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Whose land is it anyway? Energy futures & land use in India

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ABSTRACT

Modelling studies which project pathways for the future of energy in India currently have several implicit assumptions with regards to the social, institutional, and political changes necessary for energy transitions. This paper focuses on the specific question of land use change required for realising ambitious clean energy targets. Demand for land is likely to be a critical question in India's energy future given the challenges with land acquisition in the country as a result of high population density and significant rights enjoyed by landowners. Yet, there is a lack of literature relevant to India which makes a quantitative assessment of the land use impacts of different types of low carbon technologies. I calculate and compare the land requirements in India of ground based solar photovoltaic (PV) power, nuclear power, and wind energy. All three types of technologies are expected to grow substantially as a share of India's electricity mix in the coming years. The analysis suggests that land demands of ground based solar PV are likely to be substantial compared to wind energy and nuclear power, and some policy suggestions are provided which may help mitigate that challenge.

1. Introduction

In India, the world's third largest carbon emitter, renewable energy is receiving great attention as a solution to both climate imperatives and the challenge of energy poverty. India has high potential for deployment of solar energy to meet its electricity needs given the high solar insolation in the country (Khare et al., 2013). Indian Prime Minister Narendra Modi has announced a domestic goal of increasing renewable energy to 175 gigawatts (GW) by 2022, of which solar photovoltaic (PV) would make up 100 GW and wind power 60 GW. Of the 100 GW target for solar power, 60 GW is to be ground based solar while 40 GW will be rooftop solar. Several reports have however questioned the land based targets for deployment of solar energy, particularly citing challenges related to financing, grid connectivity and distribution, and last but not least, land area (Khare et al., 2013; NITI Aayog et al., 2015; Patil, 2017). Similarly in the case of wind energy, land acquisition has been highlighted as the biggest challenge to private companies operating in the sector (Rajaram, 2012; Siraj, 2015). Alongside the growing push for renewable energy sources in India, is also a simultaneous push for nuclear energy, which remains an important and growing part of India's energy mix and an integral part of India's clean energy targets to tackle climate change (Mohan, 2016). Nuclear power projects in India have however faced significant delays due to local protests at plant locations.

The main challenge in India with respect to land availability for large power projects is to do with the acquisition of land. There are several legal difficulties with the process for land acquisition for large scale infrastructure projects such as power plants as the current land acquisition laws provide significant privileges and protection to landowners. The current National Democratic Alliance (NDA) government has been attempting to amend the existing land acquisition bill but has had no progress with this agenda in the upper house of parliament. India continues to have a high degree of conflict over land and over 60% of all conflicts documented are to do with land acquisition by the government (Tata Institute of Social Sciences and The Rights and Resources Initiative, 2016). Furthermore, 15% of all land conflict in the country is linked to power projects and in Central India the figure is as high as 33% (Tata Institute of Social Sciences and The Rights and Resources Initiative, 2016). Demand for land is likely to be a critical question in India's energy future given the high population density in the country and significant rights enjoyed by landowners. Targets for expanding clean energy which is a major focus of Indian energy policy, should take into account considerations over land use and the differences between different types of energy generating technologies. There is however a lack of literature relevant to India which explores this issue and which can serve as a guide to policymaking and further research.

In this paper, I calculate the land use implications of solar power in

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terms of m^2/GWh. To put this number in perspective and facilitate comparison with other energy sources likely to play a significant role in India's energy future, I also estimate the land footprint of future nuclear power reactors in the country and the land footprint of wind energy. Previous studies in other countries have made important advances in bringing the debate on land use and electricity generation to light, but have certain shortcomings when applied to India, as I highlight. This paper will try and bridge those deficiencies and provide policymakers and researchers with up to date estimates of future land use claims by low carbon power sources in India. Finally, some policy suggestions are provided that flow from the analysis.

2. Literature review

There is limited life cycle analysis of land use by different electricity generation technologies that is pertinent to India. A scan of the literature on life cycle land use analysis of energy technologies in India reveals a neglected and under-studied field. Perhaps as a result, modelling studies which project pathways for the future of energy in India currently have several implicit assumptions over land use and land availability for large scale energy infrastructure projects. For instance, the TERI-WWF study into a 100% renewable energy scenario for India estimates a grid connected solar PV build up of up to 1200 − 1400 GW. The report notes that land availability will be a considerable constraint in the build up of solar PV in India and estimates that an installed solar capacity in this range would require land equivalent to 1% of the solar hotspots in the country (TERI and WWF-India, 2013, p. 23). However, there is little further debate on what the implications of this challenge for energy policy should be. Similarly, questions over land availability and impacts are conspicuous by their absence in the Lappeenranta University of Technology report on a renewable energy future for India by 2030 which estimates 727 GW of solar PV build up in the country but does not contain any discussions about the challenges of land acquisition for such a gigantic build up of solar power (Breyer et al., 2016). The Indian government sponsored think tank National Institution for Transforming India (NITI) Aayog has also released a report into renewable energy pathways to 2030 for India which analyses possibilities for rapid renewable energy deployment in the country. The report notes land availability as a major challenge to a dramatic scale up of renewable energy (NITI Aayog et al., 2015). Considerable sections in the report are devoted to policy options for land acquisition and planning for land availability but there is no comparative analysis of land use claims by different types of clean energy technologies (NITI Aayog et al., 2015).

