Divecha Centre for Climate Change
Indian Institute of Science, Bengaluru

Policy Brief
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Co-benefits of power sector decarbonisation for air quality and human health in India

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Highlights:

- Air pollution and associated health impacts are rapidly rising in India, in contrast to declining trends in other major economies of the World.

- India can substantially reduce air-pollution from its power sector by reducing coal use (decarbonisation scenario) and by implementing strict air pollution control norms (pollution control scenario).

- India's plan to rapidly expand its renewables capacity in the next decade could reduce coal consumption by about 500 Million tonnes (Mt) per year in 2030 (decarbonisation scenario) compared to 'Business as Usual' projections.

- Decarbonisation scenario is projected to avoid approximately 790 Mt of CO_2 emissions per year by 2030. We further estimate that India's choice of an economy-wide low carbon trajectory in the 21st century could mitigate global temperatures by 0.2°C compared to the BAU trajectory.

- Decarbonisation of Indian power sector could also significantly reduce pollutant emissions, and could reduce health risks (measured in terms of 'disability adjusted life years' - DALYs) by 36% in 2030 when compared to 'Business as Usual'.

- If implemented universally across all plants by 2030, pollution control (perfect pollution control scenario) could be far more effective than decarbonisation for limiting pollutant emissions and health risks.

- However, we find that in the face of imperfect pollution control, decarbonisation and pollution control together make for a robust strategy to mitigate air pollution and health risks from the Indian power sector.

- While full emissions control takes shape, a move towards decarbonisation would play an important role in reducing air pollution and associated public health risks in India.

Rising air pollution and health implications in India

India is the exception amongst major economies, because its air pollution (emission of particulate matter i.e. PM2.5 and PM10, SO_x and NO_x) and associated health impacts are still rapidly rising (Dey et al., 2012; IHME, 2017). Other major economies of the World, including the US, EU, China and Japan have now been able to reverse the trend in air pollution (Hasunuma et al., 2014, Green Peace, 2016). Among air-pollutants, PM2.5 is most harmful to human health. Mean annual PM2.5 concentration in India has increased by 54% in the previous two decades, from 30 $\mu g/m^3$ in 1990 to 47 $\mu g/m^3$ in 2013 (World Bank and HME, 2016), with the Indo-Gangetic plain witnessing a higher rate of increase in air pollution compared to the national average (Dey et al., 2012, Jain et al., 2017).

Ambient air pollution is estimated to have killed about 3 million people globally in 2012, with India alone accounting for about 20% of these global deaths (WHO, 2016). The effect on morbidity is much larger. Balakrishnan et al (2014) reported that in 2010 India suffered a loss of 17.8 million years of healthy life (as measured by DALYs) due to ambient air pollution, whereas this was reported to have increased to 20 Million years (DALYs) in 2012 (WHO, 2016).

Pollution from the power sector

In India the power sector contributes to about 15% of human-caused particulate matter, 30% of NO_x and 50% of SO_x emissions per year (Guttikunda et al., 2014). Pollution from coal fired power plants is most severe in interior areas of Jharkhand, Chhattisgarh, Orissa, Bihar and Eastern Uttar Pradesh. Pollution from power plants generally affects less developed rural areas located in their neighbourhood, rather than high-visibility urban centres. Rural location of harm means it does not receive its fair share of political and public attention.

Pollution from thermal power plants is relatively easy to control, since it involves large and stationary point sources. India already has pollution control standards for particulate matter emissions, and norms for SO_x and NO_x emission control have been notified to be implemented from December, 2017 (MoEFCC, 2015a). Furthermore, power sector decarbonisation (reduced coal use and expansion of renewables) in India is often discussed mainly in the context of climate change mitigation (MoEFCC, 2015b). In this policy brief we highlight the climate benefits of power sector decarbonisation and also explore its co-benefits for air quality and human health in India.

