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Cleaner air would enhance India's annual solar energy production by 6–28 TWh

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Abstract

India has set a target of 100 GW solar installation capacity by the year 2022. However, the loss of solar energy due to environmental factors like air pollution is not properly considered in renewable energy resource assessments. Here we show that India lost 29% of its utilizable global horizontal irradiance potential due to aerosol loading between 2001 and 2018. The average loss in output incurred by solar power systems with horizontal, fixed-tilt, single-axis, and dual-axis trackers due to aerosol loading is estimated to be 12%, 26%, 33%, and 41%, respectively, equivalent to a loss of 245–835 million USD annually. The successful implementation of the National Clean Air Program and the complete mitigation of household emissions through the supply of cleaner fuel for domestic use and rural electrification would allow India to generate a surplus of 6–16 TWh of electricity per year from the existing installed solar power capacity in 2018. This translates to an economic benefit of 325–845 million USD annually, which is equivalent to the implementation costs of these social programs. Mitigating air pollution would therefore accelerate India's progress towards achieving its solar energy target at a lesser installation capacity, avoiding additional expenditure for the expansion of the solar energy infrastructure.

Methods

NASA's Clouds and the Earth's Radiant Energy System (CERES SYN1deg Ed.4.1)

Modern-Era Retrospective Analysis for Research and Applications, version 2 (MERRA-2)

Radiation fluxes (2001-18)	**Aerosols**	**Clouds**
All-Sky flux (AS)	Yes	Yes
Clear-Sky flux (CS)	Yes	No
No-Aerosol-Sky flux (NAER)	No	Yes

- Aerosol attenuation: (AS-NAER)
- Soiling effect: $\tau_{soil}=\sum_{i=1}^{4}\left(E_{abs,i} + \beta_i E_{scat,i}\right) X \ PM_i$ i--> Dust, Sulfate, Organic Carbon and Black Carbon

E_{abs} , E_{scat} β, PM: *absorption, scattering coff, backscattering ratio and mass accumulation per unit area respectively.*

Figure 1. Research Plan

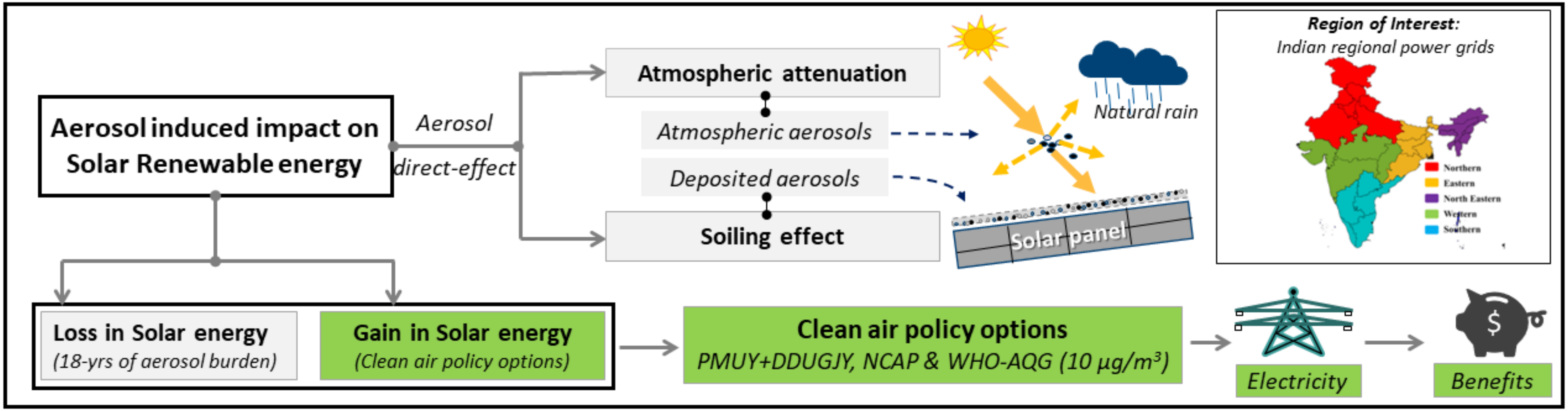
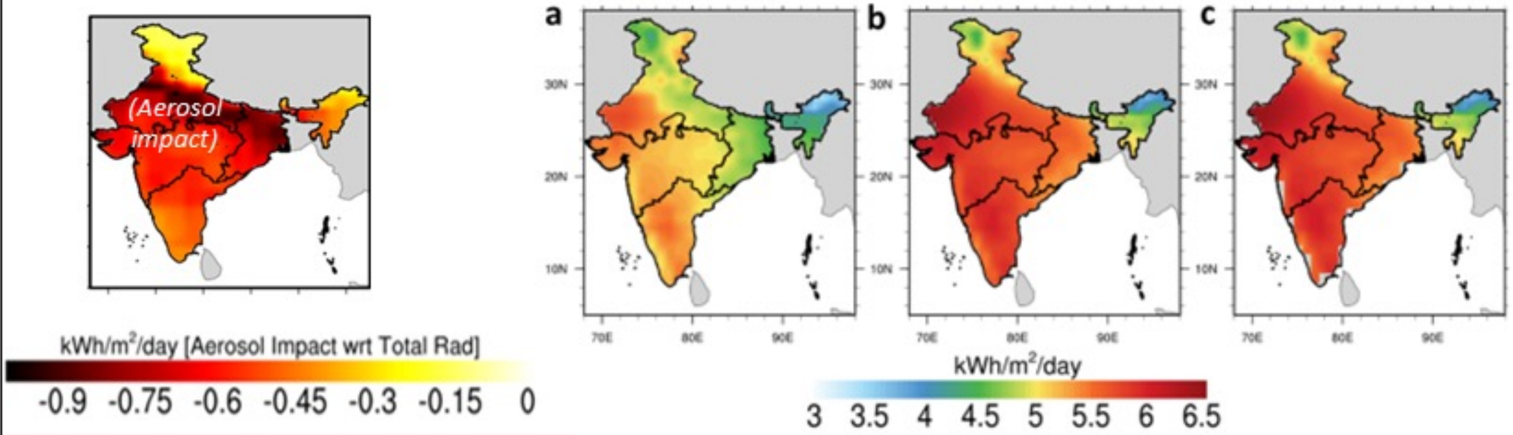


