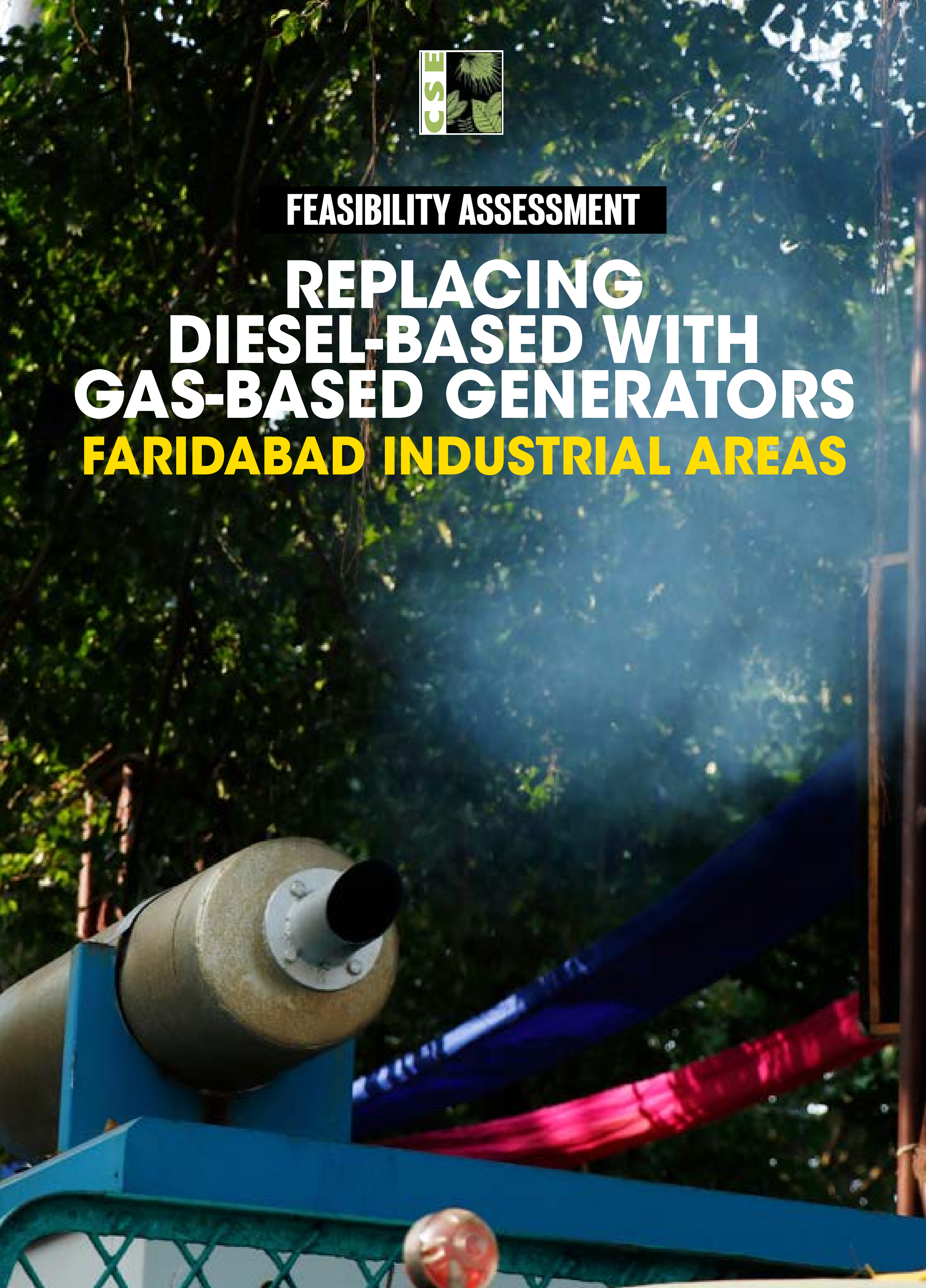
CSE

FEASIBILITY ASSESSMENT

REPLACING DIESEL-BASED WITH GAS-BASED GENERATORS

FARIDABAD INDUSTRIAL AREAS



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This report has been supported by Bloomberg Philanthropies and Shakti Sustainable Energy Foundation.

