Diesel Generators: Improving Efficiency and Emission Performance in India

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ABOUT SHAKTI SUSTAINABLE ENERGY FOUNDATION

Shakti Sustainable Energy Foundation works to strengthen the energy security of the country by aiding the design and implementation of policies that encourage energy efficiency as well as renewable energy.

ACKNOWLEDGEMENT

ICF International places on record its sincere gratitude to Shakti Sustainable Energy Foundation for providing the opportunity to undertake an assessment of the existing regulatory framework of efficiency and emission standards for Diesel Generators in India, and globally, and identify gaps, barriers, opportunities and potential areas of intervention in this sector.

ICF expresses its gratitude to Mr. Kunal Sharma and Ms. Sriya Mohanti, from Shakti Sustainable Energy Foundation, for articulating their expectations from the study and providing their assistance and guidance during different stages of study.

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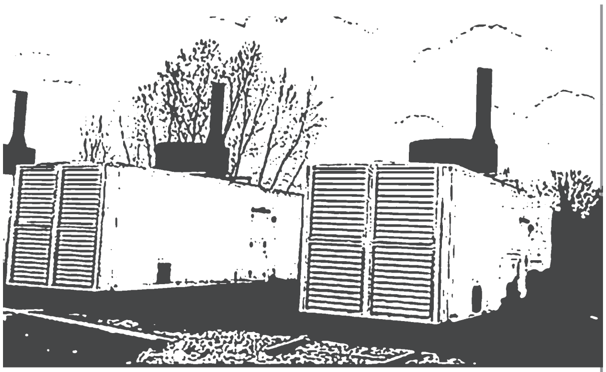


INTRODUCTION

While India's power sector struggles to provide extensive, uninterrupted and reliable grid supply, diesel generator sets assume great importance as preferred power back-up in prominent sectors like agriculture, construction, industry, households, and other commercial applications. Easy to install and operate, low space requirements and easy availability in the market make diesel generator set a preferred choice even when diesel is more expensive on a per-kilowatt-hour basis.[1]

A market review conducted in 2010 by Frost & Sullivan on Indian diesel generator sets shows that the overall annual market in terms of number of diesel generators sold was about 0.15 million in 2010.[2] This research has also indicated that the sector is likely to grow at a rate of 7.2% annually. ICF's analysis shows that at this projected growth rate, about 0.22 million number of diesel generator sets having combined generation capacity of about 17,000 MW[3] would be sold in 2015, which is likely to swell the demand for diesel further. This estimate of total sales of diesel generator sets in 2015 aligns with a study done by Petroleum Conservation Research Agency (PCRA) which reports an annual market size of roughly 0.2 million number of diesel generators in 2012.[4]

Different sizes of diesel generator sets ranging between 2 kVA[5] to 7,000 kVA are used in the country; 15 kVA to 2,000 kVA being the most commonly used. Usage of diesel generator sets of upto 75 kVA is more widespread (more than 95%). The diesel generator sets market in India has both organized (large reputed domestic brands and international brands), and unorganized (small local) manufacturers. Discussion with stakeholders suggests that 30-40% of the total market is unorganized. The presence of unorganized small-scale manufacturers is higher in case of diesel generator sets up to 25 kVA category apparently due to the use of simple technology which is easier to manufacture.

As per Ministry of Petroleum and Natural Gas of India, the country consumed 85.7 billion litres of diesel in the FY 2012-13.[6] Out of the total diesel consumption, 6-8% was consumed for power generation[7] which includes grid-connected diesel based power plants of more than 10 MW, captive diesel based power plants, and diesel generator

[1]World Bank report on "Unleashing the potential of renewable energy in India", 2010
[2]Frost & Sullivan report on "Indian Diesel Generator Set Market, 2010
[3]ICF analysis based on number of diesel generator sold in the market and operating power factor of 0.8
[4]Excerpts of presentation made during Technical committee meeting on S&L scheme for diesel engine driven generator sets held on 18.09.2012
[5]Diesel generator sets are rated in terms of kVA; kVA to kW conversion is done using power factor
[6]PPAC data of 69.175 million metric tonnes consumption in 2012-13 converted to billion liters
[7]Estimates based on Reports of PPAC/ Kirit Parikh Committee and Working Group on Petroleum (WGP)/ SIAM http://www.cseindiaorg/userfiles/diesel_press_conf.pdf

Exhibit 1: Diesel Consumption Breakup By Diesel Generator Size

Size range	Estimated diesel consumption in 2012-13 (billion litre)
upto 19 kW	1.01
19 to 75 kW	0.52
75 to 800 kW	2.98

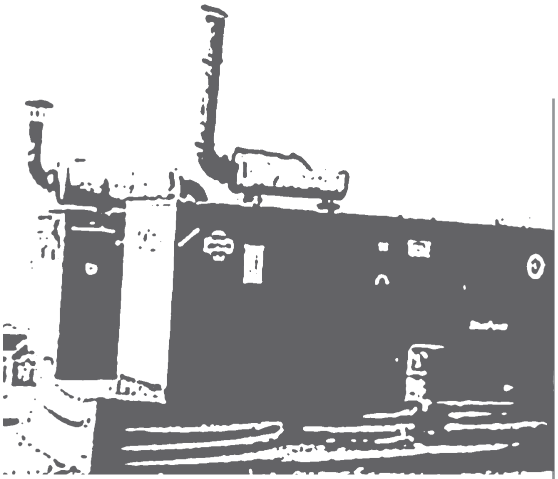
sets. Although there is no official data on diesel consumption by diesel generator sets, ICF estimates that 4.51 billion litres (worth INR 248 billion) of diesel was consumed by diesel generators in the FY 2012-13 (See Exhibit 1 for the diesel consumption breakup by diesel generator size).[8] Hence fuel efficient operation of generator sets is not only desirable but also important.

The concerns of fossil fuel consumption, implications for energy security, and emissions have shaped national policies and actions on diesel generator sets over the years. In order to ensure fuel efficient and less polluting diesel generator sets, Government of India has published regulations governing efficiency of and emissions from diesel generator sets. Some of these regulations are in place for more than a decade. So the effectiveness and adequacy of these regulations should be looked into in the current context of advancements in technology and an ever increasing focus on environmental protection. In this context, Shakti Sustainable Energy Foundation commissioned a study to analyse efficiency and emission norms for diesel generator sets in India and identify potential areas for improvement that can help reduce energy and environmental impacts of this sector.

APPROACH

The study team conducted an in-depth literature review, primary research and analysis to gather background information. Regulators, manufacturers, certification agencies, test laboratories, research organizations, and individual experts were consulted to bring additional insights to the analysis. This paper highlights the key findings of the study. While the limited availability of market data constrained a comprehensive assessment, the information presented in the paper still gives a reasonable assessment of the existing situation. In case of non-availability of data, assumptions were made based on literature review and stakeholder consultations to carry out the analysis.

