PREPARING INDIA'S OIL and GAS Sector for Changing Climate

teri

The Energy and Resources Institute

Certificate of originality

An original work by TERI done under the project 'A study on Climate Change Risks and Preparedness for Oil and Gas Sector in India'

Suggested format for citation

TERI. 2018. Preparing India's Oil and Gas Sector for Changing Climate. New Delhi: The Energy and Resources Institute 28 pp.

Disclaimer

This document is an output of a research exercise undertaken by TERI supported by the FIPI for the benefit of the Oil and Gas sector in India. While every effort has been made to avoid any mistakes or omissions, TERI and FIPI would not be in any way liable to any persons/organizations by reason for any mistake/ omission in the publication.

Published by
T E R I Press
The Energy and Resources Institute, Darbari Seth Block, IHC Complex, Lodhi Road
New Delhi-110 003, India

For more information
Project Monitoring Cell
T E R I, Darbari Seth Block
IHC Complex, Lodhi Road
New Delhi – 110 003
Tel: 2468 2100 or 2468 2111
E-mail: pmc@teri.res.in
Web: www.teriin.org

PREPARING INDIA'S OIL and GAS Sector for Changing Climate

The Energy and Resources Institute

Acknowledgements

Advisors
TERI : Mr. Prabir Sengupta, Dr. Prodipto Ghosh, Mr. P.K. Agarwal,
FIPI:N.K. Bansal, Mr. S. Rath

Authors
Manish Kumar Shrivastava, Saurabh Bhardwaj, Ritu Mathur, Barath Mahadevan, Swati M. D'Souza, Swapnil Shekhar, Prasoon Singh, Santosh Kumar Muriki, Mihir Mathur, and A. Subramanian

This issue brief is based on the initial findings of an on-going study "A Study on Climate Change Risks and Preparedness for Oil & Gas Sector in India" at TERI supported by ONGC, IOCL, HPCL, BPCL, GAIL-India, Oil India Ltd., and PLL,
and facilitated by the Federation of Indian Petroleum Industry (FIPI) and technical inputs by the Engineers India Limited (EIL).

1. Background

The Paris Agreement on climate change requires countries to better document their mitigation, adaptation challenges and efforts as well as progressively revise their nationally determined contributions (NDCs) towards achieving the global goal of limiting mean temperature rise to well below 2°C. India's NDC sets a target of reducing emission intensity of GDP by 33% to 35% from 2005 levels by 2030 with an installed non-fossil fuel based power generation capacity amounting upto 40%. Increasingly reduced reliance on fossil fuels, including oil and gas, is the essence of India's NDC. In the Indian context, the oil and gas sector, however, epitomizes the development vs. climate change debate. The sector is critical for India's energy security as well as its growth trajectory. In 2017, oil and gas constituted over one third of India's primary energy mix. India is a net exporter of refined oil products, and gas is a mainstay of India's pursuit to increase agricultural productivity through use of fertilizers, provision of cleaner and efficient cooking, and a cleaner fuel for transportation and power. Heavy reliance on oil and gas sector for transportation of people, goods, and services makes it the life-line for smooth functioning of the economy and, in the absence of alternative viable technologies, foundational to achieving high economic growth. With rapid urbanization where it is estimated that about 60% of the Indian population will live in urban areas, greater increase in provisioning of transport and cleaner cooking services would mean deeper reliance on oil and gas. Moving away from oil and gas in the immediate future, therefore, would be equivalent to deviating away from higher levels of development itself.

Various modelling studies show that achieving the target set in the Paris Agreement to limit the temperature rise to well below 2°C would require decarbonization of the energy sector and electrification of transport sector. According to the International Energy Agency, stagnation in the global consumption of oil and marginal rise in global consumption of natural gas post 2020 is anticipated. Recent policy initiatives in India on renewable energy, energy efficiency and electric vehicles align with the direction of such deviation away from fossil fuels. While both IEA and BP project India and China accounting for half of the increase in demand for oil and gas through 2030s, how long it will actually take for the oil and gas sector in India to feel the impact of transition towards low-carbon development is subject to pace of technological change in the electric vehicles and renewable energy sector.

The other side of the debate, comparatively less discussed, is the fact that unmitigated climate change poses a threat of increased frequency and intensity of extreme climatic events such as extreme rainfall, heat waves, cyclones, storm surges, droughts, etc. as well as other risks such as reduction in water availability, agricultural productivity, loss of land mass, increase in heat stress and vector borne diseases, etc. Past experience shows that, of the range of risks posed by climate change, the oil and gas sector is vulnerable primarily to extreme climatic events such as cyclones, storm surges, and floods. It is also sensitive to slow onset events, such as rise in mean ambient temperature, increased water scarcity, and declining soil moisture. The physical infrastructure as well as efficiency of processes are sensitive to climatic conditions. The impacts could range from financial losses to serious

Past experience shows that, of the range of risks posed by climate change, the oil and gas sector is vulnerable primarily to extreme climatic events such as cyclones, storm surges, and floods. It is also sensitive to slow onset events, such as rise in mean ambient temperature, increased water scarcity, and declining soil moisture

infrastructure damage. Disruption in the supply chain of the oil and gas sector can also significantly hamper other economic sectors. Given that India’s oil and gas infrastructure sustains more than a third of India’s primary energy supply, which is likely to grow in absolute terms for at least two decades, these potential impacts are a reason for worry from reliable energy supply point of view. Moreover, since these impacts may vary depending on the location, a better understanding of potential impacts is necessary for improved resilience of India’s oil and gas sector to the threats of climate change. The vast infrastructure spread across the land-locked locations, coastal areas, and deep sea make it vulnerable to a range of climatic events, such as cyclones, storm surges, floods, heat waves etc., to varying degrees. There have been instances in the past where occurrence of extreme climate events have led to damage to infrastructure or disruption in operations causing significant losses to companies as well as economic losses to the economy.

Climate change thus poses three types of challenges to the oil and gas sector. First, and the obvious, challenge is the threat to the future of industry itself due to the need for mitigating greenhouse gas emissions. Second, is the risks to the infrastructure and operations, particularly due to extreme weather events. Third, relates to the nature of the Paris Agreement requiring improved transparency in accounting of greenhouse gas emissions. In this issue brief, these three challenges are explored for India’s oil and gas sector.

> **Risk to infrastructure is a function of its vulnerability and exposure to climatic event. Vulnerability implies that the infrastructure is likely to be negatively affected if it is exposed to a climatic event. Exposure implies occurrence of a climatic event at the location of the infrastructure.**

2. Risks to infrastructure

Risk to infrastructure is a function of its vulnerability and exposure to climatic event. Vulnerability implies that the infrastructure is likely to be negatively affected if it is exposed to a climatic event. Exposure implies occurrence of a climatic event at the location of the infrastructure. It is critical to understand that the primary impact of climate change will be in terms of changed pattern of exposure at different locations. A particular climatic event, such as extreme rainfall, may become more (or less) frequent or more (or less) intense compared to past patterns. Hence, when considering climate change induced risks to infrastructure, we consider how risk profile at a given location is likely to change with respect to existing risk profile. We also consider that if similar assets are equally exposed to same climatic event, the asset with higher capacity is at higher risk in terms of financial losses.

a. Vulnerability of Oil and Gas Sector

Climatic events fall in two categories: extreme events and slow onset events. Extreme events include once in a while intense events such as cyclones, storm surges, extreme rainfalls, etc. causing high losses. Slow onset events include change in climatic conditions which will occur at a slow rate over a period of time but will have far reaching impacts, such as rise in ambient temperatures as well as sea surface temperature, sea level rise, reduction in soil moisture, etc. While infrastructure is mostly vulnerable to extreme events, processes and operations are sensitive to slow onset events as well. The infrastructure of pipelines is also sensitive to soil moisture. Based on literature review, past experiences, and interaction with technical experts running operations in the oil and gas industry, sensitivities of key infrastructure to various climatic events or impacts of climate change are summarised in Table 1 below: the projection of climatic parameters related to temperature and precipitation, regional climate model PRECIS has been used. These future projections have been combined with historical observations to avoid overstatement of change. For example, if the historical rainfall at a given location has been low then a greater change would be less significant compared to medium change

Table 1: Sensitivity of Oil and Gas infrastructure to climatic impacts

Infrastructure	Sea level rise/ Cyclone/ Storm surge	Floods	Temperature rise	Water scarcity	Change in soil moisture	Lightning
Off shore E&P	✓					
Coastal E&P	✓	✓				
Land locked E&P						
Refineries/ Petrochemical Plants	✓	✓	✓	✓		
Ports/LNG terminals	✓		✓			✓
LNG regasification plants	✓		✓			
Gas compressor stations	✓		✓			
C2/C3 Recovery plants	✓	✓	✓			
Crude, Product and LNG pipelines		✓			✓	
LPG pipelines		✓			✓	
Storage tanks		✓				✓
Road based product evacuation	✓	✓				✓

"While infrastructure is mostly vulnerable to extreme events, processes and operations are sensitive to slow onset events as well. The infrastructure of pipelines is also sensitive to soil moisture"

b. Change in exposure

Change in exposure to different climate events at different locations is projected for the time period 2020-2050 with respect to the baseline of 1970-2000. For at a location with high historical rainfall. The parameters used for projecting change in exposure in future are summarized in Table 2.

