Economic and financial viability

1 Economic analysis

Liberia, like many developing countries, does not have a robust database of crucial socio-economic variables that are required to make concrete predictions of the outcomes of different climate policy measures. As part of the outcomes, this project will build a data repository that contains a systematic track record of the changes in micro socio-economic indicators and link them to specific policy actions from which they emerged. One of the methodologies that will be employed to conduct this exercise will be system dynamics modelling.

System Dynamics was developed by Jay Forrester at the Massachusetts Institute for Technology in the late 1950s. Causal relations, feedback loops, delays and non-linearity are integral themes of this methodological approach, making it particularly suitable for representing and analysing complex real-world systems. Through the explicit representation of stocks and flow, system dynamics models run differential equations to generate future scenarios. This methodological approach is capable of identifying key economic sectors, eliciting the variables of each sector, illustrating their relationships within and across sectors, and revealing the embedded feedback processes that are not overtly understood or often not captured by standard regression models.

The procedures involved in constructing a system dynamics model are similar to and aligned with the steps employed at the United Nations (UN) integrated policymaking cycle. A five-step iterative process is involved in developing a system dynamics model: (1) problem identification, (2) dynamic hypotheses, (3) formal model development, (4) validation and (5) simulation of alternative scenarios. The system dynamics process shows the role of feedback loops in shaping future development and contributes to analysing trade-offs and potential undesired policy side-effects. System dynamics models are used to simulate exploratory 'what-if' scenarios to assess potential policy interventions and development trajectories, as opposed to other approaches that focus on optimization. The results of such an analysis reveal potential future impacts of policy interventions (desired and undesired) as well as the complementarity of policy interventions in achieving specific objectives.

System dynamics modelling is used to compute some key climate impacts in the past, present, and potential future scenarios based on the limited data available currently. System dynamics, unlike many other economic models, maps out the full feedback loops that exist among the different variables associated with a given problem. The model developed for this feasibility assessment is labelled the Liberia Climate Risk Assessment Simulation Model (LICRASIM), here forth referred to as LICRASIM.

The causal loop diagram in Figure 1 is a simple depiction of the qualitative part of the model showing the relationship between some key variables in relation to climate hazards. The arrows show the direction of cause and effect, while the polarity notation of ‘s’ and ‘o’ at the end of each arrow shows the nature of the effect, where ‘s’ means same direction and ‘o’ represent opposite direction.

In Figure 5, when GDP growth increases, GDP will also increase, hence ‘s’, and when GDP increases, the Loss to GDP ratio will decrease, hence ‘o’. An increase in the Loss to GDP ratio will result in a decrease in GDP growth. This cycle of the feedback loop is named the economic loop. The ‘R1’ notation means reinforcing loops. A loop is reinforcing when the net outcome of the relationships is positive or moves in the same direction. In the Climate loss loop, the ‘B1’ notation means a balancing loop. This is where the net outcome of relationships is negative of moves in the opposite direction.