[8]ICF's estimation based on total number of diesel generator sets, average rated capacity, average operating hours, etc. obtained from secondary sources



EFFICIENCY AND EMISSION PERFORMANCE OF DIESEL GENERATOR SETS

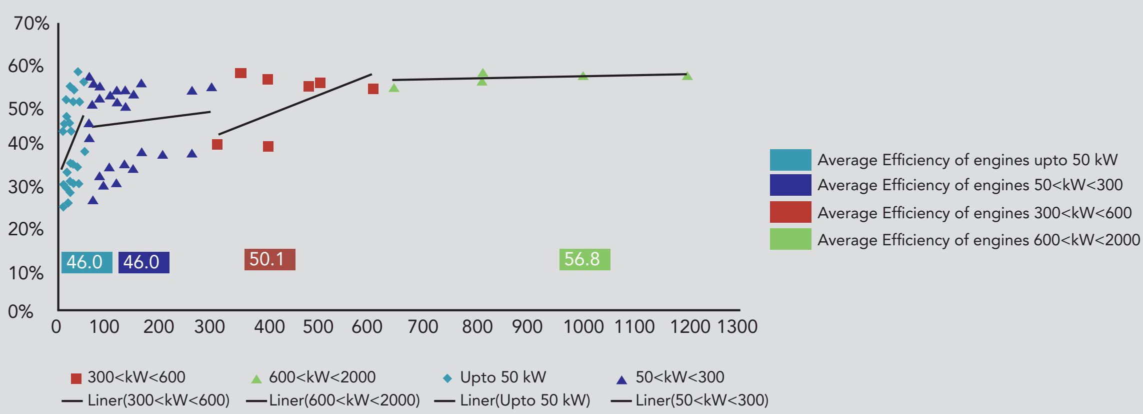
EFFICIENCY

A diesel generator set is a combination of two major components: the engine (the driver) and the alternator[9] (the driven). Thus the efficiency of diesel generator sets is expressed as a combined efficiency of these two sub-components. Typically, the combined efficiency of diesel generator sets varies between 30-55% while stand-alone efficiency of diesel engine and alternator ranges between 35-60% and 85-95% respectively.[10]

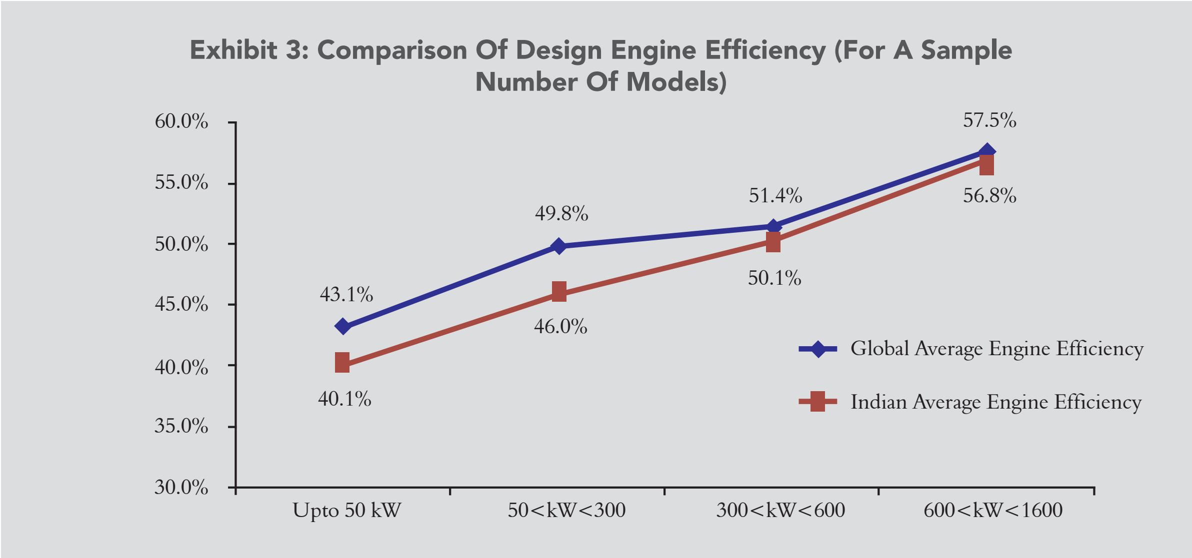
The wide range of engine efficiency is mainly attributed to design, size or capacity, mechanism for fuel control, operating speed, type of cooling mechanism, and material of construction. However, the efficiency during operation deviates from the design value because of load conditions, ambient conditions, and operation and maintenance (O&M) practices.

In order to analyze the efficiency pattern of diesel engines, efficiency information from 82 diesel generator models belonging to five major

Exhibit 2: Estimated Design Engine Efficiency Of 82 Models In India



[9]Function of an alternator or AC generator is to convert the mechanical power produced by the diesel engine into electricity. It is coupled to the shaft of diesel engine.
[10]ICF analysis based on typical fuel consumption of diesel generators available at www.dieselserviceandsupply.com/Diesel_Fuel_Consumption.aspx



manufacturers[11] was analysed as shown in Exhibit 2. Information on efficiency of diesel engines produced by the unorganized sector is unavailable, but it is believed that their efficiency levels are inferior compared to reputed brands.

The analysis shows an increase in engine efficiency with increase in size of the sets (see Exhibit 2). For up to 50 kW (~62.5 kVA [12]) category, efficiency varies between 20% and 60%. This is due to a wide variety of engine types and technologies (such as number of strokes, cylinders, fuel injection system, cooling type) adopted by manufacturers. Variation in efficiency is much lower in larger diesel generator sets (above 300 kW or 375 kVA). This is largely because scope for technology improvements increases with increase in size of the sets. This provides manufacturers with several options for improvement in engine design, engine geometry, and sophisticated fuel control mechanism. On comparing design engine efficiency with globally available diesel generator sets, ICF concludes that indigenously manufactured diesel generator sets have scope for improvement. Analysis of 38 models[13] available outside of India shows the efficiency gap between Indian and global diesel generators (Exhibit 3).

The efficiency patterns with respect to size of the diesel engines in the Indian and global markets are similar, i.e. efficiency increases with size. The global average efficiency levels are comparatively better than that of Indian models, particularly for upto 300 kW (~ 375 kVA) size categories. It is observed that there is a percentage difference of about 7% to 8% in the average design efficiency for up to 300kW size categories between Indian and global diesel engines used in diesel generator sets. As shown in Exhibit 3, the gap between the efficiency levels is smaller in the higher sized engines (600 kW and beyond).

As per discussions with stakeholders, diesel generator sets upto 50 kW are primarily used in sectors like agriculture, households, and small offices, who are more driven by price factor rather than efficiency.

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[11]Data derived from the product catalogues of Cummins, Caterpillar, Kirloskar, Powerica, and Ashok Leyland, available on websites. Typically, the catalogue shows information about the specific fuel consumption (SFC), i.e. litre of diesel consumed per hour if operating at 75% of the rated capacity. Using this information and assuming an alternator efficiency of 90%, design value of diesel engine efficiency was estimated.
[12]Conversion using typical power factor value of 0.8; 1 kW = 1.25 kVA at 0.8 power factor
[13]Data derived from the product catalogues of Cummins, Caterpillar, available on websites (other international manufacturers share information pertaining to only emissions and not fuel consumption). Typically, the catalogue shows information about the specific fuel consumption, i.e. litre of diesel consumed per hour if operating at 75% of the rated capacity. Using this information and assuming an alternator efficiency of 90%, design value of diesel engine efficiency was estimated.

A study conducted by PCRA also reveals that less than 50% consumers consider efficiency as an important parameter while purchasing new diesel generator sets.[14] Therefore it is important to spread awareness among consumers regarding the importance of efficiency and helping them to make informed choice with respect to efficiency. The small size segment (up to 50 kW) needs special attention due to wide variation in efficiency and high presence of unorganized manufacturers.

Fuel efficiency is another metric of expressing the efficiency performance of diesel generator set and it is directly linked to energy efficiency of the diesel generator (combined efficiency of engine and alternator). Specific Fuel Consumption (SFC) expressed in litre/hour or gm/kWh is an indication of the quantity of diesel required to generate one unit of electricity. This parameter is of direct relevance to end users as it relates to the operating costs of generating electricity from diesel generator sets. In order to inform buyers regarding SFC of the diesel generator set, manufacturers often provide information of designed SFC in their catalogue. The variation in SFC is influenced by operational factors such as loading [15], O&M practices, and ambient conditions. Following are the observations on parameters affecting the SFC of diesel generator sets:

- **SFC varies with size:** The SFC becomes better in larger sized sets, specifically over 500 kVA category. For example, a 500 kVA diesel generator at 100% loading has typically 12% better SFC than a 25 kVA set at the same loading. For diesel generators capacity beyond 800 kVA, there is not much variation in SFC with respect to size.

- **SFC varies with load:** SFC is typically optimum at 75-80% loading of the rated capacity. SFC worsens substantially at 25% load or below for all capacity ratings. For instance, a 500 kVA set is observed to have 20% better SFC at 75% than at 25% loading.