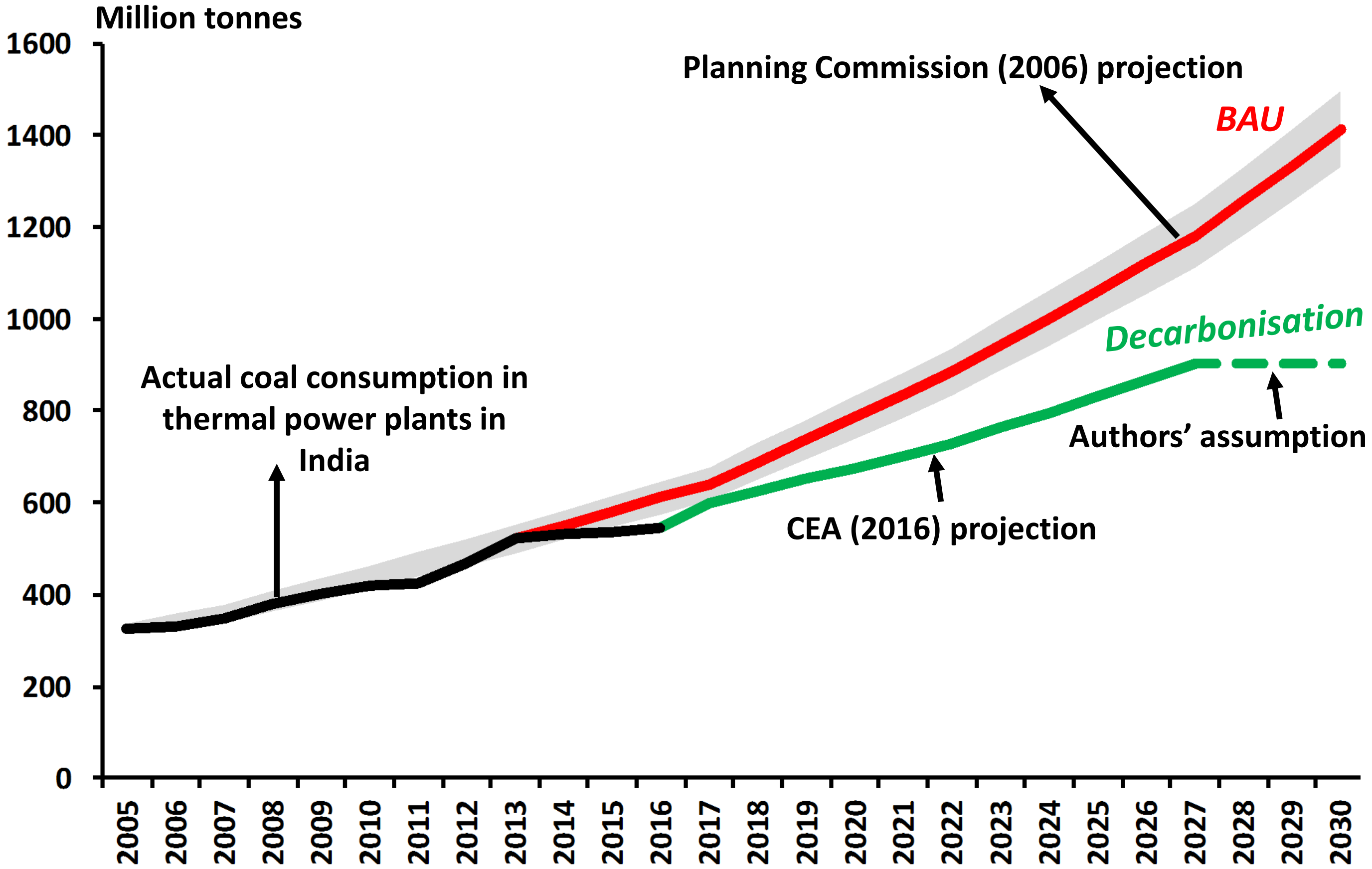


Figure 1: Scenarios for coal requirement for power generation in India [Actual coal consumption for power plants (raw coal and lignite) till 2016 are obtained from MoSPI, 2017 [BAU refers to Business as Usual]. BAU scenario's range of projections are obtained from Planning Commission, 2006. Decarbonisation scenario from 2017 to 2027 builds on projections of CEA, 2016, and over the period 2027 to 2030 the coal consumption is assumed to be stable under this particular scenario].

