CSTEP

Reducing Emissions from **Diesel Generator Sets**

Switch on, Smoke off: Reducing Emissions from Diesel Generator Sets

Yashwant Pratap Singh Yadav

Anirban Banerjee

Dr Charu Tyagi

Sameer Mishra

Dr Nirav Lekinwala

Swagata Dey

Center for Study of Science, Technology and Policy (CSTEP)

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Editor: Shayantani C

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Bengaluru

No. 18, 10th Cross, Mayura Street

Papanna Layout, Nagashettyhalli

RMV Stage 2, Bengaluru 560094

Karnataka (India)

Noida

1st Floor, Tower-A

Smartworks Corporate Park

Sector 125, Noida 201303

Uttar Pradesh (India)

Tel.: +91 (80) 6690 2500

Email: cpe@cstep.in

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Executive Summary

Executive Summary

Diesel generator (DG) sets, used for power backup across residential, commercial, and industrial sectors, are prominent hyperlocal sources of air and noise pollution throughout India. The current study estimated that a total of 14.7 lakh DG sets, with a capacity of over 5 kVA and a cumulative capacity of 2,72,576 MVA, were operational in India in 2022. These DG sets contributed to 42 Gg of particulate matter with a diameter of 2.5 μm ($PM_{2.5}$), 23 Gg of black carbon, and 877 Gg of nitrogen oxides (NO_x) in India. Additionally, older and poorly maintained DG sets tend to emit significantly more than regular ones and were termed as super-emitters in this study.

Many districts in Rajasthan, Uttar Pradesh, West Bengal, and Maharashtra show high $PM_{2.5}$ emissions, driven by high installed capacities of DG sets and frequent power cuts. The top 10 districts with the highest $PM_{2.5}$ emissions from different categories of DG sets are ranked in Table 3. Patna (Bihar), Gautam Buddha Nagar (Noida), Bengaluru Urban (Karnataka), Mumbai City (Maharashtra), and North 24 Parganas (West Bengal) have the highest $PM_{2.5}$ emissions from almost all categories of DG sets and the highest total $PM_{2.5}$ emissions from all types of DG sets.

The Central Pollution Control Board (CPCB) and State Pollution Control Boards (SPCBs) in India regulate emission standards for DG sets. The Ministry of Environment, Forest and Climate Change has promulgated stringent norms over time, especially for high-capacity DG sets, including rules on lifespan, stack height, and use of retrofit emission control devices (RECDs). In addition to these regulations, some policies have been implemented to promote cleaner alternatives, such as solar backups, gas-based or dual-fuel generators, and improved power supply through distribution companies.

Promoting reliable and cost-effective alternatives, including solar, newer DG sets like CPCB IV+ with stringent emission controls, gas-based solutions, and RECDs, is key to reducing DG set use and mitigating air pollution, till grid reliability improves and the need for DG sets is minimised.

Solar photovoltaic systems with storage offer 100% emission reduction potential but currently only meet about 30% of the DG set demand owing to high costs, land needs, and reliability concerns. Natural gas generators are another clean option, offering up to over 95% reduction in primary $PM_{2.5}$ emissions. However, key challenges include high initial costs, a poor network of gas pipelines in remote areas, and safety risks.

New DG sets using advanced emission technologies (e.g. CPCB IV+ models) can reduce PM and NO_x emissions by 80%–90% and have a lower total cost of ownership. Older DG sets can be equipped with RECDs or converted to dual-fuel mode (70% gas) to reduce pollution. While retrofitting older DG sets is costly and has limitations, especially for small or portable units, it remains a viable solution in the absence of feasible cleaner alternatives.

Broader policy (e.g. a national scrappage policy for outdated/super-emitter units) and economic support (e.g. financial incentives for rooftop photovoltaic systems incorporating battery storage or for the purchase of CPCB IV+ DG sets) is necessary to scale these measures and effectively reduce air pollution.

A comparative analysis of alternative technologies are listed below.

***Table ES1**: Comparison of alternative technologies to diesel generator (DG) sets in terms of cost estimation, levelised cost of electricity (LCOE), and emission reduction potential (ERP)*

Available alternatives	ERP (in %)	Capital cost (in INR [lakhs])	Operational and maintenance cost in 15 years (in INR [lakhs] [net present value])	Total cost of ownership in 15 years (in INR [lakhs])	Total energy produced in 15 years (in MWh)	LCOE (in INR/ kWh)*	Payback period (in years) w.r.t older DG sets + RECDs
25 kW Solar							
(Solar + storage)	100	19.32	5.06	24.38	5.19	5	~3
25 kW Solar							
(Solar + storage + land cost)	100	51.60	5.06	56.66	5.19	11	~8.5
125 kVA Gas-based generators	97.6	14.20	80.02	94.22	4.77	20	~14
125 kVA CPCB IV+ DG set	85.3	12.20	74.27	86.47	4.77	18	~8.5
125 kVA Retrofitting emission control devices in existing DG sets	70	0 (already installed)	95.55	95.55	4.77	20	-

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Table of Contents

List of Figures

List of Tables

Abbreviations

APPCB	Andhra Pradesh Pollution Control Board
ARAI	Automotive Research Association of India
BC	Black carbon
CapEx	Capital expenditure
CO	Carbon monoxide
CPCB	Central Pollution Control Board
CAQM	Commission for Air Quality Management in NCR and Adjoining Areas
CAGR	Compound annual growth rate
CNG	Compressed natural gas
DDUGJY	Deen Dayal Upadhyaya Gram Jyoti Yojana
DA-JGUA	Dharti Aaba Janjatiya Gram Utkarsh Abhiyan
DG	Diesel generator
DISCOM	Distribution company
ECD	Emission control device
ERP	Emission reduction potential
ESO	Energy storage obligation
GAIL	Gas Authority of India Limited
GA	Geographical area
GSPCB	Goa State Pollution Control Board
GARV	Grameen Vidyutikaran
GPCB	Gujarat Pollution Control Board
GRAP	Graded Response Action Plan
HSPCB	Haryana State Pollution Control Board
HCV	Heavy commercial vehicle
IBEF	India Brand Equity Foundation
IOCL	Indian Oil Corporation Limited
IPDS	Integrated Power Development Scheme
JHBDPL	Jagdishpur–Haldia–Bokaro–Dhamra Pipeline
JKPCC	Jammu & Kashmir Pollution Control Committee
KSPCB	Karnataka State Pollution Control Board
LCOE	Levelised cost of electricity
MPPCB	Madhya Pradesh Pollution Control Board
MPCB	Maharashtra Pollution Control Board

MoEFCC	Ministry of Environment, Forest and Climate Change
MNRE	Ministry of New and Renewable Energy
MoPNG	Ministry of Petroleum and Natural Gas
MoP	Ministry of Power
NAAQS	National Ambient Air Quality Standards
NCAP	National Clean Air Programme
NISE	National Institute of Solar Energy
NO_x	Nitrogen oxides
NRL	Numaligarh Refinery Limited
ONGC	Oil and Natural Gas Corporation
OIL	Oil India Limited
OpEx	Operational expenditure
OEM	Original equipment manufacturer
PM	Particulate matter
PNGRB	Petroleum and Natural Gas Regulatory Board
PPAC	Petroleum Planning and Analysis Cell
PV	Photovoltaic
PNG	Piped natural gas
PM-JANMAN	Pradhan Mantri Adivasi Nyaya Maha Abhiyan
PM-KUSUM	Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan
PIB	Press Information Bureau
PPCC	Puducherry Pollution Control Committee
RGO	Renewable Generation Obligation
RPO	Renewable Purchase Obligation
RECD	Retrofit emission control device
RDSS	Revamped Distribution Sector Scheme
RTPV	Rooftop photovoltaic
SAUBHAGYA	Sahaj Bijli Har Ghar Yojana
OSPCB	Odisha State Pollution Control Board
TNPCB	Tamil Nadu Pollution Control Board
TRAI	Telecom Regulatory Authority of India
TCO	Total cost of ownership
UDAY	Ujwal Discom Assurance Yojana
UPS	Uninterrupted power supply
VGF	Viability gap funding

Introduction

1. Introduction

In 2022–2023, India experienced a 4% peak demand deficit and a 0.5% total deficit in power supply (Press Information Bureau, 2023). To address power outages (or 'load shedding'), power backup systems are widely used in India. In 2022, India's per capita electricity consumption was 1,081 kWh, approximately one-third of the global per capita electricity consumption (3,427 kWh; Sources of Electricity Generation, n.d.). As India undergoes rapid development, the overall energy demand is bound to rise, potentially also increasing the deficit.

Diesel generator (DG) sets are widely used for power backup in industrial, commercial, and residential complexes across India to mitigate the impact of unreliable power supply, especially when power demand is high. Besides their use in Indian cities, DG sets are widely used in villages for agricultural power and off-grid electricity. They have low installation costs and are readily available in a range of sizes and power capacities, making them popular for various applications in different sectors.

However, emissions from DG sets can be a significant local contributor to air pollution, with serious implications for human health and well-being. They are also a source of ambient noise. The Ministry of Environment, Forest and Climate Change (MoEFCC), in its National Clean Air Programme (NCAP) 2019 report (Ministry of Environment, 2019), estimated that DG sets account for approximately 7%–18% of total particulate matter in non-attainment cities (cities that failed to meet the National Ambient Air Quality Standards for five consecutive years).

This study examined DG set emissions and explored feasible and cost-effective strategies to reduce their air pollution impact. The contribution of DG sets to district-level emissions of particulate matter (PM_{10} and $PM_{2.5}$), black carbon (BC), nitrogen oxides (NO_X), and carbon monoxide (CO) was estimated. Further, DG set usage in different sectors, existing emission policies for DG sets, and alternatives to DG sets were assessed. The study proposes strategies to mitigate DG set emissions, based on feasibility, levelised cost of electricity (LCOE), and the emission reduction potential (ERP) of each alternative.

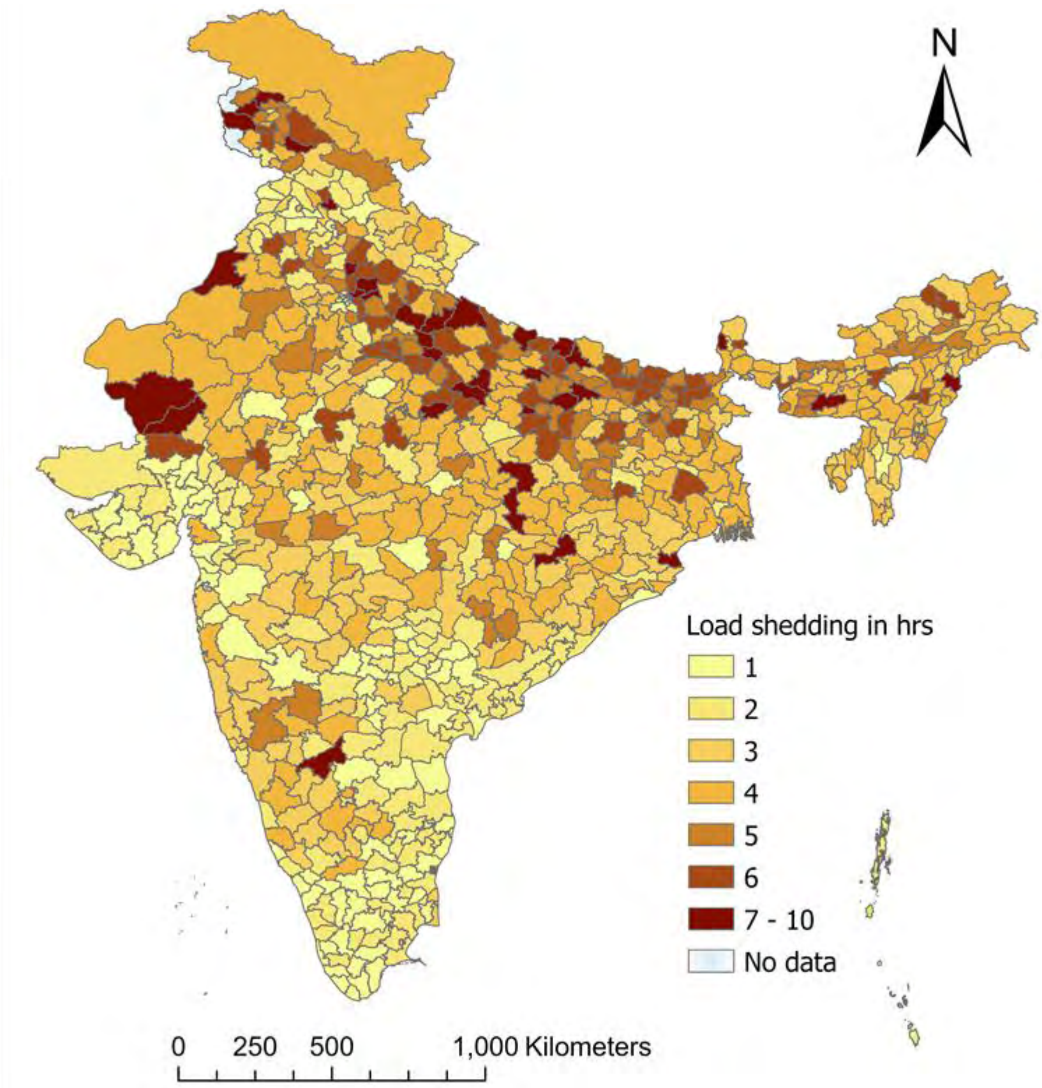
DG Set Usage and Emission Footprint in India

2. DG Set Usage and Emission Footprint in India

2.1. DG set landscape: Demand, capacity, and sectoral trends

DG sets are available in a wide range of capacities and are produced by various manufacturers. The primary use case is for backup power generation in case of load shedding. Figure 1 shows the district-wise average load shedding (power cuts) in India in 2022. Frequent power cuts inevitably lead to increased reliance on DG sets. Districts in North Indian states, including Uttar Pradesh, Rajasthan, and Haryana, along with Maharashtra and Karnataka, experienced more than 5 hours of power cuts per day in 2022.