Average SFC of analyzed models of Indian and global diesel generator sets is given in Exhibit 4.[16] It can be inferred that improving SFC for diesel generator sets (upto 300 kW) to a level closer to global average (difference of 9%) needs to be the focus.

As per ICF's analysis, each percentage improvement in the engine (design) efficiency results in an improvement of about 2.4% in the SFC. For diesel generator sets up to 50 kW, improving the engine efficiency by 3% (from 40% to 43%) and thereby moving closer to global average will improve the SFC by about 8%.

Exhibit 4: Estimated Average Design SFC of Diesel Generator Sets (Indian Vis-A-Vis Global)

Capacity range	Average SFC (gm/kWh) Indian scenario	Average SFC (gm/kWh) Global scenario
Upto 50 kW	248	216
50<kW<300	216	189
300<kW<600	199	182
600<kW<1600	175	163

[14] Excerpts of Technical committee meeting on S&L scheme for diesel engine driven generator sets held on 18.09.2012
[15] The electrical load applied to diesel generator when compared with rated capacity. For example, a 100 kVA diesel generator is 50% loaded if it is providing electrical output of 50 kVA.
[16] Average SFC calculated by taking average value of the manufacturer's declared fuel consumption data in the given capacity ranges

Exhibit 5: SFC Limits Prescribed Under IS 10001 Applicable For Upto 19 kW

Rated Engine Speed (rev/min)	SFC (max) (gm/kWh)			
	Direct Injection		Indirect Injection	
	Air cooled	Water Cooled	Air cooled	Water Cooled
Upto 1000	272	248	294	268
Above 1000 Upto 2000	276	252	276	252
Above 2000	309	282	309	282

STANDARDS AND NORMS FOR EFFICIENCY OF DIESEL GENERATOR SETS IN INDIA

Bureau of Indian Standards (BIS) is the authorised institution to set quality, safety, and performance standards for equipment and appliances. Vide IS 10001, BIS has notified mandatory maximum energy consumption limit in terms of SFC for diesel generators up to 19 kW capacities as shown in Exhibit 5. As per this notification, it is illegal to manufacture and sell a diesel generator set of upto 19 kW for which SFC exceeds the BIS specified limits.

BIS standard was initially launched for different speed categories of diesel generator sets. In 1999, the standard was amended to distinguish engine types based on Injection (Direct or Indirect) and Cooling (Air or Water) system. For diesel generators between 19 to 500 kW, BIS has prescribed preferred maximum energy consumption limit vide IS 10002 as shown in Exhibit 6. These limits are however not mandatory.

ICF's analysis shows that since 1981 when the standard was first notified, there has been a tightening of SFC limits by up to 29% for certain engine types such as direct injection (upto 19 kW category). For this engine category, discussion with a testing laboratory indicates that currently about 50-60% of the tested models have shown SFC better (12% or more) than the BIS prescribed limits.[17] ICF's analysis shows that for engine size above 19 kW, about 90% of the samples are approximately 10% more efficient than the BIS limit.[18] Since 1999, there has been no revision in BIS norms for SFC, although there is a potential for revision based on the SFC levels achieved by today's generator sets.

Bureau of Energy Efficiency (BEE) was established in 2002 under the provisions of the Energy Conservation Act, 2001. The mission of BEE is to assist in developing policies and strategies with a thrust on self-regulation and market principles, within the overall framework of the Energy Conservation Act, 2001 with the primary objective of reducing energy intensity of the Indian economy. One of the major regulatory functions of BEE includes developing energy performance standards for equipment and appliances and promoting awareness of energy efficient products through star labels. BEE, in association with Petroleum Conservation Research Agency (PCRA), has

Exhibit 6: SFC Limits Prescribed Under IS 10002 Applicable For 19 kW To 500 kW

Rated Engine Speed (rev/min)	SFC (max) (gm/kWh)	
	Direct Injection	Indirect Injection
Upto 1000	276	303
Above 1000 upto 2000	252	277
Above 2000	309	340

[17]Discussion with a NABL accredited laboratory
[18]ICF analysis based on data collected from manufacturers catalogue for diesel generator sets greater than 19 kW

initiated the process to introduce a Star Labeling (S&L) scheme for diesel generator sets. A Technical Committee has been constituted by BEE and PCRA for designing the scheme such as parameter for star labeling, star labeling thresholds, eligibility criteria for participation, testing methodology, and the implementation mechanism of the scheme.

The committee has decided to initially cover diesel generators of up to 200 kVA category and expand the scheme coverage in the subsequent revisions.[19] Similar to BEE's S&L scheme for other products and appliances, for diesel generators too, complying with BIS requirements will be kept as the minimum eligibility criteria for participation in the scheme.[20] For products already covered by BEE under S&L, star labeling is generally introduced under a voluntary labeling scheme. Transition to mandatory labeling occurs a few years later when market shifts towards more efficient products. For diesel generators too, the S&L scheme will be launched most likely as a voluntary scheme. The star labeling thresholds and testing methodology is still under discussion and the scheme is expected to be launched from early 2015. Since the scheme design is still under discussion, ICF recommends that the S&L scheme can be made mandatory for upto 19 kW category since launch, as it is already mandatory to comply with BIS specified SFC limits for this category. ICF also recommends designing scheme in such a way that it would lead to improvement in SFC by at least 5% than the existing market average SFC. This would promote additional technical modifications by manufacturers aspiring for higher star label.

EMISSIONS

Emissions from diesel generator sets (also known as 'diesel fumes') are a mixture of gases primarily comprising of Carbon Monoxide (CO), Oxides of Nitrogen (NOx), unburned Hydrocarbons (HC), and soot particles (particulate matter or PM). At the manufacturers end, these emissions can be controlled by improving the combustion process inside the diesel engine, improving the efficiency of combustion, and deployment of emission control techniques. Some of these techniques are dependent on availability of low sulphur diesel by oil retail distribution companies. At the consumer end, proper and regular O&M activities are essential to ensure that the diesel generator set delivers performance closer to the design values.

STANDARDS AND NORMS FOR EMISSIONS FROM DIESEL GENERATORS IN INDIA

India through its apex pollution control regulating agency, 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 (see Exhibit 7). These norms have been revised in December 2013 (G.S.R. 771 (E) / 11th Dec 2013 notification) and will be enacted from April 2014 (CPCB II).

Exhibit 7 shows a comparison between the old emission limits and the revised emission limits for the diesel engines upto 800 kW. The revised norms have a combined cap on NOx and HC which is in line with the practice followed in US and Europe. Both NOx and HC result in formation of secondary pollutants (like nitric acids and their salts) and hence combining the two is a reasonable step. The combined cap will also provide flexibility to a manufacturer to optimize emission reduction methods. At the time of monitoring and verification, the two pollutants will be measured separately and then added to check compliance to the norms. The revised notification has redefined the size classification of diesel generators. Earlier diesel generators upto 800 kW were further divided into three categories based on engine sizes i.e. upto 19 kW, 20-176 kW and 177-800 kW, whereas now it

[19]Excerpts of the Meeting of Core members of PCRA's Technical Committee on S&L scheme for Diesel Engine Driven Generator Sets
[20]Excerpts of PCRA's 2nd Technical Committee Meeting held on 21.11.2012 on S&L scheme for Diesel Engine Driven Generator Sets

Exhibit 7: Emission Standards For Diesel Generators In India (Upto 800 kW)

Capacity of diesel engines	Old Emission Limits (g/kWh)				Capacity of diesel engines	Revised Emission Limits w.e.f. April 2014 (g/kWh)		
	NOX	HC	CO	PM		NOx + HC	CO	PM
Upto 19kW	9.2	1.3	3.5	0.3	Upto 19kW	≤ 7.5	≤3.5	≤ 0.3
> 19 kW upto 176 kW	9.2	1.3	3.5	0.3	> 19 kW upto 75 kW	≤ 4.7	≤3.5	≤ 0.3
> 176 kW upto 800 kW	9.2	1.3	3.5	0.3	> 75 kW upto 800 kW	≤ 4.0	≤3.5	≤ 0.2

has been changed to upto 19 kW, 20-75 kW and 76-800 kW which is partially harmonized with global practices. Under the new norms, limits of NOx+HC emission have been tightened for all size categories. As deliberated in the CPCB constituted peer and core expert committee meeting, the CO norms was felt to be already at a strict level and hence did not undergo any revision (Exhibit 7).[21]

CPCB had also notified emission limits for diesel generators greater than 800 kW in 2002. Discussion with stakeholders revealed that 800 kW and above sized diesel generator sets are generally regulated by the State Pollution Control Boards or Pollution Control Committees at the site of installation.