A 'Decarbonisation' scenario for India's power sector

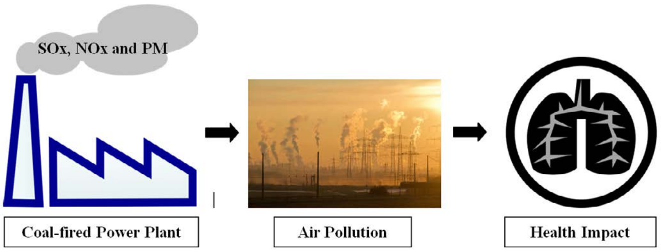
Coal is the mainstay of Indian power sector, and currently about 58% of India's installed electricity generation capacity comes from coal. India plans to increase installed renewables capacity to 175 GW in 2022 (MoEFCC, 2015b) and to 275 GW in 2027 (CEA, 2016). Already, renewables capacity is fast increasing in India especially in the last decade, as the installed renewables capacity has increased from almost zero in 1997 to 58GW in 2017. In the next decade, as per analysis carried out by CEA, 2016, this planned renewables capacity addition would allow India to avoid adding new coal based capacity except for the plants already under construction. This is likely to substantially reduce coal consumption compared to Business as Usual (BAU) projections (Planning Commission, 2006). Figure 1 shows that actual coal use for power plants has decreased in the last couple of years compared to the Planning Commission's BAU projections for this period. Under the BAU scenario, coal consumption increases from 523 Mt in 2013 to 1412 Mt in 2030. Power sector decarbonisation is an important aspect of the global policy response to climate change. In the 'Decarbonisation' scenario, coal consumption for power generation increases from 523 Mt in 2013 to 901 Mt in 2027. For the purpose of this analysis we have made an optimistic assumption that coal consumption remains stable at this level over the next three years.

Methodology

Emission inventories of GHGs and pollutants from coal power plants, during the period 2005-2030 for the BAU and the 'Decarbonisation' scenarios, are computed using the formula

Emissions = Activity data* Emission factor

where, "Activity Data" refers to the amount of coal combustion in a given year (e.g. tonnes of coal) and the emission factor refers to the amount of emissions (GHG, pollutant or particulate matter) caused by burning of a unit of coal (e.g. tonnes of SO_x per tonne of coal burning). Emission factors are obtained from Guttikunda et al (2014), CSE (2015) and Singh et al., (2016), CEA 2016a, Ghodke et al., 2012, and MoEF, 2010 .



Effect of gaseous pollutants SO_x, NO_x and particulate matter emissions on health is assessed using the disability-adjusted life years (DALYs) approach as elaborated by Hofstetter, 1998 and Eco Indicator 99 (EI99; Goedkoop and Spriensma, 2001). DALYs estimate the impacts for disease and poor health conditions, and are calculated as the sum of the years of life lost due to premature mortality in the population and the years lost due to disability for people living with the health condition and its consequences. The reference works used here (Hofstetter, 1998 and Eco Indicator 99) were implemented for conditions corresponding to population density in Europe. In the present analysis we have modified the "DALYs per kg of emission" by using the estimated and forecast population density (United Nations, 2017) of India over the period 2005 to 2030.