***Figure 1**: Hourly power cuts in a day across India in 2022*



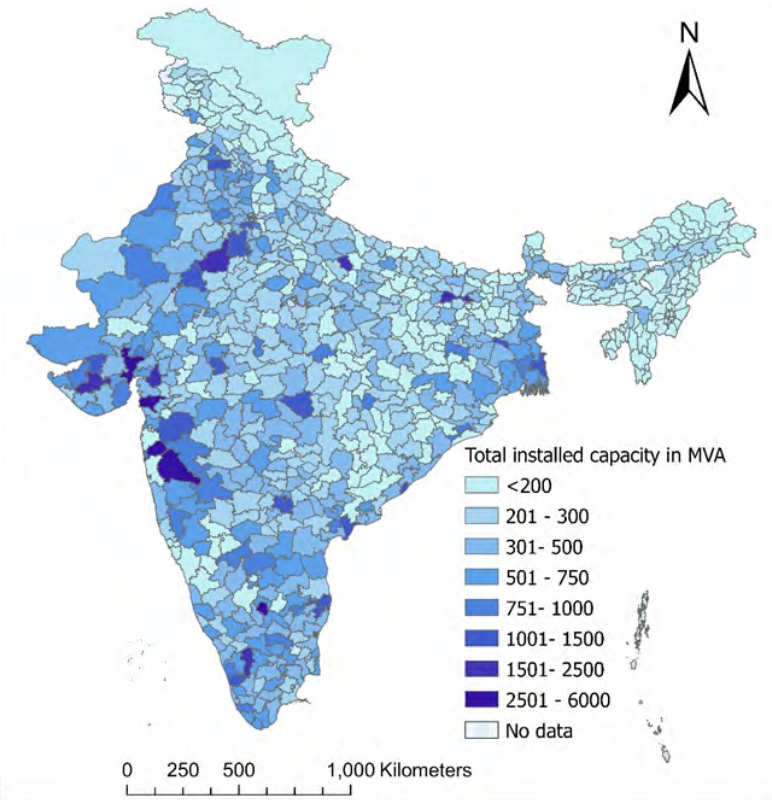
The global DG set market is expected to grow at a compound annual growth rate (CAGR) of 9.4% between 2023 and 2032, while the Indian DG set market is projected to grow at a CAGR of 8.8% (Diesel Generator Market Size, n.d.) by 2030.

Based on the commonly used DG set capacities across different sectors, this study categorised DG sets into four groups (Singh et al., 2024): 5–75 kVA, 76–375 kVA, 376–750 kVA, and above 750 kVA. District-level data for DG sets were procured from 200 districts and extrapolated to the remaining 537 districts of India. Details of the extrapolation methodology and validation are described in Appendix B. Table 1 shows the percentage share of installed DG set capacities across the four categories and their main applications. The total installed capacity of all four DG set categories at the district level across India is depicted in Figure 2.

***Table 1**: Share of installed capacity and applications across different diesel generator (DG) set categories*

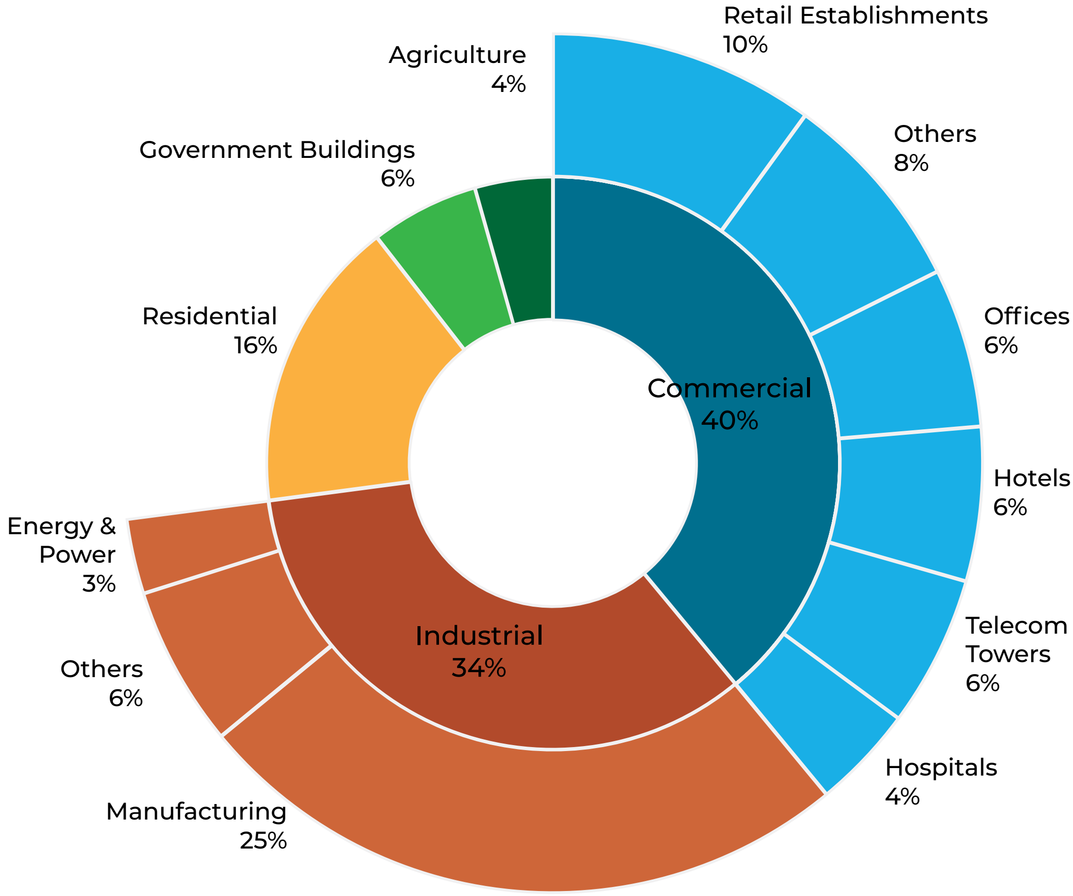
DG set categories (in kVA)	Percentage share (by installed capacity)	Applications
5–75	18%	Mainly used in residential settings and small commercial establishments
76–375	44%	Used in mid-sized apartment complexes and commercial establishments or for medium load
376–750	33%	Used in large apartment complexes and medium-scale industries
>750	5%	Used in large-scale industries

***Figure 2**: India-level total installed capacity of DG sets (in MVA)*



Based on the procured data, it was found that DG sets are most commonly used in commercial (40%) and industrial (34%) sectors (Figure 2). In the commercial sector, DG sets are used in retail establishments (25%), telecom towers (15%), hotels (15%), offices (15%), hospitals (10%), and other areas. In the industrial sector, DG sets are primarily used in manufacturing industries (74%) (Figure 3).

***Figure 3**: Usage share of DG sets*



2.2. Estimation of DG set emissions

Emissions from DG sets depend on the duration of operation, age of the DG set, and the fuel mix. The detailed methodology for emission estimation is described in Appendix A. Based on DG set installation and load-shedding data, district-level emissions were estimated for PM_{10}, $PM_{2.5}$, BC, NO_x, and CO (Table 2). Emissions were calculated considering 70% load on DG sets, as the exact load on each DG set is variable and most of the DG sets are not operated at full capacity (estimates for 50% and 100% load are shown in the Appendix to evaluate the effect of this assumption). Table 2 presents the India-wide DG set emissions estimated using two sets of emission factors: type-tested emission data from the Automotive Research Association of India (ARAI; reflecting newer DG sets with reduced emissions) and 2013 emission standards from the Central Pollution Control Board (CPCB; representing the maximum permissible emissions). More details are provided in Appendix A.

Older or poorly maintained diesel engines can violate emission standards set by the CPCB and emit significantly more than the permissible limits (Ministry of Environment, 2019). For example, diesel-fuelled heavy commercial vehicles (HCVs) that are old, poorly maintained, and overloaded and emit visible smoke are termed as super-emitters. A similar definition can be applied to DG sets. Over time, owing to a lack of maintenance, these older DG sets can emit visible smoke, often several times above the permissible limits. These DG sets can thus be termed as super-emitters.

However, while the prevalence of super-emitters among HCVs has been studied to some extent, including for the Indian on-road fleet, such data for diesel engines used in DG sets are scarce. Hence, these numbers are not included in the national estimates presented in Table 2.

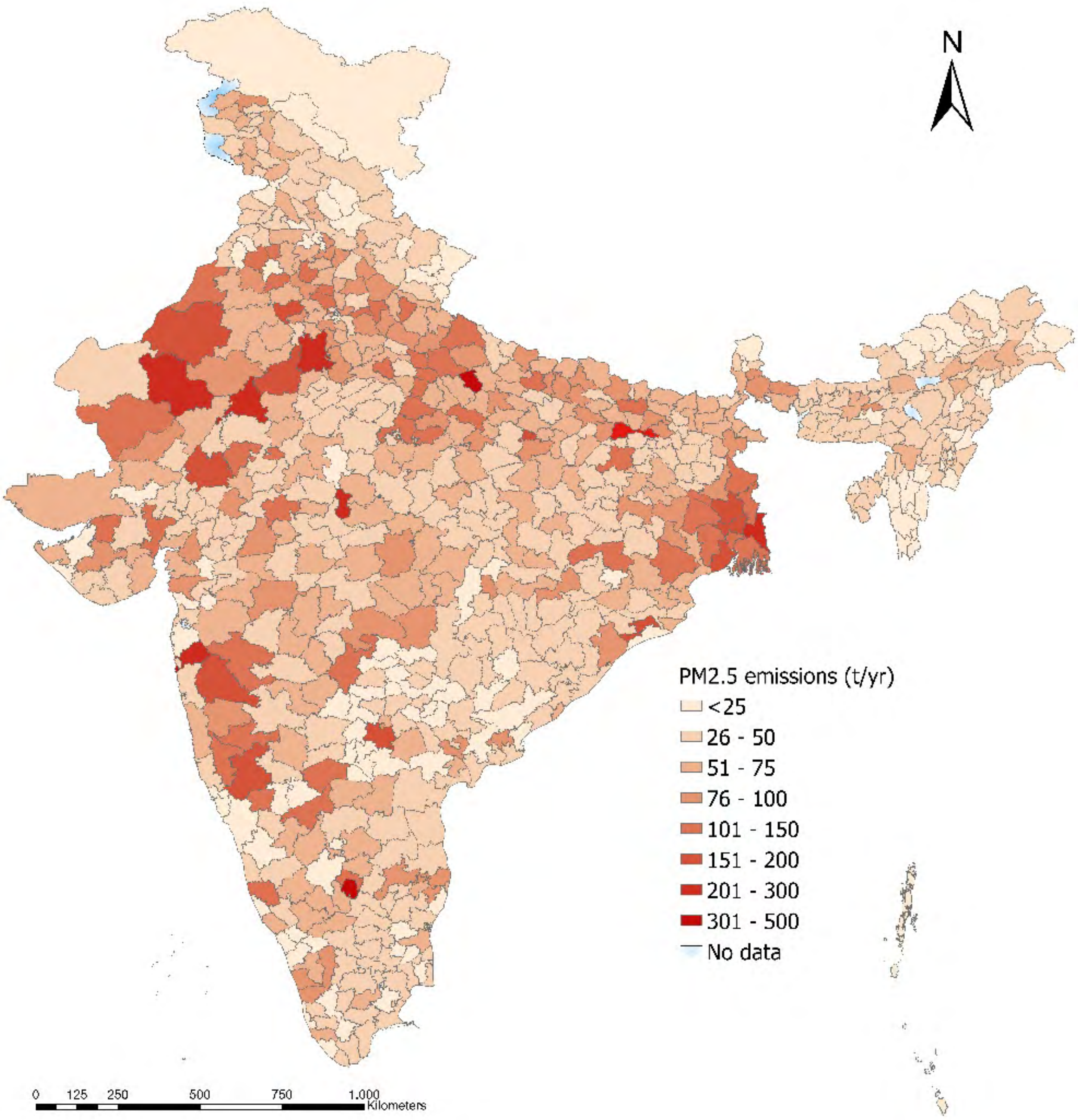
Further, Figure 4 shows the spatial plot of $PM_{2.5}$ emissions from DG sets. Similar spatial plots for PM_{10} and black carbon (BC) are shown in Appendix B.

***Table 2**: Estimated emissions of different pollutants from DG sets installed across India*

DG set category (kVA)	Emission loads (tonnes/year) *				
	PM_{10}	$PM_{2.5}$	BC	NO_X	CO
5–75	5,875[a]–10,879[c]	5,287[a]–9,791[c]	2,937[a]–5,440[c]	41,5675[a]–1,70,444[c]	41,596[a]–1,26,926[c]
76–375	11,667[a]–19,126[c]	10,500[a]–17,214[c]	5,833[a]–9,563[c]	3,40,637[a]–3,82,523[c]	1,06,533[a]–3,34,708[c]
376–750	8,605[a]–14,106[c]	7,744[a]–12,696[c]	4,302[a]–7,053[c]	2,51,231[a]–2,82,123[c]	78,571[a]–2,46,858[c]
Above 750	1,288[a]–2,111[c]	1,159[a]–1,900[c]	644[a]–1,056[c]	37,599[a]–42,222[c]	11,759[a]–36,944[c]
Total	27,434[a]–46,223[c]	24,691[a]–41,601[c]	13,717[a]–23,111[c]	7,75,142[a]–8,77,313[c]	2,38,459[a]–7,45,437[c]

**a: using ARAI type-tested emission factors; *c: using CPCB emission standards; PM_{10}: Particulate matter of 10 µm diameter; $PM_{2.5}$: Particulate matter of 2.5 µm diameter; BC: Black carbon; NO_x: Nitrogen oxides; CO: Carbon monoxide*

Figure 4: District-level $PM_{2.5}$ emission loads (tonnes/year) from DG sets



Many districts in Rajasthan, Uttar Pradesh, West Bengal, and Maharashtra show high $PM_{2.5}$ emissions, driven by high installed capacities of DG sets and frequent power cuts. The top 10 districts with the highest $PM_{2.5}$ emissions from different categories of DG sets are ranked in Table 3. Patna (Bihar), Gautam Buddha Nagar (Noida), Bengaluru Urban (Karnataka), Mumbai City (Maharashtra), and North 24 Parganas (West Bengal) have the highest $PM_{2.5}$ emissions from almost all categories of DG sets and the highest total $PM_{2.5}$ emissions from all types of DG sets.