In some cases, user of diesel generator set needs to obtain environment clearance for which Environment Impact Assessment (EIA) needs to be conducted as informed by stakeholders.

With revised norms in place, India's emission standard for diesel generators has moved closer to world benchmarks. The revised Indian norms are equivalent to Euro Stage IIIA which was prevalent in Europe till 2010 for all size categories. Currently, Stage IIIA is applicable for upto 36 kW category, Stage IIIB for 36 to 129 kW category, and Stage IV for 130 to 560 kW category in Europe. Europe Stage IV will be expanded to other size categories in 2015. It is important to note that quality of diesel (in

Exhibit 8: Mapping Of Emission Norms Vs Fuel Quality

Emission norms	Sulphur content in diesel (ppm)
India CPCB II (April 2014 onwards)	350/50
India CPCB I (2004-2013)	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

[21]Minutes of the 26th meeting of the peer and core expert committee to evolve standards for effluent & emission, ambient air & water quality, held on Nov 14th 2011

terms of sulphur content in ppm) has an important consideration while setting of emission norms for diesel engines in other countries. Sulphur content in diesel plays a role in determining the choice and effectiveness of emission control technologies. The lower the sulphur content, the wider the range of emission control options available.[22] Global emission norms and respective fuel quality requirements are shown in Exhibit 8.

In order to have an unbiased comparison of Indian emission norms with respect to global norms, emission norms of countries corresponding to same fuel quality as that of India (50 ppm for metro cities) has been compared and shown in Exhibit 9. For the sake of convenient comprehension, norms applicable to three sizes (19 kW, 75 kW, and 350 kW) have been presented in Exhibit 9. It is observed that Indian norms for CO and PM are better than the other countries. On NOx+HC limits however, there is a difference of 8-20% when compared with Japan (Japanese norm being more stringent compared to India).

The emission norm which will be prevalent in different countries by April 2014 is shown in Exhibit 10. ICF's observation shows that emission norms across countries are almost at the similar level where 10 or 15 ppm fuel is available. However, the PM emission limits in USA are exceptionally lower than other countries. For CO, India has the lowest emission limit globally which is commendable.

Stakeholder discussions suggest that all models in India (branded) were marginally meeting old PM and CO norms while satisfactorily surpassing the old NOx+HC limits (on an average 20 to 25% lesser emission compared to the limit). Since maximum limits of NOx+HC emission have been tightened under CPCB II by 38% to 71% (depending upon the size) from the old emission norms, deployment

Exhibit 9: Comparison of Emission Norms for Different Size of Diesel Generators (India Vs Global At 50 ppm)

	Country	19 kW	75 kW	350 kW
NOx+HC (in g/kWh)	India CPCB II (April 2014 onwards)[a]	7.5	4.7	4
	Japan (Tier III)b	7	4	4
	Europe (Stage IIIA)c	7.5	4	4
PM (in g/kWh)	India Revised (April 2014 onwards)	0.3	0.3	0.2
	Japan (Tier III)	0.4	0.2	0.17
	Europe (Stage IIIA)	0.6	0.3	0.2
CO (in g/kWh)	India Revised (April 2014 onwards)	3.5	3.5	3.5
	Japan (Tier III)	5	5	3.5
	Europe (Stage IIIA)	5.5	5	3.5

Sources [a]http://www.cpcb.nic.in/divisionsofheadoffice/pci2/Emission-Standards-Diesel-engin-upto-800.pdf, [b]http://cumminsemissionsolutions.com/CES/CESContent/SiteContent/en/Binary_Asset/PDF/CES_Pocketcard_Off_Highway_FINAL.pdf, [c]http://www.dieselnet.com/standards

The Category Range Used For Comparative Analysis Are:

	19 kW	75 kW	350 kW
India Revised (2014)	upto 19 kW	> 19 kW upto 75 kW	> 75 kW upto 800 kW
Japan (2011-13)	19 ≤ kW < 37	75 ≤ kW < 130	130 ≤ kW < 560
Europe (Stage IIIA)	19 ≤ kW < 37	75 ≤ kW < 130	130 ≤ kW < 560

[22]Paper on Low sulphur gasoline and diesel by Katherine O. Blumberg, Michael P. Walsh, Charlotte Pera

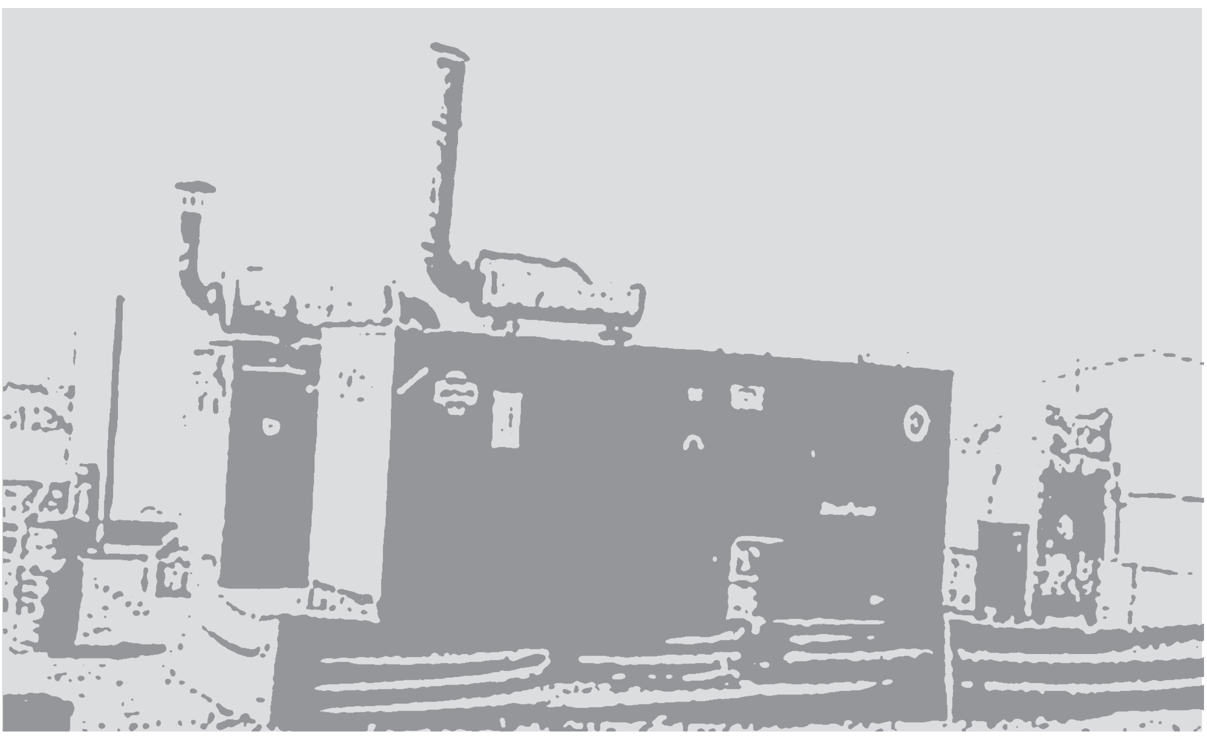
of additional measures to control emissions will be necessary by majority of the manufacturers. There is no data for the unorganized sector, but their meeting emission norms appear to be far from reality.