Table 2: Parameters for projecting change in pattern of climatic events

Climatic Event	Historical pattern	Projection of Change
Floods	➢ Past occurrences (1985-2011)[a] ➢ Exposure to cyclone[b]	➢ Change in no. of extreme rainfall days (99^{th}percentile events) during 2020-2051 over 1970-2000[c] ➢ Change in mean annual rainfall during 2020-2051 over 1970-2000[c]
Water Scarcity	➢ Drought intensity of past occurrences (1985-2011)[a] ➢ Water stress (1985-2011)[a]	➢ Change in cumulative dry days in a year during 2020-2051[c]
Lightning	➢ Average annual rainfall during 1970-2000[c]	➢ Change in no. of extreme rainfall days (99p) during 2020-2051 over 1970-2000[c]
Temperature	➢ Mean annual temperature[c]	➢ Change in mean annual temperature (2020-2051 over 1970-2000)[c] ➢ Change in number of hot days (>45^{0}C)[c] (2020-2051 over 1970-2000)
Change in Soil moisture	➢ Drought intensity of past occurrences (1985-2011)[a] ➢ Water stress (1985-2011)[a]	➢ Change in number of hot days (>45^{0}C) (2020-2051 over 1970-2000)[c] ➢ Change in cumulative dry days in a year during 2020-2051[c]
Cyclones and storm surges	➢ Past occurrences (1985-2015)[d]	➢ Extrapolated trend of sea surface temperature and sea level rise.[e]

Notes:
a: Aqueduct Global Maps 2.0
b: geographic location
c: PRECIS model results (TERI)
d: Cyclone eAtlas-IMD
e: INCCA-MoEF (2010)

c. Change in risk profile

Cyclones and Storm surges

Impacts of cyclones and sea level rise are felt in the form of storm surges in coastal areas. Historically, over a period of 1891 to 2008, it has been observed that 78% of the cyclones (485 in total) were formed over the Bay of Bengal.[1] For the Indian sub-continent May, June, September and October are the cyclone prone months. TERI's analysis over the West Bengal coast, projects that frequency of intense cyclones in the category of Cyclonic Storms (Wind speed 62-88km/h) and Severe Cyclonic Storms (wind speed 89-117 km/h) will increase during the months of September and October. Other studies conclude that the future surges on the East Coast would be 15-20% higher than the historical pattern, particularly at Visakhapatnam, Kalingapatnam, Gopalpur, Paradip, False Point and Short Island stations.[2] Accordingly, with

[1] Niyas N T, Srivastava A K and Hatwar H R, (2009): Variability and trend in the cyclonic storms over the North Indian ocean, Meteorological Monograph No Cyclone Warning - 3/2009.

[2] Unnikrishnan A.S., Ramesh Kumar M.R. and B. Sindhu, 2011, Tropical cyclones in the Bay of Bengal and extreme sea-level projections along the east coast of India in a future climate scenario, Current Science, Vol. 101, No. 3, pp. 327-331

increased frequency of intense cyclones, frequent and higher storm surges are likely on the East Coast. The West Coast is relatively less studied, yet a similar trend of rise in intensity of cyclones has been observed in the recent past.[3] A recent study[4] has reported that the sea surface temperature of the Arabian Sea has been consistently rising at a faster rate in recent decades leading to relatively higher cyclonic activity. With increasing global warming and sea surface temperature the risks to the West Coast of India with respect to cyclones are likely to increase. Most of the oil and gas assets and basins lie in the cyclone movement paths as well as near the landfall regions (Figure 1). It is also seen that most of the recent high intensity cyclonic storms have resulted in landfalls. To precisely assess the extent of infrastructural damage on a particular asset, more detailed region specific study is required taking into account the specific details of assets in that region.

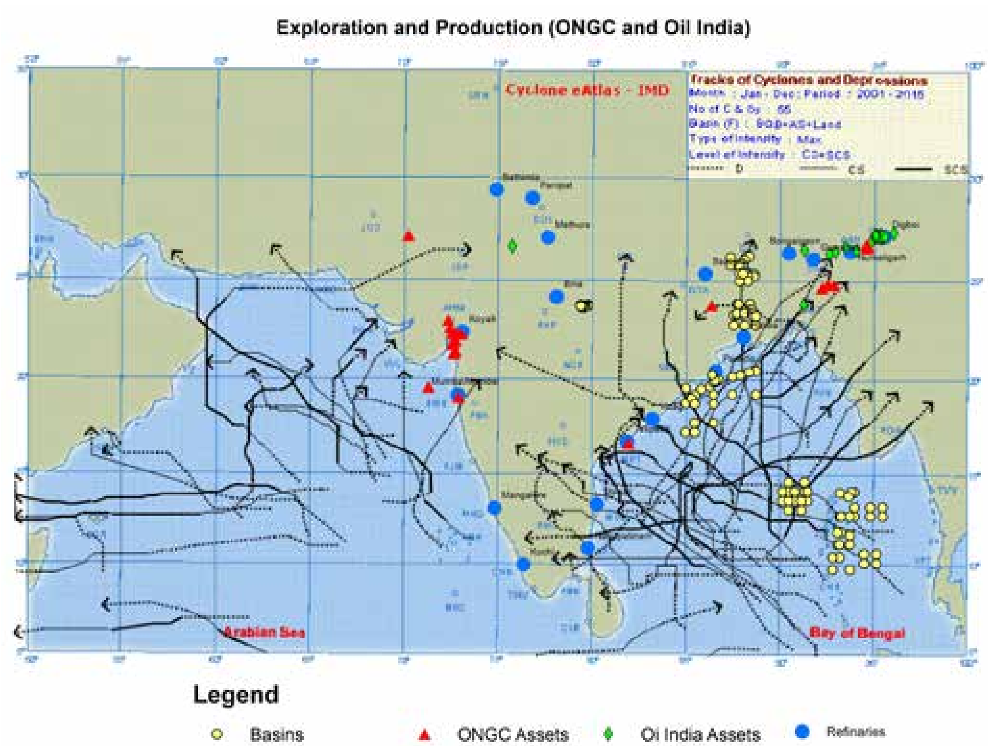

Figure 1: Tracks of cyclonic storms and depressions over Indian Coastlines from 2001-2015 with locations of Oil and Gas assets.

Most of the oil and gas assets and basins lie in the cyclone movement paths as well as near the landfall regions. It is also seen that most of the recent high intensity cyclonic storms have resulted in landfalls

[3] Murakami H., Gabriel A. Vecchi and Seth Underwood, 2017, Increasing frequency of extremely severe cyclonic storms over the Arabian Sea.Nature Climate Change, 7, 885–889.

[4] S. Prasanna Kumar, Raj P. Roshin, JayuNarvekar, P.K. Dinesh Kumar, E. Vivekanandan. Response of the Arabian Sea to global warming and associated regional climate shift.Marine Environmental Research, Elsevier, 2009, 68 (5), pp.217.

Extreme rainfall, floods, and lightning

Oil and gas operations are sensitive to flooding. Impacts include full or partial shutdown of refineries, disruption in road based supply chain, including road accidents, ruptures in pipelines, disrupted access to infrastructure for maintenance and repair, etc. This study projects an overall increase in annual rainfall upto 32% along with increase in number of extreme rainfall days in a year. This is likely to contribute to an overall increase in exposure to flood risk across India. Largest increase will be experienced in the North-Western parts of India (Figure 2a, 2b, and 2c). Accordingly,

This study projects an overall increase in annual rainfall upto 32% along with increase in number of extreme rainfall days in a year. This is likely to contribute to an overall increase in exposure to flood risk across India.