***Table 3**: Ranking of different districts based on $PM_{2.5}$ emissions from different categories of diesel generator (DG) sets*

Rank	5–75 kVA	76–375 kVA	376–750 kVA	Above 750 kVA	Total
1	Patna (BR)	Patna (BR)	Gautam Buddha Nagar (UP)	Gautam Buddha Nagar (UP)	Patna (BR)
2	North 24 Parganas (WB)	Bengaluru Urban (KA)	Patna (BR)	Patna (BR)	Gautam Buddha Nagar (UP)
3	Bengaluru Urban (KA)	North 24 Parganas (WB)	Bengaluru Urban (KA)	Ghaziabad (UP)	Bengaluru Urban (KA)
4	Mumbai City (MH)	Mumbai City (MH)	Mumbai City (MH)	Kanpur (UP)	Mumbai City (MH)
5	Bhopal (MP)	Alwar (RJ)	Ghaziabad (UP)	Gaya (BR)	North 24 Parganas (WB)
6	Thane (MH)	Ajmer (RJ)	Moradabad (UP)	Bengaluru Urban (KA)	Ajmer (RJ)
7	Khordha (OD)	Gautam Buddha Nagar (UP)	Rangareddy (TS)	Lucknow (UP)	Alwar (RJ)
8	Paschim Bardhaman (WB)	Khordha (OD)	Alwar (RJ)	Meerut (UP)	Bhopal (MP)
9	Hooghly (WB)	Jodhpur (RJ)	North 24 Parganas (WB)	Rangareddy (TS)	Thane (MH)
10	Ajmer (RJ)	Belagavi (KA)	Ajmer (RJ)	Ajmer (RJ)	Jodhpur (RJ)

**BR: Bihar; KA: Karnataka; MH: Maharashtra; MP: Madhya Pradesh; OD: Odisha; RJ: Rajasthan; TS: Telangana; UP: Uttar Pradesh; WB: West Bengal*

Regulatory Framework

3. Regulatory Framework

3.1. Emission regulations and guidelines

In India, CPCB and respective State Pollution Control Boards and Committees are responsible for regulating emissions from DG sets. Over the years, MoEFCC has notified stringent emission norms for DG set categories. CPCB has laid down guidelines for the lifespan of the DG set, permissible stack height, use of Retrofit Emission Control Devices (RECDs), etc. Table 4 lists the emission norms and guidelines issued in chronological order to reduce air pollution from DG sets. A detailed comparative table of emission standards may be found in Appendix C.

Table 4*: DG set regulations issued in India in chronological order*

Year	Notification and guideline	Brief description
2002	MoEFCC G.S.R. 371 (E) dated 17 May 2002 (Ministry of Environment and Forests, 2002) MoEFCC G.S.R. 489 (E) dated 9 July 2002 (Ministry of Environment and Forests, 2002)	Emission standards for DG sets with a capacity of up to ≥800 kW and <800 kW were notified.
2004	MoEFCC G.S.R. 448(E) dated 12 July 2004 (MINISTRY OF ENVIRONMENT AND FORESTS, 2004)	Emission standards for DG sets with a capacity of up to ≥800 kW were amended and notified again.
2013	MoEFCC G.S.R. 771 (E) dated 11 December 2013 (Ministry of Environment and Forests, 2013)	Emission standards for DG sets with a capacity of up to 800 kW were revised to be more stringent.
2015	CPCB 'IN-USE GENSETS: Guidelines for Noise and Emission Control' (Central Pollution Control Board, 2015)	Guidelines for in-use DG sets (including the operational lifetime of DG sets and maintenance) were issued.
2016	MoEFCC G.S.R. 281 (E) dated 7 March 2016 (Ministry of Environment, Forest and Climate Change, 2016)	Emission limits for DG sets running on natural gas or liquefied petroleum gas (LPG) were notified.
2022	MoEFCC G.S.R. 804 (E) dated 3 November 2022 (Ministry of Environment, Forest and Climate Change, 2022) CPCB 'System & Procedure for Emission Compliance testing of RECD for DG set up to 800kW' dated 1 February 2022 (revised on 24 July 2023) (Central Pollution Control Board, 2023)	Stringent emission standards for DG sets with a capacity of up to 800 kW were notified. Guidelines on minimum technical criteria for retrofit emission control devices (RECDs; including the durability period and minimum reduction efficiency) were issued.

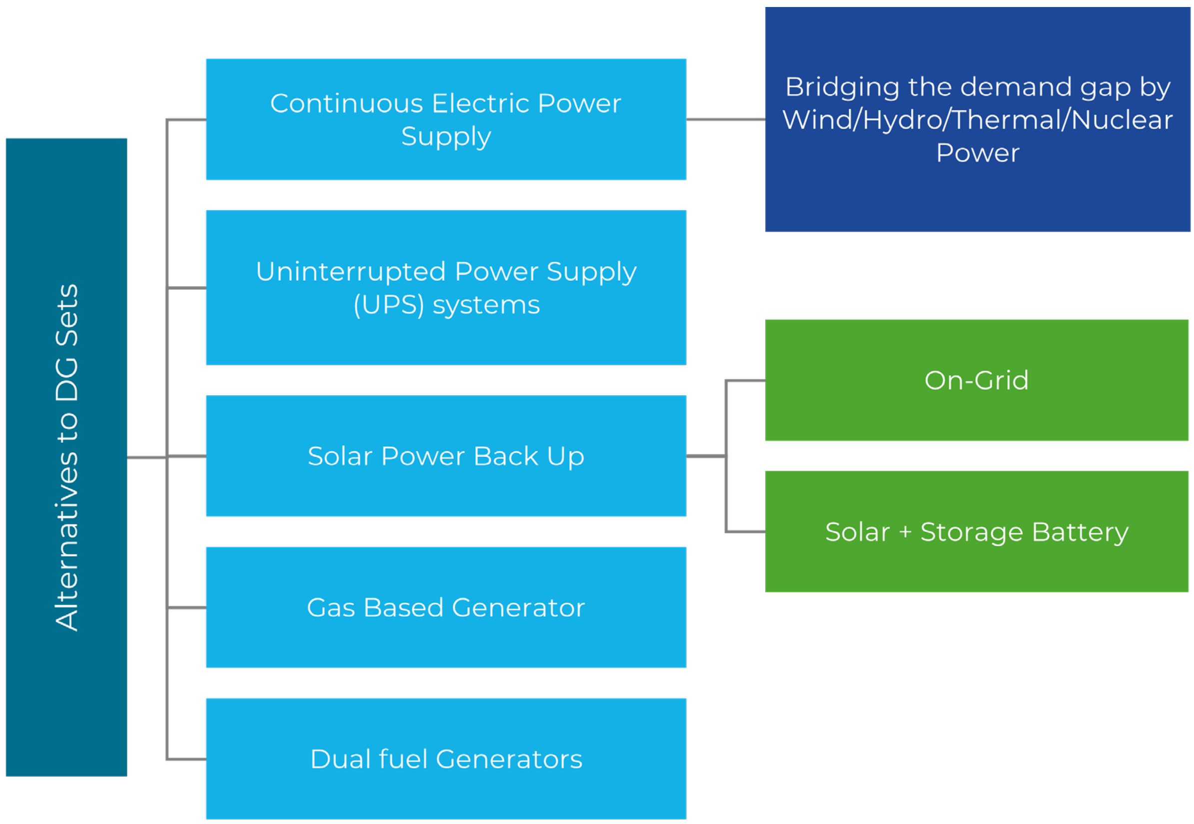
Year	Notification and guideline	Brief description
2023	CAQM Direction NO. 76 (Commission for Air Quality Management, 2023) dated 29 September 2023, to be read with the amendment dated 11 December 2024 (Commission for Air Quality Management, 2024)	Delhi and the National Capital Region (NCR) states were directed to regulate the use of DG sets in the NCR.

3.2. Alternatives to DG sets

Apart from regulating emissions from DG sets, cleaner alternatives, such as gas-based or dual-fuel generators and solar power backup, can be adopted, alongside measures to ensure a continuous power supply and reduce power losses. Figure 5 depicts various alternatives to DG sets.

The most effective solution to avoid the usage of DG sets is to reduce power cuts and ensure uninterrupted electric power supply from Distribution Companies (DISCOMs). There is a gap of 1.4% between the peak power demand and supply, which is mainly attributed to a fund shortage in DISCOMs and other system constraints (Press Information Bureau, 2023). This report elaborates on the alternatives to DG sets in the following sections.

***Figure 5**: Alternatives to DG sets for power backup*



The Central and State Governments have introduced various policy measures to incentivise the adoption of these alternatives.

3.2.1. Policy levers

Various policies and programmes have been launched at the national level to support increased solar power generation, augment the availability of natural gas infrastructure in various geographical areas across the country, and ensure a continuous power supply.

The Ministry of Power (MoP) launched the Ujwal Discom Assurance Yojana (UDAY) (Ministry of Power, 2015a) to provide financial support for DISCOMs. Schemes such as Deen Dayal Upadhyaya Gram Jyoti Yojana, Pradhan Mantri Sahaj Bijli Har Ghar Yojana (Saubhagya), and Revamped Distribution Sector Scheme (RDSS) were introduced to increase power supply and electrify unelectrified homes, some of which were reliant on DG sets for power and agricultural needs.

Some of the recent policies are summarised in Table 5 below. An exhaustive list is provided in Appendix D.

***Table 5**: Major supportive policies for alternatives to DG sets*

Major alternatives	National policies
Uninterrupted electric power supply	MoP's Ujwal Discom Assurance Yojana (UDAY) (2015–2019), and UDAY 2.0 in pipeline, announced in the Union Budget 2020–2021
	MoP's Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY; 2014–2018)
	Pradhan Mantri Sahaj Bijli Har Ghar Yojana (Saubhagya; 2017–2019)
	MoP's Integrated Power Development Scheme (2014–2022)
	MoP's Revamped Distribution Sector Scheme (RDSS; 2021–2026)
Solar power	Pradhan Mantri Surya Ghar: Muft Bijli Yojana (2024–2027)
	Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan Yojana (PM-KUSUM; 2019–2026)
	Ministry of New and Renewable Energy (MNRE) Scheme for the 'Development of Solar Parks and Ultra-Mega Solar Power Projects' (2014–2026)
	MNRE's Grid-Connected Rooftop Solar Programme (Phase II from 2019 to 2026)
	MNRE Scheme for Solarisation of Modhera, Gujarat (2020)
	MNRE National Programme on High-Efficiency Solar PV Modules 'Production-Linked Incentive Scheme (Tranche II)' (2022)
	MoP's Renewable Purchase Obligation (RPO) and Energy Storage Obligation Trajectory (2029–2030)
	MoP's Renewable Generation Obligation (2023)
Gas-based generators	Pradhan Mantri Urja Ganga Yojana (2016)
	Hydrocarbon Vision 2030 for North East (2016)
	Indradhanush Gas Grid Limited (2018)
	North East Gas Grid Subsidy (2020)

Potential mitigation strategies

4. Potential Mitigation Strategies

Measures to mitigate emissions from DG sets include reducing their operating time, switching to cleaner fuels, installing emission control devices (ECDs), or transitioning to sustainable alternatives such as solar power or gas-based generators. The following sections examine policy instruments for minimising DG set usage, explore alternative options, and address associated challenges and solutions.

4.1. Policy support for strengthening power supply and access

The most effective way to reduce DG set emissions is to minimise load shedding through a reliable power supply. To this end, the government has launched key national initiatives, including the Integrated Power Development Scheme (2014) (Ministry of Power, 2014) to enhance urban distribution, metering, and loss reduction and the Deen Dayal Upadhyaya Gram Jyoti Yojana (2014–2022) (Ministry of Power, 2014) to electrify 18,374 (Ministry of Power, 2023) remote villages and strengthen rural power infrastructure.

In addition, the Pradhan Mantri Sahaj Bijli Har Ghar Yojana (Saubhagya) was launched in 2017 (Ministry of Power, 2017) to electrify all unelectrified households in rural and urban India and ensure last-mile connectivity. Under this programme, 262 lakh households were electrified by March 2019 (Ministry of Power, n.d.-a).

In 2021, the Revamped Distribution Sector Scheme (RDSS; Ministry of Power, 2024) was launched to provide improved and reliable power supply and electrify remaining unelectrified households under Saubhagya and other schemes, including Pradhan Mantri Adivasi Nyaya Maha Abhiyan (PM-JANMAN) and Dharti Aaba Janjatiya Gram Utkarsh Abhiyan (DA-JGUA).

Further, given the operational and economic challenges faced by DISCOMs, MoP launched the Ujjwal DISCOM Assurance Yojana (UDAY) in 2015 to revive state DISCOMs, alongside reducing power cost and power losses. UDAY 2.0 was then introduced in the Union Budget 2020–2021 (Ministry of Power, n.d.-b) to ensure quality metering, better reforms, and minimal power losses.

