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The Costs of Climate Change Impacts for India

A Preliminary Analysis

VAIBHAV CHATURVEDI

ceew.in/publications

Thapar House
124, Janpath
New Delhi 110001
India

Tel: +91 11 40733300

info@ceew.in

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Author
Vaibhav Chaturvedi

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A working paper on 'The Costs of Climate Change Impacts for India: A Preliminary Analysis'.

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Council on Energy, Environment and Water
Thapar House, 124, Janpath, New Delhi 110001, India

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ABOUT THE AUTHOR

Dr Vaibhav Chaturvedi

Dr Vaibhav Chaturvedi is a Research Fellow at CEEW. Prior to CEEW, Vaibhav worked as a Post Doctoral Research Associate at the Joint Global Change Research Institute (JGCRI), collaboration between the Pacific Northwest National Laboratory, USA and the University of Maryland, College Park, USA. He holds a PhD in Economics from the Indian Institute of Management Ahmedabad, India and Masters in Forest Management from the Indian Institute of Forest Management Bhopal, India.

His research is focused on Indian and global energy and climate change mitigation policy issues- carbon dioxide emission stabilization pathways, low carbon and sustainable energy policies, modelling energy demand, and water-energy nexus within the integrated assessment modelling framework of the Global Change Assessment Model (GCAM). Vaibhav's recent work includes analyzing nuclear energy scenarios for India, Indian HFC emission scenarios, climate policy-agriculture water interactions, transportation energy scenarios, model evaluation, investment implications for the global electricity sector, and modelling the building sector energy demand scenarios for India. Vaibhav has been actively involved in global model comparison exercises like Asian Modelling Exercise (AME) and Energy Modelling Forum (EMF).

At CEEW, Vaibhav's research focuses on India within the domain of energy and climate policy, mid-range and long-range energy scenarios, HFC emission scenarios, urban energy demand pathways, and energy-water inter relationship. He has been actively publishing in leading international energy and climate policy journals.

CONTENTS

ABSTRACT

India has emphasised inclusion of adaptation as a part of Intended Nationally Determined Contributions (INDC). For understanding adaptation requirements, we need to understand and value climate change impacts first. This preliminary assessment tries to estimate the cost of global climate change impacts for India. The study aims at estimating first order costs for loss in agriculture productivity and impact on higher power generation requirement with increasing temperatures within a long term global integrated assessment modelling framework. The study also attempts to put a value on the health impacts from temperature rise.

The analysis highlights some important results. Climate change will result in significant economic losses for India across sectors. Production losses in rice, wheat and maize alone could go upto 208 Bn US$ and 366 Bn US$ in 2050 and 2100 respectively (all prices are in 2010 US$). Additional power generation could require incremental capital investment of 33 Bn US$ and 123 Bn US$ in 2050 and 2100 respectively for meeting higher cooling energy needs of India. Health impacts should be best measured in terms of deaths due to higher incidence of diseases. Diarrheal deaths will decrease with increasing incomes, deaths due to higher spread of Malaria will increase significantly to 5000 in 2050 to 19500 in 2100. Deaths related to Dengue will also increase. If disease related deaths are valued at life time earnings, then loss of economic output will be 2.5 Bn US$ and 21 Bn US$ in 2050 and 2100 respectively.

Even with a fairly limited inclusion of sectors, and linear representation of cost of impacts, we arrive at a range of .45% - 1.19% of India's GDP and .59% - 1.17% of India's GDP in 2050 and 2100 as the cost of global inaction on mitigating climate change. When non-linear impacts at higher temperatures are included and other sectors are also valued, the present estimate of cost of inaction is bound to multiply many folds.

This analysis intends to provide a solid basis for informed discussions around this issue in India as well as a as a ground for more detailed and insightful studies on costs of climate impacts for India.

1. INTRODUCTION

The Fifth Assessment Report of the IPCC (IPCC, 2014) has reiterated that climate change is real and its impact is being felt across countries of the world. Mitigation action is immediately required to limiting atmospheric concentration of greenhouse gases. Mitigation implies shifting away from current energy system to fundamentally different decarbonized energy system, and this shift entails cost. Mitigation cost is holding most governments away from investing in emission mitigation efforts at the scale and speed required to combat climate change. In absence of this investment, climate change is bound to happen, and the cost of climate change impacts will be increasingly borne by the world.

