text{GDP}_i + \varepsilon_i$$

DV=Biotech Employment (ln)	Model I	Model II	Model III
Intercept	6.30***	3.30**	4.89**
	(0.74)	(1.28)	(1.87)
Population (ln)	1.33***		0.79
	(0.22)		(0.69)
GDP (ln)		1.17***	0.51
		(0.21)	(0.61)
N	11	11	11
R2	0.80	0.78	0.77

Standard errors in parentheses, ***=significant at 1%, **=significant at 5%.

Because of the small sample size (N=11) and very strong correlation between GDP and population size ($r=0.97$), Model III is unlikely to generate significant results. Statistical non-significance, however, should not stand in the way of using Model III for inference purposes.

Using the regression results of Appendix Item #6 and matching it with Lebanon’s population of roughly 4 million and a GDP (in \$2000 PPP) of 20 billion for 2006, Lebanon would have the potential to develop a biotechnology sector that employs 1,832 (Biotech Employment = $\text{EXP}[4.89+0.79(\ln 4)+0.51(\ln 20)]$)

Appendix 2

The set of assumptions used in modeling the electricity sector are the following:

Electricity Generation (2006): 9287 GWh
Demand Growth: 3% per year
Plant Lifetime: 30 years
Discount rate: 8%

Environmental emission factors used are from the Technology and Environment Database

Fuel Oil

Process Efficiency: 34%
Maximum Availability: 80%
Capital Cost: 1 million USD/MW
Import Cost: 395 USD/metric ton

Diesel Oil

Process Efficiency: 32%
Maximum Availability: 80%
Capital Cost: 0.8 million USD/MW
Import Cost: 660 USD/metric ton

Hydro

Process Efficiency: 100%
Maximum Availability: 70%
Capital Cost: 2 million USD/MW

Wind

Process Efficiency: 100%
Maximum Availability: 50%
Capital Cost: 1.5 million USD/MW