4.2. Alternative power backup options to reduce DG set emissions

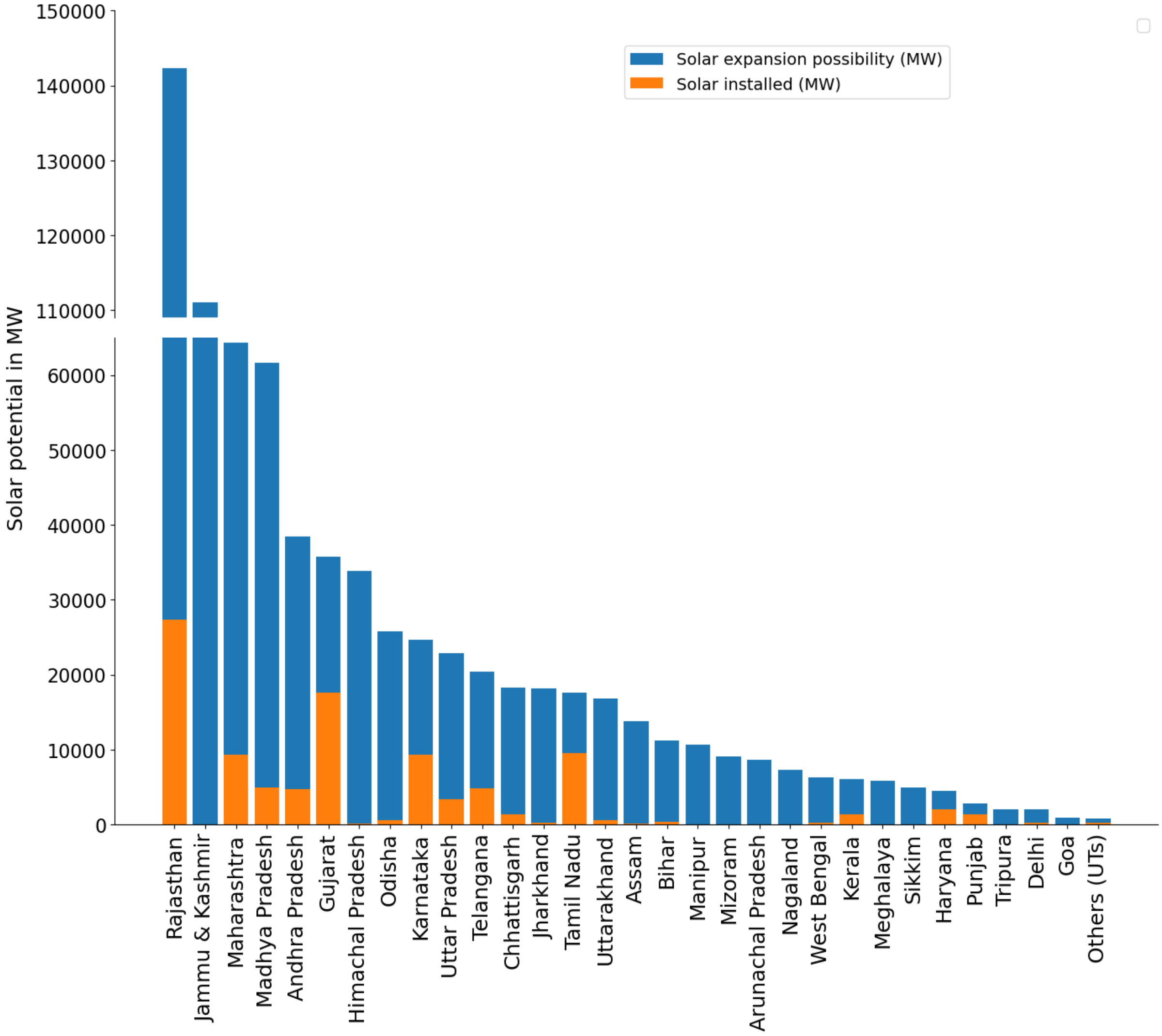
This section discusses cleaner and more sustainable alternatives to DG sets and the associated policy landscape, economics, and ERP.

4.2.1. Solar photovoltaic cells + Storage

ERP:

Solar photovoltaic cells with storage continue to be the most sustainable alternatives, offering 100% ERP. India's substantial solar potential remains largely untapped, with a few states being notable exceptions. The National Institute of Solar Energy has also estimated the total solar energy potential for India to be 7,48,990 MWp, with the highest potential in Rajasthan (1,42,310 MWp), followed by Jammu and Kashmir (1,11,050 MWp). In terms of total installed solar capacity, Rajasthan ranks first (26,490 MWp), followed by Gujarat and Tamil Nadu (Press Information Bureau, 2024a). However, the solar potential of Union Territories (UTs) and states like Jammu and Kashmir (UT) and Himachal Pradesh is largely untapped. Of the total potential solar capacity across India, the installed capacity is only around 13%. The state-wise solar energy potential and installed capacity are shown in Figure 6 (Appendix F also provides detailed state-wise data).

***Figure 6**: State-wise total solar expansion potential and installed solar capacity by 2024*



(Source: MNRE state-wise RE installed capacity as of 31 December 2024)

Considering that MoP and the National Institution for Transforming India (NITI) Aayog (India Smart Grid Forum, 2019) are pushing for energy storage along with solar plants, this study also investigated the state-wise solar potential and the possibility of replacing DG sets. Based on the results, barring eight states, all remaining states can completely replace DG sets with solar + storage wherever land is available (e.g. rooftops; Figure 10 in Appendix C).

Current policies and governance landscape:

MNRE launched the PM Surya Ghar Muft Bijli Yojana in 2024, with a financial outlay of INR 75,000 crore for setting up rooftop solar, aiming to provide electricity to 1 crore households by offering up to 300 units of free electricity every month (Ministry of New and Renewable Energy, n.d.-c). MNRE's Grid-Connected Rooftop Solar Program (Phase II launched in 2019) aims to install 4,000 MW of rooftop solar capacity by providing central financial assistance in the residential sector (Press Information Bureau, 2023b) and incentives to DISCOMs (Ministry of New and Renewable Energy, n.d.-b).

For industries, MoP offers renewable power purchase and power generation obligations, especially in the power sector. In addition, the Telecom Regulatory Authority of India mandates telecom companies and telephone tower providers to avail hybrid power (grid power + renewable energy) for tower-related power requirements.

Associated costs:

Cost estimates (capital expenditure [CapEx]), operational expenditure [OpEx], and TCO), LCOE, and ERP ($PM_{2.5}$) for solar panels with and without the land cost are shown in Table 6. In terms of ERP, solar is the most optimal solution; however, the TCO for solar is quite high because of its higher installation cost, especially in areas where rooftop space is not suitable and land has to be additionally purchased. To calculate the LCOE, 1 hour of power outage and ~17% of capacity utilisation factor (effective generation of 100 kWh for a 25 kW solar plant) were considered.

***Table 6**: Cost estimation, levelised cost of electricity (LCOE), and emission reduction potential (ERP) of solar power*

Solar panel (25 kW) with storage	Capital expenditure (in INR [lakhs])	Operational expenditure (in INR [lakhs])	Total cost of ownership (in INR [lakhs])	LCOE (INR/KWh)	ERP
Without additional land requirement	19.32*	5.06	24.38	5	100%
With land requirement	51.60	5.06	56.66	11	100%

**Cost of solar panel without storage varies from INR 25,000 to INR 40,000 per kW; subsidy for solar panels of >3 kW capacity is INR 78,000.*

Barriers, entry points, and way forward:

Longer lifetime (25 years in comparison to 15 years for DG sets), lower LCOE (INR 5) in areas having space availability, low maintenance, 100% ERP, and the availability of subsidies make solar photovoltaic an attractive alternative for locations with low-to-medium energy demand, especially in states with high solar energy potential. The availability of easy financing can thus increase adoption of solar power in residential and industrial sectors.

However, despite existing policy support at the national and state levels, the highest ERP, and the lowest LCOE, solar energy adoption remains low across all sectors. Based on stakeholder consultations and available literature, reasons for this low adoption include large rooftop and land area requirements, higher land costs, high initial installation costs, high cost of battery storage, the need for weather-proofing solar panels, shading issues in high-rise buildings, operational constraints, inconsistent power supply, technical complexities, and regulatory challenges.

In addition, while our analysis showed that achieving only 50% of the state's solar potential can eliminate the need for DG sets in most states, stakeholder feedback suggested that solar energy can only effectively replace 30% of the total DG load owing to initial installation costs, associated land requirements, and reliability concerns due to daily fluctuations in solar radiation. Hence, alternative non-solar power sources are considered next.

4.2.2. Gas-based generators

Gas-based generators can provide power backup during load-shedding hours and emit less smoke and particulates than DG sets owing to their complete fuel combustion, making them a cleaner alternative to traditional DG sets.

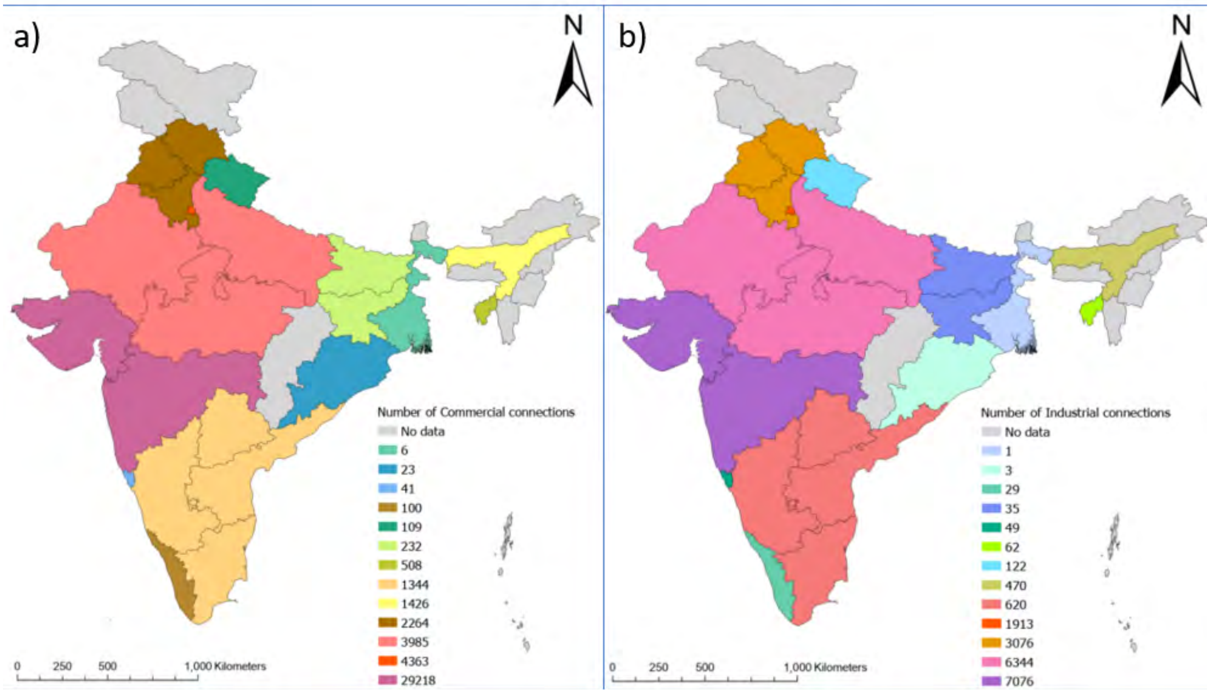
ERP:

Natural gas-fired generators are another alternative, offering a reliable power supply with lower air pollution potential (97.6% ERP for $PM_{2.5}$), lower noise pollution, and lower fuel and operating costs. Additionally, they could reduce NOx emissions by 30%–40% (Garg, 2021)compared with older DG sets.

As per the December 2024 report by the Petroleum and Natural Gas Regulatory Board (PNGRB) (Petroleum and Natural Gas Regulatory Board, n.d.-a), total approved natural gas pipeline across the country is 33,475 km, of which around 25,124 km of pipeline are already operational, and 10,676 km are under construction. As per the PNGRB district-wise list of geographical areas, out of 780 districts in the country, natural gas infrastructure is available in 731 districts (as of 10 July 2025) (Petroleum and Natural Gas Regulatory Board, n.d.-b). Andaman and Nicobar Islands and Lakshadweep are the two UTs with no piped natural gas (PNG) availability. The state-wise number of districts having natural gas availability is shown in Appendix E.

Gujarat has the highest number of PNG connections in both commercial and industrial sectors, followed by Maharashtra, Delhi, Uttar Pradesh, and Assam (Figure 7). Thus, gas-based generators in these states could serve as a reliable and cleaner alternative to DG sets owing to a deeper penetration of the PNG infrastructure.

Figure 7: Status of PNG connections in (a) commercial and (b) industrial units across states and UTs (Petroleum Planning & Analysis Cell, 2024).



Current policies and governance landscape:

The government has launched several policies and programmes to increase the availability of PNG across the country, especially in Northeast India. The Pradhan Mantri Urja Ganga Yojana was launched in 2016 to build a 3,384 km pipeline and connect it to East India, with two major pipelines: the 2,655 km Jagdishpur–Haldia–Bokaro–Dhamra Pipeline (JHBDPL) and the 729 km Barauni–Guwahati pipeline (Press Information Bureau, 2019). The Hydrocarbon Vision 2030, launched in 2016, also aims to secure natural gas supplies and expand the natural gas infrastructure in Northeast India with a 15-year roadmap (Ministry of Petroleum and Natural Gas, 2016). The Cabinet Committee on Economic Affairs in 2020 approved MoPNG's North-East Gas Grid Subsidy for the Indradhanush Gas Grid Limited, with an estimated financial outlay of INR 9,265 crore to cover up to 60% of the financing gap or capital cost (Press Information Bureau, 2020a), to expedite natural gas pipeline penetration, boost industrial development, and restrict polluting fuels.