The influential study lead by Dr. Nicholas Stern, also known as the Stern review (Stern, 2006), was instrumental in highlighting the cost of climate change impacts. Impacts are varied in terms of their nature as well as intensity. Increased temperatures are expected to reduce agriculture productivity, increase incidences of vector borne diseases, impact hydrological cycle, impact biodiversity and ecosystems, and also lead to higher frequency and intensity of extreme events like cyclones among other impacts.

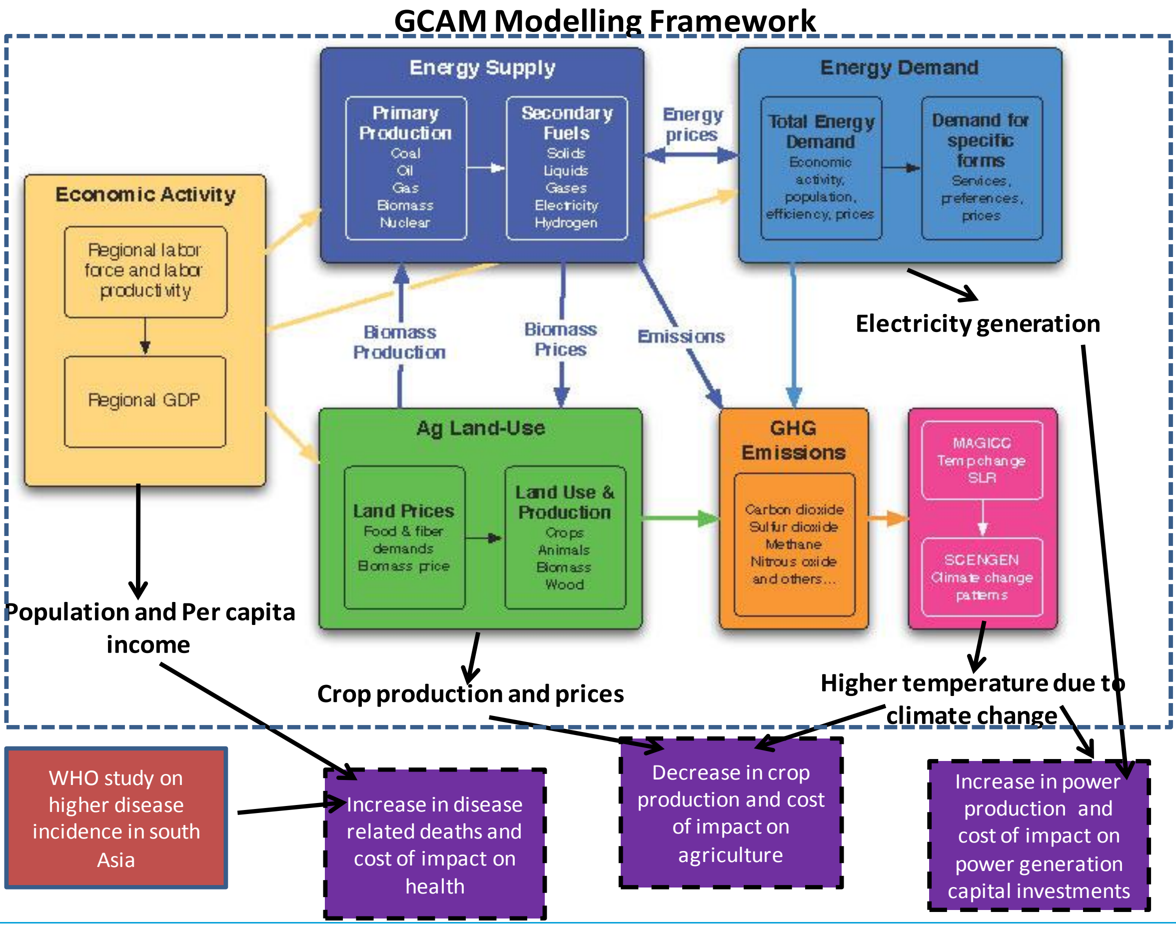
Climate change mitigation is a global challenge, however its impact will be varied across regions and temperature zones. Small island states will be hit the hardest with sea level rise. In bigger countries, India, owing to its large agricultural sector, vast population, rich biodiversity, long coastline, and high poverty levels is expected to be one of the most vulnerable countries. Also, India has pushed for inclusion of adaptation as a part of Intended Nationally Determined Contributions (INDC). For understanding adaptation requirements, we need to understand and value climate change impacts first. This short assessment tries to estimate the cost of global climate change mitigation inaction on India. We aim at estimating first order costs for loss in agriculture productivity, health impacts, and increased impact on increased power generation requirement with increasing temperatures.