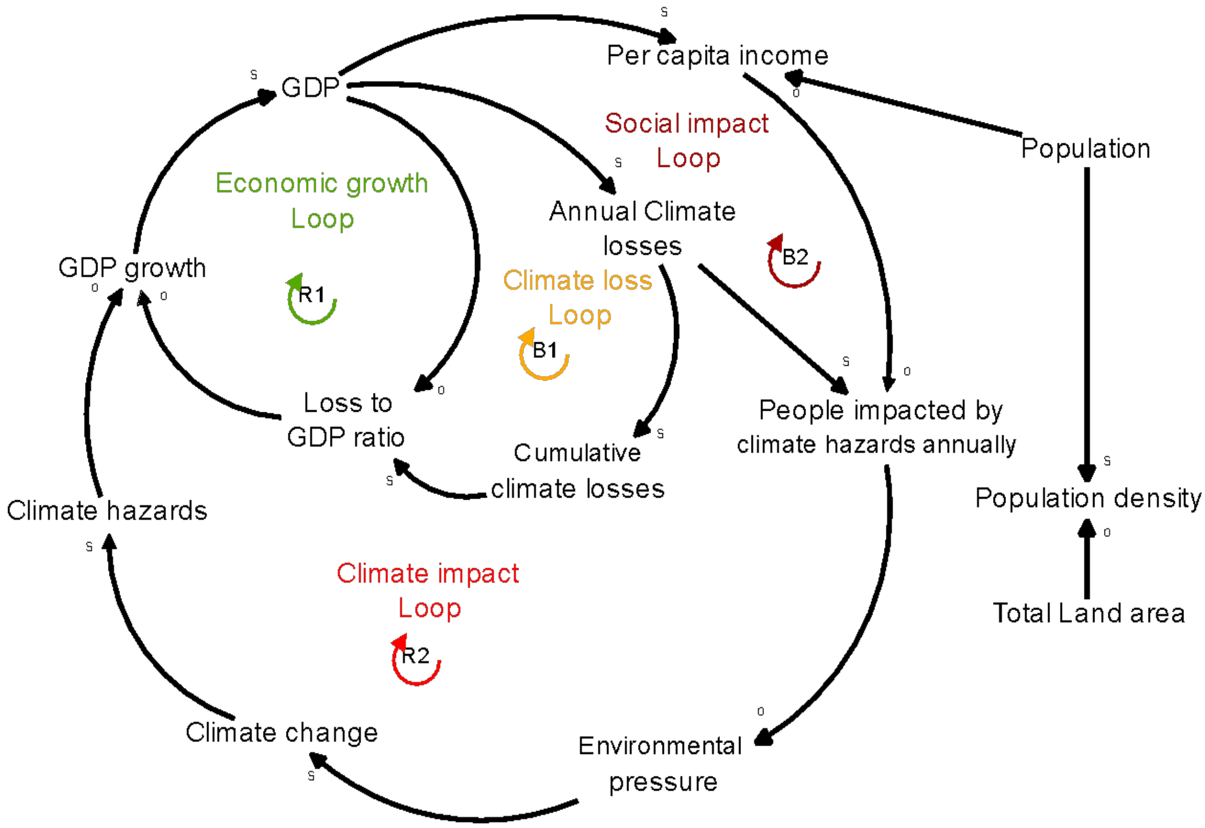

Figure 1: Causal Loop Diagram

The outer loop of the diagram depicts the relationship between GDP, per capita income, and climate change. When GDP increases, the per capita income of the country will also increase. An increase in per capita income will reduce the impact of climate hazards as people will have the economic resources to adapt. When more people are impacted by climate hazard, there will be more pressure on the environment since more effort will be required to sustain normal living status. An increase in environmental pressure will accelerate climate change, which will lead to more climate hazards, less GDP growth, and eventually feedback to GDP. This modelling approached allows for the representation of the remote effects of multiple variables on each other, leading to a much accurate depiction of real-world experiences.

There is usually an attempt to recreate the historical dynamics so as to build confidence in the model. The historical data of different variables can be compared with that of the model results over such period as a validation mechanism. It must be noted that consistency between the model and data does not necessarily mean that the model is valid. It only implies that the model cannot be rejected solely on the basis of lack of consistency with data. As such, there are other validation exercises. Structural validation ensures that the model structure, such as the relationship between the variables, represent the real-world case. Other validation test includes extreme condition test, behavioural test and sensitivity analysis. The result of the key variables identified in the model is discussed next.

1.1 Scenario assessment

The quantitative model was simulated, and seven different scenarios were assessed to ascertain some potential impact of climate change in Liberia. The different scenarios and their descriptions are provided in Table 4. The simulation covers a period of 35 years; from 2006 to 2040. The period from 2006 to 2019 is regarded as the base period.

Table 1: Scenario descriptions

Scenarios	Description
Baseline	This refers to the business-as-usual case where no different action is taken to cause a change in the current path.
25% loss increase	This is the case where there is a 25% increase in the fraction of GDP that is lost annually as a result of climate change within a five-year period. This occurs between 2021 – 2025.
25% loss decrease	This is the case where there is a 25% decrease in the fraction of GDP that is lost annually as a result of climate change within a five-year period. This occurs between 2021 – 2025.
50% loss increase	This is the case where there is a 50% increase in the fraction of GDP that is lost annually as a result of climate change within a ten-year period. This occurs between 2021 – 2030.
50% loss decrease	This is the case where there is a 50% decrease in the fraction of GDP that is lost annually as a result of climate change within a ten-year period. This occurs between 2021 – 2030.
75% loss increase	This is the case where there is a 75% increase in the fraction of GDP that is lost annually as a result of climate change within a fifteen-year period. This occurs between 2021 – 2035.
75% loss decrease	This is the case where there is a 75% decrease in the fraction of GDP that is lost annually as a result of climate change within a fifteen-year period. This occurs between 2021 – 2035.

1.2 Annual Losses due to climate change/hazards

There is a growing amount of climate risks and associated costs in Liberia. As major climate hazards such a flood, coastal erosion, windstorm, among others become frequent, the annual amount of loses in monetary value has increased. According to Kreft, Eckstein et al. (2013), Liberia loses approximately 0.02 per unit GDP from 1994 to 2013. This resulted in an estimated loss amounting to US$3.79 million in 2013 and US$ 7.44 million in 2017 (Eckstein, Künzel et al. 2017). The amount of losses attributed to climate hazards in Liberia as of 2014 was US$6.34 million (PreventionWeb 2014).

