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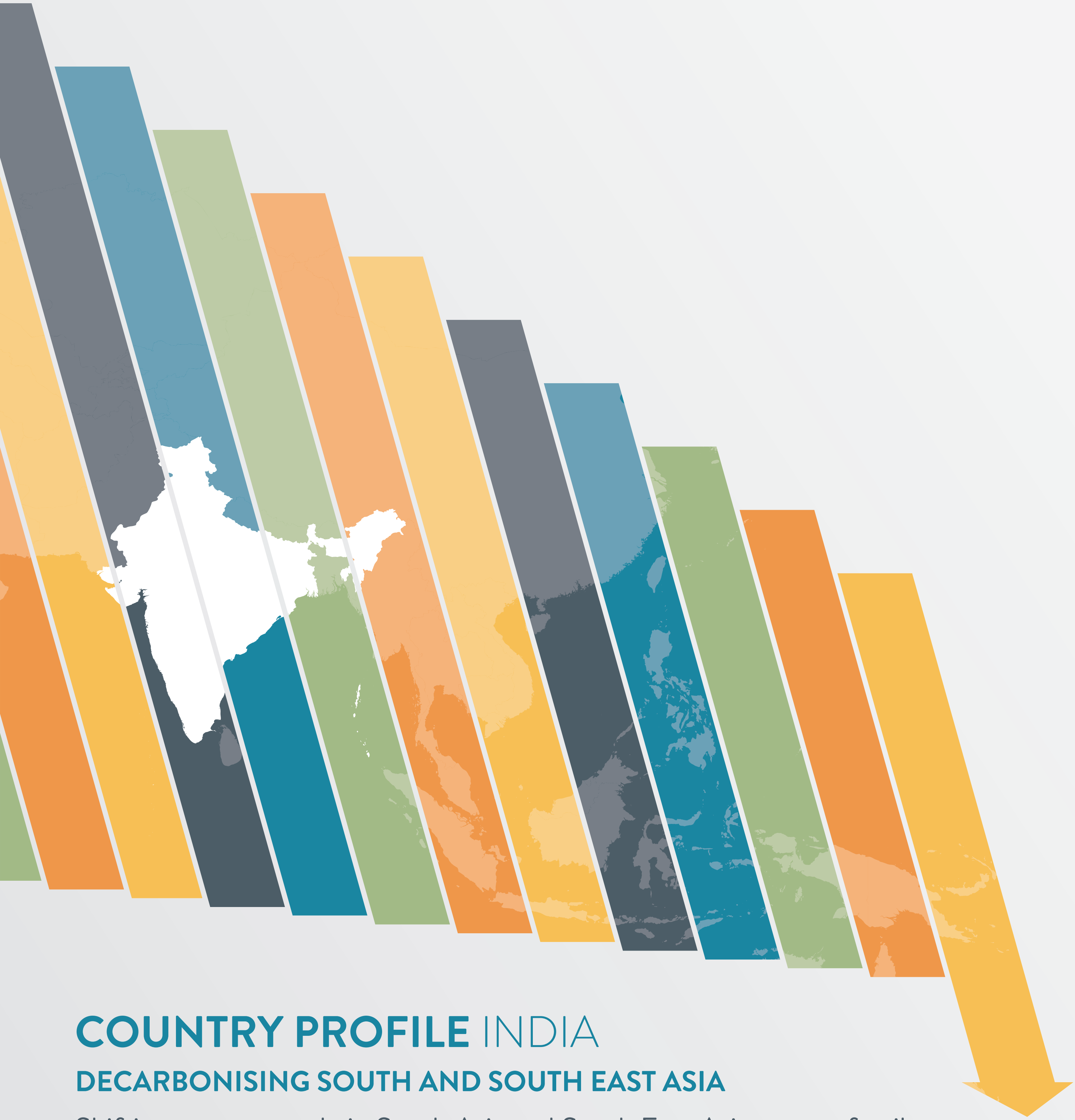


COUNTRY PROFILE INDIA

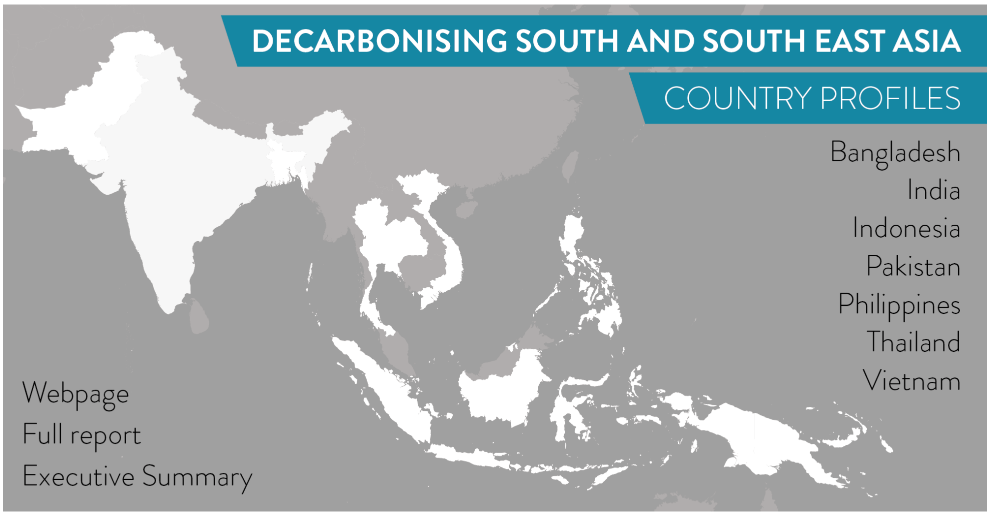
DECARBONISING SOUTH AND SOUTH EAST ASIA

Shifting energy supply in South Asia and South East Asia to non-fossil fuel-based energy systems in line with the Paris Agreement long-term temperature goal and achievement of Sustainable Development Goals

MAY 2019

This country profile is part of the ***Decarbonising South and South East Asia*** report and examines how to shift the energy supply in South Asia and South East Asia to non-fossil fuel-based energy systems in line with the Paris Agreement long-term temperature goal and achievement of Sustainable Development Goals.

Find links to other country profiles and the full report below.



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INDIA

Key Messages

Climate change impacts – Paris Agreement temperature goal matters for India

- India is already vulnerable to climate risks at current level of warming.
- Risks from flooding in a 3°C warmer world - corresponding to the warming projected for current NDCs - would increase by 9% and extreme precipitation by 23%; these values are much higher than in a 1.5°C warmer world.
- Extreme heat, which will be more frequent in a 3°C warmer world, would exceed tolerable levels for human health and labour productivity
- A world beyond 1.5°C would commit Indian coast lines to more than 2m of sea level rise in the long run.

India's energy system: push for renewable energy, but still fossil intensive

- India's electricity demand has doubled over the past decade; with growing population, progress in poverty eradication and energy access, energy consumption is expected to keep growing rapidly.
- Despite a strong push for renewable energy, India is still a net importer of oil and gas and is the second largest coal importer; the share of fossil fuel and carbon intensity of energy use has increased over the last decade.
- India's entire energy system, especially the power sector suffers from large inefficiencies; transmission losses rank among the highest in the world. Exploiting these vast untapped potentials for energy efficiency could slow down the need of supply growth to meet the increasing energy demand.
- Massive investments in power generation capacities and related infrastructure would be needed in the near future, bearing important opportunities for renewable energy deployment.
- Renewable energy deployment offers benefits such as reducing reliance on fossil fuel imports, increasing reliability of electricity supply, reducing water use, increasing access to modern energy, and reducing air pollution and related health impacts and mortality.