2. METHODOLOGY

Our approach estimates the cost of key impacts for years 2050 and 2100. The rationale behind choosing main three impacts for cost assessment is the following- (i) India's agriculture sector is a livelihood source for more than 65% population, and agriculture productivity is considered to be low compared to global agricultural productivity. Moreover, Indian government's aim is to always be self-sufficient in terms of food production. Given these realities, any decline in agriculture production is bound to be costly for the nation and this cost needs to be assessed; (ii) With a huge population exposed to health impacts due to low resilience and income, any increase in chances of negative health impacts due to increased incidence of vector borne diseases will pose additional challenge especially for people from low income categories. Health is a social concern and health provision will be further challenged due to impacts from climate change; (iii) Extreme temperatures will in all likelihood increase maximum temperatures across days of the year, which determines increased cooling requirement. This is an energy sector impact as additional power plants will need to be installed, and it is important to know if this cost will be high or low for India.

The choice of above mentioned impacts doesn't mean that other impacts are negligible, this has been done simply because understanding behind numbers associated with either biodiversity loss or increase in intensity and frequency of extreme events is highly uncertain at best. Hence this analysis limits itself to the three impacts highlighted above. Also, within these sectors we limit ourselves so some key categories, as the motivation is to present indicative numbers and approximations which can act as a ground for further discussions and studies.

Figure 1: Methodological framework for understanding cost of inaction across key sectors



Source: CEEW

For understanding the cost of climate impacts on agriculture and additional power plant generation, output from Global Change Assessment Model (GCAM) is used. GCAM is a global integrated assessment model with a separate agriculture and land use system (Clarke et al., 2008; Calvin et al., 2009; Wise et al., 2009; Shukla and Chaturvedi, 2012; Chaturvedi et al., 2013a; Chaturvedi et al, 2014a). Information on total production of rice, wheat and maize in 2050 is derived based on business as usual (BAU) model run. Literature is reviewed to understand rate of decline in crop productivity due to increase in temperature in 2050 and 2100. On the basis of this information, total crop losses have been identified and valued based on prices in respective years. Details on GCAM's agriculture and land use module can be found in Wise et al. (2009) and Chaturvedi et al. (2013b).

GCAM also models cooling and heating demand based on cooling/heating degree days and a host of other factors. This modelling analysis will give information on whether increased energy demand for cooling will imply a significant cost for India or not for additional power generation infrastructure. Details of GCAM's building sector module can be found in

Chaturvedi et al. (2014b).

Finally health impacts are determined by linking increasing temperatures to increased incidence of diseases and what it means in terms of additional health costs based on literature. WHO has already done a detailed quantified assessment for the world and various regions (WHO, 2014). This analysis borrows results for south Asia from the WHO research and derives India specific health impact numbers based on the south Asian results.

3. RESULTS

3.1 Cost of agriculture production loss

Studies have shown that agriculture production is sensitive to temperature, increasing carbon dioxide concentration as well as change in precipitation. Impacts of all these forces together imply that agriculture production will respond non-linearly to future climate change. The impact however is complex to understand and as per the IPCC categorization, there is only medium confidence on the magnitude or direction of impacts. However, there is high level of agreement across studies that the impact in all probability is going to be negative for most crop categories.

For India, three crop categories are important from the perspective of food security- rice, maize and wheat. Table 1 shows results from few studies that have researched crop production losses for these key crops in India. Based on the numbers in the table, following is the range of yield decreases. We estimate cost for the higher end and lower end of this range, as well as for the mid-point -

Loss in rice production (impact sensitivity) per 1 degree Celsius increase = 4% - 20%
Loss in maize production (impact sensitivity) per 1 degree Celsius increase = 32% - 50%
Loss in wheat production (impact sensitivity) per 1 degree Celsius increase = 5% - 20%
It should be noted that these estimates include not just impacts due to higher temperatures, but also impacts of higher carbon dioxide concentrations in the atmosphere.