The annual cost of climate in LICRASIM was computed using GDP and fraction losses rate. GDP was used as a proxy because of the lack of data at the micro-level as to the monetary value of specific climate disasters in the country. The losses per unit GDP was derived from the annual climate risks reports published by GermanWatch. The results of the simulation are shown in Table 5. Currently, approximately US$6.17 million losses are recorded in Liberia as a result of climate hazards. This figure is expected to almost double in the next decade, and triple by 2040 under the baseline scenario.

Table 2: Annual losses due to climate hazards

	Period of change			Annual Losses due to climate (in US$)						
Scenarios (change in fractional GDP Loss)	5 years (2021-2025)	10 years (2021-2030)	15 years (2021-2035)	2006	2019	2021	2025	2030	2035	2040
Baseline				2,566,000	6,171,000	6,554,000	8,764,000	11,527,000	14,948,000	18,236,000
25% loss increase	x			2,566,000	6,171,000	6,554,000	17,452,000	22,090,000	26,438,000	29,276,000
25% loss decrease	x			2,566,000	6,171,000	6,554,000	0	0	0	0
50% loss increase		x		2,566,000	6,171,000	6,554,000	30,407,000	57,035,000	57,845,000	57,845,000
50% loss decrease		x		2,566,000	6,171,000	6,554,000	0	0	0	0
75% loss increase			x	2,566,000	6,171,000	6,554,000	41,085,000	83,318,000	112,720,000	112,720,000
75% loss decrease			x	2,566,000	6,171,000	6,554,000	0	0	0	0

Under all the scenarios where the fraction of GDP loses decreases by a minimum of 25% within a period of five years, the annual losses (economic, excluding social) can be eliminated by 2025. However, in a situation where the fraction of losses increases, the annual losses to climate hazards will range between US$29.3 million under the 25% increase to 112.7 million under the 75% increase scenario by 2040. This will create an undesirable state of climate havoc. The graphical representation of these scenarios is illustrated in Figure 6.

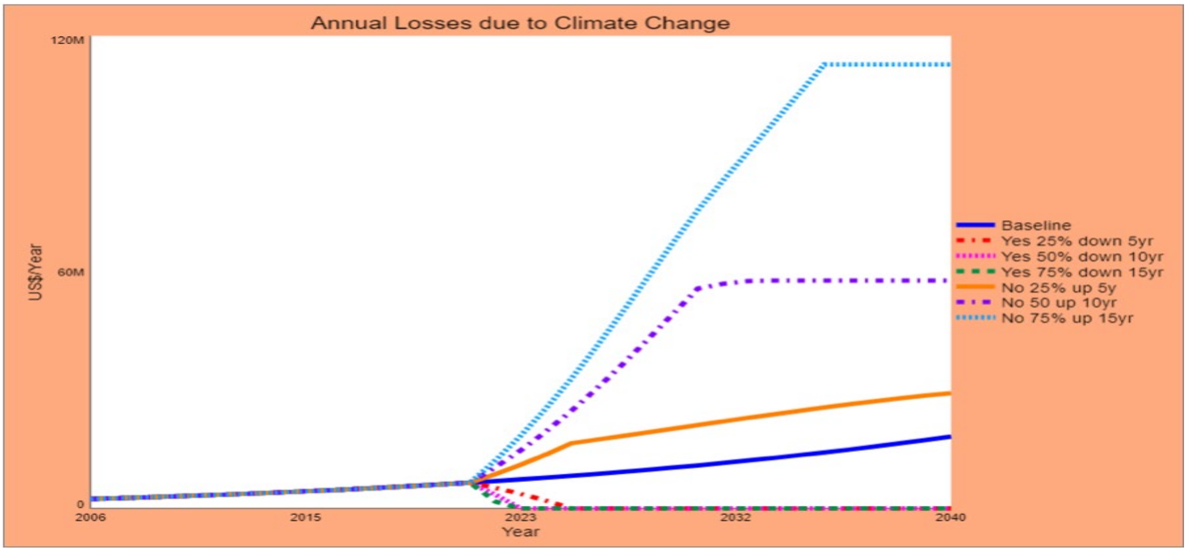

Figure 2: Annual losses due to climate hazards

1.3 People Impacted by climate hazards

There is paucity of data on the total number of people that are affected by different climate hazards in Liberia annually. The LICRASIM, therefore, computes the number of people impacted by climate hazards using the annual losses and the per capita income. This formulation enabled the model to simultaneously make adjustment to all linked variables based on the changes experienced. The results of the people impacted are demonstrated in Table 6

Table 3: People impacted by climate hazards annually

	Period of change			People impacted by climate hazard annually						
Scenarios (change in fractional GDP Loss)	5 years (2021-2025)	10 years (2021-2030)	15 years (2021-2035)	2006	2019	2021	2025	2030	2035	2040
Baseline				6,825	9,408	9,643	10,911	12,344	13,966	15,416
25% loss increase	x			6,825	9,408	9,643	21,821	24,689	27,933	30,832
25% loss decrease	x	X		6,825	9,408	9,643	0	0	0	0
50% loss increase		X		6,825	9,408	9,643	38,187	67,894	76,816	84,790
50% loss decrease		x		6,825	9,408	9,643	0	0	0	0
75% loss increase			X	6,825	9,408	9,643	51,825	104,927	160,615	177,289
75% loss decrease			X	6,825	9,408	9,408	0	0	0	0