Transition to renewable energy offers massive benefits

- India has huge untapped renewable energy potentials. Using a small fraction of its land for solar PV installations would generate seven times as much electricity as is currently produced.
- India takes advantage of only slightly over 10% of its wind energy potential.
- The costs for solar and wind energy in India are among the lowest in the world. Despite the significant decrease in costs, installation of renewable energy projects (e.g. solar rooftop capacity) is lagging behind the government's plans.
- India can benefit massively from a rollout of renewable energy, even under a conservative scenario for 2030, estimates show savings between 45 billion USD and 160 billion USD each year from reduced air pollution, a decrease the demand for coal and oil products by about 17% to 23%, 3.5 million jobs in the RE sector, GDP increase of 1% above the reference case, and avoided climate impacts by 2030 would amount to about 13 to 63 billion USD every year.
- Beyond these benefits, renewable energy technologies offer opportunities to improve the access to electricity in poor and especially remote areas, contributing to the fight against energy poverty and offer alternatives to thermal power plants, thus avoiding additional emissions and water stress.

Targets, projections, and Paris Agreement benchmarks

- India's NDC target of non-fossil fuel generation of 40% by 2030, which includes nuclear generation, is rated 2°C compatible by the Climate Action Tracker. However, the non-fossil power generation target falls short of the 51% decarbonised/renewable energy generation benchmark consistent with the Paris Agreement, derived based on the IEA B2DS scenario.
- The National Electricity plan (NEP) projects that India's non-fossil fuel-based capacity will significantly exceed the 40% NDCs goal for 2030. However, there is uncertainty as to whether all renewables projects in the pipeline will be completed on time and integrated into the grid. Based on current policies, the Climate Action Tracker projects the share of non-fossil power generation capacity to reach 60-64% in 2030, corresponding to a 40-44% share of electricity generation, which still falls short of the Paris Agreement benchmark of 51% in 2030.
- The potential generation from coal in India far exceeds the benchmarks under a Paris Agreement compatible scenario, which establishes a phase-out of coal-fired power by 2040. There is a high risk of stranded assets unless current expansion plans are revised.
- Given the dramatic decrease in the costs of renewables, several studies show that it is technologically and economically feasible for India to achieve 100% renewable electricity generation by 2050.
- There is significant scope for upgrading the NDC and developing an ambitious long-term strategy towards 100% renewable energy power generation and electrification of end-use sectors, to align India's energy future with the goals of the Paris Agreement and reap benefits for sustainable development.

Introduction

With its large population, India is a significant contributor to global GHG emissions (7% in 2016 (JRC, 2017)), however, per capita emissions levels are well below the global average. Given its growing population and development needs, with almost a fifth of the population still lacking access to electricity, how India chooses to address the growing energy demand has important implications for the global efforts to achieve the Paris Agreement Long-Term Temperature Goal.

India's energy mix has traditionally been dominated by fossil fuels, with a large and increasing share of coal and oil used for the primary energy needs. Coal based power continues to dominate India's electricity generation. However, in recent years, there has been a massive push towards higher shares of renewable energy to address growing energy demand while considering other policy objectives, such as air quality and energy security. Despite this push for renewable energy, India is still a net importer of oil and gas and is the second largest coal importer.

Investment in renewable power in India topped fossil fuels for the first time in 2017, according to the International Energy Agency (IEA), but there is uncertainty with regard to the future of fossil-fuel based generation, with national energy plans still envisaging large additions of fossil fuel fired capacity, in particular coal. These additions, if materialised, could put the achievement of the national and global mitigation targets under jeopardy, and create a large risk of stranded assets.

1 Climate Change Impacts: Risks, vulnerability and benefits of limiting mean temperature rise to 1.5°C

1.1 Present day vulnerabilities and risks

In the past thirty years, India has seen a number of climate disasters as shown in Table 1. Climate extremes have affected the country both in terms of human fatalities as well as economic losses. Flooding events have been the most frequent climate disaster with 212 occurrences in the last 30 years, resulting in highest number of deaths and highest financial losses. In terms of human fatalities, extreme temperature events are the deadliest with the highest number of deaths per event. According to the Germanwatch long-term climate risk index[1], India is 14th most vulnerable country to climate change in the world (Eckstein et al., 2018). High incidence of poverty, with tens of millions of people living under 1.90 $ per day, further exacerbates the vulnerability of the country to climate change and associated extremes[2].

Table 1: Climate disaster statistics for India based on EMDAT database[3] for the period 1989-2018

Disaster Type	Events Count	Total Deaths	Total affected (million people)	Damage (million US$)
Drought	6	20	681.12	5041.1
Extreme temperature	40	13511	50	400
Floods	212	40419	621.24	57490.3
Storm	103	21747	57.8	19983

1.2 Projections on climate impacts comparing 1.5°C and temperature increase under current pledges

With a global mean temperature increase of 3°C above pre-industrial levels, corresponding to the warming projected for current NDCs, India would face a much higher annual precipitation increase, and substantially higher risks of negative impacts from extreme events compared with a world achieving the Paris Agreement 1.5°C limit (Table 2). The number of drought days are projected to increase by more than five in a 3°C world versus an increase of less than one in 1.5°C world. Moreover, a 3°C warmer world would not only lead to a higher increase in annual mean temperature compared with a 1.5°C world than the global increase (a difference of 1.8°C, from 1.1°C to 2.9°C, for a global increase of 1.5°C, from 1.5°C to 3°C) but take the annual maximum temperatures to close to 45°C, which is very concerning considering the country's historical vulnerability to the heat extremes as shown in Table 1. Flood risk as well as extreme precipitation intensity are also projected to be substantially higher in a 3°C world compared to a 1.5°C world.

1 The Germanwatch Global Climate Risk Index is an analysis based on one of the most reliable data sets available on the impacts of extreme weather events and associated socio-economic data. However, the index must not be mistaken for a comprehensive climate vulnerability1 scoring. It represents climate-related impacts and associated vulnerabilities but, for example, does not take into account important aspects such as rising sea-levels, glacier melting or more acidic and warmer seas. https://germanwatch.org/en/cri

2 http://hdr.undp.org/sites/all/themes/hdr_theme/country-notes/IND.pdf

3 https://www.emdat.be

Table 2: Future projections of different climatic variables averaged over India, based on an ensemble of CMIP5 Global Climate Models for 1.5°C and 3°C warmer than pre-industrial worlds [4]

Indicator	Historical (1986–2015)	+1.5°C World (Paris Agreement)	+3.0°C World (Current NDCs)
Annual Averages			
Near-Surface Air Temperature (°C)	23	+1.1	+2.9
Precipitation	936 mm	+2%	+5.6%
Extreme Events			
Drought: Consecutive drought days (Days)	79	+0.6	+5.5
Heat: Annual Maximum of Daily maximum Air Temperature (°C)	42	+1.0	+2.8
Flooding: Annual Maximum 5-day Consecutive Precipitation (mm)	131	+4.8%	+9%
Extreme Precipitation: 1 in 20 year Maximum 5-day Consecutive Precipitation Event (mm)	235	+4.2%	23%

