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Energy infrastructure in India: Profile and risks under climate change

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HIGHLIGHTS

- Climate risks to energy infrastructures adversely impact energy security.
- Case studies of a port and a railway show their future climate change vulnerability.
- Managing climate-induced risks through preventive adaptation policies.

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ABSTRACT

India has committed large investments to energy infrastructure assets-power plants, refineries, energy ports, pipelines, roads, railways, etc. The coastal infrastructure being developed to meet the rising energy imports is vulnerable to climate extremes. This paper provides an overview of climate risks to energy infrastructures in India and details two case studies – a crude oil importing port and a western coast railway transporting coal. The climate vulnerability of the port has been mapped using an index while that of the railway has been done through a damage function for RCP 4.5.0 and 8.5 scenarios. Our analysis shows that risk management through adaptation is likely to be very expensive. The system risks can be even greater and might adversely affect energy security and access objectives. Aligning sustainable development and climate adaptation measures can deliver substantial co-benefits. The key policy recommendations include: i) mandatory vulnerability assessment to future climate risks for energy infrastructures; ii) project and systemic risks in the vulnerability index; iii) adaptation funds for unmitigated climate risks; iv) continuous monitoring of climatic parameters and implementation of adaptation measures, and iv) sustainability actions along energy infrastructures that enhance climate resilience and simultaneously deliver co-benefits to local agents.

1. Introduction

Post-industrial revolution era has made energy infrastructure an essential prerequisite for economic growth and development (Briceño-Garmendia et al., 2004). Energy infrastructure here denotes assets involved in the production, transportation, transformation, and transmission of energy and those, linking these asset blocks. Energy producing infrastructure assets are deployed for primary energy extraction and comprise natural assets of primary energy such as mines, oil wells, gas reserves etc. (Asif and Muneer, 2007; Brown, 2002). Primary energy sources need to be extracted, and transformed into a usable secondary energy and therefore, have to be transported to the location of transformation (Brown, 2002). These distances are high in India due to the concentration of natural energy assets in specific areas, for example, coal resources are located in the eastern states of Bihar, Jharkhand and Orissa but the transformation asset blocks like generation units are spread across the country (TERI, 2006; Santhiyavalli and Usharani, 2011). Table 1 summarizes the types of energy infrastructure blocks and the types of assets in each block.

The changing climate poses many threats for energy infrastructure assets in India. Firstly, it is creating newer risks. Infrastructure assets are planned with some visibility of magnitude and type of potential climate-induced risks (Hallegatte, 2009). With the changing climate, new dimensions are being added to the risk profile of these assets thereby changing the conceptual basis for risks (Kousky and Cooke, 2009). Some specific risks may become more critical for the asset in future, which are either not visible today or do not hold importance in the existing basket of risks (Stern, 2007). Secondly, climate change appears to enhance the

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Table 1
Energy infrastructure blocks.[a]

Production block	Transportation block	Transformation block	Transmission block
Domestic	*Domestic*	• Refineries	• Power grids
• Mines	• Pipelines	• Power plants	• Distribution lines
• Oil wells	• Rail		• Pipelines
• Gas reserves	• Road		• Road
	• IWT		• Railways
Imported	*Imported*		
• Mines	• Shipping		
• Oil wells	• Pipelines		
• Gas reserves			

[a] Authors' assessment.

risks that the assets already face. For example, physical risks due to extreme weather will become more severe in certain conditions (Hallegatte, 2009). Thirdly, climate change threatens the usable life span of the assets. Regulatory or product and technology risks could make the asset redundant sooner than the planned lifespan (Peter and Grimm, 2008). Finally, it creates allied risks that arise out of disruptions in network of infrastructure such as supply chain risks (Schenker-Wicki et al., 2010). More variations in future weather conditions, increasing economic activity, increasing population, etc. are leading to increased energy consumption.