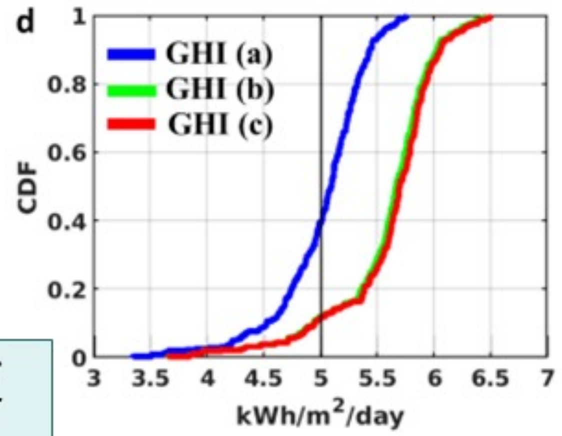
Figure 2. Aerosol impact on solar resources



*India is endowed 60% of its region suitable for SPV generation. (**Baseline**)*

***Aerosol impact** is as high as ~1kWh/m²/day on a climatology basis (2001-18).*

Avoiding two decades of atmospheric attenuation+ soiling leads to 89% of region suitable for SPV generation .
*(**w/o total aerosol effect.**)*



*Avoiding almost two decades of aerosol burden results in **29% enhancement in** regions suitable for SPV potential.*