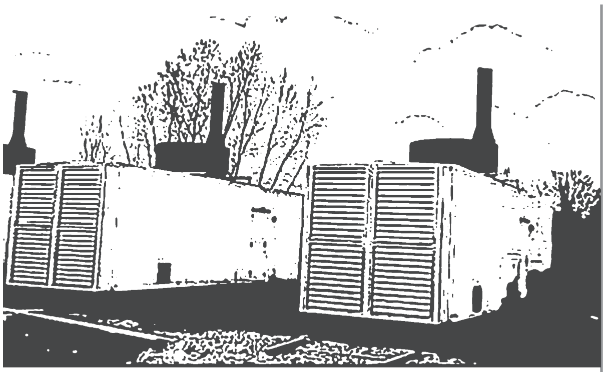
Exhibit 10: Comparison of Emission Norms (India Vs Global as on April 2014)

	Country	Fuel quality (ppm)	19 kW	75 kW	350 kW
NOx+HC (in g/kWh)	India CPCB II (April 2014 onwards)	350/50	7.5	4.7	4
	Japan Tier IV A*	10	4.7	3.49	2.19
	Europe (Stage IIIA/IIIB/IV as applicable)a**	10	7.5	3.49	0.59
	US EPA (Tier 4 Interim/Final as applicable)a***	15	4.7	3.49	0.59
PM (in g/kWh)	India CPCB II (April 2014 onwards)	350/50	0.3	0.3	0.2
	Japan Tier IV Aa*	10	0.03	0.02	0.02
	Europe (Stage IIIA/IIIB/IV as applicable)**	10	0.6	0.025	0.025
	US EPA (Tier 4 Interim/Final as applicable)***	15	0.03	0.02	0.02
CO (in g/kWh)	India CPCB II (April 2014 onwards)	350/50	3.5	3.5	3.5
	Japan Tier IV A*	10	5	5	3.5
	Europe (Stage IIIA/IIIB/IV as applicable)**	10	5.5	5	3.5
	US EPA (Tier 4 Interim/Final as applicable)***	15	5	5	3.5

Source:[a]http://cumminsemissionsolutions.com/CES/CESContent/SiteContent/en/Binary_Asset/PDF/CES_Pocketcard_Off_Highway_FINAL.pdf, http://www.cpcb.nic.in/divisionsofheadoffice/pci2/Emission-Standards-Diesel-engin-upto-800.pdf

*Japan will move to Tier IVB for 56 kW onwards from Jan 2015
** Europe will move to Stage IV for 56 kW onwards from October 2014
*** USA will move to Tier IV Final from Jan 2015





INTERVENTION OPPORTUNITIES

TECHNICAL OPTIONS TO IMPROVE EMISSION AND EFFICIENCY

To understand and identify plausible technical options to improve efficiency and emission performance of diesel generators, a review of the efficiency improvement and emission abatement technologies and techniques, and associated fuel quality requirements was carried out. Analysis of global trends shows that manufacturers relied on engine modifications and emission control technologies, such as use of Diesel Oxidation Catalyst (DOC), when the Euro II emission standards were upgraded to Euro III.

Sulphur content in diesel also plays a role in determining the choice and effectiveness of such efficiency improvement and emissions abatement technologies. Use of low sulphur content diesel would have a significant impact on emissions. The impact of low sulphur fuel on emissions is an established fact, however, its impact on engine efficiency could not be established (few stakeholders quoted 3-5% improvement in efficiency). As per the roadmap for implementation of the Bharat Stage (BS) norms for fuel quality, currently BS IV (for 30 cities) and BS III is in place for rest of the country.[23] A new committee under the chairmanship of Shri Saumitra Choudhuri, Member, Planning Commission was constituted to recommend the Auto Fuel Vision & Policy 2025. The initial recommendation from the committee is to move towards a nationwide BS IV+ standards (40 ppm) by 2017, and BS V (10 ppm) standards in next 4 to 5 years after 2017.The committee feels that oil marketing companies would be in a position to supply BS-IV+ fuel by 2017, either through expansion of their existing capacity or by adding very little new capacity. However, supplying 10 ppm diesel fuel would require at least INR 800 billion as investment.[24]

Exhibit 11 lists the technical options available for improving efficiency and reducing emissions from diesel generator sets. These options were identified based on research and consultation with few manufacturers. Exhibit 11 also indicates the minimum fuel quality requirements for ensuring the effectiveness of these technologies and the maturity level of the technologies. Barring a few technologies which are new or under R&D stage, most of these technologies are commercially available. During stakeholder interactions, few manufacturers opined that some of these technologies are already being used in India. These technology options can be used exclusively or in tandem in order to achieve the desired emission norms. Information regarding cost of these technologies in India is not available in public domain. Few global reports and publications are available publically wherein broad cost estimates for these technologies in European and US market have been provided. But those estimates are found to be quite old and have wide variation; hence it was

[23]Press Information Bureau (pib.nic.in/newsite/PrintRelease.aspx?relid=101695)
[24]Expert Committee for drafting Auto Fuel Vision and Policy, 2025 under the chairmanship of Saumitra Chaudhuri, Member, Planning Commission (http://articles.economictimes.indiatimes.com/2014-01-10/news/46066515_1_norms-emission-bs-iv)

felt inappropriate to refer to those cost estimates in the Indian context. ICF's attempt to gather cost information through primary research was unsuccessful. Besides these technology options from manufacturing side, better O&M practices are essential to maintain the performance of diesel generators at the end use. Poorly maintained generators emit vastly larger amounts of soot and

Exhibit 11: Impact Of Technical Options On Efficiency And Emissions[25]

Color code		
	Requires 150 to 500 ppm fuel or Independent of fuel quality	Requires 15 ppm fuel
		Requires 50 ppm fuel

Technology Options	Typical Reduction Potential					Minimum required sulphur in diesel[26] (ppm)	Technology Penetration
	SFC (%)	PM (%)	NOx (%)	HC (%)	CO (%)		
Modification in Diesel Engine							
1. Exhaust Gas Recirculation (EGR)	5-8	NA	25 – 40	NA	NA	500	Commercially available
2. Variable Geometry Turbocharger (VGT) with intercooler		NA	NA	NA	NA	No linkage	Commercially available
3. Micro-processor based engine control		NA	NA	NA	NA	No linkage	Commercially available
4. High Pressure Injection System	Not Verified					15	R&D, not commercialized
Emission Control Techniques							
Particulate Matter (PM) Control							
1. Diesel Oxidation Catalyst (DOC)	NA	20-50	NA	40-60	40-70	500	Highly commercialized
2. Diesel Particulate Filter (DPF)	NA	85-95	NA	60-85	90-95	50*	Commercially Available
3. Flow-Through Filter (FTF)	NA	40-50	NA	NA	NA	150	New technology
NOx Emission Controls							
4. NOx Adsorbers	1.5(+)#	NA	90-95	NA	NA	15	Not Commercialized
5. Selective Catalyst Reduction (SCR)	NA	NA	65-80	NA	NA	50	Commercially available
6. Lean NOx catalyst	NA	NA	15-40	NA	NA	50	New Technology

* DPFs should not be used with fuel sulphur levels greater than 50 ppm. Studies show that DPFs achieved greater efficiency and required less frequent regeneration when provided with fuel having sulphur level of 15 ppm or less.[26]
# SFC increases by 1.5%.

[25]Report of the Sulphur Working Group of the Partnership for Clean Fuels and Vehicles, UNEP; Technical information from Cummins Power Generation

[26]Technology is not applicable if sulphur content in the fuel exceeds this limit. In general, the lower is the sulphur content, the better it is for deployment and functioning of emission control technologies.