According to data from the GermanWatch, Liberia does not record high fatalities such as death, as a result of climate hazards. The annual climate fatality in Liberia is less than one person (Eckstein, Künzel et al. 2017). In 2006, nearly 7,000 people in Liberia were impacted by climate hazards. This impact is often in the form of loss of economic or social capital such as houses, farm products, social networks and relations, among others. Under the baseline scenario, the people impacted by climate hazards will increase 15,416 people by 2040.

Response mechanisms that result in up to 25% reduction in the fractional losses within the next five years will ensure that the economic impact of climate is eliminated. The 25%, 50%, and 75% increase scenarios, however, will see the people economically impacted by climate hazards to rise to 30,832, 84,790, and 177,289 people, respectively, by 2040. The behavioural graph people impacted annually by climate hazard under the different scenarios is shown in Figure 7.

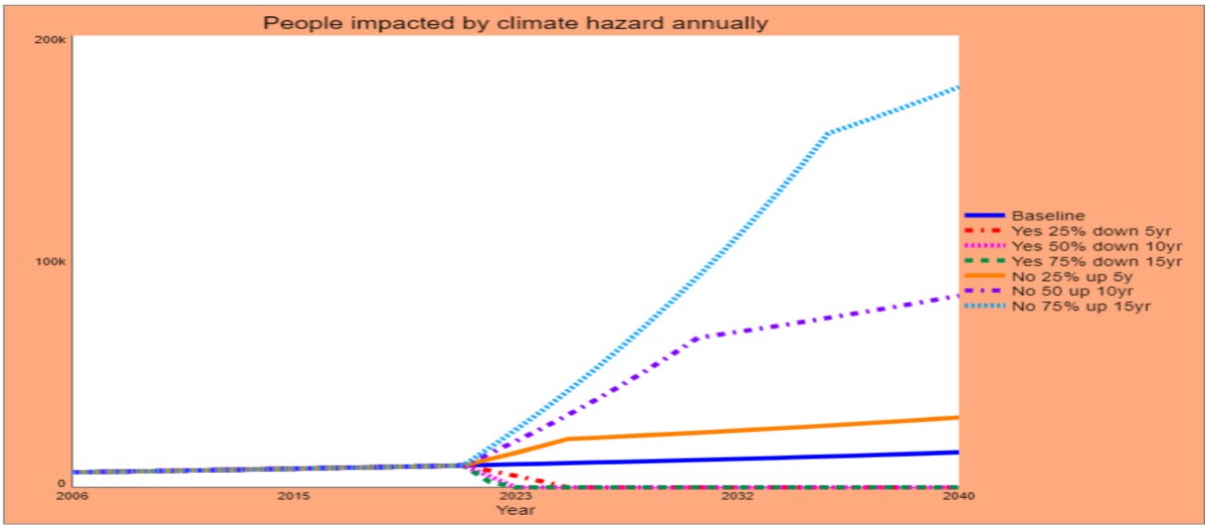

Figure 3: People impacted by climate hazards annually

1.4 Per capita income

The per capita income of Liberia increased steadily throughout the base period. In the baseline scenario, the per capita income is expected to increase from approximately US$ 680 in 2021 to US$ 934 by 2030 and US$ 1,183 in 2040 (see Table 7). The 25% increase and decrease of fractional GDP lost through climate hazard result in a per capita income of US$ 950 and US$ 1,431, respectively by 2040.

Table 4: Per capita income

	Period of change			**Per Capita Income (US$)**						
Scenarios (change in fractional GDP Loss)	5-years (2021-2025)	10 years (2021-2030)	15 years (2021-2035)	2006	2019	2021	2025	2030	2035	2040
Baseline				376	656	680	803	934	1,070	1,183
25% loss increase	X			376	656	680	800	895	946	950
25% loss decrease	x			376	656	680	807	973	1,198	1,431
50% loss increase		X		376	656	680	796	840	753	682
50% loss decrease		X		376	656	680	810	984	1,218	1,460
75% loss increase			x	376	656	680	793	794	702	636
75% loss decrease			X	376	656	680	811	987	1,223	1,467

The differences in per capita income under the different loss decrease scenarios is small throughout the simulation period. For example, under all the 25%, 50%, and 75% loss decrease scenarios, the per capita income in 2030 is US$ 973, US$ 984 US$ 987, respectively. This is because of the differences in the duration of change. The behavioural graph in Figure 8 depicts this similarity in outcome of these scenarios.