Citation: Ishita Garg 2021, *Replacing Diesel-Based with Gas-Based Generators: Faridabad Industrial Areas*, Centre for Science and Environment , New Delhi

Published by
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Contents

1. Background

Centre for Science and Environment (CSE) recently published a report titled *Assessment of Industrial Air Pollution in Delhi-NCR*. The report surveyed seven districts surrounding the national capital—namely Alwar, Bhiwadi, Gurugram, Sonipat, Panipat, Faridabad and Ghaziabad—and assessed the sources from industrial areas that contributed to the overall air pollution of the area. The presence of large numbers of diesel generator (DG) sets in industrial areas stood out.

Diesel generator sets are used in industry as a source of backup in case of power cuts. As the name suggests, these gensets use diesel as fuel. On burning, diesel emits oxides of nitrogen, carbon monoxide and particulate matter, which are major contributors to air pollution. According to a study, a standard DG set of 250 kVA capacity running at an average of three hours per day emits 0.183 kg/day of PM 10, 3.08 kg/day of NOx and 1.50 kg/day of CO.[1]

According to media reports, Faridabad was ranked as the second most polluted city in the world by a 2018 WHO report.[2] Of the areas assessed in CSE's report, Faridabad's industrial areas use the highest number of diesel-based gensets. The widespread use of DG sets can be considered a major contributor to the city's pollution.

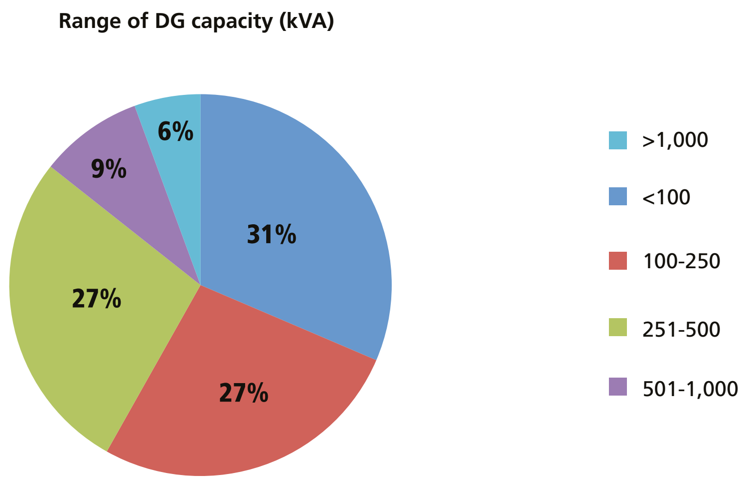
This report explores an alternative to the use of diesel gensets in Faridabad industrial areas and assesses the feasibility of replacing the standard DG by natural gas gensets (NG-GS). It takes into account technological, economic and environmental aspects of converting the DGs currently in use to NG-GS.

Status of DG sets in Faridabad

Faridabad has two industrial clusters, Faridabad and Ballabgarh. These clusters together house approximately 950 air-polluting industries, the largest number among the seven districts surveyed by CSE. The industries in the area use coal, agro, liquid fuel and biomass as fuel, mainly in boilers for steam generation or thermo pack for heating. However, according to data provided by HSPCB, a large number of industries—approximately 780—also use liquid fuel in DG sets installed in their premises. Over 1,000 DG sets of varying capacity ranging from as small as 10 kVA to as high as even 8,000 kVA are installed in these industries (see *Figure 1: Range of DG capacity in industrial areas of Faridabad*).