Table 1: Decline in production of rice, maize and wheat in India due to climate change				
Year	**Crop**	**Loss in production with approx. 1 Degree rise in temperature**	**Region**	**Reference**
NA	Rice	-20%	India	Senapati et al. (2013)
2030	Irrigated rice	4% loss in production in majority of districts	Western Ghats	Kumar et al. (2011)
2030	Irrigated rice	10% loss in production in majority of districts	Coastal Districts	Kumar et al. (2011)
2030	Irrigated rice	5% increase in production in majority of districts	North-East India	Kumar et al. (2011)
2030	Rainfed rice	10% loss in production in majority of districts	Western Ghats	Kumar et al. (2011)
2030	Rainfed rice	0% (mid point value)	Coastal Districts	Kumar et al. (2011)
2030	Rainfed rice	10% loss in production in majority of districts	North-East India	Kumar et al. (2011)
2030	Maize	50% loss in production in majority of districts	Western Ghats	Kumar et al. (2011)
2030	Irrigated maize	32% loss in production (mid point value across sub-regions)	Coastal Districts	Kumar et al. (2011)
2030	Rainfed maize	35% loss in production in majority of districts	Coastal Districts	Kumar et al. (2011)
2030	Irrigated maize	40% loss in production in majority of districts	North-East India	Kumar et al. (2011)
2030	Wheat	20% loss in production in majority of districts	North-East India	Kumar et al. (2011)
2020-30	Wheat	4-5 Mn Ton with 1 deg rise, relative to base year conditions. (In 2008 publication year, actual production was 78 Mn Ton. Implies 6% loss approx.)	India	Aggarwal (2008)
2004	Wheat	4 Mn Ton with 1 deg rise (Actual production in 2004 was 72 Mn Ton. Implies 5.3% loss approx.)	India	Samra and SIngh (2004)
Source: CEEW Analysis				

We use the following formulation to calculate the impacts of climate change on three major Indian food crops

$$CoI_{Ag,Y} = \{ Pdt_{BAU,Y} * (1 - [1 - ImS]^{Temp}{}_{Y})\} * P_{BAU,Y}$$

where

CoI is the Cost of Inaction in Million US$

Pdt is Production in Million Tonnes

Temp. is the temperature increase relative to BAU in Degree Celsius

ImS is Impact sensitivity of crop production to increase in temperature in % / Degree Celsius

P is Price in US$/Ton

Ag is the subscript denoting 'Agriculture', Y is the subscript denoting year under analysis and BAU is the subscript denoting 'Business as Usual' which implies a fixed climate.

Crop production, temperature and crop prices are outputs of GCAM. Impact Sensitivity is a crop specific constant derived from literature as highlighted above. It should be noted here that under the BAU also, crop productivity is assumed to increase across the century for all the crops in India. Temperature increase has been taken relative to 2005, which is the model base year. The function in curly brackets represents physical loss of production, which when multiplied by the price gives us the cost of loss in agricultural output. Table 2 shows us the loss in physical production as well as in terms of economic losses.

Table 2: Cost of impacts on agriculture sector food crops

	Pdt (MnTon) with fixed climate	Temperature increase relative to 2005	Impact sensitivity (% per Degree Celsius)			Global Crop Price	Loss in output (Million Tonnes)			Percentage loss in output (Relative to BAU)			Cost of Impacts- Million US$ (2010 prices)		
	Millon Tonnes	Degree Celsius	Low	Medium	High	2010 US$/kg	Low	Medium	High	Low	Medium	High	Low	Medium	High
2005															
Rice	136	0	4%	12%	20%										
Maize	15	0	32%	40%	50%										
Wheat	70	0	5%	12%	20%										
2050															
Rice	199	1.46	4%	12%	20%	2.26	11.51	33.88	55.33	6%	17%	28%	25997	76499	124931
Maize	24	1.46	32%	40%	50%	1.45	10.33	12.62	15.28	43%	53%	64%	14988	18299	22159
Wheat	115	1.46	5%	12%	20%	1.92	8.30	19.58	31.97	7%	17%	28%	15900	37518	61270
													56886	132317	208360
2100															
Rice	199	3.26	4%	12%	20%	2.18	24.80	67.82	102.86	12%	34%	52%	53994	147679	223967
Maize	27	3.26	32%	40%	50%	1.36	19.32	21.89	24.18	72%	81%	90%	26278	29777	32889
Wheat	121	3.26	5%	12%	20%	1.76	18.63	41.24	62.54	15%	34%	52%	32707	72388	109783
													112978	249844	366639

Source: CEEW Analysis

Literature shows that maize is going to impacted most due to temperature increase, followed by rice and wheat. A 3.25^{0}C increase in average temperatures by century end relative to 2005 can lead to more than 72%-90% decline in output of maize, 12%-52% decline in rice output and 15%-52% decline in wheat output. The total economic loss is 57-208 Bn US$ in 2050 and 113-367 Bn US$ in 2100. In terms of GDP share, this economic losses from these three crops amount for 0.28% -1.02% in 2050 and 0.26% - 0.84% in 2100 .