GHG mitigation under decarbonisation

In 2010, GHG emissions from coal burning accounted for about 39% of India's net emissions. CO_2 makes up for much of these emissions, with much smaller amounts of CH_4 and N_2O. Here we focus on CO_2 emissions. Figure 2 projects CO_2 emissions from coal combustion for electricity generation till 2030 under 'BAU' and 'decarbonisation scenario'. Figure 2 suggests that under the 'BAU scenario' CO_2 emissions from coal combustion for power generation increases to about 2420 $MtCO_2$ in 2030, whereas in the 'decarbonisation scenario' it increases to only about 1630 $MtCO_2$, yielding a reduction of about 790 $MtCO_2$ emissions per year comparable to present emissions from the power sector.

India's economy-wide low carbon scenario and consequence for global temperature in the 21st century

Here we project how India's economy-wide low-carbon trajectory in the 21st century could affect global mean temperature. Low carbon and BAU scenarios were based on the discussion of Chaturvedi and Mitavachan (2017), who have recently described the economy wide low carbon scenario as well as the BAU scenario using Niti Aayog's IESS tool (Ahluwalia et al., 2016). The resulting alternate emission scenarios for India are shown in figure 3(a). It is well known (Allen et al., 2009; Matthews et al., 2009) that global warming from CO_2 is roughly proportional to cumulative emissions. The sensitivity of global warming to cumulative CO_2 emissions has 5th - 95th percentile range of 0.9 – 2.5°C per 1000 GtC, with average value of 1.7 (MacDougall et al., 2017). Figure 3(b) shows average and ranges of future global warming contribution from these scenarios. Owing to the cumulative effects of CO_2 emissions as well as rising emissions in the Business as Usual scenario, India's choice of an economy-wide low carbon trajectory reduces global warming by century's end of about 0.2°C (for average sensitivity) compared to its BAU scenario. Benefits could be larger in case global warming is more sensitive to cumulative emissions.

Decarbonisation of Indian power sector could significantly reduce pollutant emissions and health risks

Coal based electricity generation not only causes GHG emissions such as CO_2 but also produces emissions of short-lived pollutants such as SO_x, NO_x and particulate matter.

We estimate that India's plan to build large-scale renewable capacity and consequently limiting the growth of coal use for power generation could significantly cut down short-lived pollutants by about 36% by 2030, in addition to reducing