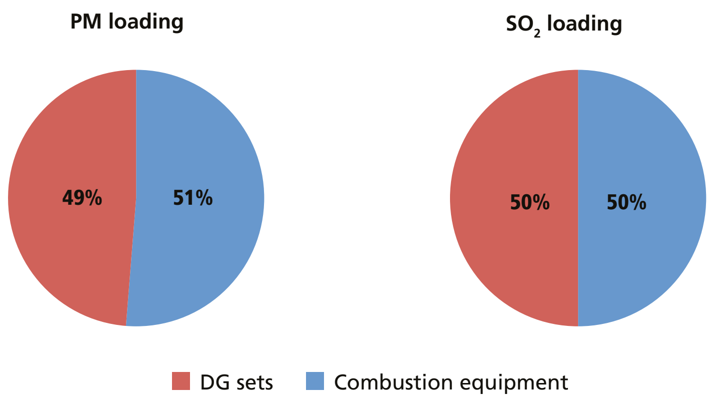
These DG sets together consume around 1.41 lakh tonnes of diesel annually, which is about 60–70 per cent of the total annual consumption of liquid fuel by industries in the region. This extensive use of DG fuel results in a high degree of pollution in the area. A rough estimate indicates that the annual contribution of DG sets in the overall pollution load of Faridabad is almost 50 per cent for both PM and SO_2, assuming daily operation of DG sets for four hours (see *Figure 2: Pollution loading from DG sets [four hours of operation]*).

Figure 1: Range of DG capacity in industrial areas of Faridabad



Source: CSE

Figure 2: Pollution loading from DG sets (four hours of operation)



Source: CSE

DG sets have several drawbacks. Their operation generates high noise levels, contributing to noise pollution. In addition, the operating cost of DG sets fluctuates with diesel prices, making it financially unstable. Also, diesel fuel needs to be procured and stored in bulk, which necessitates additional storage area in industries.

But the most deleterious effect of the use of DG sets is high emissions of PM, NO_X, unburned hydrocarbons and other toxic pollutants that along with causing air pollution have negative impacts on human health.

In view of the pollution scenario in Delhi-NCR—and to reduce the impacts—a major objective of the government is to adopt cleaner fuel. This study aligns with this objective and assesses an alternative to diesel-based gensets.

Gas-based DG sets—an alternative

A natural-gas generator works similarly to diesel generators, the only difference being the fuel used to power the units. Natural gas can be used to power both emergency and portable generators and is regarded as one of the most affordable and effective fuels among non-renewable resources for power generation.

The general impression is that diesel engines are cost-effective and energy-efficient while natural gas engines are more environmentally friendly. However, in the current scenario the price of diesel is far more than that of natural gas, which makes the operational cost of a diesel genset higher than its gas counterpart.

In terms of providing high power, response and longevity, diesel is no longer a clear winner in terms of power and response. Spark-ignited (natural gas) industrial engines are available that can optimize the RPM of these engines to make the transient response similar to that of diesel. Natural gas units that can meet the 10-second startup requirement for backup systems are also being produced—these have traditionally been associated only with diesel engines.

Advantages of gas-based gensets:

- Operating cost is 45–50 per cent lower than for diesel-powered generators;
- Natural gas is generally cheaper than liquid fuels like light diesel oil (LDO) and diesel;
- Zero emission of harmful particulate matter and smoke;
- 35–40 per cent less emission of pollutants such as NOx and CO_2;
- No scaling or sooting takes place in use of natural gas and hence maintenance cost is less than that of other fuels;
- Piped natural gas (PNG) does not require any storage tank or storage space since it is supplied through pipelines;
- Noise level generated is 4 dbA lower than noise generated by a conventional genset; and
- Natural gas does not produce a pungent odour, which is fairly common in generators powered by diesel.

Feasibility assessment

a. Technical aspects

Specific fuel consumption: Fuel efficiency is a metric of expressing the efficiency performance of a generator set. Specific fuel consumption (SFC) expressed in litre/hour or gram/kWh is an indication of the quantity of fuel required to generate one unit of electricity. This parameter is of direct relevance as it relates to the operating costs of generating electricity from generator sets.

The SFC of natural gas is 34 standard cubic metres (SCM)/hour (0.026 tonnes/hour) while that of diesel is 28 litres/hour (0.024 tonnes/hour). Although the SFC of natural gas is slightly higher, the difference in market cost of diesel (Rs 80) and natural gas (Rs 35) completely eclipses this factor as the overall operational cost of NG-GS is much lower than that of diesel gensets.

b. Economic aspects

The one-time cost of setting up a diesel generator is less than that of a natural gas generator. As previously discussed, however, due to the low operational costs, natural-gas-based gensets are more economical than their diesel counterparts.