Table 3: Future projections of Sea Level Rise (cm) as compared to today's level for India based on the data from Robert Kopp et al. (2014). Average values of 15 tide gauged stations across India are presented. The values in the brackets in the left column are the temperature difference for each future scenario between the end of 21st century (2081-2100) and pre-industrial period (1850-1900)

Sea Level Rise (cm)	2050	2100	2150	2200
RCP 2.6 (1.6°C)	25	52	75	102
RCP 4.5 (2.4°C)	26	62	98	132
RCP 8.5 (4.3°C)	29	82	137	203

India has a long coastline, which makes it vulnerable to sea level rise (SLR) due to global warming. Limiting warming to the Paris Agreement limit of 1.5°C would result in substantially lower sea level rise than for higher levels of warming, in particular in the long run, with a sea level rise of around 2 meters instead of 1 m by the end of the 22nd century in a 4.3°C world compared with a 1.6°C warmer world[5] (Table 3). Furthermore, India's flood plain area is projected to get inundated by extreme floods for non-mitigation scenario (RCP 8.5) at a higher rate than mitigation scenarios (AMP) already by the end of 21st century. This difference would double by the end of 22nd and triple 23rd century (Table 4). Risks posed

4 The presented values are based on an ensemble of general circulation models (GCMs) from CMIP5 archive. Global Mean Temperature (GMT) increase of 1.5°C and 3°C above pre-industrial levels are derived for 20-year time slices with the respective mean warming for each model separately. The warming levels are derived relative to the historical period 1986-2005 and this period is considered to be 0.6°C warmer than pre-industrial levels (1850–1900). For definitions of extremes indicators, please see (Schleussner et al., 2016)

5 Due to a lack in the scientific literature, we cannot yet provide projections for a 1.5°C scenario. However, global sea level rise by 2100 is about 10cm lower under a warming at 1.5°C compared to a 2°C scenario [IPCC 1.5°C Special Report]. Beyond 2100, only limiting warming to 1.5°C may limit global sea level rise to below 1m,at least 0.5m less than what a 2°C would entail.

by tropical cyclones are projected to increase substantially. Under a 2.4°C scenario, the number of Category 4 and 5 cyclones will increase by about 130%[6]. The severity of the tropical cyclone hazard will be further amplified by increases in extreme precipitation and sea level rise.

Table 4: Exposure of the land area (in km²) for India in the 1 in 100 year coastal flood plain in 2100, 2200 and 2300 for each mitigation (AMPs) and non-mitigation (RCP 8.5) scenario. The brackets show the values for global sea level rise and global temperature for each scenario.(Brown et al., 2018)

	Modelling Scenario			
	AMP 1.5	AMP 2	AMP 3	RCP 8.5
2100	16 639 (0.4m; 1.6°C)	17 237 (0.5m; 2°C)	17 609 (0.5m; 2.4°C)	22 206 (0.8m; 4.9°C)
2200	19 905 (0.7m; 1.4°C)	21 886 (0.9m; 1.9°C)	24 474 (1.1m; 2.8°C)	43 171 (2.5m; 8.6°C)
2300	22 571 (1m; 1.3°C)	25 828 (1.3m; 1.8°C)	31 870 (1.7m; 2.8°C)	65 796 (4.5m; 9.5°C)

6 Relative to 1986-2005 for the North Indian Ocean basin, from Bhatia K, Vecchi G, Murakami H, et al (2018) Projected Response of Tropical Cyclone Intensity and Intensification in a Global Climate Model. J Clim 31:JCLI-D-17-0898.1. doi: 10.1175/JCLI-D-17-0898.1

2 Socio-economic context

2.1 Economic background

Table 5: Overview on socio-economic characteristics and development over time (India)

Indicators on economic and human development		Source	2000	2010	Most recent (2017)
Per capita income	GDP/capita in current US$	WB-WDI	439	1 346	1 942
	GDP/capita adjusting for purchasing power (in PPP, constant 2011 international $)	WB-WDI	2 495	4 405	6 430
Economic growth	GDP growth rate per capita (annual, in %)	WB-WDI	2%	8.8%	5.5%
Human development	Human Development Index (HDI)	UNDP	0.493	0.581	0.640 *(Rank 130)*
Population	Population in millions	WB-WDI	1 053	1 231	1 339

Notes: PPP – Purchasing Power Parity. GDP – Gross Domestic Product.

Sources: WB-WDI – World Bank World Development Indicators (The World Bank, 2019). *UNDP – United Nations Development Program* (United Nations Development Program, 2018a).

With a population of 1.2 billion, India is the world's third largest economy in purchasing power parity terms (The World Bank, 2018). It is classified by the World Bank as a "lower middle-income country" since 2007 and is one of the G20 countries. In recent years India has managed to stabilise its economic growth, exhibiting annual GDP per capita growth rates of between 4 and 8% since 2010, and is expected to grow further by well over 7% per year in the next years (The World Bank, 2018). Between 2000 and 2017, India has achieved to increase its per capita income (in US$) by a factor of more than four and more than doubled it in when accounting for purchasing power in the same period (see Table 5).

India is facing multiple social transitions. Despite significant progress in reducing extreme poverty with rates dropping from 46% to about 13.4% over the two decades before 2015 (The World Bank, 2018), in 2011 still over 86% of the people have been living with less than 5.50$ (2011 PPP) a day (The World Bank, 2019). Economic development has been uneven differing between population groups and geographical regions. Rapid urbanisation poses a challenge but also opportunities for urban planning and implications for energy, in particular electricity demand. The number of people living in Indian cities and towns is expected to increase from about 435 million in 2015 to 600 million by 2030 (IRENA, 2017).

Between 1990 and 2017, India had increased its Human Development Index (HDI) value by almost 50% from 0.427 to 0.640 (United Nations Development Program, 2018b). India's 2017 HDI is below the average of all countries in the HDI-category of 'medium human development', but it is above the average for countries in South Asia. When India's 2017 HDI value is discounted for inequality, it falls to 0.468, a loss of almost 27% due to inequality (United Nations Development Program, 2018b).