3.2 Cost of health impacts

Diarrheal related child mortality

A recent report by World Health Organization (WHO, 2014) highlights that increasing temperature will increase the rate of spread of Diarrhea related death. The study uses following function to estimate climate attributable Diarrheal deaths

$$n_{c,y,i,j} = N_{c,y} \frac{\exp[\beta i(\Delta T_{c,y,j})] - 1}{\exp[\beta i(\Delta T_{c,y,j})]}$$

where n is the climate attributable Diarrheal deaths

N is the Diarrheal deaths without any climate change, for reference

Δ T is the change in temperature with climate change relative to fixed climate

β denotes the sensitivity of Diarrheal death to temperature increase, and is calculated as $\beta = \log(1+\alpha)$, where α is linear increase in Diarrheal death per degree of temperature rise

Subscripts c denote s grid cell, y denotes time slice, j represents three different scenarios of temperature anomaly, and i denotes low, medium or high level of diarrheal related deaths

Malaria related mortality

Malaria is a diseases that has shown drastic decline with time as incomes across countries have risen. However, in low income countries of the world this is still the case. Interestingly in India Malaria related cases were reported to be around 2 Mn in 1990s, though WHO estimated this figure to be 15 Mn (Kumar et al., 2007). WHO (2014) has also estimated that with increasing incomes and no climate impacts, Malaria will be eliminated from all the regions of the world except from Africa by 2050.

WHO (2014) uses a regression equation to estimate the impact of increasing temperatures, changing precipitation and increasing income on the risk of population exposed to Malaria.

$$\text{logit}(Malaria_1) = \beta_0 + \beta_1 T\_min_1 + \beta_2 PR\_max_1 + \beta_3 \sqrt{(GDPpc_1)}$$

where T_min is the mean temperature of the coldest month

PR_max is the mean precipitation of the wettest month

GDP is the GDP per capita

i is the subscript for spatial grid location

Dengue related mortality

Dengue fever is transmitted as a vector diseases. Climate effects Dengue at a high rate in tropical regions as the transmission capacity increases. It is a diseases that has shown drastic decline with time as incomes across countries have risen. As in the case of Malaria, there are many factors that impact the spread of Dengue and hence the impact of climate change is uncertain at best.

WHO (2014) uses a regression equation to estimate the impact of increasing temperatures, changing precipitation and increasing income on the risk of population exposed to Dengue.

$$\text{logit}(Dengue_i) = \beta_0 + F(Temperature_i, Precipitation_i) + \beta_1 GDPpc_i$$

where Temperature is the annual mean temperature
Precipitation is the annual mean precipitation
F is a Spline function
GDP is the GDP per capita
i is the subscript for spatial grid location

Cost of climate change induced deaths

WHO (2014) estimates are based on sophisticated modelling at the grid level across various regions of the world. However, results are presented only for south Asia. This study assumes that for 2050, India will face same share of climate induced deaths as is the case for south Asia for all the diseases under analysis. For 2100, we use assumption based on the 2030 and 2050 share of deaths as modelled for south Asia.

For getting from number of deaths to cost of deaths, we have to put a value on life of a person, which is a debatable task. Though we believe that one value cannot be put to any life, we make some assumptions for the purpose of our calculations. The study assumes that any life lost leads to a loss in GDP, equal to income forgone for 50 years of work life. For putting a value of life in 2050, we add per capita income for India from 2005 and 2055, which signifies total income for a person across his or her work life. In other words this is the income forgone when a life is lost. For value of one life in 2100, we use a same approach and per capita income is added from 2050 to 2100. Table 3describes our assumption, calculations, and final result.