A 100 kW gas generator costs about Rs 12 lakh as compared to Rs 6.5 lakh for a diesel set. A comparative analysis of the operational cost, however, indicates that the additional cost incurred in purchasing a gas generator can be recovered in about four months (assuming that the genset is used for four hours of power backup and given the fact that gas is cheaper than diesel) (see *Table 1: Estimated cost for diesel gensets and natural gas gensets for 100 kW rating*).

Table 1: Estimated cost for diesel and natural gas gensets for 100 kW rating

Particular	Diesel genset	Natural gas genset
Genset cost (Rs)	6.5 lakh	12 lakh
Daily hours of operation (assumption)	4	4
Units generated (kWH)	400	400
Diesel cost/PNG cost (Rs)	80	35
Fuel consumption at 100% load (litres/hour)	28	34 (SCM/hour)
Total cost of fuel (Rs/hour)	2,240	1,190
Per unit cost	22.40	11.90
Daily cost for four hours running (Rs)	8960	4200
Monthly cost (Rs)	2,68,800	1,26,000
Monthly cost saved (Rs)		1,42,800
Cost saved in four months	Rs 5,71,200	

Source: Technical details provided by Mahindra Powerol, analysis by CSE.

c. Environmental aspects

The operation of diesel generators emits high amounts of oxides of nitrogen (NOx), sulphur dioxide (SO_2) and soot particles (particulate matter or PM) and also contributes to CO_2 emissions. The use of NG-GS results in considerable reduction of NOx and CO_2 emissions while almost eliminating PM and SOx emissions.

Reduction in pollution loading

The pollution loading from operating gensets has been calculated for three scenarios: theoretical DG fuel consumption, theoretical NG-GS fuel consumption and the actual fuel consumption in diesel generators in the Faridabad region (data provided by HSPCB). The theoretical fuel consumption for both diesel and natural gas is calculated in tonnes/annum, assuming four hours of daily operation. The loading is calculated for PM, SO_2, NOx and CO_2 emissions in tonnes/annum for different capacity of gensets (see *Table 2: Pollution loading from generators—comparative analysis*).

The percentage reduction in pollution loading by replacing existing diesel generators with NG-GS works out to **100 per cent for PM and SO_2 while it is 43 per cent and 34 per cent for NOx and CO_2** respectively.

Table 2: Pollution loading from generators—comparative analysis[3, 4]

Capacity	Fuel consumption	PM (T/A)	SO_2 (T/A)	NO_X (T/A)	CO_2 (T/A)	Reduction in NO_X (%)	Reduction in CO_2 (%)
20 kW	Diesel (theoretical)	0.11	0.18	1.49	55.45	–	–
	NG (theoretical)	ND	ND	1.0	44.8	37	27
	Diesel (actual)	0.12	0.20	1.66	61.53	–	–
100 kW	Diesel (theoretical)	0.5	0.8	6.9	256.5	–	–
	NG (theoretical)	ND	ND	4.7	202.9	43	34
	Diesel (actual)	0.59	0.99	8.30	307.81	–	–
150 kW	Diesel (theoretical)	0.7	1.2	10.2	377.8	–	–
	NG (theoretical)	ND	ND	7.0	301.8	43	34
	Diesel (actual)	0.88	1.48	12.42	460.65	–	–
200 kW	Diesel (theoretical)	1.0	1.6	13.5	499.1	–	–
	NG (theoretical)	ND	ND	9.3	400.7	44	35
	Diesel (actual)	1.2	2.0	16.6	615.3	–	–
250 kW	Diesel (theoretical)	1.2	2.0	16.8	623.9	–	–
	NG (theoretical)	ND	ND	11.6	499.5	44	35
	Diesel (actual)	1.5	2.5	20.8	773.2	–	–
300 kW	Diesel (theoretical)	1.4	2.4	20.1	745.2	–	–
	NG (theoretical)	ND	ND	13.9	598.3	44	35
	Diesel (actual)	1.8	3.0	24.8	921.3	–	–
350 kW	Diesel (theoretical)	1.7	2.8	23.5	869.9	–	–
	NG (theoretical)	ND	ND	16.3	697.2	44	36
	Diesel (actual)	2.1	3.5	29.3	1,085.8	–	–
400 kW	Diesel (theoretical)	1.9	3.2	26.7	991.3	–	–
	NG (theoretical)	ND	ND	18.6	796.0	44	35
	Diesel (actual)	2.4	4.0	33.3	1,233.9	–	–
500 kW	Diesel (theoretical)	2.4	4.0	33.4	1,237.3	–	–
	NG (theoretical)	ND	ND	23.2	993.8	44	35
	Diesel (actual)	2.9	4.9	41.5	1,538.2	–	–
750 kW	Diesel (theoretical)	3.5	5.9	49.9	1,850.8	–	–
	NG (theoretical)	ND	ND	34.7	1,488.0	43	34
	Diesel (actual)	4.34	7.28	61.20	2,270.34	–	–
1,000 kW	Diesel (theoretical)	5	8	66	2,464	–	–
	NG (theoretical)	ND	ND	46	1,982	44	36
	Diesel (actual)	5.89	9.871488	82.9312	3,076.48	–	–