2.2 Energy System status and historic development

Table 6: Energy system indicators for India: current status and recent development

Energy system indicators		Source	2000	2010	Most recent	
					Value	Year
Primary Energy intensity of the economy (energy / GDP)	Energy intensity level of primary energy (MJ/$2011 PPP GDP)	WB-WDI*	6.95	5.35	4.56	2017
Carbon intensity of energy	kg CO_2 per MJ energy use	WB-WDI	97.99	103.86	113.63	2014
Carbon emissions per capita⁺	t CO_2 /population	EDGAR	1.01	1.50	1.92	2016
Fossil fuel share in total energy	Share in total primary energy (%)	WB-WDI	63.73	71.40	73.58	2014
Electricity use	Electric power consumption (kWh per capita)	WB-WDI	394.96	642.11	805.60	2014
Fossil fuel share in electricity production	Electricity production from oil, gas and coal sources (% of total)	WB-WDI	83.44	81.24	81.89	2015
Share of coal in electricity production	Electricity production from coal sources (% of total)	WB-WDI	68.50	67.18	75.31	2015
Modern RE share in electricity production	Electricity production from renewable sources, excluding hydroelectric (% of total)	WB-WDI	0.52	3.48	5.36	2015
Renewable energy capacities	Installed RE capacity (in MW)	IRENA				
	Wind (onshore)		941	13,184	32,848	2017
	Wind (offshore)		-	-	-	-
	Solar (Concentrated)		-	-	229	2017
	Solar (Photovoltaic)		0	0	17,644	2017
	Biogas		0	1	12	2017
	Bioenergy (Solid Biomass)		347	3,214	9,500	2017
	Hydropower		23,711	35,866	44,735	2017
	Geothermal		-	-	-	-

*Notes:**Calculation of most recent value based on latest available WB-WDI data and growth rates from BP* (BP, 2018). ⁺*CO2 emissions do not include emissions from LULUCF. PPP – Purchasing Power Parity. GDP – Gross Domestic Product.*

Sources: WB-WDI – World Bank World Development Indicators (The World Bank, 2019). *IRENA – International Renewable Energy Agency Database* (IRENA, 2019a). *EDGAR emissions database* (JRC, 2016).

In 2013, India has been responsible for almost 10% of the global growth in energy demand since 2000, increasing its share in global energy demand to 5.7% (International Energy Agency (IEA), 2015). In per capita terms however, India's energy use was only about one third of the world average in 2014 and slightly below the average of all lower middle income countries (The World Bank, 2019).

India has managed to substantially decrease the energy intensity of its economy between 2000 and 2017 (see Table 6). However, the share of fossil fuel sources in total energy consumption has risen from 63.7% in 2000 to 73.6% in 2014, contributing to a rising carbon intensity of energy use.

India's CO2 emissions per capita[7] have risen from 1 to 1.92 metric tons of CO2 between 2000 and 2016 (see Table 6), but remain low compared with the world's average of 4.8 tCO2 (JRC, 2016). Yet, India significantly contributes to global carbon emissions due to its large population and progress in poverty eradication and energy access.

India's electricity demand has increased by about 10% every year over the past decade (IRENA, 2017). Between 2000 and 2014, electricity consumption per capita has doubled. At the same time, the inequality in per capita electricity use between regions and population groups is high. With 805 kWh per capita, India's electricity consumption remains comparably low, amounting to about a quarter of the world's average (3,127 kWh/capita) but being above the average of lower middle income countries (767 kWh/capita) in 2014 (The World Bank, 2019). The CIA World Factbook estimates that India's electricity consumption has risen to 858.7 kWh/capita in 2016 (CIA, 2019).

While the share of fossil fuels in electricity production has slightly decreased between 2000 and 2015, the share of coal in electricity production has increased from 68.5% (2000) to 75.3% (2015) (see Table 6). At the same time, India has shown a massive increase of renewable energy capacity over the last years, in particular wind and solar. As a result the share of modern renewable energy (excluding hydro) in electricity generation rose by a factor of ten from 0.5% in 2000 to 5.4% in 2015. Including hydropower, the share of RE in total electricity output was 15.3% in 2015 (The World Bank, 2019).

India suffers from large inefficiencies across the entire energy system (International Energy Agency (IEA), 2015). Especially in the power sector, inefficient generation technology infrastructure, the poor state of transmission and distribution infrastructure and the low efficiency of end-use equipment contribute to low efficiency (International Energy Agency (IEA), 2015). In 2014, over 19% of electric output was lost due to transmission and distribution losses (The World Bank, 2019). India's losses rank among the highest in the world, with shares even increasing to about 50% in some regions if non-technical losses and energy theft are accounted for (IRENA, 2017). Exploiting these vast untapped potentials in increasing energy efficiency could contribute to slow down growth in energy demand. Massive investments in power generation capacities and related infrastructure would be needed in the near future, bearing important opportunities for renewable energy deployment (IRENA, 2017).

7 Excluding carbon emissions from land-use, land-use change and forestry.

2.3 Energy system and sustainable development – potential for benefits of a transition to renewable energy

Table 7: Indicators showing sustainable development implications of the current energy system and potential for benefits of a transition to renewable energy (co-benefits) (India)

Indicators for co-benefits potential		Source	Most recent	
			Value	Year
Fuel import dependency	Share of national income (GDP) spent on fuel imports (%)	WB-WDI+	5.2	2017
	Public expenditures spent on fuel imports (in billion current US$)	WB-WDI+	134.8	2017
Reliability of electricity supply	Share of firms experiencing electrical outages (%)	WB WDI	55.4	2014
	Power outages in firms in a typical month (number)	WB WDI	14	2014
	Share of sales lost for firms subject to power outages (%)	WB WDI	3.7	2014
Access to modern energy	Share of population with access to electricity (in %)	WB WDI	84.5	2016
	Share of rural population with access to electricity (in %)	WB WDI	77.6	2016
	Share of urban population with access to electricity (in %)	WB WDI	98.4	2016
	Share of primary schools with access to electricity (in %)	SDG-database	47.4	2016
	Share of population with access to clean fuels or technologies for cooking (in %)	WB WDI	41.0	2016
Indoor air pollution and health impacts	Number of deaths attributed to indoor air pollution* (per 100 000 inhabitants)	SDG-database	110	2016
Outdoor air pollution and health impacts	Share of population exposed to levels of fine particulate matter (PM 2.5) exceeding WHO guidelines (in %)	WB WDI	100.0	2016
	Number of deaths attributed to ambient air pollution* (per 100 000 inhabitants)	SDG-database	109	2016

*Note: *age standardised mortality rate of WHO. +Own calculations based on WB-WDI. GDP – Gross Domestic Product. WHO – World Health Organisation.*

Sources: WB WDI – World Bank World Development Indicators (The World Bank, 2019). *SDG-database -Sustainable Development Goals data base* (United Nations, 2019).

India's own fossil fuel resources are limited and mostly of bad quality (e.g. coal with high ash content), leading to a strong **reliance on fuel imports** and a resulting susceptibility to price shocks (IRENA, 2017). In 2017, India has spent over 5% of its GDP in fossil fuel imports, amounting to public expenditures of over 134 billion USD (see Table 7). A transition to renewable energy would reduce the reliance on fuel imports.

Lacking reliability of electricity supply is also a serious issue affecting private households as well as businesses and industry. More than half of the firms in India (55%) report to have been affected by power outages in 2014, with almost 14 outages happening every month on average (see Table 7). These firms are estimated to have lost about 3.7% of their sales due to the outages. One additional factor that has contributed to power outages is water shortage, as thermal power plants need water for cooling and water is a very scarce resource in many regions (Luo and Krishnan, 2018). Yet, almost 80% of India's new power generation capacities are expected to be built in regions which already face water-stress (IRENA, 2017). To not add to the increasing competition for water, many RE technologies offer an alternative with near-zero water requirements.