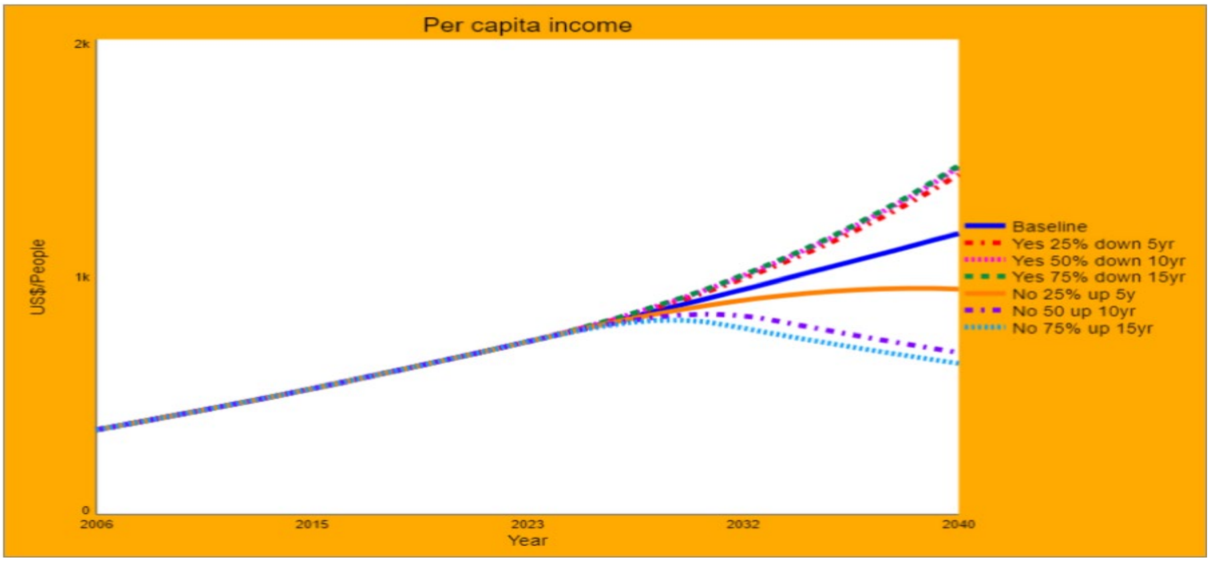

Figure 4: Per capita income

The sensitivity analysis revealed per capita income as one of the variables most sensitive to changes in the fraction of GDP recorded as climate losses. This is because per capita income is influenced by two major dynamic variables; GDP and population. The GDP and GDP growth are also significantly affected by climate hazards as economic activities are hindered.

There are various social losses that are not quantified in this model. The interpersonal relationships, the cultural activities and artefacts, the social networks, among others and not accounted for in this model. The losses presented are most likely to be an understatement rather than overestimation. Although the monetary value of climate hazard computed in this proposal may appear small, there are three critical reasons why this project is critical and should be funded:

1. The project is a sound economic investment because the returns on investment are financially profitable than the baseline scenario where this project is not executed.
2. Liberia is one of the Least Developed Countries in the world. These losses accruing from climate hazards are a menace to the country's economic output, and when juxtaposed with the annual GDP, a significant improvement in GDP growth rates will be realised.
3. The financial analysis in this proposal mainly focused on the economic aspect. The social cost of climate hazards, such as death, diseases, and loss of productive

working hours, among others, are not quantified. That paucity of socio-economic data of Liberia makes such estimates difficult. This is one of the key gaps this project responds to in its planned outputs.

The components and outputs elaborated in the proposal will lead to a climate-resilient outcome for Liberia. The project will aid in reducing the annual climate losses, result in fewer people being exposed to and impacted by climate hazards, and increase the per capita income of the country in general.

2 Financial Analysis

The paucity of consistent and accurate information on the economic and financial assessment of climate hazards in Liberia limits estimations of the potential impact of climate investment. This notwithstanding, detailed, and rigorous computations provide an understanding of the impact targeted investments, such as this project, can augment the level of accuracy of different future scenarios.

The A quantitative system dynamics model of Liberia was developed and simulated to ascertain the average annual cost of climate hazards and the number of people affected. The model made projections until 2040. The annual cost pf climate hazards, with GDP as a proxy, is then taken as the future potential cash inflow of the project since recovery is made out of these annual losses (see Table 8). Since the simulated results produced the potential future cash flow, different discount rates were then used to assess potential present value of those future cost. This resulted in the net estimated cash inflow based on recovery of climate cost recovered at different rate (see Table 9).

Once the annual present value is ascertained, periodic net present value is then calculated at five-year intervals: 2025, 2030, 2035, and 2040 for five, ten, fifteen, and twenty years scenarios (see Table 10). The matrix of discount rate and time resulted in multiple present values. These present values now reflect cash inflows while the project capital cost depicts the cash outflows. The four time periods and four discount rates yielded a total of sixteen net present values. Out of this total, only six were found to fall within a financially viable region for the project. These are highlighted in green. The other ten net present values resulted in negative net present values (highlighted in red) and are therefore not feasible cases for the project.