Increase in flood risk to oil refineries

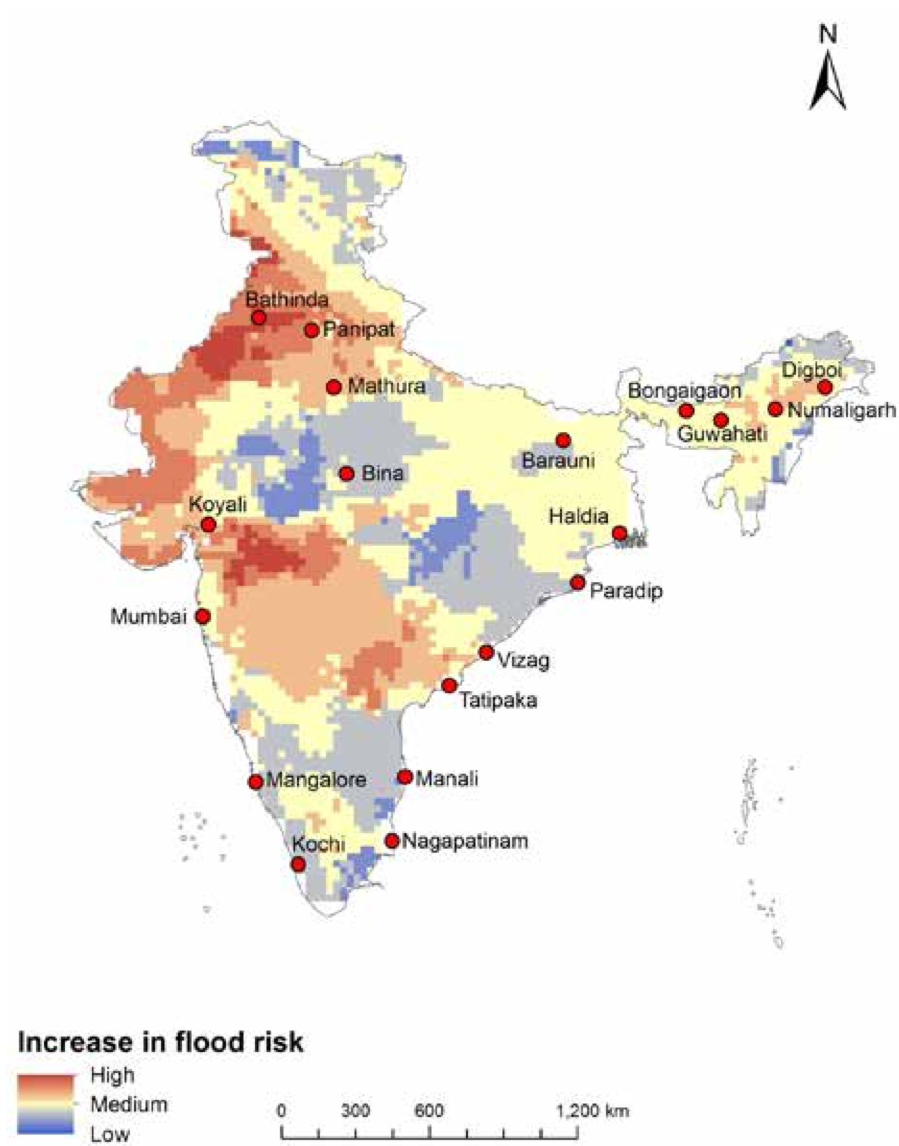

Figure 2a Change in flood risks to refineries

the disruptions and losses to oil and gas industry due to floods in this area are likely to be more stringent than earlier experiences. It must be kept in mind that actual impact of floods depends on a number of other factors as well, such as land use pattern, topography of the region, etc. Hence, detailed localised flood modelling studies for specific infrastructure in this area need to be carried out.

Statistically, a strong correlation has been found between the instances

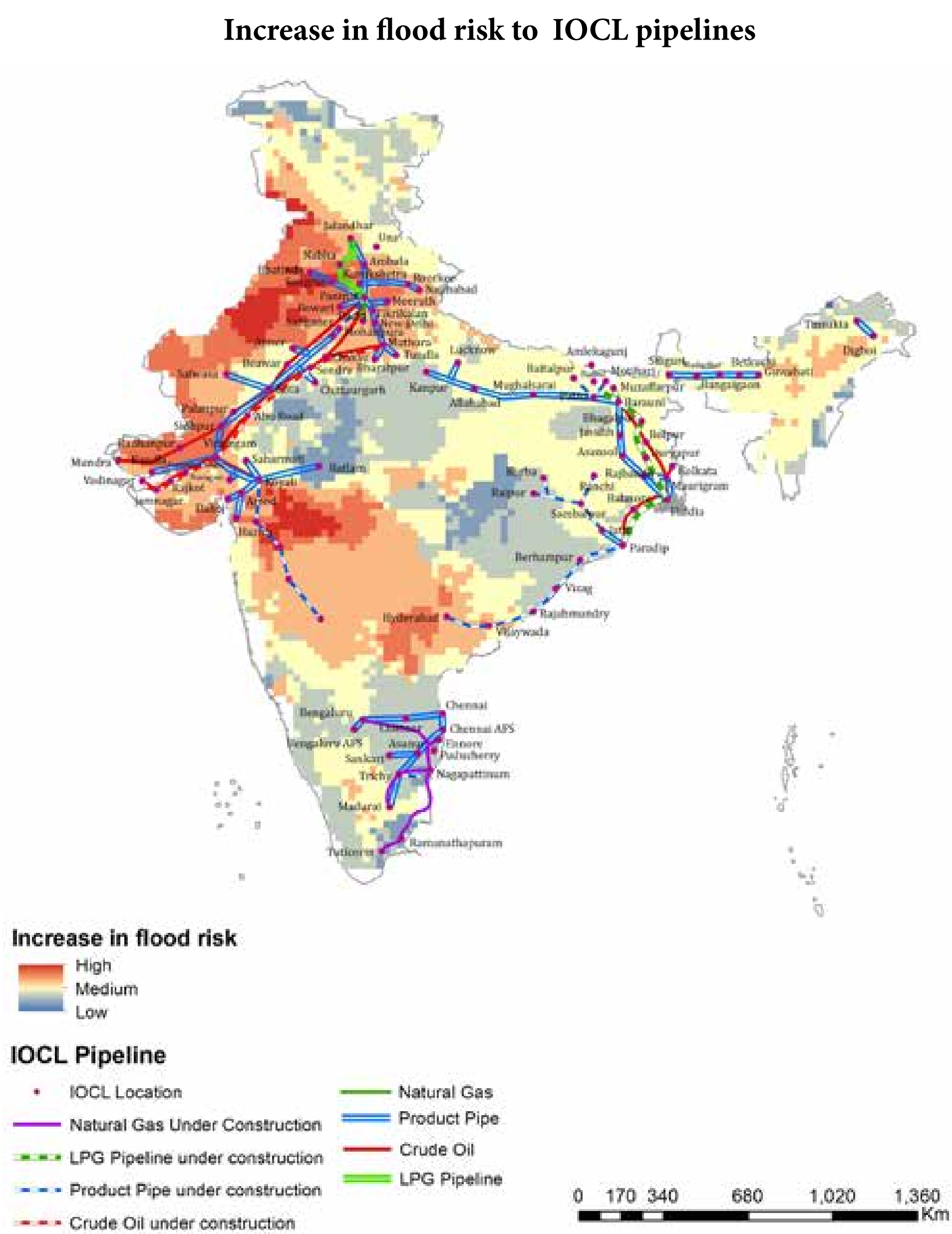

Figure 2b Change in flood risks to IOCL pipelines

of heavy rainfall and flash rates of lightning strikes.[5] Hence, in addition to lightning continuing as a risk in regions with historically high rainfalls, particularly the North-East and East Coast, its frequency and intensity is likely to increase in the North-West India where both annual rainfall as well as