India has made progress in improving **access to modern energy**. Overall, 84.5% of the population had access to electricity in 2016, with a share of 98.5% in urban areas compared to 77.7% in rural areas (see Table 7). Yet, about 205 million people have still not had access to electricity in 2016 (ESMAP, 2019). Less than half of all primary schools had access to electricity in 2016, affecting development prospects with regard to education. Renewable energy is an opportunity for providing access not only through grid-based electrification, but also mini-grid and off-grid systems, such as solar home systems, especially for rural and remote areas (see below).

Less than half (only 41%) of people have access to clean cooking fuels (see Table 7), leaving more than half of the population exposed to health hazards from **indoor air pollution** due to the burning of traditional biomass inside of dwellings, with women being disproportionately exposed and affected (IRENA, 2017). Accounting for age structure, about 110 out of every 100 000 inhabitants in India die due to indoor air pollution. The World Health Organisation (WHO) estimated the number of deaths attributed to indoor air pollution to amount to more than a million in 2016 (World Health Organisation, 2018).

With fossil fuels being used predominantly in the energy and transport sectors, **outdoor air pollution** remains a serious health concern in India, especially in urban areas. In 2016, all of India's population was exposed to fine particulate matter concentration levels exceeding WHO recommended limits. The number of deaths attributed to outdoor air pollution is estimated to amount to over 1.087 million in 2016 (World Health Organisation, 2018) with about 109 out of 100 000 inhabitants dying due to it. A very recent study found lower yet still shocking numbers estimating that in 2017 about 0.67 million people in India died from ambient particulate matter pollution (outdoor air pollution) and about 0.48 million from household air pollution (India State-Level Disease Burden Initiative Air Pollution Collaborators, 2019). Overall, the study estimates that about 12.5% of the total number of deaths in India in 2017 could be attributed to air pollution, amounting to about 1.24 million deaths. [8]

3 Policies and projections on future development

In its NDC India committed to decrease the emissions intensity of its GDP by 33-35% by 2030 compared with 2005. It has also added the target of increasing the non-fossil share of power generation to 40% by the same date, conditional on financial aid from developed countries (UNFCCC, 2015). While the emissions intensity target would result in emissions increasing by 176-184% compared with 2010, the conditional goal would slow down the increase in emissions to around 132% of the 2010 level (CAT, 2019).

In 2016, the electrification rate was at 84.5% (ESMAP, 2019) (see table 4.2). In September 2017 Prime Minister Narendra Modi launched a scheme aiming at full electrification by the end of 2018 in the

8 Due to estimation techniques and uncertainty intervals in the estimation, the sum of the estimates of deaths from indoor and outdoor air pollution do not perfectly match the overall estimate from air pollution.

framework of the Saubhagya scheme (The Economic Times, 2017). While this goal was declared as achieved, significant issues not only in terms of electricity access but also its reliability still remain (Financial Express, 2019; Forbes, 2019; Power For All, 2019).

India has already introduced renewable energy targets as early as 2010 when it launched the "National Solar Mission" and had been continuously achieving these earlier than planned, and revising them upwards. The government recently increased its previous 2022 capacity target for renewables from 175 GW to 227.6 GW (CAT 2018). By the end of 2017 India's installed renewable energy, excluding large hydro, which is not included in this target, amounted to around 60 GW (IRENA, 2019b), and investment in renewable power in India topped fossil fuels for the first time in 2017, according to the International Energy Agency (IEA, 2018a).

According to a representative of the Ministry for New and Renewable Energy, India's government is planning to auction 40 GW of energy – 30 GW solar and 10 GW wind – every year until 2028 to achieve the goal of 500 GW of renewable energy capacity, with 350 GW coming from solar and 140 GW from wind (The Economic Times, 2018).

BOX: relevant key policies related to energy supply sector

- **Nationally Determined Contribution (2015):** Reduction of GDP emissions intensity by 33-35% by 2030 from 2005 levels, and generating 40% of its electric power by non-fossil fuel-based sources by the same year (Government of India, 2015).
- **NITI Aayog National Energy Policy (2017):** Repeats the goal of achieving 175 GW of renewable energy capacity by 2022 and adds intended 10% reduction in oil imports (2014-2015 levels) by 2022 (NITI Aayog, 2017).
- **National Electricity Plan (NEP):** The plan projects that India's non-fossil fuel-based capacity will reach 49.3% by 2022, and 57.4% by 2026, significantly exceeding the 40% NDCs goal for 2030. However, the current NEP also includes expansion of coal in part due to coal compensating for a 30% reduction in hydropower generation as a result of insufficient rain/monsoons) and projects net capacity additions of 46 GW until 2027 (CAT 2018).
- **Coal cess**: introduced in 2010 at USD 0.8 per tonne, the coal tax was steadily increased to USD 3.2 per tonne in March 2016. It resulted in combined proceeds of USD 12bn between 2010-2018. At the same time subsidies to coal amounted to USD 2.3bn in 2016 only (iisd, 2018b).
- **Renewable energy auctions:** India's government organizes periodical auctions for different sources of energy resulting in prices at or below the costs of fossil fuels (iisd, 2018a). According to some statements up to 500 GW of renewable sources are to be tendered by 2028 (PV-Magazine, 2019).

There is uncertainty regarding the future of coal capacity, with the pipeline shrinking. Analysis by the Climate Action Tracker (CAT, 2018) shows that India can over-achieve even its conditional NDC target with currently implemented policies, and, specifically, the 40% non-fossil share target a decade earlier than targeted. Based on current policies the share of non-fossil power generation capacity is projected to reach 60-64% in 2030, corresponding to a 40-44% share of electricity generation (CAT, 2018).

4 Projections on planning for coal

India has the region's largest coal fleet, with 226 GW in operation and 49 GW under construction. This accounts for 12% of the global coal fleet. Coal dominates the power mix (75% in 2016), and with the majority of plants relying on sub-critical combustion technology, the emissions intensity of electricity supply is relatively high (848g CO_2/kWh in 2016) (IEA, 2018). There is still substantial uncertainty about the future of coal power capacity: although the government is committed to diversifying power supply

and supporting renewable energy, the National Electricity Plan (NEP) projects net capacity additions of 46 GW until 2027. Looking at individual project planned and announced, India is set to expand its use of coal-fired power for electricity generation by 56 GW.

Focus: The National Electricity Plan (NEP)

While there are often contradictory estimates of the amount of coal-based capacity deemed necessary, the NEP is an operational document, and hence estimates from this document are selected for a brief discussion (Central Electricity Authority, 2018).The following are a few highlights of India's NEP, which has a planning timeframe till 2027:

- Over 50 GW of operating capacity is being considered for retirement, either because the units have reached the end of their technical lifetime, or because they will not meet the SOx targets which come into place in 2021.
- Over 47 GW of coal-based capacity is already under construction, or planned, with an addition 46 GW estimated to be required between 2022 and 2027.

