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India's CO_2 emissions pathways to 2050: Energy system, economic and fossil fuel impacts with and without carbon permit trading

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ABSTRACT

Fast-emerging (yet still relatively less developed) economies such as India are understandably cautious about committing to emissions reduction targets that could be economically costly. The tensions between continuing short-term economic growth whilst investing in low-carbon technologies for long-term decarbonisation could be eased if there were significant financial and non-climate potential benefits of decarbonisation for these economies. This study explores some of the potential benefits for India, by analysing its long-term mitigation options in the context of global action towards a 2 °C target, using an energy systems model (The University College London TIMES Integrated Assessment Model, or TIAM–UCL) which represents India explicitly, as one of 16 global regions. The study finds that India could significantly over-achieve against a 2050 low-carbon target based on equal per capita emissions by 2050, at mitigation costs below the global carbon price, implying that it could earn significant revenues through selling international carbon credits, thereby offsetting some of the costs of decarbonisation. In addition, India would see much lower levels of fossil fuel consumption in a low-carbon scenario, thereby alleviating potential economic difficulties in securing access to adequate supplies of these fuels.

1. Introduction

This study presents an assessment of how a range of low-carbon technologies could in combination help India's economy and energy system remain at a relatively low level of CO_2 emissions over the next four decades, even with significant economic growth and development. This would allow India to play its part in an international effort to avoid dangerous levels of global warming. The particular aspects focused upon in this analysis are threefold:

- India's least-cost low-carbon pathway to 2050, as part of a global low-carbon scenario in line with a target to limit global warming to 2 °C above pre-industrial levels, considering scenarios with and without international carbon permit trading. This allows an assessment of the potential economic benefits to India of participating in an international carbon permit trading regime.
- A detailed analysis of the changes to the energy system across the major supply and demand sectors in India, when comparing a business-as-usual and low-carbon scenarios. This helps to highlight what energy system changes India would undertake to achieve the low level of emissions required to contribute towards a global target of 2 °C, both with and without carbon permit trading.
- An assessment of the changes to fossil fuel and other energy carrier demand when comparing the business-as-usual and low-carbon scenarios. Again, this highlights the potential opportunities and challenges for India in terms of maintaining energy security if it decarbonises as part of a global effort to achieve the 2 °C target, and what impact carbon permit trading has on this.

The motivation for such an assessment, focused on the potential impacts of carbon permit trading as well as fossil fuel consumption, is that India currently has a range of energy and economic development requirements which will affect its incentives to undertake a low-carbon development pathway.

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India is still poor by global standards, with a GNI (Gross National Income) per capita of around $3500 (in Purchasing Power Parity terms) in 2010, compared with the USA's $47,000 [1]. To develop further, India will need reliable access to increasing supplies of energy. India's TPES (total primary energy supply) per capita stood at 0.53 toe (tonnes of oil equivalent) in 2007, whereas the USA's figure was closer to 8 toe/capita. Even OECD Europe, which is much less energy-intensive than the USA, used 3.6 toe/capita in 2007 [2].

In addition, India is currently highly reliant on fossil fuels to meet its energy needs. Oil net imports made up about 70% of total oil consumption in 2011 [3]. India is the world's third largest coal producer with the sixth largest reserves [4], but these reserves have a high ash content and are concentrated in eastern states, far from the highest demand centres in western and southern India [3], which means there is an increasing reliance on coal imports too.

About 300 million people, mostly in rural areas, lack access to electricity [5]. Even for those connected to the grid, blackouts are common and capacity shortages mean that some 15% of peak power demand is not met [6]. There is chronic under-investment in the power sector generation and transmission system, stemming from capped electricity tariffs which do not repay investments [7].

Clearly economic development, energy security and energy access are therefore primary concerns for India, but there are several reasons why attention has also turned to climate issues in recent years. For one thing, India is vulnerable to climate change, which could have a number of negative economic impacts, such as decreased yields of wheat and rice (two of its major exports), as well as increased sea level and water stress [8]. For another, India's policy-makers are aware of the non-climate change benefits of a more diverse, indigenous energy supply, which is decreasingly reliant on fossil fuels. India's Planning Commission on integrated energy policy has stated that "it is not a question of choosing among alternative domestic energy resources but exploiting all available domestic energy resources to the maximum as long as they are competitive" [9].