This significantly addresses the lack of empirical data in Liberia which makes the estimation of the potential cash flow based on a given amount of investment difficult. Rather than making extensive assumptions, the financial analysis in Table 10 demonstrates a feasibility region within which the financial viability of the project becomes apparent. For example, based on the present values calculated, it is observed that, the project is financially viable at a discount rate higher than 3.5%. At 5%, the project becomes financially viable after 15 years.

It is also viable after 10 years and five years is 10% and 15% of the present value of the annual losses attributed to climate hazards are recovered.

Table 5: Present value of modelled climate losses through hazards

		Modelled annual cost of climate hazards	Present value of projected annual climate cost at different discount rates			
Year			**3,5%**	**5%**	**10%**	**15%**
2021	1	$6 171 000	$5 962 319	$5 877 143	$5 610 000	$5 366 087
2022	2	$6 554 000	$6 118 229	$5 944 671	$5 416 529	$4 955 766
2023	3	$6 957 000	$6 274 815	$6 009 718	$5 226 897	$4 574 340
2024	4	$7 378 000	$6 429 501	$6 069 899	$5 039 273	$4 218 395
2025	5	$7 820 000	$6 584 230	$6 127 175	$4 855 605	$3 887 922
2026	6	$8 281 000	$6 736 599	$6 179 410	$4 674 409	$3 580 105
2027	7	$8 764 000	$6 888 425	$6 228 411	$4 497 318	$3 294 712
2028	8	$9 270 000	$7 039 745	$6 274 301	$4 324 523	$3 030 379
2029	9	$9 798 000	$7 189 096	$6 315 878	$4 155 308	$2 785 203
2030	10	$10 350 000	$7 337 310	$6 354 002	$3 990 373	$2 558 362
2031	11	$10 926 000	$7 483 717	$6 388 206	$3 829 496	$2 348 470
2032	12	$11 527 000	$7 628 376	$6 418 665	$3 672 857	$2 154 479
2033	13	$12 155 000	$7 771 957	$6 446 056	$3 520 871	$1 975 527
2034	14	$12 810 000	$7 913 785	$6 469 920	$3 373 273	$1 810 420
2035	15	$13 493 000	$8 053 845	$6 490 364	$3 230 117	$1 658 215
2036	16	$14 206 000	$8 192 684	$6 507 932	$3 091 640	$1 518 121
2037	17	$14 948 000	$8 329 082	$6 521 763	$2 957 382	$1 389 056
2038	18	$15 721 000	$8 463 575	$6 532 400	$2 827 560	$1 270 337
2039	19	$16 526 000	$8 596 093	$6 539 899	$2 702 133	$1 161 205
2040	20	$17 364 000	$8 726 554	$6 544 309	$2 581 048	$1 060 945

Table 6: Estimated cash flow at different cost recovery rates

Year	3,5%	5%	10%	15%
2021	$208 681	$308 550	$617 100	$925 650
2022	$229 390	$327 700	$655 400	$983 100
2023	$243 495	$347 850	$695 700	$1 043 550
2024	$258 230	$368 900	$737 800	$1 106 700
2025	$273 700	$391 000	$782 000	$1 173 000
2026	$289 835	$414 050	$828 100	$1 242 150
2027	$306 740	$438 200	$876 400	$1 314 600
2028	$324 450	$463 500	$927 000	$1 390 500
2029	$342 930	$489 900	$979 800	$1 469 700
2030	$362 250	$517 500	$1 035 000	$1 552 500
2031	$382 410	$546 300	$1 092 600	$1 638 900
2032	$403 445	$576 350	$1 152 700	$1 729 050
2033	$425 425	$607 750	$1 215 500	$1 823 250
2034	$448 350	$640 500	$1 281 000	$1 921 500
2035	$472 255	$674 650	$1 349 300	$2 023 950
2036	$497 210	$710 300	$1 420 600	$2 130 900
2037	$523 180	$747 400	$1 494 800	$2 242 200
2038	$550 235	$786 050	$1 572 100	$2 358 150
2039	$578 410	$826 300	$1 652 600	$2 478 900
2040	$607 740	$868 200	$1 736 400	$2 604 600