Increased dependence on energy assets is making them more susceptible to supply side vagaries. Energy is a constrained resource that is needed in all economic sectors and climate-induced risks have implications for the 'energy security' goal in India. Climate-induced risks challenge this goal by disrupting supplies, affecting the network of energy supplies, making assets redundant, etc. (Kurian and Vinodan, 2013; Schenker-Wicki et al., 2010). These risks can affect any part of this inter-connected energy infrastructure network and when actual events occur, they have the potential to create an energy crisis through ripple effects. In the past also, extreme weather conditions have damaged transportation blocks causing serious supply constraints for India. Temporary supply interruptions induce price rise due to shortage and, to some extent, can be dealt by maintaining buffer stocks. India maintains strategic 'crude oil reserves' for two weeks (ISPRL, 2014). Similarly, power plants maintain buffer stocks of coal. However, this reserve mechanism sometimes is inadequate to meet the demands of so many energy dependent sectors of the economy and faces operations management issues of maintaining optimum stocks and disbursement to priority demand areas.

Infrastructure lock-ins reduce the flexibility to change or replace assets before their expected life span. Therefore, there is an emerging need to ensure that existing assets are more climate proof by taking appropriate risk management measures to prevent damages from climate-induced risks. In this paper, we discuss the climate-induced challenges that energy infrastructure faces and how it subsequently affects the energy infrastructure networks of the country. The following sections detail the profile of energy infrastructure assets in India and the various climate-induced risks that these assets face. The impact of climate change on two specific cases of energy infrastructure assets-one a large port (Kandla port) importing considerable volume of crude oil, and another a rail-road infrastructure (Konkan Railways) along the western coast transporting coal have been elaborated.

The objective of this paper is to analyze the current situation of these energy infrastructure assets and in light of future climatic changes how these assets can prioritize risk management through adaptation for better resilience and energy security in India. These infrastructure assets constitute important nodes in the Indian energy infrastructure set up and hence their uninterrupted functioning is important for the energy network. The paper assesses the current and future risks in the form of a vulnerability index and a risk function respectively. These cases show the potential variables that can be improved to increase resilience of the assets and ensure a smooth energy infrastructure. Finally, the paper concludes with concerns about risk management through adaptation of climate-induced events for climate proofing assets and a discussion on key takeaways for policy makers.

2. Energy infrastructure assets in India: profile and risks

2.1. Overview

India is the second most populous country and the fourth largest consumer of crude oil and natural gas in the world after the United States, China and Russia (IEA, 2014; Kumar and Jain, 2010; TERI, 2006; Vivoda, 2010). The demand for energy is much higher than the supply (IEA, 2014) making it important for the energy infrastructure network to work efficiently for a better demand-supply match across regions. Network disruptions create stresses for energy availability to millions and can have damaging spill over impacts on various sectors of the economy.

Domestic sources of coal and crude oil are not sufficient to meet internal demand and have to be supplemented by imports (Fig. 1). Planning Commission-GoI (2013) estimates suggest that

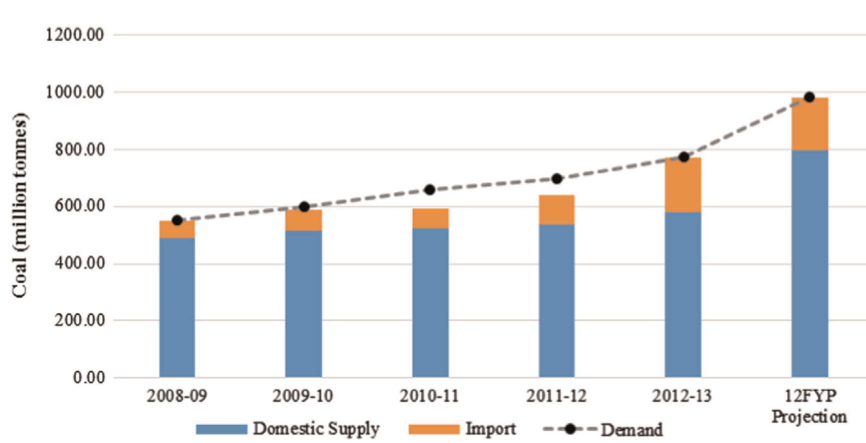

Fig. 1. Coal demand and supply (million tonnes).
Source: Ministry of Coal-GoI (2012, 2013).