Solar panel configurations

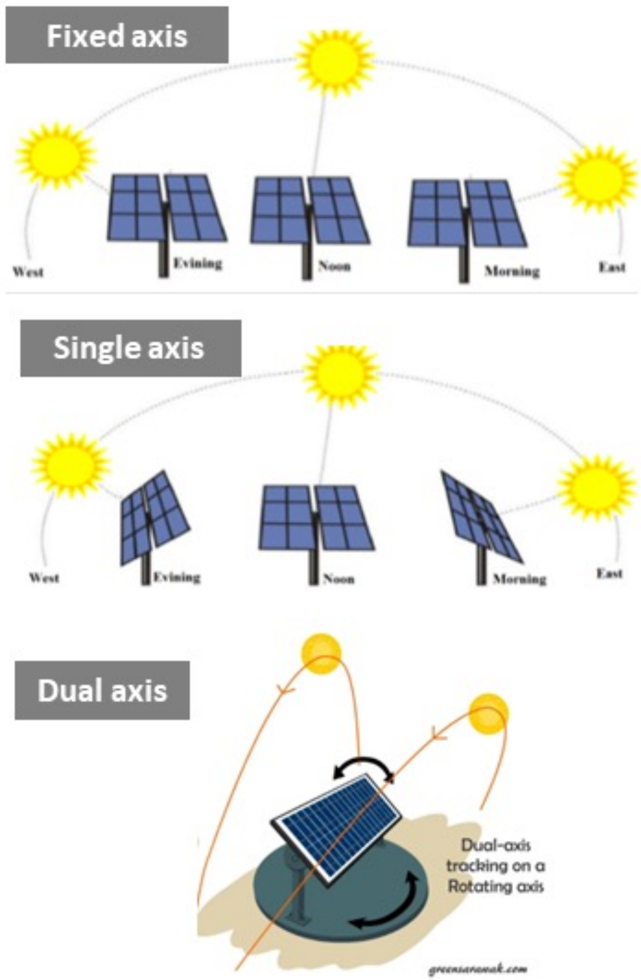
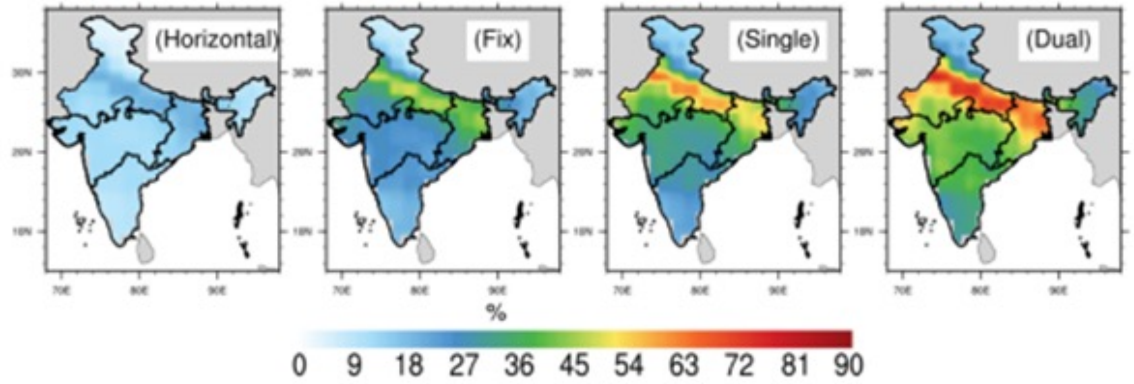


Figure 3. Sensitivity to panel settings on loss/gain (simplistic economic estimates)