Exhibit 12: Impact of Inadequate O&M on SFC*

S.No.	O&M Issues	Impact on fuel consumption
1	Poorly maintained fuel injection pump	Increases SFC by 4gm/kWh or 2%
2	Faulty nozzle	Increases SFC by 2gm/kWh or 1%
3	Blocked fuel filters	Increase SFC by 2gm/kWh or 1%
4	Loading below optimal	10 % reduction in units per liter at low loading
5	Improper lubrication	Increase in SFC by upto 0.5%
6	Poor cross ventilation can lead to higher air intake temperature thereby reducing the air fuel ratio	5% drop in air-fuel ratio results in increase in fuel consumption in the range of up to 2%
7	Deviation from optimal power factor: less than 0.8 and greater than 0.9	Increase in SFC
9	Improper cooling water circuit	Increase in fuel consumption by upto 3%

*Based on case studies of NPC, PCRA, Energy Audits, Manufacturers manual

other pollutants, making the case of regular O&M procedures even stronger. Exhibit 12 illustrates typical impacts on SFC due to inadequate O&M. ICF's analysis indicates that there could be a potential of upto 7% improvement in SFC through O&M measures for existing diesel generator sets which are greater than 75 kW in size.

In order to make the new and improved technologies (identified in Exhibit 11) available to the consumers, and promote O&M practices (identified in Exhibit 12), interventions from different aspects such as regulatory mechanism, institutional system, and awareness program will be required.

An analysis was done to understand the technology options that manufacturers might prefer in order to meet the revised standards (CPCB –II) post April 2014. Analysis for a 75 kW diesel generator set is presented as an illustration.

Case Study for a 75 kW diesel generator set

In the absence of measured or reported values in public domain, we have assumed that a 75 kW diesel generator is surpassing NOx+HC limits by 25% and just meeting the PM and CO levels. Assumption of this baseline value is based on stakeholders' feedback and ICF's research on typical emission content in diesel (Exhibit 13). Average SFC of 216 g/kWh (for 50 to 300 kW category as previously depicted in Exhibit 4) is taken as the baseline SFC. These assumptions however, are not valid for all brands.

Exhibit 13: Existing Emission Level Of 75 kW Diesel Generator Set

	NOx+HC (gm/kWh)	PM (gm/kWh)	CO (gm/kWh)
Old emission norms (CPCB – I)	10.5	0.3	3.5
Existing Baseline*	7.8	0.3	3.5
Revised emission norms (CPCB – II)	4.7	0.3	3.5

* Assumption based on stakeholder interaction and further research by ICF team

Following steps were followed for the analysis:

1. Commercial technologies applicable for 350 ppm and 50 ppm diesel were shortlisted separately.
2. For estimating emissions reductions, shortlisted technologies were applied to the baseline values (75 kW set) first individually and then in combination. Only feasible combination of technologies was considered while analyzing the collective impact of these technological interventions on emissions reductions.
3. Since a range of possible emissions reductions from application of each technology is available (refer Exhibit 10), two cases were analyzed:
   a. Case I- assuming the mean value of reduction
   b. Case II- assuming the highest possible reduction

For example, EGR has a potential to reduce NOx+HC by 25-40%. Hence, 32.5% reduction was considered in Case I, and 40% reduction was considered in Case II. Findings of the analysis are shown in Exhibit 14.

Case Study for a 75 kW diesel generator set

Exhibit 14: Illustrative Technology Selection Pathways For Meeting Cpcb II Norms

	Case I: Considering average reduction NOx +HC / PM / CO (gm/kWh)	Case II: Considering highest reduction NOx +HC / PM / CO (gm/kWh)
If 350 ppm diesel is available		
Existing Baseline	**7.8 / 0.3 / 3.5**	**7.8 / 0.3 / 3.5**
Revised Norm (CPCB II)	**4.7 / 0.3 /3.5**	**4.7 / 0.3 /3.5**
1. Engine Modification (EGR + VGT + Microprocessor based control)	5.6 / 0.3 / 3.5	5.1 / 0.3 / 3.5
2. Diesel Oxidation Catalyst (DOC)	7.4 / 0.2 / 1.6	7.3 / 0.2 / 1.1
3. Engine modification and DOC (1+2)	5.1 / 0.2 / 1.6	4.5 / 0.2 / 1.1

	Case I: Considering average reduction NOx +HC / PM / CO (gm/kWh)	Case II: Considering highest reduction NOx +HC / PM / CO (gm/kWh)
If 50 ppm diesel is available		
Existing Baseline	**7.8 / 0.3 / 3.5**	**7.8 / 0.3 / 3.5**
Revised Norm (CPCB II)	**4.7 / 0.3 /3.5**	**4.7 / 0.3 /3.5**
1. Engine Modification (EGR + VGT + Microprocessor based control)	5.6 / 0.3 / 3.5	5.1/ 0.3 / 3.5
2. Diesel Oxidation Catalyst (DOC)	7.4 / 0.2 / 1.6	7.3 / 0.2 / 1.1
3. Diesel Particulate Filter (DPF)	7.2 / 0.03 / 0.3	7.1 / 0.02 / 0.2
4. Selective Catalyst Reduction (SCR)	3.0 / 0.3 / 3.5	2.3 / 0.3 / 3.5
5. Lean NOx Catalyst (LNC) paired with DPF	5.3 / 0.03 / 0.3	4.3 / 0.02 / 0.2
6.Engine modification and DOC (1+2)	5.1 / 0.2 / 1.6	4.5 / 0.2 / 1.1
7. Engine Modification and DPF (1+3)	4.9 / 0.03 / 0.3	4.3 / 0.02 / 0.2
8. Engine Modification and SCR (1+4)	2.2 / 0.3 / 3.5	1.5 / 0.3 / 3.5
9. DOC, DPF and SCR (2+3+4)	2.2 / 0.02 / 0.1	1.4 / 0.01 / 0.1

*The red texts indicate that CPCB-II norms are not met, green texts shows that the CPCB-II norms are met.

It is observed that the CPCB II norms can be met with engine modification options and emission control technologies even with 350 ppm sulphur diesel. With 350 ppm diesel, revised norms can be technically achieved through use of EGR, electronic control, and use of DOC. Availability of 50 ppm diesel presents more emissions control options and flexibility to a manufacturer. This also indicates that further reduction of emission norms is technically possible with 50 ppm fuel and combination of technologies. However, the overall cost implications should also be looked into while considering multiple technology options. The unavailability of technology cost related information (in Indian context) and reluctance of manufacturers to share cost information because of competitive concerns prohibited an assessment of the cost economics of these technologies. Stakeholder discussions and press release by manufacturers reveal that new norms will lead to an increase of 15-20% in the price of diesel engine resulting in 7-10% increase in the overall price of diesel generator. To give additional perspective on the cost impact, a study done by ICCT in 2012 titled “Estimated cost of emission reduction technologies for light duty vehicles” shows an incremental cost of USD 337 to USD 419 when European standards were revised from Euro II to Euro III norms. This revision had required manufacturers to rely on engine modifications and emission control technologies such as use of Diesel Oxidation Catalyst (DOC).

SCENARIO ANALYSIS

ICF has done a quantitative analysis to estimate the impact of interventions on total fuel consumption and emissions till 2017 and 2022 under two scenarios taking 2013 as the base year:

Business as Usual (BAU) scenario: This scenario assumes continuation of the market trends, energy usage pattern, and few incremental initiatives by government, manufacturers and end-users.

Aggressive scenario: In addition to BAU, this scenario assumes additional initiatives by Government to influence all stakeholders i.e. manufacturers, certification & testing bodies, and end-users in addressing efficiency and emissions from diesel generator sets.

The assumptions for these scenarios are given in Exhibit 15.

