The Electricity Journal 30 (2017) 47–53

Contents lists available at ScienceDirect

The Electricity Journal

journal homepage: www.elsevier.com/locate/tej

An assessment of decarbonization in the strategic Indian electricity generation sector☆

Vedachalam N.[a,*], Surendar S.[b], Srinivasalu S.[b]

[a] National Institute of Ocean Technology, Ministry of Earth Sciences, Chennai, India
[b] Anna University, Chennai, India

ARTICLE INFO

Keywords:
Carbon tax
Electricity generation
Emissions
IESS 2047

ABSTRACT

With an eye to addressing climate change concerns while also meeting the demands of continued economic growth, the Indian electricity generation sector can achieve a cumulative reduction in greenhouse gas emissions of 24 $GtCo_2$ and hydrocarbon imports by US$730 billion during the period 2015–2047. This transformation will require a capital outlay of US$1.16 trillion and a total land requirement of 22,200 km^2.

1. Introduction

Anthropogenic climate change due to an increase in greenhouse gases (GHG) in the atmosphere is a phenomenon, capable of affecting life and planet ecology. In order to reduce GHG emissions to an average of 5% below pre-industrial levels, global investment in clean energy technologies has increased to US$0.27 trillion in 2015; a six-fold increase from 2004 levels, and is projected to reach US$2.2 trillion by 2020 (U.S. Energy Information Administration, 2015; Frankfurt School—UNEP Centre, 2016). Subsequent to the foundations of the United Nations Framework Convention for Climate Change (UNFCC) under the Kyoto protocol, the Copenhagen and the Cancun agreements, developed countries have agreed to mobilize US$100 billion annually by 2020 to assist developing countries in reducing emissions and adapting to climate change (Suzuki, 2015). As a response to these efforts, to date, some 8456 clean energy projects representing 1721 million certified emissions reduction (MCER) have been registered globally under UNFCC's clean development mechanism (CDM), a figure that is expected to reach 8648 MCER by 2020 (UNEP DTU Partnership, 2016). Renewable and fuel-switching projects contribute to 54% and 6%, respectively, of the registered certified emissions reduction (UNEP DTU Partnership, 2016). During the Paris convention (Conference of Parties) in 2015, 187 countries, responsible for more than 97% of the world's climate pollution, announced their nationally determined contributions (NDC) towards GHG emissions reduction (International Energy Agency, 2015a). The convention has set countries' minimum obligations, stronger transparency and accountability that hold the respective government accountable for their commitments.

Although India is responsible for just 3% of cumulative global GHG emissions since 1965, during the convention it committed to increase its cumulative installed non-fossil-fuel-based electricity generation capacity in the national electricity generation portfolio (EGP) to 40% by 2030 and reduce emissions intensity by 35% from 2005 levels. This commitment is made as India is presently the fifth-largest GHG emitter in the world with 40% GHG emissions from the electricity generation segment (Natural Resources Defense Council, 2015). In addition to the Paris promises, India, under its so-called New Policies Scenario, needs to achieve 100% national electrification (ensuring electricity access to 580 million people who are still without electricity access) through grid connections or mini- and off-grid systems by 2040; address electricity demand for achieving a national GDP targeted to about US$17 trillion by 2040 with a reliable power supply for the manufacturing sector; and elevate Indians' living standards by increasing the per capita energy consumption from 200 kW-h closer to the world average of 950 kW-h (International Energy Agency, 2015b).

Considering the importance of emissions reduction and its impacts on Indian agriculture, sea level rise, and water stresses due to unscheduled precipitation, nationally appropriate mitigation actions are being implemented to align carbon finance with national energy security and industrial priorities. As a result, out of the CDM registered projects in Asia, India stands second with 29.5%, behind China with 56%, reflecting the GHG emission reduction potential in the country's strategic clean energy developments (UNEP DTU Partnership, 2016). This article addresses domestic energy resources, details clean electricity generation strategies, and attempts to quantify the GHG emissions reduction potential and capital expenditure requirements under

☆ The authors gratefully acknowledge the support extended by India's Ministry of Earth Sciences in funding this research.
* Corresponding author.
E-mail address: veda1973@gmail.com (V. N.).

http://dx.doi.org/10.1016/j.tej.2017.04.016

Available online 10 June 2017

Table 1
Energy resources in India (U.S. Energy Information Administration, 2015; Central statistics office, 2015; Ministry of Petroleum and Natural Gas, Economics and Statistics division, 2015; Vedachalam et al., 2015; NITI Aayog, Government of India, 2015; NITI Aayog, 2015).

Resources	Estimated quantity in place	Exploitation level as on 2015
Conventional		
Oil	5.5 BB	38 Mt
Natural gas	4.9 TCM	48 BCM
Coal	66.8 BT	582 MTPA
Unconventional		
Coal bed methane	1.23 TCM	Nil
Shale gas	2.72 TCM	Nil
Shale oil	3.8 BB	Nil
Natural gas hydrates (Marine)	1894 TCM	Nil
Renewable		
On-shore wind	102 GW	23 GW
Solar	> 220 GW from 10,000 km^2 of waste lands	< 1 GW
Hydroelectric	150 GW	44 GW
Biomass	1843 TW-h/yr	2.5 GW
Waste to energy	6 GW	154 MW
Off shore wind	350 GW	Nil
Ocean thermal	Several Terawatts	Nil

policy implementation efforts in the electricity generation sector.