This paper is structured as follows: Section 2 reviews recent studies on India's potential low-carbon transition; Section 3 sets out the details of the modelling framework used in this study, and the key assumptions used in the modelling to project future energy demand across India's economic sectors; Section 4 presents the results from the modelling, highlighting the impact of emissions trading on India's decarbonisation options and costs, the changes to India's energy systems across the major economic sectors, when comparing the high and low carbon scenarios, as well as the implications for India's fossil fuel usage; Section 5 discusses the main outcomes from the modelling and concludes.

2. Studies on India's low-carbon options

Energy has in recent years included studies projecting India's energy needs and low-carbon options over the medium-term, to 2020 and 2030. Parikh (2012) reports on the analysis of the Planning Commission's Expert Group to produce a Low Carbon Strategy for Inclusive Growth, in order to assess India's options to achieve its Copenhagen Accord voluntary commitment of a 20–25% reduction in its GHG intensity (per unit GDP) compared to its 2005 level, by 2020 [10]. The four scenarios presented – a "determined" and even more "aggressive" effort scenario for two assumed real economic growth rates (8% and 9% per annum) would in theory achieve an intensity reduction of between 24% ("determined") and 33–34% ("aggressive"). Policy measures would promote more efficient lighting and appliances, implementation of energy efficient building codes, better labelling for industrial equipment and the use of more energy efficient manufacturing plant including variable speed drives, as well as a range of measures to achieve modal shifts towards public transport, and greater efficiency of vehicles. In addition, a range of measures in the power sector, including a 4–6% increase in coal plant efficiency, and a large increase in wind capacity (to 30 GW by 2020) and solar capacity (to 20 GW by 2022) are assumed. The targets are deemed to be achievable, but will need determined policy efforts, as well as reform of energy pricing to remove distorting subsidies, to encourage and support the uptake of energy efficiency measures.

Parikh and Parikh (2011) look to 2030 to assess the potential reduction in CO_2 emissions available from a range of mitigation measures, in an economic scenario with an 8% real annual growth rate to 2030 [11]. They use a cost-optimising IESM (Integrated Energy System Model) (described in detail in Ref. [12]) to explore how India's projected energy needs could be met, with and without measures to minimise CO_2 emissions. The most significant measures (maximising hydro and nuclear potential, reducing transport energy demand, accelerating renewables deployment and above all achieving reduced electricity demand through greater energy efficiency) could together reduce CO_2 emissions by about 30% compared to the 5.23 billion tonnes in the base case, at a total discounted present value cost of $91 billion (US$2005) over the period 2005–2030.

The role of key technologies in India's potential low-carbon pathways has also been explored in *Energy*'s (2009) special issue on "Energy and its sustainable development for India". For example, carbon capture and storage could play an important part in reducing CO_2 emissions in the future, given India's likely continuing reliance on coal use due to its significant reserves, with analysis suggesting that capturing emissions from up to 10 large point sources could save up to 13 $GtCO_2$ cumulatively over the period 2010–2030 [13]. A range of renewable technologies could also make an important contribution to energy supply in India, with analysis suggesting that renewables could make up to 10% of energy by 2022 [14]. Long-term potentials for key technologies include up to 100 GW for wind (onshore and offshore), up to 15 GW of small hydro, and over 100 GW of biomass generation [15].

A number of additional studies have been undertaken to assess India's longer-term (to 2050) low-carbon possibilities and their implications. For example, the International Energy Agency's Energy Technology Perspectives 2012 [16] shows a significant role for the power sector to decarbonise, with increased shares of nuclear, renewables and CCS (carbon capture and storage) displacing coal by 2050. Additional low-carbon measures include energy efficiency across all sectors, and increased electrification and use of biofuels in transport.

Shukla et al. (2008, 2009) [17,18], also show the major mitigation measures for India to 2050, again for a business-as-usual scenario and also for two different low-carbon scenarios. The first low-carbon scenario (called "carbon tax scenario") considers a more conventional economic development pathway allied to a carbon tax. The second ("sustainability") scenario places a much greater emphasis on sustainability measures, such as dematerialisation, energy efficiency, and sustainable consumption. Both scenarios achieve a deep decarbonisation in India which is commensurate with a 2 °C global warming target, although in the carbon tax scenario, there is a very heavy reliance on supply-side technologies such as CCS and nuclear (which together account for over half of all CO_2 reductions, compared to less than 20% of reductions in the sustainability scenario) and much higher costs (with a carbon price of more than $200/tCO_2$ in 2050, compared to about $120/tCO_2$ in the sustainability scenario).

Massetti (2011) [19] uses the WITCH integrated assessment model to explore the cost impacts of different carbon taxes applied to India in the context of a global effort to reduce GHG emissions. The study concludes that – owing to the assumptions made about