Increase in flood risk to GAIL pipelines

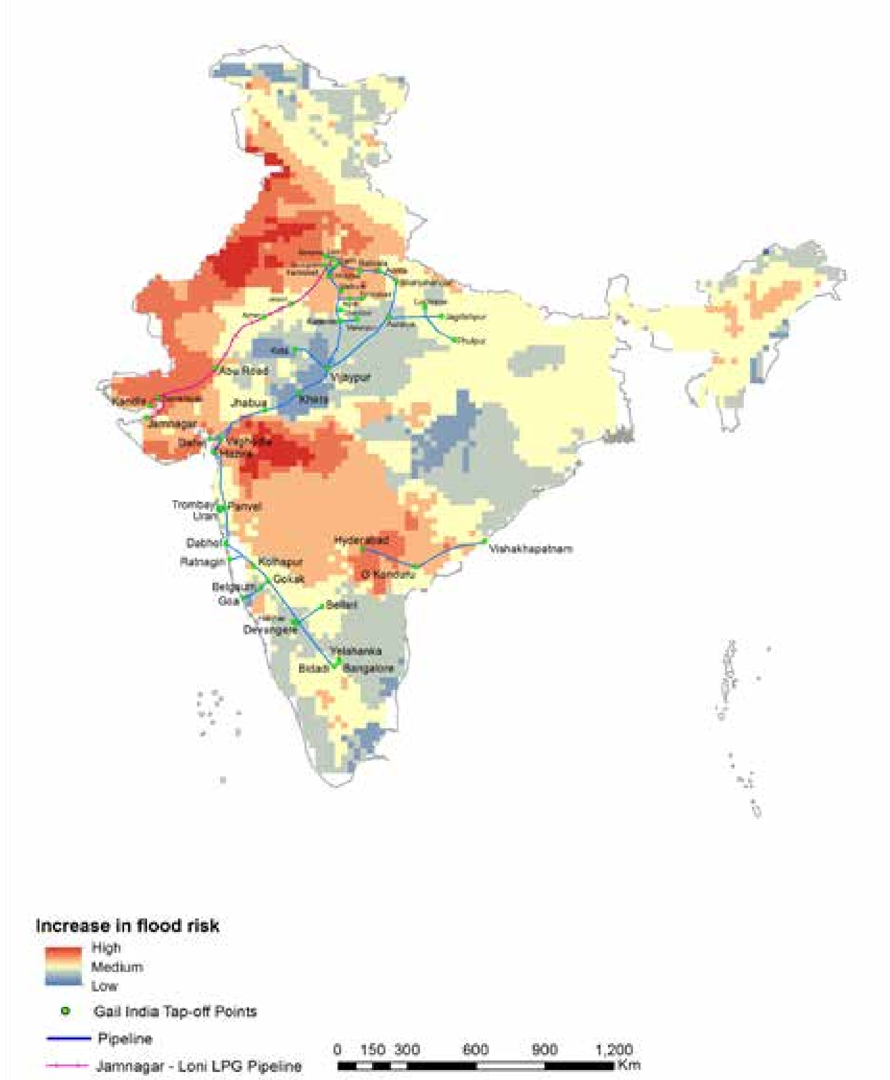

Figure 2c: Increase in flood risk to GAIL pipelines

> **Frequency and intensity of lightning strikes is likely to increase in North-West India where both annual rainfall as well as extreme rainfall days are projected to increase**

[5] S. Michaelides, K. Savvidou, and K. Nicolaides , 2010, Relationships between lightning and rainfall intensities during rainy events in Cyprus, Advances in Geosciences, 23, 87–92; CAREY, L.D. and RUTLEDGE, S.A., 2000, The Relationship between Precipitation and Lightning in Tropical Island Convection: A C-Band Polarimetric Radar Study, American Meteorological Society, 128, 2687-2710; Murugavel P, Pawar S.D., Gopalakrishnan V., 2014, Climatology of lightning over Indian region and its relationship with convective available potential energy, International Journal Of Climatology, 34, 3179–3187.

extreme rainfall days are projected to increase.

Water Scarcity

Fresh water is critical for refineries and petrochemical plants. Changes in the availability of fresh water can affect the throughput and cost of water. Large water intensive plants will be more vulnerable to change in fresh water availability due to climate change. This study indicates that water scarcity will increase more acutely in North-Western India compared to other regions. This is on account of historically high water stress in this region, coupled with increase in number of cumulative dry days. Accordingly, the refineries and petrochemical plants located in the North-Western India are likely to face a greater pressure for water efficiency compared to their current situation. Already water stressed plants located in other regions will experience little change in the risk profile related to water stress due to climate change implying that their current status may continue or change on account of non-climatic factors. A preliminary analysis by TERI using a systems dynamics

Increase in water scarcity due to climate change

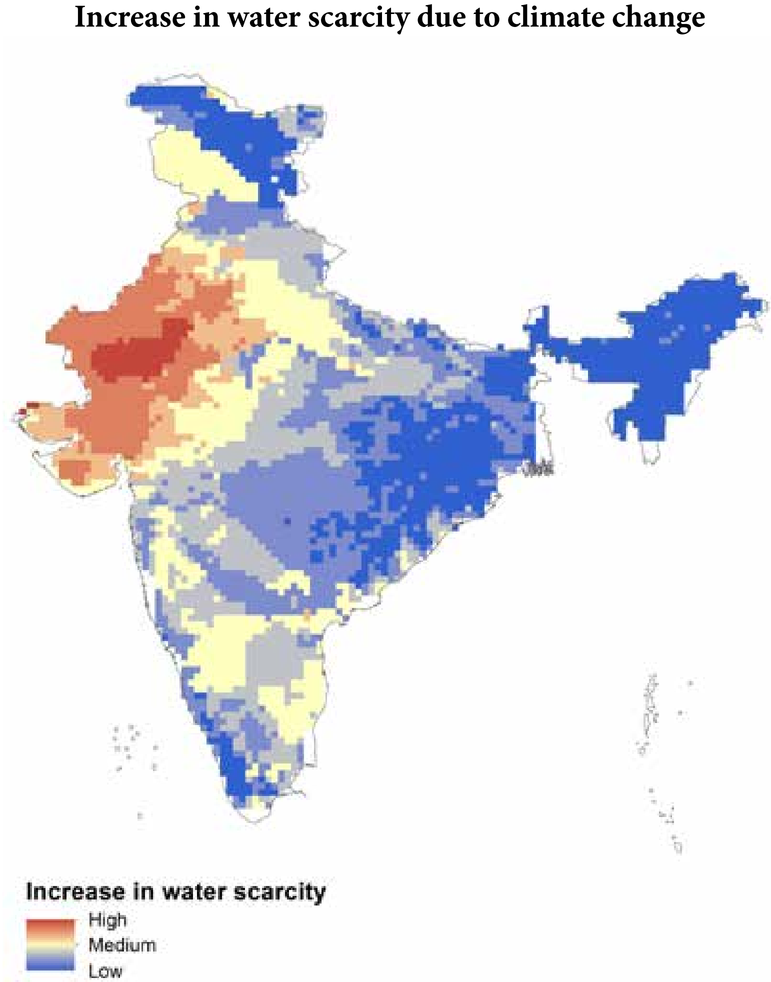

Figure 3: Increase in water scarcity due to climate change

> **Water scarcity will increase more acutely in North-Western India compared to other regions on account of historically high water stress coupled with increase in number of cumulative dry day**

> **The general trend shows an increasing sea surface height over most of the Indian coastal cities. Chennai shows the least increasing trend whereas Garden Beach station (proxy for Kolkata) shows the largest increase in sea surface height**

model suggests that a 5% reduction in the availability of fresh water may result into a decline of more than 5% in total throughput of a refinery. Of course, this impact would vary depending upon the water intensity of a refinery or petrochemical plant.

Temperature rise

Variation in ambient air temperature affects efficiency of cooling towers at refineries and petrochemical plants and heat exchangers at LNG regasification plants, energy consumption at gas compressor stations and recovery rates at gas processing units. Except for LNG regasification plants rise in ambient air temperature will lead to increased energy consumption. The gas processing units recovering C2 and C3 may experience reduced average productivity. However, in the absence of sufficient time series data any initial estimates could not be arrived at. It is important to note that rise in temperature will also manifest in increased number of heat waves (more than 5 consecutive days with temperature greater than 45°C) as well as total number of extremely hot days in a year, impacts of which may add to the impacts of water scarcity. The PRECIS model result show that average temperatures may rise beyond 2°C with the maximum change being in the North, Central and North-West India.

Sea level rise

Sea level rise is not an immediate threat in terms of leading to submergence of coastal areas. However, the rising trend of both sea surface temperature and sea level may contribute to storm surges as discussed above. The global mean sea level has risen by 0.19 (0.17 to 0.21) m over the 1901-2010 time period (IPCC, 2013) with a higher observed rate during (1993-2010). Most of these assessments have indicated high variability over North Indian Ocean. Studies have estimated the regional sea level changes at close to 2.0 mm/yr over North Indian Ocean and 4 mm/yr over the Bay of Bengal region. Studies using tide gauge data find that Kolkata shows the highest trend on net sea level rise of 5.74 mm/yr, with Kochi showing 1.75 mm/yr, Mumbai with 1.20 mm/yr and Visakhapatnam with 1.09 mm/yr.[6] Historical analysis of sea level rise over a few coastal cities of India has been carried out using the observational tidal records available online at the PSMSL.[7] Figure 4 below shows the time series of the yearly mean sea surface height for different coastal cities. It is seen that despite some missing data, the general trend shows an increasing sea surface height over most of the Indian coastal cities. Chennai shows the least increasing trend whereas Garden Beach station (proxy for Kolkata) shows the largest increase in sea surface height.

---

[6] Unnikrishnan A S and Shankar D, 2007, Are sealevel-rise trends along the north Indian Ocean coasts consistent with global estimates?, Global and Planetary Change, 57, 301- 307.