* Percentage reduction for NO_X and CO_2 is calculated between diesel (actual) and NG (theoretical)
Source: CSE.

STANDARDS AND NORMS FOR EMISSIONS FROM DIESEL GENERATORS IN INDIA[5]

The Central Pollution Control Board (CPCB) has been regulating emissions from diesel generators at the manufacturing stage (through product certification) since 2005. The emission norms in India cover CO, NOx, PM, and HC and are specified based on the number of grams of these compounds present in diesel exhaust when one kilowatt-hour of electricity is generated. These norms were revised in December 2013 (G.S.R. 771 (E)/11 December 2013 notification) and have been enacted from April 2014 (CPCB II) (see *Table 3: CPCB's revised emission norms for diesel engines*).

Table 3: CPCB's revised emission norms for diesel engines

Capacity of diesel engines	Old emission limits (g/kWh)				Capacity of diesel engines	Revised emission limits with effect from April 2014 (g/kWh)		
	NOx	HC	CO	PM		NOx + 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
>19 kW up to and 176 kW	9.2	1.3	3.5	0.3	> 19 kW and up to 75 kW	<=4.7	<=3.5	<=0.3
>176 kW and up to 800 kW	9.2	1.3	3.5	0.3	> 75 kW and up to 800 kW	<=4.0	<=3.5	<=0.2

The revised norms have a combined cap on NOx and HC that is in line with the practice followed in USA and Europe. At the time of monitoring and verification, the two pollutants are measured separately and then added to check compliance to the norms. CPCB had also notified emission limits for diesel generators greater than 800 kW in 2002. Discussion with stakeholders revealed that diesel generator sets of size 800 kW and above are generally regulated by the State Pollution Control Boards or Pollution Control Committees at the site of installation.

With revised norms in place, India's emission standard for diesel generators has moved closer to world benchmarks (see *Table 4: Emission norms for diesel gensets in different countries*). It is important to note that quality of diesel (in terms of sulphur content in ppm) is an important consideration during setting of emission norms for diesel engines.

Table 4: Emission norms for diesel gensets in different countries

Emission norms	Sulphur content in diesel (ppm)
India CPCB II (April 2014 onwards)	350/50
India CPCB I (2004–13)	500/350
Japan Tier III (2011–13)	50
Japan Tier IV (2014–16)	10
Europe Stage IIIA (current for 18–36 kW)	50
Europe Stage IIIB (current for 37–129 kW)	10
Europe Stage IV (current for 130–560 kW)	10
US EPA-Tier 4 (2008–14)	15