2. Energy resources and strategies

India's energy resources and their exploitation levels are shown in Table 1.

India has 7.1%, 0.33%, and 0.07% of reserves of global conventional coal, oil and natural gas (NG), respectively. Without import substitution, and with the present rate of fossil resource consumption, domestically available coal, oil, and NG could last only for 77, 4.5, and 19.6 years, respectively (U.S. Energy Information Administration, 2015; International Energy Agency, 2015b). During 2015, in order to meet demand, more than 21% of the nation's coal requirements were imported from Indonesia, Australia, and South Africa. Electricity generation from coal-fired plants faces challenges due to their aging infrastructure (40% of the plants are 25–40 years old), sub-critical technologies with operating efficiencies of < 34% (compared to super-critical, ultra-super critical, and integrated gasification combined cycle (IGCC) plants with efficiencies of 41%, 43%, and 42%, respectively) (Liang et al., 2013), a geographical mismatch between the major coal mines and the power generating plants (which requires every ton of coal to travel about 500 km by rail before getting converted into electricity), a lack of technology for mining deep coal reserves, the ecological impacts of open cast mining, a lower calorific value of domestically mined coal (4500 compared to 6000 kCal/kg for imported varieties),beneficiation needs for domestically mined coal and the unavailability of carbon capture and sequestration (CCS) due to the socio-ecological implications of safe storage (with the identified possibilities for sequestrating 105, 360, and 200 $GtCo_2$ in deep saline aquifers, deep water, and basalt formations, respectively). Taking into consideration all these challenges, coal-based electricity generation capacity is set to reach 297 GW in 2027 and 379 GW in 2047 with the supercritical technology and IGCC getting commercialized in India during 2017 and 2027, respectively. IGCC is anticipated to contribute 50% of the capacity added during 2042–47, and the share of SCC is anticipated to be 55% in 2047. CCS should cumulatively contribute 1 GW through 2022 and 35 GW through 2047 (International Energy Agency, 2015b; NITI Aayog, Government of India, 2015). With the contribution of clean-coal-based technologies, the overall efficiency of the national coal-based electricity generation fleet should reach 38% by 2047, with a further increase from the retirement of subcritical plants.

In the conventional NG segment, 1.57, 1.81, and 1.48 TCM of reserves are located onshore, in shallow offshore and in deep waters, respectively. During 2015, about 30% of domestic production was from onshore fields and 70% from offshore fields. About 90% of onshore production is concentrated in the basins located in the states of Assam, Gujarat, Andhra Pradesh, and Tamilnadu, while the majority of offshore resources are located in the Krishna-Godavari (KG) basin (Central statistics office, 2015). During 2015, in order to meet the demand-supply gap, about 40% of NG requirements were imported from Qatar in the form of liquefied natural gas. In order to meet the widening demand-supply gap, with a cumulative NG demand of 4.3 TCM during 2017–2047, India has planned to increase NG imports through cross-border pipelines. The Iran-Pakistan-India (IPI), Turkmenistan-Afghanistan-Pakistan-India (TAPI), and Myanmar-Bangladesh-India (MBI) pipeline projects worth US$16.5 billion, if realized, could together deliver about 59 BCM of NG annually to India. The TAPI alone could save US $0.25 billion annually by avoiding the use of LNG carriers (Nathan et al., 2013).

Domestically available unconventional hydrocarbon resources constitute 1.2, 2.72, and 1870 TCM of coal bed methane (CBM), shale gas, and marine natural gas hydrates, respectively (Ministry of Petroleum and Natural Gas, Economics and Statistics division, 2015). Shale gas resources are located in the Cambay, KG, Cauvery, and Damodar basins.

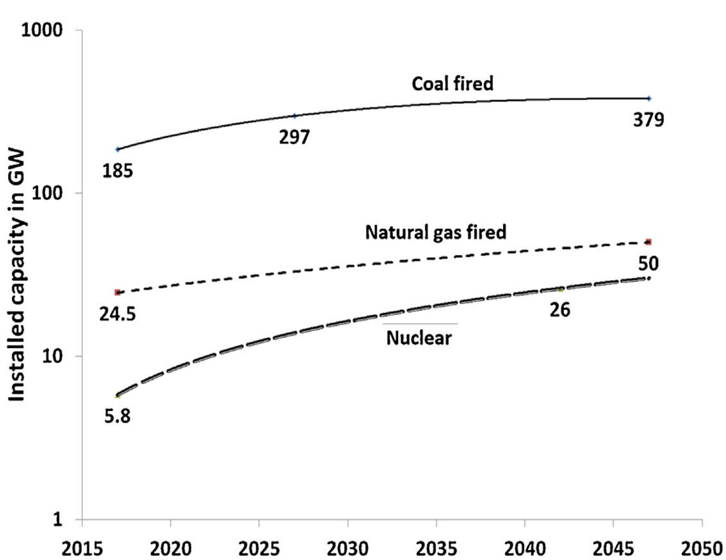

Fig. 1. Strategies for expansion of coal, NG and nuclear plants.