[7] PSMSL- Permanent Service Mean Sea Level from National Oceanographic Center; NOC and National Environmental Research Council; NERC

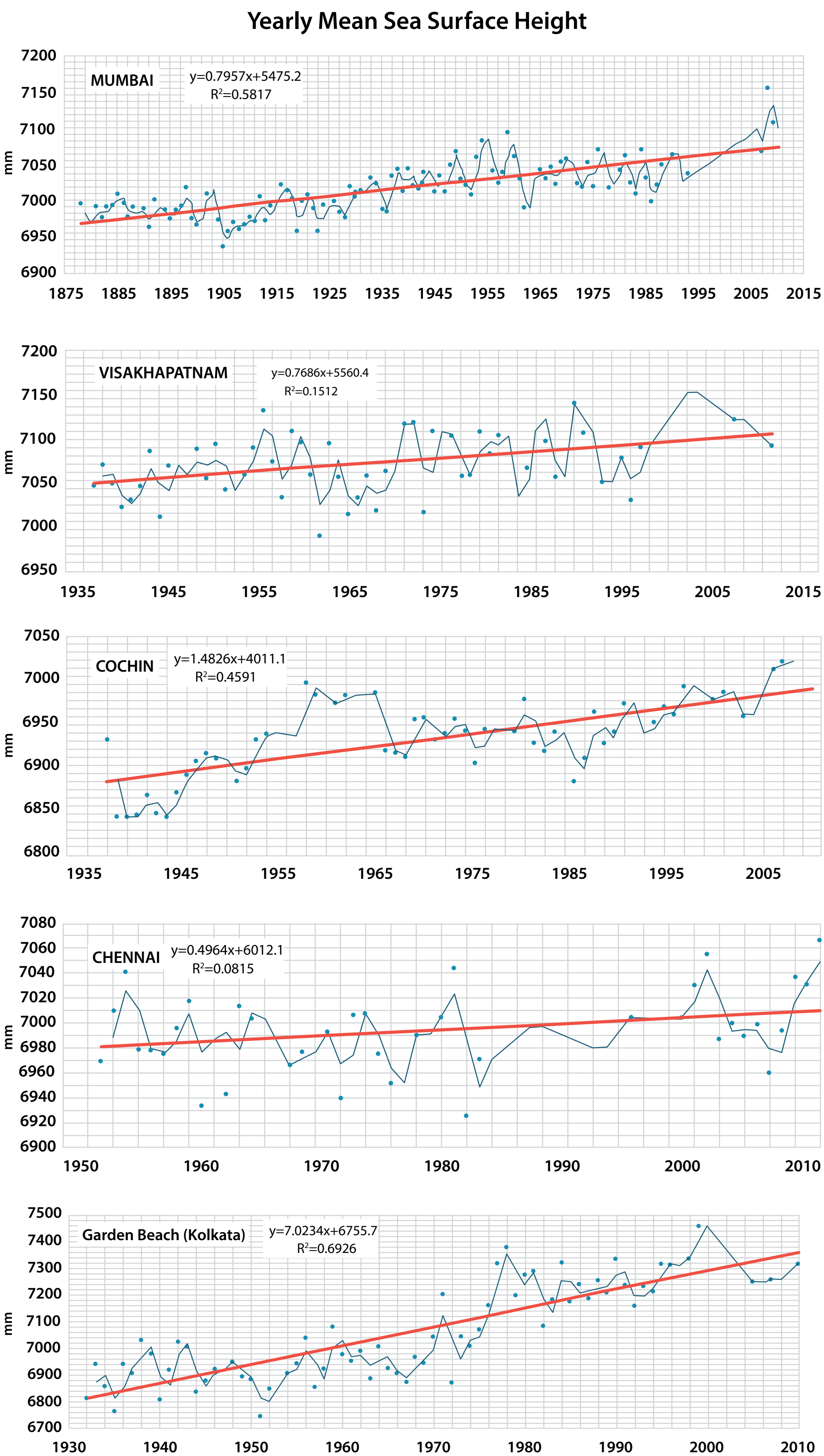

Figure 4: Tide gauge values of five coastal stations available from PSMSL dataset shows a general increasing trend of mean sea surface height for the historical period.

Decline in soil moisture

Soil moisture is an important parameter to consider in laying pipelines. There are a number of factors that affect the level of soil moisture, climate related parameters such as number of dry days, and numbers of extremely hot days, contribute only partially. However, the Indian subcontinent is assessed as highly vulnerable to desertification which may be further intensified by change in climatic conditions. Based on the PRECIS model projections on change in precipitation pattern and temperature

Reduction in soil moisture due to climate change

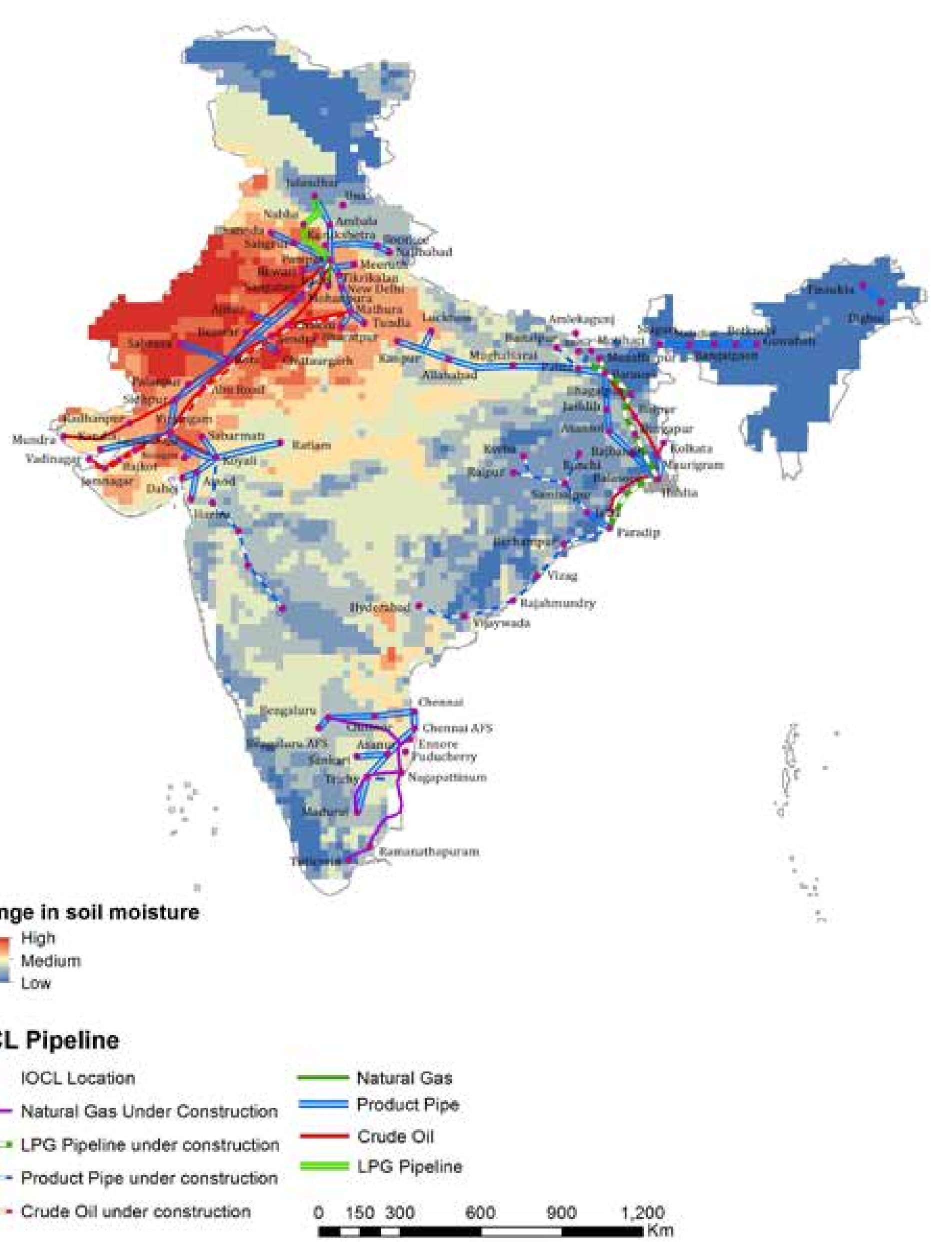

Figure 5a: Exposure of pipeline infrastructure of IOCL to change in soil moisture

profile over India, and current status of soil moisture measured through proxy indicators of drought severity and water stress, North and North-West India will be more vulnerable to decline in soil moisture. It is important to note that a significant part of India's pipeline infrastructure including crude, product, LPG and NG pipeline is concentrated in this region (Figure 5a and 5b).