Table 3: Cost of impacts on human health due to higher disease burden

	2030	2050	2100	Source
South Asia				
Population (Million)	2749.43	3188.78		GCAM
Diarrheal Deaths	14870	7717		WHO (2014)
Malaria Deaths	1875	9343		WHO (2014)
Dengue Deaths	39	209		WHO (2014)
Diarrheal Deaths as a %	0.00054%	0.00024%	0.00005%	2100 value is an assumption based on 2030 and 2050 values
Malaria Deaths as a %	0.00007%	0.00029%	0.00126%	
Dengue Deaths as a %	0.000001%	0.00001%	0.00003%	
India				
Population (Million)		1736	1552	GCAM assumption
Diarrheal Deaths		4201	776	Based on WHO(2014). Percentages calculated for south Asia have been multiplied by Indian population
Malaria Deaths		5086	19537	
Dengue Deaths		114	470	
Assumed value of life (US$, 2010 prices)		265000	10,62,000	Based on per capita GDP in GCAM
Value of lives lost due to climate change induced effects				
Diarrheal Deaths (Million US$, 2010 prices)		1113	824	
Malaria Deaths (Million US$, 2010 prices)		1348	20748	
Dengue Deaths (Million US$, 2010 prices)		30	499	

Source: CEEW Analysis

As is evident, the results include the positive impact of rising incomes in India across century. Diarrheal risk should be eliminated by 2050 if there is no climate change impacts. However, climate change does lead to increase in deaths compared to the no climate change scenario. Most importantly, deaths related to Malaria are bound to increase significantly and the resulting loss of economic output is 20.7 Bn US$ in 2100 for Malaria alone.

3.3 Increased investment in electricity generation infrastructure

Climate change induced temperature increase is bound to increase space cooling demand in both residential and commercial sector. GCAM uses a detailed approach including technical and economic factors for modelling space cooling demand (Chaturvedi et al., 2014b). Following functional form is used for modelling cooling service demand-

$$d_C = k_C(CDD\eta r + \lambda_C IG)\left[1 - \exp\left(-\frac{\ln 2}{\mu_C}\frac{i}{P_C}\right)\right]$$

where d_c is the demand for cooling service per unit floorspace in EJ-output/m^2
CDD is cooling degree days in hr^{o}C which change over time,
η is thermal conductance or building U-value in GJ/m^2 $hr^{-1o}C^{-1}$,
r is building floor-to-surface area ratio representing the size of building shell exposed to outdoor temperature,
IG is the amount of building internal gains in GJ/m^2 and
λ_C is internal-gain scalar accounting for the potential mismatch of the time when space conditioning is required and the time when the internal gains are produced.
i is per capita income
P_c is the price of cooling service, which is endogenously determined
μ_c represents the parameter determining speed with which service demand increases in response to change in income and prices towards the satiation level

The term 'CDD' is what changes between a fixed climate and a changing climate. Fixed climate represents CDD for 2005, while changing climate corresponds to the higher temperature increase, close to 4^0 C observed by the century end. GCAM does not model peak and base load demand separately and treats all the technologies equally, which can be regarded as a limitation of the model. Hence, in the model, this increased demand for electricity production is distributed between different technologies like coal, gas, nuclear, solar, etc on the basis of relative cost dynamics. However, it is assumed here that all this increase will be for meeting peak energy demand and hence a gas based power plant is most suitable for meeting peak power demand. On the basis of GCAM output as well as capital cost assumptions based on Annual Energy Outlook (AEO, 2013), we calculate the increase in power plant related investment requirements (Table 4).

Table 4: Cost of impacts on power sector for meeting higher peak energy demand

	2050		2100		Source
	Fixed climate	Changing climate	Fixed climate	Changing climate	
Electricity production (EJ)	27.41	27.87	34.78	36.50	GCAM
Increase in production (EJ)		0.46		1.72	GCAM
Conversion: KWh/GJ		277.78		277.78	
Increase in production (GWh)		128846.80		476942.82	
Gas power plant capacity factor		0.40		0.40	Assumption
Hours in a year		8760.00		8760.00	
Increase in production (GW)		36.77		136.11	
Capital cost of gas power plant (US$/KW of installed capacity, 2010 prices)		905.00		905.00	AEO (2013)
Total additional investment (Million US$, 2010 prices)		33278		123183	

Source: CEEW Analysis

Temperature induced higher peak load and cooling energy demand will lead to additional installed capacity of 36 GW in 2050 and 136 GW in 100. Total generation capacity needs to increase by 9-10 folds by 2100 for power consumption equal to average developed country levels, or above 2000 GW of installed capacity in the distant future across all technologies like nuclear, solar, coal, etc. If the additional power demand is met by a technology with higher average capacity factor like say coal, then the additional installed capacity will be much lower. However, it makes most sense to install gas based power production for meeting additional peak load demands as this technology gives low cost flexibility to meet hourly power generation requirements.