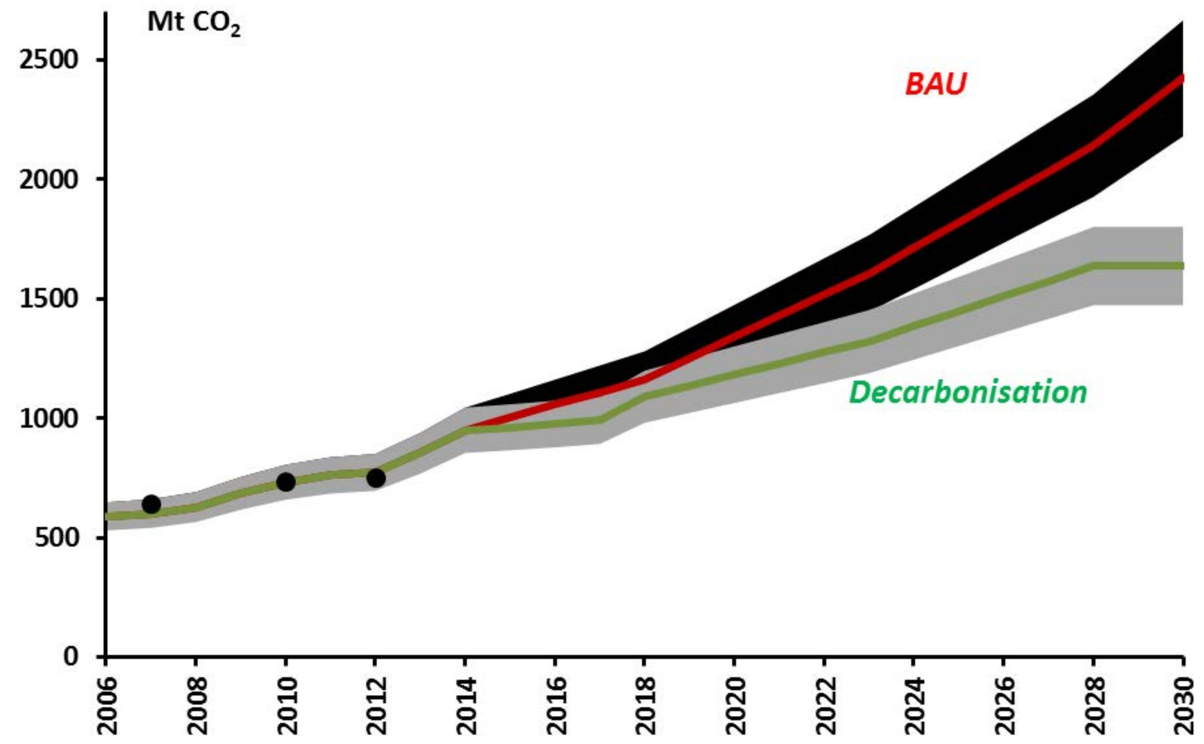


Figure 2: CO$_2$ emissions under the BAU and decarbonisation scenario. CO$_2$ emission estimates for the years 2007 (MoEF, 2010), 2010 (MoEFCC, 2015b) and 2012 (CEA, 2016) are shown as black dots in figure.

long-lived GHGs such as CO$_2$, compared to the BAU scenario. We also estimate that the implementation of decarbonisation scenario leads to saving of 1 million (Mn) DALYs by 2022 and 3.5 million DALYs by 2030 compared to the BAU scenario (Figure 4a).

Pollution control is far more effective in reducing health risks from thermal power plants

The pollution control scenario builds on previous literature examining the effectiveness of pollution control in lowering emission factors. The full implementation of particulate matter control (PMC), flue-gas desulfurization (FGD; controlling SO$_x$ emission) and selective catalytic reduction (SCR), for converting NO$_x$ to Nitrogen, could reduce SO$_x$ and NO$_x$ emissions by up to 70% and 90% respectively (Singh et al., 2016). Indian power plants are already subjected to PM control, however the implementation of these controls is weak. There is also evidence that full implementation of PMC could reduce particular matter emissions from thermal power plants by up to 90% (Guttikunda et al., 2014, CSE, 2015 and Singh et al., 2016).

Under the BAU scenario, with no decarbonisation and no pollution control, projected DALYs rise to 5.7 million and 9.7 million in 2022 and 2030 respectively, from the 2015 level of 3.2 Million. Assuming full implementation of pollution control in 2030, DALYs decrease to 4 million and 1.2 million respectively by 2022 and 2030 (Figure 4b), indicating a reduction in DALYs by 88% in 2030, when compared to BAU. Figure 4 suggests that a perfect pollution control scenario is far more effective in comparison to the decarbonisation scenario (88% reduction from the BAU scenario in 2030 compared to the 36% reduction in case of the decarbonisation scenario) in reducing DALYs from power generation in India.