Reduction in soil moisture due to climate change

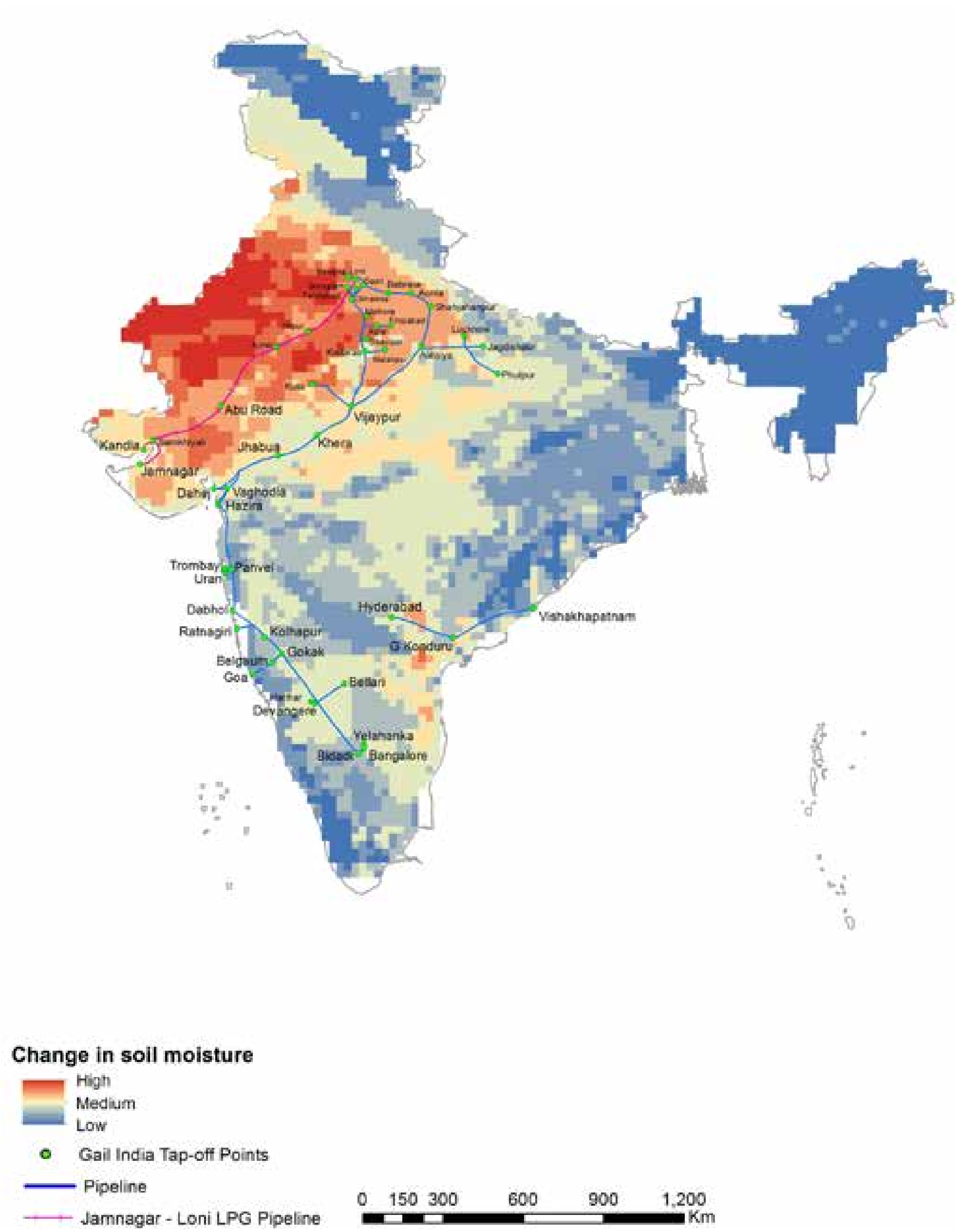

Figure 5b: Exposure of pipeline infrastructure of GAIL to change in soil moisture

3. Market outlook under NDCs

a. The national scenario

In the context of the NDCs, India's long term energy demands are expected to be influenced not only by its economic growth targets, but also with the way Government policies and consequently alternative technologies evolve in terms of their costs and efficiencies. While the current NDCs set 2030 as terminal year, the five year cycle of NDC revision under the Paris Agreement may imply higher targets for subsequent periods for all countries, including India. In order to assess the implications of alternative energy development paths for India, a scenario based analysis using TERI's MARKAL model is undertaken. In keeping with the intent of achieving and maintaining a high rate of economic growth for achieving India's development objectives, as mentioned in India's current NDC, we assume the same economic growth rates across all scenarios for this study. The three scenarios developed for this study vary in terms of the stringency of mitigation requirements and expectations regarding policies towards end-use efficiency and uptake of alternative fuels and technologies.

- Reference scenario (REF) considers the continuation of policies and trend of improvement in energy efficiency and renewable energy share as it was in 2015 till 2050.
- Balanced scenario (BAL) considers a balance between use of fossil fuels and non-fossil fuels for meeting India's current NDC target, and assumes that the rate of reduction in emission intensity of GDP will continue through 2050. It does not force any aggressive implementation of energy efficiency and renewable energy share beyond current NDCs.
- Ambition scenario (AMB) visualizes deeper rates of GHG emission reductions consistent with the target of 20C, and forces aggressive pursuit of renewable energy supply along with rapid adoption of electric vehicles.

Fuel mix and emission intensity of GDP associated with the three scenarios is exhibited in Table 3 and Table 4 respectively. Under the three scenarios India is able to meet the NDC targets if the trajectory remains the same in subsequent periods. The demand for oil and gas is also set to increase under all the scenarios. While total commercial energy consumption increases by a factor of 4, 3.6 and 3 between 2021 and 2051 in the REF, BAL, AMB scenarios respectively, the final consumption of oil increases by a factor of 4.5, 3.7 and 3.4 respectively. The consumption of gas, however, plays a more significant role in the Bal scenario, where it increases by a factor of 5.1 compared to a factor of 4.1 and 3.2 in REF and AMB scenarios, respectively. Hence, for subsequent decades the oil and gas sector does not face any serious challenge in terms of absolute aggregate demand. However, the rate of growth will vary depending upon the emission reduction target India adopts in subsequent NDCs.

The variation in demand, however, would be felt for some products due to

> **In subsequent decades, the oil and gas sector does not face any serious challenge in terms of absolute aggregate demand. But, the growth rate will vary depending upon the emission reduction target India adopts in subsequent NDCs**

Table 3: Primary Energy Mix in different scenarios (Mtoe)

Year	Scenario	Coal	Oil	Natural Gas	Nuclear	Hydro	Solar	Wind	Others
2021	Reference	591.9	258.5	65.0	19.7	18.4	4.5	7.2	8.4
	Balanced	576.4	252.1	72.5	19.7	18.4	14.7	11.1	8.7
	Ambition	576.8	257.3	64.8	19.7	18.4	14.7	11.1	5.0
2026	Reference	837.6	345.1	88.5	21.1	21.6	7.0	9.3	10.9
	Balanced	788.9	322.0	113.7	21.1	21.6	18.4	14.7	11.5
	Ambition	754.7	324.4	86.8	21.1	20.9	43.0	28.3	6.8
2031	Reference	1147.2	453.9	113.1	26.8	24.3	9.6	11.8	16.2
	Balanced	1048.6	403.0	165.2	26.8	24.3	22.1	19.2	17.1
	Ambition	920.4	415.4	124.1	26.8	24.0	71.4	48.9	14.0
2036	Reference	1439.4	592.4	148.6	32.2	28.5	12.1	13.3	22.8
	Balanced	1308.9	499.2	213.6	32.2	28.5	30.6	27.2	24.8
	Ambition	1063.2	486.2	139.3	32.2	27.0	174.7	66.5	21.2
2041	Reference	1760.6	750.2	165.9	37.5	29.6	14.6	14.8	32.2
	Balanced	1551.9	612.3	245.1	37.5	32.7	39.0	38.5	34.4
	Ambition	1162.8	589.9	161.4	37.5	26.9	221.2	84.2	31.5
2046	Reference	2031.1	983.1	201.1	42.8	30.8	17.3	16.3	43.2
	Balanced	1731.6	806.2	314.9	42.8	36.9	48.9	49.8	45.7
	Ambition	1223.2	769.8	182.5	42.8	27.4	268.0	101.6	42.4
2051	Reference	2262.1	1155.5	268.2	48.1	31.9	19.8	17.7	55.9
	Balanced	1899.3	934.1	369.8	48.1	41.1	68.3	67.9	58.8
	Ambition	1266.7	871.1	206.5	48.1	27.8	314.7	119.2	54.9

Table 4: Emission intensity under different scenarios (kgCO_2/Re)

	2006	2016	2021	2026	2031	2036	2041	2046	2051
Ambition	0.035	0.028	0.028	0.024	0.019	0.014	0.011	0.008	0.007
Balance	0.035	0.028	0.028	0.025	0.021	0.017	0.014	0.011	0.009
Reference	0.035	0.028	0.028	0.026	0.023	0.019	0.015	0.013	0.011

fuel switching. For example, increased penetration of electric based cooking may moderate demand for LPG or PNG. The use of LPG in 2021 is around 14Mtoe across the three scenarios. However, it increases significantly in the AMB scenario to 54.6Mtoe in 2041 and then declines to 26 Mtoe in 2051, whereas in other two scenarios, LPG consumption continues to grow at a slower rate. Consumption of PNG continues to grow across all scenarios, maximum being 13Mtoe in 2051 in Ambition scenario.

Diesel may be replaced by CNG based as well as electric vehicles. Increased penetration of electric pumps will have definite impact on diesel consumption in the agriculture sector accounting for a difference of upto 8Mtoe between REF and AMB scenarios in 2051. Solar pumps substitute only upto 4 Mtoe by 2051 in the AMB scenario.