DEVELOPMENT IN THE FIELD OF NATURAL GAS GENERATORS

Indraprastha Gas Ltd aims to replace diesel generators by gas generators—which it has pitched as a cheaper and an environment-friendly option—in housing complexes and factories in the National Capital Region. The company is about to launch its services in Rewari and aims to supply 1 lakh cubic metres per day to the factories of the region. The company also plans to install gas-based generators in two or three housing complexes in Indirapuram on the outskirts of Delhi, which will serve as a model for other areas.[6]

Mahindra Powerol launched India's first CPCB-II-approved gas genset of 125 kVA capacity in Delhi on 11 April 2018. As per the claims by the company, this gas-based genset will reduce the operating cost by 45 per cent as compared to diesel gensets.[7]

Table 5: Overall comparison between diesel and natural gas gensets

Parameter	Diesel genset	Natural gas genset
Purchase cost	Low	High
Fuel price	High	Low
Fuel supply	Intermittent (storage required)	Continuous
O&M cost	High	Low
Noise generation	High	Low
PM and smoke emissions	High	Nil
NOx and CO_2 emissions	High	Low

Source: CSE.

CASE STUDY

To strengthen the findings of this research, CSE's team visited an industrial facility that had shifted its operation from a diesel to a gas generator. The objective of the visit was to understand and document the experience of using a gas generator and compare it with that of using a diesel generator.

The team visited Hamdard Laboratories based in Okhla, Delhi. This industry previously used a 100 kVA diesel generator which they replaced by a 125 kVA gas generator. The cost of their new gas-based generator was in the range of Rs 10–11 lakh while the diesel generator of a similar capacity cost Rs 7–8 lakh. Although the initial cost of a gas-based genset was higher than that of its diesel counterpart, there are advantages in the long run.

Industries consuming less than 500 standard cubic metres (SCM) per day and switching to gas as fuel in the state of Delhi receive a one-time subsidy of Rs 50,000; industries consuming more than 500 SCM per day get a one-time subsidy of Rs 1 lakh.

Natural gas generator installed at Hamdard Laboratories

The Hamdard factory received an initial subsidy of Rs 50,000. The annual maintenance cost of their gas genset is approximately Rs 15,000 while for their older diesel generator the annual maintenance cost was around Rs 30,000. This indicates the low requirement and cost of maintenance for gas gensets. Fuel-cost economics based on data shared by the industry shows that the fuel for diesel gensets costs around Rs 12.6 kVA/hour while the cost of fuel of a gas genset is around Rs 6.06 kVA/hour. This shows that although gas gensets need more initial investment, the price of fuel for operating them is almost 50 per cent less than that of diesel-based gensets. Also, the use of gas gensets forestalls regulatory actions and penalties on industries (see *Table 6: Comparison between gas and diesel gensets by an industry*).

Table 6: Comparison between gas and diesel gensets by an industry

S. no.	Aspect	Diesel genset	Gas genset
1.	Initial cost (Rs)	7 lakhs	10–11 lakhs
2.	Maintenance cost (Rs/year)	15,000	30,000
3.	Regulatory measures	Subjected to them from time to time	No regulatory measures shall be possible
4.	Fuel cost (Rs/kVA)	12.6	6.06
5.	Subsidy	No subsidy	Subsidy in Delhi
6.	Noise	Very high	Negligible

Source: CSE

2. Proposed model for Faridabad

Faridabad's industrial areas face frequent power cuts due to which use of diesel generator sets in industries as a source of power back up is common. These industrial areas comprise approximately 1,200 DG sets of total capacity of 378 MW and consume around 1.41 lakh tonnes of fuel annually. Their contribution in the overall pollution load is significantly high, in the range of 15–50 per cent, depending on the hours of operation (see *Table 7: Estimated pollution load from gensets, combustion equipment and overall loading in Faridabad*).

Table 7: Estimated pollution load from gensets, combustion equipment and overall loading in Faridabad

Parameters	Loading from combustion equipment (tonnes/ annum)	Loading from DG sets (tonnes/ annum)	Total (tonnes/ annum)	Contribution of DG sets (%)
DG operation: four hours				
PM	2,344	2,228	4,572	49
SO_2	3,156	3,736	6,893	54
DG operation: two hours				
PM	2,685	1,114	3,799	29
SO_2	5,704	1,868	7,572	25
DG operation: one hour				
PM	2,856	557	3,413	16
SO_2	6,978	934	7,912	12%

Source: CSE

The following section discusses a proposal for replacing DG sets with natural gas gensets to combat the issue of pollution in Faridabad industrial areas.