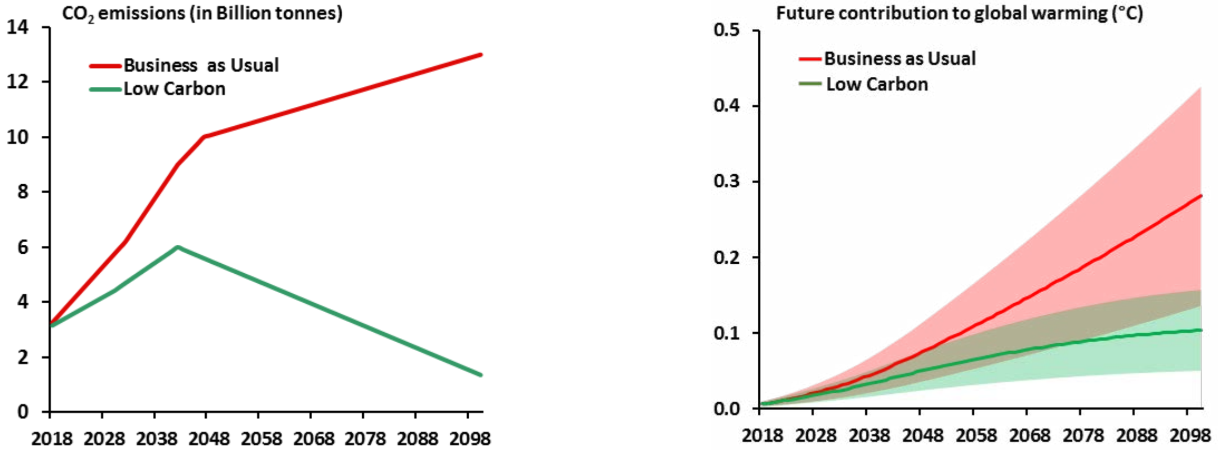


Figure 3 (a-left): Alternate 21st century CO$_2$ emission scenarios for India, **(b)** Future contribution to warming from India in the two scenarios.

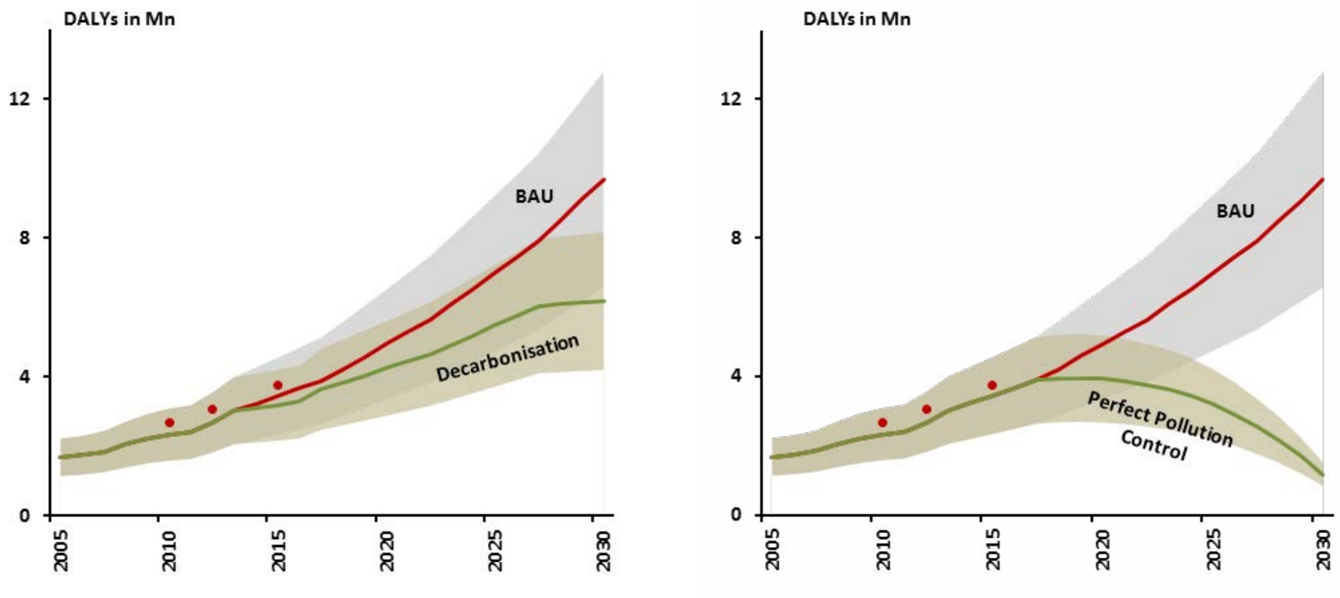


Figure 4: Role of **(a-left)** 'decarbonisation' and **(b)** 'perfect pollution control' in mitigating health impacts of pollution from Indian power plants (Red dots show estimates from Balakrishnan et al., 2014 (for year 2010), from WHO, 2016 (for year 2012) and from IHME, 2017 (for year 2015), assuming 15% PM contribution from the power sector).