"Decrease in diesel consumption for road based freight transportation occurs only because of increase in share of railways. Demand for gas in power sector may also increase in an aggressive renewable energy deployment case."

Nevertheless, diesel remains a major fuel in the long term even in the Ambition scenario. For road based freight transport diesel will remain primary fuel till commercial viability of LNG based vehicles is achieved. Decrease in diesel consumption for road based freight transportation occurs only because of increase in share of railways. Demand for gas in power sector may also increase in an aggressive renewable energy deployment case. The analysis also shows that the demand of certain distillates (naphtha, ATF) will increase while that of others (gasoline) is likely to fall.

On the whole, there seems to be limited substitutability of petroleum products in the transport sector. The pace of introduction of electric vehicles may have the largest implications for the substitution, but there are mixed responses about the potential at this point in time. Accordingly, the scenarios also do not indicate a very large change in the use of petroleum products in the transport sector. Hence, climate policy would require the industry, in addition to continued efforts to improve energy efficiency, to take into account those distillates which are expected to face reduced demand.

On the whole, there seems to be limited substitutability of petroleum products in the transport sector. The pace of introduction of electric vehicles may have the largest implications for the substitution, but there are mixed responses about the potential at this point in time.

b. Exports under NDCs

Exports of petroleum products by India include Liquified Petroleum Products (LPG), Motor Spirits (MS), Naphtha, ATF, Kerosene, High Speed Diesel (HSD), Light Diesel Oil (LDO), Lube Oil, Fuel Oil (FO), Bitumen and others. Total exports by India have increased at the rate of almost 14% from ~8 million tonnes (MT) in 2000-01 to ~65 MT in 2016-17 (PPAC, 2018). Of these, the share of MS, Naphtha, ATF, HSD and FO has increased from 76% in 2000-01 to ~93% of the total product exports in 2016-17 with HSD constituting ~45% of the total product exports (figure 6). In terms of net exports, ATF has seen the highest growth of 27% since 2000-01 while growth of Naphtha, MS and HSD have been 19%, 17%, and 19% respectively. However, given growing concerns over emissions from consumption of diesel as well regulations on consumption of Naphtha (such as in California) as also fuel switching to cleaner options to increase efficiency, consumption of these products in international markets could decrease.

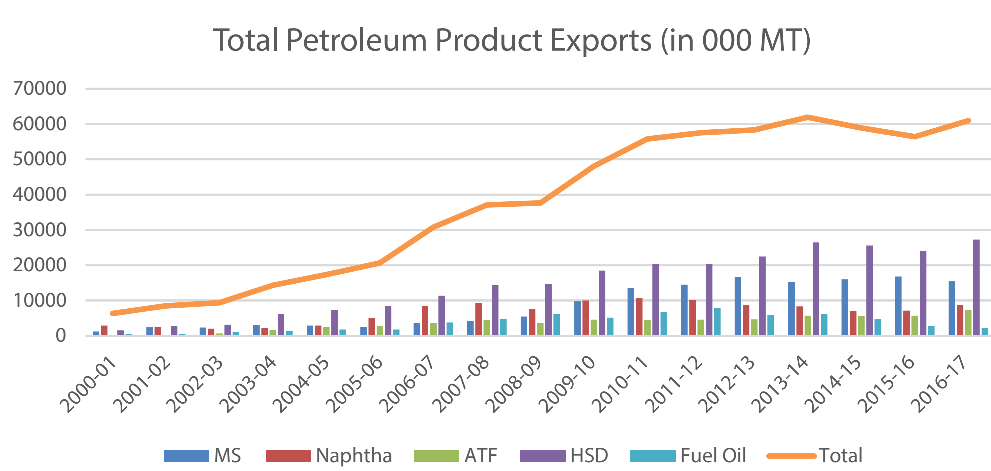

Figure 6: Top five petroleum product exports by Indian Refiners
Source: *(PPAC, 2018)*

While consumption of diesel in domestic markets may very well compensate this fall in demand (as has been seen in the last two years), nevertheless Indian exporters would need to be cognizant of these changes and seek alternate export destinations.

Singapore has consistently been the top country to which India has exported petroleum products since 2011-12 followed by UAE and Saudi Arabia (figure 7). Some other countries where India is a keen exporter of petroleum products include USA, Netherlands, Turkey, South Africa, Tanzania, and People 's Republic of China, Korea, Malaysia and Oman. India's exports to Brazil which were significant until 2014-15 have seen a fall from ~3MT in 2011-12 to ~74000 metric tonnes in 2016-17. Similarly, export to Gibraltar picked up only in 2016-17.

countries such as Oman, Turkey, South Africa are conditional on international financial support. While the NDCs and other climate policies state that they would cover all sectors of the economy – IPPU, Agriculture, Energy, Transport Land-Use Change, and Forestry and Waste – their focus hinges primarily on reducing energy consumption in energy intensive industries and other sectors, through increased focus on energy efficiency, increasing the share of renewables in the electricity mix, and sustainable transport. The focus on energy efficiency in energy intensive industries cuts across different climate policies where countries are looking to invest heavily in energy efficient technologies. Most importantly, they are also considering fuel switching in demand technologies where fuel oil is directly burned to meet heating needs.

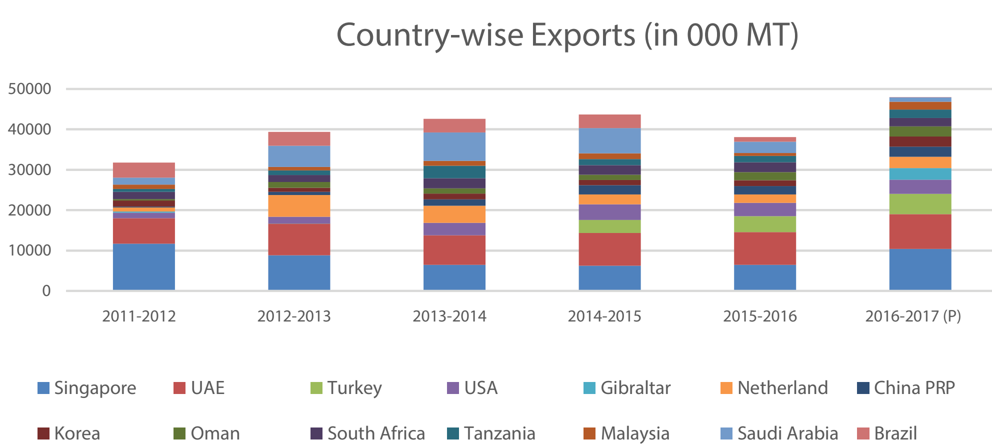

Figure 7: Top 14 countries to which India exports petroleum products

NDCs and climate policies in each of these 14 countries aim at limiting their emissions intensity between 21% and 40%. The starting year for accounting differs in each of these countries depending on various parameters such as their level of economic development. Moreover, many features in NDCs of

Countries such as Turkey, Oman, UAE and Korea are seen to focus more on the transport and power sectors. In the transport sector, while there is no explicit commitment on electric vehicles, climate policies are seeking options to reduce petrol and diesel consumption by increasing usage

NDCs and climate policies in each of these 14 countries aim at limiting their emissions intensity between 21% and 40%.

and share of public transport, cleaner fuels, and technologies for private and public transport, building infrastructure to encourage cleaner multi-modal transportation complemented by tax reductions on hybrids and electric vehicles, carbon tax on polluting cars, etc.

Given the increasing shift towards cleaner fuels in the top 14 countries India exports to, the exports of MS and HSD could decline. Alternatively, given an increase in domestic consumption, India may not remain a net exporter of MS and HSD unless new refining capacity comes up, and India finds newer markets for exports of these products. The market for ATF though continues to remain strong, given that so far no alternative fuel or technology has become commercially viable for air travel. Naphtha consumption is seen increasing within India, however, using naphtha as feedstock can double the emissions per metric ton of ethylene. Given the existing ban on using naphtha in some countries across the world, increasing natural gas reserves and the possibility of substituting naphtha with natural gas in the petrochemical sector would mean that Indian refiners use naphtha for domestic uses, while seeking to export sustainable feedstock.

4. Transparency Challenges

"The increasing shift towards cleaner fuels in the top 14 countries India exports to, could lead to decline in exports of MS and HSD. Moreover, given an increase in domestic consumption, India may not remain a net exporter unless new refining capacity comes up"

Implementation of the Paris Agreement hinges upon credible transparency practices adopted by the countries, in particular precise accounting and monitoring of GHG emissions from various sources. The reporting of GHG emissions from India's oil and gas sector under the NATCOM (National Communications to the United Nations Framework Convention on Climate Change) is as per IPCC guidelines2 and covers the following aspects summarized in the Table 5 below. The methodology adopted for the estimation of GHG emissions is the basic 'Tier 1' approach which employs activity data that is relatively coarse such as nationally or globally available estimates, national industrial production statistics, global land cover maps, etc. and default emissions factors provided by the IPCC for developing countries. More comprehensive approaches use more granular activity data and country specific emission factors (Tier 2 Approach) or rely on models and inventory measurement systems tailored to address national circumstances, repeated over time and driven by disaggregated levels (Tier 3 Approach). In general, it has been observed that the default emission factors for developing countries are significantly higher compared to the default emission factors for developed countries (Table 6). Considering that India's oil and gas sector is technologically at par with developed countries, continued use of default emission factors for developing countries in GHG emissions accounting from the sector may result in over reporting of emissions. This may also result in undue pressure on the industry to reduce GHG emissions, which is likely to increase further with subsequent revisions of NDCs.