Associated costs:

Our stakeholder consultations revealed that gas-based generators can cost 15%–20% more than DG sets of a similar capacity. However, a Centre for Science and Environment (CSE) report (Garg, 2021) suggests that the additional cost can be recovered in approximately 4 months, assuming 4 hours of operations per day, as the operating costs of gas-based generators are lower. Table 7 shows the costs and ERP of gas-based generators (125 kVA), considering 1 hour of daily operations.

***Table 7**: Cost estimation, levelised cost of electricity (LCOE), and emission reduction potential (ERP) for gas-based generators*

Generator type	Capital cost (in INR [lakhs])	Operational cost for 15 years (in INR [lakhs])	Total cost of ownership (in INR [lakhs])	LCOE (in INR/KWh)	ERP
Gas-based generator (125 kVA)	14.20	80.02	94.22	20	97.6%

Barriers, entry points, and way forward:

Dependence on reliable natural gas pipeline infrastructure, last-mile gas connectivity, higher purchase cost, and safety concerns, particularly during natural disasters and construction work, are key challenges with gas-based generators.

Given the availability of gas infrastructure in most districts and industrial areas of the states and the government programmes that further promote it, DG sets can be easily replaced with gas generators by simply increasing PNG connectivity, especially in industrial and commercial establishments.

4.2.3. CPCB IV+ DG sets*

Newer DG sets complying with the latest emission norms can be used as an alternative to older, polluting DG sets for power backup.

ERP:

Newer DG sets complying with MoEFCC GSR 804 E dated 03 November 2022 (Ministry of Environment, Forest and Climate Change, 2022) with innovative emission control technologies, such as exhaust gas recirculation systems, diesel particulate filters, and selective catalytic reduction, have lower pollutant emissions and offer better fuel efficiency. Hence, they are a cleaner option in the existing DG set ecosystem. Emission norms for DG sets have become more stringent over the years, with the latest emission norms issued in 2022 (details provided in Appendix D). On average, CPCB IV+ DG sets are designed to reduce PM and NO_x emissions by 80%–90%.

Associated costs:

The CapEx of CPCB IV+ DG sets is lower than that of gas-based generators. These DG sets are also more fuel efficient than older-generation DG sets. The LCOE of CPCB IV+ DG sets is found to be INR 18 per kWh (Table 8).

***Table 8**: Cost estimation, levelised cost of electricity (LCOE), and emission reduction potential (ERP) for CPCB IV+ DG sets*

Generator type	Capital cost (in INR [lakhs])	Operational cost (in INR [lakhs])	Total cost of ownership (in INR [lakhs])	LCOE (in INR/kWh)	ERP
CPCB IV+ DG set (125 kVA)	12.20	74.27	86.47	18	85.3%

Barriers, entry points, and way forward:

To phase out old DG sets and encourage a shift towards new DG sets with lower pollution potential, it is important to promulgate a scrapping policy at the national and state levels similar to the Vehicle Scrappage Policy and immediately phase out older DG sets manufactured and installed before 01 July 2004, in line with the statutory orders from various states such as Odisha and Jammu and Kashmir(please refer to Appendix I). Till then, the impact of cleaner systems will not translate into noticeable air quality gains.

4.2.4. Retrofitting existing DG sets with ECDs

Emission control options for existing DG sets include conversion to dual-fuel mode (70% gas and 30% diesel/petrol) and retrofitting with ECDs. CPCB, through its 31 December 2024 order (Central Pollution Control Board, 2025), provided RECD vendor lists, system guidelines (2022, revised 2023), and durability norms (6 years [4,000 or 6,000 operational hours based on ratings]) (CPCB, 2015). Central and state agencies have also mandated RECDs (with ≥70% PM reduction), dual-fuel retrofits, or a shift to gas-based generators.

States such as Andhra Pradesh, Gujarat, Haryana, Maharashtra, and Tamil Nadu have also issued jurisdictional orders. Most target DG sets in the 125–1000 kVA range, while CPCB, Commission for Air Quality Management in National Capital Region and Adjoining Areas (CAQM), and other pollution control agencies considered 61–800 kW DG sets. Odisha and Jammu and Kashmir have mandated the scrapping of non-compliant pre-2004 units. CAQM mandates RECDs for 19–41 kW DG sets and dual-fuel retrofits for 41–800 kW ones, unless replaced with compliant units under MoEFCC GSR 804(E) (03 November 2022). A list of these orders is given in Appendix I.

For 41–800 kW DG sets, combining RECDs with dual-fuel conversion aligns with CAQM guidelines. However, for units ≤ 41 kW, RECDs are not readily available, and dual fuel is also not feasible, particularly for <19 kW portable units. Further, cost remains a concern, with retrofitting a 125 kVA unit costing ~INR 3 lakh (about 40% of the cost of a new DG set [older generation]).

Associated costs:

Given the large number of DG sets across the country and challenges associated with solar- and gas-based generators, it is important to retrofit the existing DG sets in their remaining lifetime as per standards (15 years or 50,000 hours of operation, whichever is earlier) with ECDs with a minimum capture efficiency of 70%. Comparative cost economics, LCOE, and ERP of new and existing DGs are presented in Table 9.

***Table 9**: Cost estimation, levelised cost of electricity (LCOE), and emission reduction potential (ERP) for retrofitting existing DG sets with emission control devices*

Generator type	Capital cost (in INR [lakhs])	Operational cost (in INR [lakhs])	Total cost of ownership (in INR [lakhs])	LCOE (in INR/KWh)	ERP
Existing DG sets (125 kVA) + RECD	6.70 (0 for existing DG sets)	95,55,116	1,02.25 (95.55 for existing DG sets)	21	70%

Barriers, entry points, and way forward:

High retrofitting cost for ECDs (INR 3 lakh for 125 kVA DG set, around 40% of the purchase cost as per stakeholder consultations), high conversion cost for partial gas usage (70% gas and 30% diesel), back pressure loss due to the use of ECDs over time, and lower lifetime of ECDs (6 years compared to 15 years for DG sets) are some challenges. However, in case of non-availability of other alternatives, from a pollution control perspective, this may be a desirable solution, as the overall cost of conversion is around 40%–50% of the cost of a new CPCB IV+ DG set. However, the estimated TCO for CPCB IV+ DG sets is lower, and the capital cost can be paid back in about 8.5 years through savings in operational costs (considering daily runtime of 1 hour). Thus, CPCB IV+ DG sets are more economical than retrofitting older DG sets.

4.2.5. Biodiesel as fuel

Another way to reduce diesel emissions from power generators is to use less-polluting fuels. Biodiesel is a low-carbon alternative fuel derived from vegetable oils, animal fats, recycled cooking oil, etc. OEMs have launched 100% biodiesel-based generator sets with power outputs ranging from 7.5 kVA to 62.5 kVA. Biodiesel has similar properties to diesel but offers better lubrication and a low sulphur content. However, limited fuel availability and DG set capacities specifically developed for biodiesel are some challenges. Since India introduced a biodiesel policy in 2018, many DG set manufacturers have started making DG sets compatible with biodiesel (or a variant of biodiesel). However, usage data are not currently available, so this alternative was not considered further in this study.

Suggestions for specific LCOE and ERP combinations are provided in Table 10.

***Table 10**: Comparison of alternatives to diesel generator (DG) sets based on emission reduction potential (ERP) and levelized cost of electricity (LCOE)*

	Low ERP (70%)	Medium ERP (85%)	High ERP (98%–100%)
High LCOE	DG + RECD	CPCB IV+ DG sets	Gas-based generators
Medium LCOE	-	-	Solar + Storage + Land cost
Low LCOE	-	-	Solar + Storage

**: LCOE (INR/kWh) = Total cost of ownership (INR) / Total energy produced (kWh)*

Summary

5. Summary

To reduce emissions from DG sets, it is necessary to ensure a continuous electricity supply through various sources. However, DG sets are likely to remain in use in the near future; thus, it is important to switch to alternatives that are economical and have high pollution reduction potential. A list of alternatives along with their corresponding feasibilities, challenges, required policy instruments, and desirability as discussed in Chapter 4 is shown in Table 11. For low-, medium-, and high-capacity DG sets, more than one alternative solution is feasible, and the final choice largely depends on resource availability and economics.

***Table 11**: Snapshot of possible alternatives to DG sets, listed in the order of their emission reduction potentials (highest to lowest)*

Alternate technologies	Feasibility	Challenges for implementation	Required policy instruments
Solar (Solar +Storage) A 25 kW solar will cost around INR 20 lakhs and can total cost of ownership for 15 years can cost upwards of INR 24.38 lakhs.	• Recommended for areas with low- or medium- energy demand and availability of land • Profitable in the long run and has a payback period of around 3 years.	• Higher installation cost • Requires a large area for installation • High storage cost • Requires protection against adverse weather conditions • Utilisation up to 30% of peak load	**Incentives and capping schemes may be increased.** For instance, for PM Surya Ghar Muft Bijli Yojana, the subsidy is up to 3 kW. However, many households in India have a daily electric power utilisation of 7–15 kWh. So, quite a few households need to depend on additional sources of power. Simplify the application process for subsidies and ensure easy availability of loans under the schemes for enhanced implementation. Enable a single-window clearance wherever possible.
Gas-based generators A 125 kVA gas-based generator will cost around INR 14.2 lakhs and can total cost of ownership for 15 years can cost upwards of INR 94.22 lakhs.	• Desirable for places having last-mile PNG connectivity. • It has a payback period of around 14 years.	• Last-mile gas connectivity and requires dependable natural gas infrastructure. • Higher purchase (15%–20%) and maintenance (20%) costs than CPCB IV+ DG set.	At the state level, only 12 states/UTs PCBs/PCCs have statutory orders for DG sets shifting to gas-based generators/partial gas usage. All states/UTs should issue statutory orders on similar lines

Alternate technologies	Feasibility	Challenges for implementation	Required policy instruments
CPCB IV+ DG Sets A 125 kVA new DG set will cost around INR 12.2 lakhs and can total cost of ownership for 15 years can cost upwards of INR 86.47 lakhs.	• Can meet peak loads in all sectors • Optimal for areas where implementing gas-based generators and solar power is not feasible. • Lower lifetime LCOE than comparable gas-based generators and retrofitted older DG sets. • Profitable in the long run and has a payback period of around 8.5 years.	Higher purchase cost than that for older DG sets (50%–70% higher for 100 kW DG sets).	DG sets manufactured and installed before 2013 may be phased out completely by 2028–2029 based on their operational lifetime and hours. **The phasing out of super-emitter DG sets (especially older than 2004) should be prioritised**. **A scrapping policy for DG sets** (similar to the Voluntary Vehicle Scrapping Policy) may be introduced.
Dual-fuel DG sets	Suitable for >41–800 kW DG set capacities in conjunction with RECDs.	• High modification cost (around INR 2.8 lakh for a 125 kVA DG set) • Reliant on dependable natural gas infrastructure • High maintenance cost • Emission optimisation is a challenge owing to the fuel mix	**A combination of dual-fuel DG sets with RECDs may be promoted across India.** The cost of RECD and dual-fuel conversion needs to be regulated to ensure uniform pricing across vendors. This will expedite conversion and uptake. In addition, states may come up with statutory orders/ directions to retrofit older DG sets and convert them to dual fuel in line with the CAQM mandate.
Retrofitting RECDs in existing DG sets Even without installation cost, total cost of ownership for 15 years can cost upwards of INR 95.55 lakhs.	Suitable for >41–800 kW DG set capacities	• High retrofitting cost (INR 3 lakh for a 125 kVA DG set, which is about 40% of the purchase cost) • Back pressure loss issue in exhaust • Higher overall operational cost due to decreased engine power and lower fuel efficiency • Need to replace RECDs after 6 years or after 4,000 operational hours	

A comparative study of different technologies was conducted to analyse the ERP, LCOE, and payback period over 15 years for a daily power outage of 1 hour (100 kW), as shown in Table 12.

Table 12*: Cost estimation, levelised cost of electricity (LCOE), and emission reduction potential (ERP) for alternative technologies*

Available alternatives	ERP (in %)	Capital cost (in INR [lakhs])	Operational and maintenance cost in 15 years (in INR [lakhs] [net present value])	Total cost of ownership in 15 years (in INR [lakhs])	Total energy produced in 15 years (in MWh)	LCOE (in INR/ kWh)*	Payback period (in years) w.r.t older DG sets + RECDs
25 kW Solar (Solar + storage)	100	19.32	5.06	24.38	5.19	5	~3
25 kW Solar (Solar + storage + land cost)	100	51.60	5.06	56.66	5.19	11	~8.5
125 kVA Gas-based generators	97.6	14.20	80.02	94.22	4.77	20	~14
125 kVA CPCB IV+ DG set	85.3	12.20	74.27	86.47	4.77	18	~8.5
125 kVA Retrofitting emission control devices in existing DG sets	70	0 (already installed)	95.55	95.55	4.77	20	-

Recommendations

6. Recommendations

On comparing the alternatives to DG sets, we found that a 25 kW solar system with storage (excluding land costs) is the most economical and efficient option, with 100% energy replacement potential, the lowest total cost of ownership (INR 24.38 lakh over 15 years), a competitive LCOE of about INR 5/kWh, and the fastest payback period of around 3 years. When the land cost is included, however, the total ownership cost more than doubles (INR 56.66 lakh), pushing the payback period to 8.5 years. In contrast, 125 kVA gas-based generators and CPCB IV+ DG sets have lower upfront costs but very high operational and maintenance expenses, leading to total ownership costs above INR 86 lakh and significantly higher LCOE values (INR 18/kWh) and a payback period of 8.5 years. While gas and diesel options offer energy replacement potential of 98%, their payback periods are much longer (14 years), making them less attractive than solar-based systems.