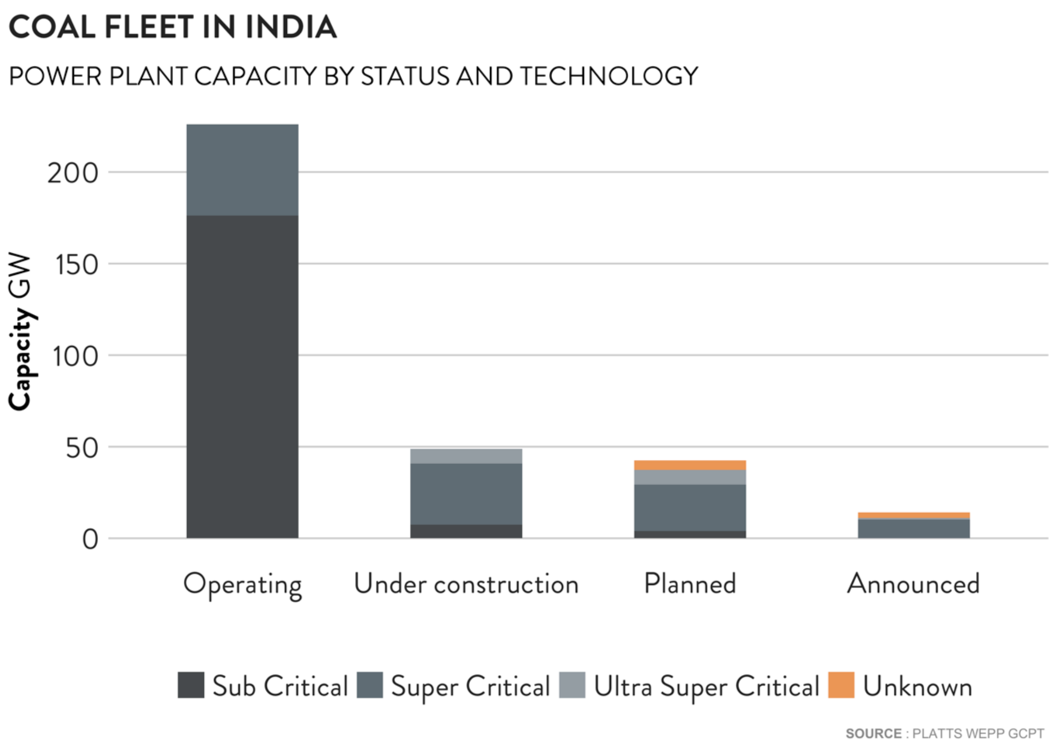

Figure 1: India's coal fired power generation capacity

India's coal-fired expansion plans amount to nearly 21% of the current capacity[9] (Figure 1). This accounts for 16% of the global coal-fired power plant expansion plans. Expansion plans for coal in India have been found inconsistent with lower demand projections in independent studies (Shearer et al., 2017). This is likely to exacerbate the current problem of low utilisation rates of coal power plants, with a significant impact on their profitability, threatening to exacerbate the already perilous financial position of Distribution Companies in India (Kale et al., 2018).

[9] Here, we define current capacity as total operating capacity + capacity under construction, and to expansion plans as planned capacity (permitted and pre-permitted units that have not started construction) + announced capacity.

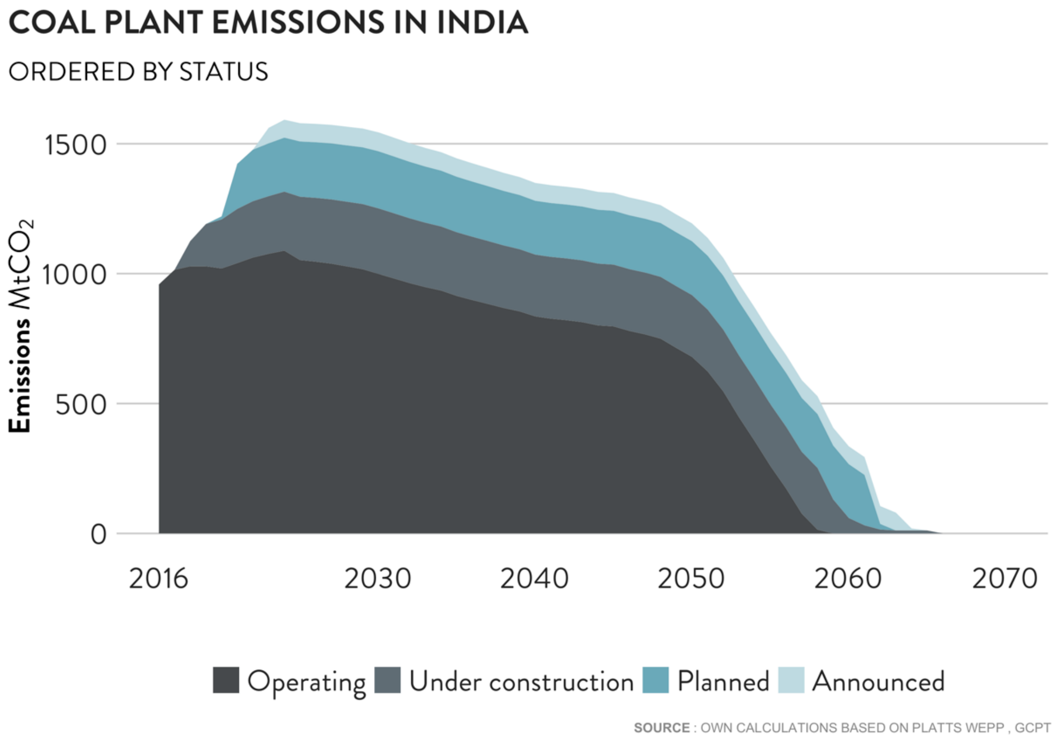

Figure 2: Committed emissions from India's coal plants

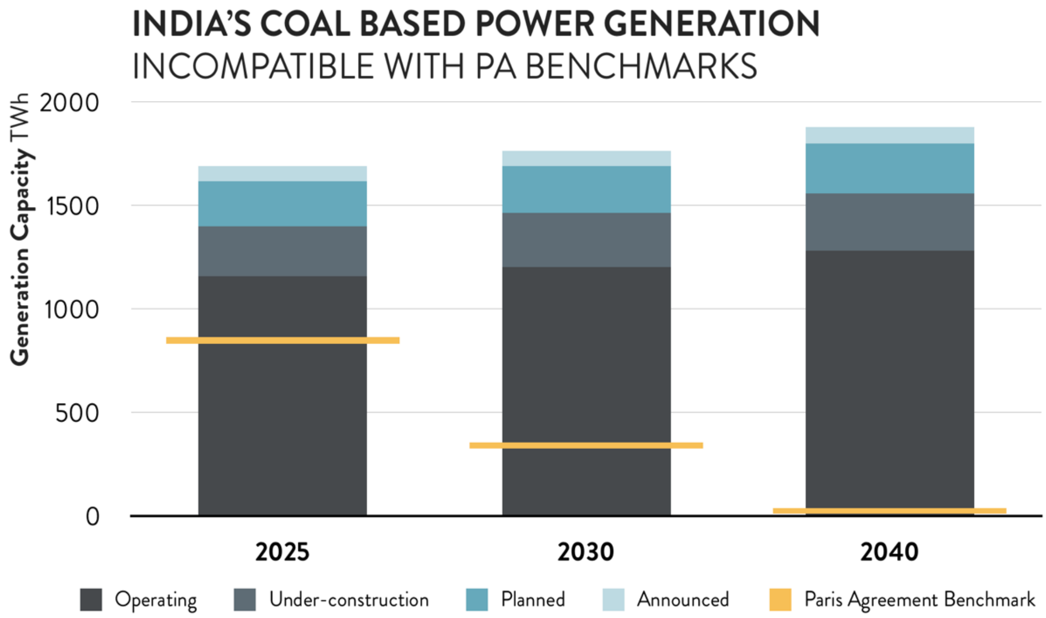

Figure 3: Coal projected generation under BAU and Paris Agreement scenarios

Despite the likely retirements of sub-critical power plants (which have relatively higher emission intensities), in favour of super- and ultra-super critical power plants (with relatively lower emission intensities), the committed emissions from these power plants still represent a significant addition to India's emission profile (Figure 2).