Table 5: Coverage of oil and gas sector GHG emissions in NATCOM

Sector	Sub-sector	Code	Description
Energy	Refining	1A1b	Stationary combustion of fuel in refineries
Energy	Fugitive Emissions (Refining)	1B2b(i)	Includes emissions from venting; flaring; well drilling, servicing and testing; gas processing; gas transmission and storage; distribution
Energy	Fugitive Emissions (Exploration)	1B2b(ii)	Includes emissions from flaring and other sources

Table 6: Default emission factors for developing and developed countries (Gg CO2/unit Activity Data)

Industry Segment	Sub-category	Default emission factor for CO2		Default emission factor for CH4	
		Developing countries	Developed countries	Developing countries	Developed countries
Oil Production	Conventional Oil	0.0485	0.041	2.95E-05	2.1E-05
	Default Weighted Total	0.0405	0.034	2.5E-05	2.1E-05
	Heavy Oil/Cold Bitumen	0.026	0.022	0.000165	0.00014
	Thermal Oil Production	0.032	0.027	1.9E-05	1.6E-05
Well Drilling	All	0.0009	0.0001	0.0002965	3.3E-05
Gas Processing	Default Weighted Total	0.0675	0.04		
	Sour Gas Plants	0.1065	0.063		
Gas Transmission	Transmission	5.2E-06	3.1E-06	0.000392	000182

Source: *IPCC*

"It has been observed that the default emission factors for developing countries are significantly higher compared to the default emission factors for developed countries. Given that India's oil and gas sector is technologically at par with developed countries, continued use of default emission factors for developing countries in GHG emissions accounting from the sector may result in over reporting of emissions."

5. Preparedness of the sector

> **While the sector is exposed to the range of climatic events and their potential impacts such as storm surges, floods, water scarcity, heat waves, etc., there is little preparatory planning for assessing how it may vary in future due to climate change.**

Of the three types of challenges posed by climate change, the sector is broadly aware of the impacts of climate policies as far as mitigation is concerned. A review of the sustainability reports of the companies suffices to assess their ongoing efforts at improving energy efficiency and promoting renewable energy use. Companies also keenly observe the developments in the market as well as projections by agencies such as the BP and IEA. However, the developments on the climate policy front in the export destinations and their impact on the future market is less well understood. Similarly, companies are increasingly maintaining data on energy consumption and GHG emissions. However, that data is not fully incorporated into national inventory of GHGs. There is need to streamline the transparency aspects related to GHG emissions from the sector.

The most glaring gap in terms of sector's preparedness with respect to climate change is the understanding of potential changes in the pattern of climatic activities and precise understanding of the resilience of the sector. While the sector is exposed to the range of climatic events and their potential impacts such as storm surges, floods, water scarcity, heat waves, etc., there is little preparatory planning for assessing how it may vary in future due to climate change. The current practice of taking into account the historical trend at the designing stage may prove insufficient under climate change. Similarly, regulatory framework and guidelines too need to be aligned with current scientific findings on climate change and its impact on Indian sub-continent.

6. Way forward

From the above discussion it appears that in the context of climate change the Indian oil and gas sector should be concerned more from the resilience point of view than mitigation of GHG emissions. The regions which can be considered as hot-spots are North West India and the East Coast. These areas need to be further studied more comprehensively to better assess the vulnerability and resilience of oil and gas industry. Nevertheless, climate change poses different challenges to the sector over different time horizons. In order to better align its growth with the mitigation and adaptation imperatives of the threat of climate change, the sector should adopt an explicitly articulated strategy. Broad contours of such a strategy may be divided into the following categories of actions:

Immediate actions: These preparatory actions primarily pertain to the existing infrastructure and should be taken by concerned companies within the next 5 years. The four most important actions are conducting location specific flood modelling exercises, exploration of plant specific water efficiency improvement options, building a database to properly establish impact of temperature rise on energy consumption and efficiency of operations, and develop plant specific GHG emissions database using Tier 2 or Tier 3 methodologies.

- Considering that the occurrences of floods may disrupt the supply chain as well as operations, it is important to properly assess the resilience of different assets as well as backward-forward linkages to different intensities of floods. To start with local flood modelling studies should be undertaken at locations which are flood prone and where this study projects increase in flood occurrence due to change in pattern of extreme rainfall. The benefits of such an exercise would go beyond the companies and contribute to building climate resilience of the concerned region. For example, TransCanada has implemented a slew of measures to minimize the damage caused by extreme precipitation and cyclone events. The company has asset specific teams that interpret, model and manage physical risks with the commercial and engineering teams of each business.[8]
- Unlike the threat of floods, water stress will become severe over time. However, it is a known risk, with or without climate change. Hence, a more concerted effort at water efficiency and water conservation is warranted. It would be advisable that such efforts are implemented in cooperation with other actors in the region, either responsible for water resource management, or dependent on water resources. For example, StatOil develops water management plans based on projections of water availability six years into the future. In addition, a substantial portion

[8] Climate Change 2016 Information Request, TransCanada. Link: https://www.transcanada.com/globalassets/pdfs/commitment/environment/transcanada-2016-carbon-disclosure-project-report.pdf Access Date: 30/01/2018

of the R&D budget worth NOK 3.0 billion is allocated for water management projects.[9]

- The impact of temperature rise may offset the achievements of companies on energy efficiency. It is important that companies begin to compile and analyse data on temperature variations, energy consumption, and efficiency of operations. It will not only help them better assess impacts of climate change, but also provide more opportunities to improve energy efficiency.
- Companies do maintain detailed data on materials balance. It should not be difficult therefore to develop plant specific GHG emissions inventory and develop country specific emission factors for the sector.

Long term actions: These actions pertain to existing as well as planned infrastructure and relate to building institutional capacities at national level in terms of building strategic knowledge as well as aligning regulatory framework to capture the specific challenges posed by climate change. Precise nature of these actions should be based on further studies incorporating engineering aspects of the industry as well. The broad direction of these actions can be summarized as follows:

- Revision of practices and guidelines to determine design parameters to accommodate projected change in climatic events and impacts, particularly intensity and frequency of wind speed and storm surges at coastal areas. The current practice is to consider only past patterns, which are likely to get altered due to climate change. For example, British Petroleum (BP) has adopted a proactive approach that addresses the issue starting from the design phase of the project based on due consideration of asset design parameters.[10]
- A comprehensive scientific program involving industry, academic institutions and government agencies to build necessary knowledge base and integrated impact models to better assess coastal vulnerability. For example, Chevron has collaborated with experts at the National Centre for Atmospheric Research as well as federal and state governments to better understand the possible changes in the frequency and magnitude of hurricanes in the Gulf of Mexico over the next 50 years so as to better use the information from the work to support development of new design parameters (meteorology and oceanography) specifically for offshore Gulf of Mexico assets.[11]
- A comprehensive R&D strategy to enable the industry to build resilience to physical as well as policy threats due to climate change. For example,
- A framework to periodically assess the fitness of infrastructure in the light of latest scientific assessments on climate change,

[9] Climate Change 2015 Information Request, Statoil ASA. Link: https://www.statoil.com/content/dam/statoil/documents/sustainability-reports/carbon-disclosure-project-reports/Statoil-2015-CDP%20Statoil%20response.pdf. Access Date: 30/01/2018

[10] Climate Change 2016 Information Request, British Petroleum. Link: https://www.bp.com/content/dam/bp/en/corporate/pdf/sustainability-report/group-reports/bp-cdp-submission-2016.pdf Access Date: 30/01/2018

[11] Chevron. 2017. Managing Climate Change risks – A Perspective for Investors. Link: https://www.chevron.com/-/media/shared-media/documents/climate-risk-perspective.pdf Access Date: 30/01/2018

- Regulations to improve water use efficiency in the industry along the line of the Perform, Achieve and Trade scheme for improving energy efficiency,
- Exploration of pathways to better integrate the large infrastructure and supply network of the oil and gas sector into India's transition to low carbon development trajectory.
- A long term plan for transition of oil and gas companies into energy companies consistent with low-carbon energy system.

teri | FIPI

IndianOil | ONGC | GAIL | HP | Bharat Petroleum | Oil India Limited — Conquering Newer Horizons | PETRONET LNG LIMITED | ENGINEERS INDIA LIMITED