Exhibit 15: Assumptions For Different Scenarios

Areas	Business As Usual (BAU) scenario assumptions	Aggressive Scenario assumptions (in addition to BAU)
Market	• 7.2% annual growth in number of diesel generators based on market research forecasts • Usage pattern of 1500 hours per annum is considered as per historical trend	• 7.2% annual growth in number of diesel generators based on market research forecasts • Usage pattern of 1500 hours per annum is considered as per historical trend
CPCB norms for emissions from diesel generator sets	• The CPCB II emission norms are enacted from 2014 and expected to be adhered to with stringent compliance mechanisms. No further revision in norm till 2022. New diesel generator sets are expected to just meet the applicable CPCB norms.	• CPCB norms getting revised in 2020 and becoming equivalent to Euro Stage III B (under the assumption that 10 ppm fuel is available by 2020). CO norms since already at world class level, would remain unchanged from CPCB II levels. New diesel generator sets are expected to just meet the applicable CPCB norms.
Low sulfur diesel fuel availability	• 50 ppm diesel is made available to 50 cities by 2015 under Bharat Stage IV country wide implementation	• 40 ppm diesel is made available across the country by 2017; 10 ppm from 2020 onwards
S&L scheme for DG sets	• S&L scheme is launched in 2015 for diesel generators upto 200 kVA size as a voluntary scheme; BIS standard (IS 10001 and IS 10002) will be the eligibility criteria for manufacturers to participate in S&L • Average SFC for star labeled products will be 5% better than the average market SFC. Participation rate is assumed to start with 10% in first year, increasing by 10% in every subsequent year upto 50% participation. This is in line with the trend typically observed for other products/appliances in S&L. • No further revision in threshold will happen until 2022	• S&L mandatory for up to 19 kW category in 2015 • Average SFC for star labeled products will be 5% better than the average market SFC. Participation rate is assumed to start with 10% in first year, increasing by 20% in every subsequent years and reaching up to 90% participation • Star label norms revised in 2019 by 5% additional improvement in average SFC
Regulatory and Institutional	• Existing practice would continue with few incremental initiatives	• SFC of existing diesel generator sets (75 kW and above) improving by 7% from 2016 onwards on account of better O&M through energy audits and awareness

Exhibit 16 shows the comparative analysis of the savings potential in two scenarios.

Exhibit 16: Savings Estimation Under Different Scenarios

		Base year	Business as Usual scenario (cumulative upto year*)		Aggressive Scenario (cumulative upto year*)	
	Unit	**2013**	**2017**	**2022**	**2017**	**2022**
DIESEL CONSUMPTION						
Total Consumption	Billion Litre	4.45	23.53	50.03	23.21	48.48
Saving w.r.t. BAU	Billion Litre	-	-	-	0.32	1.56
Savings w.r.t. BAU	%	-	-	-	1.35%	3.11%
EMISSIONS						
NOx+HC Emission	Thousand tonnes	141.42	489.35	980.78	489.35	890
Reduction w.r.t. BAU	Thousand tonnes	-	-	-	0	90.77
Reduction w.r.t. BAU	%	-	-	-	0	**9.3%**
PM Emission	Thousand tonnes	5.26	22.35	46.51	22.35	36.58
Reduction w.r.t. BAU	Thousand tonnes	-	-	-	0	9.93
Reduction w.r.t. BAU	%	-	-	-	-	**21.4%**
CO Emission	Thousand tonnes	61.31	321.35	688.65	321.35	688.65
Reduction w.r.t. BAU	Thousand tonnes	-	-	-	0	0
Reduction w.r.t. BAU	%	-	-	-	0	0

*Adding yearly values from 2013 upto that year, so fuel consumption figures in 2022 mean cumulative fuel consumption from 2013-2022

Note: Since it is assumed that new diesel generator sets will cause emissions equal to the CPCB norms, there is no change in the emissions between BAU and Aggressive scenario till 2017, CPCB norms being the same in both the scenarios till 2017. A revision in CPCB norm in 2020 is assumed in Aggressive scenario (except for CO), hence the emission numbers differ if we look at cumulative impact till 2022.

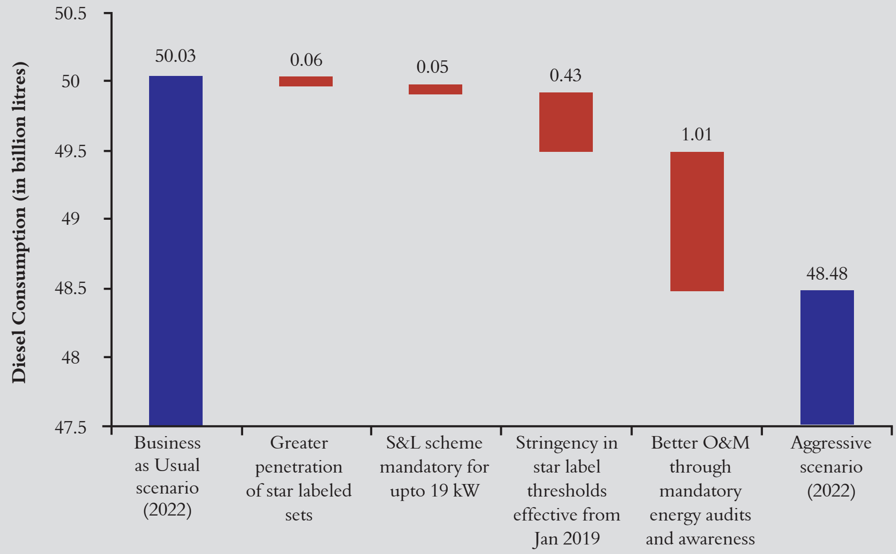
ICF's analysis indicates the following:

Potential reductions in fuel consumption: There is a cumulative diesel saving potential of 0.32 billion litres and 1.56 billion litres by 2017 and 2022 respectively in the aggressive scenario compared to BAU. This amounts to a saving of INR 85 billion (~1.4 billion USD) to the nation by 2022. The savings potential is attributed to the following reasons (Exhibit 17):

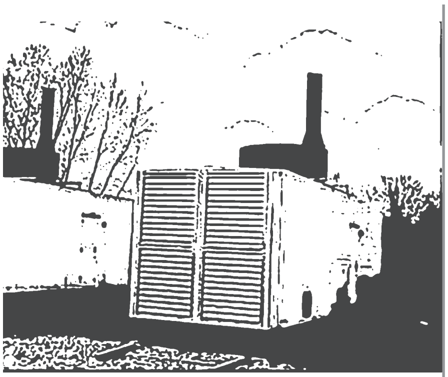
- Better O&M practices especially for diesel generator sets greater than 75 kW could alone lead to 65% of the total fuel savings potential by 2022.
- S&L scheme has 0.43 billion litres potential of cumulative diesel savings by 2022 if thresholds for star label are made stringent by additional 5% from 2019 onwards. Interestingly, if S&L scheme is made mandatory for upto 19 kW category, additional diesel savings potential would be 50 million litres by 2022.

Emissions reductions potential: Aggressive scenario has a reduction potential of 90.8 thousand tonnes of NOx+HC emissions or 9.3% reduction in emissions by 2022 as compared to BAU. This reduction is equivalent to annual NOx emission avoidance from 3,700 MW coal power plant.

Exhibit 17: Diesel Savings Potential In Aggressive Scenario (Upto 2022)



These reductions are mainly due to the assumed transition to CPCB III norms (equivalent to Europe Stage IIIB norms) in 2020. The PM emissions would be reduced by 21.4% in 2022 from the BAU scenario. This is equivalent to annual PM emission avoidance from 1,800 MW coal plant. Since no revision in CO norms is assumed in 2020, there will not be any additional reduction in CO and it will remain at the BAU levels.



RECOMMENDATIONS

India has already taken steps to curb emissions from diesel generators. However, strengthening of the efficiency and emission performance standards and ensuring complete compliance will increase the potential of reduction in energy consumption and emissions from this sector. As described under the analysis of the two scenarios, BAU and Aggressive scenarios, the latter can yield additional benefits for diesel savings and emission reductions. Assuming all the proposed interventions under the Aggressive scenarios, are to be implemented, a five point agenda is suggested for consideration by the policy makers and implementing agencies. The five point agenda will need to be done in a time bound manner as illustrated in Exhibit 18.