In Chapter 3, we compared these plans against the regional benchmarks discussed in Chapter 2. The potential generation from coal-based generation in India far exceeds the generation benchmarks under a Paris Agreement compatible scenario (**Figure 3**).

While the benchmark establishes a phase-out of coal-fired power by 2040, if all the plants under consideration come online as planned, emissions from coal power generation would only peak around 2025 and be phased out around 2065. These findings are backed up by other studies, which see this potential expansion as a threat to the achievement of India's NDC targets (Edenhofer et al., 2018). Moreover, even if all the planned capacity were to be cancelled, a full phase-out would only be expected in the mid 2050's assuming average lifetime and utilisation factors of coal power plants. This implies that plant owners should seriously consider the risks of stranded assets as a large number of units would need to retire of early or operate at starkly reduced utilisation rates.

5 Transition to renewable energy – pathway characteristics, benchmarks, options, potentials, benefits

5.1 Potential and technology options for renewable energy

Potentials and costs

India has the largest solar energy potentials among the countries of both regions. This is not only due to its size – it covers more than a third of the territory of all the 14 countries combined – but also high radiation rate. Covering 1.5% of the country with solar PV would result in 9.877 TWh of electricity only from this source – equivalent to seven times the total electricity generation in 2017 (BP, 2018; NREL, 2014). According to another estimate, covering 3% of the country's wasteland with solar power plants would result in an installed capacity of 750 GW or twice the installed capacity at the beginning of 2019 (CEA, 2019; IRENA, 2017).

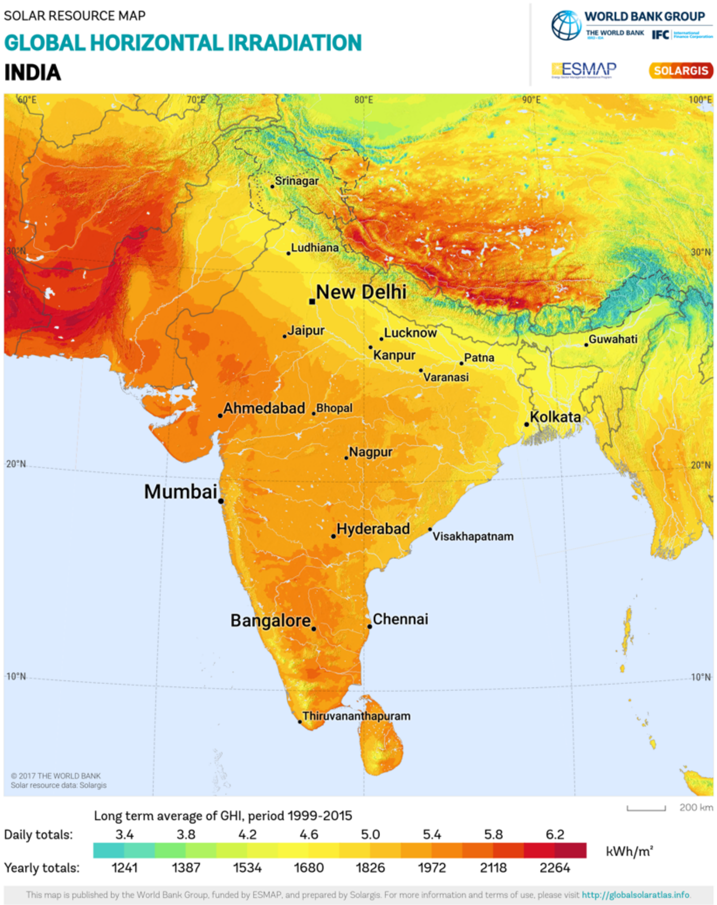

Figure 4. Global horizontal irradiation based on Global Solar Atlas (The World Bank Group, 2016)

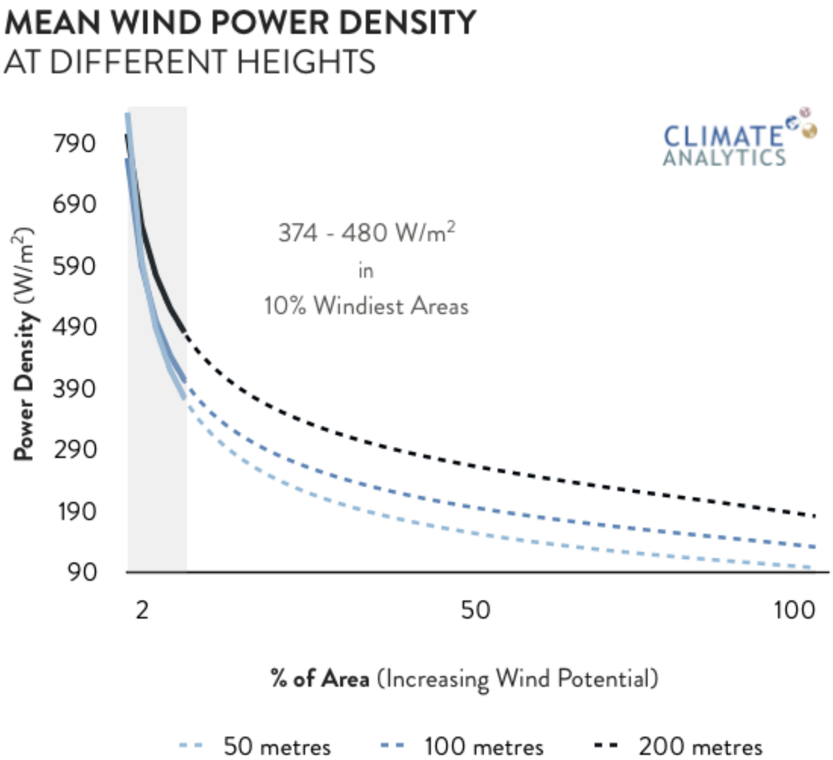

Figure 5. Mean wind power density is between 374 and 480 m2 in 10% windiest countries in the region

So far only a small percentage of this potential is used – by the end of 2018 the total installed capacity amounted to 28 GW (Bridge to India, 2019). However, the dynamic accelerates, with the capacity expected to exceed 38 GW by the end of 2019 (Quartz, 2019). The main reason for this acceleration is on one hand improving investment climate (BloombergNEF, 2018), and India's goal of increasing installed solar energy capacity to 350 GW by 2030 on the other (The Economic Times, 2018).

The costs of solar in India are among the lowest in the world. While the average costs of solar PV fell to 88 USD/MWh in 2017 (IRENA, 2018), the costs in some auctions in 2018 fell to 34 USD/MWh (PVTech, 2018). Despite the significant decrease in costs, India's solar rooftop capacity is lagging behind the government's plans. This is mainly due to high upfront investment costs as well as lack of customer awareness (Quartz, 2018).