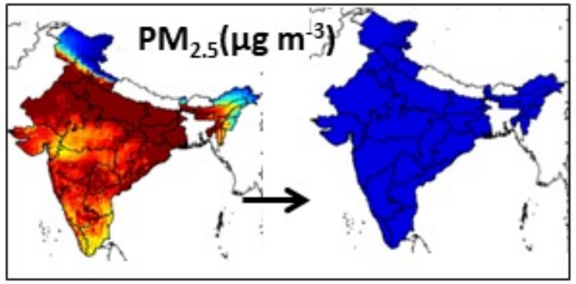
Percentage Loss



Percentage loss in radiation

Dual > Single > Fix > Horizontal

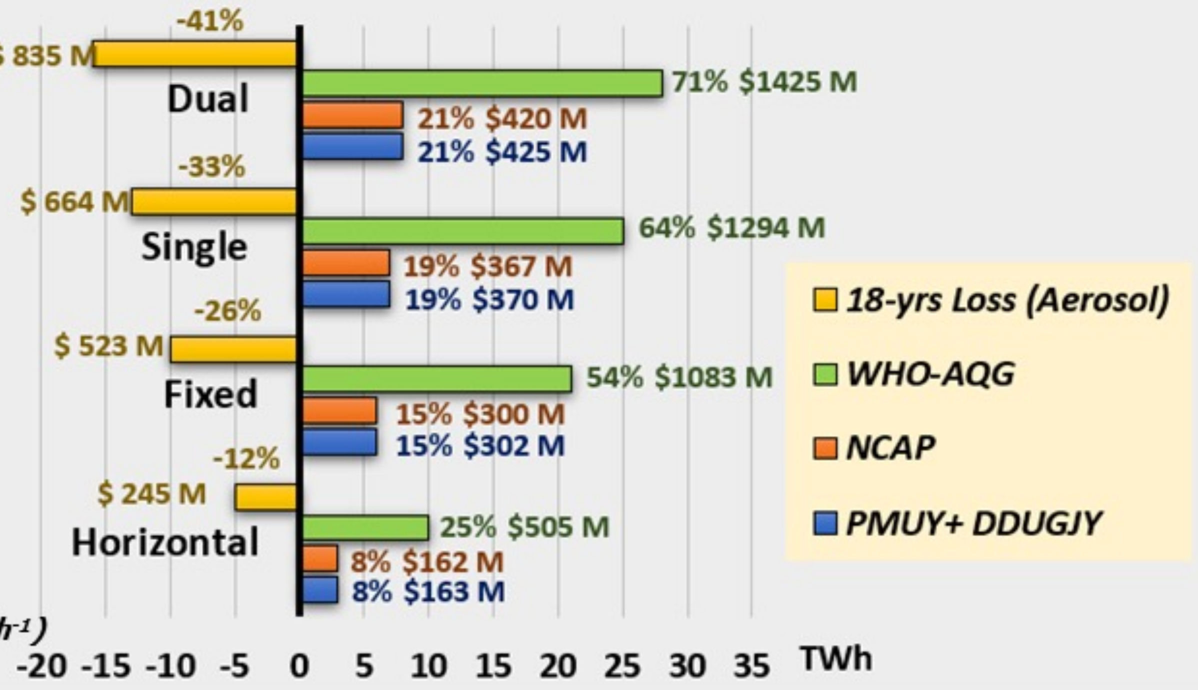
Policy options



PMUY

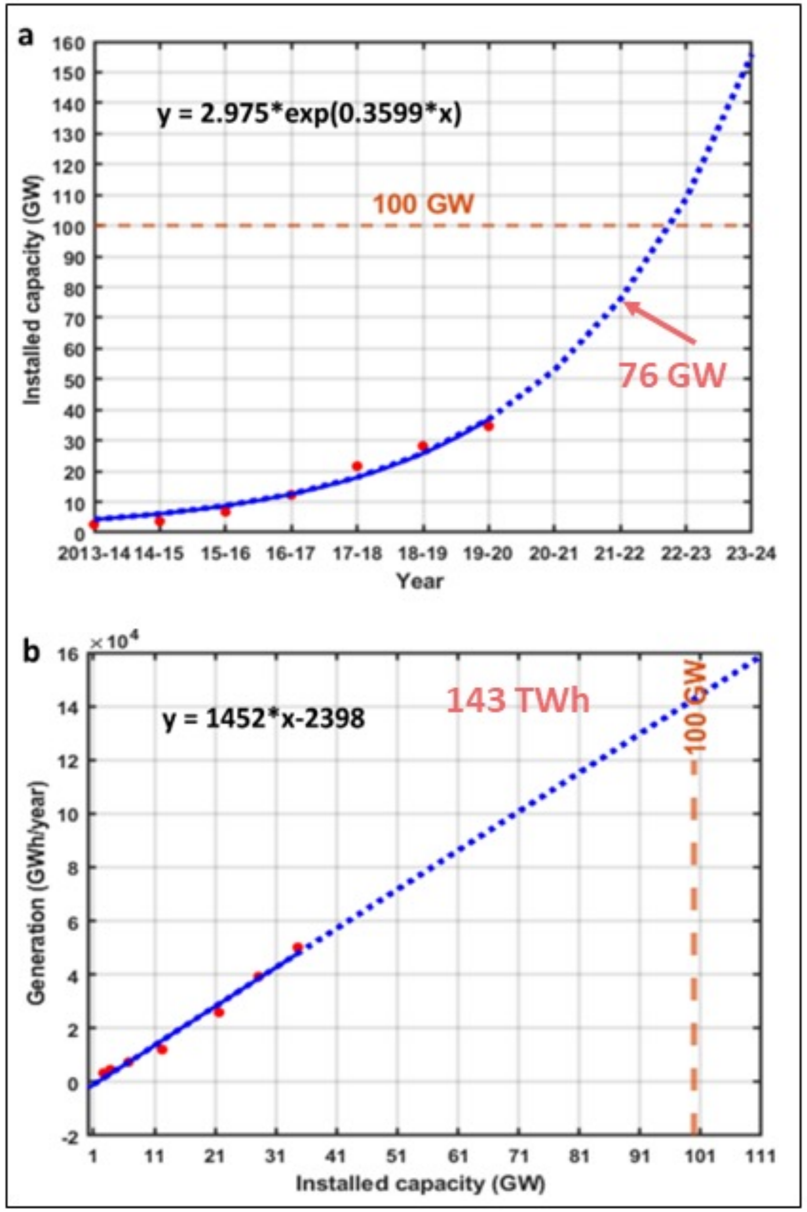
NCAP

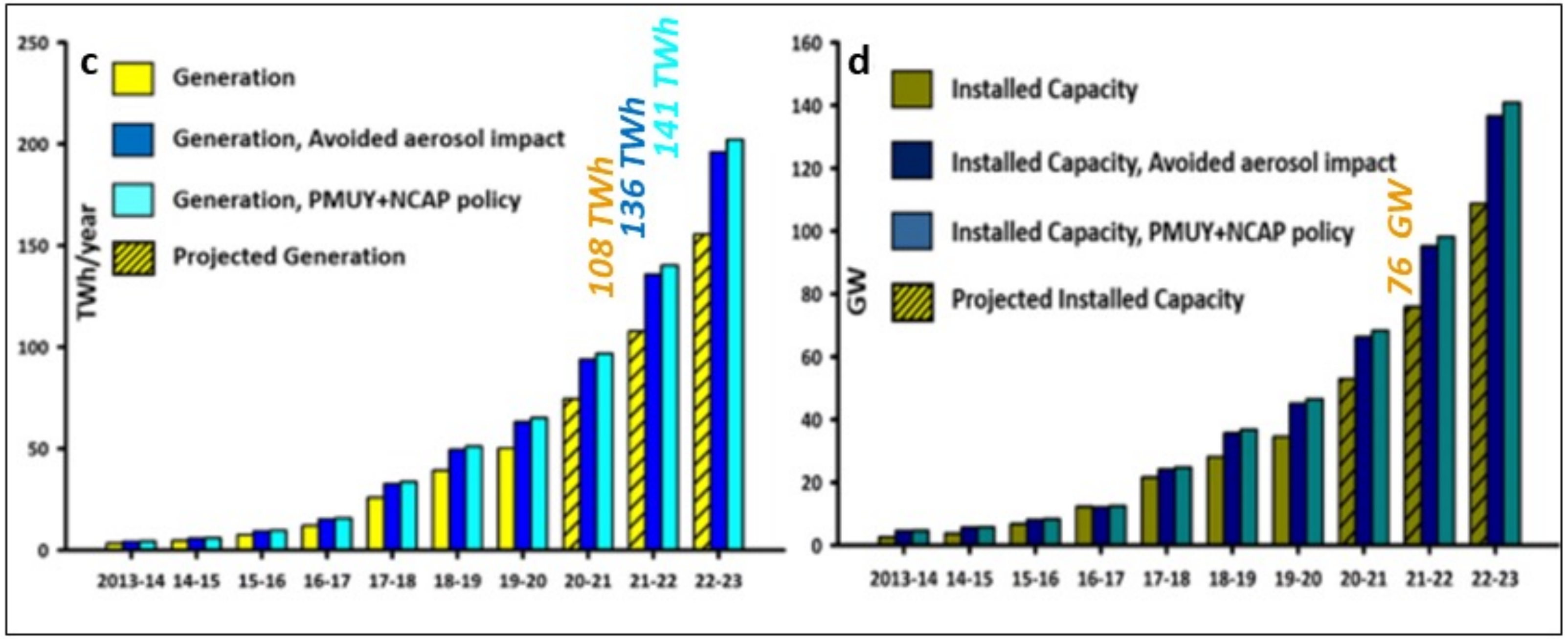
WHO AQG: 10 $\mu g\ m^{-3}$



Si module (20%), 7hrs of bright sunshine, CERC per unit electricity (0.052 USD kWh^{-1})

Figure 4. Accelerated progress towards 100GW





- 100 GW can produce 143 TWh per year (Ghosh et al 2022)
- If India can completely **avoid air pollution** or **strictly implement** the **PMUY and NCAP**, then with a mere 76 GW installation (proposed in FY 2021–22), it can achieve **95%** and **98%** of the equivalent generation from 100 GW of installed capacity respectively.
- Additional ~24 GW installation cost can be avoided.

Conclusion

- India has lost ~29% of its potential solar resources due to aerosol burden between 2001 to 2018.
- The average loss in output incurred by solar power systems with horizontal, fixed-tilt, single-axis, and dual-axis trackers due to aerosol loading is estimated to be 12%, 26%, 33%, and 41%, respectively, equivalent to a loss of 245–835 million USD annually.
- The successful implementation of the National Clean Air Program and the complete mitigation of household emissions through the supply of cleaner fuel for domestic use and rural electrification would allow India to generate a surplus of 6–16 TWh of electricity per year from the existing installed solar power capacity in 2018. This translates to an economic benefit of 325–845 million USD annually, which is equivalent to the implementation costs of these social programs.
- Mitigating air pollution would therefore accelerate India's progress towards achieving its solar energy target at a lesser installation capacity, avoiding additional expenditure for the expansion of the solar energy infrastructure.
- Cleaner air would enhance clean energy output. Again penetration of more cleaner energy have positive feedback towards clean environment.

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