Table 7: Financial viability regions based on NPV

Period	Project cost	PV - 3,5%	NPV - 3,5%	PV – 5%	NPV - 5%	PV - 10%	NPV - 10%	PV - 15%	NPV - 15%
2025 (5 years)	$20 273 975	**$1 213 496**	**-$19 060 479**	**$1 744 000**	**-$18 529 975**	**$3 488 000**	**-$16 785 975**	**$5 232 000**	**-$15 041 975**
2030 (10 years)	$20 273 975	**$2 839 701**	**-$17 434 274**	**$4 067 150**	**-$16 206 825**	**$8 134 300**	**-$12 139 675**	**$12 201 450**	**-$8 072 525**
2035 (15 years)	$20 273 975	**$4 971 586**	**-$15 302 389**	**$7 112 700**	**-$13 161 275**	**$14 225 400**	**-$6 048 575**	**$21 338 100**	**$1 064 125**
2040 (20 years)	$20 273 975	**$7 728 361**	**-$12 545 614**	**$11 050 950**	**-$9 223 025**	**$22 101 900**	**$1 827 925**	**$33 152 850**	**$12 878 875**

Appendices

Appendix A

	Period of change				Annual Losses due to climate (in US$)					
Scenarios (change in fractional GDP Loss)	5 years (2021-2025)	10 years (2021-	15 years (2021-2035)	2006	2019	2021	2025	2030	2035	2040
Baseline				2,566,000	6,171,000	6,554,000	8,764,000	11,527,000	14,948,000	18,236,000
25% loss increase	x			2,566,000	6,171,000	6,554,000	17,452,000	22,090,000	26,438,000	29,276,000
25% loss decrease	x			2,566,000	6,171,000	6,554,000	0	0	0	0