The direct solar radiation also makes India an ideal destination for Concentrated Solar Power (CSP). There are already ten CSP plants built with combined installed capacity of 521 GW (NREL, 2019). While their LCOE costs are much higher than electricity from solar PV, due to their flexibility such plants offer the opportunity to reduce dependency on natural gas (SolarPACES, 2017).

India's has 300 GW of wind energy potential, concentrated mainly along the western coast and in the south, according to India's Ministry of New and Renewable Energy (MNRE) estimates (MNRE, 2018). By the end of 2018 only slightly more than 10% of this potential has been utilised (WWEA, 2019). The average costs of wind energy between 2013 and 2015 were around USD 80/MWh, however prices reached slightly below USD 80/MWh in 2018 auctions (MERCOM, 2018).

There is also some potential for electricity generation from bioenergy, estimated by the MNRE at around 25 GW (MNRE, 2018). This is in addition to the 9.5 GW of already installed biomass capacity, contributing 1.3% of electricity generated (IRENA, 2019a). However it can be assumed that most of the remaining waste biomass can be more efficiently utilised for cooking or transport (IRENA, 2017).

The remaining hydro energy potential amounted to 100-150 GW, in addition to 15-28 GW of small hydropower. Combined, this constitutes four times the already installed capacity (IRENA, 2017). While India's government doesn't include large hydro in its renewable energy statistics, it is strongly promoting small hydro (up to 25 MW) leading to the construction of new and modernisation of existing plant projects (MNRE, 2018).

Scenarios

According to IRENA's REmap scenario, India's power generation is expected to grow to 3 527 TWh in 2030 – a 3.5-fold of the power generation in 2010. The share of renewables in the power sector – including large hydro energy – would increase from 14% to almost 35% with the largest contribution from wind (13% of the overall generation) and solar (9.6% including CSP). This increased share of renewables takes place despite higher electricity consumption compared with the Reference Scenario resulting from electrification of the other sectors, especially transport (IRENA, 2017). However, this scenario falls far short of the analysis of projections based on current policies (CAT 2018) and also short of what is needed to achieve the 1.5°C temperature limit (see chapter 2).

According to another scenario, India could rely only on renewable sources of energy in the electricity sector by the middle of the century. This would not only significantly reduce India's emissions and decrease air pollution, but would also lead to a decrease in electricity prices from €58/MWh in 2015 to €52/MWh in 2050. The large share of solar PV contributing almost two-thirds of the electricity generated in 2050 is supported by different forms of storage, mostly batteries. Their combined storage capacity is expected to amount to a third of the annual energy demand (Gulagi et al., 2017).

5.2 Reaping opportunities of transitioning to renewable energy: Implications for local jobs and affordability of energy

India can benefit massively from a rollout of renewable energy. IRENA (IRENA, 2017) has estimated these benefits for a scenario which is very conservative and falls far short of current projections and what is needed to be in line with the Paris Agreement. But even this conservative scenario showed the following benefits:

- ***Reducing air pollution and related health impacts.*** IRENA estimates suggest that India could save between 45 billion USD and 160 billion USD each year from reduced air pollution for the REmap scenario.
- ***Reducing fossil fuel import dependency.*** The RE technology options in the REmap Scenario for India are estimated to decrease the demand for coal and oil products by about 17% to 23% by 2030 compared to the reference case reducing the burden on public expenditures for fossil fuel imports.
- ***Create local job opportunities in the RE sector.*** IRENA estimates that if India implemented the REmap Scenario, the number of people employed in the modern renewable energy sector in India could grow to as much as 3.5 million people in 2030 which would be an increase by a factor of about seven compared to current levels.
- ***Contribute to sustainable economic development.*** Beyond creating employment opportunities, investments in renewable energy were found to also positively impact economic growth and welfare, with increased investments leading to positive effects throughout the economy. IRENA estimates suggest that India's GDP under full exploitation of REmap options could be about 1% higher in 2030 than in the reference case (IRENA, 2017).
- ***Reducing impacts from climate change.*** Being a major contributor to global emissions, India's decision with regard to its energy sector can have an impact on expected damages from climate change. Assessing the emission reduction potential for 40 REmap countries, IRENA finds that India together with China and the US could account for about half of the total global emission reduction potential (IRENA, 2017). IRENA furthermore estimates that the resulting benefits for India in terms of avoided climate impacts by 2030 would amount to about 13 to 63 billion USD every year if India fully exploited its options outlined in the REmap scenario (IRENA, 2017).

IRENA estimates that the savings from implementing the REmap scenario would largely outweigh the costs. Even when accounting only for benefits from reduced air pollution and climate impacts, benefits could be up to 12 times higher than the costs for India (IRENA, 2017).

Beyond these benefits, with their local and decentralised nature, and low and decreasing costs, many RE technologies offer opportunities to improve the access to electricity in poor and especially remote areas, contributing to the fight against energy poverty. Moreover, most modern RE technologies offer alternatives to thermal power plants, thus avoiding additional water stress due cooling needs and power outages caused by water scarcity issues.

6 Gap analysis: targets, projections, and Paris Agreement benchmarks

In its NDC, India commits to a 33-35% reduction in emission intensity of GDP below 2005 levels by 2030. In addition, India's NDC contains a commitment to 40% non-fossil generation by 2030, which includes nuclear generation. The Climate Action Tracker rates Indis's NDC target as 2°C compatible (Climate Action Tracker, 2018). However, the non-fossil power generation target falls short of the 51% decarbonised/renewable energy generation benchmark consistent with the Paris Agreement, derived based on the IEA B2DS scenario (chapter 2 of main report).

The National Electricity plan (NEP) projects that India's non-fossil fuel-based capacity will reach 49.3% by 2022, and 57.4% by 2026, significantly exceeding the 40% NDCs goal for 2030 and consistent with the Paris Agreement benchmark of at least 51% decarbonised electricity generation by 2030. However, there is uncertainty as to whether all renewables projects in the pipeline will be completed on time and integrated into the grid (Climate Action Tracker, 2018). Based on current policies, the Climate Action Tracker (CAT, 2018) projects the share of non-fossil power generation capacity to reach 60-64% in 2030, corresponding to a 40-44% share of electricity generation.

The current NEP also includes expansion of coal in part due to coal compensating for a 30% reduction in hydropower generation as a result of insufficient rain/monsoons) and projects net capacity additions of 46 GW until 2027.

The potential generation from coal far exceeds the generation benchmarks under a Paris Agreement compatible scenario, which establishes a phase-out of coal-fired power by 2040. If all the plants under consideration come online as planned, emissions from coal power generation would only peak around 2025 and be phased out around 2065. These findings are backed up by other studies, which see this potential expansion as a threat to the achievement of India's NDC targets (Edenhofer et al., 2018).

Given the dramatic decrease in the costs of renewables, several studies show that it is techno logically and economically feasible for India to achieve 100% renewable electricity generation by 2050. There is thus significant scope for enhanced NDC ambition and developing an ambitious long-term strategy towards 100% renewable energy power generation and electrification of end-use sectors, to align India's energy future with the goals of the Paris Agreement and reap benefits for sustainable development.

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