Recommendations for government stakeholders:

Addressing super-emitters: Older DG sets often emit pollutants multiple times above their permissible standards, as noted in the NCAP report (Ministry of Environment, 2019). These ageing units may be termed super-emitters that significantly contribute to air pollution, particularly in urban areas with frequent power outages. Identifying these high-emitting DG sets is critical for implementing effective air pollution mitigation strategies (e.g. scrappage and replacement). The government should mandate regular emission testing to identify non-compliant units and implement corrective measures, such as retrofitting or replacement.

Scrapping old DG sets and replacing them with CPCB IV+ DG sets: Drawing inspiration from India's Vehicle Scrappage Policy, 2021, to phase out old, polluting vehicles, a similar policy for DG sets could incentivise owners to retire outdated, high-emission units. Existing DG sets should be scrapped and replaced with CPCB IV+ DG sets, as the initial investment will be paid back over the lifetime owing to lower operating costs. This will also reduce emissions from DG sets. Further, these new DG sets should be subject to extended producer responsibility (EPR), so that the manufacturers guarantee cleanup at the end of life. To further encourage owners to make the cleaner choice, governments could provide a financial incentive, such as tax rebates, bridging the gap between the purchase price of a used DG set and a new DG set. This policy could also stimulate the market for indigenous cleaner technologies.

Promoting renewable energy alternatives: To reduce reliance on DG sets, particularly in low- and medium-load categories (e.g. 5–75 kVA and 76–375 kVA), the government should provide additional incentives for rooftop solar power systems paired with energy storage (as some states already do, but this is not yet a nationwide scheme). These incentives, ideally proportional to installed capacity (without a cap), would make solar + storage solutions financially viable for residential and small commercial users. For instance, solar + storage systems can provide reliable power during outages, directly competing with DG sets in these sectors. Additionally, targeted incentives for energy storage in non-commercial sectors could enhance affordability, enabling households and small businesses to adopt battery storage systems, further decreasing DG set usage.

Mandating gas-based generators: In industrial areas where the government is expanding the PNG infrastructure, mandating the use of gas-based generators offers a cleaner alternative to diesel. Natural gas generators produce lower PM emissions. By enforcing this transition in industrial zones, the government can reduce emissions while leveraging existing infrastructure investments.

Establishing a centralised monitoring system: To enhance regulation and compliance, the government should develop a centralised dashboard for registering all DG sets across India, especially in the commercial and residential sectors. This system would track the number, capacity, age, and emission compliance status of DG sets, enabling data-driven policymaking. For example, authorities could identify regions with high concentrations of super-emitters and prioritise interventions. The dashboard would also facilitate the enforcement of emission standards set by CPCB, ensuring that non-compliant units are addressed promptly.

By combining these measures, such as incentives for renewables in residential and small commercial settings, mandates for gas-based generators in industrial areas, and a robust monitoring system, the government can significantly mitigate air pollution from DG sets. Additionally, a compliance programme to identify super-emitters among DG sets (for subsequent retrofitting or scrappage) and promulgation of a scrappage policy for older DG sets could significantly reduce emissions. These could then be replaced with CPCB IV+ DG sets. These proposed actions align well with India's broader environmental goals, such as those outlined in the National Clean Air Programme (NCAP) and promote sustainable energy practices.

Recommendations for original equipment manufacturers (OEMs):

Boosting technological innovation: OEMs should invest more in research and development towards cleaner technologies and process optimisation to enable the production of cleaner DG sets. Reducing PM and NOx emissions by technological innovation is key to making DG sets more eco-friendly. There is an urgent requirement for more variants in the alternative fuel-based generator segment because the options for gas-based gensets are currently limited.

Introducing EPR to help replace older DG sets: OEMs must take the lead in taking back older units for scrappage and providing incentives to customers buying new DG sets in exchange for older units.

Recommendations for end users:

A major fraction of DG set usage is in commercial and residential spaces, and the hyperlocal emissions and associated noise impact communities. It is thus imperative for end users (market associations, homeowners, communities, and building managers) to follow recommended maintenance protocols. This could start with building awareness of government norms and compliance procedures. Further, end users should maintain DG sets properly, with periodic checks, and install required air pollution control devices. A transition to solar + storage could also solve the noise issue.

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Appendices

8. Appendices

8.1. Appendix A: Methodology

8.1.1. Emission estimation

To estimate the emissions from DG sets, we used the following formula:

$$E_p(\frac{t}{yr}) = N \times C \times Pf \times Lf \times L \times EF_p \times 365/10^6,$$

where E_p (t/yr) is the emission of pollutant p in tonnes per year, N is the number of DG sets, C is the capacity of DG sets in kVA, Pf is the power factor, Lf is the load factor, L is load shedding in hours, and EF_p is the emission factor in g/KWH for pollutant p.

For our calculations, we considered the power factor to be 0.8 and the load factor to be 0.7.

Data sources used in estimating the emission load are mentioned in Table A1.

***Table A1**: Data sources used in emission estimation*

Parameter	Data type	Source
Activity data	No. of DG sets	DG sets data for 200 districts of India from Prescient & Strategic (P&S) Intelligence Pvt. Ltd. and extrapolated for rest of the districts.
	Installed capacity of DG sets (kVA)	
	Run time/power cut (hours)	Prescient & Strategic (P&S) Intelligence Pvt. Ltd.
Emission factors	Pollutant-specific emission factors	ARAI and CPCB
Spatial allocation	District boundary	ArcGIS India basemap

8.1.2. Data collection and extrapolation

CSTEP purchased DG set data for 200 districts of India from Prescient & Strategic (P&S) Intelligence Pvt Ltd. The data include annual district-wise DG set numbers by use and power rating (5–75 kVA, 76–375 kVA, 376–750 kVA, and >750 kVA) from 2017 to 2023. DG set data for other districts were extrapolated based on gross district domestic product, build-up area density, Human Development Index, and daily power cut hours. A multi-linear model with all possible combinations of these four variables was developed to estimate the number of DG sets in all four categories.

The best model was selected based on the R-value for the training data and the significance of each variable in the outcome. The model selected was often the simpler one, with complex models selected if they significantly improved the R-value of the test dataset. The GPPD variable was observed to contribute the most to the model's outcome. Table A2 shows the list of variables used and their coefficients to estimate the number of DG sets in a particular capacity range.

Table A2: Equation for extrapolation of DG set data

DG set capacity (in kVA)	Variables used in the model	Equations
5–75	GDDP, HDI, PC	$n = 0.024 \times GDDP - 1005.5 \times HDI - 81.06 \times PC$
76–375	GDDP, BUAD, HDI, PC	$n = 0.014 \times GDDP - 0.012 \times BUAD - 26.5 \times HDI - 11.62 \times PC$
376–750	GDDP, HDI, PC	$n = 4.5 \times 10^{-3} \times GDDP + 85 \times HDI - 0.86 \times PC$
>750	GDDP, PC	$n = 3.3 \times 10^{-4} \times GDDP - 1.67 \times PC$

GDDP: Gross district domestic product; BUAD: Build-up area density; HDI: Human Development Index; PC: Power cut

8.1.3. DG set emission factors

A literature survey was performed to identify the appropriate emission factors. The findings are summarised in Table A3.

Table A3: Literature survey summary of DG set emission factors (EFs)

Study/Source	About study	EF/Emission rates used	Remarks
Sahu et al., 2015	Estimated emissions for 12–25 kW DG sets used in the telecom sector	PM: 9 g/kWh NO_x: 18.8 g/kWh, BC: 3.4-4.4 g/ kWh, CO: 4.06 g/ kWh	Estimated emissions for only low-capacity DG sets (EFs are obtained from USEPA)
Suthar et al., 2018	Created an emission inventory for 24 DG sets (62–1650 kVA) used in wedding gardens (16), malls (6), and shopping centres (2) in Jaipur city	$NOx \left(\frac{g}{s}\right) = \frac{3.85 \times DG\ sets\ capacity\ in\ HP}{3600}$ $PM_{10} \left(\frac{g}{s}\right) = \frac{0.24 \times DG\ sets\ capacity\ in\ HP}{3600}$ $CO \left(\frac{kg}{h}\right) = 15.32 \times 10^{-3} \times P^{0.68} \times N$	Used NO_x and PM_{10} emission rates from Brajmohan et al., 2018 and CO emission rates from Rukmani et al., 2014. Both studies used empirical formulas for emission rates.
Shakya et al., 2022	Estimated emissions from captive diesel generators in Kathmandu, Nepal	$PM_{10} \left(\frac{g}{L}\right) = -0.10\ ln(x) + 0.884$ $PM_{2.5}\left(\frac{g}{L}\right) = 0.1089e^{-0.005x}$ $CO\left(\frac{g}{L}\right) = 29.276e^{-0.016x}$ Where, X=DG capacity in KVA The average EF value of PM_{10} is 0.55 (g/L), $PM_{2.5}$ is 0.08 (g/L) and CO is 16.78 (g/L)	These equations are based on measurement data

Given the outdated nature of the existing emission factor (EF) data, we approached the Automotive Research Association of India (ARAI) to obtain more recent information. While ARAI did not have specific EFs for DG sets, they provided us with type testing data. Using these data, along with applicable emission standards Table A4, we estimated the emissions from DG sets. Since type-tested data pertains to newer models, it may not accurately represent emissions from the broader fleet of DG sets that includes many older DG sets. To establish an upper bound, we referred to the emission standards, under the assumption that all DG sets must emit below these thresholds.

Table A4: *Automotive Research Association of India (ARAI) type-tested data and Central Pollution Control Board (CPCB) emission standards (2013)*

	Engine Category	NOx	CO	PM_{10}	$PM_{2.5}$	BC
ARAI Type tested DG EF (g/kwh)	5–75 kVA	4.017	1.147	0.162	0.146	0.081
	76–375 kVA	3.562	1.114	0.122	0.110	0.061
	376–750 kVA	3.562	1.114	0.122	0.110	0.061
	Above 750 kVA	3.562	1.114	0.122	0.110	0.061
CPCB limits for DG (g/kwh)	5–75 kVA	4.70	3.50	0.30	0.27	0.150
	76–375 kVA	4.00	3.50	0.20	0.18	0.100
	376–750 kVA	4.00	3.50	0.20	0.18	0.100
	Above 750 kVA	4.00	3.50	0.20	0.18	0.100

**$PM_{2.5}$ is taken as 90% of PM_{10} and BC is taken as 50% of PM_{10}*

8.2. Appendix B: Estimated emissions

8.2.1. DG set emissions at 50% load and 100% load

Table A5: *Diesel generator (DG) set emissions at 50% load*

DG set category (in kVA)	Emission loads (tonnes/year)*				
	PM_{10}	$PM_{2.5}$	BC	NO_X	CO
5–75	4196[a]– 7771[c]	3777[a]–6994[c]	2098[a]–3963[c]	104054[a]–121746[c]	29711[a]–90662[c]
76–375	8334[a]–13662[c]	7500[a]–12295[c]	4167[a]–6967[c]	243312[a]–273231[c]	76095[a]–239077[c]
376–750	6146[a]–10076[c]	5532[a]–9068[c]	3073[a]–5139[c]	179451[a]–201517[c]	56122[a]–176327[c]
>750	920[a]–1508[c]	828[a]–1357[c]	460[a]–769[c]	26856[a]–30159[c]	8399[a]–26389[c]
Total	19596[a]–33016[c]	17636[a]–29715[c]	9798[a]–16838[c]	553673[a]–626652[c]	170328[a]–532455[c]

**a: using Automotive Research Association of India (ARAI) type-tested emission factor (EF); *c: using Central Pollution Control Board (CPCB) emission standards; PM_{10}: Particulate matter of 10 µm diameter; $PM_{2.5}$: Particulate matter of 2.5 µm diameter; BC: Black carbon; NO_x: Nitrogen oxides; CO: Carbon monoxide*

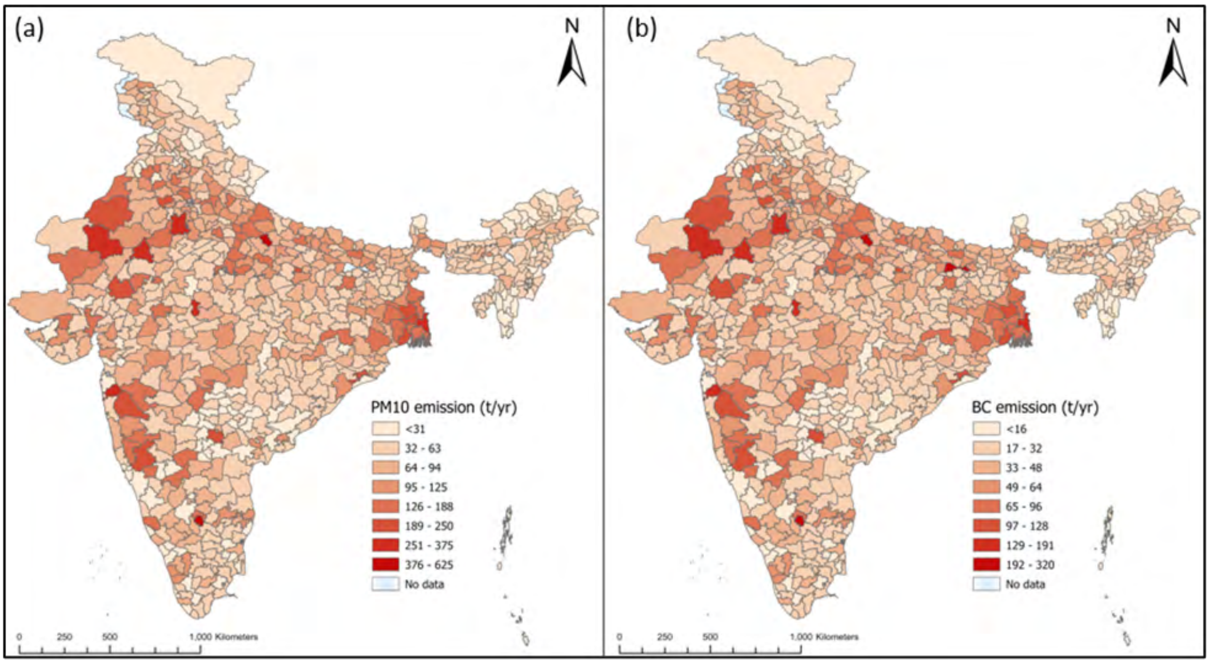
__Table A6__: Diesel generator (DG) set emissions at 100% load