1. Launch of Standards & Labeling scheme for Diesel generator sets

BEE's decision to launch S&L scheme for upto 200 kVA is a step in the right direction as this segment necessitates priority intervention due to wide variation in efficiency levels and gap in efficiency with respect to global models. The star labeling scheme should encourage manufacturers to make additional efforts to get eligible for the label. Since the scheme design is still under discussion, a proposal by the BEE constituted technical committee for improving SFC by at least 5% above the existing market average SFC will promote technical modifications by manufacturers aspiring for higher star label. Making the S&L scheme mandatory for '19 kW and below' category would be a constructive step. Empanelment of independent institutions for application approval processes and check testing will help in smooth implementation of the S&L scheme. For instance, PCRA can be given the responsibility to conduct the application approval process and testing support. In order to accelerate the penetration of energy efficient diesel generator sets in market, Directorate General of Supplies and Disposal (DGS&D) can incorporate a guideline for purchase of star labeled diesel generator sets in public procurement.

2. Strengthening the Regulatory and Institutional Framework

There is a need to strengthen the process of standards setting, approval processes, testing processes, through involvement of designated agencies at both central (BEE, SPCBs) and state levels (SDAs and SPCBs). For instance, there has to be a defined procedure for the formation of technical committee which is currently not properly represented in case of BEE. Improved co-ordination between central and state agencies during standards setting and enforcement is required. For diesal generator sets of 300 kVA and above, emissions norms stringent than the CPCB-II norms can be mandated by respective SPCBs of critically identified cities (88 cities identified by State Pollution Control Boards (SPCBs). This would require users of diesel generator sets to install additional technologies and means for emission control. Another regulatory intervention would be to introduce a policy for mandatory retirement of diesel generator sets once they outlive their designed

[27]Energy manager guidebook, Bureau of Energy Efficiency

operational life (typically 6 to 8 years). The diesel generator set market in India also consists of a 30-40% small-scale unorganized sector. These brands have sizeable regional markets. There is a dire need to enforce compliance for this segment else it will continue to distort the market and lead to policy failure. This is going to be extremely challenging to implement and would require political will. But it should not be ignored any further as it offers huge potential for fuel savings and emissions reductions. On the awareness front, the importance of proper sizing, selection, installation, and O&M needs to be propagated more to the users. Awareness promotion regarding the use of waste heat from exhaust flue gas for heating/cooling purpose is another area where fuel/electricity savings can occur. Typically 33% of the total input energy is lost through flue gases, and its recovery has been found to be technically and economically feasible.[27]

3. Fixing onus for end users of diesel generators

In many countries, the responsibility for reducing diesel emissions is moving more towards owners and operators rather than being fixed only to manufacturers (such as in US). It is the operating performance of diesel generators which determines fuel consumption and emission. The responsibility for consumers should not be limited to purchase of efficient and environment friendly diesel generators but should also cover their efficient operation. Hence, O&M practice if exercised properly is one of the most cost-effective measures for improving SFC and thus reducing operating costs of diesel generators especially for units above 75 kW. State agencies should start enforcement of better O&M practices by mandating owners to conduct energy audit of their diesel generator sets. To begin with, all government owned Hotels, Hospitals, and Offices having 75kW and bigger diesel generators can be mandated to conduct energy audit periodically. Random monitoring through inspection by state agencies can be done to inculcate these practices. State pollution control boards need to be proactive in stipulating tighter norms and strict compliance check for users of large diesel generator sets. This falls within the purview of their powers. State Designated Agencies (SDAs) and State Pollution Control Boards can also provide facilitation support for capacity building of operators/users through workshops, trainings, and awareness campaigns.

4. Nationwide availability of low sulphur diesel

50 ppm diesel is currently available in only 33 cities and the plan is to make it available to 50 cities by 2015. Since CPCB has notified revised emission standards which will be enacted from April 2014, there should be immediate focus to provide nation-wide availability of at least 50 ppm diesel. Present thinking to introduce BS IV+ norms (40 ppm) by 2017 and BS V (10 ppm) norms in 4 to 5 years after 2017 is a good step. However, making BS V available by 2020 would be a constructive step though economic challenges in implementing BS V fuels will be huge. It is estimated that INR 800 billion of investment will be required by refineries to deliver BS V quality diesel.[28] According to a study done by ICCT, the impact of investment for up-gradation to 10 ppm diesel will be increase in cost of diesel by INR 0.40 to 0.55 per litre.[29] But it has been observed worldwide that benefits exceed the investment multi fold and hence could be implemented for overall national benefit as done in other countries. For example, US EPA found that human health and environmental benefits due to sulphur reduction were ten times higher than the costs. Furthermore, a European study showed that near-zero sulfur fuels significantly reduce total fuel costs by increasing fuel economy.[30] Such findings are understood to have been used by policy makers while design emission roadmap for the sector.

5. Greater focus to foster R&D activities and Industry-Institute collaboration

The CPCB II norms will require technology

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[28]Expert Committee for drafting Auto Fuel Vision and Policy, 2025 under the chairmanship of Saumitra Chaudhuri, Member, Planning Commission (http://articles.economictimes.indiatimes.com/2014-01-10/news/46066515_1_norms-emission-bs-iv)
[29]Briefing on costs and benefits of cleaner fuels and vehicles in India, ICCT
[30]Paper on Low sulphur gasoline and diesel by Katherine O. Blumberg, Michael P. Walsh, Charlotte Pera

upgrades in existing diesel generators, entailing new investments by manufacturers. Diesel generators equipped with advanced exhaust emission-reduction technologies are available today, which not only help to meet the mandated emission standards, but also offer improved energy efficiencies. Technological innovation such as high-pressure fuel injection system which is presently under R&D should be given greater attention in order for it to become commercialized. Government can facilitate collaboration between industry and research institutes to provide thrust to R&D activities for availability of these technologies at lower cost.

Diesel generators are run on diesel, a commodity dependent on expensive imports of crude oil. Diesel combustion in these generators also contributes to air pollution, and therefore improving performance of diesel generators demands urgent attention. The activities identified under five point agenda could be of immense help to policymakers (e.g. BEE, BIS, CPCB) while formulating future strategies and to implementers (SDA, SPCB, Testing bodies) while ensuring enforcement. These activities can be initiated quickly in next 12 to 18 months by the concerned department/authority to tap the potential of diesel savings and emission reductions by 2022.

Exhibit 18: Time Schedule For Implementing Five Point Agenda

	2014	2015	2016	2017	2018	2019	2020
1. Launch of S&L scheme							
Launch the voluntary S&L scheme of BEE upto 200 KVA diesel generator set with suitable standard	★						
Launch the mandatory S&L scheme of BEE upto 19 KVA diesel generator	★						
Empanelment of independent institutions for compliance check in S&L scheme		★					
2. Strengthening of Regulatory and Institutional Framework							
Introduce policy for retirement of old diesel generator sets (say 8 years) in critically and severally affected cities identified by CPCB		★					
Include diesel generator set in schemes like ECBC and state climate change program			★				
Awareness campaign for purchase and use of energy efficient diesel generator sets	★	★	★	★	★	★	★
Introduction of strict penalty procedures for non-compliance		★					
Develop and promote awareness for standard installation guideline and O&M		★	★	★	★	★	★
Capacity Building of CPCB, SPCB, BEE and SDA	★	★	★	★			
3. Fixing onus for end users of diesel generator sets							
Mandatory energy audit for large consumers in major diesel generatorusing states		★					
Mandatory Energy Audit of diesel generator of 100 kVA and above across country		★					
Stringent norms in critically cities for making mandatory use of after-treatment		★					
4. Nationwide low sulphur diesel availability							
Making fuel with at least 50 ppm available in in all major cities		★					
Making fuel with at least 40 ppm available in all major cities				★			
Making fuel with at least 10 ppm available in all major cities							★
5. Greater focus to foster R&D activities and Industry-Institute collaboration							
Facilitate technology transfer in emission control	★	★	★	★	★	★	★
Promote Industry-Institute Interaction for taking up R&D for improving engine efficiency and emission	★	★	★	★	★	★	★

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