The most notable analysis of comparative land use claims in India is by Mitavachan and Srinivasan (2012) who compare the respective land footprint of nuclear, solar PV, hydro, and coal power. Their data for nuclear energy land use is based on two studies that they cite as references. The first is the study by Jacobson (2009) that compares energy technologies in the United States and includes a section on nuclear power. The second set of numbers for nuclear energy land use presented by Mitavachan and Srinivasan (2012) is based on a seminal study by Fthenakis and Kim (2009) which compares the life cycles of different energy technologies. Both Fthenakis and Kim (2009) and Jacobson (2009) however use numbers relevant to the United States for their nuclear power land use calculations and therefore these studies cannot provide an accurate reflection for Indian nuclear energy land use. There are three reasons for this. Firstly, laws regarding siting of nuclear power plants are extremely unique to countries. Some countries require extensive exclusion zones that significantly increase the land area required while others do not. Secondly, their calculations for the nuclear fuel cycle, particularly the front end of the nuclear fuel cycle – fuel extraction, conversion, enrichment and fabrication – are once again unique to the United States. Out of the 21 nuclear reactors currently operating in India, 17 are Pressurised Heavy Water Reactors (PHWRs) which use natural uranium as fuel and for which enrichment is therefore not a consideration. Third, the numbers used in their analysis for the back end of the fuel cycle by Fthenakis and Kim (2009) for instance, particularly waste disposal, are drawn from a calculation of the percentage of land a particular reactor would require from the total area of the Yucca Mountain repository and are relevant to an open fuel cycle. India's fuel cycle is however closed, which means that most of the spent fuel is reprocessed and that in turn significantly reduces the area required for waste disposal. Given these differences in the nuclear reactor siting and fuel cycle process between India and the United States, the numbers used by Mitavachan and Srinivasan (2012) are not representative of the land use claims of nuclear energy in India. Mitavachan and Srinivasan (2012) also do not include wind power in their study despite the strong prospective growth of wind energy in the country.

3. Methodology

My assessment of land use is from direct metrics of life cycle land transformation, i.e. the land area used to generate electricity as well as land use associated with the fuel cycle process. Land transformation from the power plant site is calculated by dividing the total land area of the reactor site (m^2) by the expected total electricity produced by the plant over its lifetime (GWh) using Eq. (1) below. CF is the capacity factor of the power plant, h/y is the number of hours per year, and y is the expected number of years of operation.

$$\text{Land Use}\left\{\frac{m^2}{GWh}\right\} = \frac{Land\ Area}{Net\ Rated\ Capacity\ (GW)^*(h/y)^*CF^*y} \tag{1}$$

Equation 1: Land Use from Power Plant Site

Land use from the fuel cycle process is also calculated in terms of m^2/GWh and therefore the total land use of a particular energy generating technology is simply the summation of the land use at the reactor site and that of the fuel process.

For Solar PV, I have chosen an upcoming solar park project of 1000 MW in Rajasthan for the comparative analysis in this paper. The choice of the state of Rajasthan is because this state is listed by the Ministry of New & Renewable Energy (MNRE) as having the highest potential in the country for future growth in solar energy according to a report by the National Institute of Solar Energy (2014), and currently has one of the highest amounts of installed capacity of solar PV power in India. It is as a result, a useful example to estimate land use claims by future solar power projects in the country.

For nuclear power, I have selected the project site for two twin prospective new Indian PHWRs at a site in Gorakhpur, Haryana. As mentioned before, PHWRs constitute the majority of India's currently operating reactors as well as the majority of reactors currently under construction in the country. The selection is therefore a good representative of the current and future nuclear energy production process in India. Data for land use in the case of the Gorakhpur reactor site is also readily available. To improve on the Indian numbers for nuclear energy in particular compared to previous studies, I use India specific data for the nuclear plant site; remove enrichment considerations from the life cycle assessment as Indian PHWRs use natural uranium as fuel; and use the French closed fuel cycle as a useful estimate for land use claims of reprocessing and fuel disposal. These three steps enable a more accurate estimation of nuclear energy's land footprint in India. For uranium mining and fuel fabrication, I employ numbers from previous international studies in the absence of India specific data.

In the case of wind energy, no project specific data is available for the existing wind farms in the country. However, the National Institute of Wind Energy in India estimates the average energy density of installed wind energy capacity in India to be 6 MW per square kilometre as per its latest annual report (National Institute of Wind Energy, 2016). This figure is comparable to other countries. For instance, the National Renewable Energy Laboratory (NREL) in the United States assumes an