DG sets category (in kVA)	Emission loads (tonnes/year) *				
	PM_{10}	$PM_{2.5}$	BC	NO_X	CO
5–75	8393[a]–15542[c]	7553[a]–13988[c]	4196[a]–7771[c]	208107[a]–243491[c]	59422[a]–181323[c]
76–375	16667[a]–27323[c]	15000[a]–24591[c]	8334[a]–13662[c]	486624[a]–546462[c]	152190[a]–478154[c]
376–750	12293[a]–20152[c]	11063[a]–18137[c]	6146[a]–10076[c]	358901[a]–403033[c]	112245[a]–352654[c]
>750	1840[a]–3016[c]	1656[a]–2714[c]	920[a]–1508[c]	53712[a]–60317[c]	16798[a]–52778[c]
Total	39192[a]–66033[c]	35273[a]–59429[a]	19596[a]–33016[a]	1107346[a]–1253304[a]	340655[a]–1064909[c]

**a: using ARAI type tested EF; *c: using CPCB emission standards*

8.2.2. PM_{10} and BC emissions from DG sets

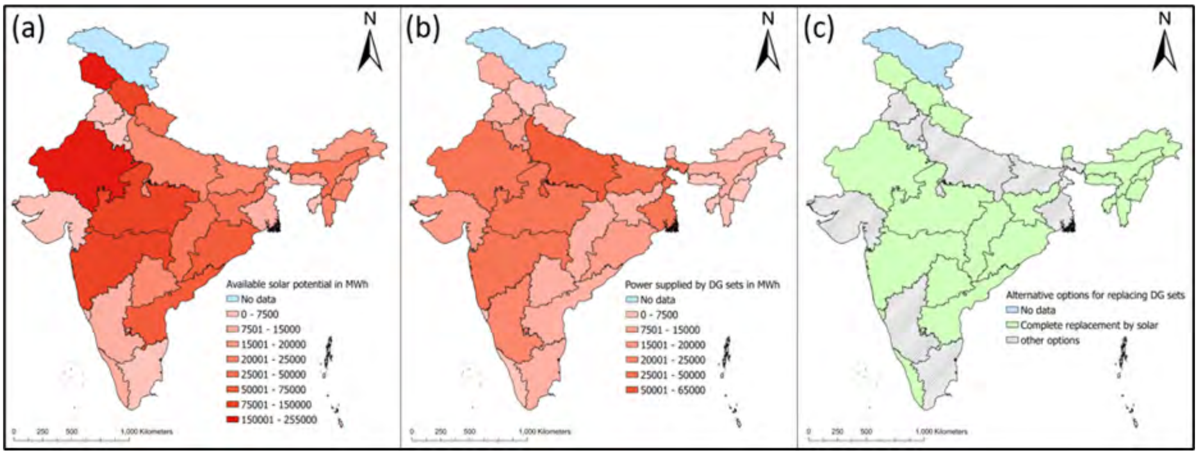
__Figure A1__: District-level emission spatial map at 50% load for (a) PM_{10} and (b) black carbon (BC) in tonnes/year



8.3. Appendix C: Availability of solar to completely replace DG sets

We have taken state/UT-wise solar potential data from the Ministry of New and Renewable Energy (MNRE) reported values (Press Information Bureau, 2024a) and the solar installed capacity data from the MNRE (Ministry of New and Renewable Energy, n.d.-d) and hypothesised that the states can achieve only up to 50% of the total solar potential. Here, we have presented which states can completely replace the DG sets using solar energy if they can use up to 50 % of the total solar potential. Figure A2(a) shows the per day available solar potential energy (MWh), which is the difference between 50% of the total solar potential (MWh) and already installed solar potential (MWh). Figure A2(b) shows the per day energy generated using DG sets (MWh), which depends on the power cut and the DG sets' capacity. Figure A2(c) shows the alternative options for replacing DG sets.

***Figure A2**: (a) Available solar potential in MWh or solar potential that is not installed yet (considering states can achieve 50% of total solar potential), (b) Power supplied by DG sets in MWh, and (c) Alternative options for replacing DG sets*



8.4. Appendix D: Emission standards for DG sets

***Table A7**: Emission Standards for DG sets up to and above 800 kW capacity*

Emission limits up to 800 kW capacity DG set (g/kWh)														
MoEFCC GSR 448 (E) dated 12 July 2004					**MoEFCC GSR 771 (E) dated 11 December 2013**				**MoEFCC GSR 804 (E) dated 3 November 2022**					
	NO_x	HC	CO	PM		NO_x+HC	CO	PM		NO_x	HC	NO_x +HC	CO	PM
up to 19 kW	9.2	1.3	3.5	0.3	up to 19 kW	≤7.5	≤3.5	≤0.3	P≤8	-	-	7.5	3.5	0.30
>19kW - 176 kW	9.2	1.3	3.5	0.3	>19 kW - 75 kW	≤4.7	≤3.5	≤0.3	8<P≤19	-	-	4.7	3.5	0.30
>176kW-800kW	9.2	1.3	3.5	0.3	>75 kW- 800 kW	≤4.0	≤3.5	≤0.2	19<P≤56	-	-	4.7	3.5	0.03
									56<p≤560	0.40	0.19	-	3.5	0.02
									560<P≤800	0.67	0.19	-	3.5	0.03

Emission standard for more than 800 kW capacity DG set (mg/Nm^3)

MoEFCC G.S.R. 489 (E), dated 9 July 2002

PM at 15% O_2	50 mg/Nm^3
NO_x at 15% O_2	650 mg/Nm^3
CO at 15% O_2	100 mg/Nm^3

8.5. Appendix E: Government policies

***Table A8**: Salient features of various policies/schemes issued for promoting Solar, PNG connectivity & ensuring continuous Electric power supply.*

Policy	Salient Features	Benefit
SOLAR POWER		
PM Surya Ghar- Muft Bijli Yojana (MNRE) (2024-2027) (Press Information Bureau, 2024b)	• Rooftop Solar Panel Installations in the Residential Sector • Target to cover One Crore Household. • Up to 300 units of free electricity per month. • Financial Outlay: 75,021 crores	• Accelerate Solar Power adoption. • Reduce DG Set usage. • Reduce dependency on Coal based Thermal Power. • Reduce Pollution from DG set & Coal based Thermal Power Generation.
Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM-KUSUM) (2019-2026) (Ministry of New and Renewable Energy, n.d.-c)	• Solar power installation in rural areas • Add Solar capacity of about 30,800 MW • 3 components: • Decentralised solar power plants • Stand-alone solar pumps in off-grid areas • Solarizing of grid-connected agricultural pumps • Financial Outlay: 34,422 crores	• Reduce dependence on Diesel operated Water pumps. • Ensure Solar based Electric Power & Water Security. • Reduce Pollution load from DG sets.

Policy	Salient Features	Benefit
MNRE scheme “Development of Solar Parks and Ultra-Mega Solar Power Projects” (2014-2026) (Ministry of New and Renewable Energy, n.d.-a)	• Solar parks for fast installation of grid connected solar power projects. • Primarily applicable for > 500 MW solar parks • Capacity enhanced from 20,000 MW to 40,000 MW. • Parks proposed to be set up by 2025-26. • Financial Assistance: • Up to Rs. 25 lakhs for DPR per Solar project. • CFA up to Rs. 20.00 lakh per MW or 30% of project cost.	• Faster installation of Solar power projects. • Reduced dependency on Electric Power from Non-Renewable sources. • Beneficiary States (as per sanctions): Andhra Pradesh, Chhattisgarh, Gujarat, Jharkhand, Karnataka, Kerela, Madhya Pradesh, Maharashtra, Mizoram, Odisha, Rajasthan, Uttar Pradesh.
MNRE Grid Connected Rooftop Solar Programme (Phase II), 2019-2026 (Ministry of New and Renewable Energy, 2022)	• 40,000 MW by 2026 from Grid Connected Rooftop Solar (RTS) projects. • CFA/Subsidy for residential consumers and DISCOMs. • Implementation by DISCOMs/State Agencies	• Increase in Solar Powered Electricity • Increased Rooftop Solar Installation • Reduced dependency on DG Sets
MNRE Scheme for Solarisation of Modhera town, Gujarat, 2020 (Ministry of New and Renewable Energy, n.d.-e)	• Complete solarisation of Gujarat’s Modera town (having Sun Temple)	• Solar powered residential, commercial and agricultural electricity needs. • Reduced dependency on DG sets. • Pollution Reduction from DG sets, Industries etc.

Policy	Salient Features	Benefit
MNRE National Programme on High Efficiency Solar PV modules “Production linked incentive scheme (Tranche II), 2022 (Ministry of New and Renewable Energy, 2022b)	• Aimed at establishing India’s solar PV manufacturing capacity. • To bring cutting edge technology to the country and ensure manufacturing of high efficiency modules. • Target is to achieve domestic solar PV module manufacturing capacity of 39,600 MW.	• Reduce dependency on import and increase domestic solar PV manufacturing. • Reduce the solar PV cost and increase adoption.
MoP Renewable Purchase obligation (RPO) and Energy storage obligation (ESO) (Ministry of Power, 2022b)	• RPO mandates electricity consuming entities to purchase specific % of electricity from Renewable energy including solar.	• Decline in reliance on Non-renewable energy sources. • Promote renewable energy usage like of solar power • Reduce emissions
MoP Renewable Generation Obligation, 2023 (Renewable Generation Obligation as per Revised Tariff Policy, 2016, 2023)	• Mandates power generating company establishing Coal/Lignite based Thermal Power Plant to establish at least 40% of renewable power generation or procure/supply equivalent renewable power.	Promote switch towards renewable energy including solar power.
AUGMENT NATURAL GAS AVAILABILITY		
MoPNG Pradhan Mantri Urja Ganga Yojana, 2016 (Press information Bureau, 2019)	• Jagdishpur – Haldia & Bokaro – Dhamra Pipeline (JHBDPL). • Total length-3384 Km • Natural gas for industries, CNG for vehicles and PNG for homes. • 5 Beneficiary States: Uttar Pradesh, Bihar, Jharkhand, Odisha and West Bengal. • 8 major Cities - Varanasi, Patna, Bokaro, Jamshedpur, Kolkata, Ranchi, Bhubaneswar and Cuttack.	• Gas pipeline Infrastructure in concerned States/DG Sets. • Increase in adoption rate of Gas based Generators. • Less use of Polluting Fuels.

Policy	Salient Features	Benefit
MoPNG Hydrocarbon Vision 2030 for North East India, 2016 (Ministry of Petroleum and Natural Gas, 2016)	• Plan for Natural Gas Infrastructure in North-East. • Market development for offtake. • Double the production of Oil Equivalent Gas	• Increased availability and offtake of Natural Gas. • Gas based Generators in Commercial/Industrial units.
Indra Dhanush Gas Grid Limited, 2018 (Press Information Bureau, 2020b)	• Joint Venture of IOCL, ONGC, GAIL, OIL & NRL. • To support MoPNG Hydrocarbon Vision 2030 for North East. • Total pipeline length:1656 KM. • Beneficiary North-Eastern states = Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura. • Connect Barauni- Guwahati pipeline under MoPNG Urja Ganga Project.	• Ensure uninterrupted Gas supply. • Discourage use of Polluting fuels like Kerosene, Coal, Wood etc. • Increased adoption of Gas based Generators in placed of DG Sets.
MoPNG North East Gas Grid Subsidy, 2020 (Press Information Bureau, 2020b)	• VGF/Capital grant @ 60% for development of North East Gas grid pipeline under Indraprastha Gas Grid Limited Project • Financial outlay: Around 9265 Cr	• Accelerate laying of Natural Gas pipeline in North East. • Support Industrial Establishment • Increased usage of cleaner Environment Friendly fuel.
UNINTERRUPTED SUPPLY OF ELECTRIC POWER		
MoP Ujjwal DISCOM Assurance Yojana (UDAY), 2015-2019. (Ministry of Power, 2015b) UDAY 2.0 in pipeline, announced in Union Budget 2020-21 (Press Information Bureau, 2020c)	• Financial support for revival of DISCOMs • 22 States/UTs signed MoUs with Central Govt. • UDAY web portal for monitoring	• Ensure uninterrupted Power supply. • Reduced power outage.

Policy	Salient Features	Benefit
MoP Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY), 2014-2018 (Ministry of Power, 2014)	• Ensure Rural Electrification • GARV-II App launched for transparent tracking of status of rural Electrification	• Accelerated rural electrification and ensured grid connectivity of remote villages • 18,374 remote villages electrified (Ministry of Power, 2023)
Pradhan Mantri Sahaj Bijli Har Ghar Yojana (SAUBHAGYA), 2017-2019 (Ministry of Power, 2017)	• Aimed at Universal household electrification. • Financial Outlay: 16,320 crores	• 262 lakh households electrified under the scheme.
MoP Integrated Power Development Scheme 2014-2022 (Press Information Bureau, 2022)	• Improve the electricity distribution infrastructure in Urban areas.	• Under the scheme, distribution works in 547 circles were successfully completed.
MoP Revamped Distribution Sector Scheme (RDSS), 2021-2026 (Ministry of Power, 2022a)	• Financial Outlay: 3,03,758 crores • Reduce AT&C losses • Improve smart metering & distribution system. • Financial support to public DISCOMs for Distribution Infrastructure works. • Improve the Electricity supply to farmers through separating the agriculture feeders & mixed feeders and prioritising the agriculture ones. • Promote solarisation of separated feeders through the PM-KUSUM scheme.	• Reduce power outage. • Improved electricity supply in rural areas for agriculture will reduce dependence on DG.