In the face of imperfect pollution control, 'Decarbonisation' is a robust strategy to mitigate pollution related health risks in India

Perfect Pollution control would require not only installation of available emission control technologies in all coal powered units, but also constant monitoring and management of compliance. Indian power plants are already subjected to PM controls. SO_x and NO_x controls were expected to come into operation from December, 2017. Only the power plants that are built after 2017 will be subjected to the strictest pollution control norms, whereas older plants are subjected to less stringent norms. In the face of weak monitoring and compliance mechanisms it has been reported that even the existing norms for PM control are not being adhered to (Bhati and Ramanathan, 2016; Gosh, 2015).

Hence, we develop a scenario that takes into account that 'perfect emission control' might not be achievable in the next decade. Under an imperfect pollution control scenario (assuming 50% leakage due to technology, standards, implementation and compliance related reasons) the DALYs rise to 5.5 million in 2030 (Figure 5). Figure 5a shows that perfect pollution control reduces 88% of DALYs in 2030, and even imperfect pollution control substantially reduces the DALYs (by 4.2 million DALYs) compared to the BAU (figure 5b). However, if we add 'Decarbonisation' in addition to imperfect pollution control it further reduces the DALYs by 2 million in 2030 (figure 5b).

Figure 5 suggests that Decarbonisation and Pollution control together make for a robust pollution mitigation strategy for India's power sector, because the benefits for reducing DALYs become less sensitive to the inadequacies in implementing pollution control.

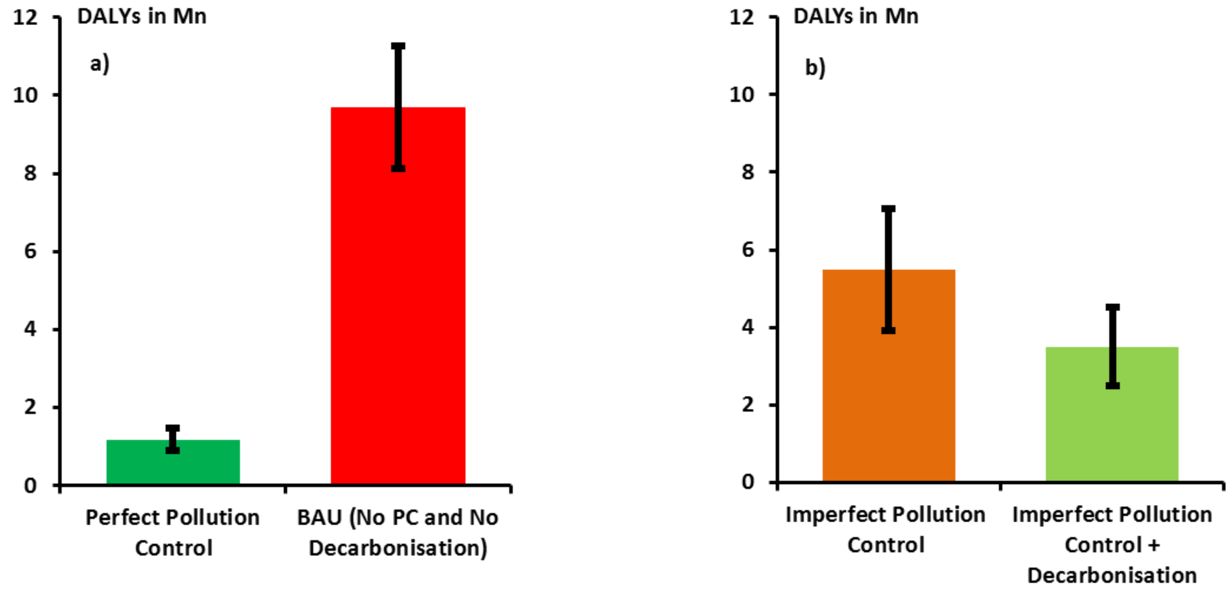


Figure 5: Projected DALYs in 2030 under different scenarios ('PC' stands for Pollution control).