4. CONCLUSION AND LIMITATIONS

The Stern Review (Stern, 2006) highlights that the total cost of climate change under BAU is estimated to be at least 5% of the value of global per capita consumption over the next two centuries. Indeed India is one of the most vulnerable countries to climate change impacts. Climate change impacts are many and varied, and the present analysis only offers limited initial insights.

The study aims at only first order approximations, and the motivation behind this analysis is to start a wider discussion for a more robust assessment of climate impacts and their valuation across sectors in India, all within the same analytical framework. Hence in the agriculture sector, the study has looked only at output losses of three major food crops- rice, maize and wheat. However climate change will impact all categories of crops ranging from oilseeds to fruits and vegetables. Health impacts of climate change include mortality at old age due to heat waves, higher incidence of malnutrition, etc. while we have focused on deaths related to three important diseases- Diarrhea, Malaria, and Dengue.

Impacts on energy infrastructure will be many, the analysis has focused on increased requirement of power generation for meeting peak hour demand of electricity. Apart from the three sectors that have been included in the study, climate change impacts hydrological flows, biodiversity, etc. and increased intensity and frequency of extreme events are also critical. Table 5 summarizes the cost of inaction calculated across sectors focused in this study.

Table 5: Summary of cost of inaction across sectors

	Cost of inaction in absolute terms				As percentage of GDP	
	2050	2100			2050	2100
GDP	20456125	43792770	Million 2010 US$		100%	100%
Agriculture						
Rice	25997-124931	53994-223967	Million 2010 US$		0.13% - 0.46%	0.12% - 0.51%
Maize	14988-22159	26278-32889	Million 2010 US$		0.07% - 0.11%	0.06% - 0.08%
Wheat	15900-61270	32707-109783	Million 2010 US$		0.08% - 0.30%	0.07% - 0.25%
Total	56886-208360	112978-366639	Million 2010 US$		0.28% - 1.02%	0.26% - 0.84%
Health						
Diarrheal Deaths	1113	824	Million 2010 US$		0.01%	0.00%
Malaria Deaths	1348	20748	Million 2010 US$		0.01%	0.05%
Dengue Deaths	30	499	Million 2010 US$		0.00%	0.00%
Total	2491	22072	Million 2010 US$		0.01%	0.05%
Electricity						
Gas based peak power	33278	123183	Million 2010 US$		0.16%	0.28%
GRAND TOTAL	**92-244**	**258-522**	**Billion 2010 US$**		**0.45% - 1.19%**	**0.59% - 1.17%**

Source: CEEW Analysis

The analysis highlights some important results. Climate change will result in significant economic losses for India across sectors. Major food crops losses could go upto 208 Bn US$ and 366 Bn US$ in 2050 and 2100 respectively (all prices are in 2010 US$). Additional power generation requirements could require additional capital investment of 33 Bn US$ and 123 Bn US$ in 2050 and 2100 respectively for meeting higher cooling energy needs of India. Health impacts should be best measured in terms of deaths due to higher incidence of diseases. Diarrheal deaths will decrease with increasing incomes, deaths due to higher spread of Malaria will increase significantly to 5000 in 2050 to 19500 in 2100. Deaths related to Dengue will also increase. If disease related deaths are valued at life time earnings, then loss of economic output will be 2.5 Bn US$ and 21 Bn US$ in 2050 and 2100 respectively. Even with a fairly limited inclusion of sectors, and linear representation of cost of impacts, we arrive at a range of .45% - 1.19% of GDP and .59% - 1.17% of GDP in 2050 and 2100 as the cost of inaction. When non-linear impacts at higher temperatures are included and other sectors are also valued, the present estimate of cost of inaction is bound to multiply many folds.

The present analysis, though indicative in nature, is instrumental in giving a good sense of magnitude of the cost of climate change impacts on some key sectors within India. There would be alternative methodological approaches to understand and evaluate impacts of climate change for different sectors within India. The analysis intends to provide a solid basis for informed discussions around this issue in India as well as a as a ground for more detailed and insightful study on costs of climate impacts in India.

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Council on Energy, Environment and Water,
Thapar House, 124, Janpath, New Delhi 110001, India

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