50% loss increase		x		2,566,000	6,171,000	6,554,000	30,407,000	57,035,000	57,845,000	57,845,000
50% loss decrease		x		2,566,000	6,171,000	6,554,000	0	0	0	0
75% loss increase			x	2,566,000	6,171,000	6,554,000	41,085,000	83,318,000	112,720,000	112,720,000
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Baseline				376	656	680	803	934	1,070	1,183
25% loss increase	X			376	656	680	800	895	946	950
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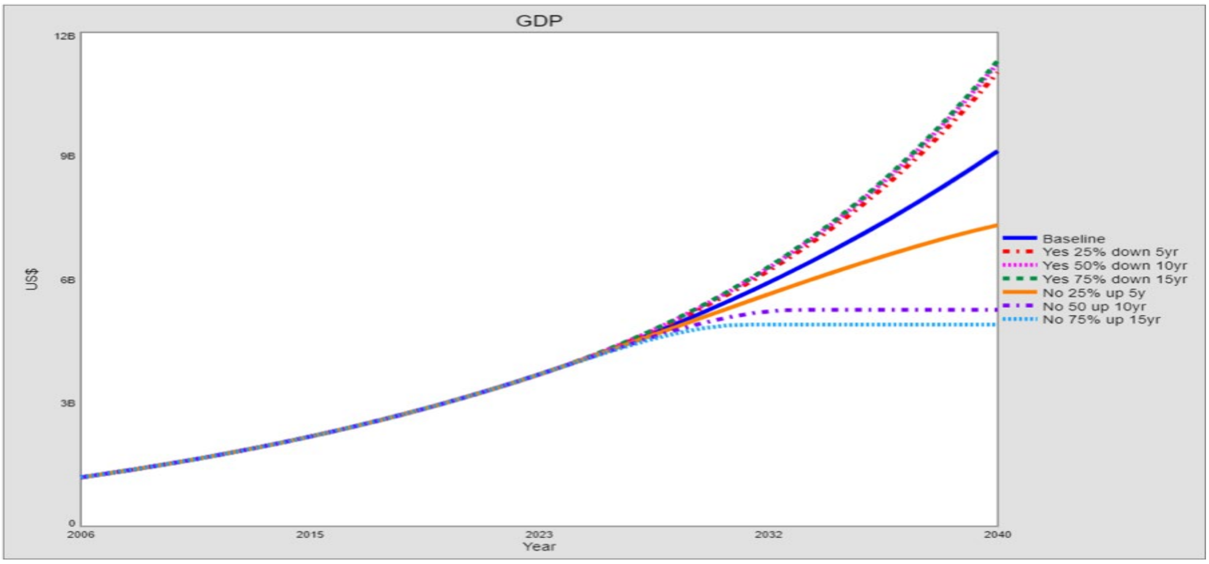
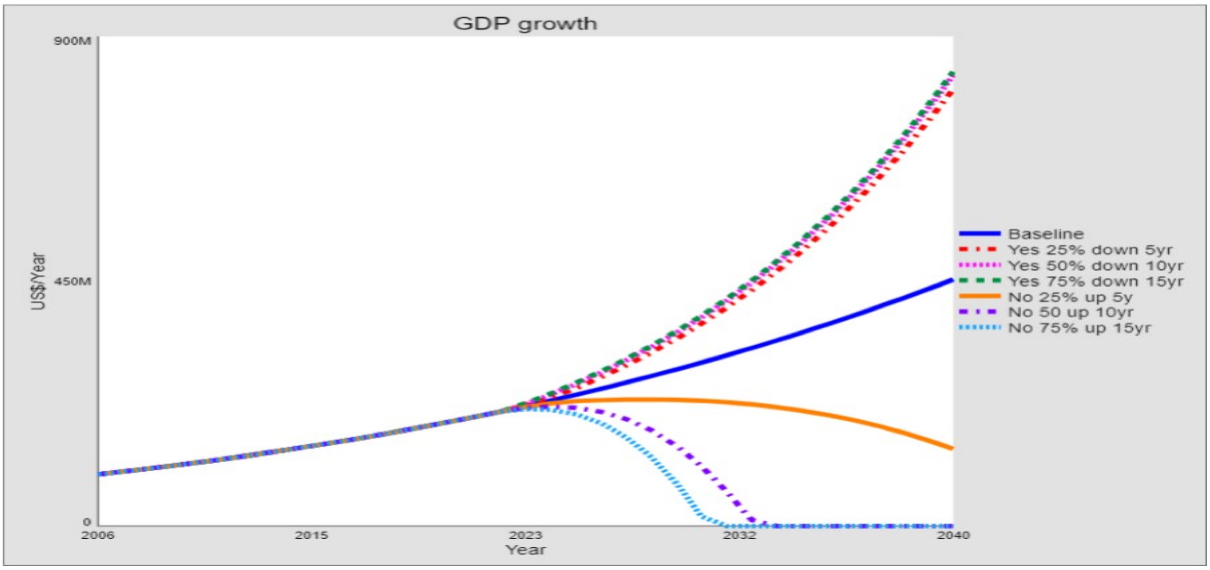
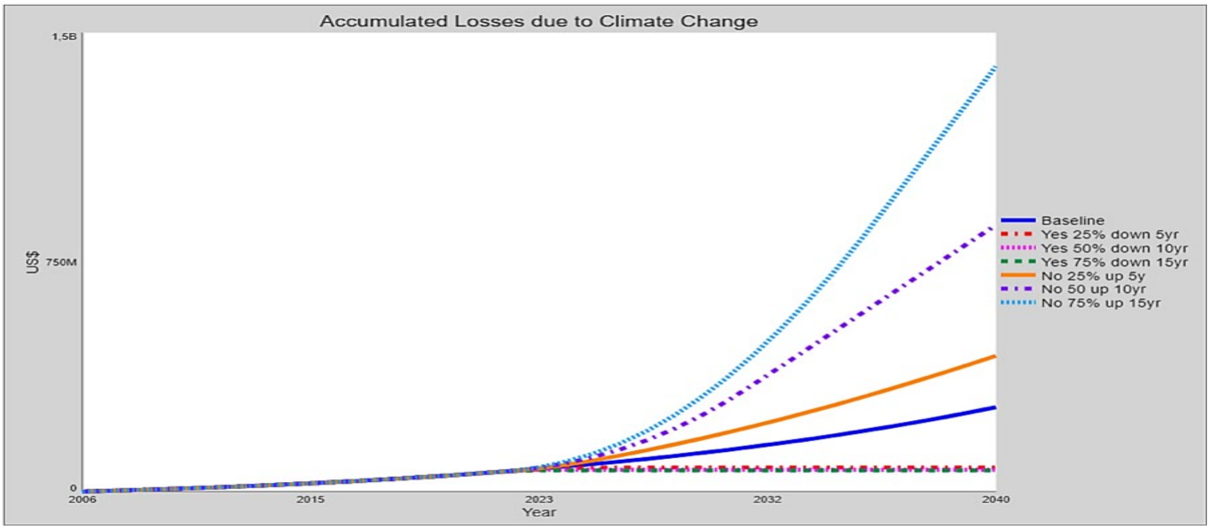
50% loss increase		X		376	656	680	796	840	753	682
50% loss decrease		X		376	656	680	810	984	1,218	1,460
75% loss increase			x	376	656	680	793	794	702	636
75% loss decrease			X	376	656	680	811	987	1,223	1,467

Appendix B


GDP
12B
9B
6B
3B
0
US$
2006
2015
2023
2032
2040
Year
Baseline
Yes 25% down 5yr
Yes 50% down 10yr
Yes 75% down 15yr
No 25% up 5y
No 50 up 10yr
No 75% up 15yr


GDP growth
900M
450M
0
US$/Year
2006
2015
2023
2032
2040
Year
Baseline
Yes 25% down 5yr
Yes 50% down 10yr
Yes 75% down 15yr
No 25% up 5y
No 50 up 10yr
No 75% up 15yr


Accumulated Losses due to Climate Change
1,5B
750M
0
US$
2006
2015
2023
2032
2040
Year
Baseline
Yes 25% down 5yr
Yes 50% down 10yr
Yes 75% down 15yr
No 25% up 5y
No 50 up 10yr
No 75% up 15yr