Figure 1 shows that India's coal consumption for its thermal power plants have already switched to the 'Decarbonisation' trajectory for 2022 and beyond. India has already increased its installed renewable capacity by 70% in the short span of just two years from 34 GW in January 2015 to 58 GW in August 2017. Going forward, India has outlined a clear work plan to achieve the renewables goal of 2022, including the decision to auction 77 GW of solar capacity by March 2020 (PIB, 2017). However, on the pollution control side, weak implementation of existing norms continues and India is likely to miss its December, 2017, deadline for implementing the new MoEFCC 2015a pollution control norms (Bhati and Ramanathan, 2016; Gosh, 2015). Media reports suggest that implementation of pollution control for Indian thermal power plants may take six more years (Singh, 2017).

While recognizing Government of India's efforts in ushering in a low carbon transition in the power sector, we also recommend that India must not let the implementation of pollution control norms for its thermal power plants slip, as it is vital for reducing ambient air pollution in India (Figure 4b). According to a World Bank estimate (World Bank and HME, 2016), in 2013 India suffered a welfare loss of about 8% of its GDP (PPP basis) due to air pollution and its health impacts.

High cost of emission control equipment and high operation cost is often cited as a reason for delay in installing and operating pollution control equipment (CSE, 2017). It has been estimated that full implementation of pollution-controls will increase the generation costs of coal power plants by 5-7 percent (Tongia and Seligsohn, 2017). Generation costs are only a part of the electricity tariff paid by consumers, and coal is only about 60% of installed capacity, so these figures are likely to be an upper bound on electricity rate increases. Considering a benchmark tariff of Rupees 3 per kWh and per-capita electricity consumption in FY 2015-16 of 1075 kWh. **A 7% increase in generation costs from pollution-control translates to Rupees 225 per capita annually. This is less than 1/450th of per-capita GDP (Economic Times, 2017). This is a small price to pay, being comparable to the price of a retail item such as a 'T-shirt'. Pollution control in the Indian power sector involves the choice whether individuals and government would be willing to pay a small fraction of income for reducing a significant public health risk.** Furthermore, the cost of reducing a DALY is much lower than per-capita income, and this is a cost-effective route to improving public health.

We conclude that implementation and compliance of stringent pollution control norms is vital for reducing pollution and associated health risks. However, while full emission control and suitable implementation and compliance mechanisms evolve, decarbonisation and a shift to renewables could play a significant role in reducing air pollution and associated health risks in India in the next decade.

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Illustrations: Coal-fired power plant and human lung graphic is taken from microsoft clipart. Air-pollution illustration is taken from (https://static.pexels.com/photos/221012/pexels-photo-221012.jpeg)

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About Divecha Centre for Climate Change

Divecha Centre for Climate Change was established at Indian Institute of Science in January 2009 with a generous financial contribution from Arjun and Diana Divecha and the Grantham Foundation for the Protection of the Environment.

The primary goal of this centre is to understand climate variability and climate change and its impact on the environment. The Centre has undertaken outreach activities to create awareness among citizens and policy makers about climate change and its consequences. This has been done through workshops, lectures and quiz contests. An annual invited public lecture called the 'Jeremy Grantham Lecture on Climate Change' is organized.

The centre has identified technologies to mitigate climate change in collaboration with entrepreneurs and different engineering department in Indian Institute of Science. The centre is also working with Grantham Institute for Climate Change at Imperial College, London.

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