Availability of infrastructure for gas pipeline

Adani Gas Ltd is a prime supplier of natural gas in Faridabad industrial areas and for laying down the pipeline network in the area. As per data provided by Adani Ltd, Adani has a well laid out pipeline infrastructure for natural gas supply in nine out of a total of thirteen areas industrial areas in Faridabad (see *Table 8: Distribution of gas line infrastructure in different industrial areas of Faridabad*). This implies that these nine areas can immediately switch to natural gas gensets. Areas that do not have a gas pipeline can switch to NG-GS in a phased manner.

Table 8: Distribution of gas line infrastructure in different industrial areas of Faridabad

Industrial areas of Faridabad	Availability of gas pipeline
DLF Industrial Area	Yes
Sector 27 (A, B, C, D)	No
Sector 4	Yes
Sector 6	Yes
Sector 24	Yes
Sector 25	Yes
Sector 58	Yes
Sector 59	Yes
IMT	Yes
NIT	Yes

Source: Adani Ltd

Reduction in pollution load

The economic feasibility of natural gas gensets (NG-GS) has been discussed in the previous section from the point of view of industries. With regard to pollutant emissions, Faridabad industrial areas will be able to reduce overall NOx and CO_2 loading by 37 and 27 per cent respectively while PM and SOx loading will be nil with a 100 per cent switch to NG-GSs (see *Table 9: Percentage reduction in pollution loading by converting from DGs to NG-GSs in Faridabad industrial areas*).

Table 9: Percentage reduction in pollution loading by converting from DGs to NG-GSs in Faridabad industrial areas

	Total DG capacity (MW)	Fuel consumption (tonnes/ annum)	PM loading (tonnes/ annum)	SO_2 loading (tonnes/ annum)	NOx loading (tonnes/ annum)	CO_2 loading (tonnes/ annum)
Diesel gensets	378	1.41 lakh	2,227.56	3,736.23	31,388	1,164,406
Natural gas gensets		1.53 lakh	0	0	19,773	848,052
Percentage reduction		–	100	100	37	27

Source: CSE

Conclusion

Replacing the use of diesel generators with natural gas generators shows substantial reduction in emission of pollutants, thereby improving the environment along with monetary benefits to users—a win-win situation.

The following steps are needed to replace existing DG sets with gas generators:

- **Policy roadmap for power in Faridabad:** Use of a large number of generators in the industrial areas of Faridabad points to the inadequacy of power supply in the region. To discourage use of generators as power backup, improvement of power supply in the region must be the prime focus. The policy for the city should be either continuous electricity supply or use of gas generators. Use of diesel-based gensets should be strictly prohibited.

- **Transition to gas gensets:** For new installations, only natural gas generators must be allowed. Existing generators should be converted into gas-based ones within one year.

- **Ensure uninterrupted supply of gas**: Many areas that have gas pipelines often face issues with non-continuity of supply. Continuous supply of gas must be be ensured as an interrupted supply could act as an argument for continued use of diesel generators.

- **Handholding support:** Regulators should inventorize DG sets installed in each industrial region and provide handholding for the switchover. More stakeholder interaction is required to understand the cost economics and benefits of installing natural gas gensets.

- **Monitoring for compliance:** Random monitoring of DG set needs to be conducted to ensure compliance.

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A 2018 WHO report ranks Faridabad as the second most polluted city in the world. To assess the sources of industrial air pollution, CSE surveyed seven districts in Delhi-NCR. The study revealed that diesel generators contributed significantly to air pollution in the studied regions. Faridabad had the highest number of DG sets among the districts surveyed.

This report assess the feasibility of converting existing diesel generators to natural gas generators, with technical, economic and environmental aspects taken into account. The analysis shows that a shift to natural gas generators will result not only in significant reduction in air pollution but will also prove to be cost-effective for users.

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