8.6. Appendix F: States and their solar potential

***Table A9**: States and their solar potential*

S.N.	Name of States/ UTs	Solar Potential (MWp)	S.N.	Name of States/ UTs	Solar Potential (MWp)
1	Rajasthan	142310	17	Bihar	11200
2	Jammu & Kashmir	111050	18	Manipur	10630
3	Maharashtra	64320	19	Mizoram	9090
4	Madhya Pradesh	61660	20	Arunachal Pradesh	8650
5	Andhra Pradesh	38440	21	Nagaland	7290
6	Gujarat	35770	22	West Bengal	6260
7	Himachal Pradesh	33840	23	Kerala	6110
8	Odisha	25780	24	Meghalaya	5860
9	Karnataka	24700	25	Sikkim	4940
10	Uttar Pradesh	22830	26	Haryana	4560
11	Telangana	20410	27	Punjab	2810
12	Chhattisgarh	18270	28	Tripura	2080
13	Jharkhand	18180	29	Delhi	2050
14	Tamil Nadu	17670	30	Goa	880
15	Uttarakhand	16800	31	Others (UTs)	790
16	Assam	13760			

8.7. Appendix G: PNG infrastructure

***Table A10**: Details of state-wise PNG infrastructure*

State	Total No. of Districts	No. of Districts with a City Gas Distribution Network
Andhra Pradesh	26	13
Arunachal Pradesh	27	27
Assam	35	35
Bihar	38	38
Chhattisgarh	33	27
Goa	2	2
Gujarat	34	30
Haryana	22	22
Himachal Pradesh	12	12
Jharkhand	24	24
Karnataka	31	31

State	Total No. of Districts	No. of Districts with a City Gas Distribution Network
Kerela	14	14
Madhya Pradesh	55	55
Maharashtra	36	36
Manipur	16	16
Meghalaya	12	12
Mizoram	11	5
Nagaland	17	17
Odisha	30	30
Punjab	23	22
Rajasthan	41	33
Sikkim	6	6
Tamil Nadu	38	34
Telangana	33	31
Tripura	8	8
Uttar Pradesh	75	75
Uttarakhand	13	13
West Bengal	23	22
Union Territories		
Andaman & Nicobar	3	0
Chandigarh	1	1
Dadar & Nagar Haveli and Daman & Diu	3	3
Jammu & Kashmir	20	20
Ladakh	2	2
Lakshadweep	1	0
Delhi	11	11
Puducherry	4	4
Total	780	731

Source: PNGRB State & Entity wise list of geographical areas

8.8. Appendix H: State-wise DG set regulations

***Table A11**: State-wise regulations for diesel generator (DG) sets*

State	Salient points from the Circular/Order
Andhra Pradesh APPCB notification dated 05.11.2020 (Andhra Pradesh Pollution Control Board, 2020)	Retrofitting of ECDs in DGs of 125 kVA and above capacity / Shift to Gas Generators / retrofit existing DG set for partial gas usage.
Goa GSPCB circular dated 06.01.2021 (Goa State Pollution Control Board, 2021)	Retrofitting of ECDs in DGs of 125 kVA and above capacity / Shift to Gas Generators / retrofit existing DG set for partial gas usage.
Gujarat GPCB circular dated 26.10.2023 (Gujarat Pollution Control Board, 2023)	Retrofitting of ECDs in DGs of 125 kVA and above capacity / Shift to Gas Generators / retrofit existing DG set for partial gas usage.
Haryana HSPCB order dated 23.06.2020 to be read with order dated 28.09.2020 (Haryana State Pollution Control Board, 2020)	All DG sets of capacity 500 kVA and above, either to retrofit with ECDs or shift to gas-based generators, or retrofit existing DG for partial gas usage in the 5 NCR districts, Faridabad, Gurugram, Bahadurgarh, Sonipat and Panipat.
CAQM Direction No. 76 dated 29.09.2023, read with the amendment dated 11.12.2024 for the NCR districts of Haryana	No restriction in NCR even during the Graded Response Action Plan (GRAP) period on the following: • new complying DG sets (CPCB IV+) and gas-based Generators. • Retrofitted existing DG sets for partial gas usage and ECDs for capacities between 41 kW and 800 kW. • Retrofitted existing DG sets for partial gas usage for capacities 19-61kW.
Karnataka Karnataka State PCB order dated 25.05.2023 (Karnataka State Pollution Control Board, 2023)	All DG sets of capacity 125 kVA and up to 800 kW (1,000 kVA) to be retrofitted with ECDs Or Shift to gas-based generators Retrofit existing DG sets for partial gas usage
Kerela KSPCB order 28.09.2024 (Kerala State Pollution Control Board, 2024)	No requirement of RECDs for Gensets complying with revised MoEFCC emission norms issued vide G.S.R. 804 E dated 03.11.2022 for DG set. DG sets older by 5 years and more are to be retrofitted with RECD as per CPCB RECD norms.
Madhya Pradesh MPPCB order dated 06.01.2025 (Madhya Pradesh State Pollution Control Board, 2025)	Retrofitting of ECDs in DGs of 125 kVA – 1000 kVA capacity. Shift to Gas Generators.
Maharashtra MPCB order dated 02.06.2023 (Maharashtra Pollution Control Board, 2023)	Retrofit DG sets manufactured/imported after 2004 and complying with CPCB stage I and II emission norms of 2002 and 2013 (amended in 2014) with RECDs with a minimum 70% PM capture efficiency. Or shift to new gas-based generators/retrofit for partial gas usage.

State	Salient points from the Circular/Order
Odisha OSPCB order dated 14.11.2023 (Odisha State Pollution Control Board, 2024)	DG manufactured/installed before 01.07.2004 or not complying with Stage-I and/or Stage-II emission limits are to be scrapped. Retrofit DG sets manufactured/imported after 2004 and complying with CPCB stage I and II emission norms of 2002 and 2013 (amended in 2014) with RECDs with a minimum 70% PM capture efficiency. Or shift to new gas-based generators/retrofit for partial gas usage.
Tamil Nadu TNPCB notification dated 30.07.2024 (Tamil Nadu Pollution Control Board, 2024)	Retrofit DG sets of capacity 61–800 kW, older than 5 years from the date of manufacturing and up to its lifetime (i.e. 15 years from manufacturing or 50,000 operational hours, whichever is earlier). Or shift to gas-based generators or dual fuel gensets up to 800 KW up to useful life. Or Shift to new DGs strictly complying Emission norms as per MoEFCC GSR 804 E dated 03.11.2022.
Jammu & Kashmir J&K Pollution Control Committee order dated 18.10.2024 (Jammu and Kashmir Pollution Control Committee, 2024)	DG manufactured/installed before 01.07.2004 or not complying with Stage-I and/or Stage-II emission limits are to be scrapped. Retrofit DG sets of capacity 61kW to 800 kW, older than 5 years from the date of manufacturing and up to its lifetime (i.e., 15 years from manufacturing or 50,000 operational hours, whichever is earlier). Or shift to gas-based generators or dual fuel gensets up to 800 KW up to useful life. Or shift to new DGs strictly complying with emission norms as per MoEFCC GSR 804 E dated 03.11.2022.
Puducherry PPCC order dated 04.12.2023 (Government of Puducherry, 2023)	Retrofitting of ECDs in DGs of 125 kVA and above capacity / Shift to Gas Generators / retrofit existing DG set for partial gas usage/ shift to new compliant DG set.
CAQM Direction No. 76 dated 29.09.2023, (Commission for Air Quality Management, 2023), read with the amendment dated 11.12.2024 (Commission for Air Quality Management, 2024) for the National Capital Region, including Delhi	No restriction on running of following Gensets during GRAP: • Generator sets running on LPG/ Natural Gas/Biogas/ Propane/ Butane • New DG sets complying with MoEFCC GSR 804(E) dated 03.11.2022 • Retrofitted existing DG sets for partial gas usage and ECDs for capacities between 41Kw to 800 kW. • Retrofitted existing DG sets for partial gas usage for capacities 19-61 kW. • Restriction on the operation of existing portable older DG sets (below 19 kW) with no pollution control devices during the GRAP period.

8.9. Appendix I: Findings from stakeholder consultation

This section summarises the key insights from our stakeholder consultation and captures the important topics covered during the consultation, along with the path forward. In line with Chatham House Rules, the insights and takeaways included here are not attributed to any individual participant.

Summary:

Sl. No.	Proposed control measures	Review by the stakeholders
1	Installation of retrofitted emission control devices (RECD)	Installation of RECDs or switching to partial or full gas induction is needed to reduce emissions from DG sets by 70%. The cost of the RECDs needs to be reduced for greater acceptance by the end users. The 'type' approval and tuning for the dual fuel kits need to be mandated. At present, these are merely guidelines.
2	Mandatory certification for the CNG kits	A mandatory certification for CNG kits is required for all OEMs by an agency like ICAT or ARAI. Details of certification should include 'type approval', safety features, and data from 100 hours of testing.
3	Prioritising scrapping over banning for the DG sets	Development and phase-wise implementation of a mandatory scrappage policy for DG sets based on lifespan, hours of operation, type of technology, and extent of non-compliance with emission standards, instead of a blanket ban.
5	Switching to cleaner fuels (Solar and CNG)	Solarisation of agriculture through sustained subsidy mechanisms to help shift away from DG sets. Improving financial access and promoting rooftop solar with battery storage offer a cost-effective alternative to diesel generator sets, especially in urban areas. CNG-based generator sets require type approval on an immediate basis.

Key Takeaways: The following were the major takeaways from the stakeholder consultation meeting:

1. Retrofitting and Emission Control:
    - Retrofitting ECDs or switching to partial or full gas induction were identified as key strategies to reduce emissions from DG sets.
    - Several manufacturers have demonstrated their ability to reduce particulate matter (PM) emissions by over 70%, as mandated by regulations, with some achieving up to 73.5% PM reduction.
2. Regulatory Challenges and Testing:
    - The lack of proper post-delivery testing facilities for DG sets often leads to incorrect use of CPCB's Part III standards for static stacks. Accurate testing should follow ISO 8178 Part IV protocols to ensure compliance.

- Many state boards require annual compliance reports, yet there is a gap in ensuring that DG-specific emission standards are fully adhered to by OEMs and end users across various sectors, including industrial and commercial.
- There is a need to emphasise the latest fuel efficiency norms and their implementation on the ground throughout the country, as it has been done in Delhi.

3. Economic Feasibility of Alternatives:

- While retrofitting and using cleaner fuels like CNG or hydrogen are viable options, the economic feasibility remains a concern.
- It was pointed out that in case of power outages, DG sets provide continuous operation. Alternatives like CNG sets, which may not be reliable during outages, could lead to process disruptions and economic losses.
- A mandatory certification for CNG kits is required for all OEMs by ICAT (International Centre for Automotive Technology, Manesar, Haryana) and ARAI (The Automotive Research Association of India, Pune, Maharashtra).
- Despite challenges in agricultural solarisation (3HP solar pump to replace diesel pumps – and gradually increase to 10HP), improving financial incentives and promoting rooftop solar with battery storage offer a cost-effective alternative to diesel generator sets, especially in urban areas. However, solar energy alone cannot meet peak power demands effectively.

4. Policy and Compliance Gaps:

- A structured policy approach is needed, which mandates the retirement (scrappage) of DG sets after they exceed their operational lifespan of 15 years/ 50,000 hours of operation; thus, allowing for their replacement with more efficient models.
- Ensuring proper regulatory oversight and performance testing of retrofitted systems is essential for effective implementation.

5. Data and Research Requirements:

- Real-time data collection and development of an emissions inventory for DG sets could improve policy decisions; however, it's essential to consider stage-wise categories before and after the implementation of CPCB II (2014) and CPCB IV+ (2023) to assess reductions effectively.
- Future recommendations must consider the feasibility, cost-effectiveness, and user acceptance of the proposed technologies.
- A greater focus is needed to enhance research and development (R&D) activities, exploring retrofit options for DG sets. Consider pilot programs or funded projects to explore advanced retrofitting solutions, with a focus on affordable technologies that can be scaled and adopted widely.
- Free flow and access to DG set data are crucial to best understand and utilise opportunities related to particulate matter and BC mitigation. Currently, such data are unavailable.

6. Other issues

    - Regulations for Residential and Commercial Sectors: It is important to have policies and regulations in place that account for the emissions from residential, small commercial sectors, and other users.
    - Engagement and Education for End Users: Develop awareness programs and technical guidance for end users, helping them understand the importance of retrofitting, compliant fuel usage, and regulatory requirements. At present, DG sets are not considered a major source of pollution in the mainstream discourse.
    - Establishing a Sector-wise Emissions Inventory: Building a comprehensive, real-time inventory of DG set emissions across sectors (industrial, residential, commercial, agricultural) can provide valuable insights and allow targeted regulatory measures. This will help tailor policies and assess the progress of emissions reduction over time.

List of attendees:

1. Dr Prasanna Bhat, ARAI
2. Prof Gufran Beig, NIAS
3. Dr Sushil Kumar Tyagi, CPCB
4. Mr Manoj V More, ARAI
5. Dr Nitin Labhasetwar, NEERI
6. Mr Neelkanth Marathe, ECMA
7. Mr Saptak Ghosh, CSTEP
8. Mr Tushar Batham, Chakr Innovation
9. Mr Vikram Bisht, Chakr Innovation

CSTEP

Center for Study of Science, Technology & Policy

Bengaluru
#18, 10th Cross, Mayura Street, Papanna Layout,
Nagashettyhalli (RMV II Stage),
Bengaluru – 560094, Karnataka, India

Noida
1st Floor, Tower-A, Smartworks
Corporate Park, Sector-125,
Noida-201303, Uttar Pradesh,
India

www.cstep.in
+91-8066902500
cpe@cstep.in
@cstep_India